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METHODOLOGY FOR EVALUATION OF SEAL-COATED, GRAVEL, AND DIRT ROADS

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16. Abstract

The objective of this research project was to develop methodologies for the evaluation of different types of seal-coated, gravel, and dirt roads by using a best-practice-oriented pavement-management system in Illinois. A statewide survey comprised of 13 questions collected 133 responses from county engineers and highway commissioners. Many counties and townships in Illinois performed similar practices to maintain seal-coated, gravel, and dirt roads. The subjective windshield surveys were often conducted on a weekly basis to identify the most common distresses, such as potholes, rutting, and roadside drainage. Several seal-coated, gravel, and dirt roads were evaluated using a field distress-survey manual method based on the newly developed Seal-Coated Road Condition Index (SCRCI) and an Unsurfaced-Road Condition Index (URCI) that was adopted to measure surface conditions of gravel and dirt roads. In addition, some of the commercially available cell phone applications, or apps, were investigated for their effectiveness next to the use of a rolling or high-speed profilometer for assessing roughness conditions of seal-coated, gravel, and dirt roads in this research study. Future research is recommended to fully establish guidelines about the use of a cell phone app to be adopted by the Illinois Department of Transportation (IDOT) and for use by local agency officials in Illinois. In conclusion, this research project established a database to develop a best-practice guide for effectively evaluating unpaved roads maintained by local agencies.

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EXECUTIVE SUMMARY

Local agencies have limited or no road-management guidelines applicable to evaluating surface conditions of unpaved roads. These local roads and streets are low-volume roads, often surfaced with chip seals, slurry seals, microsurfacing, or just gravel, and dirt roads. Most pavement-management systems collect visual distress surveys, measurement-based distress surveys, and automated roughness measurements. These distresses observed on flexible and rigid pavements are not applicable to the unpaved roads. Furthermore, the evaluation of dirt and gravel roads is more challenging because the subgrade materials infiltrate the surface gravel/aggregate cover from below. In spite of these difficulties, performance monitoring is a vital component of an asset-management system and is certainly needed for evaluating conditions of unpaved local roads. A knowledge gap exists for providing effective and proven unpaved-road maintenance and preservation strategies. Local agency engineers need better guidance for maintaining and managing unpaved roads. Therefore, the intent of this research study was to bridge the gap in this area so that agencies could allocate their limited resources effectively.

The objective of this research was to develop methodologies for the evaluation of different types of seal-coated, gravel, and dirt roads by using a best-practice-oriented pavement-management system in Illinois. For establishing a best-practice guide, the methodologies developed in this research project required the following tasks: (1) a comprehensive literature review encompassing both national and international research studies; (2) conducting a statewide survey to identify best practices for the evaluation and treatment of unpaved roads; (3) conducting follow-up interviews with personnel at a number of local agencies to document in detail their practices; (4) conducting both manual and automated distress identifications and developing a new condition index for seal-coated road conditions; (5) examining historical maintenance and field-performance records and documenting current maintenance practices of selected in-service roads having different surface characteristics and structural design factors, and carrying different traffic volumes; and (6) determining maintenance cost for several distress treatments applicable for different types of unpaved roads.

This statewide survey was comprised of 13 questions and, to facilitate responses, provided short descriptions of the seal-coated, gravel, and dirt roads; their distress types; and the various techniques and strategies to overcome the distresses. In total, 72 paper responses and 61 online responses were collected from the statewide survey, which revealed that many counties and townships in Illinois performed similar practices to maintain seal-coated, gravel, and dirt roads. County engineers and highway commissioners typically conduct windshield surveys to evaluate rural roads. Note that windshield surveys are often subjective, and distress quantification cannot be achieved. In contrast, the windshield survey gives local agencies an opportunity to assess the rural roads more frequently, such as evaluations on a weekly basis. Counties and townships maintain most visual surveys of distresses such as potholes, rutting, and roadside drainage.

Several seal-coated, gravel, and dirt roads were evaluated using a field distress-survey manual method. As part of the research efforts in this project, a Seal-Coated Road Condition Index (SCRCI) method was developed to measure the seal-coated road-surface condition using the manual method. The SCRCI was then used to perform surface evaluations of several seal-coated roads in Illinois.

Further, the Unsurfaced-Road Condition Index (URCI) was adopted to measure surface conditions of gravel and dirt roads. Both SCRCI and URCI required extensive data collection and then used tables and charts to determine the numeric rating. These methods are time-consuming and labor-intensive; and lane closure was often needed while taking the measurement, which might otherwise pose a safety issue to the surveyor. For this reason, automated methods may be considered or preferred to evaluate seal-coated, gravel, and dirt roads.

Because fully developed and sophisticated road-surface profilers are expensive to measure rural road conditions and skilled operators are needed, local agencies commonly intend to explore other inexpensive but reliable techniques as new alternatives to evaluate rural roads. For this reason, this research effort explored using cell phone applications, or apps, for assessing roughness conditions of seal-coated, gravel, and dirt roads. Some of the commercially available cell phone apps were used to measure International Roughness Index (IRI) values of seal-coated, gravel, and dirt roads. The study results indicate that the Roadroid cell phone app provided somewhat better results in measuring IRI values, as compared to the IRI data obtained by using RoadBump. The Roadroid IRI results were reasonably close to the IRI data as measured by a high-speed profilometer. A consistent set of IRI data could be obtained from different vehicles operated at speeds of 20 to 30 mph on the surveyed low-volume roads. Roadroid app also provided consistent results for both smooth and rough pavements. A dashboard mount with the Roadroid app was found to offer the most reliable IRI values. Because this study included limited data and research scope, a definitive conclusion is often difficult to make regarding the most suitable vehicle among a sedan car, van, and truck utilized herein to mount the cell phone and test the cell phone app performance. The sedan car, however, provided better results in general for measuring IRI with the Roadroid app. Future research is recommended to fully establish guidelines about the use of a cell phone app to be adopted by IDOT and for use by local agency officials in Illinois.

In conclusion, this research project established a database to develop a best-practice guide for effectively evaluating unpaved roads maintained by local agencies. The guide was prepared as part of the project-implementation plan to include treatment alternatives for the most commonly observed distresses of seal-coated, gravel, and dirt roads in Illinois, as well as their severity levels and extents. The guide establishes unpaved-road maintenance strategies to include schedules and associated costs for the different levels of field maintenance and rehabilitation efforts.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

In the United States, the overall public-access road network is 4.1 million miles, with rural roads comprising 2.9 million miles, or 71% (*Congressional Research Service: Rural Highways* 2018). Rural roads can be paved or unpaved. Paved roads are constructed using hot-mix asphalt (HMA) or Portland cement concrete (PCC) materials commonly on top of base and subbase layers above the compacted subgrade. These HMA and PCC surface layers carry vehicle loads and transfer the load into unbound aggregate or stabilized base and subbase layers to protect the weakest subgrade layer from excessive wheel-load stress and deformation. In contrast, unpaved roads generally do not have a strong, paved surface layer; they have fewer or thinner structural layers and ideally a smooth surface provided by a seal coat. The smooth surface improves ride quality and makes an impervious layer on top of the pavement structure. Another type of rural road, known as unimproved roads, does not have any seal coat but has a gravel or rock surface to protect the native soil, or the road consists of only the natural subgrade as the native soil. Unimproved roads are also known as gravel and dirt roads.

Illinois is at the transportation crossroads with a population of 12.8 million and annual vehicle miles traveled of about 108 billion ("Transportation Fast Facts" 2018). Illinois Department of Transportation (IDOT) oversees 146,890 miles of total road network, of which the paved roads are 61,669 miles and the unpaved roads are 85,221 miles; accordingly, unpaved roads comprise 58% of the total road mileage in Illinois (*Illinois Highways and Street Mileage Statistics* 2015). IDOT defines paved roads as a block, brick, PCC pavement, and asphalt concrete (AC) surface of 1.0 in. or more, where the combined surface and base thickness is 7.0 in. or more. In contrast, the unpaved roads are defined as AC surface where the combined surface and base thickness is less than 7.0 in., seal coat, and earth/gravel roads. Counties in Illinois oversee 9,650 miles of paved and 6,838 miles of unpaved roads; and townships and municipalities manage 35,886 miles of paved and 78,252 miles of unpaved roads. Among the unpaved roads, counties in Illinois maintain 675 miles of gravel and 5 miles of dirt roads; townships and municipalities maintain 22,141 miles of gravel and 2,700 miles of dirt roads.

Roads can be defined based on traffic volume as well, such as low- and high-volume roads. Low-volume roads may be paved, seal-coated, graveled, or dirt roads. Low-volume roads, either rural or urban, are defined as roads with traffic volumes ranging from 400 to 1,000 vehicles per day (Keller and Sherar 2003; Zegeer et al. 1994). Roads serving fewer than 400 vehicles per day are known as very-low-volume roads (Johnson 2008). They serve rural and urban areas and often are used for accessing tougher terrains than high-volume standard paved highways. Low-volume roads are used to provide access from small cities, subdivisions, villages, townships, and farms to the highway transportation system and other necessary places like health, education, and outdoor recreational facilities. They have enormous impacts on economies, communication, and social interaction. Figure 1 shows typical low- and very-low-volume rural and urban roads in Illinois. Figure 1(a) shows a seal-coated road, and the top surface of the road is constructed with chip seal; Figure 1(b) shows another seal-coated road, and the top surface of the road is constructed with a slurry seal; Figure 1(c) shows a gravel road; and Figure 1(d) shows a dirt road. In this report, the seal-coat, gravel, and dirt roads are referred to as *rural roads* unless otherwise specified.

(a) Rural seal-coated road **(b) Urban seal-coated road**

(c) Gravel road **(d) Dirt road**

Figure 1. Low- and very-low-volume roads in Illinois.

Rural roads are different from traditional highway engineering standards regarding geometric design, drainage design, pavement structural design, and slope stability and erosion control (Keller and Sherar 2003). Rural roads are single-lane roads, they have adequate width for truck maneuvering and turning, but often there are no pavement markings. Rural roads are generally constructed with a chip seal over a gravel base layer or chip seal over existing old asphalt-concrete pavement. In addition to chip seal, various other seal-coating options, such as scrub seal, sand seal, slurry seal, and microsurfacing, are available; however, chip seal is the most popular surface type for rural roads in Illinois. Seal coat provides smoothness and increases water runoff over the roads, and the vehicular loads are carried by a gravel base layer and subgrade. In addition, local aggregates are used as a base material to reduce construction cost.

In addition to regular vehicles, oftentimes farm machinery, tractors, and haul trucks use rural roads to carry local crops from farmlands. Figure 2 shows agricultural vehicles that have unconventional tire size and shape, and process heavy loads on rural roads. Like other paved roads, rural roads are exposed to damages and distresses, but the damages are often severe because the rural roads are used by slow-moving heavy vehicles. In addition, the materials’ strength is lower for the rural roads because the least expensive local aggregates are used. Moreover, rural roads have fewer structural layers, as compared to traditional asphalt concrete and cement concrete pavements; and fewer layers are not adequate to transfer vehicle loads to the subgrade, which results in accelerated pavement damage. Many rural roads show excessive damage in early spring due to weak subgrade conditions caused by the melting of snow and thawing of soil, and the roads may become inaccessible to vehicles (Saarenketo and Aho 2005).

Figure 2. Typical agricultural vehicles that frequently use rural roads.

1.2 PROBLEM STATEMENT

Approximately 2.9 million miles, or 71%, of roads are in rural areas across the nation, where 30% of annual vehicle miles traveled are over rural roads, which require reconstruction and improvement, as they experience significant damage due to heavy agricultural vehicles (*Congressional Research Service: Rural Highways* 2018). However, less funding is available for rural road maintenance and restoration, as compared to Interstate and state highways. Rural roads receive federal funding, which is distributed among highways, Interstate highways, and high-volume urban and rural roads; however, low-volume rural roads under county or local governments are not eligible to use these funds, where the share of about 37% was allocated to rural roads during FY 2009–FY 2015 (*Congressional Research Service: Rural Highways* 2018). Table 1 shows a comparison between funding for urban and rural roads across the nation. It should be noted that rural road funding has also decreased over the past years. In addition to insufficient funding, lack of data recording road damage or distress hinders planning rural roads' maintenance schedules. Moreover, a recent trend is also observed of converting rural paved roads to unpaved roads due to the lack of maintenance budget available for rural paved roads (Dobson et al. 2014; Fay et al. 2015).

Table 1. Comparison Between the Federal Funding Received by Rural and Urban Roads in a Million Dollars (*Congressional Research Service: Rural Highways* 2018)

	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
Rural	21,615	16,409	14,179	14,331	14,327	13,668	14,002
Urban	35,136	29,452	23,816	21,865	24,186	24,549	23,082
Total	56,750	45,861	37,995	36,196	38,513	38,216	37,084
Rural %	38.1%	35.8%	37.3%	39.6%	37.2%	35.8%	37.8%

In Illinois, rural roads are maintained by townships; and the head of a township is known as the highway commissioner. Illinois has the highest number of local governments of any state in the nation, consisting of 102 counties, 1,457 townships, and 1,297 municipalities (Winkelman 2015). A county has a few townships and one county engineer, who provides technical support to the townships, coordinates rural road maintenance plans, and assures funding from IDOT. Often, a highway commissioner is not an engineer but has experience on rural road maintenance and management. Highway commissioners use their expertise to access road damages or distress by evaluating roads while driving a truck and looking around through the windshield. This method is known as a *windshield survey,* which is subjective and might lead to spending road maintenance funds in rural roads in an inefficient manner.

The degree of road damage can be assessed by measuring distresses such as cracks, potholes, patches, and ruts with measuring tapes and straightedges, and recording the distress measurement according to American Society of Testing and Materials (ASTM) standards. Several graphs can be used to normalize pavement distresses; and with use of an equation, the condition of the road can be quantified. Several scales are available to express road condition, such as the Pavement Serviceability Rating (PSR), Pavement Condition Index (PCI), and Pavement Surface Evaluation Rating (PASER), Unsurfaced-Road Condition Index (URCI) (Eaton and Beaucham 1992; McGhee 2004; *Pavement Surface Condition Rating Manual* 2012; "Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys" 2008; Walker et al. 2001a; Yoder and Milhous 1964). Note that physical measurements of pavement distresses are often time-consuming and labor-intensive. Beyond that, because many local officials do not have a technical background, they do not want to go through this complicated process to measure road distresses. Instead, they commonly prefer doing subjective windshield surveys.

Pavement damage is an important characteristic that indicates the condition of a road. Nowadays, the most commonly used measure of road-surface damage is the International Roughness Index (IRI) (Arhin et al. 2015; Sayers et al. 1986). IRI is currently the most widely used and accepted indicator or road-surface roughness measuring index and is often represented in units of m/km or in./mile. IRI is computed by using a mathematical model of a quarter car, which represents the single-tire system, to measure the profile of the road ("Standard Practices for Simulating Vehicular Response to Longitudinal Profiles of Traveled Surfaces" 2012). A higher IRI value indicates rougher or significantly distressed roads, whereas a lower IRI value suggests smoother roads.

Some standard methods and equipment have been used for measuring IRI, like a profilograph, response-type instruments mounted on vehicles, walking profilers, and inertial profilers (Chang et al. 2009; Gillespie et al. 1980; Magnusson and Arnberg 1976; McGhee 2004; “Measuring and Specifying Pavement Smoothness” 2016). There are various pros and cons of each method. Nowadays, most highway agencies and local transportation agencies collect IRI data using a laser sensor or high-speed profilers. Such equipment measures surface profiles at normal traffic speeds and provides reasonably accurate IRI results. These types of devices are mounted on a full-size van or a trailer; therefore, they are difficult to use on roadways for short periods and are expensive, as well as delicate, complicated, and time-consuming; and they require a professional operator.

1.3 RESEARCH OBJECTIVE

The objective of this research project is to develop methodologies for the evaluation of different types of seal-coated, gravel, and dirt roads by using a best-practice-oriented pavement-management system in Illinois. For this objective, this project compiled and investigated the current practices of local transportation officials in an effort to provide better and more reliable methods to evaluate rural road distresses. Upon our successful accomplishment of the research objective, the local transportation official will be able to make a rational decision and allocate limited maintenance funds according to the needs.

For establishing a best-practice guide, the methodologies were developed in this project based on the following:

1. A comprehensive literature review encompassing both national and international research studies
2. Conducting a statewide survey to identify best practices applied by local agencies for the evaluation and treatment of unpaved roads
3. Conducting follow-up interviews with a number of personnel at local agencies to document in detail their practices and collect their data for proven field effectiveness
4. Examining historical maintenance and field-performance records of selected in-service roads having different surface characteristics and structural design factors, and carrying different traffic volumes
5. Determining maintenance cost for several distress treatments applicable for different types of unpaved roads

1.4 RESEARCH APPROACH

The research efforts in this study have been undertaken through the following six tasks:

- *Literature review:* National and international practices of evaluating and maintaining rural roads were reviewed. Published literature such as research reports, peer-reviewed journal articles, conference papers, and national and international standard protocols were collected and reviewed to document current practices followed by other states and countries to evaluate and maintain rural roads.

- *Statewide survey:* After we documented national and international practices of the evaluation and maintenance of rural roads, a set of survey questions was prepared to collect State of Illinois practices. The survey questionnaire was prepared to evaluate statewide maintenance practices by counties and townships. The survey responses revealed the challenges and difficulties faced by those units in evaluating and maintaining rural roads.
- *Manual distress evaluation of rural roads:* The traditional labor-intensive method to evaluate rural roads was undertaken in this task. The yearlong distress measurement was performed to better understand the conditions of rural roads under various climatic conditions.
- *Automated distress evaluation of rural roads:* The traditional automated method, as well as a cost-effective method, to measure rural roads was undertaken. The traditional automated method, the low-cost innovative method, and the manual distress-evaluation efforts were compared. A guideline document was prepared to establish an innovative, cost-effective method to measure rural road distresses.
- *Collecting maintenance and cost information:* Data on the traditional maintenance techniques of rural roads followed by counties and townships were collected and reported in this document. The overall maintenance costs in terms of labor and road maintenance were compiled and reported in this report.
- *Recommendation:* A recommendation is made for future research for a more effective and efficient way of evaluating rural roads.

CHAPTER 2: LITERATURE REVIEW

2.1 BACKGROUND

In this report, the seal-coated, gravel, and dirt roads are referred to as *rural roads* unless otherwise specified. The following information is summarized from the document *Roadway Design Standards for Rural and Suburban Subdivisions* (Wiegand and Stevens 2007) unless otherwise indicated.

2.2 CHARACTERISTICS OF RURAL ROADS

Rural roads are the backbone of the transportation system. Rural areas commonly lack public transportation; and residents depend on their private vehicles to get them to work, school, and shopping sites. Rural roads also serve millions of recreational users every year. Rural roads are a transportation chain from agricultural fields to local markets or the main highway network. In emergencies such as wildfire and flooding events, rural roads provide the means for emergency response and evacuation. They may be “legacy” roads that evolved to serve existing uses from their original purposes as railroad grades, wagon trails, or historical logging roads. They are commonly one to two lanes wide, with natural, gravel, or another surfacing. Rural roads consist of paved roads, seal-coated roads, gravel roads, and dirt roads. This literature review is focused on seal-coated, gravel, and dirt roads only.

2.2.1 Seal-Coated Roads

Gravel roads that have been treated with an asphalt seal coat (such as chip seal or oil and chip) to maintain a comfortable ride, weatherproof the surface, and eliminate dust problems are called *seal-coated roads*. Figure 3 shows a seal-coated road in rural Illinois.

Figure 3. Typical seal-coated road.

2.2.2 Gravel Roads

Roads with a harder surface made by the addition of material such as uncrushed gravel (i.e., washed or river rock) and crushed gravel/stone are called *gravel roads.* Figure 4 shows a typical gravel road in rural Illinois. A minimum of 1.5 to 2.0 in. of gravel surfacing is generally necessary to be considered a gravel road (Walker et al. 2002). More gravel is needed to provide a good level of service.

Figure 4. Typical gravel road.

2.2.3 Dirt Roads

Roads made from the native soil or subgrade material are known as *dirt roads*. Dirt roads are also known as *earth roads*. Figure 5 shows a typical dirt road in rural Illinois.

Figure 5. Typical dirt road.

2.3 GEOMETRICS OF RURAL ROADS

Roadway geometrics are based on the function of design speed, which can be determined by assessing the use of the road, the use of the adjacent land, and the expected traffic volume on the road. Other geometric-related indices are vertical grade, stopping-sight distance, pavement-surface crown, right-of-way width, superelevation, shoulder width, minimum curve radius, maximum degree of curvature, vertical clearance, and slope (Beckemeyer and McPeak 1995). Establishing the design speed is the most critical factor in the geometrics of any roadway design.

Rural roads are divided into local, minor-collector, and major-collector roads. The primary purpose of all these connecting and collector roads, except the major-collector roads, is to provide access to private property. Rural roads carry a considerable amount of average daily traffic: fewer than 400 vehicles per day for a local road, more than 400 vehicles per day but less than 1,500 vehicles per day for a minor-collector road; however, the average daily traffic is more on major-collector roads, as for safety purposes they are not used to access private property. The speed limits to travel on these roads are set to be 30 mph for local roads with urban cross sections, and 45 mph for rural cross sections; the speed limit for minor-collector roads for urban roads is set to be 35 mph, and 55 mph for rural cross sections.

2.4 RURAL ROAD'S CROSS SECTION

Each type of road cross section has specific characteristics that define what is included in the roadway, e.g., traffic lanes, shoulders. Rural cross sections vary with different types of rural roads. The minimum cross-section requirements for the rural connector of design speed 60 mph should have a right-of-way of 80 ft, with a pavement width of 24 ft plus 8-ft shoulders and a minimum slope of 4:1. The right-of-way for the rural collector of design speed 50 mph should be a minimum of 66 ft, consisting of 22-ft pavement width, 5-ft shoulders, and a slope of 3:1. The roadway surface of a defined speed limit of 45 mph should have a right-of-way of 66 ft with 4-ft shoulders and a slope of 3:1. Rural cross sections include drainage ditches, which are adjacent to an elevated roadway and are designed to accommodate drainage from the roadway and adjacent properties. The required land for the right-of-way of a local road with a rural cross section exceeds 80 ft.

2.5 DISTRESSES IN RURAL ROADS

2.5.1 Distresses in Seal-Coated Roads

Cracks are the defects most seen in rural roads, and their severity levels depend on the width of the crack. As the width increases, severity level increases; and new cracks may appear in the form of block, alligator, fatigue, edge-transverse, and reflection cracking.

2.5.1.1 Fatigue, or Alligator, Cracks

Fatigue, or alligator, cracks are mostly instigated on the road surfaces subjected to repeated traffic loadings. Fatigue failure shows up in the form of fatigue cracks; can be characterized by interconnected cracks; and forms patterns of many-sided, sharp-angled pieces that resemble that of an alligator's skin or chicken wire. Therefore, a fatigue crack is also known as an alligator crack. Fatigue cracks propagate under the wheel-path surface due to excessive stress or strain as parallel longitudinal cracks. Figure 6(a) shows fatigue cracks observed in a seal-coated road in rural Illinois. Fatigue cracks initiate from the bottom of the pavement (i.e., bottom-up cracks), as well as from the top of the pavement (i.e., top-down cracks) (*Top-Down Fatigue Cracking of Hot-Mix Asphalt Layers* 2004).

2.5.1.2 Transverse Cracks

Transverse cracks are predominately perpendicular to the pavement centerline. They are mainly caused by the combination of thermal gradient curling and shrinkage of materials. Transverse cracks also appear in the asphalt-concrete overlay when the overlay is placed on the cement-concrete pavement; due to thermal expansion and contraction, joints exist and cracks initiate in the cement-concrete layer, and the crack propagates through the asphalt concrete (Smith and Romine 1999). This report considers only transverse cracks due to the temperature gradient and shrinkage of seal-coated materials. This type of a crack is often observed in Illinois due to a long, cold winter season. Figure 6(b) shows transverse cracks observed in a seal-coated road in rural Illinois.

(a) Fatigue, or alligator, cracks **(b) Transverse cracks**

(c) Longitudinal cracks **(d) Edge cracks**

Figure 6. Various cracks observed in seal-coated roads.

2.5.1.3 Longitudinal Cracks

Longitudinal cracks occur parallel to the pavement centerline and are not in the wheel path. Longitudinal cracks are both load- and non-load-associated. Load-associated longitudinal cracks are similar to fatigue cracks, and they are known as top-down cracks. Non-load-associated cracks are caused by improper paving operations and are not associated with loads (Raught 2007). Figure 6(c) shows a longitudinal crack in a seal-coated road in rural Illinois.

2.5.1.4 Edge Cracks

Edge cracks apply only to pavements with unpaved shoulders. Crescent-shaped cracks or fairly continuous cracks intersect the pavement edge and are located within 2-ft of the pavement edge, adjacent to the shoulder. Edge cracks occur due to repeated tire pressure from oversized vehicles that drive close to the shoulder, also due to lack of lateral support in seal-coated roads in the absence of a paved shoulder. Figure 6(d) shows edge cracks in seal-coated roads in rural Illinois.

2.5.1.5 Rutting

Rutting is defined as a depression in the longitudinal surface in the wheel path. Rutting is associated with transverse displacement of material under heavy traffic loads. Transverse displacements in the material are caused due to shear failure of the road material. Figure 7(a) shows the rutting measurement using straight edges, and Figure 7(b) shows a closer look at the gap between the seal-coated road and the straight edge. Rutting causes vehicles to hydroplane and could impose severe safety concerns if vehicles are traveling at high speeds on rural roads.

(a) Rut-depth measurement **(b) A closer look at the rut depth**

Figure 7. Rutting in seal-coated roads.

2.5.1.6 Potholes

Potholes are bowl-shaped holes of various sizes in the pavement surface with a minimum dimension of 6-in. Figure 8(a) shows a pothole in a seal-coated road. Potholes are created from the progression of fatigue cracks. Cracks allow water to penetrate through the seal coat, and the water makes the pavement weak. Due to repeated traffic loading, the weak pavement starts to break into small pieces and creates a hole in the pavement. The gap expands as more water gets into the weaker pavement. Figure 8(b) shows a pothole that is not associated with cracks; it was created due to loss of seal in the pavement. Potholes are mostly seen after the winter season, when the snow melts, or in the beginning of spring season, when seasonal rain occurs.

(a) Pothole associated with cracks **(b) Pothole associated with chip loss**

Figure 8. Potholes in seal-coated roads.

2.5.1.7 Patching/Patch Deterioration

Patching is done to cover potholes. However, larger size and too many patches in the pavement are also treated as pavement distresses. Also, patches deteriorate by showing cracks and ruts. Figure 9(a) shows a patch in a seal-coated road; and cracks start to grow in the patch, deteriorating the pavement. Figure 9(b) shows multiple patches in a seal-coated road.

(a) Patch deterioration with cracks

(b) Multiple patches

Figure 9. Patch in seal-coated roads.

2.5.1.8 Bleeding

The combination of an excessive amount of asphalt binder used in the seal coat and heavy tire pressure is the cause of bleeding or flushing, which occurs on the seal-coated pavement surface and is usually found in the wheel paths. Figure 10 shows bleeding of asphalt binder in a seal-coated road in rural Illinois. Bleeding occurs mostly in summer, when the binder is soft and tends to flow. The flushed binder makes a sticky surface on the road and sometimes gets stuck to tires. When binder sticks to tires, it pulls off seal coat from the pavement and makes a hole. This hole allows water to penetrate, create a pothole, and cause additional damage to the road.

Figure 10. Bleeding of asphalt binder in seal-coated road.

2.5.1.9 Polished Aggregate

This distress occurs when the surface binder is worn away to expose coarse aggregate and is the effect of repeated traffic loadings. It can be easily visible on the pavement surface when some parts of aggregates extend or arise above the asphalt, which leads to polishing and no skid resistance. Figure 11 shows the polished aggregate surface of a seal-coated road.

Figure 11. Polished aggregate in seal-coated road.

2.5.1.10 Chip Loss

The loss of the adhesive bond between asphalt cement and aggregate, most often caused by the presence of water in a seal-coated road, may result in raveling in the seal-coated road. Chip loss from a seal-coated road is shown in Figure 12.

Figure 12. Chip loss in a seal-coated road.

2.5.2 Distresses in Gravel and Dirt Roads

2.5.2.1 Improper Cross Section

Gravel and dirt roads should have a proper cross section to drain water to the ditch. Ponding of water will make the road weaker, causing rut development, which may lead to potholes or excessive deformation. Figure 13(a) shows a gravel road that lost gravel in the wheel path, and the rocks are pushed toward the edge and the crown. Figure 13(b) shows a dirt road with a clearly identified wheel path and a raised, grass-covered crown. There is no grass in the wheel path, due to abrasion of the wheel. Also, the dirt road does not have a proper ditch to drain off water.

(a) Gravel road

(b) Dirt road

Figure 13. The improper cross section in gravel and dirt roads.

2.5.2.2 Rutting

Ruts are developed in wheel paths due to lateral movement of gravel and soil under heavy traffic loading and due to shear failure of the materials. Rutting leads to ponding after rainfall because water cannot drain from the pavement. Figure 14(a) shows ponding in a gravel road due to rutting, and Figure 14(b) shows rutting in a dirt road.

(a) Gravel road

(b) Dirt road

Figure 14. Rutting in gravel and dirt roads.

2.5.2.3 Inadequate Roadside Drainage

Due to an insufficient crown, insufficient cross slope, and inadequate ditch, ponding occurs at the edge of the gravel and dirt road. Figure 15(a) shows inadequate roadside drainage in a gravel road, and Fig 15(b) shows inadequate roadside drainage in a dirt road.

2.5.2.4 Insufficient Gravel in Gravel Road

The gravel surface layer distributes heavy wheel loads and protects the soil from excessive deformation. Insufficient gravel causes the subgrade soil to carry the entire wheel load and eventually deform due to shear failure. Figure 16 shows a gravel road without sufficient gravel on the pavement.

(a) Gravel road

(b) Dirt road

Figure 15. Inadequate roadside drainage caused ponding on gravel and dirt roads.

Figure 16. Insufficient gravel on gravel road.

2.5.2.5 Dust

Vehicles on dry gravel and dirt roads can generate dust. Figure 17 shows dust on a gravel road. The fines present in the gravel layer can be picked up under the action of traffic and become airborne. Dust on gravel and dirt roads creates several problems, e.g., visibility can be severely restricted under heavy dust conditions thus creating a traffic hazard. Dust is a form of air pollution and can be very objectionable to nearby property owners. The loss of the fine material forms an unfirmly graded gravel surface that can eventually lead to a loss of stability. Without the fine binder materials, the larger particles become unstable and are dislodged by traffic.

Figure 17. Dust on a gravel road.

2.5.2.6 Washboarding, or Corrugation

Washboarding, or corrugation, is closely spaced ridges and valleys (ripples) at fairly regular intervals (Eaton et al. 1988). The ridges are perpendicular to the traffic direction. This type of distress is usually caused by repeated traffic loading and may cause the loss of aggregate. Figure 18 shows washboarding, or corrugation, on the dirt road.

Figure 18. Washboarding, or corrugation, on dirt road (Jones and Paige-Green 2015).

2.6 RURAL ROAD SURFACE-EVALUATION METHODS

2.6.1 Windshield Inspection

In this type of inspection, evaluators are required to rate the condition of the road on the basis of visual identification of the type, severity level, and extent of the distress, as observed from inside a moving vehicle on the road. This approach is more qualitative, even subjective, because inspection results may vary considerably from one person to another for the same the road segment. Few subjective evaluations of rural roads are given below. Note that specifications often require both observation and physical measurement of distresses.

2.6.1.1 Pavement Surface Evaluation and Rating (PASER)—Manual Method for Seal-Coated Road

Table 2 below shows the evaluation criteria of seal-coated road surface using a method called Pavement Surface Evaluation Rating (PASER) (Walker et al. 2001a).

Table 2. PASER Criteria for Evaluating Seal-Coated Roads

Surface rating	Condition	Visual distress	Maintenance and repair	Surface age
5	Excellent	No distress. Excellent surface and ride.	New surface condition. Excellent drainage. No maintenance required.	1-year old
4	Good	Slight surface wear from traffic. Slight loss of surface aggregate. Minor flushing or tracking.	Excellent or good drainage. Little or no maintenance required.	2- to 4-years old
3	Fair	Moderate surface wear and/or flushing. Slight edge cracking. Occasional patch or loss of the top layer of seal coat.	Good or fair drainage. May need a spot repair. Drainage improvement and/or minor patching. Preventive maintenance. Seal coat recommended.	3- to 5-years old
2	Poor	Severe wear or flushing. Moderate to severe edge cracking or patching. Potholes or significant loss of surface seal coat. Alligator cracking.	Fair or poor drainage. Ditching or culvert improvements needed. Patching or surface edging is needed. New surface seal coat required.	More than 5-years old
1	Failed	Extensive loss of surface seal coat. Severe edge cracking and/or alligator cracking. Extensive patching in poor condition and/or rutting.	Extensive poor drainage. Needs base improvement and new double seal coat.	More than 5-years old

The rating is qualitative and consider*s* visual observation of wear and flashing, loss of surface, edge cracking, alligator cracking, patching, potholes, and drainage. The rating also considers the age of the surface. The rating ranges from 5 to 1, with 5 meaning *excellent* and 1 meaning *failed*.

2.6.1.2 Pavement Surface Evaluation and Rating (PASER)—Manual Method for Gravel Road

Table 3 shows the PASER evaluation criteria of a gravel road surface (Walker et al. 2002). The rating is a combination of qualitative and quantitative, as several distress measurements are needed. Five road conditions are used to evaluate and rate gravel roads; and they depend on road crown; road drainage; gravel layer; surface deformation such as washboarding, potholes, and ruts; and surface defects such as dust and loose aggregate. Rating 5 means *excellent* and rating 1 means *failed*. The physical measurement is needed for the crown, washboarding, rutting, and loose aggregate.

Table 3. PASER Criteria for Evaluating Gravel Roads

Surface rating	Condition	Visual distress	General condition/treatment measures
5	Excellent	No distress. Dust controlled. Excellent surface condition and ride.	New construction—or total reconstruction. Excellent drainage. Little or no maintenance needed.
4	Good	Dust under dry conditions. Moderate loose aggregate. Slight washboarding.	It has been recently regraded. Good crown and drainage throughout. Adequate gravel for traffic. Routine grading and dust control may be needed.
3	Fair	Good crown (3”–6”). Adequate ditches on more than 50% of the roadway. Gravel layer mostly adequate, but additional aggregate may be needed in some locations to correct washboarding or isolated potholes and ruts. Some culvert cleaning needed. Moderate washboarding (1”–2” deep) over 10%–25% of the area. Moderate dust, partial obstruction of vision. None or slight rutting (less than 1” deep). An occasional small pothole (less than 2” deep). Some loose aggregate (2” deep).	Shows traffic effects. Regrading (reworking) necessary to maintain. Needs some ditch improvement and culvert maintenance. Some areas may need additional gravel.
2	Poor	Little or no roadway crown (less than 3”). Adequate ditches on less than 50% of the roadway. Portions of the ditches may be filled, overgrown, and/or show erosion. Some areas (25%) with little or no aggregate. Culverts are partially full of debris. Moderate to severe washboarding (over 3” deep) over 25% of the area. Moderate rutting (1”–3”), over 10%–25% of the area. Moderate potholes (2”–4”) over 10%–25% of the area. Severe loose aggregate (over 4”).	Travel at slow speeds (under 25 mph) is required. Needs additional new aggregate. Major ditch construction and culvert maintenance also required.
1	Failed	No roadway crown, or road is bowl-shaped with extensive ponding. Little if any ditching. Filled or damaged culverts. Severe rutting (over 3” deep), over 25% of the area. Severe potholes (over 4” deep), over 25% of the area. Many areas (over 25%) with little or no aggregate.	Travel is difficult, and the road may be closed at times. Needs complete rebuilding and/or new culverts.

2.6.1.3 Pavement Surface Evaluation and Rating (PASER)—Manual Method for Unimproved-Road

Table 4 is used to rate the unimproved road based on PASER criteria (Walker et al. 2001b). The unimproved road is referred to as an *earth road* or a *dirt road*. The rating is qualitative and considers road profile, ride quality, drainage, surface material, road crown, accessibility due to weather condition, rutting, and washboarding. The rating ranges from 4 to 1, with 4 meaning *very good* and 1 meaning *poor*. The rating is also based on ride quality with a driving speed of 10 to 25 mph.

Table 4. PASER Criteria for Evaluating Dirt Roads

Surface rating	Condition	General condition, distress, and recommended improvement
4	Very good	Graded with cut and fill areas. Crown present. Ditches and culverts may be present. Comfortable ride over 25 mph possible. No significant ruts or potholes. Sandy or stable surface material. Access normally available in all weather. No improvement needed.
3	Good	May have some limited grading, crown or drainage. Slight rutting, less than 3 in. deep. Very few potholes, little washboarding. Comfortable ride at 15–20 mph. Good access and stable surface except in severe weather or unusual conditions. Routine maintenance or spot-grading helpful.
2	Fair	Road follows natural terrain. The road not graded, with cuts or fill areas. Little or no crown. Limited or no ditches or culverts. Ruts may be very common, some over 6 in. deep. Occasional potholes and uneven surface conditions. The ride usually requires speeds lower than 15 mph. Access may be limited during and after rainfall. Significant grading required to improve drainage, repair ruts and potholes, and improve the road to good condition.
1	Poor	Very poor surface and driving conditions. The recreational trail, limited use. Severe rutting and/or extensive potholes. The surface condition often limits speed to less than 10 mph. Access for cars and trucks may be restricted for extensive periods. Reconstruction needed to provide improved access, repair severe distress, and improve the road to good condition.

2.6.1.4 Rural Road Condition-Survey Guide

A gravel road rating system was developed by Beckemeyer (1995), with a range from 0 to 100; and the rating was established based on a survey conducted by a group of panel members. Based on the rating system, rural road conditions were determined; and subsequently, a maintenance strategy was developed. Table 5 gives a summary of the gravel road rating system. The numerical rating 100–81 means *excellent* gravel road condition, and 20–0 represents a *failed* gravel road. The survey is to be conducted by a rating team of at least two members. The rating is obtained after driving over the entire length of a selected pavement section. After the initial drive-over, a representative portion of the section is selected. The raters then exit the vehicle, and each rater evaluates the area of the section that is identified as representative of the typical condition of the entire section. The rating is a combination of visual observation and measurements needed for the road crown, washboarding, rutting, and loose aggregates.

Table 5. Gravel Roadway Rating and Evaluation Scheme

Rating	Condition	Visual distress and overall roadway condition	Maintenance and repair	Level of repair
100–81	Excellent	Roadway surface is in excellent condition, with very good ridability. Good gravel thickness and excellent drainage. No distresses in the roadway, with the exception of dusting in dry conditions.	Little or no maintenance needed. Routine blading.	None
80–61	Good	Adequate gravel thickness, good pavement crown, and good drainage. Moderate loose aggregate and slight washboarding. Slight rutting (<25 mm [1 in.]) in some areas during wet weather.	Routine blading. Cut out washboard areas and re-lay the gravel when moisture is present.	Routine/ preventive maintenance
60–41	Fair	Good crown of 75 to 150 mm (3 to 6 in.). Primary ditches present on more than 50 percent of the roadway. Some culvert cleaning is necessary. Secondary ditches are beginning to develop along portions of the shoulder line. Gravel layer is adequate, but additional aggregate is necessary for isolated areas. Moderate washboarding (25 to 50 mm [1 to 2 in.] deep) over 10% to 25% of the area. Moderate rutting (25 to 50 mm [1 to 2 in.] deep), especially in wet weather. Occasional small potholes (<50 mm [2 in.] deep). Some loose aggregate (50 mm [2 in.] deep).	Regrading of the surface is necessary to eliminate washboarding and secondary ditch. The regrading should be done when moisture is present. Some areas may need additional gravel. Some ditch improvement and culvert cleaning may be necessary.	Heavy maintenance
40–21	Poor	Travel at slow speeds (< 40 kph [25 mph]) is required. Little or no roadway crown (<75 mm [3 in.]). Adequate primary ditches on less than 50 % of the roadway. Deep secondary ditches located along more than 50 % of the roadway length. Some areas (up to 25 %) with little or no aggregate. Culverts partially filled with debris. Moderate to severe washboarding (>75 mm [3 in.] deep) over 25 % of the area. Severe rutting (>75 mm [3 in.]) in 10% to 25% of the roadway during wet weather. Moderate potholes (50 to 100 mm [2 to 4 in.] deep) over 10% to 25% of the area. Severe loose aggregate (>100 mm [4 in.])	Reshaping of the roadway surface and shoulders is necessary, along with the placement of additional aggregate. Major ditch reconstruction and culvert maintenance are also required.	Rehabilitation
20–0	Failed	Travel on the roadway is very difficult. No roadway crown or the road is bowl-shaped with extensive ponding. Little, if any, primary ditches. Deep secondary ditches are located along most of the roadway. Culverts are damaged or filled with debris. Severe rutting (>75 mm [3 in.]) on more than 25% of the area, especially in wet weather. Severe potholes (over 100 mm [4 in.] deep) over at least 25% of the area. Many areas (over 25%) with little or no aggregate.	The entire roadway cross section must be reshaped, and a new gravel layer must be constructed. Ditches must be reestablished, and new culverts are typically needed.	Reconstruction

2.6.1.5 Ride-Quality Rating Guide

The ride-quality rating guide is a modified version of the PASER gravel and unimproved guide (*Ride Quality Rating Guide* 2010). Table 6 summarizes the rating system. The rating ranges from 10-1, where 10 represents a gravel and dirt road in *excellent* condition and 1 represents *failed* gravel and dirt roads. The individual roadway may not have all of the types of distresses listed for any particular rating; they may have only one or two types. The passenger-car speeds are based on surface condition, which links to rider comfort (i.e., does not spill driver's coffee) and minimal vehicle wear and tear, assuming no safety or geometric constraints.

Table 6. Ride-Quality Rating for Gravel and Dirt Roads

Rating		Speed (mph)	Distress description	Comment
10	Excellent	65+	N/A	Rides like good asphalt pavement. Rare. May be hazardous if alignment and shoulders don't allow for safe travel at high speeds.
9	Very good	55–65	N/A	Rides like worn asphalt pavement. Uncommon. Often dangerous due to speeds too high for the alignment.
8	Good	50–55	Dust under dry conditions; moderate loose aggregate; slight washboarding.	Minor roughness and surface distress.
7	Good	45–50		Significant roughness, distresses, and loose aggregate.
6	Fair	35–45	Moderate washboarding (1"–2" deep) over 10%–25% of area; moderate dust, partial obstruction of vision; none or slight rutting (less than 1" deep); an occasional small pothole (less than 2" deep); some loose aggregate (2" deep).	Washboards, potholes, loose aggregate, and fear of isolated, substantial roughness reduces comfortable travel speeds
5	Fair	25–35		Roughness and distresses are prevalent and occasionally severe, significantly reducing speeds.
4	Poor	17–25	Moderate to severe washboarding (over 3" deep) over 25% of area; moderate rutting (1"–3") over 10%–25% of area; moderate potholes (2"–4" deep) over 10%–25% of area; severe loose aggregate (over 4").	Threat of dangerous roughness and vehicle damage substantially reduces speeds.
3	Poor	10–17		High risk of vehicle damage as speeds increase. Dodging hazards is a frequent driving task.
2	Very poor	5–10	Severe rutting (over 3" deep) over 25% of area; severe potholes (over 4" deep) over 25% of area; many areas (over 25%) with little or no aggregate.	Dodging hazards is a constant driving task. Passenger vehicles at risk of bottoming out.
1	Failed	0–5		Dodging hazards is a constant driving task. Passenger vehicles may not be able to pass.

2.6.2 Manual Distress Measurement

In the manual distress-evaluation system, each distress is measured and reported based on a certain scale. This type of distress measurement is generally quantity based, and the evaluation of the severity level and the extent depends on objective quantitative measurements and analyses. Manual distress measurement is available for both Portland cement concrete (PCC) and asphalt concrete (AC) pavements in terms of the Pavement Condition Index (PCI) rating ("Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys" 2008). For PCC and AC pavements, PCI is well accepted and the most used rating system. However, the method requires extensive data collection and analysis using standard protocols. A method has been developed similar to PCI for unsurfaced roads, and that method is described below.

2.6.2.1 Unsurfaced-Road Condition Index (URCI)

This index is a numerical indicator, based on a scale of 100–0, that measures the road's integrity and operational condition (Eaton et al. 1988, 1987; Eaton and Beaucham 1992). The URCI is determined by measuring surface distress of unsurfaced roads, i.e., gravel and dirt roads. Table 7 presents the URCI rating system: the range 100 to 75 indicates an *excellent* condition, and the range 25 to 0 indicates a *poor* condition.

Table 7. URCI Rating System (Eaton et al. 1987)

URCI Rating	Condition
100–75	Excellent
50–75	Good
25–50	Fair
0–25	Poor

This method requires a physical measurement of distresses and then use of specified graphs to calculate a few parameters named as *deduct values* and then use of an equation to calculate URCI. Table 8 presents a standard method to record seven types of distresses observed in unsurfaced roads and their measuring units. The inspection sheet requires general information about the road and also a sketch of a representative section. The sketch shows the length and width of the representative section and the distress location with its severity level.

Table 8. Inspection Sheet Used to Record the Severity of Various Distresses Found in Unsurfaced Roads

<table>
<tr><th colspan="9">Unsurfaced-road inspection sheet</th></tr>
<tr><td colspan="3">Branch</td><td colspan="3">Section</td><td colspan="3">Date</td></tr>
<tr><td colspan="3">Sample unit</td><td colspan="3">Area of sample</td><td colspan="3">Inspector</td></tr>
<tr><td colspan="4">Sketch</td><td colspan="5">Distress type
1. Improper cross section (Linear feet)
2. Roadside drainage (Linear feet)
3. Corrugations (Square Feet)
4. Dust (Table)
5. Potholes (Number)
6. Rutting (Square Feet)
7. Loose aggregate (Linear feet)</td></tr>
<tr><td colspan="9">Distress quantity and severity</td></tr>
<tr><td colspan="2">Distress type</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td rowspan="3">Quantity and severity</td><td>L</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>M</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>H</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">8. Calculation</td></tr>
<tr><td colspan="2">Distress type</td><td>Density</td><td>Severity</td><td colspan="2">Deduct value</td><td colspan="3" rowspan="5">9. Remarks</td></tr>
<tr><td colspan="2"></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="3">Total deduct value =</td><td>q =</td><td colspan="2">URCI =</td><td colspan="3">Rating =</td></tr>
</table>

The severity level—low (L), medium (M), or high (H)—is measured following Tables 9, 10, and 11. A detailed URCI calculation is given in the articles mentioned above.

Table 9. Guideline to Determine Distress Severity Used in the Inspection Sheet

	Distress severity (→)		
Distress type (↓)	**L (low)**	**M (medium)**	**H (high)**
Improper cross section	Small amounts or evidence of ponding water on the road surface, a completely flat road surface (no cross-slope), or both.	Moderate amounts or evidence of ponding water on the road surface, a bowl-shaped road surface, or both.	Large amounts or evidence of ponding water on the road surface, severe depressions in the wheel paths on the road surface, or both.
Roadside drainage	Small amounts of the following: 1. Ponding water or evidence of ponding water in the ditch. 2. Overgrowth or debris in a ditch.	Moderate amounts of the following: 1. Ponding water or evidence of ponding water in the ditch. 2. Overgrowth and debris in the ditch. 3. Evidence of erosion of ditch into shoulder or roadway.	Large amounts of the following: 1. Ponding water or evidence of ponding water in the ditch. 2. Water running across or down the road. 3. Overgrowth and debris in the ditch. 4. Erosion of ditch into shoulder or roadway.
Corrugations	Corrugations less than 1” deep, low-severity roughness, or both.	Corrugations 1” to 3” deep, medium-severity roughness, or both.	Corrugations 1” to 3” deep, medium-severity roughness, or both.
Dust (Refer to Table 10.)	Thin dust that does nor obstruct visibility.	A moderately thick cloud that partially obstructs visibility and causes traffic to slow down.	A very thick cloud that severely obstructs visibility and causes traffic to significantly slow down or stop.
Potholes	Refer to Table 11.		
Rutting	Ruts less than 1” deep, low-severity roughness, or both.	Ruts 1” to 3” deep, medium-severity roughness, or both.	Ruts deeper than 3”, high-severity roughness, or both.
Loose aggregate	Loose aggregate on the road surface, an aggregate berm on the shoulder or less-traveled roadway area of less than 2”, or both.	Moderate (2” to 4“) aggregate berm on the shoulder or less traveled roadway area; excessive fines are usually found on the roadway surface.	Large (greater than 4”) aggregate berm on the shoulder or less-traveled roadway area.

Table 10. Severity of Dust Determined for Unsurfaced Roads

Dust is not rated by density. The deduct value for the levels of severity are as follows:	
Low (L)	2 points
Medium (M)	5 points
High (H)	15 points

Table 11. Severity of Potholes Determined for Unsurfaced Roads

Maximum Depth (↓)	**Average Diameter (→)**			
	Less than 1′ (0.8 m)	1′–2′ (0.8 m–0.6 m)	2′–3′ (0.6 m–1 m)	More than 3′ (1 m)
0.5″–2“(1.5–5 cm)	L	L	M	M
2″–4" (5–10 cm)	L	M	H	H
>4″(>10 cm)	M	H	H	H

2.6.3 Distress Measurement by Automated Vehicles

A moving vehicle equipped with cameras and measurement devices collects and synthesizes complete data on the visual type, severity level, and extent of the distress prevailing on the road surface and evaluates the road condition through data analyses. Distress data can be used to calculate PCI or IRI. A few of the automated techniques are explained below.

2.6.3.1 International Roughness Index (IRI)

The IRI was established in 1986 by the World Bank (Sayers et al. 1986). It is produced using a quarter-car model and the longitudinal road profile. The total vertical movement of a standard passenger vehicle accumulated as an output from the mathematical model is referred to as the *quarter-car model* and is divided by the longitudinal profile length to produce the IRI value with units of in./mi. or m/km. The smaller values represent a smoother road, and higher values are indicative of a rougher one. Figure 19 shows the IRI standard values for various types of roads and surface types (Sayers and Karamihas 1998). IRI is based on simulation of roughness response of a standard quarter car at a speed of about 80 km/h. The IRI model comprises a series of differential equations that relate the motions of a simulated quarter car to the road profile. The IRI is the accumulation of the motion between the spring and the length of the longitudinal profile (Park et al. 2007). The output of IRI accumulation is the result of the spring constant (K) and dampening factor (D), shown in Figure 20 (“Pavement Technology Advisory—Data Collection Vehicles—PTA-T2” 2005). Various vehicle-mounted instruments are used to measure IRI.

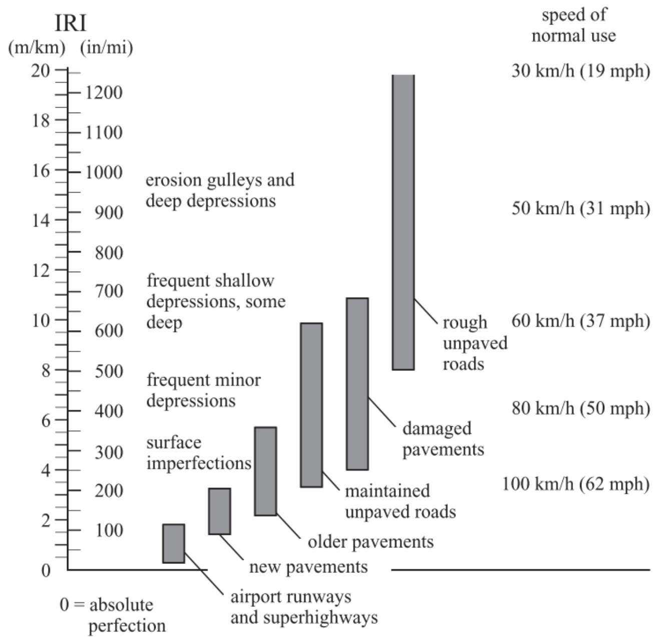


Figure 18. Variation of IRI for various road-surface types (Sayers and Karamihas 1998).

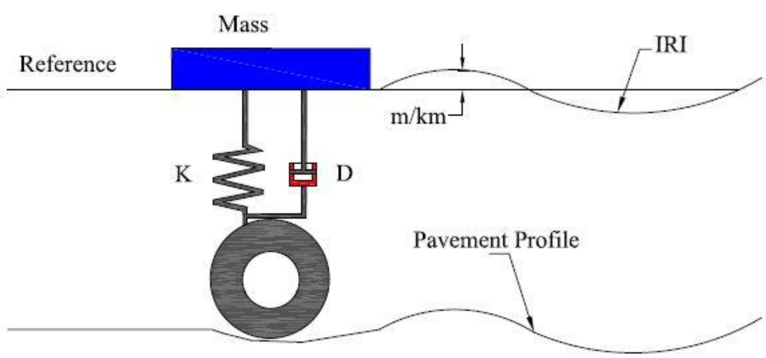


Figure 19. Typical quarter-car model (redrawn from "Pavement Technology Advisory—Data Collection Vehicles—PTA-T2" 2005).

2.6.3.2 High-Speed Inertial Profilers

The laser-survey vehicles measure the road-profile direction and collect pavement-condition data, independent of the speed, at 30- to 65-ft intervals. The principal components of a high-speed profiler are laser-based height sensors, an accelerometer, and an accurate distance-measuring system. The height sensors record the distance of the pavement surface from the vehicle, and accelerometers record the vertical acceleration of the sensors. Figure 21 shows the high-speed inertial profiler with its parts (Sayers and Karamihas 1998). Figure 22 shows a high-speed laser profilometer used by IDOT.

Figure 22(a) shows the displacement transducer; Figure 22(b) shows the laser source; Figure 22(c) shows the laser beam on the ground; and finally, Figure 22(d) shows the data-collection system mounted on the truck. The recorded results are accurate; however, a skilled operator is needed, and the device is quite expensive, costing about $55,000 to $75,000 and not affordable for all local transportation agencies.

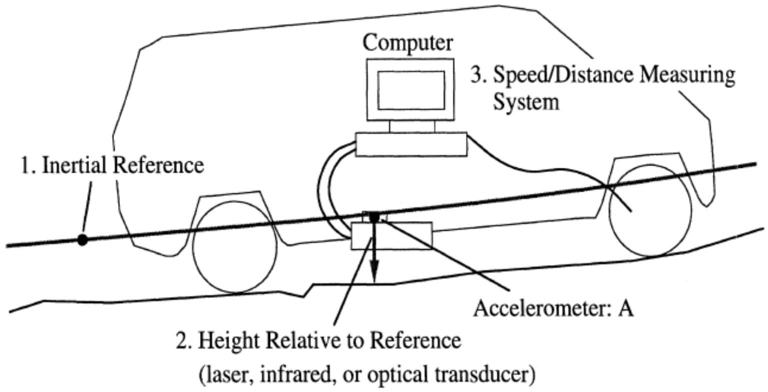
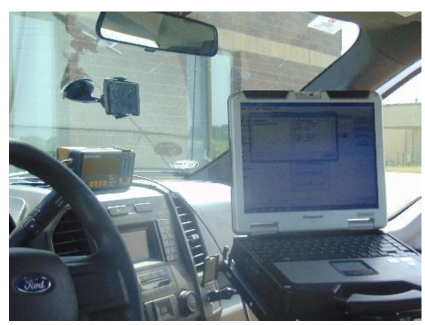


Figure 20. Schematic of high-speed inertial profiler (Sayers and Karamihas 1998).

(a) High-speed profiler mounted on truck and displacement transducer attached to the wheel

(b) Accelerometer and laser-beam source

(c) Laser beam projected on the ground



(d) Data-collection system

Figure 21. High-speed laser profilometer used by IDOT.

2.6.3.3 Lightweight Profilers

This type of profiling system is installed on lightweight vehicles such as a golf cart or all-terrain vehicle and usually is used to evaluate new pavements, as shown in Figure 23. The profiling system installed in lightweight profilers is similar to the one installed in the high-speed inertial laser profiler. The profilographs are obtained using different pavement sections; and they help to generate the profile index and bump locations, which aid in determining other roughness-related indices such as the IRI.

(a) Lightweight profilometer with the guidance system

(b) Lightweight profilometer with sensors

Figure 22. Lightweight profilometer (Perera et. al. 2005).

2.6.3.4 Walking Profilometer

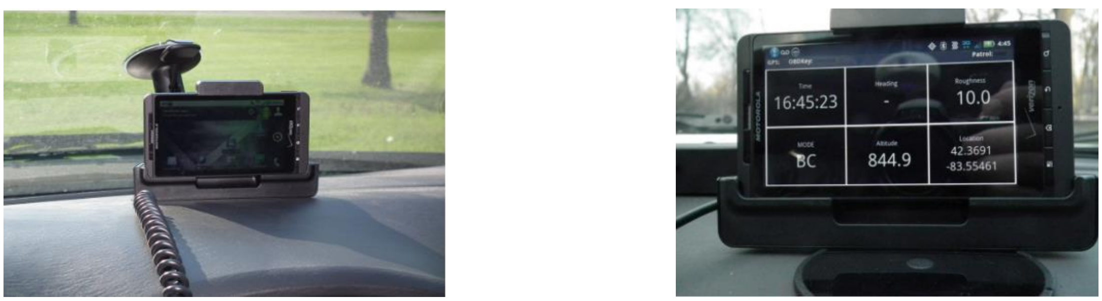
The walking profilometer uses an inclinometer that is fixed between the support wheels on either side to evaluate the surface profile, as shown in Figure 24. The measurement results are collected and verified with the high-speed profiler data.

Figure 23. Walking profilometer used by IDOT.

2.6.4 Use of Cell Phone Apps to Measure IRI

With the advent of smartphones, various applications are introduced on a daily basis for public use; the applications are easy to access and free to use. They are often available without Internet connection on smartphones. As a result, smartphone-based applications are used nowadays to quantify road roughness, as they are equipped with sensors and accelerometers. Only a few studies could be found in the literature on measuring IRI using cell phones (Aleadelat et al. 2018; Arhin et al. 2015; Islam et al. 2014; Schlotjes et al. 2014). A built-in accelerometer in a cell phone can measure road roughness, and the relationship between the accelerometer data and road roughness has been shown to be linear (Douangphachanh and Oneyama 2014).

A recent study conducted in Illinois showed that cell-phone-measured IRI and inertial-profilometer-measured IRI showed good correlations with the data obtained on smooth pavements at an operating speed of 50 mph (Islam et al. 2014). Another study, in Wyoming, indicated that the cell-phone-measured IRI data varied with speed; and the most variation was seen when the vehicle was driven at 50 mph (Aleadelat et al. 2018). In Michigan, researchers conducted a similar study to measure IRI using their cell phone application; the data at the initial state showed low accuracy. However, a much higher accuracy was achieved when the driver took repeated data on the same road segment (Belzowski and Ekstrom 2015). Figure 25 shows a typical setup of a cell phone and the use of the cell phone app to measure the IRI of pavement.



(a) A cell phone mounted on the car to measure IRI **(b) Cell phone app to measure IRI**

Figure 24. Use of cell phone app to measure the IRI of pavements (Belzowski and Ekstrom 2015).

2.6.5 Use of Unmanned Aircraft or Drones to Evaluate Rural Roads

Remote-sensing technologies can overcome the barriers of cost versus data quality that have hindered unpaved-road management by providing usable data that are compatible with a decision-support system. They can be cost effective for collecting data quickly and in a repeatable manner. An unmanned helicopter and drone, shown in Figure 26, were used for data collection, which proved to be more efficient and less time-consuming than the ordinary profilometers (Dobson et al. 2014). A cost analysis of the automated approach determined that this method is cheaper than current manual inspections. Manual methods incorporating the use of two 100-ft representative segments may cost at least $160/mi, whereas evaluating the total road segment using the automated system would cost only $19.42 per measured mile.

(a) Unmanned helicopter

(b) Drone

Figure 25. Use of unmanned helicopter and drone mounted with a camera to collect images of rural roads (Dobson et al. 2014).

2.6.6 Advantages and Disadvantages of Various Profilers

The assessment of road roughness can be done by using the above-mentioned road-roughness measuring devices that collect the pavement-condition data and measure the longitudinal road profiles for the selected site. Most of them are used and operated by professionals. Survey-related techniques have proven accurate, but they are not viable because they are cost-prohibitive. However, inertial laser profilers in use nowadays commonly perform acceleration measurements that are inaccurate at low speeds, e.g., less than 10 mph (Sayers and Karamihas 1998). Table 12 presents the different road-roughness measuring devices with their initial costs. The information was collected from email communication with Surface Systems & Instruments, Inc. on 2/12/2019.

Table 12. Initial Cost and Accuracy of Three Types of Profiler

Road-Roughness Measuring Device	Initial Cost
High-speed inertial profiler	$55,000–$75,000
Lightweight profiler	$60,000–$70,000
Walking profiler	$30,000–$35,000

2.7 SUMMARY

Both subjective and objective methods have been used in the past to evaluate rural road conditions. Also, fully developed and sophisticated profilers are available to measure rural road conditions, although they are expensive and require skilled operators. Local agencies commonly intend to explore other inexpensive but reliable techniques as new alternatives to evaluate rural roads. For this reason, this research effort explored using cell phone applications, or apps, for assessing roughness conditions of seal-coated, gravel, and dirt roads. Some of the commercially available cell phone apps were used to measure IRI values of seal-coated, gravel, and dirt roads. Also, the research efforts in this project developed a Seal-Coated Road Condition Index (SCRCI) method to measure the seal-coated road-surface condition using the manual method. Further, the Unsurfaced-Road Condition Index (URCI) was introduced in this chapter for the intended use of measuring gravel and dirt road-surface conditions.

CHAPTER 3: STATEWIDE SURVEY

3.1 BACKGROUND

A statewide survey was conducted to compile and document the current practices of local transportation officials. The survey questions are given in Appendix A. The survey was prepared using the SurveyMonkey web tool. The online subscription was purchased to prepare a professional survey portal, record the survey responses, and conduct a preliminary analysis of the survey results. The SurveyMonkey survey link was emailed to contacts in Illinois counties and townships by the project TRP chair. Also, the project team attended two seminars, the West Central Illinois Highway Commissioners Association Summer Seminar on 6/14/2016 and the Summer Seminar of Highway Commissioners on 8/1/2016, to collect paper-based survey responses. The TRP chair and several TRP members were present at these seminars to introduce and facilitate the survey questionnaires and also to communicate with highway commissioners to emphasize the need for the research project. In total, 72 survey responses were collected from the two seminars; and 61 online survey responses were collected.

The complete survey document, which can be found in Appendix A, included the following:

- Definition of seal-coated, gravel, and dirt roads
- Definition of windshield inspection, manual distress measurement, and distress measurement by automated vehicles
- The frequency of inspection of seal-coated, gravel, and dirt roads
- The strategy of inspecting seal-coated, gravel, and dirt roads
- Various distresses observed in seal-coated, gravel, and dirt roads
- Rank of distresses in seal-coated, gravel, and dirt roads according to the priority of maintenance
- Description of maintenance equipment used to maintain seal-coated, gravel, and dirt roads
- Description of maintenance techniques apply to maintain seal-coated, gravel, and dirt roads
- Questions regarding maintenance techniques applied and equipment used for each distress type observed in seal-coated, gravel, and dirt roads
- Type of seal coats applied on gravel roads
- Subgrade stabilization techniques practiced by counties and townships
- Field-testing methods to determine the structural condition of seal-coated, gravel, and dirt roads
- Data collected to perform a maintenance-management program
- Records on recently performed maintenance of seal-coated, gravel, and dirt roads

- Plans on maintaining seal-coated, gravel, and dirt roads
- Best practices of counties and townships for maintaining seal-coated, gravel, and dirt roads

County engineers and township highway commissioners provided survey responses on 151 seal-coated roads, 39 gravel roads, and 11 dirt roads. Figure 27 shows the locations of counties and townships responding to the online and paper-based survey.

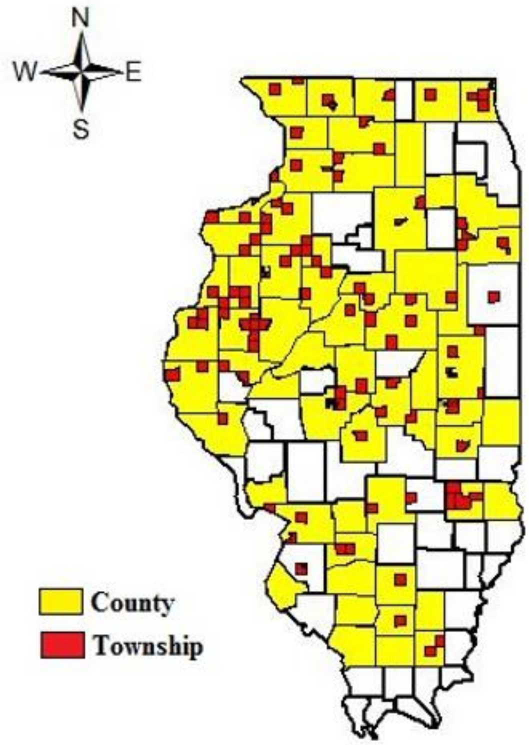


Figure 26. The map shows the locations of counties and townships that responded to the survey.

3.2 SURVEY-RESPONSE ANALYSIS

The survey responses were analyzed and categorized based on responses from county engineers and township highway commissioners. The survey responses are shown in various graphs. Appendix-B includes all the graphs.

3.2.1 Evaluation Frequency

Figure B-1 shows the evaluation frequency of seal-coated, gravel, and dirt roads by counties and townships. Most of the counties and townships evaluate seal-coated and gravel roads weekly and dirt roads once a month. 34% of the counties and 40% of the townships surveyed evaluate seal-coated roads weekly; 37% of the counties and 38% of the townships evaluate gravel roads weekly; and 43% of the counties and 45% of the townships evaluate dirt roads weekly. These county engineers and township highway commissioners drive on the rural roads and do a windshield survey; and for this reason, they evaluate the conditions of the rural roads very frequently, e.g., on a weekly basis.

3.2.2 Evaluation Method

Figure B-2 shows the evaluation method used by counties and townships. Most of the counties and townships use a windshield inspection method to evaluate seal-coated, gravel, and dirt roads. 76% of the counties and 74% of the townships surveyed use the windshield method to evaluate seal-coated roads; 87% of the counties and 85% of the townships use the windshield method to evaluate gravel roads; 91% of the counties and townships use the windshield method to evaluate dirt roads. Comparing Figure B-1 and Figure B-2, the weekly evaluation of the rural road is possible only when the windshield inspection method is used because the county engineers and township highway commissioners evaluate the conditions of the rural roads while driving on the road. However, only a few counties and townships also do manual distress measurement; and very few can do automated distress surveys.

3.2.3 Maintenance Priority for Seal-Coated Roads

Figure B-3 shows the maintenance priority for fixing distresses in seal-coated roads. Pothole maintenance is the topmost priority for both counties and townships. Rutting maintenance is the second most important priority for the counties, but bleeding maintenance is the second most important priority for the townships. Cracking maintenance is the third priority for the counties, and roadside-drainage maintenance is the third priority for the townships.

3.2.4 Maintenance Priority for Gravel Roads

Figure B-4 shows the maintenance priority for fixing distresses in gravel roads. Pothole maintenance is the topmost priority for both counties and townships. Rutting maintenance is the second most important priority for both counties and townships. Roadside-drainage fixing is the third priority for both counties and townships.

3.2.5 Maintenance Priority for Dirt Roads

Figure B-5 shows the maintenance priority for fixing distresses in dirt roads. Maintaining potholes and improper cross section and reducing dust are the top priorities for the counties. Maintaining improper cross section and reducing dust are the top priorities for the townships. Maintaining rutting and roadside drainage are secondary priorities for the counties. Maintaining rutting, potholes, and roadside drainage are secondary priorities for the townships. Maintaining crown and corrugation is a third priority for both counties and townships.

3.2.6 Maintaining Improper Cross Section

Figure B-6 shows the percentages of counties and townships that follow different methods for maintaining improper cross section. 33% of the counties and townships surveyed re-grade the seal-coated roads with a grader; 34% of the counties and 32% of the townships re-grade the gravel roads with a grader; and 37% of the counties and townships re-grade the dirt roads with a grader or perform a blading.

3.2.7 Maintaining Fatigue or Alligator Cracks in Seal-Coated Roads

Figure B-7 shows the maintenance techniques used to fix fatigue cracks. 43% of the counties and 45% of the townships improve drainage to reduce the progression of fatigue cracks in seal-coated roads.

3.2.8 Maintaining Edge Cracks in Seal-Coated Roads

Figure B-8 shows the maintenance techniques used to fix edge cracks. 59% of the counties and 57% of the townships reseal the edge cracks.

3.2.9 Maintaining Rutting in Seal-Coated, Gravel, and Dirt Roads

Figure B-9 shows the maintenance techniques followed by counties and townships to fix rutting in seal-coated, gravel, and dirt roads. 43% of the counties and 51% of the townships add aggregate to fix rutting in seal-coated roads; 47% of the counties and townships blade to fix rutting in gravel roads; 60% of the counties and 59% of the townships blade to fix rutting in dirt roads.

3.2.10 Maintaining Potholes in Seal-Coated, Gravel, and Dirt Roads

Figure B-10 shows the maintenance techniques followed by counties and townships to fix potholes in seal-coated, gravel, and dirt roads. 78% of the counties and townships surveyed use cold-mix or hot-mix in potholes and compact to fix potholes in seal-coated roads; 54% of the counties and 55% of the townships scarify, cut, and grade to fix potholes in gravel roads; 64% of the counties and 65% of the townships scarify, cut, and grade to fix the potholes in dirt roads.

3.2.11 Maintaining Patching on Seal-Coated Roads

Figure B-11 shows the maintenance techniques followed by counties and townships to fix patching on seal-coated roads. 50% of the counties and 49% of the townships use cold-mix materials to fix the patching on seal-coated roads.

3.2.12 Maintaining Loose Aggregates on Seal-Coated and Gravel Roads

Figure B-12 shows the maintenance techniques followed by counties and townships to fix the loose aggregates on seal-coated, gravel, and dirt roads. 43% of the counties and 34% of the townships do not take any action to fix the loose aggregates on the seal-coated roads; 61% of the counties and 62% of the townships use a grader to re-grade a gravel road to fix the loose-aggregate problem.

3.2.13 Maintaining Roadside Drainage for Seal Coated, Gravel, and Dirt Roads

Figure B-13 shows the maintenance techniques followed by counties and townships to fix roadside drainage in seal-coated, gravel, and dirt roads. 36% of the counties and 34% of the townships clean ditches to fix the roadside-drainage issue in seal-coated roads; 38% of the counties and 39% of the townships clean ditches to fix the roadside-drainage issue in gravel roads; 63% of the counties and 62% of the townships clean the ditches to fix roadside-drainage issues in dirt roads. A significant percentage of counties and townships clean culverts to fix roadside-drainage issues.

3.2.14 Maintaining Corrugation, or Washboarding, in Gravel and Dirt Roads

Figure B-14 shows the maintenance techniques followed by counties and townships to fix corrugation, or washboarding, in gravel and dirt roads. 47% of the counties and 44% of the townships do grading to fix corrugation, or washboarding, in gravel roads; 53% of the counties and 52% of the townships do grading to fix corrugation, or washboarding, in dirt roads.

3.2.15 Managing Dust on Gravel and Dirt Roads

Figure B-15 shows the techniques followed by counties and townships to reduce dust on gravel and dirt roads. 38% of the counties and townships do not act to manage dust on gravel roads; 57% of the counties and 58% of the townships do not act to manage dust on dirt roads. Though 28% of the counties and 26% of the townships use resins to reduce dust on gravel roads, only 13% of the counties and townships use resins to reduce dust on dirt roads. The word *resins* is used to differentiate any adhesive liquid other than asphalt, such as waste oil, to control dust on the gravel and dirt roads.

3.2.16 Type of Seal Coat Used on Gravel Roads

Figure B-16 shows the type of seal coats used on gravel roads by counties and townships. 54% of the counties and 55% of the townships use chip seal on gravel roads. Chip seal is the most popular sealing method used on gravel roads.

3.2.17 Soil-Stabilization Techniques for Gravel and Dirt Roads

Figure B-17 shows soil-stabilization techniques used for gravel and dirt roads. Most of the counties and townships do not use any chemical or mechanical soil-stabilization techniques on gravel and dirt roads. 7% of the counties and townships use calcium chloride to stabilize gravel roads; 10% of the counties and 9% of the townships use emulsion to stabilize dirt roads. 3% of the counties and townships use geosynthetics-based soil stabilization on gravel roads, and 2% of the counties and townships use geosynthetics-based soil stabilization on dirt roads.

3.2.18 Field Testing Performed on Seal-Coated, Gravel, and Dirt Roads

Figure B-18 shows field tests to evaluate the strengths and structural capacities of seal-coated, gravel, and dirt roads. Most of the counties and townships do not perform any field tests to evaluate seal-coated, gravel, and dirt roads. 4% of the counties and 5% of the townships use a falling-weight deflectometer (FWD) to evaluate the structural capacities of seal-coated roads.

3.2.19 Record Keeping of Project and Maintenance Data

Figure B-19 shows record keeping of project and maintenance data by counties and townships. Most of the counties and townships do not keep records for seal-coated, gravel, and dirt roads. 29% of the counties and 26% of the townships have construction-history records of the seal-coated roads; 20% of the counties and 18% of the townships keep summer maintenance-activity records of the gravel roads; 16% of the counties keep construction-history records and summer maintenance records of the dirt roads, and 15% of the townships keep construction-history records and summer maintenance records of dirt roads.

3.3 SUMMARY

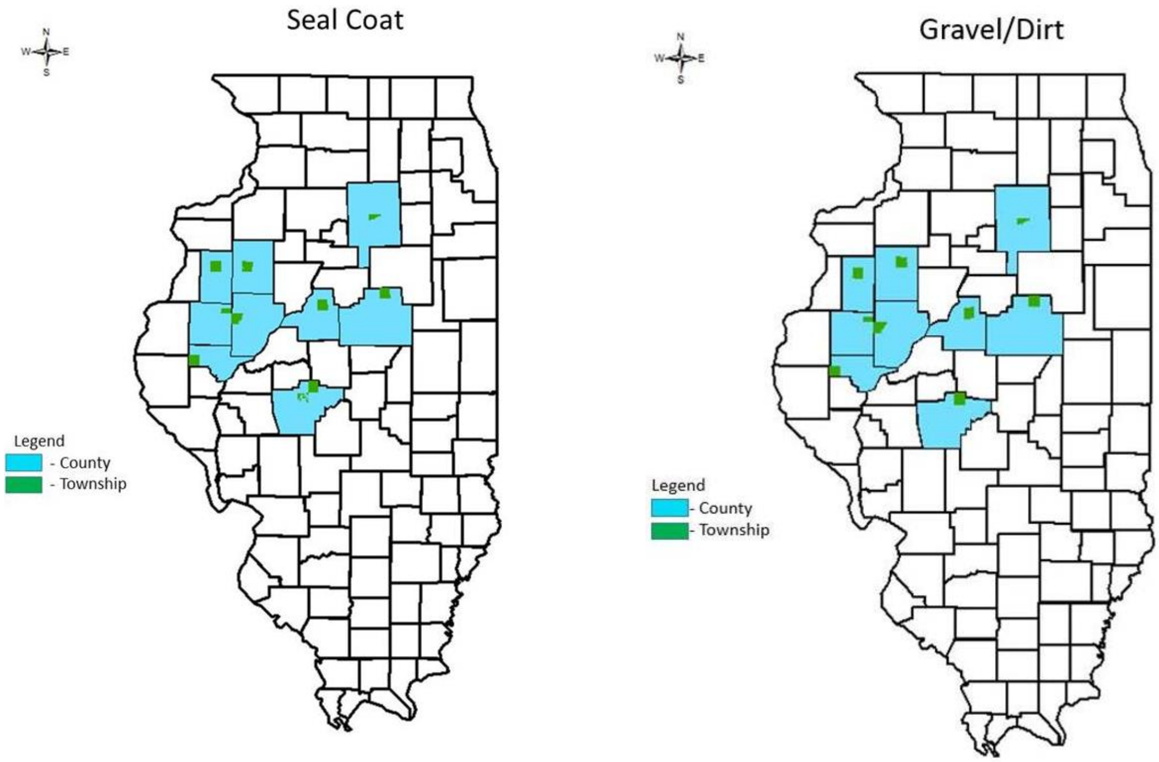
The statewide comprehensive survey revealed that counties and townships in general use similar practices to maintain seal-coated, gravel, and dirt roads. For example, they conduct windshield surveys to evaluate rural roads. The windshield survey is subjective, and distress quantification cannot be achieved. However, the windshield survey gives them an opportunity to assess the rural roads more frequently, such as weekly evaluations. Counties and townships maintain most visual distresses such as potholes, rutting, and roadside drainage. Standard practices are commonly followed to correct these road distresses.

CHAPTER 4: DISTRESS-DATA COLLECTION—MANUAL METHOD

4.1 BACKGROUND

Rural road-distress data can be collected by measuring distresses onsite and recording them into a specific format. A manual distress-measurement standard is available for asphalt concrete (AC) and Portland cement concrete (PCC) pavements and unsurfaced roads (Eaton et al. 1988; "Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys" 2008). AC and PCC pavements are commonly evaluated in terms of PCI (Pavement Condition Index), and unsurfaced roads are assessed in terms of URCI (Unsurfaced-Road Condition Index). Both surface-evaluation indices range from 100 to 0. The term *unsurfaced roads* refers to a road that does not have any paved surface or seal coat. The current literature does not show any manual distress-measurement method for seal-coated roads; however, subjective evaluation techniques such as PASER are available for seal-coated roads (Walker et al. 2001a). For this reason, a seal-coated road distress-measuring method has been developed in this research effort by combining the PCI and URCI methods. Further, the current URCI method is also used to evaluate gravel and dirt roads. Appendix C-1, C-2, and C-3 provide the inspection sheets used to evaluate seal-coated, gravel, and dirt roads, respectively.

Several rural road sites in Illinois were selected for investigation through conversations with county engineers and highway commissioners. Information was sought to answer several questions regarding the field investigations of seal-coated and unpaved roads, for example, whether maintenance had been done recently or was planned for the roads during the upcoming year. The project team typically called the county engineer and highway commissioner to set up a date to collect data and finalize the location of the site. Next, the team visited the survey site with the highway commissioner or other county officials for data collection. Figure 28 shows the location of counties and townships visited to evaluate seal-coated, gravel, and dirt roads. Several sites were visited, and manual distress data were collected to evaluate surface conditions; and at many other sites, data were collected using automated methods instead. This chapter provides evaluation results of rural road distresses obtained from manual data collection.



(a) Seal-coated roads

(b) Gravel and dirt roads

Figure 27. Locations of seal-coated, gravel, and dirt roads visited and evaluated.

4.2 DEVELOPMENT OF SEAL-COATED ROAD-CONDITIONING INDEX (SCRCI)

An objective or manual measurement-based seal-coated road condition index (SCRCI) has been developed based on the available PCI and URCI method. Seal-coated roads show few distresses similar to those also found in asphalt concrete pavements, such as alligator cracking, edge cracking, rutting, potholes, patching, bleeding, and longitudinal and transverse cracking. Seal-coated roads also show loose-aggregate distress similar to that found on gravel roads. For this reason, SCRCI has been developed by combining PCI and URCI ratings. The rating scale is 100 to 0, as for PCI and URCI. Table 13 lists the SCRCI rating ranges, which are similar to URCI ranges.

Table 13. SCRCI Rating Ranges (Similar to Those of the URCI)

SCRCI Rating	Condition
100–75	Excellent
50–75	Good
25–50	Fair
0–25	Poor

A blank inspection sheet for seal-coated roads is provided in Table 14. Tables C-3 to C-10 list the various distresses observed in seal-coated roads and their severity levels. The inspection sheets were completed based on the severity levels. Table C-3 lists the various severity levels observed for alligator or fatigue cracking in seal-coated roads in Illinois and shows the graph used to determine the deduct values. Table C-4 presents the various severity levels observed for edge cracking in seal-coated roads in Illinois and the graph used to determine the deduct values. Table C-5 lists the various severity levels observed for rutting in seal-coated roads in Illinois and shows the graph used to determine the deduct values. Table C-6 presents the various severity levels observed for potholes in seal-coated roads in Illinois and the graph used to determine the deduct values. Table C-7 lists the various severity levels observed for patching in seal-coated roads in Illinois and shows the graph used to determine the deduct values. Table C-8 presents the various severity levels observed for loose aggregate in seal-coated roads in Illinois and the graph used to determine the deduct values. Table C-9 lists the various severity levels observed for bleeding in seal-coated roads in Illinois and shows the graph used to determine the deduct values. Finally, Table C-10 presents the various severity levels observed for longitudinal and transverse cracking in seal-coated roads in Illinois and the graph used to determine the deduct values.

Table 14. SCRCI Rating Inspection Sheet

<table>
<tr><th colspan="13">ROAD-INSPECTION SHEET—SEAL-COATED ROAD</th></tr>
<tr><td colspan="5">1. BRANCH</td><td colspan="4">2. SECTION</td><td colspan="4">3. DATE</td></tr>
<tr><td colspan="5">4. SAMPLE UNIT</td><td colspan="4">5. AREA OF SAMPLE</td><td colspan="4">6. INSPECTOR</td></tr>
<tr><td colspan="6">7. SKETCH</td><td colspan="7">DISTRESS TYPES
1. Alligator/Fatigue Cracking (square feet)
2. Edge Cracking (linear feet)
3. Rutting (square feet)
4. Potholes (number)
5. Patching (square feet)
6. Loose Aggregate (linear feet)
7. Bleeding (square feet)
8. Longitudinal Cracking/Transverse Cracking (linear feet)</td></tr>
<tr><td colspan="13">8. DISTRESS QUANTITY AND SEVERITY</td></tr>
<tr><td colspan="2">TYPE</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">QUANTITY AND SEVERITY</td><td>L</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>M</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>H</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="13">9. URCI CALCULATION</td></tr>
<tr><td colspan="2">DISTRESS TYPE</td><td colspan="2">DENSITY %</td><td colspan="2">SEVERITY</td><td colspan="2">DEDUCT VALUE</td><td colspan="5" rowspan="4">10. REMARKS</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">TOTAL DEDUCT VALUE =</td><td colspan="2">q =</td><td colspan="2">SCRCI =</td><td colspan="5">RATING</td></tr>
</table>

Using the inspection sheet and the preestablished severity criteria, the distresses were recorded. The density for each distress was calculated as follows,

$$Density = \left(\frac{Quantity\ or\ area\ of\ distress}{Area\ of\ sample}\right) \times 100$$

The deduct values were measured using the curve given in the corresponding distress pictured in Tables C-3 to C-10. The total deduct value was calculated by adding all the individual deduct values. The number of deducts greater than 5 points is referred to as q.

The corrected deduct value was calculated using Figure 29.

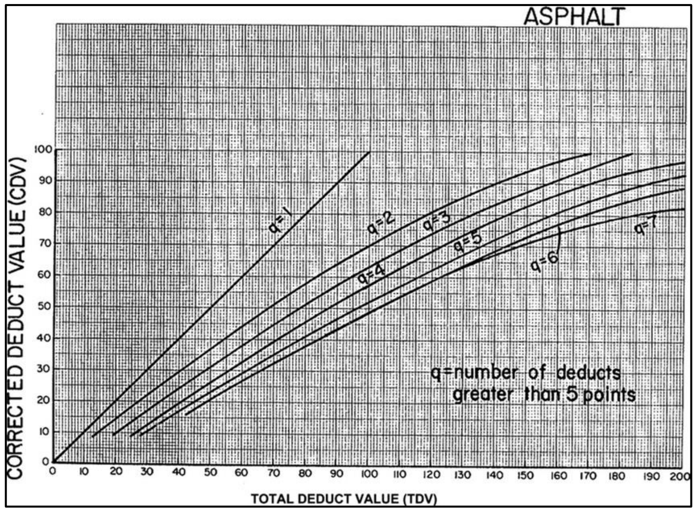


Figure 28. Corrected deduct-value curve.

4.2.1 Use of URCI Inspection Sheet

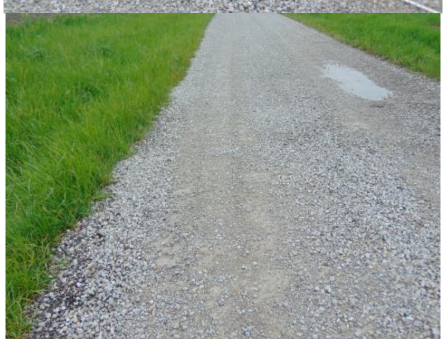
4.2.1.1 Gravel Road, Williamsville Township, Sangamon County

The site is located in Williamsville Township. The road is Guest Road. The field distress data were collected on 5/11/2017 and showed in Figure 30. The inspection sheet with calculation of distresses showed in Table 15.

(a) Improper cross section, low severity

(b) Inadequate roadside drainage, low severity

(c) Rutting, high severity



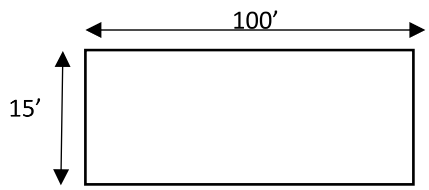
(d) Loose aggregate, low severity

Figure 29. Various distresses with their severity levels recorded for Guest gravel road in Williamsville Township.

Table 15. The Completed Inspection Sheet for Guest Road (Gravel) in Williamsville Township

UNSURFACED-ROAD INSPECTION SHEET—GRAVELROAD		
1. BRANCH: Guest Road	2. SECTION: Gravel Road	3. DATE: 05/11/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 1,500 sq ft	6. INSPECTOR: Praveen

7. SKETCH



DISTRESS TYPES

1. Improper Cross Section (linear feet)
2. Inadequate Roadside Drainage (linear feet)
3. Corrugations (square feet)
4. Dust
5. Potholes (number)
6. Rutting (square feet)
7. Loose Aggregate (linear feet)

8. DISTRESS QUANTITY AND SEVERITY

TYPE		1	2	3	4	5	6	7
QUANTITY AND SEVERITY	L	100	100					100
	M							
	H						40	

9. URCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	6.7	L	18
2	6.7	L	10
6	2.7	H	12
7	6.7	L	10

10. REMARKS

Density = (Quantity of distress/Area of sample) * 100

URCI = 100 – CDV
= 100 – 26 = 74
(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 50	q = 4	URCI = 74	RATING = Good

4.2.2 Use of URCI Inspection Sheet

4.2.2.1 Dirt Road, Huntsville Township, Schuyler County

The site is located in Huntsville Township. The road identified as dirt road. The field distress data and showed in Figure 31. The inspection sheet with calculation of distresses showed in Table 16.

(a) Improper cross section, high severity

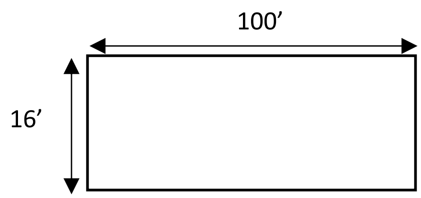
(b) Inadequate roadside drainage, medium severity

(c) Rutting, high severity

Figure 30. Various distresses, with their severity levels recorded, on a dirt road in Huntsville Township.

Table 16. The Completed Inspection Sheet for a Dirt Road in Huntsville Township

UNSURFACED-ROAD INSPECTION SHEET—DIRT ROAD		
1. BRANCH: Run Deer Road	2. SECTION: Dirt Road	3. DATE: 3/23/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 1,600 sq ft	6. INSPECTOR: Praveen

1. SKETCH	**DISTRESS TYPES**
	1. Improper Cross Section (linear feet) 2. Inadequate Roadside Drainage (linear feet) 3. Corrugations/Washboarding (square feet) 4. Dust 5. Potholes (number) 6. Rutting (square feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6
QUANTITY AND SEVERITY	L						
	M		100				
	H	60					400

9. **URCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE	10. REMARKS
1	3.75	H	18	Density = (Quantity of distress/Area of sample) * 100
2	6.25	M	18	URCI = 100 – CDV = 100 – 42 = 58
6	25	H	30	(CDV: Corrected Deduct Value)
TOTAL DEDUCT VALUE = 66		q = 3	URCI = 58	RATING = Good

4.3 SUMMARY

Several seal-coated, gravel, and dirt roads were evaluated using a field distress-survey manual method. The Seal-Coated Road Condition Index (SCRCI) was developed based on the pavement-condition index (PCI) and Unsurfaced-Road Condition Index (URCI). The SCRCI was then used to perform surface evaluations of several seal-coated roads in Illinois. The URCI method was used to evaluate several gravel and dirt roads. Both SCRCI and URCI required extensive data collection and then used tables and charts to determine the numeric rating. These methods are time-consuming and labor-intensive; and lane closure is often needed during data collection, which might otherwise pose a safety issue to the surveyor. For this reason, automated methods may be considered or preferred to evaluate seal-coated, gravel, and dirt roads.

CHAPTER 5: DISTRESS-DATA COLLECTION—AUTOMATED METHOD

5.1 BACKGROUND

Profilometers are generally used to evaluate surfaced or asphalt concrete (AC) and Portland cement concrete (PCC) pavements. Profilometers are accurate and provide a surface evaluation in terms of PCI or IRI. However, the profilometer method requires a skilled technician and delicate and expansive equipment. Only a certain number of profilometers are available to IDOT for performing surface-roughness quality control and assurance of AC and PCC pavements. Most of the counties and townships do not have access to these profilometers. A high-speed profilometer cannot always be operable in rural roads because the roads have often lower posted speeds due to geometrical design restrictions, such as narrow lane width and insufficient shoulder space. For this reason, relatively cheaper and user-friendly technology is needed to access rural road conditions.

More recently, cell phone-based apps have been introduced to measure pavement condition in terms of IRI. With the advent of advanced technology, cell phones with various sensors and a global positioning system (GPS) are used for road-condition assessment. Apps can compute IRI values with the accumulation of vertical displacements of vehicles over the respective distance. Cell phone apps allow users to map the road surface; the method is less time-consuming and easy to use. Most of the previously completed research studies reported on cell phone app development specific to research projects and did not make their app available for professional use. A limited number of studies has measured IRI using cell phone apps and provided them as available for purchase from online stores (Schlotjes et al. 2014; Uddin 2015). The cell phone app developers also have performed a few studies that showed promising results with their apps (Forslöf and Jones 2015).

5.2 IRI DATA COLLECTION USING HIGH-SPEED PROFILERS

A high-speed inertial profilometer produces one of the most accurate and repeatable kinds of surface-profile data. It is a dual-track system that allows the operator to profile both wheel paths at the same time without requiring a lane closure. The main components of an inertial profilometer are a distance-measuring instrument (DMI) or transducers, laser sensors, accelerometers, and a computer, as shown in Figure 32. A high-speed inertial profilometer can be calibrated using computer-guided instructions for bounce test, laser verification, and accelerometer and distance calibrations.

(a) Displacement transducer **(b) Accelerometer and laser source** **(c) Recording IRI using a laptop**

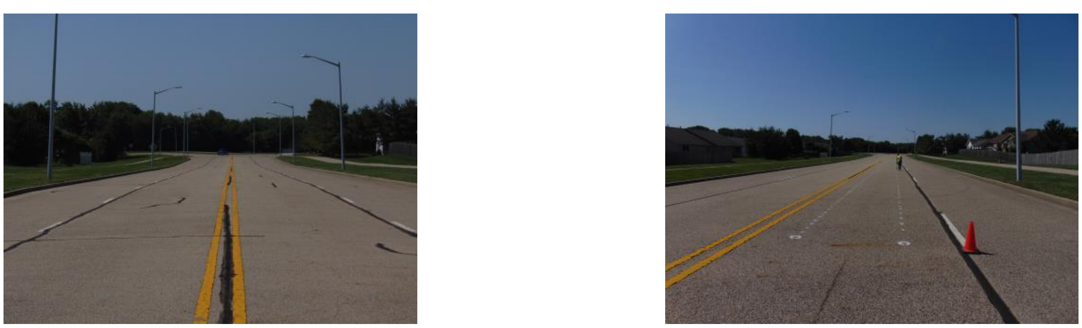
Figure 31. High-speed inertial laser profilometer.

As part of the research activities, the profilometer was first calibrated with respect to its displacement transducer, accelerometer, and laser. The calibration distance for the profiler was 660-ft. Figure 33 shows a technician calibrating the profilometer before taking the IRI data.

(a) Technician measures the distance to calibrate profilometer. **(b) Technician ends measuring the 660-ft calibration distance.**

Figure 32. Calibration of profilometer in Peoria, Illinois.

IDOT also has a designated track in Springfield, Illinois, to calibrate laser profilers. Figure 34 shows the designated track in Springfield where the calibration is done.



(a) Profilometer calibration track in Springfield, Illinois **(b) The white line shows the driving path, for calibrating the profilometer**

Figure 33. Profilometer-calibration track in Springfield, Illinois.

5.3 IRI DATA COLLECTION USING WALKING PROFILER

IDOT also uses a walking profilometer to measure IRI data. A walking profilometer is more precise than a laser-based, high-speed profilometer; and for this reason, a walking profilometer is also used to calibrate and precision-check laser profilometers. Figure 35 shows the walking profilometer and the track located in Rantoul, Illinois, used to calibrate the profilometer.

(a) A walking profilometer used by IDOT

(b) Track to calibrate walking profilometer; white dots indicating driving path

Figure 34. Walking profilometer and calibration track in Rantoul, Illinois.

5.4 IRI DATA COLLECTION USING CELL PHONE APPS

Three cell phone apps (Roadroid, RoadBump, and TotalPave) were used in this project. However, not all of them were used on all rural roads surveyed in this project. Figure 36 shows the apps installed on the smartphone. One cell phone, a Samsung S3, was used to collect the IRI data. The installation process and data retrieving process showed in Appendix C-4. The apps were not available for the iOS operating system; and for this reason, only Android-based operating system software was used.

(a) Roadroid **(b) RoadBump** **(c) TotalPave**

Figure 35. Cell phone apps used to measure IRI of rural roads.

The vehicle was driven 25 to 55 mph. For a specific target speed, the vehicle was driven in both directions, i.e., northbound and southbound; and the data were averaged for both directions. Recorded data for Roadroid and TotalPave were uploaded on the developer’s website from a registered cell phone IMEI number. Therefore, roughness values could be evaluated through website display of results; however, RoadBump IRI values were shown by the cell phone app right after each run.

5.5 DATA COLLECTION

5.5.1 Establishing Speed Range

The cell phone IRI data were collected on North Trigger Road, Edwards, in Peoria County. The data were collected by (1) a cell phone mounted in the sedan car, (2) cell phone mounted in the truck, and (3) profilometer attached to the truck. The speed for both the sedan car and the truck varied from 25 to 55 mph. Roadroid recommended 25 mph as the lowest speed to collect data, and a maximum of 100 mph speed was recommended. However, driving at 100 mph on seal-coated roads would not be safe; and for this reason, the maximum driving speed was set close to the posted speed.

5.5.1.1 N Trigger Road, Edwards, Peoria County

The IRI values obtained from a sedan car with Roadroid, a truck with RoadBump, and a truck hosting profilometer are shown in Figure 37. According to the graph, as expected, the profilometer data varied with an increase in speed. However, IRI values increased when the cell phone was mounted in the sedan car and the truck; and the IRI values increased with an increase in vehicle speed. The increase of IRI was greater in the truck, as compared to the sedan car. The average IRI measured by the profilometer was 137.4 inch/mile; and the average IRI measured by the cell phone with Roadroid app mounted in the car was 167.9 inch/mile, which is 22.2% higher than the profilometer measurement. In contrast, the average IRI measured by the cell phone with Roadroid app mounted in the truck was 251.9 inch/mile, which is 83.3% higher than the profilometer measurement. The RoadBump app average IRI was the highest of all four average IRI values, 389 inch/mile.

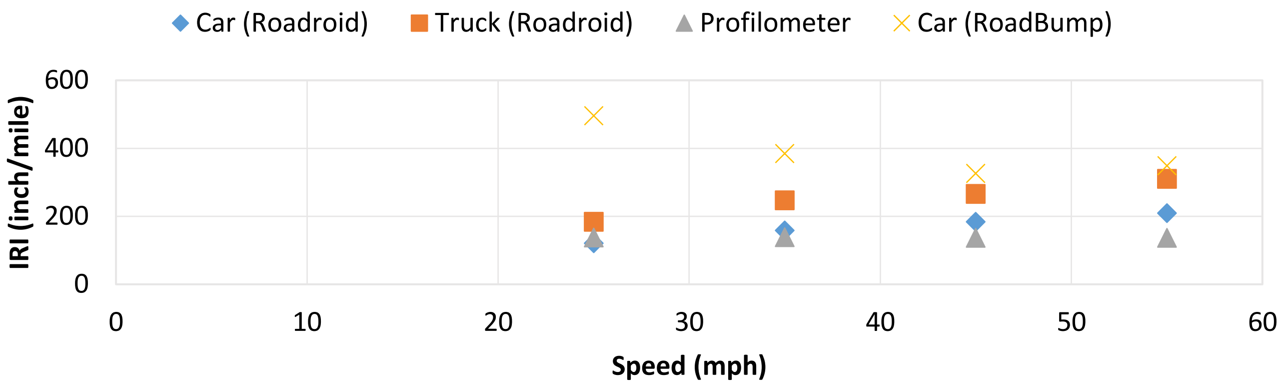


Figure 36. Variations in IRI values at different driving speeds using profilometer and cell phone apps, N Trigger Road, Peoria County.

5.5.1.2 N Odom Road, Benton, Franklin County

During the N Odom Road site visit, the IRI data were collected using the Roadroid app by (1) a cell phone mounted in the sedan car and (2) a cell phone mounted in the truck. The speed limit for both the sedan car and truck varied from 25 mph to 35 mph. This speed limit was chosen from our experience with the Peoria County data (i.e., Figure 37) collection, which indicated that higher speed gave higher IRI values. The vehicle was driven both ways (i.e., eastbound and westbound) at a given speed, and the IRI values were averaged for both directions. Figure 38 shows the average IRI data measured by the cell phone Roadroid app in the sedan car and in the truck. According to the results, the average IRI values measured by the cell phone app were 113.8 inch/mile in the car and 211.2 inch/mile in the truck, approximately 85.6% higher than in the car.

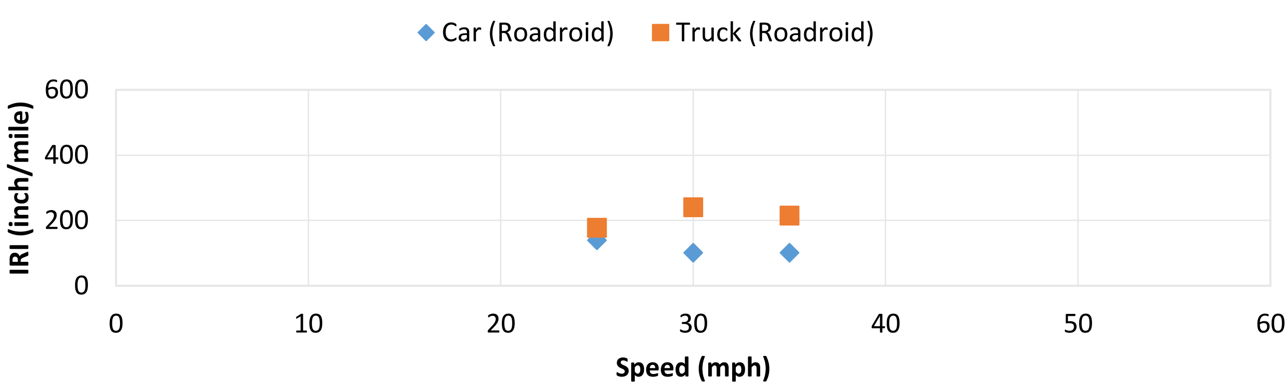


Figure 37. Variations of IRI values at different driving speeds using profilometer and the cell phone app Roadroid, North Odom Road, Franklin County.

5.5.1.3 Mt. Zion Road, Benton, Franklin County

The same process was followed as in the case of N Odom Road, but the readings from placing the cell phone in the truck were problematic due to some technical problems in the cell phone; it was running out of battery power. According to this site visit, the road was newly surfaced; however, the site had a severe condition of loose aggregates exposed on the pavement surface.

The speed limit followed was the same as for North Odom Road. Figure 39 shows the IRI data measured by cell phone in the sedan car. Comparing N Odom and Mt. Zion roads, the average IRI value measured on Mt. Zion Road is higher (i.e., 231.3 inch/mile) than the North Odom Road IRI value (i.e., 113.8 inch/mile). A higher IRI value indicates rougher pavement, and a lower IRI value indicates smoother pavement. The newly surfaced Mt. Zion Road indicated rougher pavement. The loose aggregates on the pavement surface could influence the IRI data recorded by the cell phone. Note that the IRI values calculated for the Mt. Zion Road and the N Odom Road were more consistent when compared to the N Trigger Road data in Peoria County. Lower speeds gave more consistent IRI readings for the seal-coated roads.

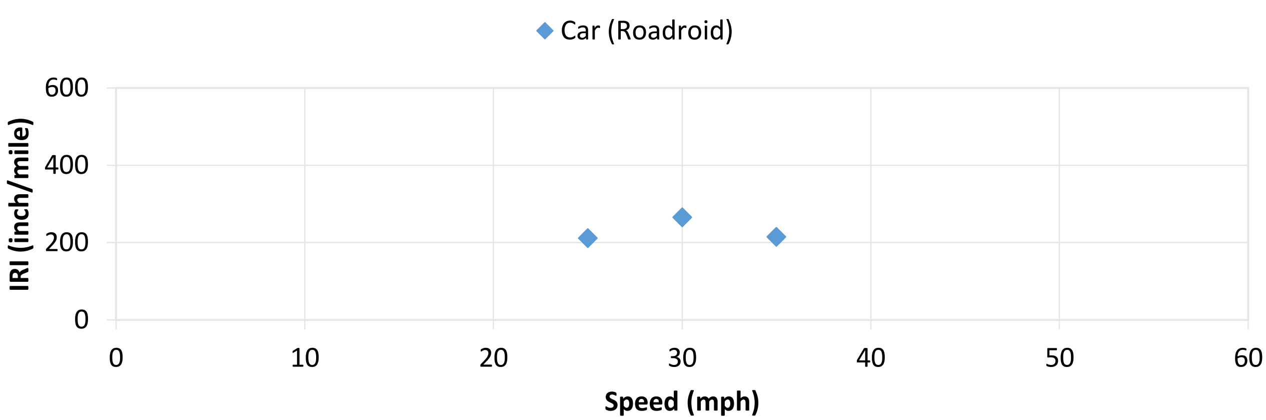


Figure 38. Variations of IRI values at different driving speeds using the cell phone app Roadroid, Mt. Zion Road, Franklin County.

5.5.1.4 1200 N Road, Monticello, Piatt County

During the 1200 N Road site visit, the data were collected by a cell phone mounted in the sedan car to record the IRI values at speeds set for 25 to 35 mph in both directions. Figure 40 shows the IRI data measured by the cell phone in the sedan car. According to Roadroid app performance trends, if the speed is increased, the Roadroid app typically gives lower roughness values. However, the IRI values measured were 171.1 inch/mile and 215.4 inch/mile at speeds of 25 mph and 35 mph, respectively. This difference is a 25.9% increase at 35 mph over the IRI value at 25 mph.

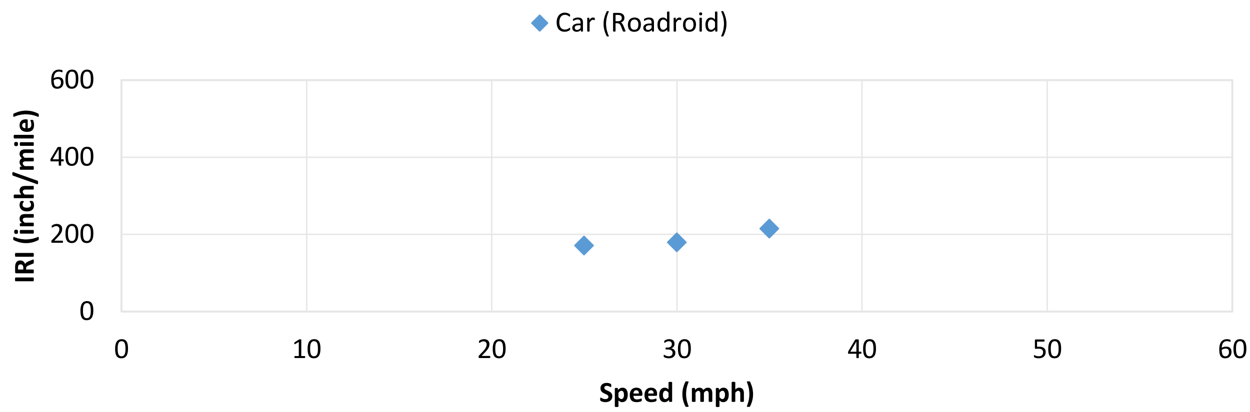


Figure 39. Variations of IRI values at different driving speeds using the cell phone app Roadroid, 1200 N Road, Piatt County.

5.5.1.5 N 730 E Road, Springfield, Sangamon County

For the N 730 E Road site visit, the data were collected by (1) a cell phone mounted in the sedan car, (2) a cell phone mounted in the truck, and (3) a profilometer attached in the truck. Figure 41 shows the IRI data measured by cell phone in the car, cell phone in the truck, and profilometer in the truck. Profilometer-based IRI values decrease with an increase in speed; and the result is the same for the IRI values measured by the cell phone in the car—IRI values decrease with increasing speed. However, the IRI value increased for the cell phone in the truck, especially at 40 mph. The increase in the IRI value is greater in the truck, as compared to the sedan car. The average IRI measured by the profilometer is 293 inch/mile; and the average IRI measured by the cell phone mounted in the car is 226 inch/mile, 22.9% lower than the profilometer measurement. In contrast, the average IRI measured by the cell phone mounted in the truck is 239.7 inch/mile, 18.2% lower than the profilometer measurement.

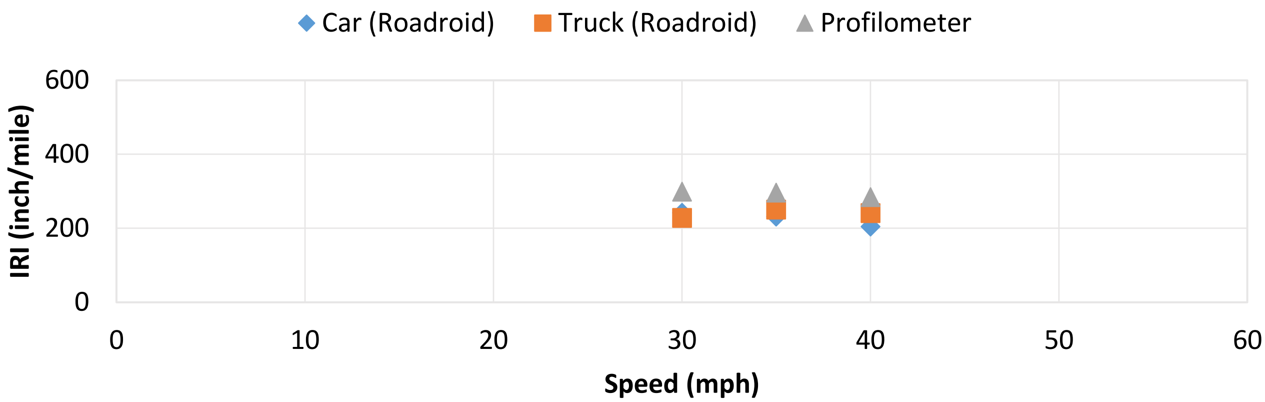


Figure 40. Variations of IRI values at different driving speeds using the cell phone app Roadroid, N 730 E Road, Sangamon County.

From Figure 41, it can be seen that more consistent IRI readings could be achieved by mounting the cell phone in the car driven at about 25 to 40 mph. However, the IRI data obtained from the truck indicated higher values, as compared to those from the car.

5.6 CELL PHONE APP IRI DATA COMPARED WITH THAT FROM WALKING AND LASER PROFILERS

IDOT has several dedicated road sections for calibrating high-speed profilers. One of those sections located in Rantoul, Illinois, was selected to collect IRI data using the handheld rolling profiler, and the cell phone-based Roadroid and RoadBump apps. One of the lanes was smooth, one rough. Both lanes were marked to measure IRI data for a pavement section of about 660-ft, and the lanes were also marked under the wheel path to take consistent data by driving a truck or sedan car.

5.6.1 IRI Data Comparisons between Rolling Profiler and Cell Phone Apps

Figure 42 shows the IRI data measured using the rolling profiler and the Roadroid and RoadBump apps. The data were collected at four different speeds. For the smooth lane, the rolling profiler measured an IRI value of 114 inch/mile. Using the RoadBump app, IRI values increased with an increase in vehicle speed. However, Roadroid-measured IRI values were consistent and comparable with the RoadBump-measured data. Roadroid measured an average IRI value of 82.6 inch/mile, while RoadBump measured an average IRI value of 169.7 inch/mile.

For the rough lane, the rolling profiler measured an IRI value of 297.8 inch/mile. The Roadroid-measured average IRI value was 84 inch/mile, while the RoadBump-measured average IRI value was 213.9 inch/mile. The IRI values were not significantly affected by smooth and rough lanes when Roadroid was used; however, RoadBump-measured IRI values increased substantially from the smooth lane to the rough lane. Note that both the Roadroid and RoadBump apps underpredicted IRI values in the rough lane.

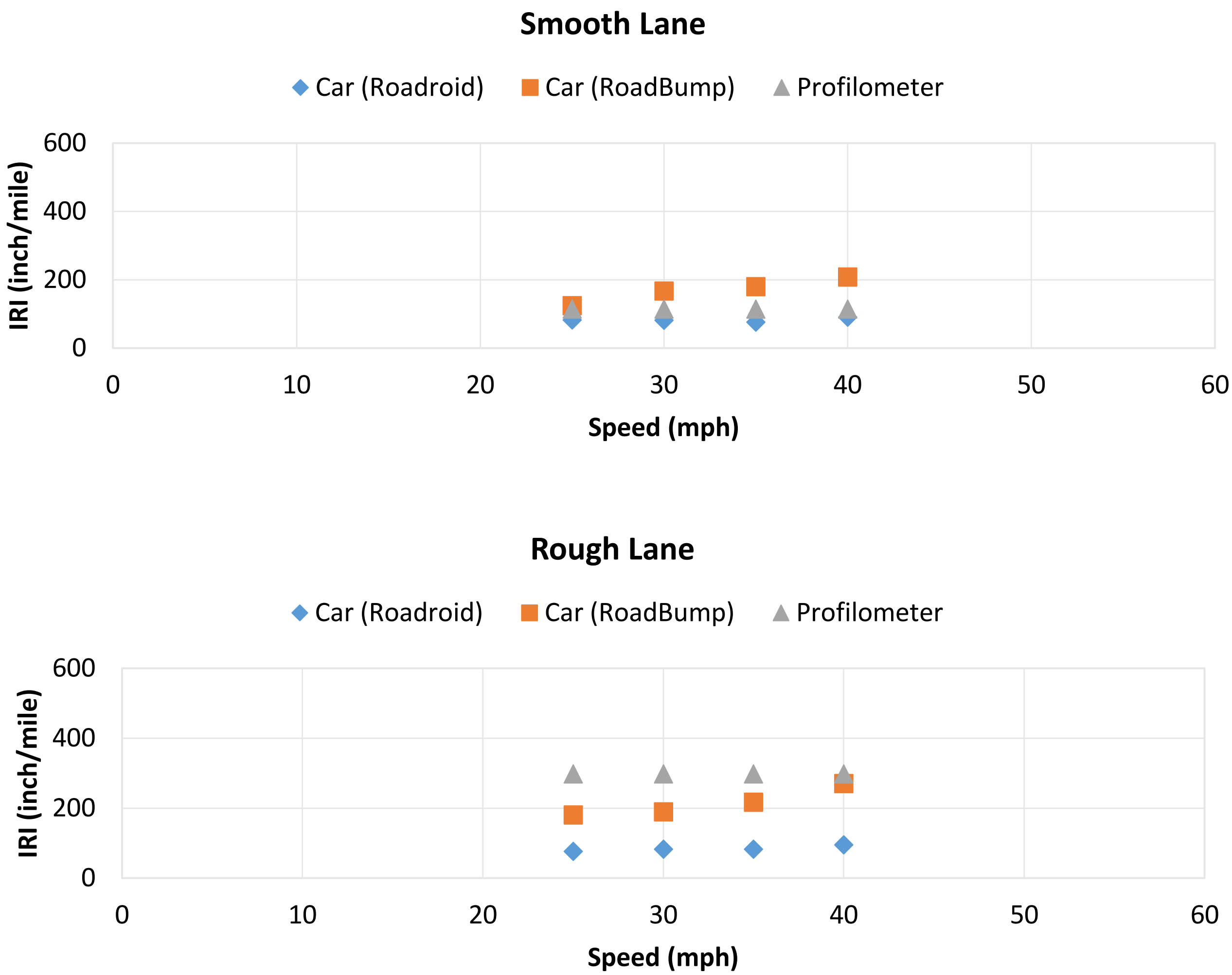


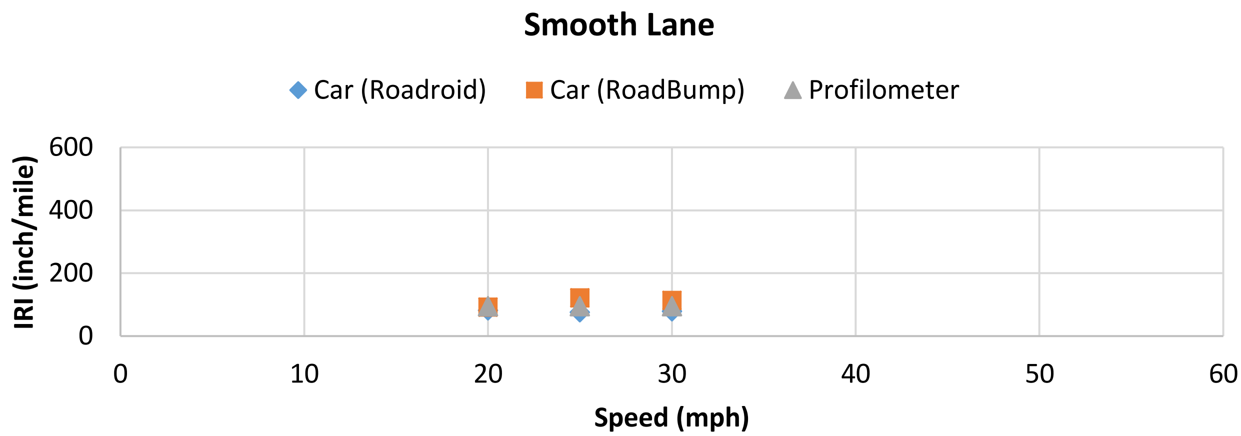
Figure 41. IRI values measured using a rolling profiler, and Roadroid and RoadBump apps.

5.6.2 IRI Data Comparisons Between Laser Profiler and Cell Phone Apps

Figure 43 shows the IRI values measured using the laser profiler and the Roadroid and RoadBump apps. The data were collected at three different speeds. For the smooth lane, the laser profiler measured an IRI value of 95.04 inch/mile. Using the RoadBump app, IRI values increased with an increase in the vehicle speed. However, the Roadroid-measured IRI values were consistent when compared to those measured by the RoadBump app. The Roadroid-measured average IRI value was 79.2 inch/mile, while the RoadBump measured an average IRI value of 109.3 inch/mile.

For the rough lane, the laser profiler measured 114.05 inch/mile. Roadroid measured an average IRI value of 87.7 inch/mile, and RoadBump measured an average IRI value of 148.9 inch/mile. It should be noted that the IRI values are more consistent at various speeds when measured by the cell phone apps. RoadBump again overpredicted IRI values, as compared to those of the Roadroid app.

Comparing IRI values from the rolling profiler with those from the laser profiler, the rolling profiler's were higher. The reason is that the rolling profiler can capture small undulations of pavement; often, a rolling profiler is used to calibrate a laser profiler.



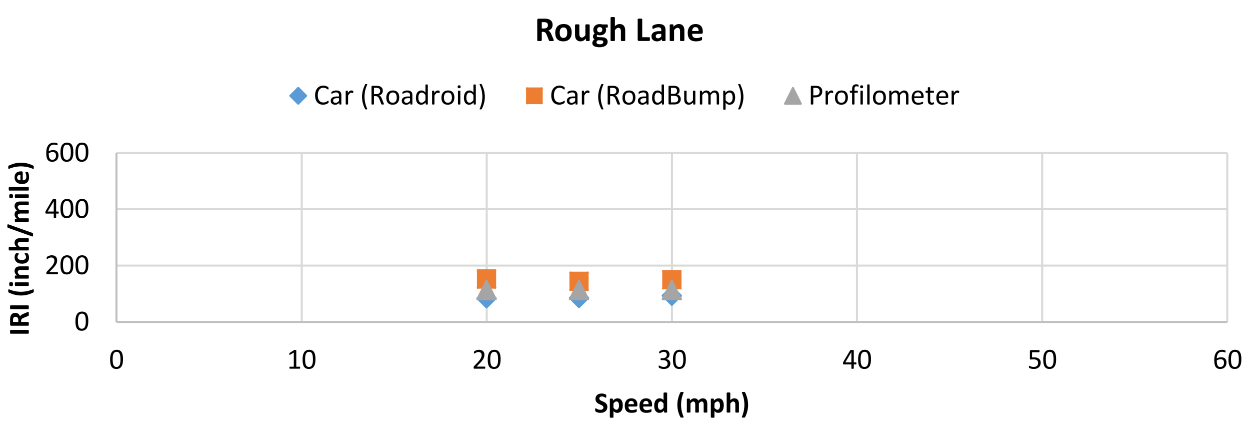


Figure 42. IRI values measured using a laser profiler, and Roadroid and RoadBump apps.

5.7 EFFECT OF VEHICLE TYPE ON MEASURED IRI DATA

Roadroid and RoadBump apps were used, together with the profilometer installed on an SUV, a lightweight van, a heavyweight van, and a sedan car. The results are tabulated in Tables 17 and 18. The individual IRI value for each vehicle and the average IRI value of all vehicles are compared.

Using the Roadroid app in the smooth lane, the sedan car gave IRI values comparable with the profilometer-measured IRI data. Light- and heavyweight vans did not show appreciable differences at the same operating speed. The SUV gave lower IRI values, as compared to both the sedan and the van at low speeds. Using RoadBump in the smooth lane, the sedan car gave higher IRI values than the profilometer-measured IRI data. Light- and heavyweight vans did not show consistent results when compared to the results obtained from the sedan car and SUV.

Using the Roadroid app in the rough lane, the sedan car underpredicted the profilometer IRI data. However, the van and SUV showed higher IRI values on a rough surface when compared to the values obtained on the smooth surface. Using RoadBump in the rough lane, the sedan car showed higher values compared to the profilometer-measured IRI data. In general, the lightweight van showed higher IRI values when compared to those obtained from the heavyweight van. Comparing the results from the SUV and the vans, lower IRI values were reported from the SUV when compared to the heavy- and lightweight vans. In most cases, RoadBump showed higher IRI values when compared to those reported by the Roadroid app. In both smooth and rough lanes, the sedan car gave more consistent results than other vehicles. However, it is difficult to make a definitive conclusion from the limited data.

Table 17. Roadroid and RoadBump IRI Comparisons with Profilometer IRI Values in Smooth Lane

Speed (mph)	IRI (inch/mile)					
	Roadroid (Smooth Lane)					
	SUV	Van (5 Persons)	Van (2 Persons)	Sedan	Average	Profilometer
20	76.0	82.4	82.4	88.7	82.4	95.0
25	69.7	76.0	76.0	82.4	76.0	95.0
30	76.0	76.0	76.0	88.7	76.0	95.0
	RoadBump (Smooth Lane)					
20	63.4	76.0	107.7	120.4	95.0	95.0
25	69.7	158.4	133.1	126.7	120.4	95.0
30	69.7	133.1	120.4	133.1	114.0	95.0

Table 18. Roadroid and RoadBump IRI Comparisons with Profilometer IRI Values in Rough Lane

Speed (mph)	IRI (inch/mile)					
	Roadroid (Rough Lane)					
	SUV	Van (5 Persons)	Van (2 Persons)	Sedan	Average	Profilometer
20	82.4	88.7	82.4	82.4	82.4	114.0
25	88.7	88.7	82.4	82.4	88.7	114.0
30	88.7	95.0	88.7	101.4	95.0	114.0
	RoadBump (Rough Lane)					
20	88.7	152.1	228.1	139.4	152.1	114.0
25	101.4	164.7	152.1	158.4	145.7	114.0
30	88.7	171.1	177.4	164.7	152.1	114.0

5.8 EFFECT OF CELL PHONE MOUNT ON IRI DATA

Cell phone apps collect data based on the vehicle's response while driving. Many things can change to affect results while recording the IRI data. The IRI data collection might vary in different cell phones, cell phone mounts, and vehicles used. This study included use of one cell phone, a Samsung S3, and four different mounts, i.e., windshield with a short arm, windshield with a long arm, air-vent mount, and dashboard. Roadroid recommended using a Samsung S3 or higher model; and for this reason, the Samsung S3 model was used in this study. Other similar or comparable cell phone models can be used, and the IRI result may vary based on the cell phone model. Figure 44 shows the four cell phone mounts used in this study.

Windshield mount with a short arm

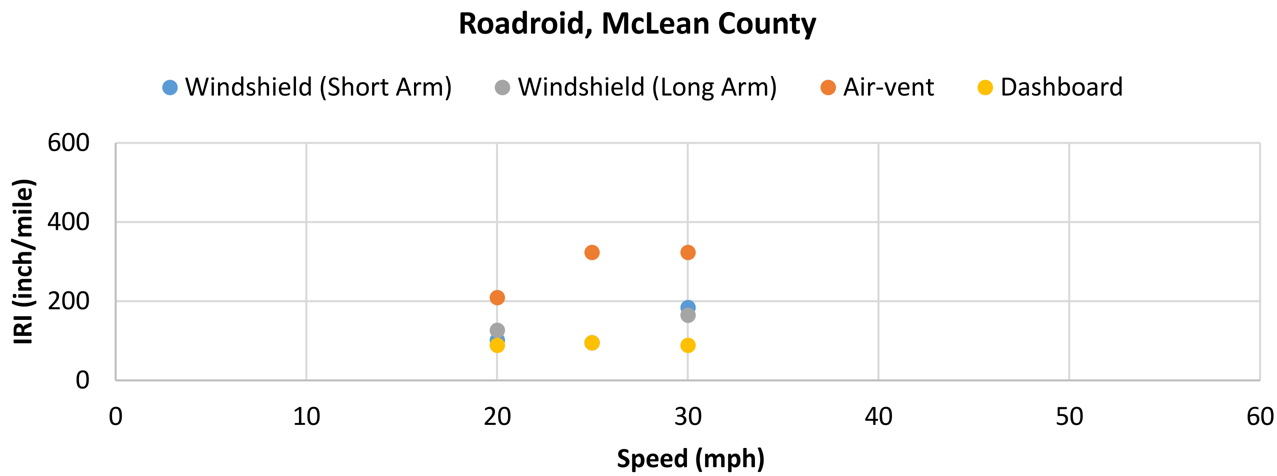
Windshield mount with a long arm

Air-vent mount

Dashboard mount

Figure 43. Different types of cell phone mounts used to collect IRI data.

Figure 45 shows the IRI data measured using four cell phone mounts. The data were collected at three different speeds. The average IRI measured using the Roadroid app and with windshield (short arm) mount was 126.72 inch/mile; with windshield (long arm) mount, 128.83 inch/mile; with air-vent mount, 285.12 inch/mile; and with dashboard mount, 90.12 inch/mile. The average IRI measured using the RoadBump app and with windshield (short arm) mount was 228.10 inch/mile; with windshield (long arm) mount, 257.66 inch/mile; with air vent-mount, 394.94 inch/mile; and with dashboard mount, 244.99 inch/mile. As expected based on the previous experience, the RoadBump-measured IRI value was higher than the one measured by the Roadroid app.



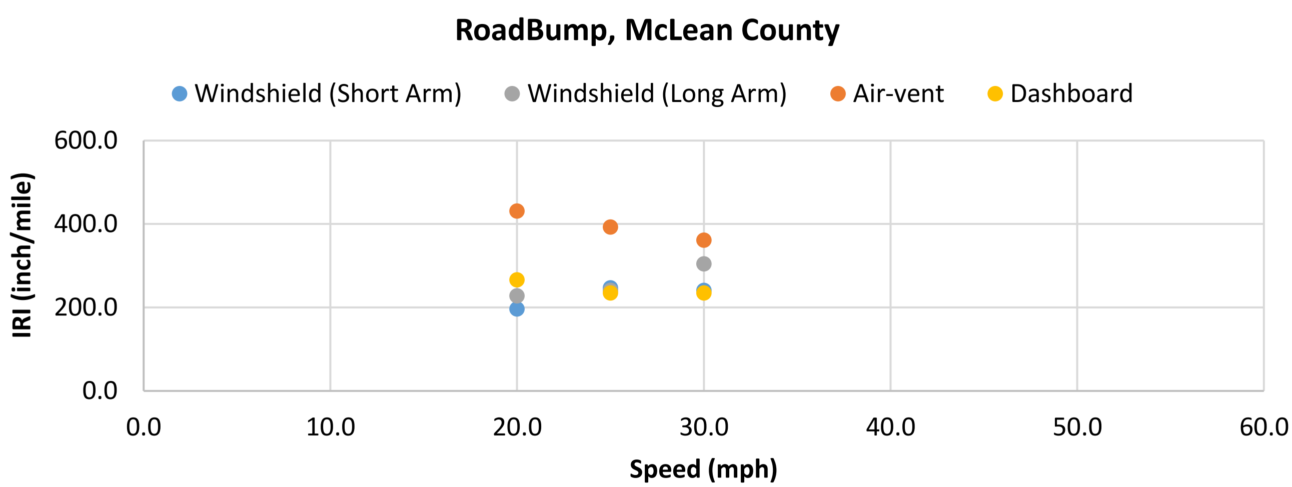
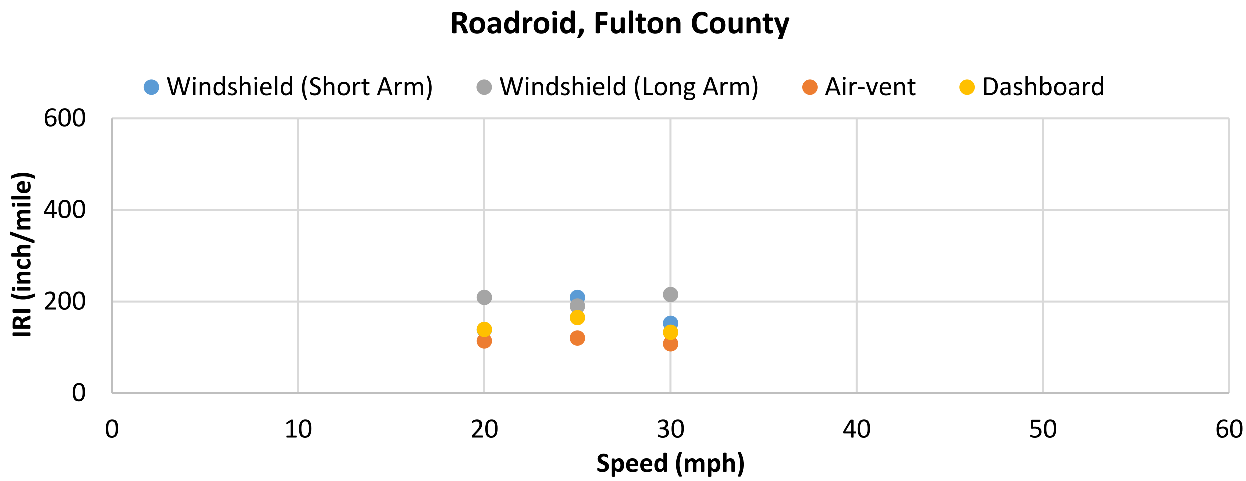


Figure 44. IRI data measured using four cell phone mounts on a seal-coated McLean County road.

A second seal-coated road was tested with both apps, and Figure 46 shows the IRI data measured with four cell phone mounts. The data were collected at three different speeds. The average IRI measured using the Roadroid app and with windshield (short arm) mount was 166.63 inch/mile; with windshield (long arm), 204.86 inch/mile; with air-vent mount, 114.05 inch/mile; and with dashboard mount, 145.73 inch/mile. The average IRI measured using the RoadBump app and with windshield (short arm) mount was 348.48 inch/mile; with windshield (long arm) mount, 538.56 inch/mile; with air-vent mount, 424.51 inch/mile; and with dashboard mount, 382.27 inch/mile. The RoadBump-measured IRI values were again higher than the Roadroid-measured ones.



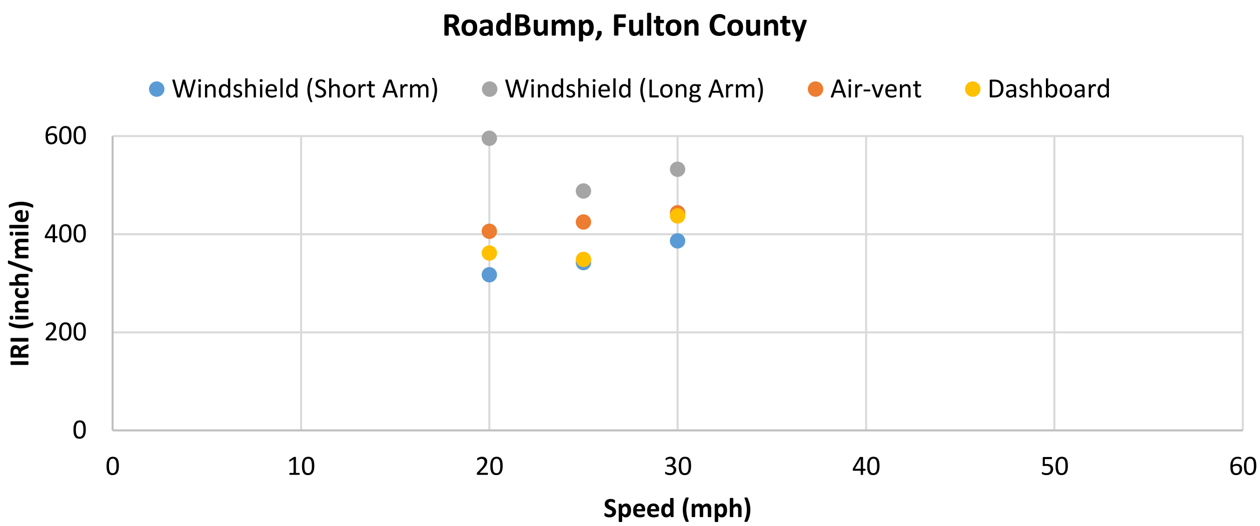
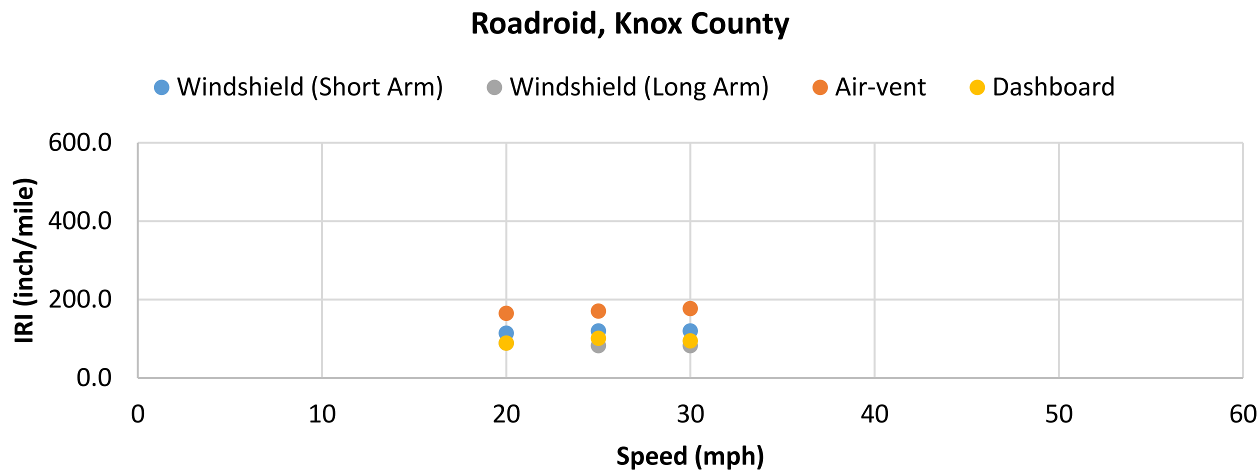


Figure 45. IRI data measured using four cell phone mounts on a Fulton County seal-coated road.

A third seal-coated road was tested with both apps, and Figure 47 shows the IRI data measured with four cell phone mounts. The data were collected at three different speeds. The average IRI measured using the Roadroid app with windshield (short arm) mount was 92.93 inch/mile; with windshield (long arm) mount, 86.59 inch/mile; with air-vent mount, 92.93 inch/mile; and with dashboard mount, 95.04 inch/mile. The average IRI measured using the RoadBump app with the windshield (short arm) mount was 249.22 inch/mile; with windshield (long arm) mount, 225.98 inch/mile; with air-vent mount, 414.06 inch/mile; and with dashboard mount, 458.30 inch/mile. As expected, the RoadBump-measured IRI values were again higher than those with the Roadroid app.

Figure 46. IRI data measured using four cell phone mounts on a Sangamon County seal-coated road.

Four different mounts were further evaluated in Knox County, and the results are presented for Roadroid and RoadBump apps in Figure 48. As expected, the RoadBump app showed higher IRI values, as compared to those obtained using the Roadroid app. Again, more consistent IRI values were obtained using the Roadroid app for all four mounts.



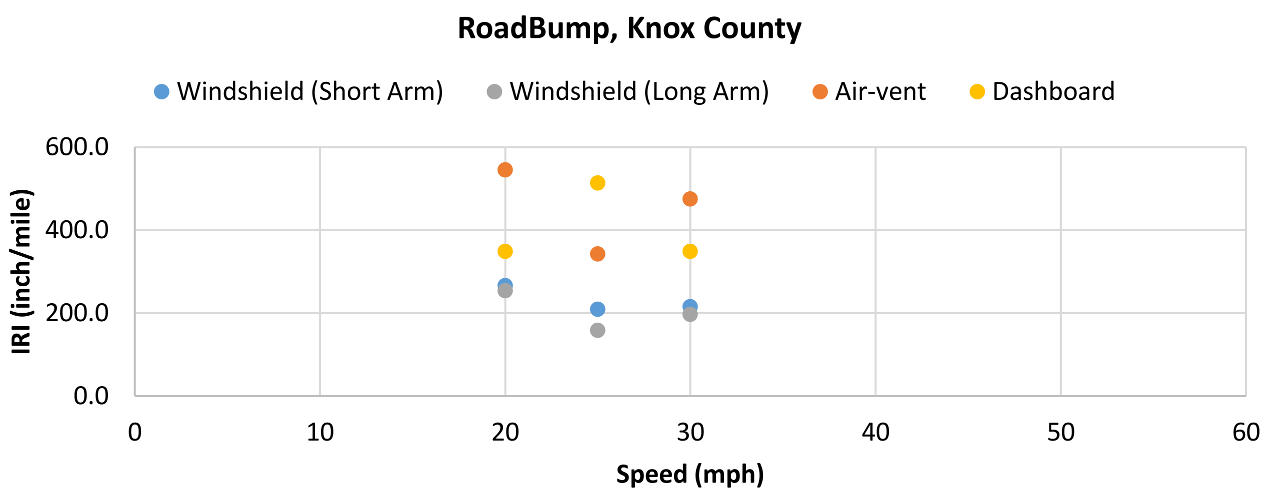


Figure 47. Effect of cell phone mounts on RoadBump-app-measured IRI data.

5.9 IRI DATA MEASURED BY ROADROID, ROADBUMP, AND TOTALPAVE APPS

Figure 49 presents a comparison made among the IRI measurements obtained from the three apps. The average IRI results observed from Roadroid and TotalPave are, in general, consistent except for those taken on E 1850 N Road at Danvers; an extremely high IRI of 285.1 inch/mile was measured by Roadroid, as compared to 121.0 inch/mile by TotalPave. In contrast, the RoadBump average IRI values were consistently high for all the road locations shown in Figure 49. The graphical representation itself shows the hike in RoadBump average IRI values compared to Roadroid and TotalPave average IRI values. In case of E 1850 N road RoadBump IRI value is 1.4 times higher than Roadroid IRI and 3.2 times higher than TotalPave IRI value; for CR-38 road RoadBump IRI value is 3.7 times higher than Roadroid IRI and 2.7 times higher than TotalPave IRI value; for Augusta road RoadBump IRI value is 2.7 times higher than Roadroid IRI and 2.3 times higher than TotalPave IRI value; for Kennel Lake road RoadBump IRI value is 3.5 times higher than Roadroid IRI and 2.6 times higher than TotalPave IRI value; for Tennessee ave. RoadBump IRI value is 2.1 times higher than Roadroid IRI and 2.5 times higher than TotalPave IRI value; for N Trigger road RoadBump IRI value is 2.3 times higher than Roadroid IRI and 2.6 times higher than TotalPave IRI value; for Lester road RoadBump IRI value is 2.2 times higher than Roadroid IRI and 1.7 times higher than TotalPave IRI value; for Stuttle road RoadBump IRI value is 4.4 times higher than Roadroid IRI value and 3.9 times higher than TotalPave IRI value.

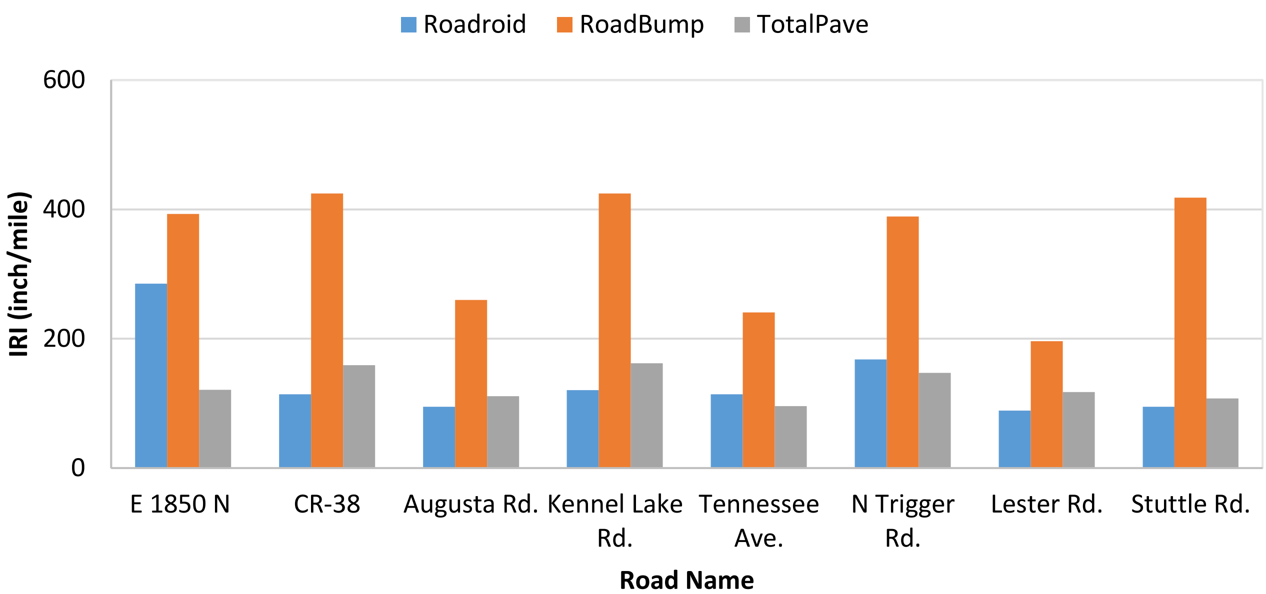


Figure 48. IRI results obtained using Roadroid, RoadBump, and TotalPave apps at multiple sites.

5.10 SUMMARY

Cell phone apps can be used to measure roughness of low-volume roads. The study results indicate that Roadroid app provides somewhat better results in measuring IRI values, when compared to the IRI data obtained by using RoadBump. The Roadroid IRI results were reasonably close to the IRI data measured by the high-speed profilometer. A consistent set of IRI data could be obtained from different vehicles operated at 20 to 30 mph speeds on the surveyed low-volume roads. The Roadroid app also provided consistent results for both smooth and rough pavements. The dashboard mount with Roadroid app was found to offer the most reliable IRI values. Because this study included limited data and research scope, a definitive conclusion is often difficult to make regarding the most suitable vehicle among a sedan car, van, and truck utilized herein to mount the cell phone and test the cell phone app performance. The sedan car, however, provided better results in general for measuring IRI with the Roadroid app.

CHAPTER 6: MAINTENANCE TECHNIQUES AND COST ASSESSMENT

6.1 BACKGROUND

Several counties and townships were visited to document maintenance practices followed by local officials. Note that most of the rural low-volume roads are chip-sealed roads, and the others are either slurry-seal or chip-seal urban low-volume roads. Different maintenance practices were documented, such as crack seal and patching in Appendix D. Gravel road maintenance techniques were also documented in Appendix D. Some rural and urban seal-coat maintenance projects were also visited; however, only a few were selected to be presented in this chapter.

6.2 SUMMARY

Chip seal is the maintenance activity most often used on rural roads. However, chip-seal maintenance costs varied a lot, depending on the location of the project. Slurry seal or microsurfacing is the most popular for urban roads and around cities.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

7.1 CONCLUSIONS

The objective of this research project was to develop methodologies for the evaluation of different types of seal-coated, gravel, and dirt roads by using a best-practice-oriented pavement-management system in Illinois. For this objective, this project compiled and investigated the current practices of local transportation officials so that better and more reliable methods could enable evaluation of rural road distresses. Through a comprehensive literature review covering both national and international sources, rural road maintenance and management methods were compiled. A statewide survey was conducted to collect input data from the IDOT local agencies currently responsible for maintaining the networks of seal-coated, gravel, and dirt roads. In addition, for selected sites of rural roads, both manual and automated methods of distress assessment of seal-coated, gravel, and dirt roads were used. Through site visits and interviews with the local agency contacts, the research team gathered essential information on the maintenance and management methods of rural roads and documented it in this report. This project therefore established a database to develop a best-practice guide for the maintenance, repair, and rehabilitation of seal-coated, gravel, and dirt roads in Illinois. Such a best-practice guide will help transportation officials in making rational decisions to allocate limited maintenance funds according to local agency needs.

The statewide survey revealed that counties and townships performed similar practices to maintain seal-coated, gravel, and dirt roads. Counties and townships typically conduct windshield surveys to evaluate rural roads. Note that windshield surveys are often subjective, and distress quantification cannot be achieved. In contrast, the windshield survey gives local agencies an opportunity to assess the rural roads more frequently, such as on a weekly basis. Counties and townships maintained most visual surveys of distresses, such as potholes, rutting, and roadside drainage. More routine standard practices were commonly followed to maintain roads having these distresses for the type, severity level, and extent.

Both subjective and objective methods have been used in the past to evaluate rural road conditions. Also, fully developed and sophisticated profilers are available to measure rural road conditions although they are expensive and skilled operators are needed. Local agencies commonly intend to explore other inexpensive but reliable techniques as new alternatives to evaluate rural roads. For this reason, this research effort explored using cell phone applications, or apps, for assessing roughness conditions of seal-coated, gravel, and dirt roads. Some of the commercially available cell phone apps were used to measure International Roughness Index (IRI) values of seal-coated, gravel, and dirt roads. Also, the research efforts in this project developed a Seal-Coated Road Condition Index (SCRCI) method to measure the seal-coated road surface condition using the manual method. Further, the Unsurfaced-Road Condition Index (URCI) was used to measure surface conditions of gravel and dirt roads.

Several seal-coated, gravel, and dirt roads were evaluated using a field distress-survey manual method. The SCRCI was developed based on the Pavement-Condition Index (PCI) and Unsurfaced-Road Condition Index (URCI). The SCRCI was then used to perform surface evaluations of several seal-coated roads in Illinois. The URCI method was used to evaluate several gravel and dirt roads. Both SCRCI and URCI required extensive data collection and then used tables and charts to determine the numeric rating. These methods are time-consuming and labor-intensive; and lane closure is often needed during data collection, which might otherwise pose a safety issue to the surveyor. For this reason, automated methods may be considered or preferred to evaluate seal-coated, gravel, and dirt roads.

Cell phone apps can be used to measure roughness of low-volume road. The study results indicate that the Roadroid app provides somewhat better results in measuring IRI values, as compared to the IRI data obtained by using RoadBump. The Roadroid IRI results were reasonably close to the IRI data measured by a high-speed profilometer. A consistent set of IRI data could be obtained from different vehicles operated at speeds of 20 to 30 mph on the surveyed low-volume roads. The Roadroid app also provided consistent results for both smooth and rough pavements. A dashboard mount with the Roadroid app was found to offer the most reliable IRI values. Because this study included limited data and research scope, a definitive conclusion is often difficult to make regarding the most suitable vehicle among a sedan car, van, and truck utilized herein to mount the cell phone and test the cell phone app performance. The sedan car, however, provided better results in general for measuring IRI with the Roadroid app.

In conclusion, this research project established a database to develop a best-practice guide for effectively evaluating unpaved roads maintained by local agencies. The guide was prepared as part of the project implementation plan to include treatment alternatives for the most commonly observed seal-coated, gravel, and dirt road distresses in Illinois and their severity levels and extents. The guide establishes unpaved-road maintenance strategies, including schedules and associated costs for the different levels of field maintenance and rehabilitation efforts.

7.2 RECOMMENDATIONS FOR FUTURE RESEARCH

The following recommendations can be offered for future research studies:

- The commercial cell phone apps require monthly or yearly subscription; and for this reason, it would be beneficial if a cell phone app can be developed for use by IDOT and local agencies. Such an app available to the local transportation officials in Illinois would help to evaluate seal-coated, gravel, and dirt roads, as well as low-volume roads, quite frequently, e.g., on a weekly basis. Better correlations with more accurate rolling and high-speed profilers would make the IRI results of this cell phone app even applicable to other state highway and medium- to high-volume roads.
- The cell phone app can be calibrated for installation on various off-road vehicles such as SUVs and trucks, as most of the local transportation officials routinely drive these vehicles.

- The IRI values measured by cell phone can be correlated to the SCRCI and URCI indices in relation to various distresses observed; and the overall approach can be used for maintenance scheduling for seal-coated, gravel, and dirt roads.

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APPENDIX A: SURVEY QUESTIONS PREPARED FOR RECORDING ILLINOIS LOCAL TRANSPORTATION ENGINEERS' PRACTICES ON EVALUATING SEAL COAT, GRAVEL, AND DIRT ROADS

Methodology for Evaluation of Seal Coat, Gravel, and Dirt Roads

Statewide Survey Questions

The objective of this survey is to develop a best practice guide for the identification of distresses, evaluation of distresses, and the maintenance, repair and rehabilitation practices of Seal coat, Gravel and, Dirt roads.

June 24, 2016

1.Objective of this Survey

The objective of this survey is to develop a best practice guide for the identification of distresses, evaluation of distresses, and the maintenance, repair and rehabilitation practices of **Seal coat, Gravel, and Dirt roads.**

2. Scope and Importance of the Research

The Illinois Department of Transportation (IDOT) reports 146,890 miles of total road network, of which the paved roads are 61,669 miles and unpaved roads are 85,221 miles; accordingly, unpaved roads comprise of 58% of total road mileage in the Illinois as of 2015. (Source: 2015 Illinois Highway and Street Mileage Statistics).

With increasing demand for transportation, there is a need to better monitor the performance of transportation assets and provide the public with a sustainable and efficient road network. To achieve this goal, it is of utmost importance that transportation agencies properly evaluate the road conditions. At present IDOT does not provide Districts and Counties with a practice guide for the maintenance of Seal Coat, Gravel, and Dirt roads.

The purpose of this survey is to collect input data from the IDOT local agencies that are currently responsible for maintaining the seal coat, gravel and dirt road networks. This will establish a database to better understand the current practices applied on a daily basis, which will further help to conduct important site visits/interviews, as needed, to develop the best practice guide for the maintenance, repair and rehabilitation of Seal Coat, Gravel, and Dirt Roads.

3. Contents of this Survey

This survey comprises of 13 questions. Short description of the Seal Coat, Gravel and Dirt roads, their distress types and the various techniques and strategies to overcome the distresses are provided to facilitate the responder. Estimated time to complete this survey is 15 to 20 minutes.

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5. Definitions

5.1 Seal Coat Roads

Gravel roads that have been treated with an asphalt seal coat (such as chip seal or oil and chip road.) to maintain a comfortable ride, weatherproof the surface and eliminate dust problems are called as **Seal Coat Roads**.

5.2 Gravel Roads

Roads with a harder surface made by the addition of material such as uncrushed gravel (i.e. washed or river rock) and crushed gravel/stone are called **Gravel Roads**.

5.3 Dirt Roads

Roads made from the native soil or subgrade material are known as **Dirt Roads**. Dirt road also known as Earth Roads.

<u>**6. Distress measurement methods for Seal Coat, Gravel, and Dirt Roads**</u>

6.1 Windshield Inspection

In this type of inspection, the evaluators are required to rate the condition of the road on the basis of visual identification of the type, severity level and extent of the distress observed from inside a moving vehicle on the road. This approach is more qualitative but yet subjective since inspection results may vary considerably from one person to another for the same the road segment.

6.2 Manual Distress Measurement

In this manual distress evaluation, each distress is measured and reported based on a certain scale. Dip Stick is one of the most common scales used for the measurement of ruts and potholes. This type of distress measurement is generally quantity based and the evaluation of the severity level and extent depends on objective quantitative measurements and analyses.

Monitoring the condition of unpaved roads with remote sensing and other technology, **South Dakota State University**

6.3 Distress Measurement by Automated Vehicles

A moving vehicle equipped with cameras and measurement devices collects and synthesizes complete data on the visual type, severity level and extent of the distress prevailing on the road surface and evaluates the road condition through data analyses.

Question 1. Please select how frequently your agency conducts inspections for the evaluation of the Seal Coat, Gravel and Dirt Roads? *[Please check (√) all that apply]*

Inspection Frequency	**Seal Coat Roads**	**Gravel Roads**	**Dirt Roads**
Weekly	☐	☐	☐
Once a month	☐	☐	☐
Twice a month	☐	☐	☐
Once a year	☐	☐	☐
Once in 2 years	☐	☐	☐
Once in 3 years	☐	☐	☐
Once in 5 years	☐	☐	☐
Please specify any other maintenance interval adopted by your agency			
Not Applicable: *(Please Check (√) this box if your agency does not evaluate and maintain any of this road type)*	☐	☐	☐

Question 2. Which of the following strategy is adopted by your agency for the evaluation of Seal Coat, Gravel, and Dirt Roads? *[Please check (√) all that apply]*

EXAMPLE: If an agency performs *manual inspection* for Seal Coat roads then the check mark will be placed for **Manual measurement of each distress.** If the agency performs *Windshield inspection* for gravel and dirt roads then the check will be for **Windshield inspection** for gravel and dirt road

Inspection Type	Seal Coat Roads	Gravel Roads	Dirt Roads
Windshield Inspection	☐	☑	☑
Manual Measurement of each Distress	☑	☐	☐
Distress Measurement by Automated Vehicles	☐	☐	☐
Please specify any other maintenance strategy adopted by your agency			

Please check (√) all that applies for your agency:

Inspection Type	Seal Coat Roads	Gravel Roads	Dirt Roads
Windshield Inspection	☐	☐	☐
Manual Measurement of each Distress	☐	☐	☐
Distress Measurement by Automated Vehicles	☐	☐	☐
Please specify any other maintenance strategy adopted by your agency			

7. Common Distresses for Seal Coat Roads

7.1. Improper Cross-section

7.2. Alligator/Fatigue Cracking

7.3. Edge Cracking

7.4. Rutting

7.5. Potholes

7.6. Patching

7.7. Loose Aggregate

7.8. Roadside Drainage

7.9 Shoving

7.10 Bleeding

Question 3. Rank the distresses from the highest priority (1) to the lowest by your agency for maintaining the Seal Coat, Gravel, and Dirt roads? *(Please circle the numbers to rank your order)*

EXAMPLE: Local agency maintains a seal coated road only and the road is exposed to severe alligator cracking. Under this circumstance, the alligator cracking will be the number 1 priority for the local agency. The number 2 priority could be maintaining loose aggregate of the seal coated road and other distresses may be ranked with lower priority, e.g., patching

Example: Rank Order of Distresses									
Distress Type		**Seal Coat Roads**							
		HIGH							**LOW**
1.	Improper Cross-section	1	2	3	4	5	6	**7**	8
2.	Alligator/Fatigue Cracking	**1**	2	3	4	5	6	7	8
3.	Edge Cracking	1	2	**3**	4	5	6	7	8
4.	Rutting	1	2	3	**4**	5	6	7	8
5.	Potholes	1	2	3	4	**5**	6	7	8
6.	Patching	1	2	3	4	5	**6**	7	8
7.	Loose Aggregate	1	**2**	3	4	5	6	7	8
8.	Roadside Drainage	1	2	3	4	5	6	7	**8**
Other Distress Type with Priority Scale									

Please circle the numbers to rank the order for your agency:

Question 3.1. Rank the distresses from the highest priority (1) to the lowest (10) by your agency for maintaining the **Seal Coat roads**? *(Please circle the numbers to rank your order)*

3.1 Rank Order of Distresses											
Distress Type		**Seal Coat Roads**									
		HIGH							**LOW**		
1.	Improper Cross-section	1	2	3	4	5	6	7	8	9	10
2.	Alligator/Fatigue Cracking	1	2	3	4	5	6	7	8	9	10
3.	Edge Cracking	1	2	3	4	5	6	7	8	9	10
4.	Rutting	1	2	3	4	5	6	7	8	9	10
5.	Potholes	1	2	3	4	5	6	7	8	9	10
6.	Patching	1	2	3	4	5	6	7	8	9	10
7.	Loose Aggregate	1	2	3	4	5	6	7	8	9	10
8.	Roadside Drainage	1	2	3	4	5	6	7	8	9	10
9.	Shoving	1	2	3	4	5	6	7	8	9	10
10.	Bleeding	1	2	3	4	5	6	7	8	9	10
Other Distress Type with Priority Scale											

8. Commons Distresses for Gravel Roads

8.1. Improper Cross-section

8.2. Crown

8.3. Rutting

8.4. Corrugation / Wash-Boarding

8.5. Potholes

8.6. Loose Aggregate

8.7. Dust

8.8. Roadside Drainage

Please circle the numbers to rank the order for your agency:

Question 3.2. Rank the distresses from the highest priority (1) to the lowest (8) by your agency for maintaining the **Gravel roads**? *(Please circle the numbers to rank your order)*									
3.2 Rank Order of Distresses									
Distress Type		**Gravel Roads**							
		HIGH							**LOW**
1.	Improper Cross-section	1	2	3	4	5	6	7	8
2.	Crown	1	2	3	4	5	6	7	8
3.	Rutting	1	2	3	4	5	6	7	8
4.	Corrugation / Wash-Boarding	1	2	3	4	5	6	7	8
5.	Potholes	1	2	3	4	5	6	7	8
6.	Loose Aggregate	1	2	3	4	5	6	7	8
7.	Dust	1	2	3	4	5	6	7	8
8.	Roadside Drainage	1	2	3	4	5	6	7	8
Other Distress Type with Priority Scale									

9. Commons Distresses for Dirt Roads

9.1. Improper Cross-section

9.2. Crown

9.3. Rutting

9.4. Corrugation / Wash-Boarding

9.5. Potholes

9.6. Dust

9.7. Roadside Drainage

Please circle the numbers to rank the order for your agency:

Question 3.3. Rank the distresses from the highest priority (1) to the lowest (7) by your agency for maintaining the **Dirt roads**? *(Please circle the numbers to rank your order)*

3.3 Rank Order of Distresses		
Distress Type		**Dirt Roads**
		HIGH **LOW**
1.	Improper Cross-section	1 2 3 4 5 6 7
2.	Crown	1 2 3 4 5 6 7
3.	Rutting	1 2 3 4 5 6 7
4.	Corrugation / Wash-Boarding	1 2 3 4 5 6 7
5.	Potholes	1 2 3 4 5 6 7
6.	Dust	1 2 3 4 5 6 7
7.	Roadside Drainage	1 2 3 4 5 6 7
Other Distress Type with Priority Scale		

10. Different Equipment Types and Maintenance Strategies for Seal Coat, Gravel, and Dirt roads

Equipment Description | **Equipment Image**

Rotograder: The rotograder can perform surface milling of seal coat roads and pulverize gravel road using a cutter drum and bits inside the drum.

CMI Reclaimer/Stabilizer: The reclaimer also performs surface milling of seal coat roads as well as use to deep soil stabilization.

Road Drag: The road drag is used to trim the surface of gravel or dirt road by pulling it behind a tractor.

Articulated grader with moldboard: A moldboard can be used to trim routinely and provide the proper angle to the road surface. During maintenance by providing a proper angle to moldboard one can also avoid the spillage of aggregate.

Improvement of Ditches using regrading. Motor Grader is commonly used to regrade, clean the ditch and reshape the ditch to maintain proper slope.

Front Dozer with Carbide Bits: An efficient tool for dealing with washboard areas; the front dozer is equipped with Carbide bits.

Retriever with Shouldering Disk: The Retriever is a road shoulder tool that efficiently conditions the shoulder material for reuse on the road surface. The Retriever mulches and separates the road side vegetation from the existing gravel and then moves it to the road surface

Compacting Rollers: Compacting roller is mounted on a motor grader, and is perfect for gravel road maintenance. This equipment allows the user to blade and compact at conserving moisture in dry spells or sealing out moisture during a wet spell.

11. Different Maintenance Techniques used by Agencies to Remedy Distresses

Resealing: Resealing top layer of Seal coated road with thin bitumen layer seals the cracks and increases the road's service life.

Patching: Patching the edge of the road with asphalt mix controls cracks and minimizes material loss on the surface.

Spray Injection: This spray injection equipment is used as a maintenance application for sealing cracks.

Pothole Repair: Filling of Potholes with cold mix, followed by compaction.

Stabilization: Use of chemical or adhesive materials to gain strength and reduce loss of materials such as dust. Generally a truck has a pressurized spray bar with a computerized application system that helps to spray the chemical or adhesive materials with extreme accuracy.

Question 4. For the following types of distresses, please select the appropriate maintenance techniques/strategies practiced by your agency related to Seal Coat, Gravel, and Dirt Roads?
[Please check (√) all that apply]

4.1 Seal Coat Roads			
Distress Types and their Maintenance Strategies			
Improper Cross-Section			
1.	Re-grading with Road Grader or Rotograder	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Cutting, Scarifying & Reshaping the Cross-section	☐	
3.	Addition of Gravel Aggregate (to Maintain Gravel Layer)	☐	
Other maintenance technique (please state)			
Alligator/Fatigue Cracking			
1.	Base repair by Scarification and Recoat with Seal Coat	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Improving Drainage	☐	
Other maintenance technique (please state)			
Edge Cracking			
1.	Patching of the Edges by Resealing	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Improving Drainage	☐	
Other maintenance technique (please state)			
Rutting			
1.	Scarification, Cutting and Resealing	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Addition of Aggregate	☐	

<table>
<tr><td colspan="4">Other maintenance technique (please state)</td></tr>
<tr><td colspan="4">Potholes</td></tr>
<tr><td>1.</td><td>Addition of cold-mix/hot-mix into Pothole and Compaction</td><td>☐</td><td rowspan="2">Not Applicable: Please Check (√) this box if your agency does not follow any maintenance strategy for fixing this distress
☐</td></tr>
<tr><td>2.</td><td>Scarification, Cutting and Regrading</td><td>☐</td></tr>
<tr><td colspan="4">Other maintenance technique (please state)</td></tr>
<tr><td colspan="4">Patching</td></tr>
<tr><td>1.</td><td>Crack Sealing</td><td>☐</td><td rowspan="5">Not Applicable: Please Check (√) this box if your agency does not follow any maintenance strategy for fixing this distress
☐</td></tr>
<tr><td>2.</td><td colspan="2">Patch Repairs with</td></tr>
<tr><td></td><td>(a.) Cold-mix Asphalt material</td><td>☐</td></tr>
<tr><td></td><td>(b.) Hot-mix Asphalt material</td><td>☐</td></tr>
<tr><td>3.</td><td>Spray Injection Patching</td><td>☐</td></tr>
<tr><td colspan="4">Other maintenance technique (please state)</td></tr>
<tr><td colspan="4">Loose Aggregate</td></tr>
<tr><td>1.</td><td>Re-grading with Patrol Grader</td><td>☐</td><td rowspan="3">Not Applicable: Please Check (√) this box if your agency does not follow any maintenance strategy for fixing this distress
☐</td></tr>
<tr><td>2.</td><td>Addition of Proper Aggregate</td><td>☐</td></tr>
<tr><td>3.</td><td>Compaction</td><td>☐</td></tr>
<tr><td colspan="3">Other maintenance technique (please state)</td><td></td></tr>
<tr><td colspan="4">Roadside drainage</td></tr>
<tr><td>1.</td><td>Ditch Cleaning by Loading and Hauling Excess Material</td><td>☐</td><td rowspan="4">Not Applicable: Please Check (√) this box if your agency does not follow any maintenance strategy for fixing this distress</td></tr>
<tr><td>2.</td><td>Scarifying to Maintain a Uniform Ditch Slope</td><td>☐</td></tr>
<tr><td>3.</td><td>Seeding the Soil and Installing Erosion Control</td><td>☐</td></tr>
<tr><td>4.</td><td>Replacing Head-walls and Rip-rap to Prevent Erosion</td><td>☐</td></tr>
</table>

5.	Cleaning of Culverts	☐	☐
Other maintenance technique (please state)			

Shoving			
1.	Remove the distorted seal and patch	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Re-seal	☐	
Other maintenance technique (please state)			
Bleeding			
1.	Apply layer of aggregate	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Removal of bleeding pavement surface and replace with new seal coat	☐	
Other maintenance technique (please state)			

4.2 Gravel Roads			
Improper Cross-Section			
1.	Re-grading with Patrol Grader	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Blading	☐	
3.	Cutting, Scarifying & Reshaping the Cross-section	☐	
4.	Addition of Gravel Aggregate (to Maintain Gravel Layer)	☐	
Other maintenance technique (please state)			
Rutting			
1.	Blading	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarification, Cutting, and Regrading	☐	
3.	Addition of Aggregate	☐	
Other maintenance technique (please state)			
Corrugation / Wash-Boarding			
1.	Routine Grading (for slight corrugation)	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarification, Cutting, and Regrading	☐	
3.	Addition of Aggregate	☐	
4.	Compaction for maintaining proper Road surface	☐	
Other maintenance technique (please state)			
Potholes			
1.	Addition of Granular Material into Pothole and Compaction	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarification, Cutting, and Regrading	☐	
Other maintenance technique (please state)			

Loose Aggregate			
1.	Re-grading with Patrol Grader	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Addition of Proper Aggregate	☐	
3.	Compaction	☐	
Other maintenance technique (please state)			

Dust			
1.	Use of Stabilizer to Control Dust		**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
	(a.) Chlorides (Flake or Liquid form)	☐	
	(b.) Resins/Tree sap (Lignin Sulfonate)	☐	
	(c.) Emulsified Asphalt	☐	
	(d.) Acidulated Soybean Oil Soapstock	☐	
2.	Regular Compaction	☐	
Other maintenance technique (please state)			

Roadside Drainage			
1.	Ditch Cleaning by Loading and Hauling Excess Material	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarifying to Maintain a Uniform Ditch Slope	☐	
3.	Seeding the Soil and Installing Erosion Control	☐	
4.	Replacing Headwalls and Rip-rap to Prevent Erosion	☐	
5.	Cleaning of Culverts	☐	
Other maintenance technique (please state)			

4.3 Dirt Roads			
Improper Cross-Section			
1.	Re-grading with Patrol Grader	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Blading	☐	
3.	Cutting, Scarifying & Reshaping the Cross-section	☐	
4.	Addition of Soil	☐	
Other maintenance technique (please state)			
Rutting			
1.	Blading	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarification, Cutting and Regrading	☐	
3.	Addition of Soil	☐	
Other maintenance technique (please state)			
Corrugation / Wash-Boarding			
1.	Routine Grading (for slight corrugation)	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarification, Cutting, and Regrading	☐	
3.	Addition of Soil	☐	
4.	Compaction for Maintaining Proper Road Surface	☐	
Other maintenance technique (please state)			
Potholes			
1.	Addition of Granular Material into Pothole and Compaction	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarification, Cutting, and Regrading	☐	

Other maintenance technique (please state)

Dust			
1.	Use of Stabilizer to Control Dust		**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
	(a.) Chlorides (Flake or Liquid form)	☐	
	(b.) Resins/Tree Sap (Lignin Sulfonate)	☐	
	(c.) Emulsified Asphalt	☐	
	(d.) Acidulated Soybean Oil Soapstock	☐	
2.	Regular Compaction	☐	
Other maintenance technique (please state)			

Roadside Drainage			
1.	Ditch Cleaning by Loading and Hauling Excess Material	☐	**Not Applicable:** Please Check *(√)* this box if your agency does not follow any maintenance strategy for fixing this distress ☐
2.	Scarifying to Maintain a Uniform Ditch Slope	☐	
Other maintenance technique (please state)			

Question 5. What type of Seal Coat is applied on unpaved roads in your agency?
[Please check (√) all that apply]

☐ **Chip Seal**
☐ **Asphalt Emulsions**
☐ **Cutback Asphalt**
☐ **Acrylics**
Other types of Seal Coat (please state):

Question 6. Which of the following subgrade soil or base layer stabilization technique(s) is/are practiced by your agency? *[Please check (√) all that apply]*

Chemical Stabilization Techniques		Gravel Road	Dirt Road
1.	Bitumen Emulsions	☐	☐
2.	Calcium Chloride	☐	☐
3.	Sodium Chloride	☐	☐
4.	Soil-Cement Stabilization	☐	☐
Other Chemical Stabilization Technique (please state):			
Not Applicable: Please Check *(√)* this box if your agency does not follow chemical stabilization techniques for any of the road type		☐	☐
Mechanical Stabilization		**Gravel Road**	**Dirt Road**
5.	Geo Synthetic Materials	☐	☐
6.	Fiber-Reinforcement	☐	☐
Other Mechanical Stabilization Technique (please state):			
Not Applicable: Please Check *(√)* this box if your agency does not follow mechanical stabilization techniques for any of the road type		☐	☐

Question 7. Does your agency perform field testing to evaluate strength and structural capacity of Seal Coat, Gravel, and Dirt Road? *[Please check (√) all that apply]*

Road Type		Yes	No
1.	Seal Coat Roads	☐	☐
2.	Gravel Roads	☐	☐
3.	Dirt Roads	☐	☐

Question 8. If you answered "No" to all road types in Question 7 then move on to Question 9. Which of the following method(s) is/are used by your agency to evaluate structural capacity of a road by field testing? Note that pictures of commonly used field tests are given below *[Please check (√) all that apply]*

Structural Measurement Method		Seal Coat Roads	Gravel Roads	Dirt Roads
1.	Static Cone Penetrometer (SCP)	☐	☐	☐
2.	Dynamic Cone Penetrometer (DCP)	☐	☐	☐
3.	Lightweight Deflectometer (LWD)	☐	☐	☐
4.	Falling Weight Deflectometer (FWD)	☐	☐	☐
5.	Geo-Gauge	☐	☐	☐
Other equipment used for structural capacity evaluation (please state):				
Not Applicable: Please Check *(√)* this box if your agency does not follow structural measurement techniques for any of the road type		☐	☐	☐

Static Cone Penetrometer (SCP)

Dynamic Cone Penetrometer (DCP)

Light Weight Deflectometer (LWD)

Falling Weight Deflectometer (FWD)

Geo-Gauge

Question 9. Does your agency collect the following project specific data for the Seal Coat, Gravel, and Dirt Roads? *[Please check (√) all that apply]*

Description of Project Data	Seal Coat Roads	Gravel Roads	Dirt Roads
Construction History Record	☐	☐	☐
Record for smoothness and ride-ability of road surface	☐	☐	☐
Maintenance Activity Record - Summer	☐	☐	☐
Maintenance Activity Record - Winter	☐	☐	☐

Question 10. Did your agency perform any maintenance activity for the following types of roads recently? *[Please check (√) all that apply]*. If yes, please also state the date (month/year) of completion of your recent maintenance activity?

Road Type	Yes	No	Date (month/year)
Seal Coat Road	☐	☐	
Gravel Road	☐	☐	
Dirt Road	☐	☐	

Question 11. Is your agency planning to perform any maintenance activity for the following types of roads in near future? *(Please check all that apply)*. If yes, please state the anticipated start date (month / year) of your maintenance activity.

Road Type	Yes	No	Date (month/year)
Seal Coat Road	☐	☐	
Gravel Road	☐	☐	
Dirt Road	☐	☐	

Question 12: What is a best practice that your agency follows to maintain Seal Coat Road, Gravel Road, and Dirt Road? Please state briefly.

Seal Coat Road Maintenance Best Practice:

Gravel Road Maintenance Best Practice:

Dirt Road Maintenance Best Practice:

Your cooperation with this survey is greatly appreciated. Your feedback will facilitate the development of a **"Best Practice Guide"** for Seal Coat, Gravel, and Dirt Roads. In order to make this project successful, your agency's help and guidance will be critical. We look forward to better understand problems your agency might be facing so that in our efforts we can formulate the most effective solutions.

Question 13. Would your agency be interested in providing more assistance and advice to this research project for formulating best practices?	
Yes	☐
No	☐

Contact Information of Road Authority:

(Please fill this section even if your answer to Q13. is a NO)

Name of the Responder:

Designation:

District Number and County Name:

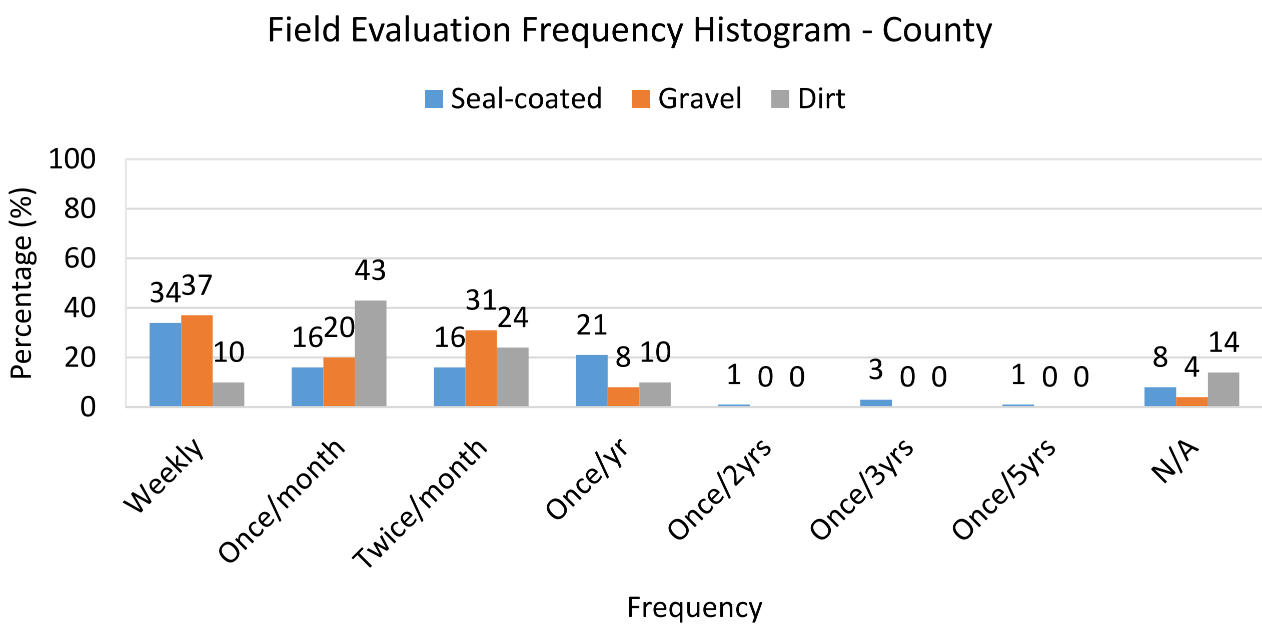
Township/Municipality Name:

Phone No.:

Email Address:

Office Address:

APPENDIX B: SURVEY RESPONSES



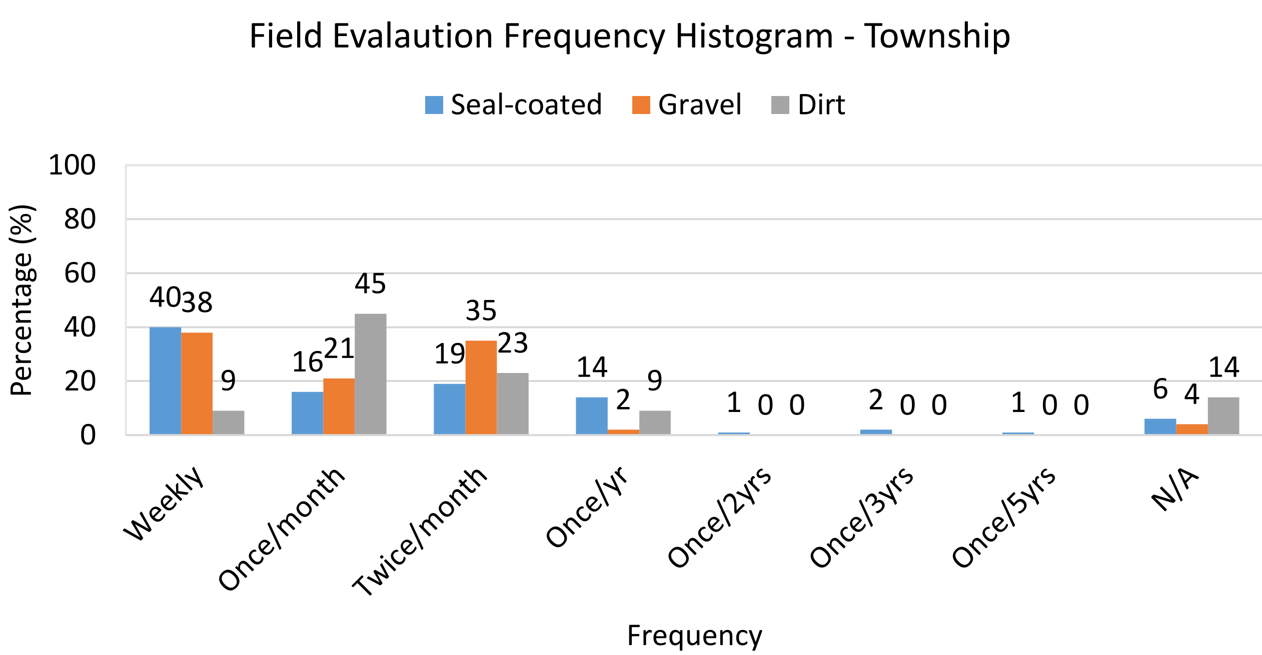
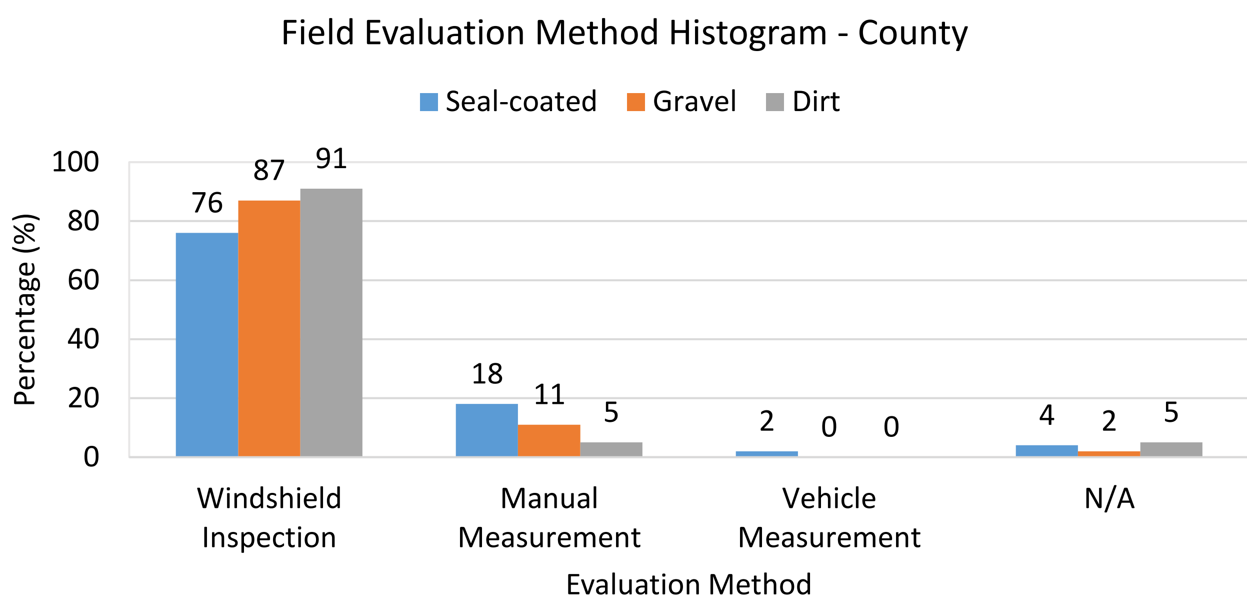


Figure B-1. Evaluation frequency of seal-coated, gravel, and dirt roads by counties and townships.



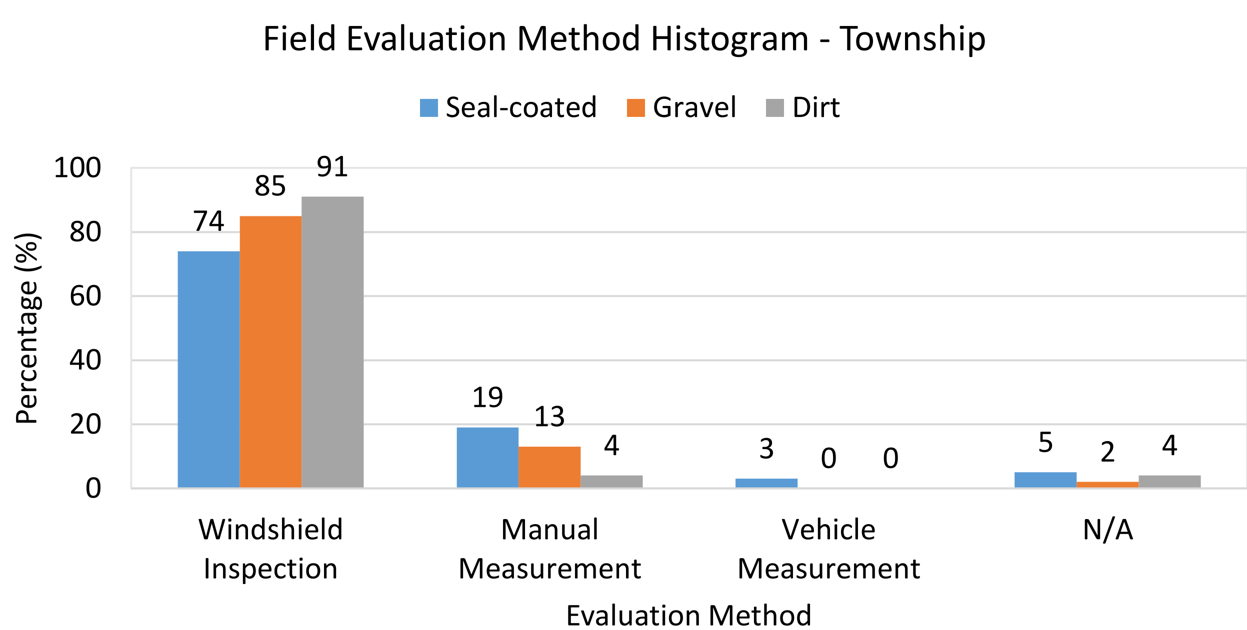
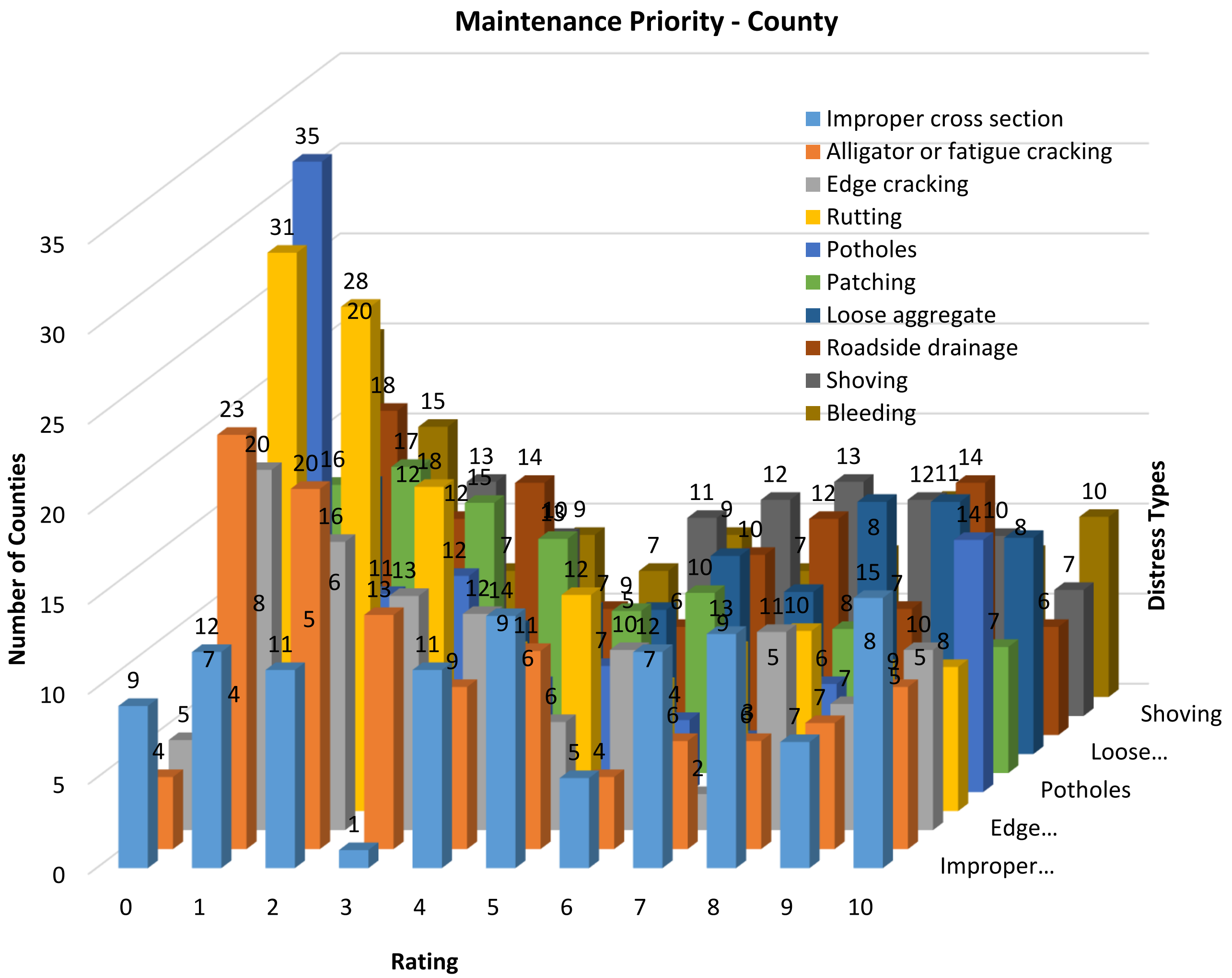


Figure B-2. Evaluation method followed by counties and townships.


Maintenance Priority - County
Number of Counties
0
5
10
15
20
25
30
35
Rating
0
1
2
3
4
5
6
7
8
9
10
Distress Types
Improper…
Edge…
Potholes
Loose…
Shoving
Improper cross section
Alligator or fatigue cracking
Edge cracking
Rutting
Potholes
Patching
Loose aggregate
Roadside drainage
Shoving
Bleeding

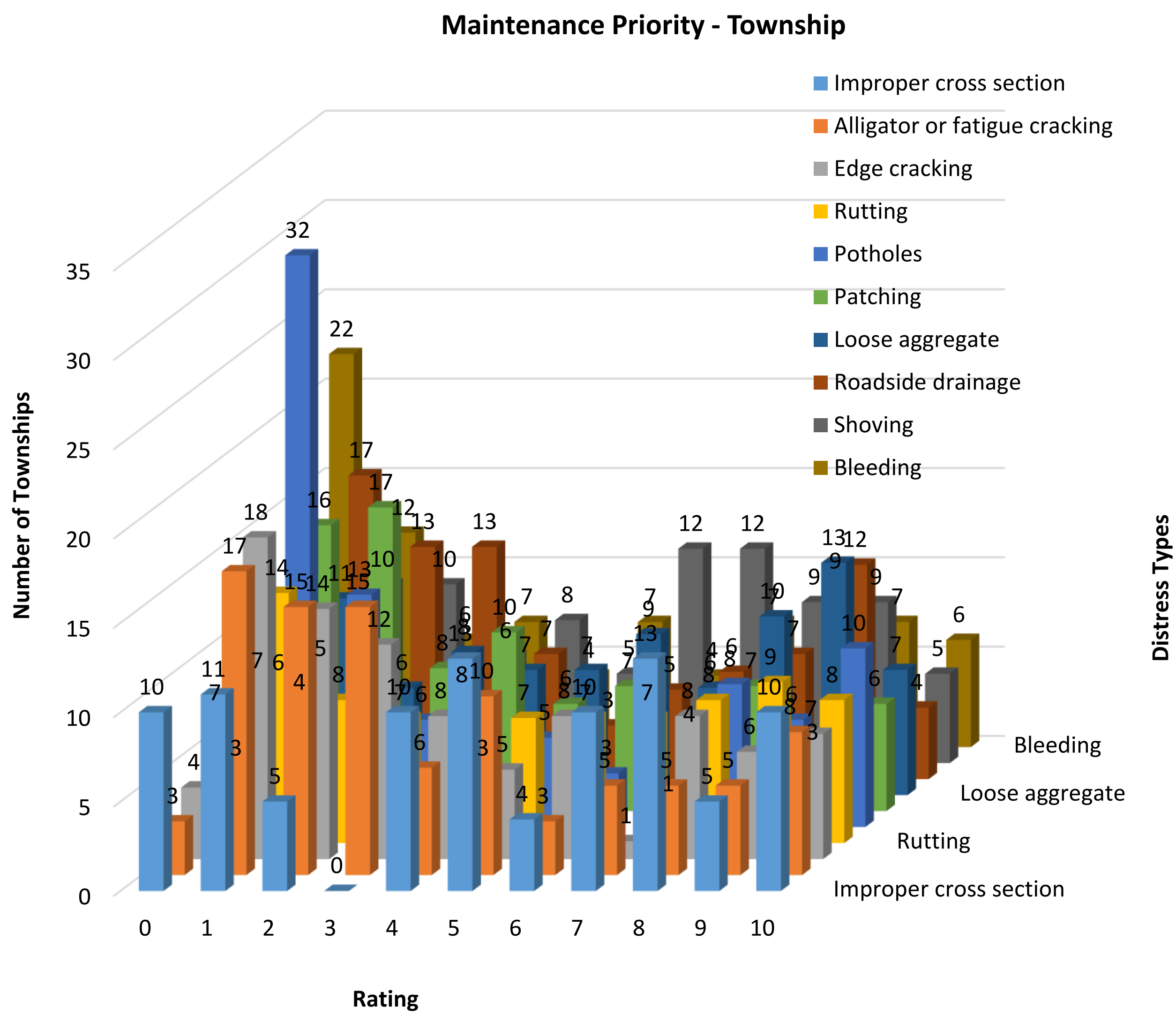
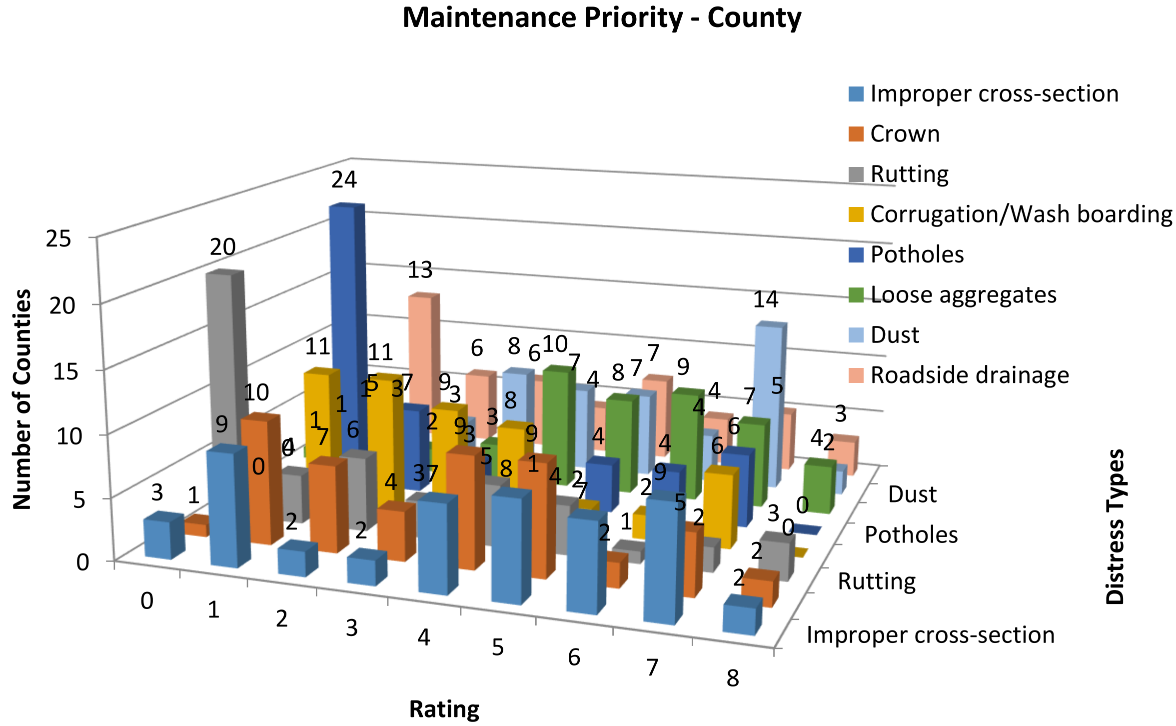


Figure B-3. Maintenance priority in seal-coated roads followed by counties and townships.



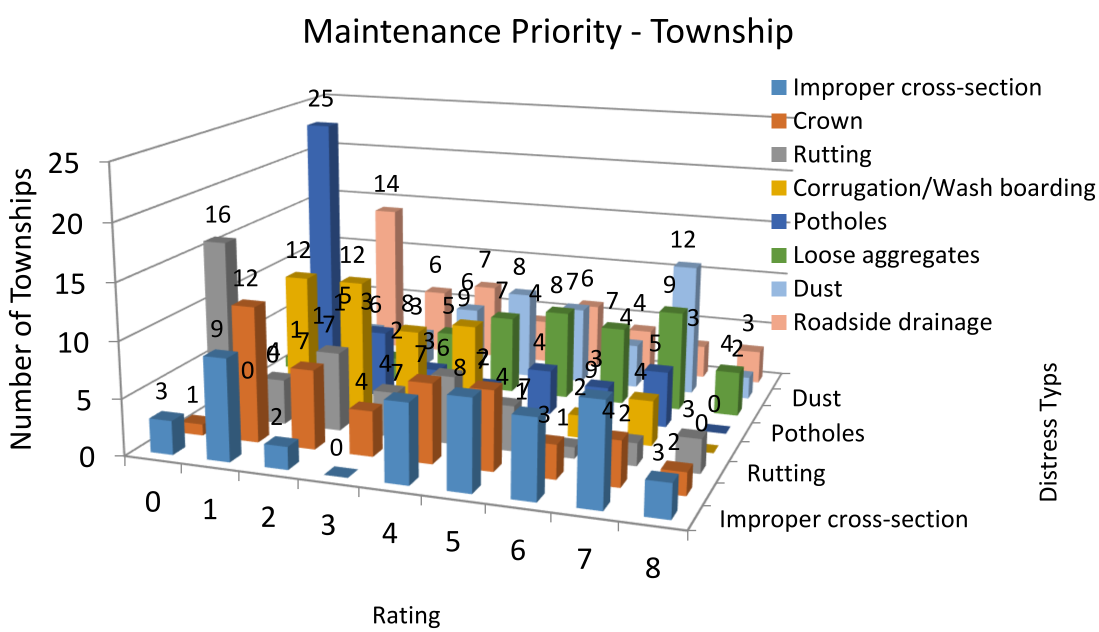
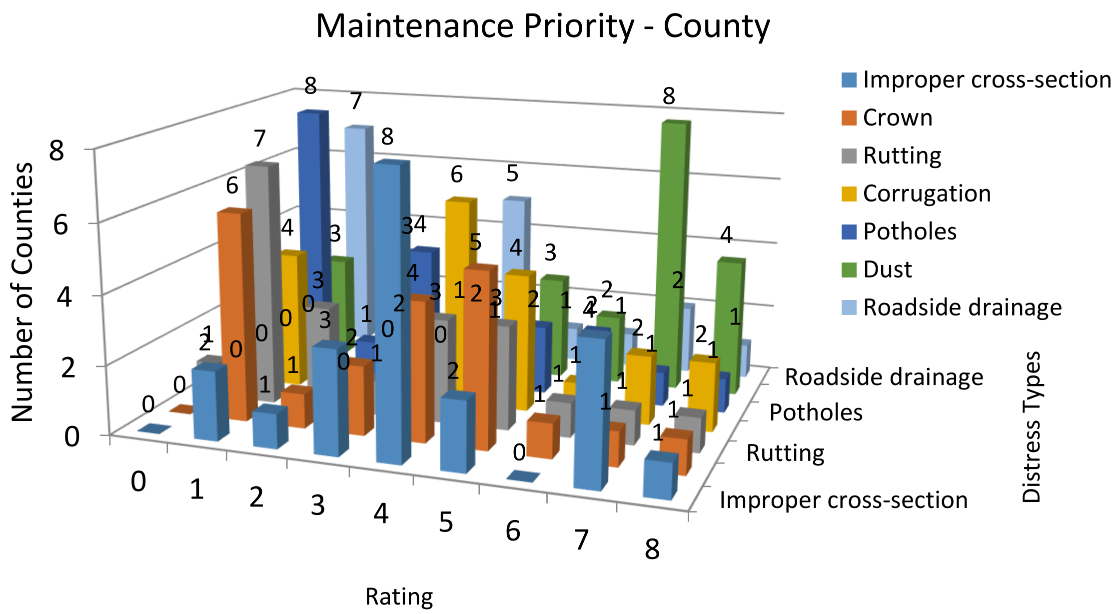


Figure B-4. Maintenance priority in gravel roads followed by counties and townships.



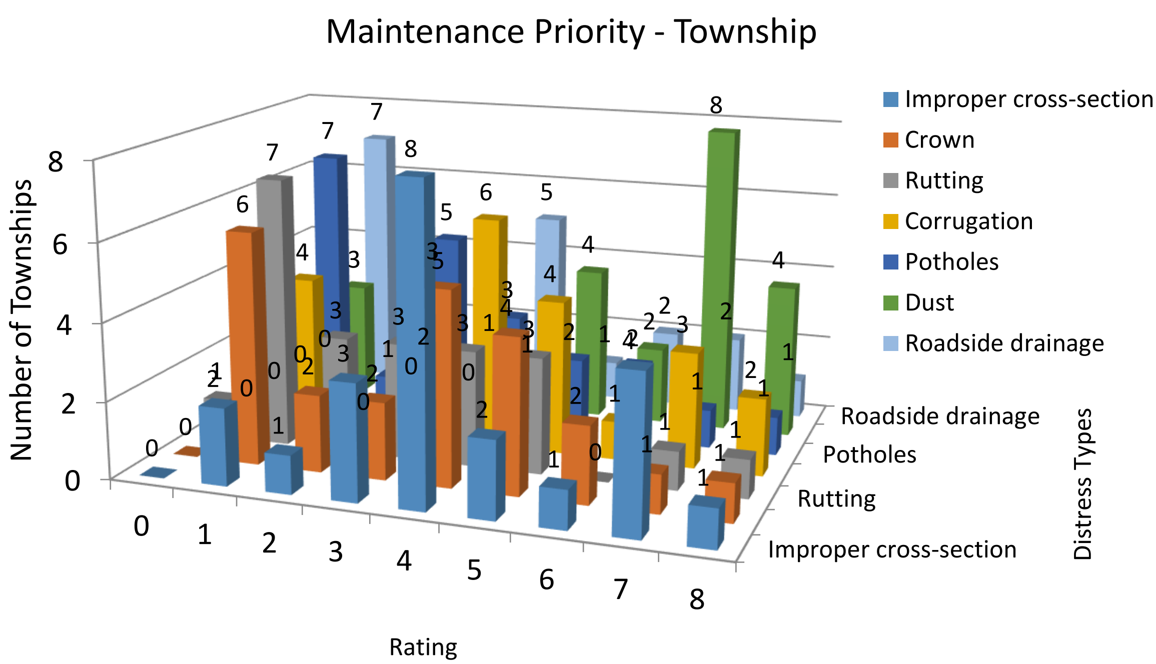
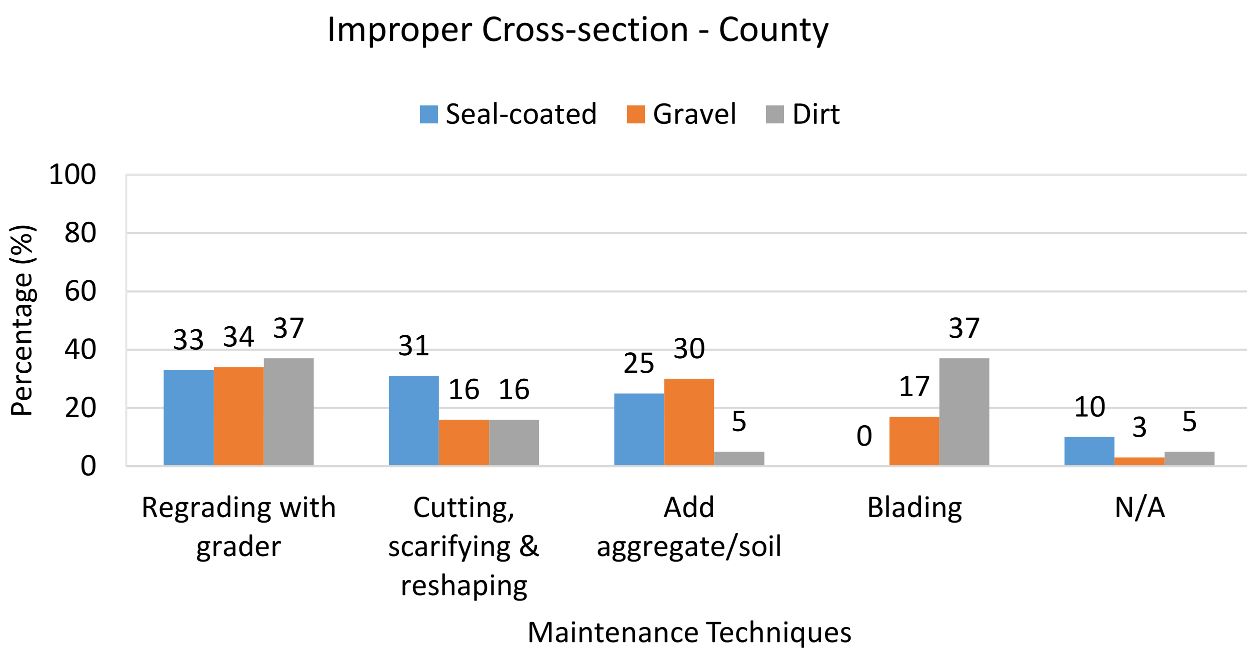


Figure B-5. Maintenance priority in dirt roads followed by counties and townships.



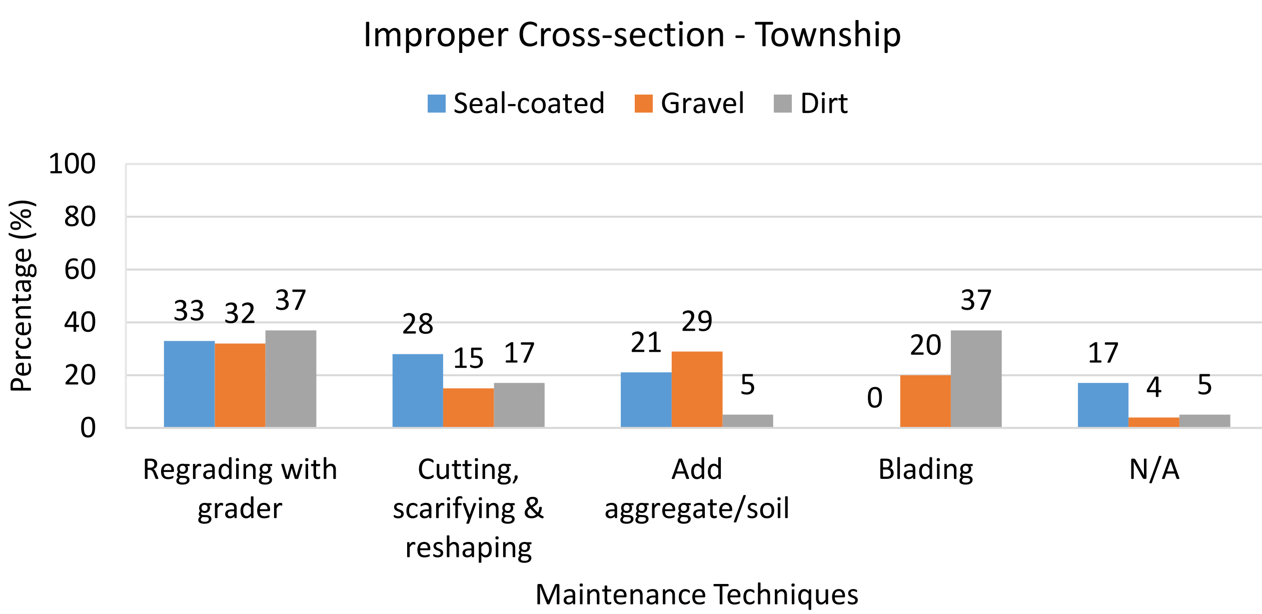


Figure B-6. Maintenance techniques followed by counties and townships to fix improper cross-sections of seal-coated, gravel and dirt roads.

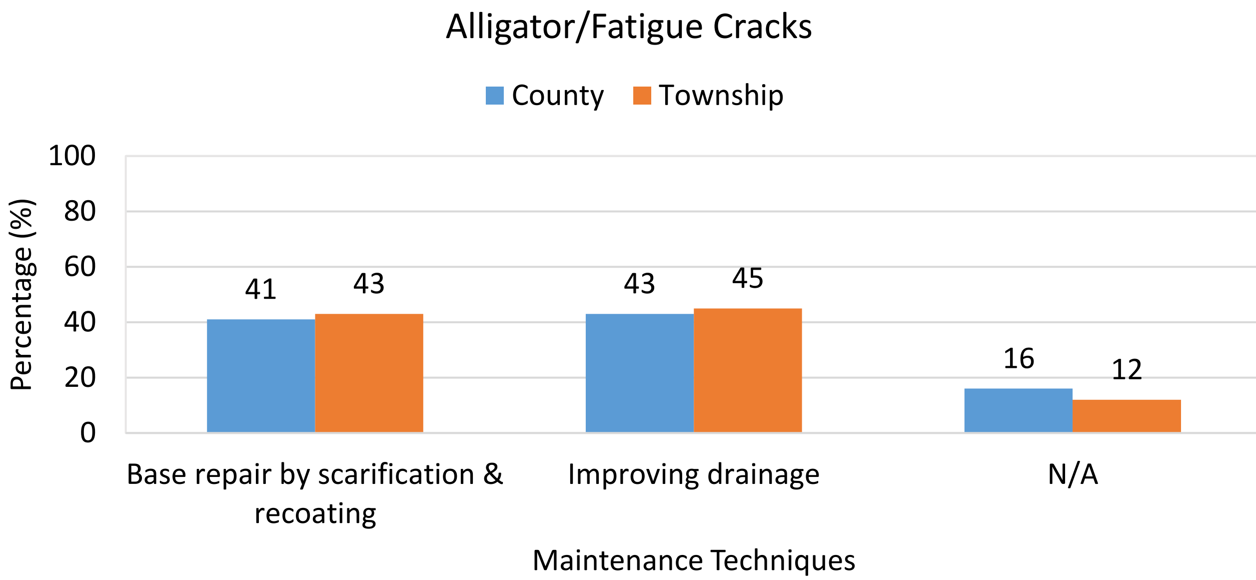


Figure B-7. Maintenance techniques followed by counties and townships to fix fatigue cracks.

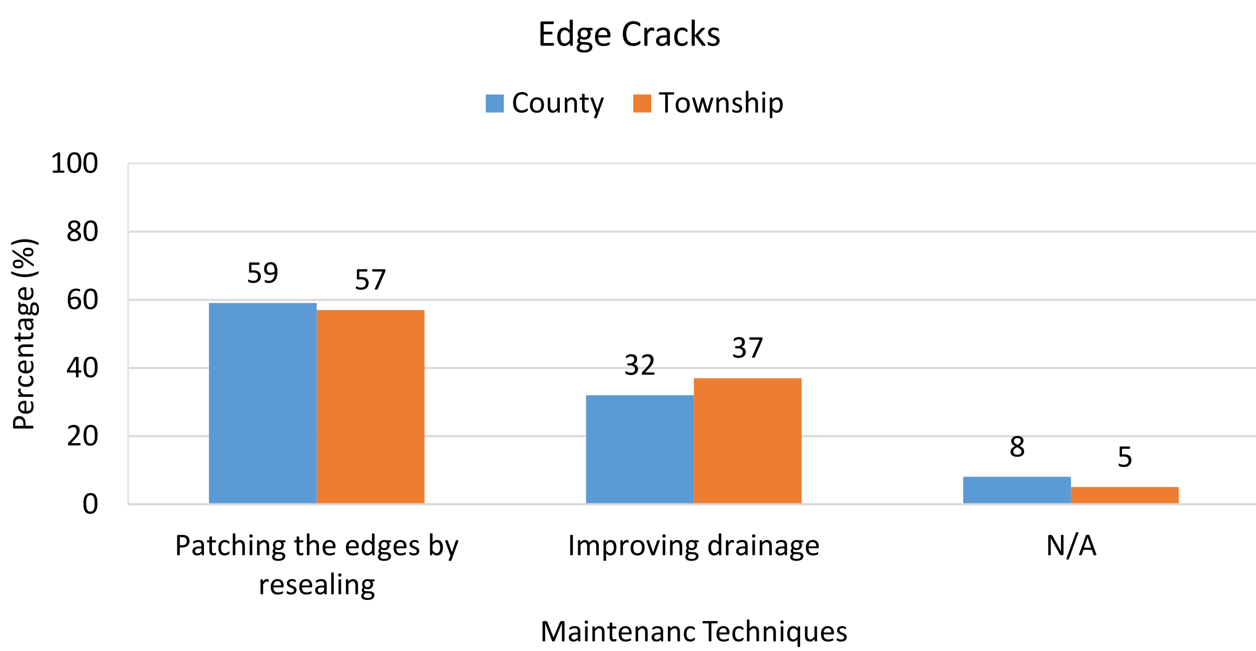
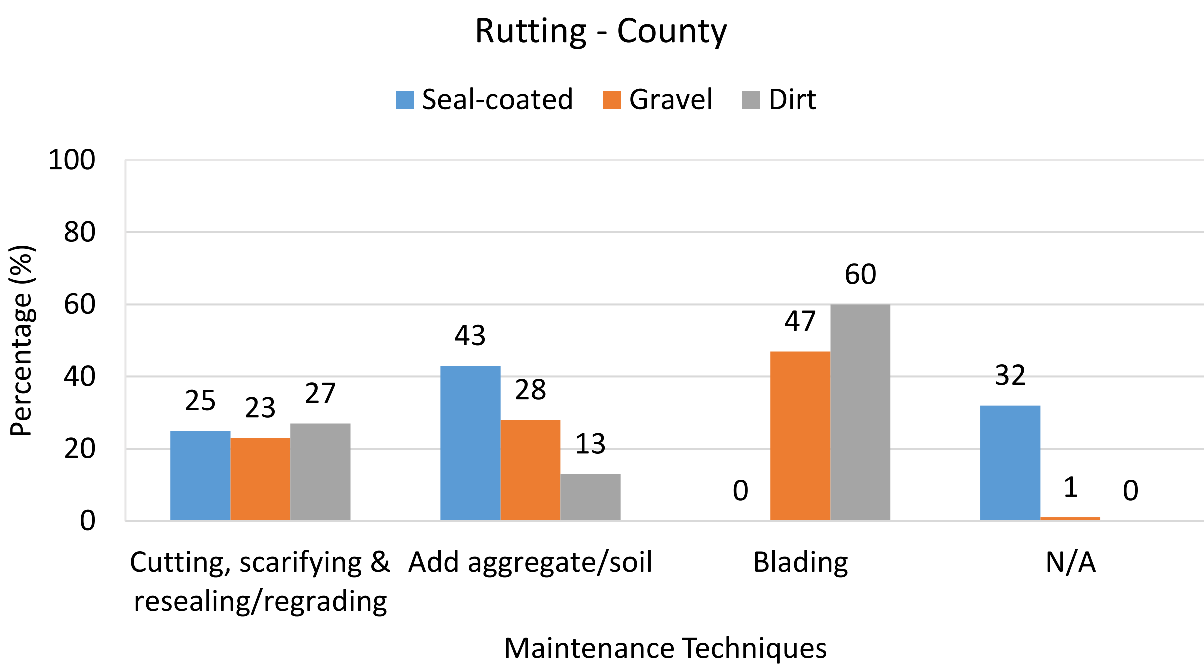


Figure B-8. Maintenance techniques followed by counties and townships to fix edge cracks.



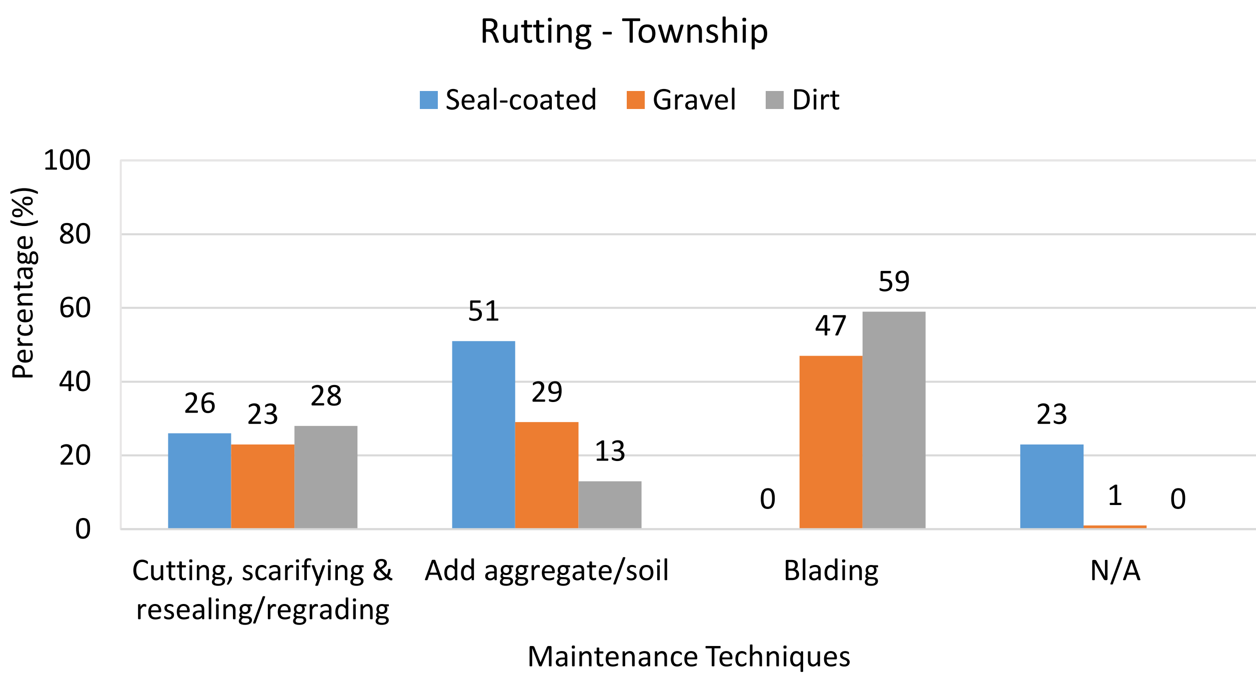
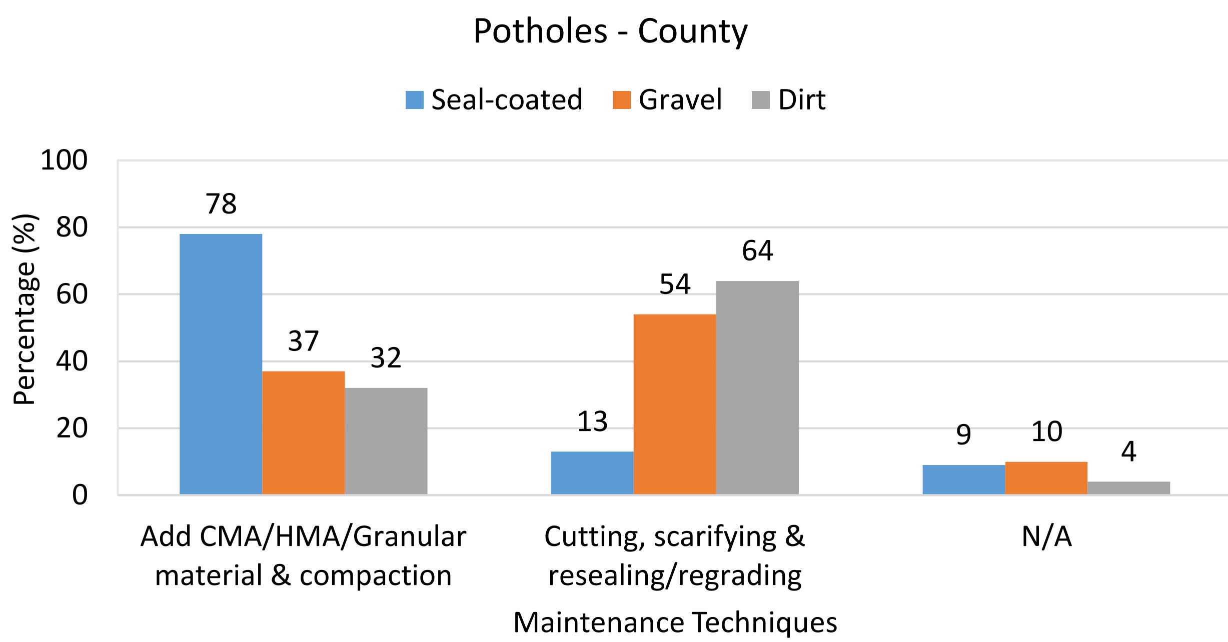


Figure B-9. Maintenance techniques followed by counties and townships to fix rutting.



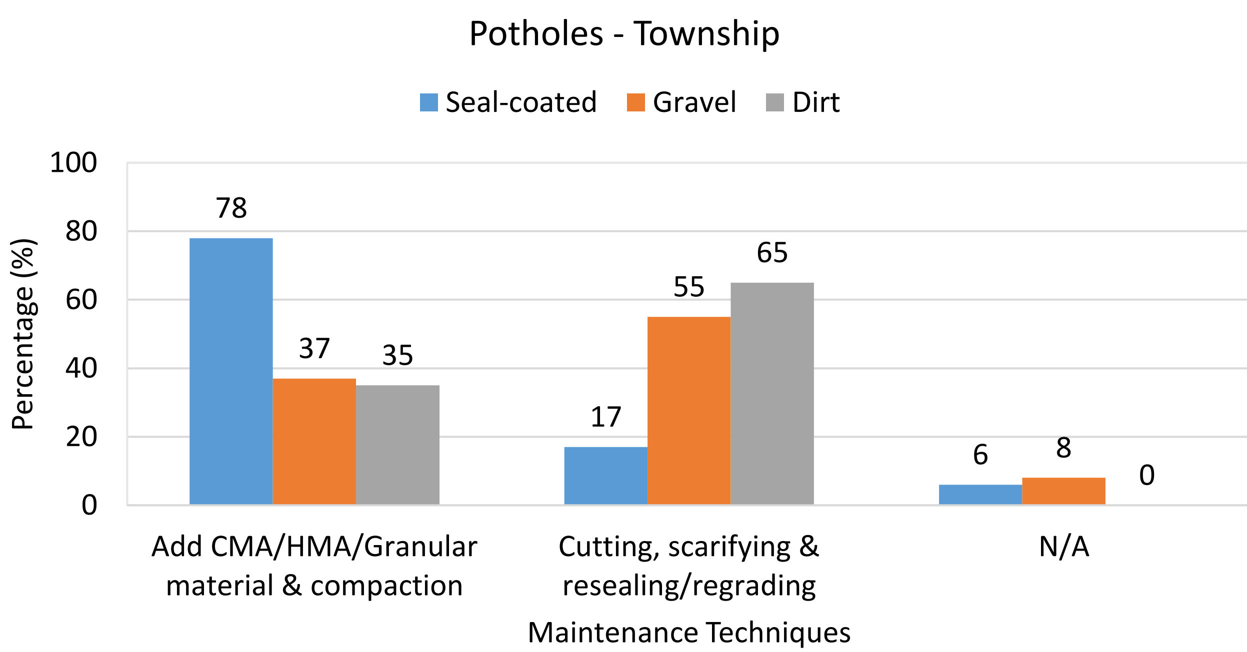


Figure B-10. Maintenance techniques followed by counties and townships to fix potholes.

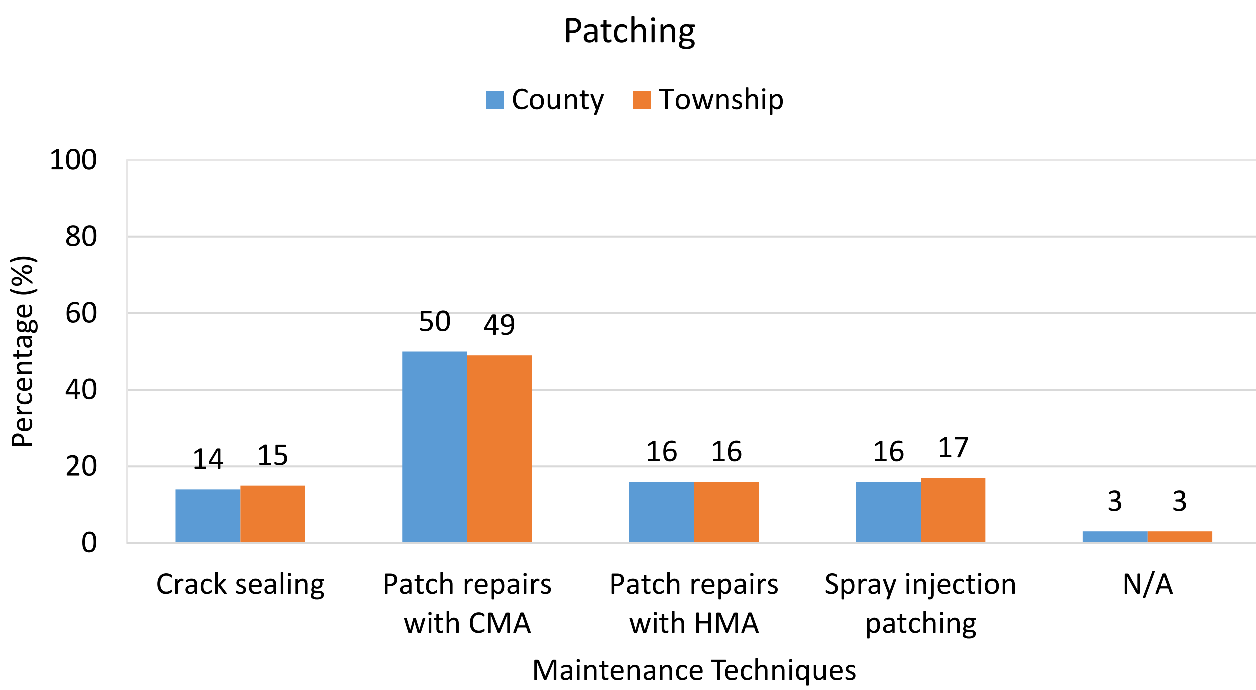
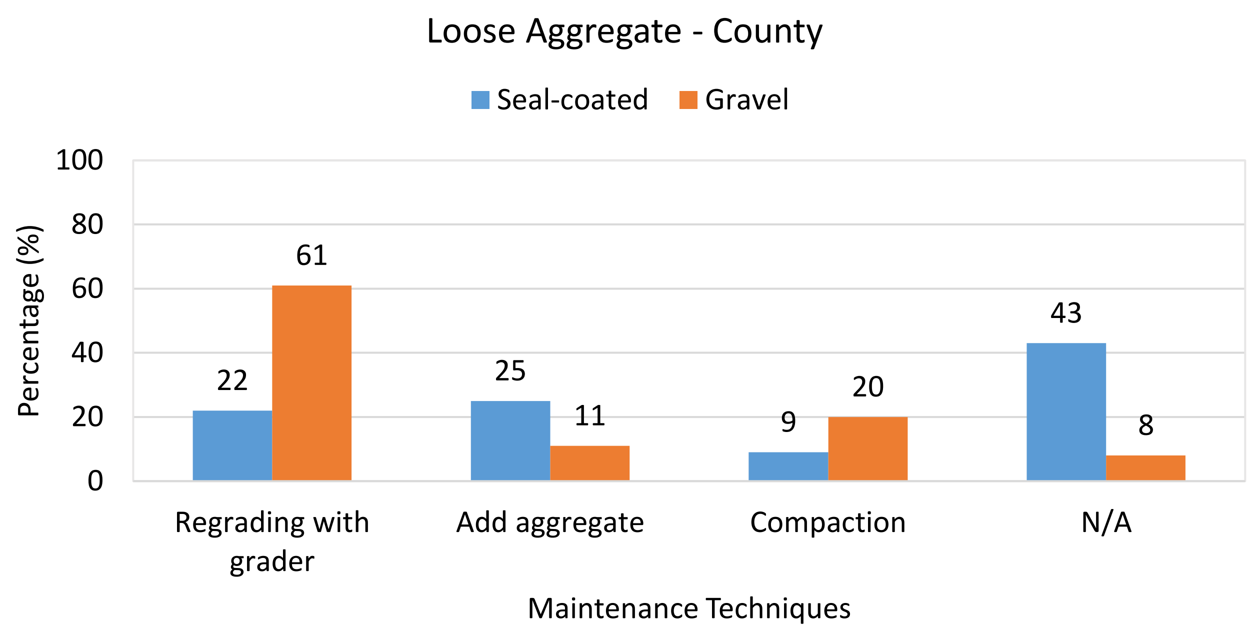


Figure B-11. Maintenance techniques followed by counties and townships to fix patching.



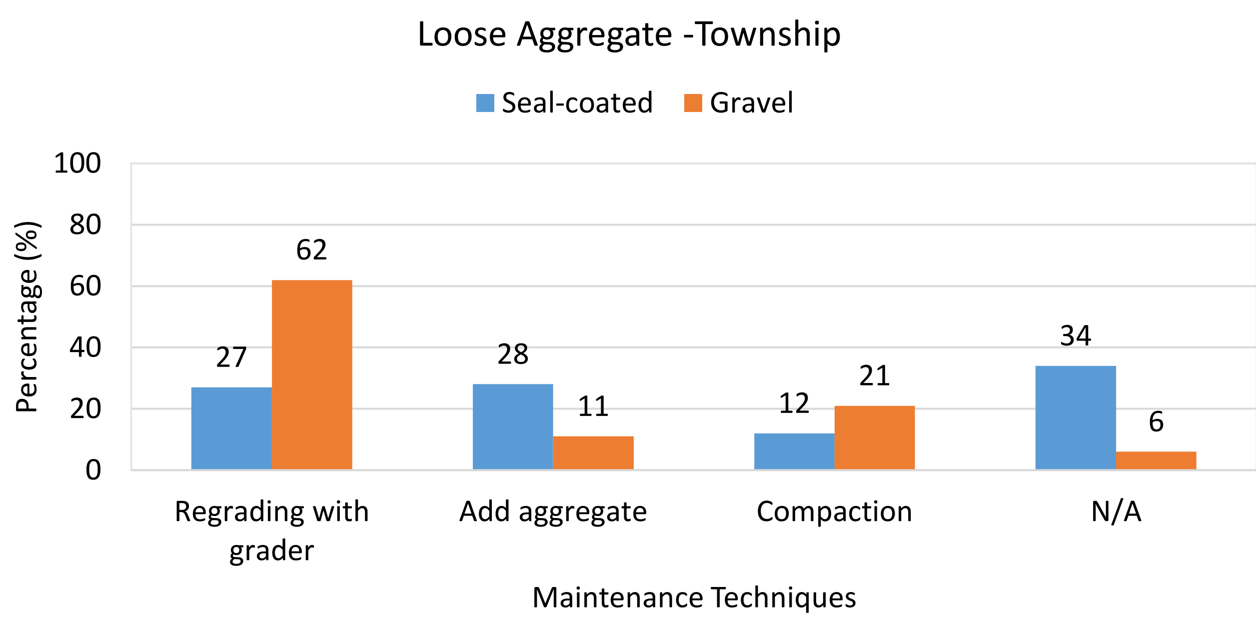
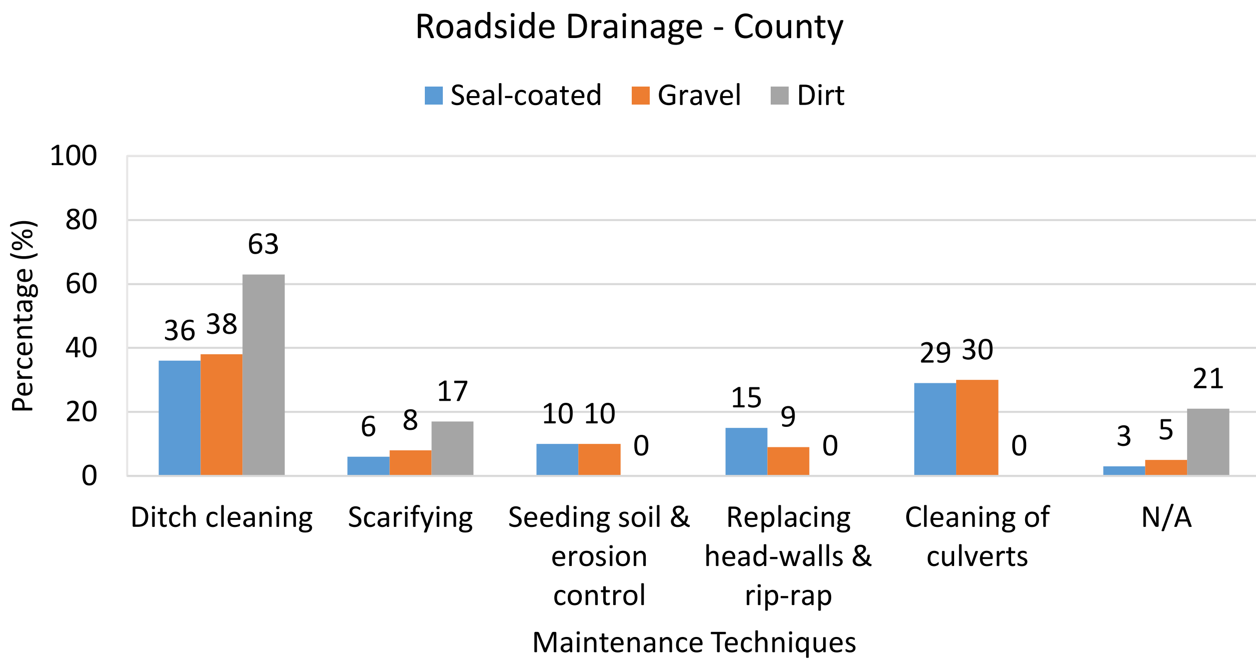


Figure B-12. Maintenance techniques followed by counties and townships to fix loose aggregates.



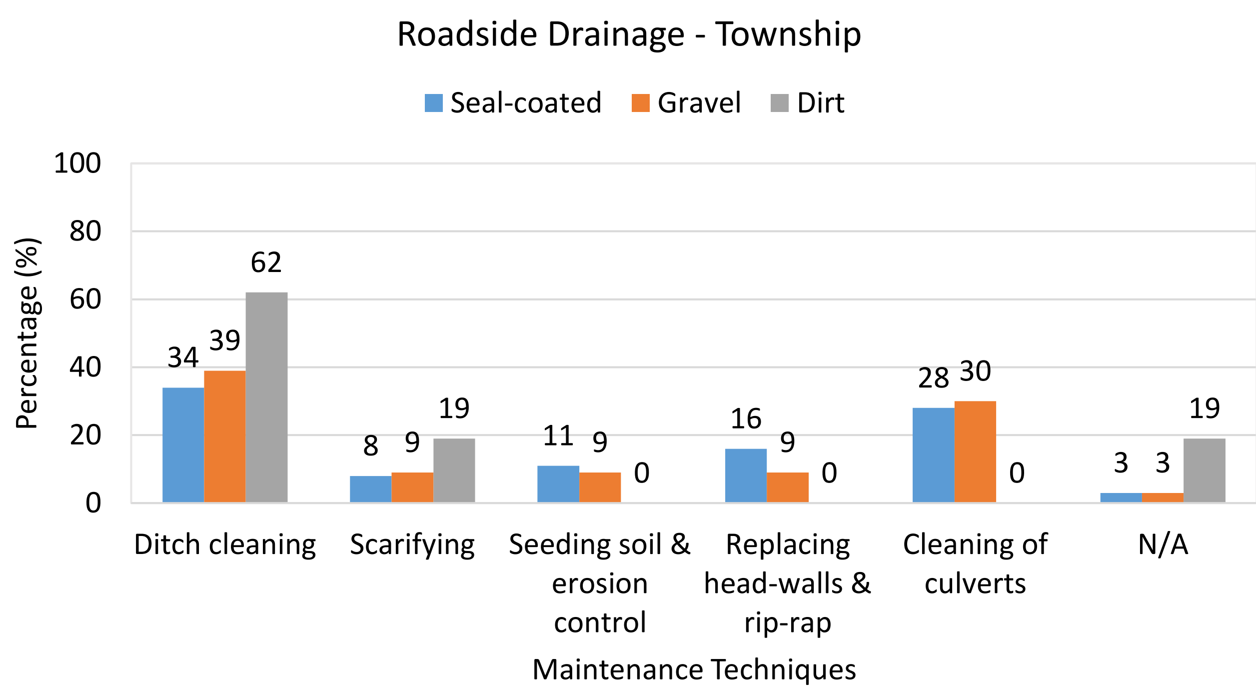
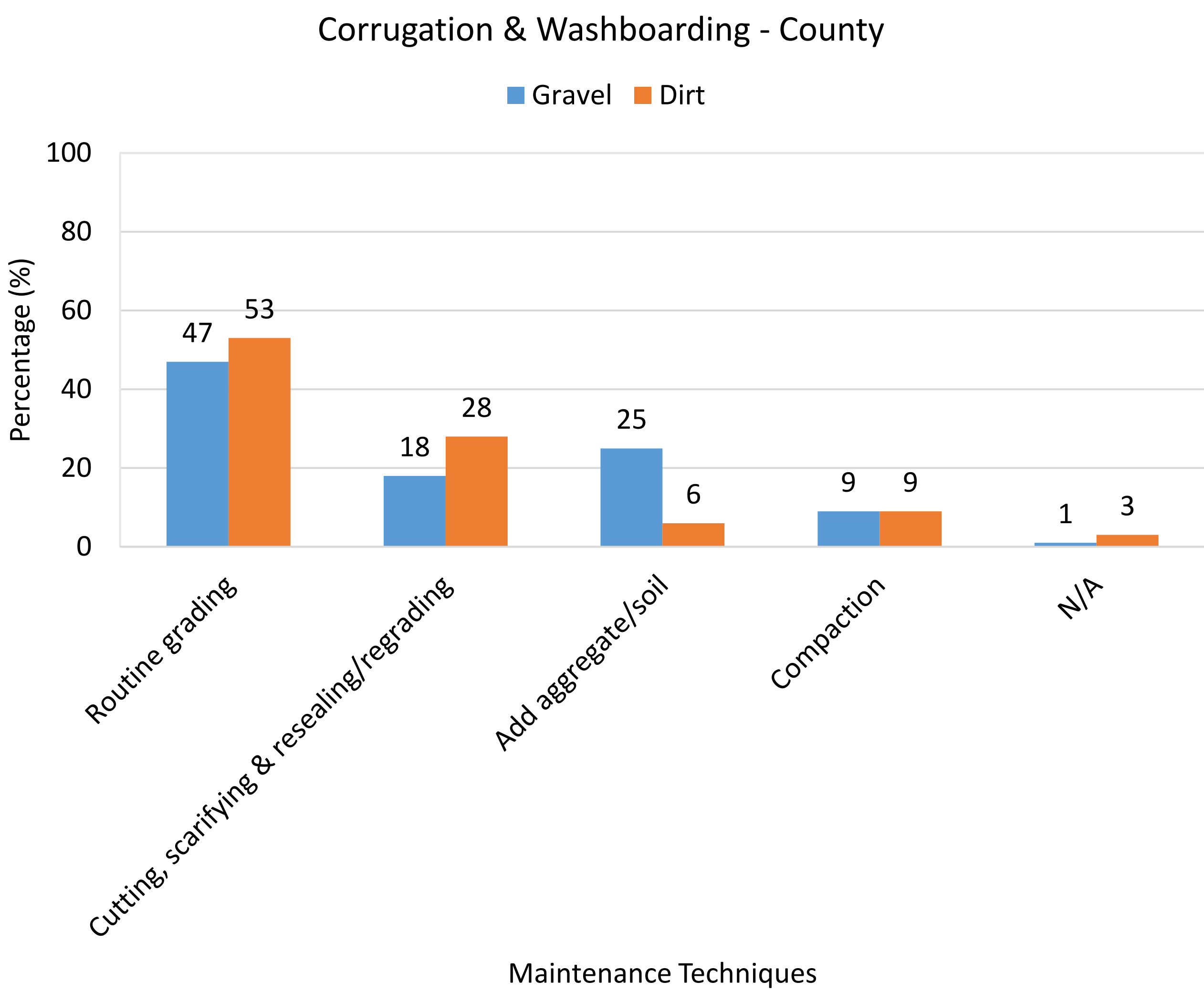


Figure B-13. Maintenance techniques followed by counties and townships to fix roadside drainage.


Corrugation & Washboarding - County
Gravel
Dirt
100
80
60
40
20
0
Percentage (%)
47
53
18
28
25
6
9
9
1
3
Routine grading
Cutting, scarifying & resealing/regrading
Add aggregate/soil
Compaction
N/A
Maintenance Techniques

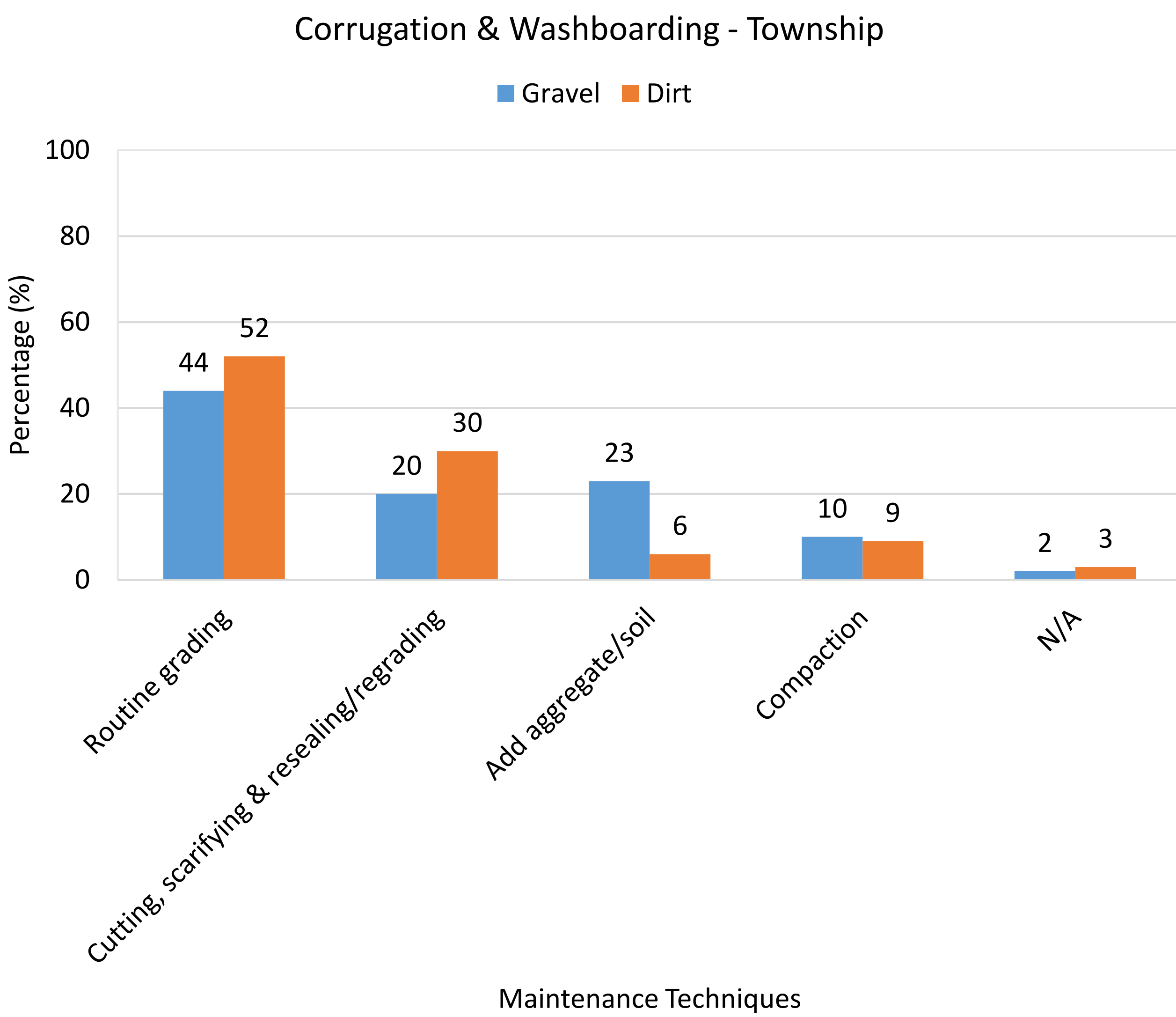
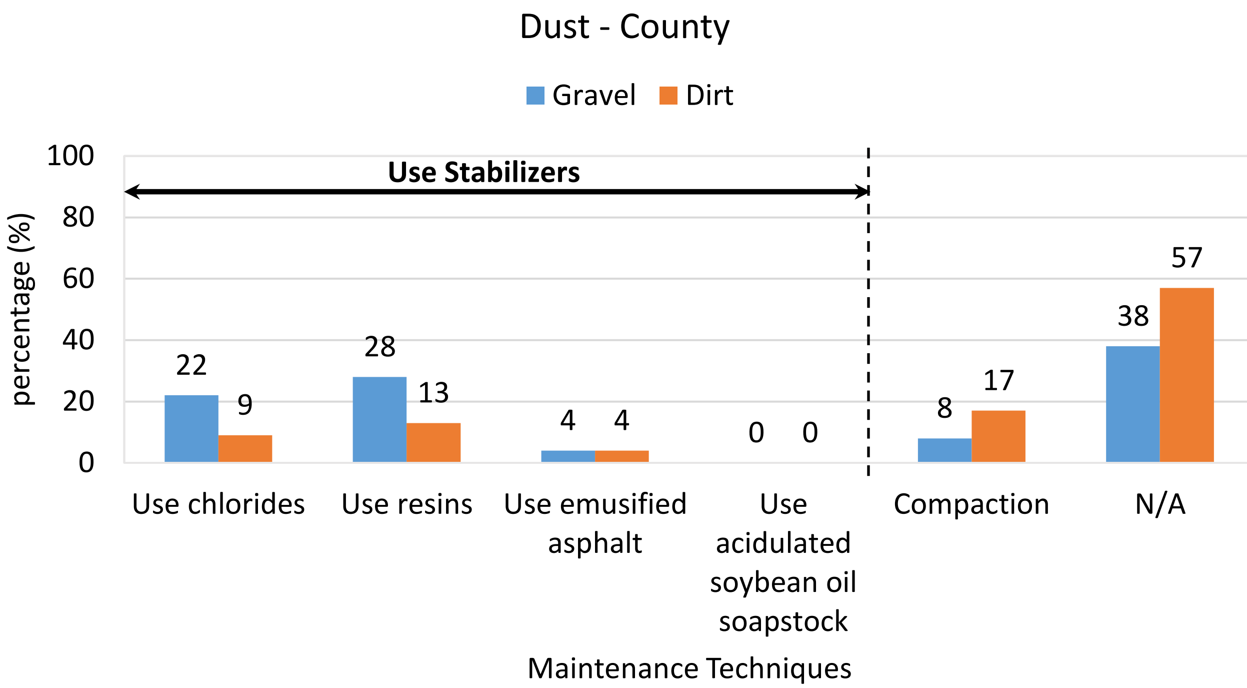


Figure B-14. Maintenance techniques followed by counties and townships to fix corrugation or washboarding.



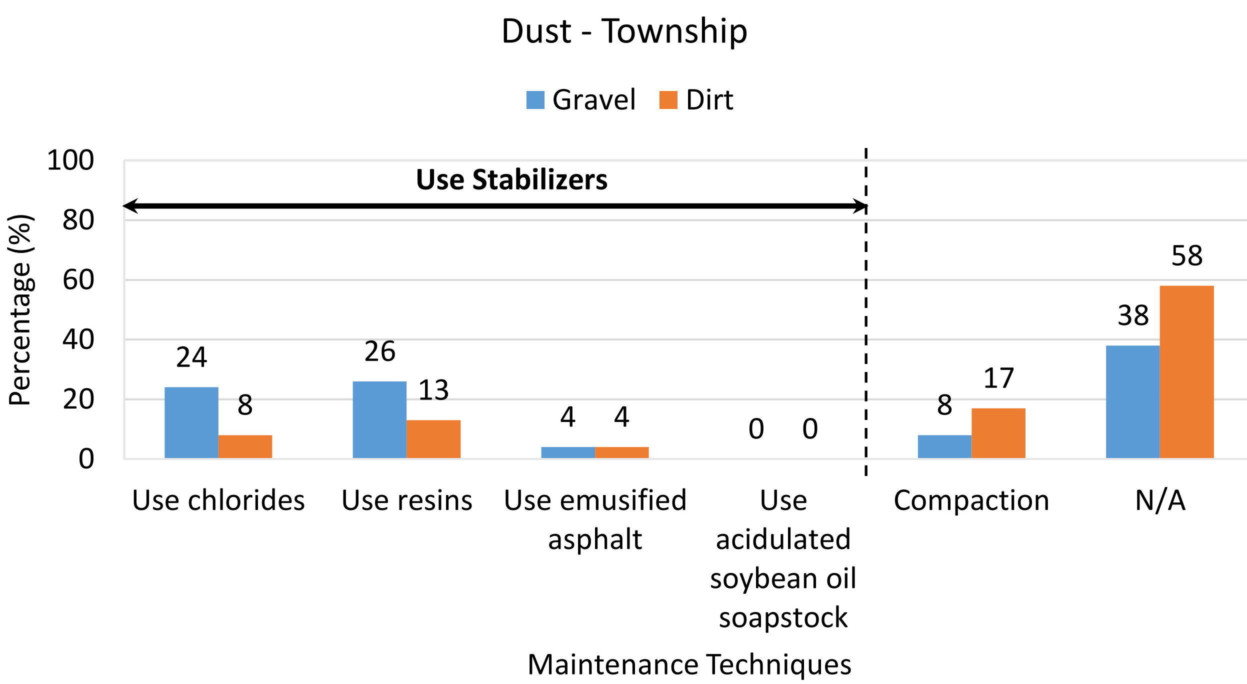


Figure B-15. Management techniques followed by counties and townships to reduce dust.

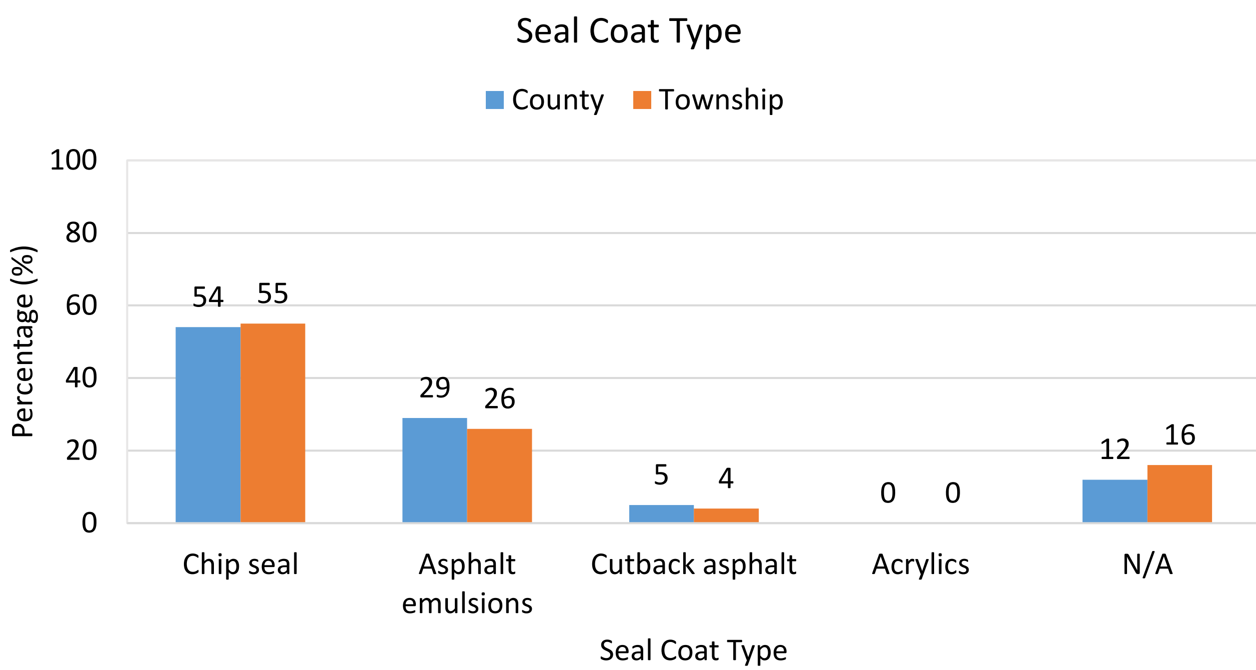
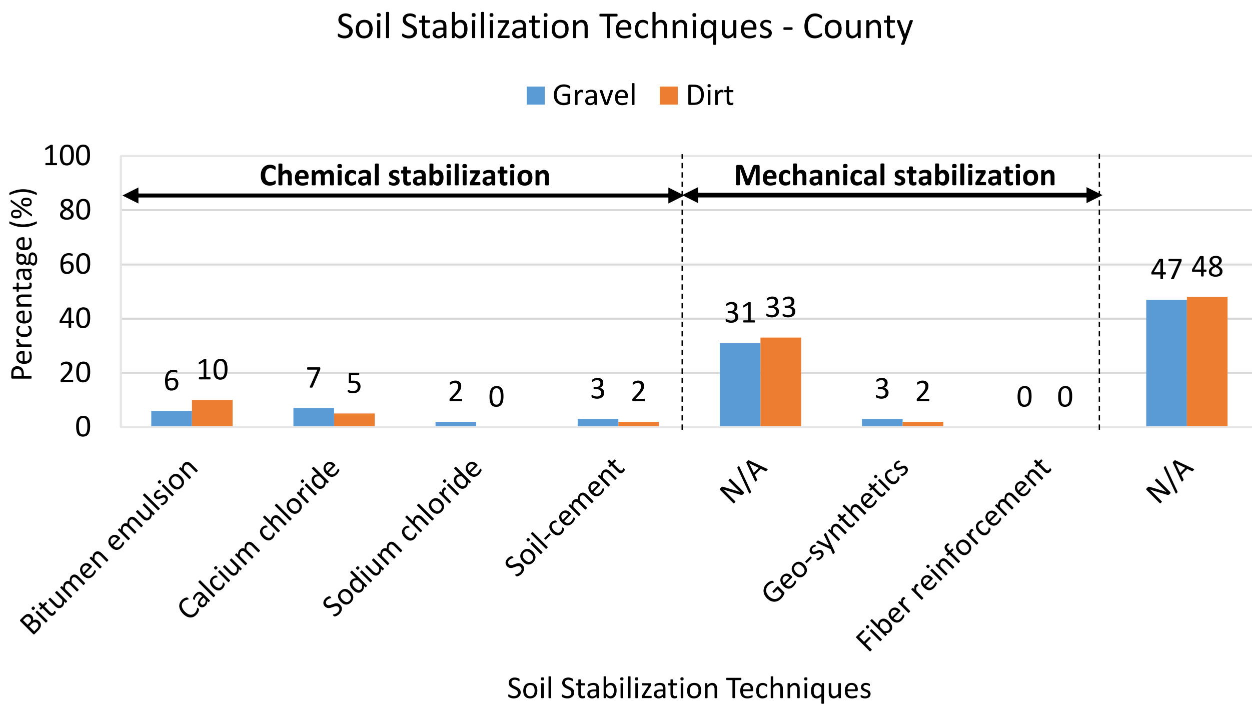


Figure B-16. Type of seal coat used in gravel roads by counties and townships.



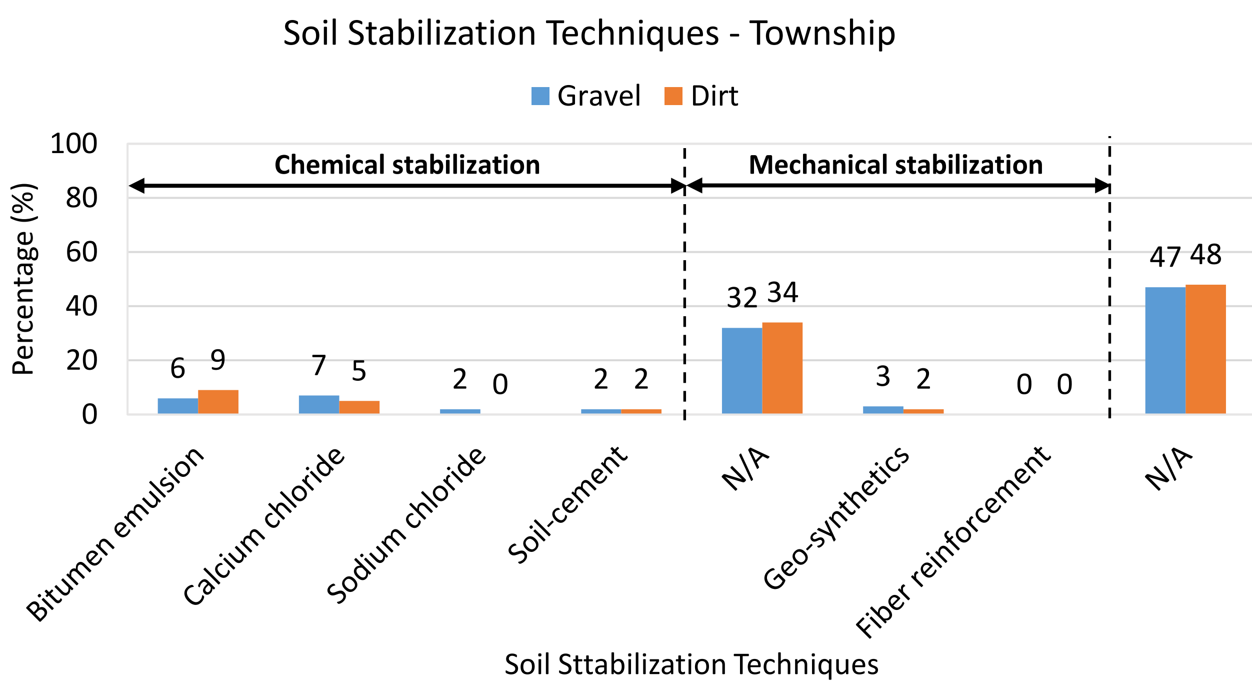
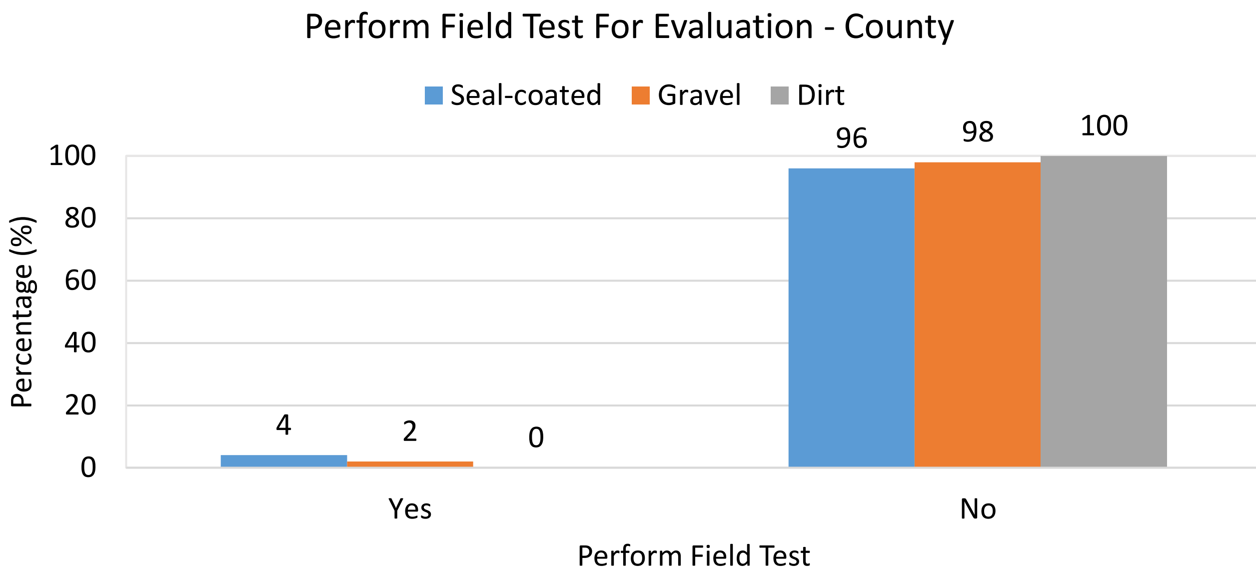


Figure B-17. Soil stabilization techniques used by counties and townships.



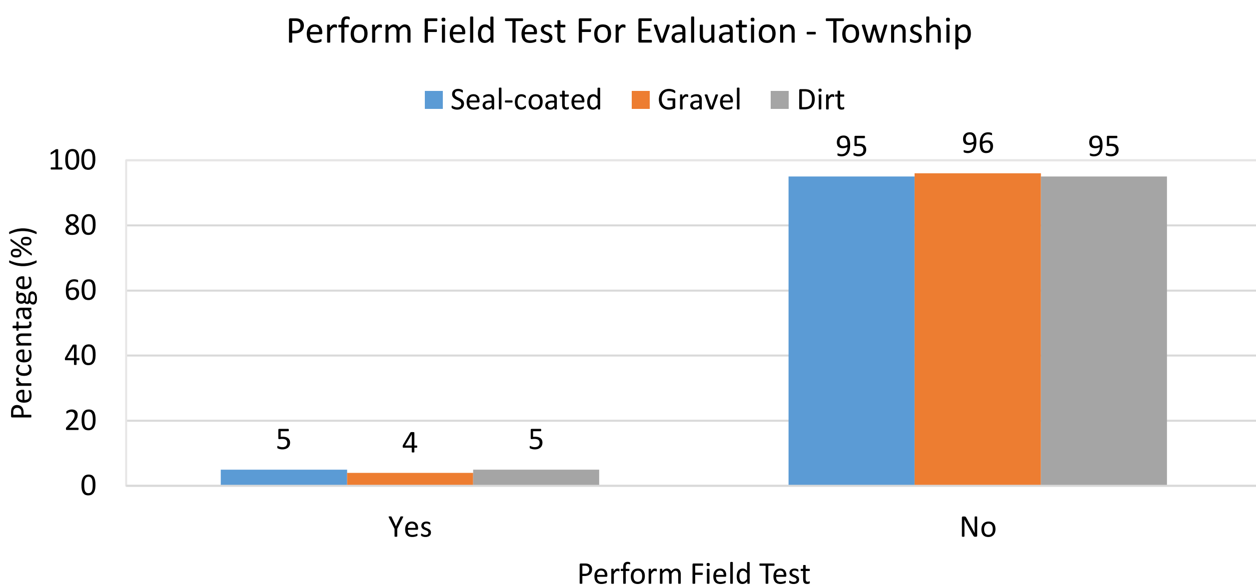
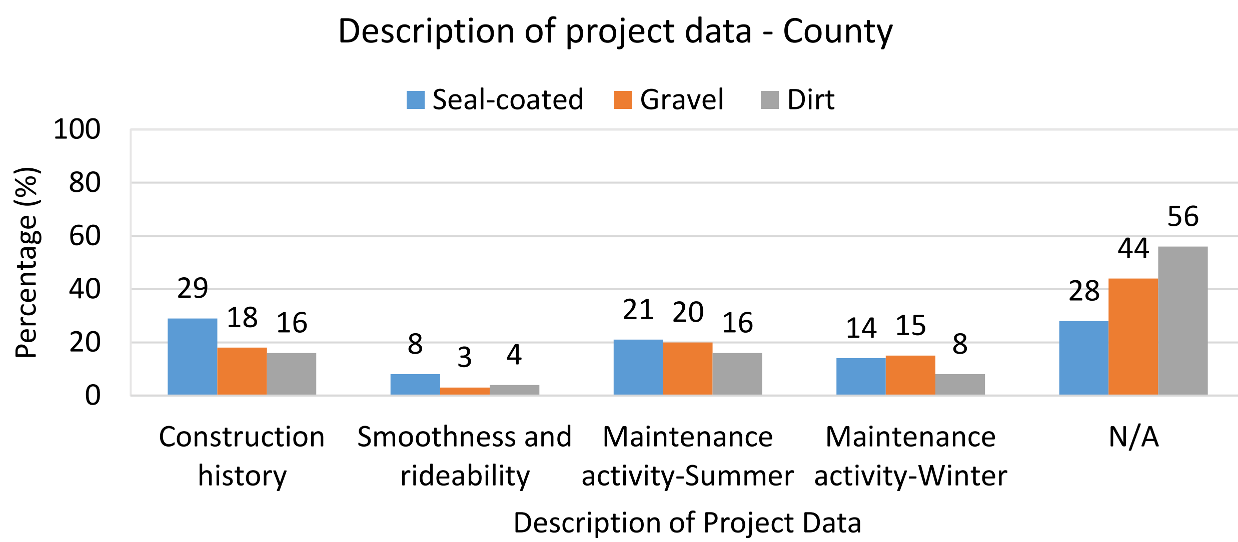


Figure B-18. Field testing performed by counties and townships.



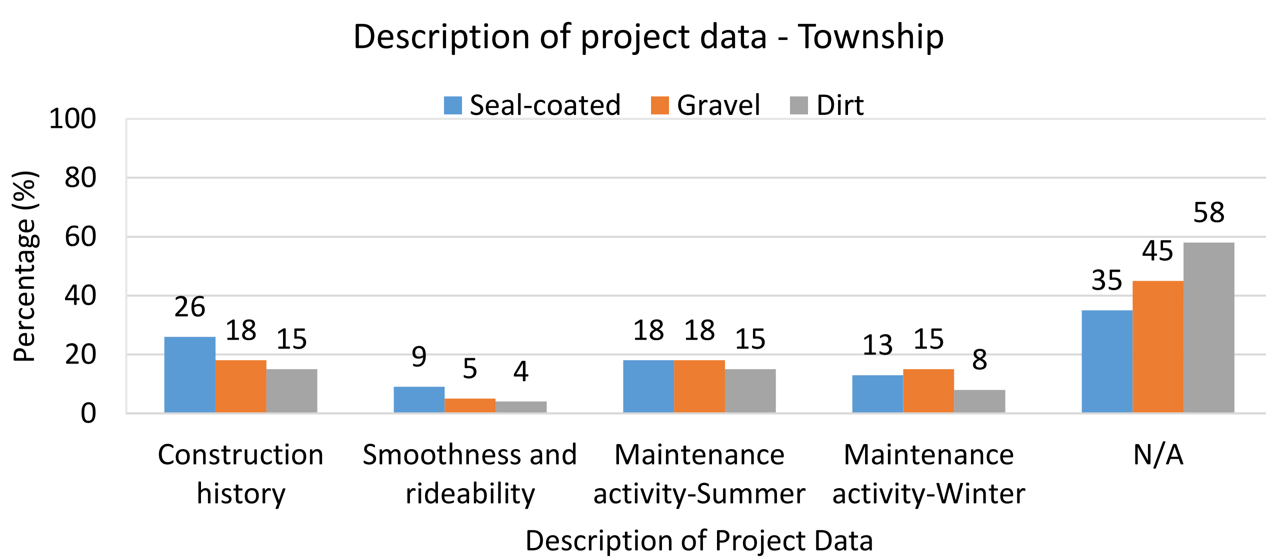


Figure B-19. Record keeping by counties and townships.

B-1: BEST MAINTENANCE PRACTICES: SEAL COATED ROADS

Some of the best maintenance practices reported by counties and townships for maintaining seal coated roads are as follows:

- Add cold mix to re-establish crown then seal coat with emulsion. If slope and x-slope are ok, then reseal
- Fix deficiencies promptly and re-seal coat either in a specific area of distress/repair or the entire road depending on overall road surface condition
- Regular seal coat program with patching as necessary
- Provide a major patch and reseal on all roads every four years
- A good grader man, cold BAM applied to restore proper crown & systematic approach to resealing on a regular basis as money allows
- Cut shoulders and maintain the crown
- Keep patched and resealed
- Apply seal coat every 8 to 10 years
- Patch and reseal
- Reseal every 4 to 5 years or when the pavement is showing distress
- Seal coat roads about every 4 -5 years
- Reseal
- Maintain roadside drainage, patch holes and spread chips on bleeding roads
- Drainage, Base, and seal every 6 years
- Windshield Inspection and addressing top priorities to prevent further degradation of the roadway
- Blade Patching - Thin layer of HMA Mix overlay using grader. Winnebago County has a program to chip seal road 50 miles/Year starting in mid-July every year
- Patch by spot resealing
- Assuming the road was built with good drainage in mind and a more than the adequate aggregate base, resealing becomes an "as needed" operation. That is and has been our goal in Woodford County. Our reseal program is made up of some full-width locations, but many more strip seal locations. The application rate of the oil is most important in getting a good result--this cannot be stressed enough
- Inspect roadways each winter/spring. Patch potholes and edges. Place cold B.A.M. Special with a grader to correct ruts and cross-slope, then reseal over B.A.M and patches and other areas as needed

- Re-seal of existing seal coated roads that are generally in good condition with low traffic volume. The higher traffic volume roads will likely get recycled and resealed or HMA if high enough traffic volume
- Apply a new layer of oil and chip every six to seven years
- Regular maintenance
- Seal coat as needed. If the road is distressed, re-grade, add new aggregate, and seal coat A-3
- Patch potholes as necessary. Seal Coat every 3-5 years depending upon traffic and distresses
- Patch with the cold patch (or rock, during wet Spring rainy season). Sealcoat all roads on a scheduled rotation
- Communication. Need to know about problems to address them
- Use hfe150 at .35 then cover with 30# per square yards steel slag
- Eliminate bumps, maintain drainage for smoother surfaces. The better road will last sweep loose debris off of the road, so oil binds with existing surface better
- Chip seal county highways roads on a 3-year cycle
- Additional chip and seal coat
- Blacktop areas and Oil and Chip surfaces
- Correct minor surface problems with cold mix. Sealcoat every few years, as needed
- Seal them on a five-year interval to preserve the roadways if the fund is obtainable
- I wouldn't say we necessarily have a best practice. The current approach has been in place for about 20 years. There are drainage and base issues on some seal coat streets that remain unaddressed because the project funding is not set up to deal with anything outside of re-sealing and repairs to localized areas
- Application Spray Patching to distressed areas
- Needs outpace resources so with a limited budget we have moved to segmental sealing based upon condition rather than cyclical sealing based on age
- Keep problems patched
- In the spring thaw cycle post weight restrictions on the roads to eliminate heavy loads, keep ditches open, so water flows away from roads, use hot oils such as SC-3000 for seal coating, these oils are more pliable to prevent cracking
- Windshield inspection
- Constant checking for potholes and bleeding
- Drainage
- Fix damages as quickly as possible. our roads were built in the 1960s and 1970s they cannot withstand today's weights of equipment and trucks, it’s a never-ending battle

- Rotate all roads in the township to keep them good
- Oil and chip
- Reseal every 5 years
- Inspection
- Watch it, drive it. If it needs attention, and the area is big enough put it on the schedule, and create a plan and time frame for repair
- Spray injection patching and cold mix patching
- Apply pug with a grader to severe areas-cold patch potholes & re-seal roads as funding allows. Only receive enough oil to re-seal 12 miles out of 62 miles in my township annually. Must choose worst 12 miles each year to re-seal
- Maintenance on a daily level if necessary. Problems are dealt with upon discovery
- Oiling and chipping before potholes start to form
- Annual seal coat program is utilizing MFT funds. Prior to contracting out these work City forces perform repairs as needed on all areas to be completed under contract for resealing
- The evaluation process, in general, keeps a good list to track and follow our unimproved roads so we can keep regular track of our maintenance and make sure our program continues annually
- Use good quality materials, maintain drainage
- We are a small town of 650 people. With limited MFT and Local funds, we seal coat as funds are available, not necessary when it is needed. Heavier traveled streets are seal coated on a longer cycle than they should be. We were able to contract with the County to perform skim patching this year and include our seal coat project in the County Letting with County and Township seal coat project to receive better unit prices.
- Rotate resurfacing every third year. Use the total patcher yearly
- Annual Condition Rating Survey
- Seal coat when needed
- Re-seal every 4 years
- Re-seal 5-year rotation
- FEP 150 ½ chips, 46.28 ½ chips
- Patch Reseal
- Reseal if no wheel lanes, correct drainage, and alligator cracking
- Build proper base first then reseal as needed
- Patch and seal with oil

- Load limits- Gravel chips for bleeding- reseal every five years
- In the spring thaw cycle post weight restrictions on the roads to eliminate heavy loads, keep ditches open, so water flows away from roads, use hot oils such as SC-3000 for seal coating, these oils are more pliable to prevent cracking
- Constant checking for potholes and bleeding.
- Spray patching, resealing and shoulder drainage
- The cold patch also will reseal with an asphalt overlay
- Keeping all heavy traffic off in spring of the year
- Maintenance on a daily level if necessary. Problems are dealt with upon discovery

B-2: BEST MAINTENANCE PRACTICES: GRAVEL ROADS

Some of the best maintenance practices reported by counties and townships for maintaining gravel roads are as follows:

- Blading
- Routine use of tractor/7-way road drag, reshaping with motor grader once or twice a year
- Re-grade every Spring. Add gravel to areas with potholes while re-grading
- Good material and proper base
- Periodic blading
- Tailgating gravel as needed and grading as needed
- Blade roads wet, remix the fines if time allows repacking the material while wet. In the early spring cut the shoulders to establish a slope from the center of the road to the ditch. It cannot be emphasized enough that the water must be able to get to the ditch as quickly as possible
- Grade and drag regularly as needed to add more gravel regularly as needed
- In the summer months, we use a shoulder disc to eliminate any high shoulders that would pond water, Grade gravel roadways when needed, keep ditches open by ditching with a motor grader, and in spring we have a side-mount rotary ditcher to eliminate sediment blockage from farm fields. In the spring when gravel roads are too soft and wet to operate the motor grader, we have a road drag pulled by a tractor to drag gravel roads regularly
- Routine blading with a road dragger when the roads are moist after an annual rainfall application of lignan for dust control and road stabilization
- Grade after every rain
- Grade roads with motor grader and road drag, add aggregate as needed. Remove soil infiltration due to runoff with grader and wheel loader, finish shape with a motor grader. Dust control added yearly. Weekly inspection of all roads, approx. 13 miles

- Re-grading
- We run a road drag on a routine basis. We also use a road grader on a routine basis
- Regular preventative maintenance to identify and correct small problems
- Keep good gravel, drainage, and crown. Grade when needed and drag with road drag
- Grading every year
- Keep road high and dry, No potholes
- Grade and add rock when needed
- Grade and add maintenance rock
- Re-grade and add aggregate when needed
- Maintain crown and drainage and as much rock as we can afford using calcium when affordable
- Drainage- add gravel yearly
- Grade or drag roads as much as possible and fix problems as quickly as possible
- Road drag
- Grade and drag add gravel
- Routine grading and addition of gravel
- Regular preventative maintenance to identify and correct small problems.

B-3: BEST MAINTENANCE PRACTICES: DIRT ROADS

Some of the best maintenance practices reported by counties and townships for maintaining gravel roads are as follows:

- Have only a couple of "field lane" type dirt roads, with little traffic. Best practice is actually to disk up sod and level to fill ruts and allow water to get off the road
- Grade only
- Blading
- Grade annually
- Frequent grading to prevent vegetation from growing
- Dirt roads are dragged in the spring with tractor/drag, then in the summer months they are bladed with the motor grader, then in the fall the tractor/drag will be periodically used till the road surfaces freezes in the winter months.
- Regular grading with a motor grader or road dragger
- Try to keep smooth

- Re-grade, correct drainage
- Grade
- Blade and ditch cleaning
- Frequent grading to prevent vegetation from growing
- Grade road as much as possible.
- Grade when needed.

APPENDIX C: BEST PRACTICE GUIDELINE TO MEASURE PAVEMENT DISTRESSES

C-1. MANUAL METHOD – DEVELOPMENT OF SEAL COATED ROAD CONDITIONING INDEX

An objective or manual measurement-based Seal-coated Road Condition Index (SCRCI) has been developed based on the available PCI (Pavement Condition Index) and URCI (Unsurfaced-Road Condition Index) method. Seal coated roads show few similar distresses to those also found in asphalt concrete pavements, such as alligator cracking, edge cracking, rutting, potholes, patching, bleeding, longitudinal and transverse cracking. Seal coated roads also show loose aggregate distress that is similar the one found in gravel roads. For this reason, SCRCI has been developed by combining PCI and URCI ratings. The rating scale is 100-0 as it is the case for PCI and URCI. Table C-1 lists the SCRCI rating ranges that are similar to URCI rating.

Table C-1. SCRCI rating ranges similar to those of the URCI rating.

SCRCI Rating	Condition
100-75	Excellent
50-75	Good
25-50	Fair
0-25	Poor

An empty inspection sheet for seal coated road is provided in Table C-2. Tables C-3 to C-10 list the various distresses observed in the seal coated roads and their severity levels. The inspection sheets were completed based on the severity levels. Table C-3 lists the various severity levels observed for alligator or fatigue cracking in seal coated roads in Illinois and the graph that is used to determine the deduct values. Table C-4 presents the various severity levels observed for edge cracking in seal coated roads in Illinois and the graph that is used to determine the deduct values. Table C-5 lists the various severity levels observed for rutting in seal coated roads in Illinois and the graph that is used to determine the deduct values. Table C-6 presents the various severity levels observed for potholes in seal coated roads in Illinois and the graph that is used to determine the deduct values. Table C-7 lists the various severity levels observed for patching in seal coated roads in Illinois and the graph that is used to determine the deduct values. Table C-8 presents the various severity levels observed for loose aggregate in seal coated roads in Illinois and the graph that is used to determine the deduct values. Table C-9 lists the various severity levels observed for bleeding in seal coated roads in Illinois and the graph that is used to determine the deduct values. Finally, Table C-10 presents the various severity levels observed for longitudinal and transverse cracking in seal coated roads in Illinois and the graph that is used to determine the deduct values.

Table C-2. SCRCI rating inspection sheet.

<table>
<tr><th colspan="13">SCRCI ROAD INSPECTION SHEET-SEAL COATED ROAD</th></tr>
<tr><td colspan="4">1. BRANCH</td><td colspan="4">2. SECTION</td><td colspan="5">3. DATE</td></tr>
<tr><td colspan="4">4. SAMPLE UNIT</td><td colspan="4">5. AREA OF SAMPLE</td><td colspan="5">6. INSPECTOR</td></tr>
<tr><td colspan="6">7. SKETCH</td><td colspan="7">DISTRESS TYPES
1. Alligator/Fatigue Cracking (square feet)
2. Edge Cracking (linear feet)
3. Rutting (square feet)
4. Potholes (number)
5. Patching (square feet)
6. Loose Aggregate (linear feet)
7. Bleeding (square feet)
8. Longitudinal cracking/Transverse Cracking (linear feet)</td></tr>
<tr><td colspan="13">8.DISTRESS QUANTITY AND SEVERITY</td></tr>
<tr><td colspan="2">TYPE</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">QUANTITY AND SEVERITY</td><td>L</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>M</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>H</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="13">9. URCI CALCULATION</td></tr>
<tr><td>DISTRESS TYPE</td><td colspan="2">DENSITY %</td><td colspan="2">SEVERITY</td><td colspan="2">DEDUCT VALUE</td><td colspan="6" rowspan="6">10. REMARKS</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
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<tr><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="3">TOTAL DEDUCT VALUE =</td><td colspan="2">q =</td><td colspan="2">SCRCI =</td><td colspan="6">RATING</td></tr>
</table>

Table C-3. Alligator cracking severity measurement in seal coated roads.

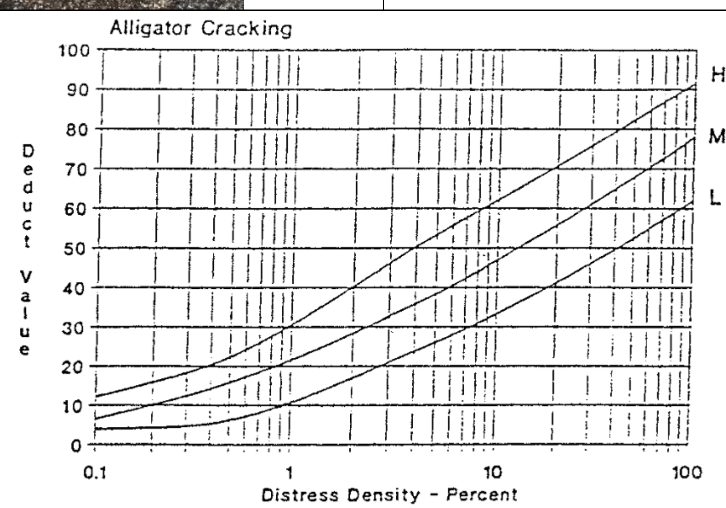
Alligator Cracks, measuring unit: square feet	Severity level
	Low (L)- An area with only a few cracks which are not spalled
	Moderate (M)- An area with interconnected cracks forming a pattern and are slightly spalled
	High (H)- An area with severely spalled interconnected cracks forming a complete pattern. The pieces may move when they come in contact with traffic. Cracks may be sealed and led to pumping
	

Table C-4. Edge cracking severity measurement in seal coated roads.

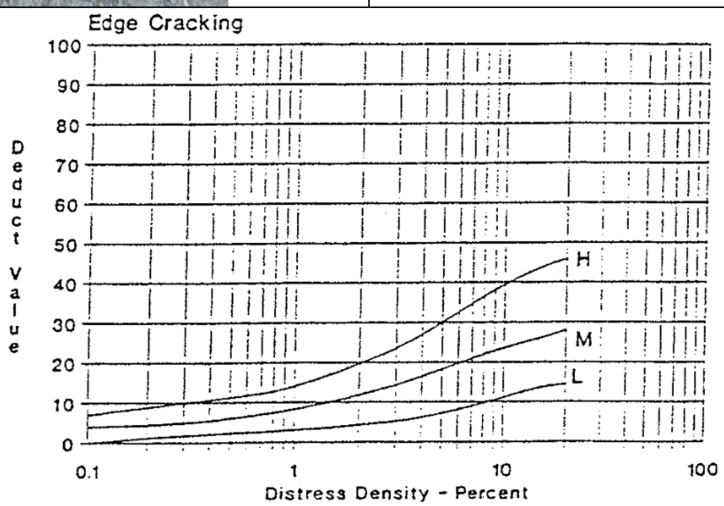
Edge Cracks, measuring unit: linear feet	Severity level
	Low (L)- Cracks with no breakup or loss of material
	Medium (M)- Cracks with some breakup and loss of material
	High (H)- Cracks with a considerable amount of breakup and loss of material
	

Table C-5. Rutting severity measurement in seal coated roads.

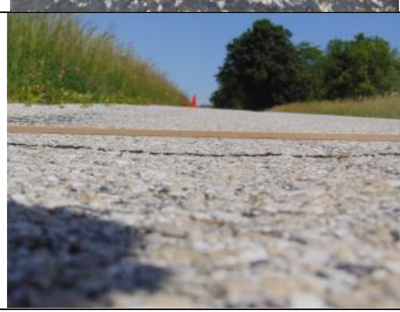
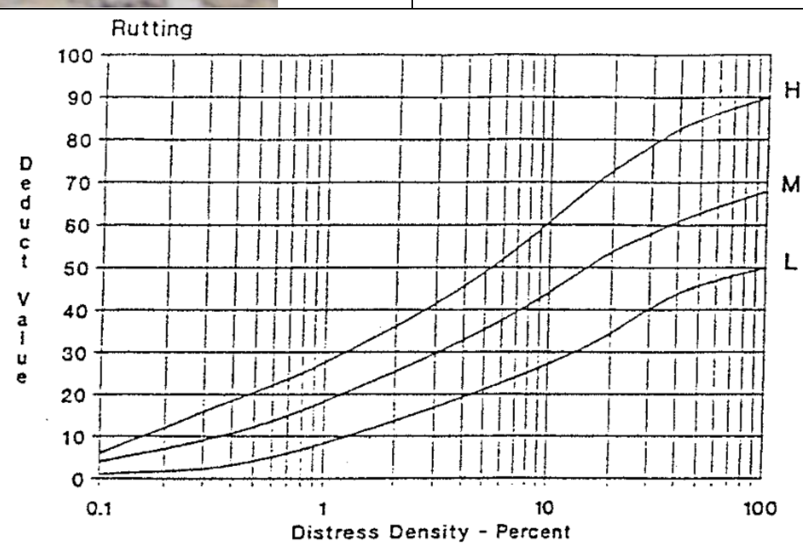
Rutting, measuring unit: square feet	Severity level
	Low (L)- Rut depth ¼ in. to ½ in.
	Medium (M)- Rut depth > ½ in. but < 1 in.
	High (H)- Rut depth > 1 in.
	

Table C-6. Potholes severity measurement in seal coated roads.

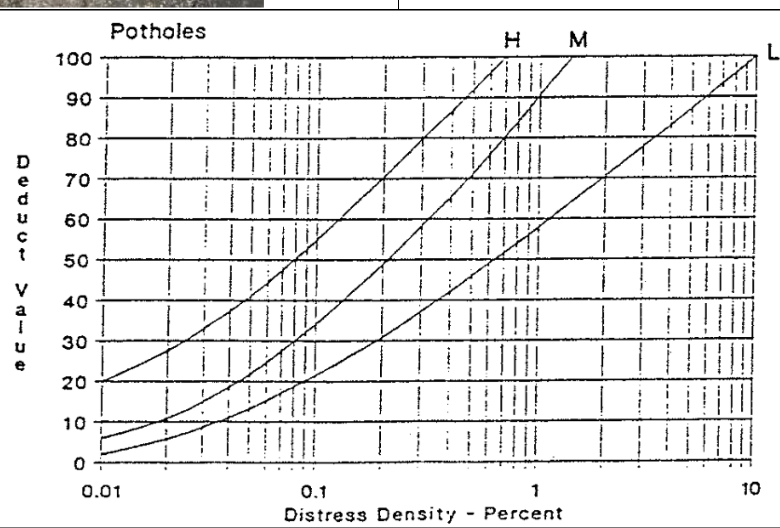
Pothole, measuring unit: number	Severity level
	Low (L)- Pothole < 1 in. deep
	Medium (M)- Pothole > 1 in. and < 2 in. deep
	High (H)- Pothole > 2 in. deep
	

Table C-7. Patching severity measurement in seal coated roads.

Pathing, measuring unit: square feet	Severity level
	Low (L)- Patch is in good condition and satisfactory
	Medium (M)- Patch is in moderate condition
	High (H)- Patch is badly deteriorated

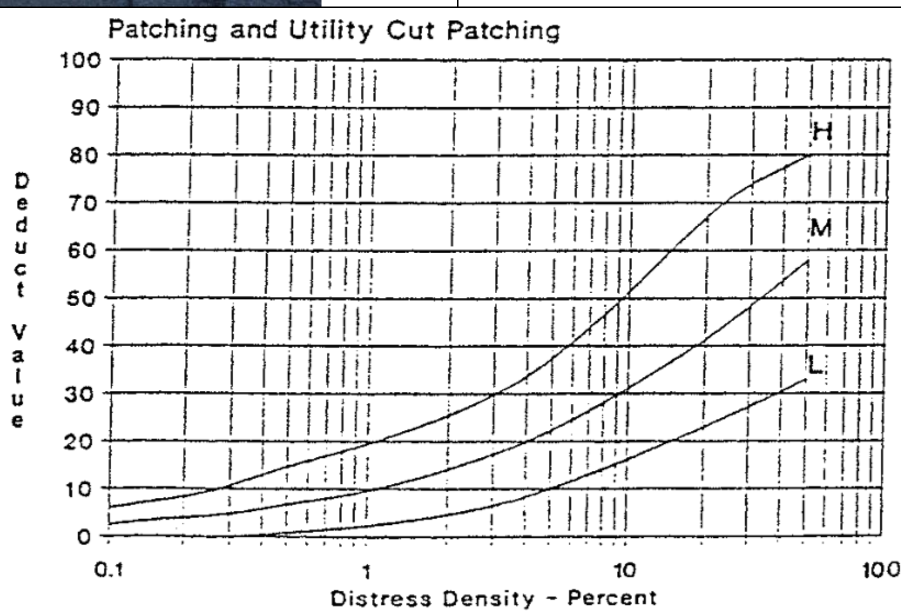


Table C-8. Loose aggregate measurement in seal coated roads.

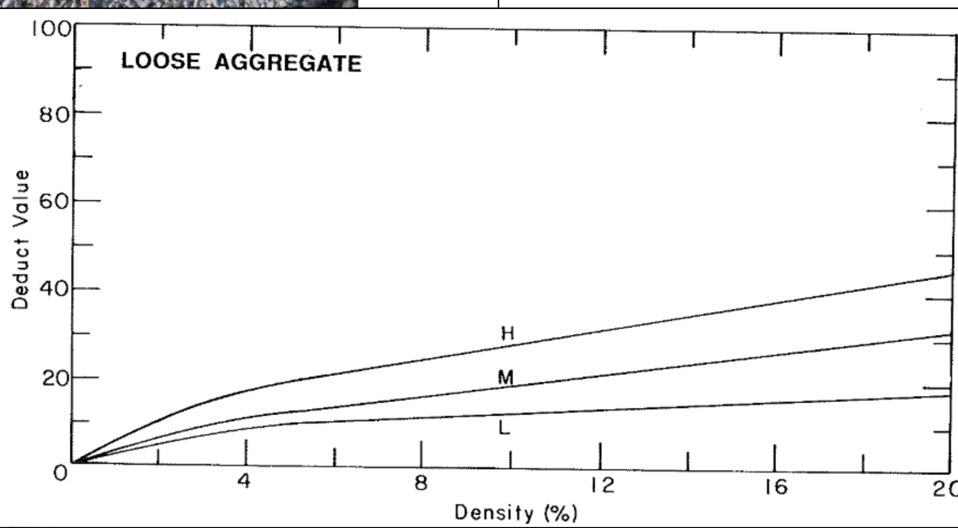
Loose aggregate, measuring unit: linear feet	Severity level
	Low (L)- Loose chips are found on the road surface
	Medium (M)- Excessive fines are usually found on the roadway surface
	High (H)- Excessive fine and chips are found on the roadway surface
	

Table C-9. Bleeding measurement in seal coated roads.

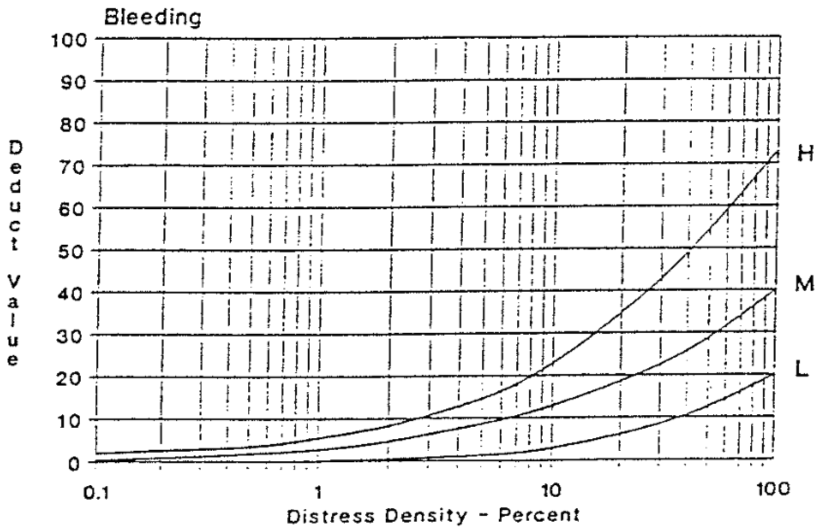
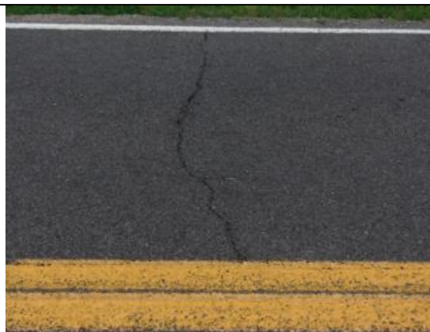
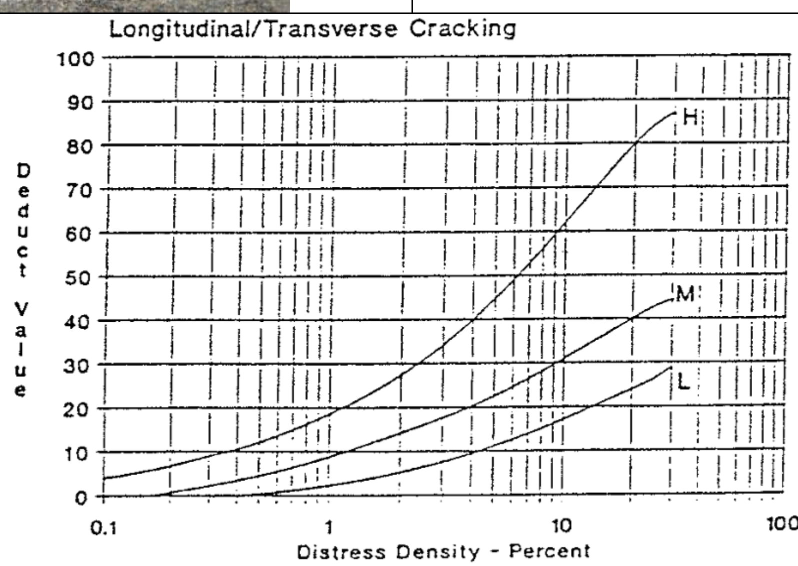
Bleeding, measuring unit: square feet	Severity level
	Low (L)- Bleeding only have occurred to a very slight degree and asphalt does not stick to shoes or vehicles
	Medium (M)- Bleeding has occurred to the extent that asphalt stick to shoes and vehicles
	High (H)- Bleeding has occurred extensively, and considerable asphalt sticks to shoes and vehicles
	

Table C-10. Longitudinal and transverse cracking measurement in seal coated roads.

Longitudinal and transverse cracking, measuring unit: linear feet	Severity level
	Low (L)- A crack with a mean width ≤ 3/8 in.
	Medium (M)- Any crack with a mean width > 3/8 in. and ≤ 3 in.
	High (H)- Any crack with a mean width > 3 in.
	

C-1.1 Use of SCRCI Inspection Sheet

Seal Coated Road, Location: Knox County, Township: Copley

The site is located in Copley Township. The seal coated road is shown on the Google Earth map in Figure C-1. The road is 1750 E Knox road. The field distress data were collected on July 14, 2017.

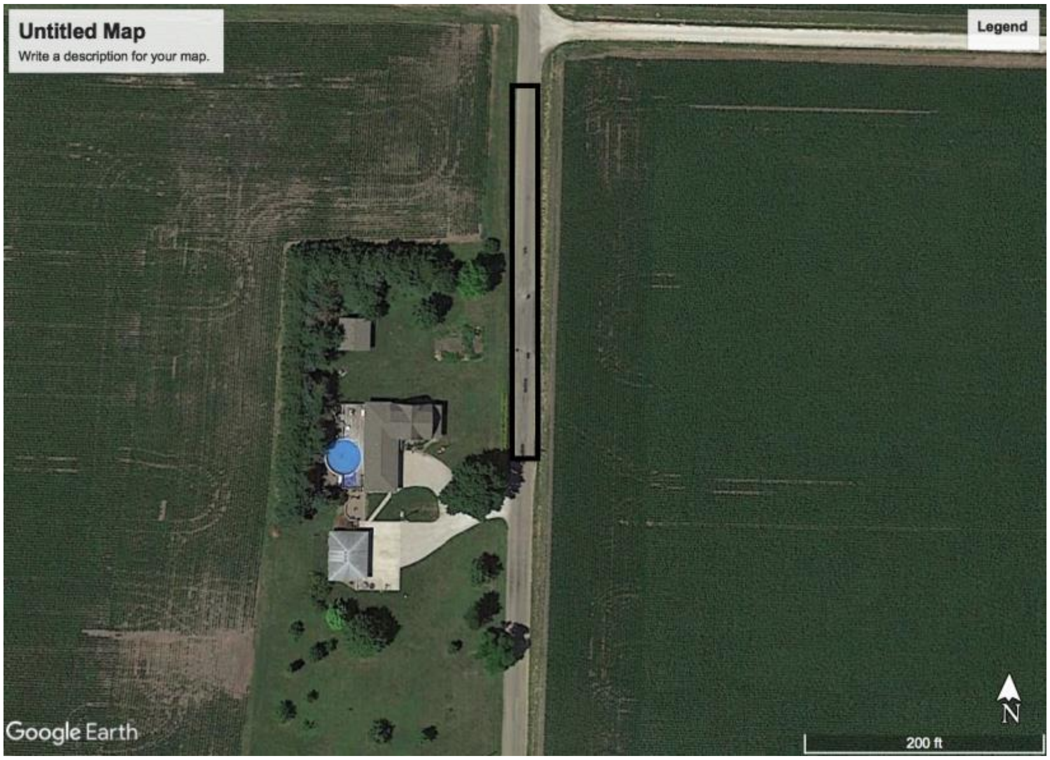


Figure C-1. Location of seal coated 1750 E Knox road, Copley Township.

After driving on the road, a representative section was chosen and approximately 100 ft length was marked.

(a) Alligator cracking, medium severity

(b) Edge cracking, medium severity

(c) Pothole, medium severity

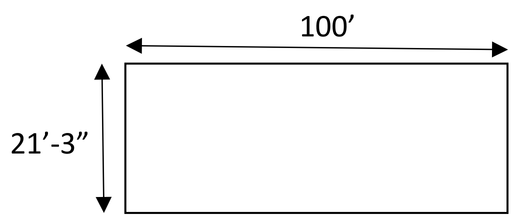
Figure C-2. Various distresses observed with their severity levels recorded on the seal coated 1750 E Knox road, Copley Township, Illinois.

Table C-11. Completed inspection sheet for seal coated 1750 E Knox road, Copley Township.

ROAD INSPECTION SHEET-SEAL COATED ROAD

1. BRANCH: 1750 E Knox	2. SECTION: Seal Coat	3. DATE: 07/14/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 2,125 sq ft	6. INSPECTOR: Furquan ul Haq

7. SKETCH



DISTRESS TYPES

1. Alligator/Fatigue Cracking (square feet)
2. Edge Cracking (linear feet)
3. Rutting (square feet)
4. Potholes (number)
5. Patching (square feet)
6. Loose Aggregate (linear feet)
7. Bleeding (square feet)
8. Longitudinal cracking/Transverse Cracking (linear feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6	7	8			
QUANTITY AND SEVERITY	L			50		8	71	6’-5”				
	M	100	100	40	3							
	H											

9. **SCRCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE
1	4.71	M	38
2	4.71	M	18
3	2.35	L	15
3	1.88	M	21
4	0.14	M	60
5	0.38	L	0
6	3.34	L	8
7	0.31	L	0

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

SCRCI=100 - CDV
= 100 -77 = 23.

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 160	q = 6	SCRCI =26	RATING: Poor

Using the inspection sheet and the pre-established severity criteria, the distresses wre recorded. The density for each distress was calculated as follows,

$$Density = \left(\frac{Quantity\ or\ area\ of\ distress}{Area\ of\ sample}\right) \times 100$$

The deduct values were measured using the curve given in the corresponding distress pictured in Tables C-3 to C-10. The total deduct value was calculated by adding all the deduct values. The numbers of distresses are referred to as *q*.

The corrected deduct value was calculated using Figure C-3.

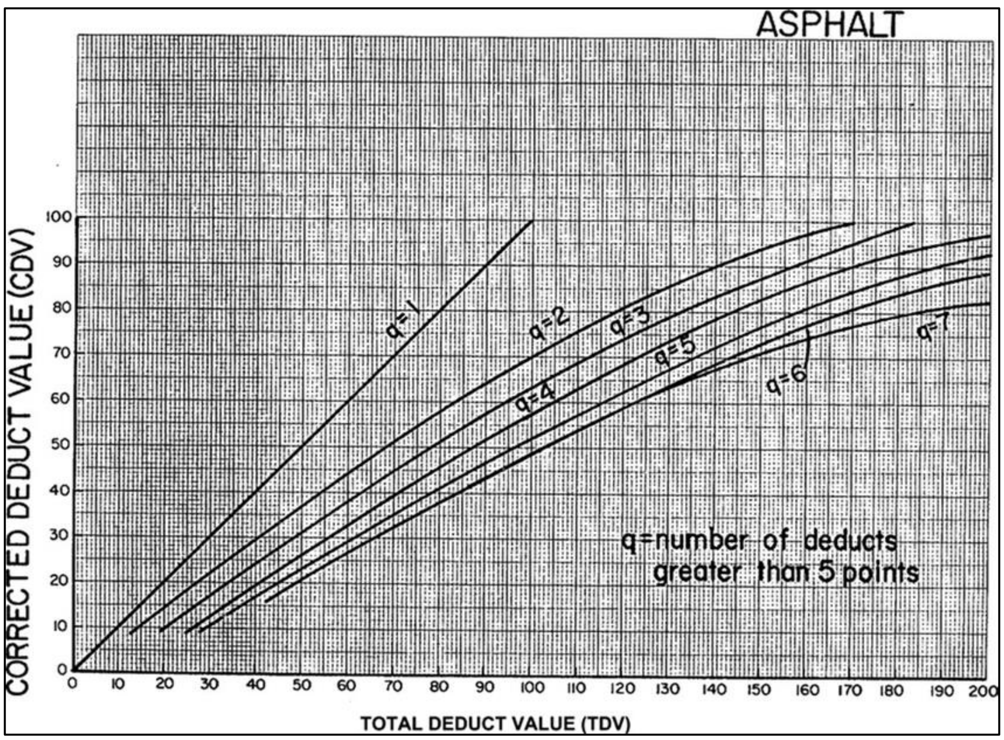


Figure C-3 Corrected deduct value curve.

4.2.1.2 Seal Coated Road, County: Saline, Township: Eldorado

The site is located in Eldorado Township. The seal coated road is shown on the Google Earth map in Figure C-4. The road is E 2350 street. The field distress data were collected on June 1, 2017.

Figure C-4. Location of seal coated E 2350 street in Eldorado Township.

(a) Alligator cracking, medium severity

(b) Edge cracking, low severity

(c) Rutting, high severity

(d) Bleeding, low severity

(e) Longitudinal cracking, low severity

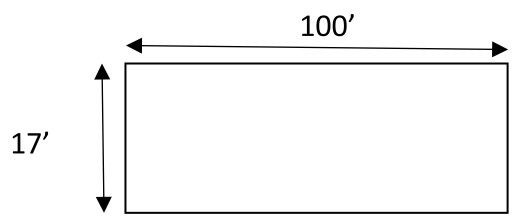
Figure C-5. Various distresses with their severity levels recorded for the seal coated E 2350 street in Eldorado Township.

Table C-12. The completed inspection sheet for seal coated E 2350 street in Eldorado Township.

ROAD INSPECTION SHEET-SEAL COATED ROAD

1. BRANCH: E 2350 Street	2. SECTION: Seal Coat	3. DATE: 06/01/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 1,700 sq ft	6. INSPECTOR: Furquan ul Haq

7. SKETCH



DISTRESS TYPES

1. Alligator/Fatigue Cracking (square feet)
2. Edge Cracking (linear feet)
3. Rutting (square feet)
4. Potholes (number)
5. Patching (square feet)
6. Loose Aggregate (linear feet)
7. Bleeding (square feet)
8. Longitudinal cracking/Transverse Cracking (linear feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6	7	8			
QUANTITY AND SEVERITY	L		7’-10”					400	3’			
	M	21’										
	H			200								

9. **SCRCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE
1	1.24	M	22
2	0.46	L	2
3	17.8	H	70
7	23.52	L	8
8	0.18	L	0

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

SCRCI=100 - CDV
= 100- 58= 42

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 102	q = 3	SCRCI =42	RATING: Fair

Seal Coated Road, County: Saline, Township: Eldorado

The site is located in Eldorado Township. The seal coated road is shown on the Google Earth map in Figure C-6. The road is N 350th street. The data was collected on June 1, 2017.

Figure C-6 Location of seal coated N 350th street in Eldorado Township.

(a) Bleeding, low severity

(b) Loose aggregate, low severity

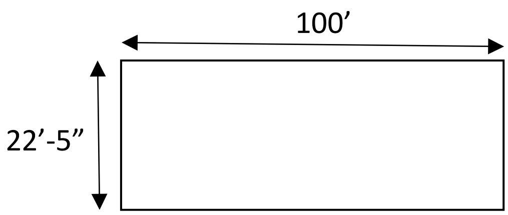
Figure C-7. Various distresses with their severity levels recorded for seal coated N 350th street in Eldorado Township.

Table C-13. The completed inspection sheet for seal coated N 350th street in Eldorado Township.

ROAD INSPECTION SHEET-SEAL COATED ROAD

1. BRANCH: N 350 Street	2. SECTION: Seal Coat	3. DATE: 06/01/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 2,241.7 sq ft	6. INSPECTOR: Furquan ul Haq

7. SKETCH



DISTRESS TYPES

1. Alligator/Fatigue Cracking (square feet)
2. Edge Cracking (linear feet)
3. Rutting (square feet)
4. Potholes (number)
5. Patching (square feet)
6. Loose Aggregate (linear feet)
7. Bleeding (square feet)
8. Longitudinal cracking/Transverse Cracking (linear feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6	7	8			
QUANTITY AND SEVERITY	L						100’	10’				
	M											
	H											

9. **SCRCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE
6	4.5	L	10
7	0.44	L	0

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

SCRCI=100 - CDV
= 100 - 10= 90

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 10	q = 1	SCRCI =90	RATING: Excellent

Seal Coated Road, County: Sangamon, Township: Williamsville

The site is located in Williamsville Township. The road is Lester road. The field distress data were collected on May 11, 2017.

(a) Edge cracking, medium severity

(b) Edge cracking, high severity

(c) Bleeding, high severity

(d) Loose aggregate, high severity

(e) Longitudinal cracking, medium severity

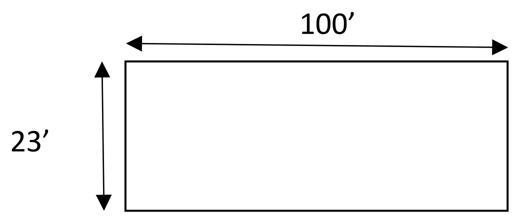
Figure C-8. Various distress with their severity levels recorded for seal coated Lester road in Williamsville Township.

Table C-14. The completed inspection sheet for seal coated Lester road in Williamsville Township.

ROAD INSPECTION SHEET-SEAL COATED ROAD

1. BRANCH: Lester road	2. SECTION: Seal Coat	3. DATE: 06/01/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 2,300 sq ft	6. INSPECTOR: Praveen

7. SKETCH



DISTRESS TYPES

1. Alligator/Fatigue Cracking (square feet)
2. Edge Cracking (linear feet)
3. Rutting (square feet)
4. Potholes (number)
5. Patching (square feet)
6. Loose Aggregate (linear feet)
7. Bleeding (square feet)
8. Longitudinal cracking/Transverse Cracking (linear feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6	7	8			
QUANTITY AND SEVERITY	L											
	M		18						30			
	H		10				3	100				

9. **SCRCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE
2	0.78	L	4
2	0.43	H	8
6	0.13	H	2
7	4.35	H	14
8	1.30	H	20

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

SCRCI=100 - CDV
= 100 - 30= 70

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 48	q = 3	SCRCI =70	RATING: Good

4.2.1.4 Seal Coated Road, County: Sangamon, Township: Williamsville

The site is located in Williamsville Township. The road is Knollwood Drive. The field distress data were collected on May 11, 2017.

(a) Alligator cracking, medium severity

(b) Alligator cracking, high severity

(c) Edge cracking, high severity

Potholes, low severity

Potholes, medium severity

Loose aggregate, medium severity

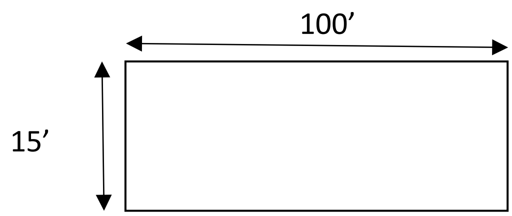
Figure C-9. Various distresses with their severity levels recorded for seal coated Knollwood Drive in Williamsville Township.

Table C-15. The completed inspection sheet for Knollwood Drive in Williamsville Township.

ROAD INSPECTION SHEET-SEAL COATED ROAD

1. BRANCH: Knollwood Drive	2. SECTION: Seal Coat	3. DATE: 05/11/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 1,500 sq ft	6. INSPECTOR: Praveen

7. SKETCH



DISTRESS TYPES

1. Alligator/Fatigue Cracking (square feet)
2. Edge Cracking (linear feet)
3. Rutting (square feet)
4. Potholes (number)
5. Patching (square feet)
6. Loose Aggregate (linear feet)
7. Bleeding (square feet)
8. Longitudinal cracking/Transverse Cracking (linear feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6	7	8			
QUANTITY AND SEVERITY	L				5		17					
	M	224			2							
	H	216	54									

9. **SCRCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE
1	14.9	M	52
1	14.4	H	66
2	3.6	H	25
4	0.33	L	38
4	0.13	M	36
6	1.13	L	2

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

SCRCI=100 - CDV
= 100 - 95= 5

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 219	q = 5	SCRCI =5	RATING: Poor

C-2. URCI INSPECTION SHEET FOR GRAVEL ROAD

Table C-16. URCI rating inspection sheet.

UNSURFACED ROAD INSPECTION SHEET-GRAVEL ROAD		
1. BRANCH	2. SECTION	3. DATE
4. SAMPLE UNIT	5. AREA OF SAMPLE	6. INSPECTOR

7. SKETCH	**DISTRESS TYPES**
	1. Improper Cross Section (linear feet) 2. Inadequate Roadside Drainage (linear feet) 3. Corrugations (square feet) 4. Dust 5. Potholes (number) 6. Rutting (square feet) 7. Loose Aggregate (linear feet)

8. **DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6	7
QUANTITY AND SEVERITY	L							
	M							
	H							

9. **URCI CALCULATION**

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE	10. REMARKS

TOTAL DEDUCT VALUE =	q =	URCI =	RATING =

Gravel Road, County: Saline, Township: Eldorado

The site is located in Eldorado Township. The gravel road is shown on the Google Earth map in Figure C-10. The road is N 350th street. The field distress data were collected on June 1, 2017.

Figure C-10. Location of N 350th gravel road in Eldorado Township.

(a) Inadequate roadside drainage, low severity

(b) Dust, low severity

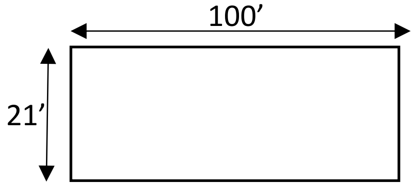
Figure C-11. Various distresses with their severity levels recorded for N 350th gravel road in Eldorado Township

Table C-17. The completed inspection sheet for N 350th gravel road in Eldorado Township

UNSURFACED ROAD INSPECTION SHEET-GRAVEL ROAD

1. BRANCH: N 350th Street	2. SECTION: Gravel Road	3. DATE: 06/01/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 2,100 sq ft	6. INSPECTOR: Furquan ul Haq

7. SKETCH



DISTRESS TYPES

1. Improper Cross Section (linear feet)
2. Inadequate Roadside Drainage (linear feet)
1. Corrugations (square feet)
2. Dust
3. Potholes (number)
4. Rutting (square feet)
5. Loose Aggregate (linear feet)

8. DISTRESS QUANTITY AND SEVERITY

TYPE		1	2	3	4	5	6	7
QUANTITY AND SEVERITY	L		100’		Low			
	M							
	H							

9. URCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUC VALUE
2	4.8	L	8
4	-	L	2

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

URCI=100 - CDV = 100 - 8
= 100 - 10= 90

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 10	q = 1	URCI = 90	RATING = Excellent

Gravel Road, County: Piatt

(a) Inadequate roadside drainage, severity low

(b) Rutting, severity medium

(c) Loose aggregate, medium severity

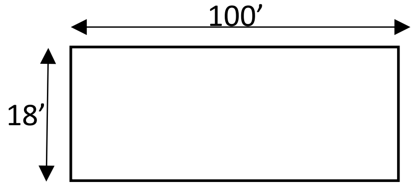
Figure C-12. Various distress with their severity levels recorded in a gravel road in Piatt County.

Table C-18. The completed inspection sheet for a gravel road in Piatt County

UNSURFACED ROAD INSPECTION SHEET-GRAVEL ROAD

1. BRANCH: 1300 N	2. SECTION: Gravel Road	3. DATE: 11/07/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 1,800 sq ft	6. INSPECTOR: Furquan ul Haq

7. SKETCH



DISTRESS TYPES

1. Improper Cross Section (linear feet)
2. Inadequate Roadside Drainage (linear feet)
3. Corrugations (square feet)
4. Dust
5. Potholes (number)
6. Rutting (square feet)
7. Loose Aggregate (linear feet)

8. DISTRESS QUANTITY AND SEVERITY

TYPE		1	2	3	4	5	6	7
QUANTITY AND SEVERITY	L		100					
	M						900	100
	H							

9. URCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
2	5.56	L	7
6	50	M	30
7	5.56	M	17

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

URCI=100 - CDV
= 100 – 35 =65

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 54	q = 3	URCI = 65	RATING = Good

C-3. URCI INSPECTION SHEET FOR DIRT ROAD

Table C-19. SCRCI rating inspection sheet.

UNSURFACED ROAD INSPECTION SHEET-DIRT ROAD		
1. BRANCH	2. SECTION	3. DATE
4. SAMPLE UNIT	5. AREA OF SAMPLE	6. INSPECTOR

7. SKETCH	**DISTRESS TYPES** 1. Improper Cross Section (linear feet) 2. Inadequate Roadside Drainage (linear feet) 3. Corrugations/ Wash Boarding (square Feet) 4. Dust 5. Potholes (number) 6. Rutting (square feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6
QUANTITY AND SEVERITY	L						
	M						
	H						

9. **URCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE	10. REMARKS
TOTAL DEDUCT VALUE =		q =	URCI =	RATING =

Dirt Road, County: Piatt

(a) Rutting, medium severity

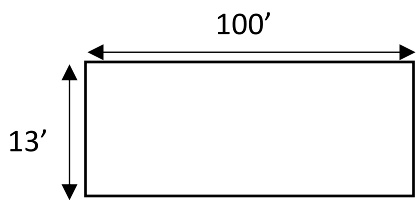
Figure C-13. Distress with severity level recorded in a dirt road in Piatt County.

Table C-20. The completed inspection sheet for a dirt road in Piatt County.

UNSURFACED ROAD INSPECTION SHEET-DIRT ROAD

1. BRANCH: 600 E	2. SECTION: Dirt Road	3. DATE: 11/07/2017
4. SAMPLE UNIT: 1	5. AREA OF SAMPLE: 1,300 sq ft	6. INSPECTOR: Furquan ul Haq

8. SKETCH



DISTRESS TYPES

1. Improper Cross Section (linear feet)
2. Inadequate Roadside Drainage (linear feet)
3. Corrugations/ Wash Boarding (square feet)
4. Dust
5. Potholes (number)
6. Rutting (square feet)

8.**DISTRESS QUANTITY AND SEVERITY**

TYPE		1	2	3	4	5	6
QUANTITY AND SEVERITY	L						
	M						400
	H						

9. **URCI CALCULATION**

DISTRESS TYPE	DENSITY %	SEVERITY	DEDUCT VALUE
6	30.77	M	28

10. REMARKS

Density = (Quantity of distress / Area of sample) * 100

URCI=100 - CDV
= 100- 28= 72

(CDV: Corrected Deduct Value)

TOTAL DEDUCT VALUE = 28	q = 1	URCI =72	RATING = Good

C-4. GUIDELINE TO MEASURE PAVEMENT DISTRESS: AUTOMATED DATA COLLECTION METHOD

C-4.1 IRI data collection using Cell Phone Apps

Three cell phone apps Roadroid, RoadBump, and TotalPave were used in this project. However, not all of them were used on all rural roads surveyed in this project. Figure C-14 shows the apps installed on the smartphone. One cell phone, Samsung S3 was used to collect the IRI data. The apps were not available for the iOS operating system and for this reason only Android-based operating system software was used.

(a) Roadroid **(b) RoadBump** **(c) TotalPave**

Figure C-14. Cell phone apps used to measure IRI of rural roads.

The vehicle was driven 20 to 55 mph. However, 20 to 30 mph speed provides consistent result while collecting IRI values. For a specific target speed, the vehicle was driven in both directions, i.e., northbound and southbound, and the data were averaged for both directions. Roadroid and TotalPave recorded data were uploaded on the developer's website from registered cell phone IMEI number. Therefore, roughness values could be evaluated through website results; however, RoadBump IRI values were shown by cell phone app instantly after each run.

C-4.2 Installation and data collection procedure of Cell Phone Apps

ROADROID

Roadroid app can be installed using the following Figure C-15, as well as the steps followed. It can easily be installed using the website address as "www.roadroid.com". A subscription fee is needed for professional use. For this study, the latest or updated version of Roadroid app is used mentioned as Pro2 v2.4.1.

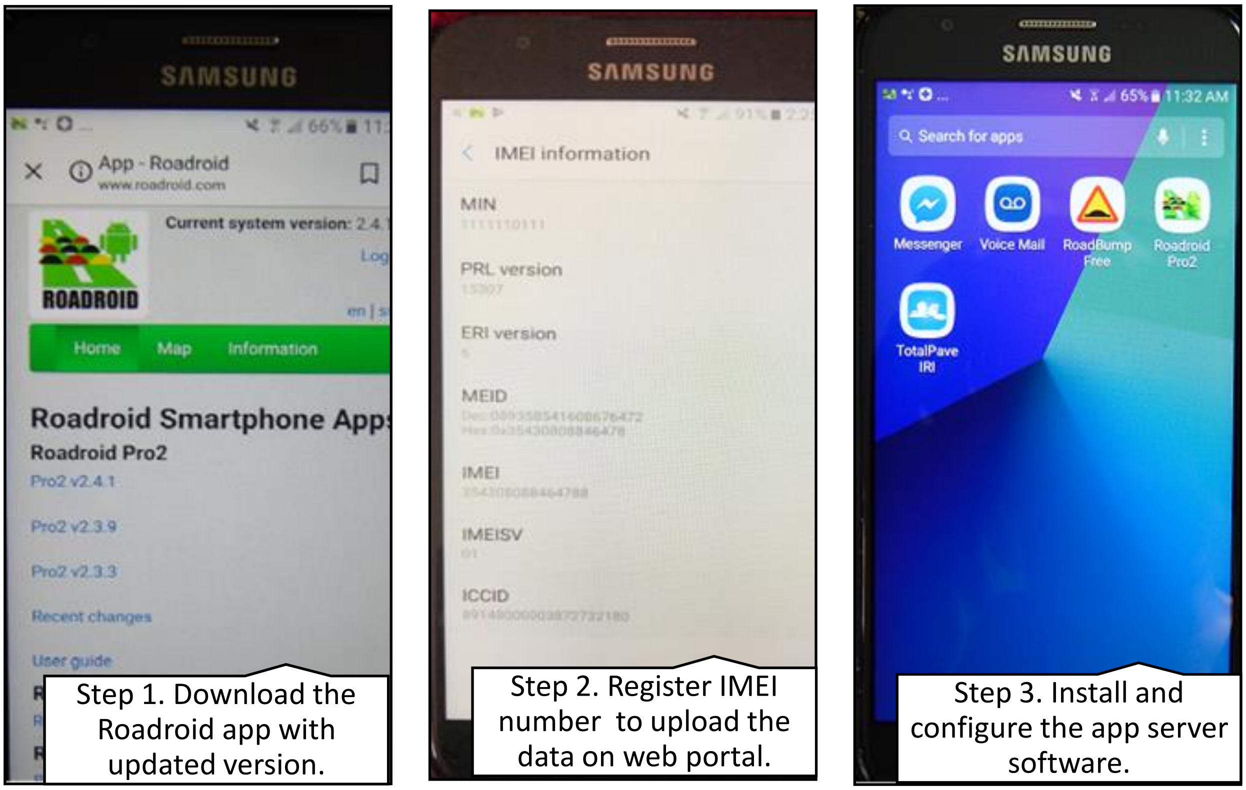


Figure C-15. Roadroid app steps to be followed while installation.

<u>Step 1.</u> Download the Roadroid app with an updated version.

<u>Step 2.</u> Register smartphone IMEI number and phone model to be able to upload the data on the web portal.

<u>Step 3.</u> Install and configure the app server software, and ready to use.

DATA COLLECTION

Step 1. Mount the phone in the horizontal direction, open the app and click on yellow flashing option to set the coordinates as shown in Figure C-16 and C-17.

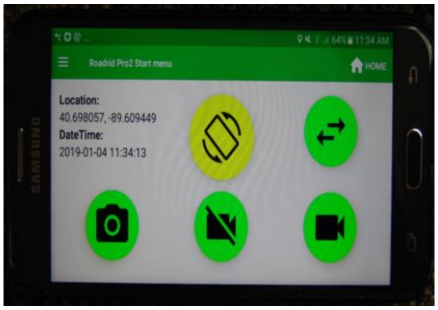


Figure C-16. The main screen of the Roadroid app.

Step 2. After setting the coordinates to zero, the app allows to proceed further showing correct green flashing arrow and can be clicked as represented in Figure C-17.

Figure C-17. Calibration of coordinates.

Step 3. To start the data collection procedure, press on the icon shown below in Figure C-18.

Figure C-18. Recording the survey by clicking on the showed direction.

Step 4. Start the vehicle and record the reading by pressing the bold red icon with green background depicted in Figure C-19.

Figure C-19. Data recording starting screen page.

Step 5. To stop, at the end of the pavement selected length, press the bold red icon with a black square in it showed in Figure C-20.

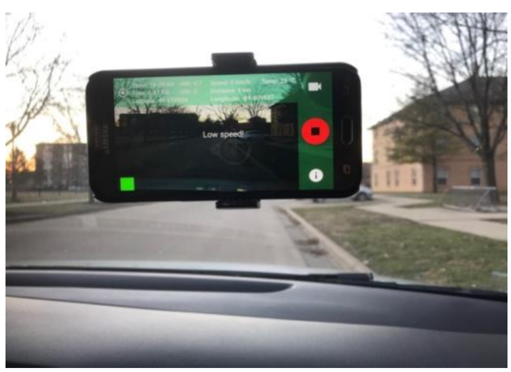


Figure C-20. The screen showed the option to stop the data collection.

Step 6. Upload or transfer the survey data on web portal using Figure C-21.

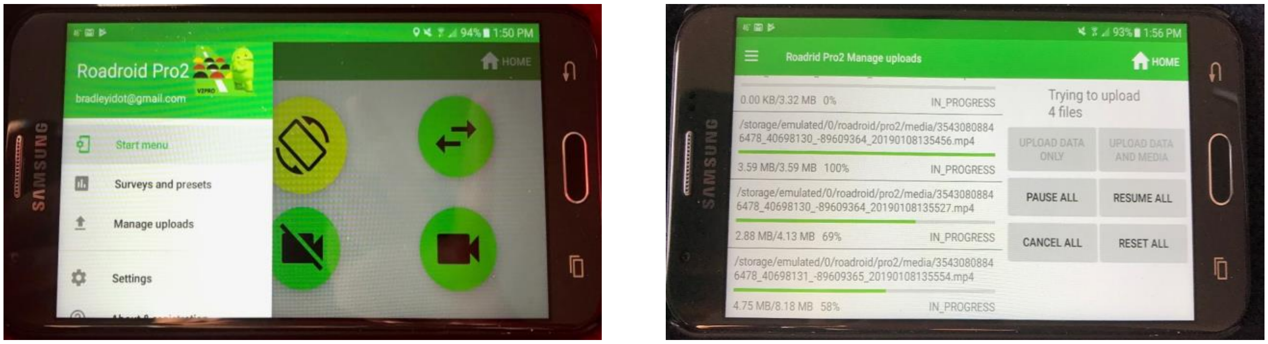


Figure C-21. Steps to transfer the data from app to portal.

Step 7. Open the web portal as shown in Figure C-22 and shows the detailed survey results.

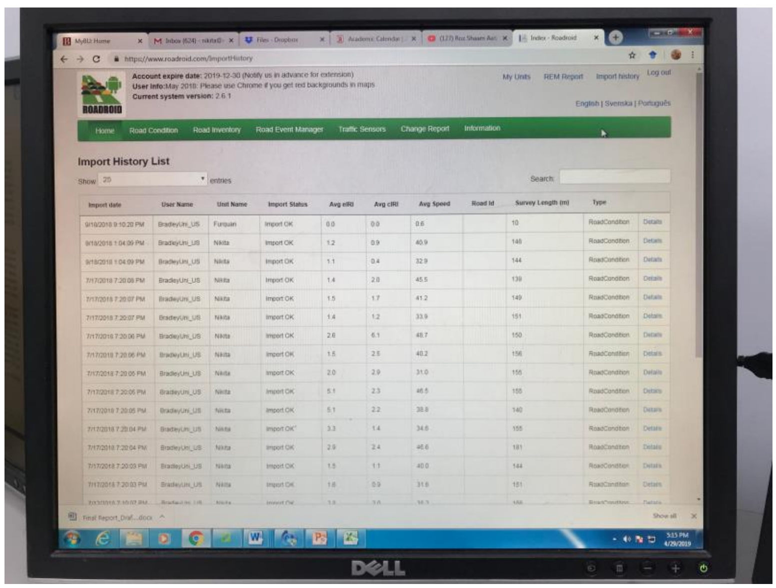


Figure C-22. Web portal with different values evaluated from a survey from the app.

After data collection from Roadroid app, the data is transferred to website using internet or Wi-Fi connection. Figure C-22 shows the representation of data from Roadroid app after uploading. Each run data is available in the form of aggregate file under import data. The aggregate file shown in Table C-21 for different speed runs with available values of latitude, longitude, distance, speed, altitude, and IRI mentioned as eIRI and cIRI. eIRI is the estimated international roughness index and based on a Peak and Root Mean Square (RMS) vibration analysis – which is correlated to Swedish laser measurements on paved roads. cIRI is the calculated international roughness index based on the quarter-car simulation (QCS) for sampling during a narrow speed range such as 60-80 km/h. When measuring cIRI, the sensitivity of the device can be calibrated by the operator to a known reference. The average of cIRI and eIRI gives the close values of average IRI of each speed limit. In this research, eIRI is used as an IRI value. Roadroid provides IRI outputs in SI units (i.e., m/km). The vehicle was driven following US units (i.e., mph).

Table C-21. Data retrieved from the website as aggregate file after uploading on Roadroid website.

Seal Coated Road

Driving Speed- 20 mph

Run 1

Avg. eIRI - 2.0 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h)	Altitude (m)	eIRI	cIRI
6/14/2018 /10:53	40.71131	-88.8126	100	33.06	190.36	2.24	1.05

Run 2

Avg. eIRI - 1.9 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h) (mph)	Altitude (m)	eIRI	cIRI
6/14/2018 /10:57	40.7113	-88.8125	100	31.84	191.08	2.23	1.13

Run 3

Avg. eIRI - 1.7 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h) (mph)	Altitude (m)	eIRI	cIRI
6/14/2018 /10:56	40.7113	-88.8125	100	32.76	187.09	1.91	0.89

Driving Speed- 25 mph

Run 1

Avg. eIRI - 1.6 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h)	Altitude (m)	eIRI	cIRI
6/14/2018 /10:59	40.71131	-88.8126	100	39.85	192	1.96	1.46

Run 2

Avg. eIRI - 2.0 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h)	Altitude (m)	eIRI	cIRI
6/14/2018 /11:01	40.71131	-88.8126	100	40.98	190	2.16	1.78

Run 3

Avg. eIRI - 1.9 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h)	Altitude (m)	eIRI	cIRI
6/14/2018 /11:03	40.71131	-88.8125	100	39.41	190.9	2.13	1.57

Driving Speed- 30 mph

Run 1

Avg. eIRI - 1.7 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h)	Altitude (m)	eIRI	cIRI
6/14/2018 /11:06	40.71134	-88.8106	100	47.74	188.88	1.63	1.16

Run 2

Avg. eIRI - 1.8 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h)	Altitude (m)	eIRI	cIRI
6/14/2018 /11:07	40.7113	-88.8126	100	48.38	189.88	1.97	1.6

Run 3

Avg. eIRI - 1.7 m/km

Date/Time	Latitude	Longitude	Distance(m)	Speed (km/h)	Altitude (m)	eIRI	cIRI
6/14/2018 /11:08	40.7113	-88.8125	100	47.75	190.88	1.93	1.78

Table C-22. Simplified form of IRI data from aggregate file.

Roadroid

No. of Runs	**Driving Speed (mph)**	**IRI (m/km)**	**Avg. IRI**
1	20	2	1.9
2		1.9	
3		1.7	

No. of Runs	**Driving Speed (mph)**	**IRI (m/km)**	**Avg. IRI**
1	25	1.6	1.8
2		2	
3		1.9	

No. of Runs	**Driving Speed (mph)**	**IRI (m/km)**	**Avg. IRI**
1	30	1.7	1.7
2		1.8	
3		1.7	

RoadBump

All Android- based cell phones have in a built app named as “Play Store” that has a number of applications. To install RoadBump, open Play Store and it is available there to install for free of cost named as “RoadBump Free” showed in Figure C-23. The free app is used for this study but subscription can be purchased for professional use.

<u>Step 1.</u> The RoadBump app can be downloaded from Play Store in android phones.

<u>Step 2.</u> Download the app.

<u>Step 3.</u> App installed and appears on the screen and ready to use.

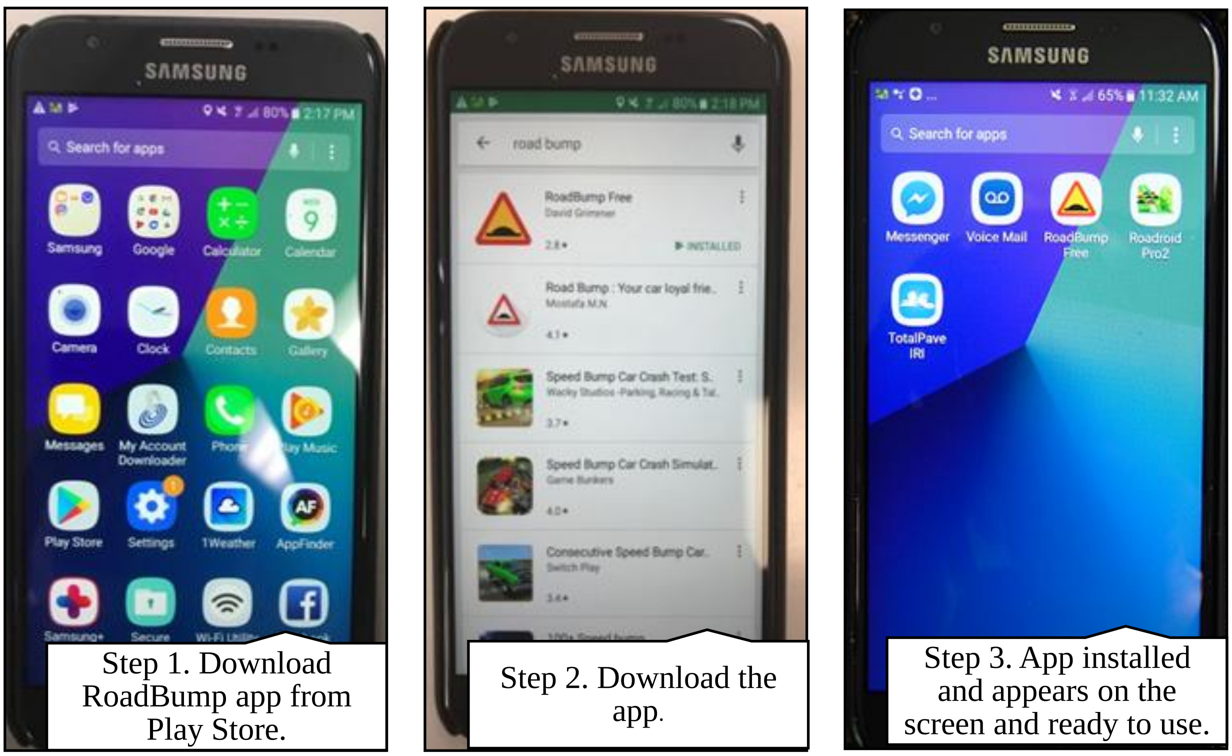


Figure C-23. RoadBump app steps to be followed while installation.

DATA COLLECTION

<u>Step 1.</u> Mount the phone in the vertical direction, open the app represented in Figure C-24.

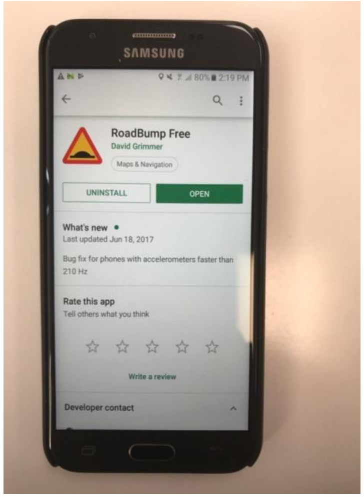


Figure C-24. The main screen of the RoadBump app.

<u>Step 2.</u> Opening to the main screen of the app appears to be shown in Figure C-25 below.

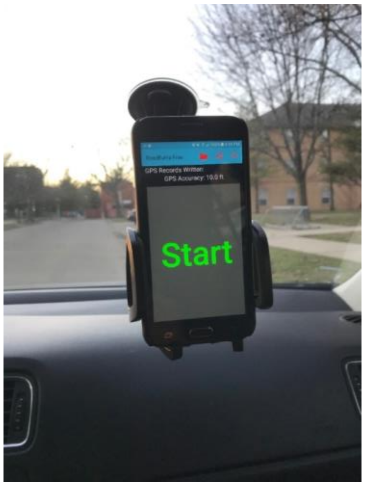


Figure C-25. Start page of the app to proceed with the data collection.

Step 3. RoadBump does not require any setting of coordinates, and the main page appears "Waiting for GPS." Now click on the Start button to record the survey and Stop to stop the recording showed in Figure C-26

Figure C-26. GPS for site location, start and stop the data collection options to collect data.

Step 4. IRI values can be obtained by the option to Review Map and Graphs showed in Figure C-27.

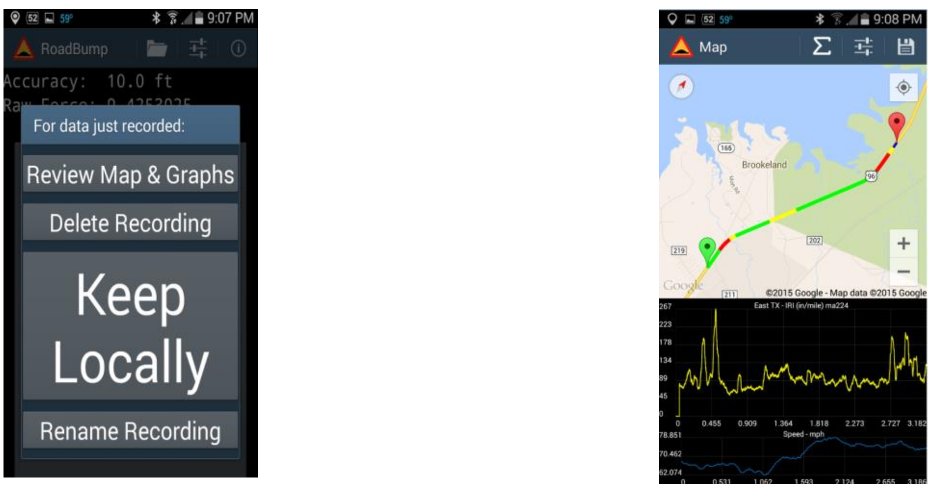


Figure C-27. Different options selection after the data collection.

Step 5. By this option, click on "∑" as a summary, the path recorded graphs of the road roughness and speed, IRI values, PSR, start and end longitude, start and end latitudes coordinates are visible as shown in Figure C-28.

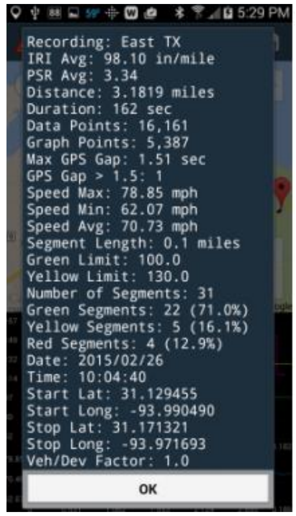


Figure C-28. Different indices values covered in the summary section of RoadBump app.

TotalPave

Using the Play Store app on Android-based cell phones, TotalPave app can be installed easily using the following steps mentioned in Figure C-29. For this study, the service provider allowed to use this app for only a few sections for free of cost. Although this app also requires an annual subscription.

Step 1. The TotalPave app can be downloaded from Play Store in android phones.

Step 2. Download the app.

Step 3. App installed and appears on the screen and ready to use.

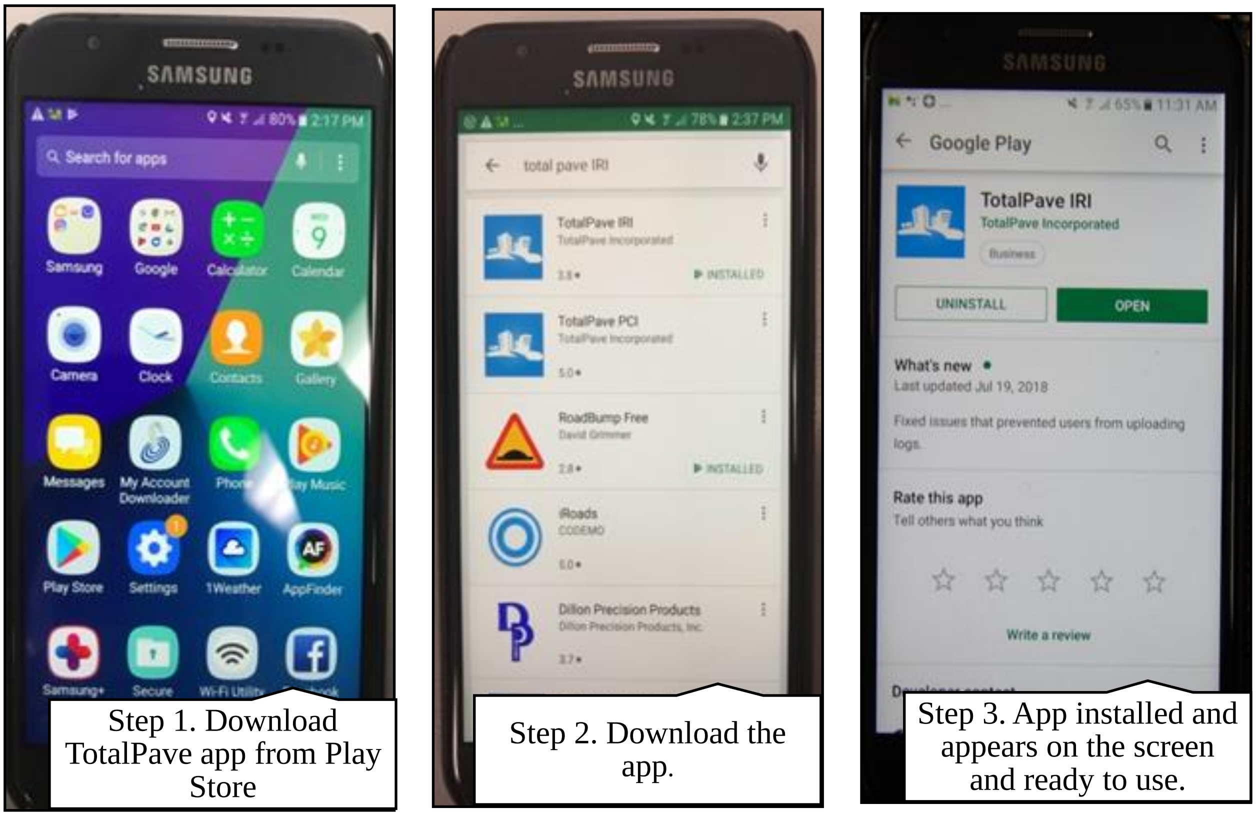


Figure C-29. TotalPave app steps to be followed during app installation.

DATA COLLECTION

Step 1. Mount the phone and open the TotalPave IRI app as shown in Figure C-30.

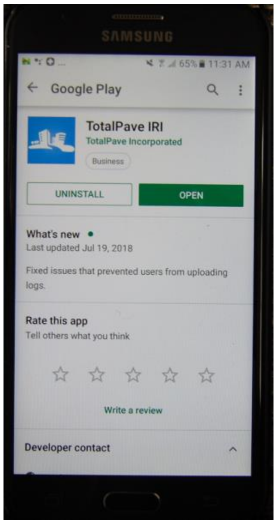


Figure C-30. The main screen of the TotalPave app.

Step 2. Register the e-mail address to upload or transfer the recorded data on the portal.

Step 3. The main screen of the app to start data collection showed in Figure C-31.

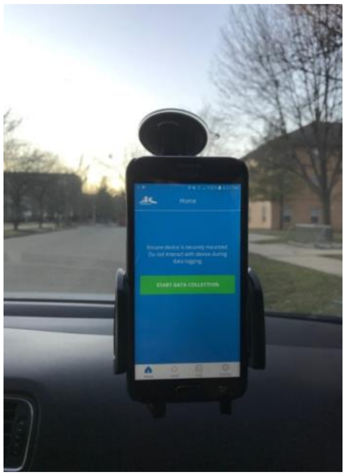


Figure C-31. Start the data collection option with green flashing option.

Step 4. Now set the coordinates by placing the blue circle on the dotted blue circle represented in Figure C-32.

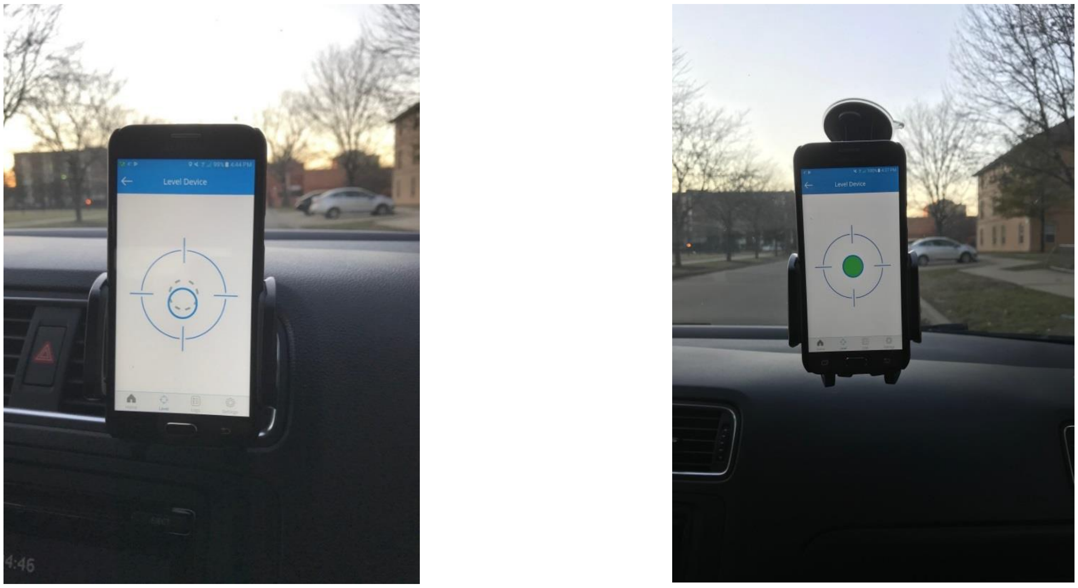


Figure C-32. Calibrating the app by moving it to a designated dotted circle.

Step 5. Start the data collection by clicking on Start the data collection and stop the reading at the end of the survey showed in Figure C-33.

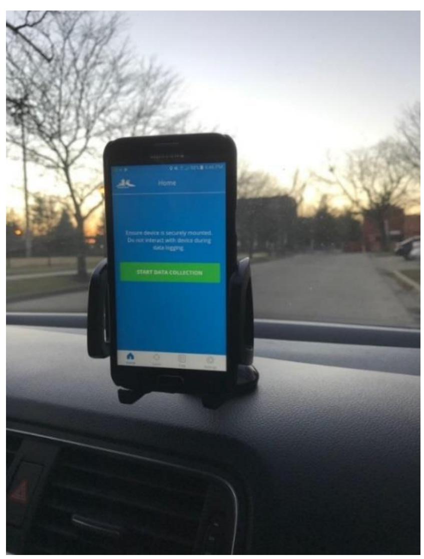


Figure C-33. Option after data collection to start or end the survey.

Step 6. Open the IRI logs to transfer the data on web portal shown in Figure C-34.

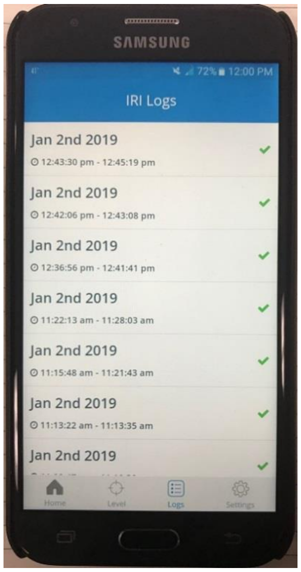


Figure C-34. Data collection or logs of results.

Step 7. Login into account and road sections covered appears on the portal with graphs and IRI values displayed in Figure C-35.

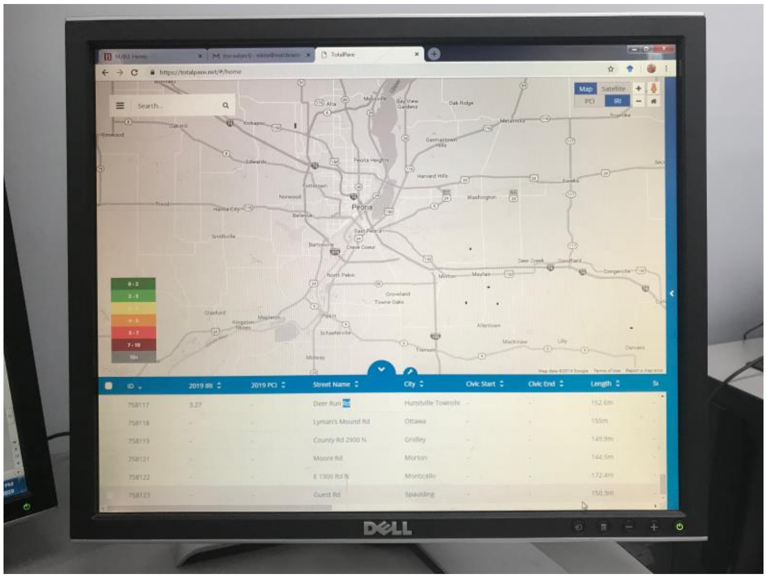


Figure C-35. Web portal results for all road sections covered with IRI values.

APPENDIX D: MAINTENANCE TECHNIQUES AND COST ASSESSMENT

D-1 CHIP-SEAL MAINTENANCE TECHNIQUES

One chip-seal road project visited was located on South Harkers Corner Road in Glasford, Illinois. Materials, labor, and maintenance equipment and methods were documented.

D-1.1 Materials

- 3/8” chips
- PG 52-28 binder at 250°F

D-1.2 Labor

- 1 oil-tank driver
- 1 driver per dump truck (5 total)
- 1 driver per roller (3 total)
- 2 spreader operators
- 2 laborers controlling traffic at road ends

D-1.2.1 Maintenance Equipment and Methods

The following maintenance equipment and methods were used to do the chip sealing.

The oil tank was lined up with its back-end spray bar parallel to the start of the maintenance area. The spreader was positioned a short distance behind it, with the first dump truck connected to its back end. All three rollers were staggered behind the dump truck.

The oil truck extended the spray bar out to cover the 24-ft width of the road and began applying the binder at 0.38 gal/yd^2. The bar was prepositioned 12 in. above the top of the pavement, and each nozzle was pre-angled to allow for a ¾-in. overlap on the pavement. Due to driver experience, the end nozzles were pitched significantly different than the middle nozzles to allow for uniform coating around curves.

Hooked back-end to back-end to the spreader, the dump truck lifted its bed to transfer the 3/8-in. aggregate chips into the spreader, then uniformly applied the chips over the freshly oiled pavement surface.

Oil tank and spreader lined up to start the maintenance work.

The oil tank spread the oil at a specified rate.

The spreader spread the chips at a specified rate.

The chip dump truck was attached to the spreader and continuously dumped chips in the spreader.

A pneumatic tire roller was used to press the chips into the oil.

The chip-seal road was opened to traffic after the maintenance work.

D-1.3 Slurry-seal/microsurfacing Maintenance techniques

One slurry-seal road project visited was located at North North Street in East Peoria, Illinois. The project area was approximately 76,000 sq yd. Materials, labor, mix design, and maintenance equipment and methods were documented.

D-1.3.1 Slurry-Seal Mix Design

- Portland cement—1.0%
- Water—9.0%
- Emulsion—13%
- Emulsion type—CSS-1hLM
- Emulsion source—Tri State Asphalt, LLC
- Aggregate source—Granite City Slag-Beelman 033FM21MS
- Unit cost is $3.80 sq yd (includes labor wages)

D-1.3.2 Labor

- 4 drivers
- 2 laborers for transferring material from STV to paver
- 3 laborers for laying down slurry from spreader box
- 3 laborers for leveling
- 2 laborers for spreading fine-crushed aggregates on turning points on a wet slurry seal
- Labor wage—$29/hour

D-1.3.3 Equipment

- 1 M1E continuous paver
- A truck containing crushed rocks and emulsion or slurry transport vehicle (STV)—2
- One mini truck containing fine-crushed aggregates to spread over wet slurry on turning points of roads
- 1 blowers
- 3 wipers for leveling

D-1.3.4 Maintenance Methods

The following slurry-seal construction methods were used.

The road was cleaned by using blowers and fogging of water on road.

A truck containing rocks (crushed steel slag which is a byproduct of steel) and emulsion (latex, modified quick-set) were brought in separate containers and transferred to the M1E continuous mix paver.

In the paver, materials were mixed; the required amount of water was added for workability with the half percent of cement.

Then, the slurry seal was laid on the road by spreader box and machine in three parts; and leveling from sides was done by laborers.

On turning point, they put some crushed stones, so that the slurry coating did not get harmed.

The slurry-seal coating needed at least 3 to 5 hours to cure after application.

D-1.4 crack-sealing maintenance techniques

One crack-sealing project was visited; and materials, labor, and methods were documented. The project was located on Trigger Road in Peoria, Illinois. This seal coated road is originally constructed over a distressed asphalt concrete pavement. Multiple chip seal layers are placed one over another for many years of maintenance.

D-1.4.1 Labor

- 1 truck driver
- 1 laborer with air jet
- 1 laborer with asphalt hose
- 1 laborer with soap-water jet
- 2 laborers controlling traffic at either end

D-1.4.2 Maintenance Materials and Methods

Crack-sealing materials and methods are described below.

BERAM 195 crack sealant was used in this project. Each box contained 50 lb of material.

The crack-sealant dispense temperature was around 365°–392°F.

One heated-hose machine was used in the project. The night before the crack sealing, the heated-hose machine was preheated and kept at a temperature of 100°F, with a little asphalt added in. On the day of crack sealing, the crack-sealant cubes were dumped into the machine one-and-a-half hours ahead of time and the temperature turned to the required temperature around 500°F to make sure the sealant came out from the nozzle. The product was heated at 500°F in the machine; however, the asphalt dispense temperature was 375°F.

The high-pressure air jet was applied to clean the cracks before applying the sealing materials.

Crack sealing was applied in the cracks with a hot hose.

Soap water was sprayed over the crack sealant so that the vehicle tires did not stick to the sealant.

The sealed cracks are opened for traffic right after application of the sealant materials.

D-1.5 patching maintenance techniques

One hot-mix asphalt patching project was visited; and materials, labor, and methods were documented. The project was located at Sheridan Road and Mail Street in Peoria, Illinois.

D-1.5.1 Labor

- 2 drivers for milling machine
- 1 driver for pneumatic machine
- 3 laborers for laying of the asphalt mix
- 1 laborer with a blower
- 2 truck drivers

- 1 flagger

D-1.5.2 Maintenance Methods

Patching maintenance methods are described below.

Milling machine was used to mill off defective areas.

The milled materials were cleaned by shoveling the discarded materials into the bucket.

The blower was used to clean the dust from the cut section.

Hot-mix asphalt (HMA) was dumped into the cut section.

The pneumatic roller was used to compact the HMA.

D-1.6 Gravel Road Maintenance Techniques

One gravel road maintenance operation was documented. The location was 2050 North Road in Copley Township in Knox County. Only the highway commissioner was doing the maintenance, and no additional material was used in the maintenance work. The equipment and procedure are described below.

A road drag was attached to a tractor and pulled over the gravel road. Generally, gravel road maintenance is done after a heavy rain because the road is softer and gravel is easier to pull.

The drag blades were aligned at a certain angle; and the inner side of the blade was raised, as compared to the outer side, so that a proper crown could be maintained while drag over the gravel road.

A drag was used to drag the gravel road.

A drag was used to dislodge the gravel and spread it again. No additional gravel was used in this project.

Dragged surface and undragged surface of a gravel road.

D-1.7 Maintenance Cost

A few other chip-seal, asphalt-overlay, and reconstruction projects were visited; and field practices were documented. Table D-1 lists the county and road names that were visited in 2017 to record maintenance projects. The county engineers or respective highway commissioners were contacted to collect the material, labor, and cost information to determine the total costs of the projects. In a few cases, the project cost was not broken down into material and labor cost; but rather, the total cost was given. Table D-2 lists the total cost and per mile cost of each project. The lowest cost of chip seal, in Sangamon County, was $120/mile, whereas the highest cost of chip seal, in Schuyler County, was $2,679/mile.

Table D-1. Counties and Roads Visited to Document Maintenance Projects

County	Township	Maintenance	Road Name(s)	Miles
Knox	Copley	Chip seal	1800 E and Bear School Road	3.25
Schuyler	Huntsville	Chip seal	Jersey Street and Augusta Road	1.4
Knox	Galesburg	Asphalt overlay	Moshier Avenue	0.4
Peoria	Glasford	Chip seal	Harkers Corner Road	0.5
Peoria	Trivoli	Chip seal	Stone School Road	1.25
Sangamon	Williams	Chip seal	Guest Road	1
Peoria	-	Crack seal	North Sheridan Road	-
Peoria	-	Patching	North Sheridan Road	-

Table D-2. Total Maintenance-Project Costs and Cost/Mile

Road Name(s)	Miles	Total	Material	Equipment	Labor	Total/mile	Material cost/mile	Equipment cost/mile	Labor cost/mile
1800 E and Bear School Road	3.25	$32,435	$27,502	$3,220.50	$1,712.46	$9,980.11	$8,462.28	$990.92	$526.91
Jersey Street and Augusta Road	1.4	$24,503	$16,600	$4,153.70	$3,750.12	$17,502.73	$11,857.14	$2,966.93	$2,678.66
Moshier Avenue	0.4	—	$2,729	—	—	—	$6,822.90	—	—
Harkers Corner Road	0.5	$2,689	$937	$987.80	$764.93	$5,379.70	$1,874.24	$1,975.60	$1,529.86
Stone School Road	1.25	$4,369	$1,603	$1,358.60	$1,407.16	$3,495.35	$1,282.74	$1,086.88	$1,125.73
Guest Road	1	$7,943	$7,673	$150.00	$120.00	$7,943.40	$7,673.40	$150.00	$120.00
N. Sheridan Road	-	$3,188	$19.80	$875.76	$2,293.25	-	-	-	-
N. Sheridan Road	-	$28,06	$4,839	$11,531.28	$11,694.40	-	-	-	-

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