Visual Assessment System for Rating Unsealed Roads

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During the past decade the Wyoming Technology Transfer Center has developed two complementary guides for visually assessing unsealed roads. The *Ride Quality Rating Guide* (RQRG) assesses the quality of an unsealed road's ride as perceived by the traveling public. The *Gravel Roads Rating System* (GRRS) provides standard evaluations of seven distresses, including potholes, rutting, washboards, loose aggregate, dust, crown, and roadside drainage. These guides have been used by many individuals on several projects. The guides described in this paper have been revised, updated, and improved several times. Manual methods are better than automated systems for assessing the condition of unsealed roads because the conditions can change quickly and sensors provide a measurement only for the path or location on which they are placed. Some methods are too simplified, and others are so complex that they require excessive resources to perform. The RQRG and the GRRS rating systems were developed by combining the use of photographs that illustrate the various rating levels resulting from different types and combinations of distresses, rating of seven distresses, use of a rating scale of 1 to 10 (a rating of ≤2 equals failed; a rating of ≥9 equals excellent), and simplified data collection procedures. The guides described are based most directly on the pavement surface evaluation and rating (PASER) manuals produced by Wisconsin's Transportation Information Center. The primary source is the *Gravel PASER Manual*, which rates roads as failed, poor, fair, good, or excellent; assigns numerical values of 1 to 5, respectively; and incorporates many of the same distresses as the guides presented in this paper.

During the past decade, the Wyoming Technology Transfer Center–Local Technical Assistance Program (WYT2–LTAP) has been involved in several projects in which visual evaluations of unsealed road segments were an integral element. Initially, these evaluations were based on modified versions of Wisconsin's gravel pavement surface evaluation and rating (PASER) manual (*1*). The ratings performed by the WYT2–LTAP Center sought to evaluate the individual distresses that helped to assess the overall quality of a road. By incorporating the scale of the *Gravel PASER Manual* and assessing individual distresses and ride quality, the guides described in this paper, the *Gravel Roads Rating System* (GRRS) (*2*) and the *Ride Quality Rating Guide* (RQRG) (*3*), provide more information about a road's condition than the single number provided by the PASER manual.

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The performance of unsealed roads is heavily influenced by precipitation (*4*) and therefore by climate (*5*). The county roads for which these guides were developed are mainly, but not exclusively, from areas with less than 20 in. of precipitation per year. However, the specificity of these guides, particularly in relation to travel speeds and their inherent calibration with numerous high-resolution photographs, means that they may be used for unsealed roads in any region or climate.

The objective of this research was to develop simplified procedures for rating unsealed roads that local agencies could implement with minimal training and resources. Local agencies will be able to identify the condition of all their roads so that funding can be spent efficiently.

LITERATURE REVIEW

In the simplest terms, two types of roadway assessment are possible—manual and automated. Automated systems, such as the Canadian Opti-Grade, have been used to assess and direct maintenance practices on unsealed roads, a practice that has led to decreased maintenance costs (*6*). Automated systems such as this one consist of vehicle-mounted equipment with sensors that measure roughness. However, there are some inherent problems with these methods, in particular because unsealed road conditions change quickly. Also, they depend on the path taken by the data collection vehicle (*7*).

Manual methods may be further subdivided into visual evaluation methods and measurement methods. The distinction between these is that for visual methods, evaluators do not need to get out of their vehicles, but for measurement methods, they do. The following discussions describe two measurement methods and two visual assessment methods similar to the one described in this paper. A more complete discussion of methods for assessing the condition of unsealed roads is available elsewhere (*8*).

A well-established, measurement-based unsealed road assessment procedure was developed by the U.S. Army Corps of Engineers (USACE) (*9*). The USACE system generates an unsurfaced road condition index (URCI) using the measurements of several distresses. The extent of each distress and the severity level are measured either linearly or by area, except for dust, which is assessed visually. Criteria for each severity level are established for these distresses:

- Cross section,
- Roadside drainage,
- Corrugations (washboards),
- Dust,
- Potholes,
- Ruts, and
- Loose aggregate.

Once the extent of each of these distresses at each severity level (low, medium, or high) is established, deduct values are determined for each distress. The severity level is defined for each distress in the USACE report (*9*). These deduct values are then used to determine an overall URCI on a scale from 1 to 100. Similar systems assessing the same seven distresses are provided by the New Hampshire Technology Transfer Center (*10*) as part of its road surface management system and by the Utah LTAP Center's Transportation Asset Management Software system (J. Jones, personal communication, 2011).

A less rigorous method was developed in Australia (*11*). It evaluates deformations, surface texture, and potholes. No cumulative rating is generated. The distresses evaluated include channels (erosion channel, scour, and rills), corrugations (ripples), rutting, shoving, loose material, coarse texture, and potholes. This method makes no attempt to evaluate overall quality or to rate on a common scale.

An unsealed road rating system was developed in South Africa by the Council for Scientific and Industrial Research (CSIR) (*12, 13*). This method is comprehensive and highly detailed, but it relies less on direct measurement and more on training with field calibration than the USACE URCI method. It generates assessments of the following characteristics:

- General performance,
- Moisture condition,
- Gravel quantity and layer thickness,
- Gravel quality,
- Ability to shed water (crown),
- Roadside drainage,
- Riding quality,
- Dust,
- Trafficability (passability),
- Isolated problems, and
- Required maintenance action.

Assessing these characteristics requires considerable skill and training on the part of those performing the evaluations. The manual recommends collecting a full suite of information desirable for making decisions as to how one should maintain unsealed roads, for example, with regard to moisture condition, gravel thickness, and maintenance needed. The visual assessments rely heavily on the knowledge and experience of the evaluators; for this method, it is essential that evaluators be trained and calibrated (*13*).

For the evaluation of ride quality, the South African rating system provides descriptions and estimated comfortable speeds (unaffected by geometric constraints or road width) for a privately owned passenger car as described in Table 1.

Another visual assessment method was developed by FHWA's Central Federal Lands Highway Division to provide comparative ratings of dust, washboards, raveling, potholing, and rutting (*14*). In this method, an arbitrary starting point is assumed for each distress and other roads are rated on an 11-point scale relative to the initial road's rating of 5 for each distress. As such, the method provides relative ratings when conducted by the same three individuals.

TABLE 1 Assessment of Riding Quality (*12*)

Rating	Descriptor	Estimated Comfortable or Safe Speed [km/h (mph)]
1	Very good	>100 (62)
2	Good	80–100 (50–62)
3	Average	60–80 (37–50)
4	Poor	40–60 (25–37)
5	Very poor	<40 (25)

Probably the most commonly used unsealed roads assessment system, at least in western North America, is the PASER system developed in Wisconsin. It is simple and easy, and it provides a quick assessment on a fixed scale as established by the published manuals. For this reason, the manual presented in this paper adopts the scale of the PASER gravel manual (*1*). The PASER unimproved roads manual (*15*) and the drainage manual (*16*) also influenced the development of the guides presented in this paper. The *Gravel PASER Manual* rates roads as excellent, good, fair, poor, or failed; numerical values of 5, 4, 3, 2, and 1, respectively, are assigned. These ratings incorporate the following specific distresses:

- Crown;
- Drainage;
- Gravel layer;
- Surface deformation:
  - Washboard,
  - Potholes, and
  - Ruts; and
- Surface defects:
  - Dust and
  - Loose aggregate.

The *Gravel PASER Manual* provides verbal descriptions of these distresses for the various rankings, along with general conditions and treatments needed. A critical point in the *Gravel PASER Manual* is a travel speed of 25 mph, which separates fair and poor roads. This dividing line is maintained in the RQRG described here. The *Gravel PASER Manual* provides several example photographs for each of the five ratings. Finally, it provides advice on how to perform the ratings.

The South African CSIR system requires considerably more effort and skill on the part of the evaluators. Also, it is on a somewhat different scale, with the cutoff between average and poor at 60 km/h (37 mph) (*12*), while the PASER system separates fair and poor at 40 km/h (25 mph) (*1*). This distinction indicates a possible difference in expectations for the smoothness of unsealed roads in South Africa and Wisconsin, a fairly predictable situation considering that South Africa has a considerably drier climate, so unsealed roads can successfully serve traffic in higher functional classes, with higher traffic volumes, and at higher speeds. With that said, there is no consensus among users and maintainers of unsealed roads in Wyoming as to what constitutes a good, fair, or poor road. Still, to provide any consistency in ratings when different individuals carry out the ratings, or even when the same evaluator rates roads over several months or years, standards are needed.

The URCI is designed to provide consistent ratings by providing well-defined cutoffs for severity levels and by measuring the extent of the distresses (*9*). In the WYT2–LTAP experience, this method is comparable in its consistency with more straightforward, subjective visual methods (*17*). However it is too time-consuming to be practical for evaluating hundreds or thousands of miles of unsealed roads for management purposes. It is probably best suited to research purposes, though it may not be as effective as the GRRS system presented in this paper. The other problem with this method is that, when performing the surveys, one must determine the point, for example, at which washboards go from medium to low severity. Should the cutoff be where a single corrugation's deepest part is more than 1 in.? Where its average depth is greater than 1 in.? Such decisions are inherently arbitrary, so the severity and extent methods are not nearly as rigorous as they seem on paper. Similar problems probably also exist with the Austroads method. The URCI and Austroads methods do not provide as much of an improvement in objectivity and independence from evaluators' bias as one might hope.

RATING SYSTEM DEVELOPMENT

Asset Management for Wyoming Counties Pilot Study

Development of the guides began in 2004 when WYT2–LTAP began a 3-year pilot asset management program for three Wyoming counties; the program is described in more detail elsewhere (*18, 19*). As part of this program, about 1,825 centerline miles (2,937 km) of unsealed roads were rated by people hired to spend the summer evaluating roads and road features—sealed roads, unsealed roads, culverts, signs, and cattle guards. Because of the extensive nature of these counties' unsealed road networks, quick visual condition assessments had to be made. Training and guidance materials were initially developed for this effort by WYT2–LTAP staff. These materials were developed largely according to the standards presented in the PASER manual. The primary reason for not simply using the PASER manuals was that they provide only a single value for unsealed roads, but ratings of individual distresses were desired. The collection of individual distress ratings allowed the development of several analytical procedures.

A preliminary analytical effort using the individual distress data collected in this 3-year project developed improvement recommendations for unsealed roads (*20*). Road segments were assigned to one of four functional classes (resource, local, minor collector, or major collector); minimum acceptable conditions were assigned to each class. These minimum acceptable conditions were determined according to the ratings of overall condition, washboards, ruts, and potholes. For those segments that were not at acceptable levels for their functional class, recommended improvements were generated on the basis of their class and the various distress condition ratings. These results, combined with information as to whether or not each road segment was being affected by oil and gas drilling traffic, were used to determine the cost of improvements needed on those road segments affected by oil and gas traffic relative to otherwise similar unaffected road segments (*21*). The effects of dust, rutting, and potholes had the greatest influence on the increased cost of maintaining roads, particularly collectors, affected by oil and gas traffic.

At the start of the third year of this 3-year project, three ratings teams were formed. One team had an entire summer of experience, a second had only a few weeks of experience, and a third consisted of the engineer who developed the ratings guides. The engineer conducted the training, and the teams were taken on a tour performing independent but simultaneous evaluations of 37 road segments, which were determined by dividing the network into maintenance management sections. Each rating group was in a separate vehicle, and results were not discussed until after all ratings had been performed. Results of this comparison are presented later in this paper.

To fulfill the needs of several other smaller projects, a single parameter assessing unsealed roads' surface condition from the general public's point of view was desired. This need was met with the development of the RQRG (*3*). This guide has since been revised and updated several times. These revisions were based on extensive direct experience and conversations with others using the RQRG.

Oil and Gas Study

A second major project assessing impacts and potential impacts of oil and gas drilling operations on county roads in four southeastern Wyoming counties was undertaken in 2011 and 2012 (*22*). To provide a better assessment of the road segment's conditions, the GRRS was developed on the basis of the training and guides developed during the course of the earlier pilot asset management program (*2*). For this project, the RQRG and the GRRS were used in conjunction. The RQRG provided an assessment of the way the public perceives the quality of the road. As such, it is a proxy for user costs. The GRRS provided detailed information about the condition of the road segments. This information, along with the proximities of oil and gas drilling operations and truck and total traffic volumes, was used to generate lists of roads in need of improvement (*22*) using previously developed methods (*21*).

RATING SYSTEM METHOD

The RQRG and the GRRS are designed to be used to perform quick visual assessments of unsealed roads. The guides provide brief verbal descriptions. To define ride quality levels, they use highly subjective verbal descriptions along with approximate traffic speeds that vary widely from operator to operator and from vehicle to vehicle. Such subjective standards frequently do not yield reproducible results, which greatly limits their utility. Similar descriptions, though without any approximate speeds, define the individual distress levels. Because the systems suffer from different evaluators' methods of internally averaging conditions over an entire road segment, the use of photographs is still highly effective in yielding consistent, reproducible road ratings. Photographs taken with at least 3-megapixel digital cameras provide standard, reproducible values.

Photography

The selection of photographs for the RQRG was done to provide examples of instances in which the same ride quality rating was assigned to different segments displaying a wide variety of distresses. Different individuals and vehicles respond differently to different distresses. Many hours of discussion have gone into establishing the standards presented in the RQRG and the GRRS. In addition, for each of the WYT2–LTAP projects in which unsealed roads are rated, photographs, often more than one of each segment, are taken. This approach provides WYT2–LTAP with a large repository from which to select photographs that illustrate the various rating levels resulting from different types and combinations of distresses. The best of these were rated and included in the two guides to provide as concise a portrayal of the various ratings as possible. Some photographs were eliminated because they were deemed to be right on the edge of two rating levels. Through multiple iterations, a consistent system has been developed by relying on pictures of the various distress ratings.

A final revision was performed during the winter of 2014. It consisted primarily of adding many additional high-resolution photographs, along with minor changes to the verbiage. Tables 2 through 4 show the number of photographs for each distress and level in the current editions of the RQRG and the GRRS. The GRRS's current version has 119 photographs; the previous version had 58. The RQRG's

TABLE 2 Number of Photographs in the RQRG and GRRS for Each Distress and Level

Distress Type	Rating 10 (Excellent)	9 (Very Good)	8 (Good)	7 (Good)	6 (Fair)	5 (Fair)	4 (Poor)	3 (Poor)	2 (Very Poor)	1 (Failed)	Total
RQRG ride quality	1	6	12	16	20	22	10	12	2	4	105
GRRS											
Rutting	NA	0	2	2	2	3	2	3	2	2	18
Potholes	NA	0	3	2	3	4	4	2	1	0	19
Washboards	NA	0	3	3	5	3	2	1	0	0	17
Loose aggregate	NA	1	3	3	4	3	4	2	0	0	20

NOTE: NA = not available.

TABLE 3 Number of Photographs in the GRRS for the Various Dust Levels

Distress Type	Rating 4 (None)	3 (Low)	2 (Medium)	1 (High)	Total
Dust	1	5	4	2	12

current version has 105 photographs; the previous version had 66. The use of additional pictures more precisely defines the various ratings under a wider variety of situations. Pictures can be observed in the gravel road quality rating guides located on the Wyoming LTAP Center's website under the asset management section (*2, 3*). Through a decade of experience in a wide variety of circumstances, the current editions provide well-defined, concise definitions and descriptions of a wide range of unsealed road distresses and ride qualities.

Rating Distresses

One of the most difficult aspects of assessing ride quality involves how one derives ratings of the different distresses. The relative importance of different distresses is highly dependent on vehicle type as well as on the drivers' personal preferences and their perceived safety awareness. In general, passenger car suspensions are better adapted to smoother roads, while light trucks and sports utility vehicles are better adapted to rougher roads. Vehicle wear and tear is a bigger issue if the driver, not the driver's employer, must pay for any necessary repairs. Some drivers fear loss of control less, so they are willing to drive fast enough to skim the tops of washboards, reducing the roughness they induce. It is assumed throughout these guides that drivers do not do this, but it is well known that many engage in this potentially dangerous practice. Balancing the relative effect of different distresses on ride quality was perhaps the greatest challenge in developing the RQRG.

TABLE 4 Number of Photographs in the GRRS for the Various Crown and Drainage Levels

Distress Type	Rating 3 (Good)	2 (Fair)	1 (Poor)	Total
Crown	14	8	12	34
Drainage	12	9	13	34

Scaling System

A final issue was the selection of an expanded scale, going from the five rating levels in the PASER manuals to a nine-point or a 10-point scale. The decision to go from a five-point to a 10-point scale was made for a simple reason. The error introduced when raters choose between two adjacent ratings is reduced by providing a scale with more levels. The most common example of this conclusion involves deciding whether to rate a road as fair or as good. Two evaluators in the same vehicle are often off by 20% with a five-point scale, but they are only off by 10% with a 10-point scale when they select ratings that differ by one point. It is believed that the RQRG and the GRRS successfully reduce rating error because of their expanded scales.

Data Collection Time and Costs

No specialized equipment is needed to perform evaluations with the RQRG or the GRRS. One needs a vehicle and a device for entering and storing data. A GPS unit is useful for locating (and often defining) segments. Acquiring and developing such data collection methods can be time-consuming but can also be done quite easily. A uniformly segmented inventory is critical to the success of any unsealed roads monitoring program, so roads must be segmented before, or possibly while, the roads are being rated (*23*).

The time it takes to evaluate roads is highly dependent on the complexity of the network. Issues such as travel time to the roads to be evaluated and the ability to avoid long trips between the rated roads will all affect the mileage that evaluators can rate in an hour or a day. Typical average production rates are about 15 mi an hour. This rate does not seem to be appreciably increased by having a two-person crew although quality is probably improved when two people discuss and evaluate the segments. It generally takes a few minutes to enter the data. Having a second person means data can be entered while the vehicle is moving; but discussion time increases, often resulting in stops at the end of each section that may be longer than if a single evaluator simply enters the data and moves on.

RESULTS

June 2006 Side-by-Side Ratings

In June 2006, the final year of the WYT2–LTAP 3-year pilot asset management program, three separate road evaluating crews drove the same roads simultaneously. Each crew rated the roads independently. No results were compared until the end of the day. One crew consisted of the professional engineer (PE) who developed the ratings system riding alone, another consisted of an experienced two-person crew that was beginning its second summer of data collection, and the third was a novice two-person crew that had been collecting data for only a few weeks. The two-person crews had both been trained by the engineer at the beginning of each season. In the previous two seasons, the engineer rode along with each rating crew, discussing ratings in an attempt to provide more consistent, repeatable ratings. The independent rating procedure was selected in part to provide information as to how successful the ratings systems were. Many of the refinements made to the ratings system later were influenced by the results of this side-by-side comparison.

Thirty-seven segments were rated for loose aggregate, potholes, gravel quality, gravel sufficiency, washboards, rutting, crown, roadside drainage, and dust. A PASER rating, a rating of the overall road segment quality, was also performed, and crown and top width were measured. All characteristics were rated with the PASER gravel scale of 10 (excellent), 8 (good), 6 (fair), 4 (poor), or 2 (failed). The differences in ratings between the three crews were calculated for each characteristic on each segment. Figure 1 graphs these differences.

Ideally, all ratings would have a narrow spike centered on a difference of zero. A most prevalent difference of zero would indicate no bias, and a sharp peak would indicate minimal error. The ratings for loose aggregate best approximate this ideal, with the differences between each crew tending toward zero, indicating negligible bias, and fairly steep peaks indicating minimal variability. The ratings for washboards, potholes, and drainage and the PASER overall rating all showed very good agreement between the experienced crew and the engineer, with the novice crew rating these features somewhat higher. Gravel sufficiency, gravel quality, dust, rutting, and crown ratings all showed considerably more variability, indicating that these characteristics were not being evaluated as consistently. Dust is inherently difficult to rate visually since it is such a subjective assessment, and no ratings were off by more than 2, so efforts were made to clarify how dust was rated and to reduce the bias. It was concluded that gravel quantity and sufficiency are not easy to assess, particularly for those with relatively limited experience. It is often hard to determine whether material is subgrade or gravel. This problem is often exacerbated by the common practice of using local materials similar to the subgrade as surfacing aggregate. For rutting, it was concluded that better training and guidance were needed. For potholes, rutting, drainage, and the PASER rating, further discussion was needed to eliminate the bias between the novice crew and the others. Overall these results were encouraging though they also indicated that there was plenty of room for improvement. No data were removed, so the ratings could be properly evaluated.

The results from this comparison were used a few years later when the next major round of improvements to the WYT2–LTAP gravel roads assessment tools was made and the first versions of the RQRG and the GRRS were developed.

May and June 2012 Ratings Comparisons

In May and June of 2012, two evaluators, a professional engineer and a civil engineering graduate student, rated 141 segments within a few weeks of each other. These evaluators had spent several days during October 2011 rating the roads together, trying to calibrate their eyes, and using the GRRS and the RQRG as guides. Figure 2 shows the changes from the mostly May evaluations by the graduate student to the mostly June evaluations by the engineer.

For all the rated distresses, the most prevalent change from evaluator to evaluator is no change—a difference of zero. This result is a very positive one. It indicates that the ratings are, on the whole, repeatable.

CONCLUSIONS

This paper presents an unsealed road rating system intermediate between Wisconsin's PASER system and South Africa's CSIR system—it is nearly as fast as the PASER although it does not provide as much detail for project-level decisions as the CSIR system does. For those seeking more detailed network-level analysis combined with good starting points for project-level analysis, the GRRS combined with the RQRG provides an excellent solution.

The RQRG alone may be used to assess an unsealed road segment's performance in regard to user satisfaction and costs. Motor grader operators may spend less than a minute per day evaluating the ride with the RQRG, providing valuable information about the effectiveness of a routine blade maintenance program. The RQRG also provides a reasonable proxy for user costs.

For research purposes, the GRRS may provide a critical tool in developing more precise performance measures. As has been noted by WYT2–LTAP staff and others, the USACE's URCI system often lacks sufficient sensitivity (*14*). There may be highly significant changes in performance within a single distress severity level as described by the URCI, particularly at medium severity levels. By using the GRRS as a basis for more sensitive discrimination between distress levels and then measuring the length of road within a segment at each GRRS rating, one could develop a highly sensitive and robust rating system for unsealed roads. In essence, such a system would replace the subjective averaging of a road segment's distress levels as recommended by the RQRG and the GRRS by measuring the length at each distress rating level in a road segment. This step could easily be done by using the RQRG and GRRS in their current formats and simply recording the point at which a road goes from one rating level to another. Of course, algorithms would need to be developed to convert the fractions of the road segment at each rating level into an overall rating for each distress. In addition, it might be desirable to convert all of these into a single, overall condition rating for a road segment.

At this point, one is back to a value similar to that of the PASER rating. Then the question becomes one of repeatability. Would such an approach provide more repeatable results? The answer is almost certainly yes. Such results would also provide far greater detail, indicating not just that a road has changed its condition but also how it had changed, which would very likely indicate a deterioration mechanism. This approach might indicate how such deterioration could be prevented or minimized. Though too time-consuming for unsealed road management, such a procedure could be very useful and effective for research projects. The guides described in this paper quickly assess unsealed roads on a common scale.

The benefits of this rating system include providing local agencies with a simplified procedure to assess the condition of their unpaved roads quickly and efficiently. The expanded 0 to 10 scale decreases the error level of multiple evaluators, providing a more accurate rating of the condition. Also, the rating of different distresses provides a more comprehensive evaluation so that better maintenance decisions can be made. Finally, the extensive volume of high-quality photographs provides evaluators with a more precise ability to properly rate the condition of the roads.

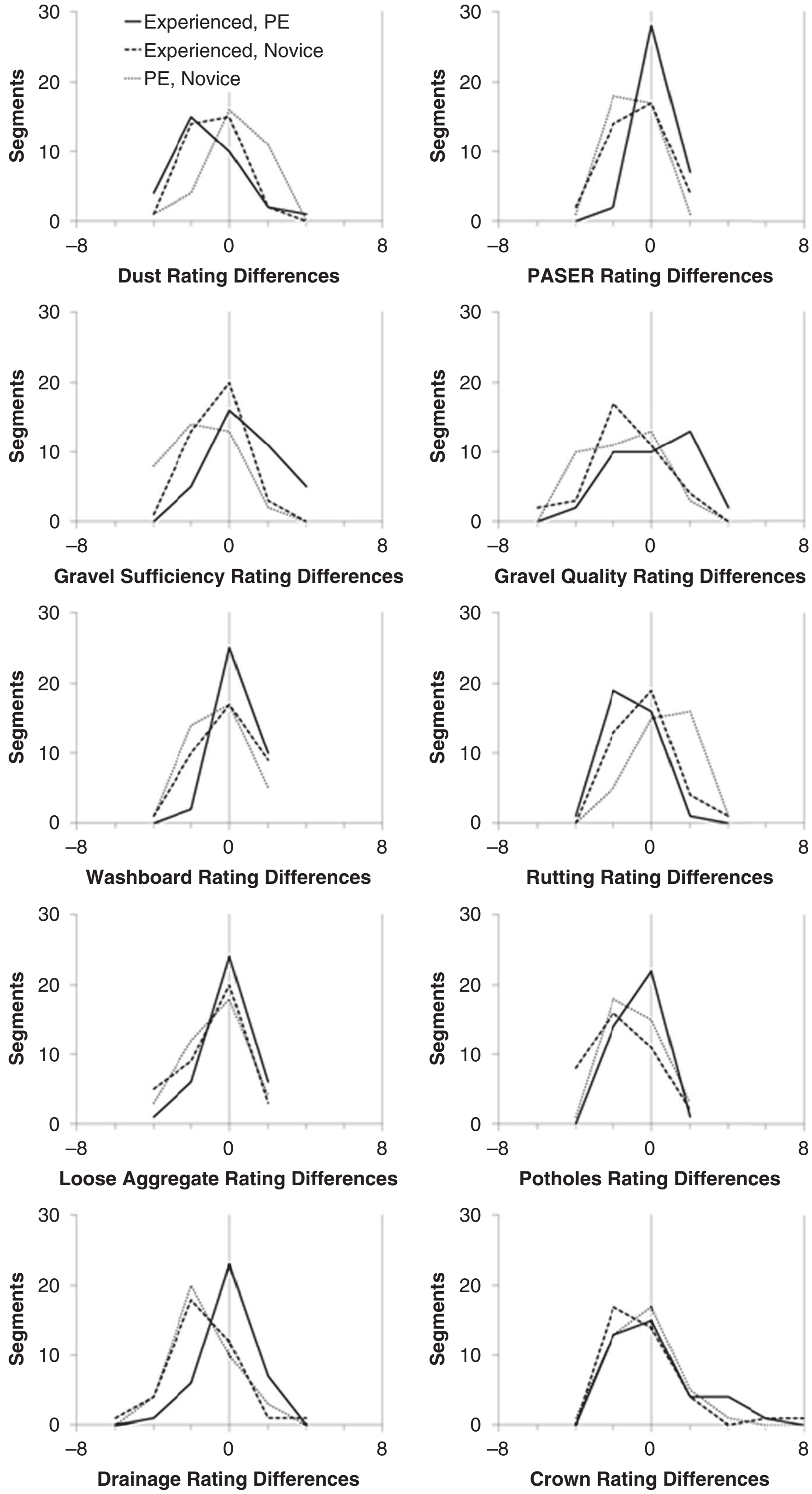

FIGURE 1 Rating differences on side-by-side ratings, June 2006.

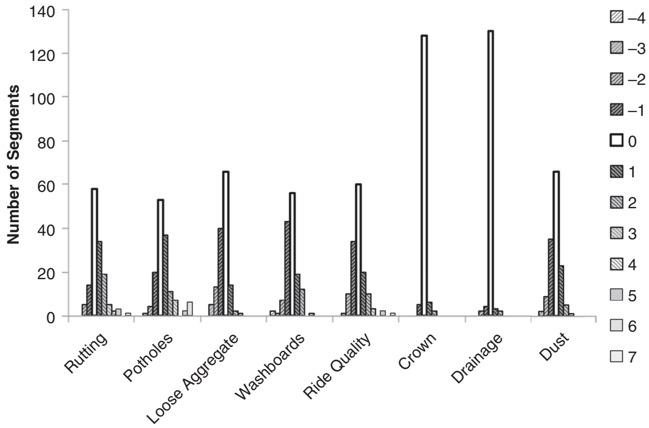

FIGURE 2 Changes in ratings from May to June (crown and drainage on a 3-point scale, dust on a 4-point scale, and others on a 9-point scale).

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