Research Article

Appraisal of Road Pavement Evaluation Methods

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Abstract

Road pavement evaluation methods are based either on simple index of a surface characteristic, such as International Roughness Index (IRI) for roughness, Rut Depth (RD) for rutting, Sideway Force Coefficient (SFC) for skid-resistance; or, otherwise, on a complex index such as Pavement Condition Index (PCI), related with an overall consideration of the surface condition. Complex indices are commonly used in the frame of Pavement Management Systems (PMS) by road authorities worldwide, in order to assess the pavement condition and to program maintenance and rehabilitation activities along with keeping their road network up to a safe level for the users. Nowadays, these complex indices are considered to be more reliable and suitable to evaluate pavement condition and prioritize future rehabilitation actions. The first-line question is: is it really so? Meaning that, are indices like Present Serviceability Index (PSI) capable of revealing the real condition without misunderstanding or hidden issues? Can they be implemented in all cases and if so, are they enough accurate to lead road authorities to a safe conclusion and subsequently to the right and effective maintenance activities without misleading and useless costs? In the frame of the present paper, some of the most commonly used evaluation methods are enlightened, so as to dig up their advantages and their deficiencies and finally to assess their degree of efficiency.

In terms of appraising pavement evaluation methods using complex indicators, the most common methods used are hereafter examined in an attempt to determine the best one for each case. Although the Australian method seems to be the most complete and reliable one, there is no absolute answer for all the cases, meaning that the best one in terms of mitigated implementation cost is suitable for cases with serious financial constraints, whilst in case of evaluations regardless of budget, the most accurate method is the appropriate one.

Keywords: Pavement, Appraisal, Evaluation, Highway management

1. Introduction and Commonly Used Indices Overview

Road pavement evaluation is continuously being improved by using increasingly complicated methods. Nowadays, complex indicators, such as PSI, PCI, etc. stand for the main tools for assessing surface condition, considered to be multilateral and more complicated methods, compared to formerly used simple indices, such as IRI, RD, etc., that deal with one and only surface characteristic for each indicator. The upgraded point of the complex indices is considered to be a multilateral approach that takes into account more than one pavement feature, in contrast to the simple indices. Thus, it is assumed that the relevant results, depict the real surface condition in a comprehensive and reliable way.

The main disadvantage of simple indicators is their function to assess one pavement feature without considering the whole picture. So, they may lead road authorities to mistaken conclusions for maintenance programming. The primary reason for these faulty conclusions is the fact that all other pavement features are not evaluated.

On the other hand, a pavement, for example, that presents an unacceptable level of skid-resistance may at the same time present a good performance in terms of rutting. If this is the case, the question raised as regards complex indicators, is whether their output enables the authorized personnel to get a reliable decision for maintenance activities programming, inasmuch, depending on the weight each feature affects the output, the complex indicator probably presents an acceptable level although one or more features are below limit values.

Pavement evaluation is conducted by measuring pavement characteristics’ indicators such as SFC, IRI, RD, in the context of a PMS. All variable methods present strong points and drawbacks at the same time, compared to each other. Usually, costly ones - in terms of financing and required time - are more precise whilst less time-consuming are proven to be implemented with less expenses, yet they are less accurate. The usual practice, especially in developing countries, stands for low-budget options and fast results.

Since 60’s, subjective evaluation of pavement condition based on engineering experts’ opinion was the common case, meaning that pavement was either satisfactory or unsatisfactory [1]. On that time, the firstly presented PSI as shown in Fig. 1, stands for the pavement condition indicator dealing with rating ride comfort on a scale from 0 (poor) to 5 (excellent) [2, 3]. Present Serviceability Rating (PSR) is another expression of PSI by using averaged rating for each road segment [2].

Other indicators for pavement performance evaluation are the Riding Comfort Index (RCI) [4], the IRI [5, 6] and the PCI [7]. Federal Highway Performance Monitoring System [8] has adopted IRI as the main indicator for evaluating road profile [9].

As it is easily perceptible, each method evaluating
pavement condition is implemented by varied equipment, sometimes, completely different from the equipment of the other methods. Thus, in order to build potential of methods’ comparability as well as for the standardization of pavement characteristics, correlation formulas have been established [10].

Fig. 1. Concept of pavement performance using Present Serviceability Index (PSI) [22]

As regards the PCI, it has been developed by the U.S. Army Corps of Engineers [11] and the relevant value is a rating based on the distress identification according to the type of pavement.

Karan et al. [12] propose the pavement quality index (PQI), by rating 40 segments for riding comfort, structural adequacy and surface distress. FHWA presented an index that incorporates various measurements of pavement status [13].

Juang and Amirkhanian [14] used the concept of fuzzy sets to propose the unified pavement distress index. Zhang et al. [15] developed a detailed pavement rating index based on fuzzy set theory, namely overall acceptance index, considering roughness, surface discomfort, structural strength and skid-resistance. Shoukry et al. [16] introduced Fuzzy Distress Index (FDI) and dependent on this, a maintenance ranking was set. On the basis of PSI and PCI, Thube et al. [17] proposed pavement distress evolution models for low-volume roads of India. Meanwhile, Gharaibeh et al. [18], found that phenomenally similar pavements may present differentiated condition indices, despite their similarities.

Fig. 2 Photographs from Asphalt PASER [19]

Pavement Surface Evaluation and Rating Manual (PASER) [19] was introduced by the University of Wisconsin-Madison. It is a rather simple manual, using a ten-grade ranking system according to the best match of inspected pavement with one of the photographs the manual provides as shown in Fig. 2.

Another evaluation method, VIZIR [20], lies on a scheme of three damage levels, where each pavement inspected can be attributed at one of them. Flexible pavements stand for the main subject of the method. The type, the severity and the extent of the damage are recorded accordingly. The survey can be conducted either manually or using the LCPC’S DESYROUTE equipment. Fig. 3 depicts a catalogue of distress and accordingly a method of graphical presentation as guidance for the inspector. Severity values as shown in Fig. 3, are average values suitable for many roads.

Table 1: Level of severity of type A damage

Table 2: Level of severity of type B damage

Australian authority “Austroads” provide the Australian Pavement Evaluation manual in parallel with Part 5 of Austroads Guide to Pavement Technology: Pavement Evaluation and Treatment Design (AGTPT Part 5) [21]. The inspector must refer to the visual assessment sections in both manuals. Pavement evaluation process is illustrated on Fig. 4.

2. Pavement Evaluation Framework

When appraising various evaluation methods, the most important factors considered are reliability and effectiveness, because whether the method does not work properly and adequately, then there is no meaning in implementing. Also, different methods treat for different hazards, and it is helpful to know what each method will be treating for. The next important factors stand for simplicity, scope, integration in PMS, and apply cost. Thus, the appraisal of the most common evaluation methods concludes to fruitful and comprehensive ascertainties, laid on widely accepted factors, avoiding at the same time, costly solutions. In this context, applicability, algorithm, recording process and results of each method, need
to be thoroughly assessed. Additionally, the pavement type along with the road category are potentially prohibitive factors, that subsequently exclude pavement evaluation methods that are not suitable for such cases, as shown in Tab. 1. The flow diagram of Fig. 5 presents the evaluation framework proposed.

![Flow diagram of pavement evaluation methods](image)

**Fig. 5. Flow diagram for pavement evaluation methods appraisal**

### Table 1. Suitable method(s) according to pavement type and road category

| Pavement type | PS I | PCI | PASE R | VIZI R | AUSTRALIAN |
|---------------|------|-----|--------|--------|------------|
| Flexible      | √    | √   | √      | √      | √          |
| Rigid         | √    | √   | √      | -      | -          |
| Composite     | √    | √   | √      | -      | -          |
| Gravel        | -    | -   | -      | -      | -          |
| Road category | All  | All | All    | All    | All        |

3. Appraisal of Evaluation Methods

Appraising evaluation methods by comparative analysis is undoubtedly a difficult task. Though, there are certain distinct differences that enlighten advances and drawbacks for each one as compared with the others. Such a differentiation lies on the pavement type each method is suitable for evaluating, meaning that whilst all methods are competent for flexible pavements, gravel pavements cannot be evaluated by any method except PCI. Apart from the above, the road category to be examined is undoubtedly a decisive criterion as well, as shown in Tab. 1.

Considering necessary equipment and staff training requirements, PASER is the less demanding method, for as much as visually surface rating stands for the cornerstone of the evaluation procedure. On the other hand, the Australian method requires the most complex equipment to complete the survey, including ground penetrating radar (GPR), NAASRA roughness meter and other special machinery, which may not be the common case for a road authority. At the same time, the Australian method demands highly trained and specialized personnel in order to be implemented. VIZIR stands for the second in raw, with basic equipment requirements and elemental staff training. The next one is PSI, requiring a more advanced, but not sophisticated training level. As for PCI, the main drawback is installing the expensive device to measure IRI.

![Flow diagram of pavement evaluation methods selection](image)

**Fig. 6. Flow diagram for pavement evaluation methods selection**

As regards the characteristics of the algorithm each method is based on, the Australian one appears to be the most complete as it performs a holistic approach by using a data map of several measured and observed pavement features and materials.

Given the above, Tab. 2 contains succinct remarks for main features appraised for each pavement evaluation method and Tab. 3 shows appraisal outcomes for several crucial criteria, namely applicability, algorithm, impact level, recording, results and measurements repetition.

Fig. 6 provides a representation of the types of evaluation methods available to the agencies and the related simplicity and resources required to collect the necessary information according to evaluation outcomes from Tab. 2 and Tab. 3.
Table 2. General appraisal of pavement evaluation methods

| Features                      | PSI                  | PCI                  | PASER               | VIZIR                | AUSTRALIAN                      |
|-------------------------------|----------------------|----------------------|---------------------|----------------------|---------------------------------|
| Advantages                    | No panel required    | Accuracy             | Easy implementation, costless | Easy implementation | Accuracy, predicted future conditions evaluated |
| Deficiencies                  | Limited distress types | Panel developed, subjective | Subjective | Limited distress types | Special equipment needed |
| Completeness                  | Moderate             | High                 | Moderate             | Moderate             | Highest                          |
| Reliability                   | Statistical estimate of the mean of the PSR | According to panel experts | Low due to visual objective rating | Due to evaluation of limited distress types | Fairly with certain flaws due to demanding resources |
| Simplicity                    | Fairly               | Fairly               | Highest              | Yes                  | No                              |
| Scope (application field)     | Pavement performance evolution | Maintenance priorities | Maintenance objectives | Maintenance objectives | PMS asset |
| Integration in PMS            | √                    | √                    | √                   | √                   | √                               |
| Cost                           | Moderate             | High                 | Extremely low        | Moderate             | Highest                          |

Table 3. Appraisal of pavement evaluation methods in terms of certain characteristics

| Criteria                          | PSI                  | PCI                  | PASER               | VIZIR                | AUSTRALIAN                      |
|-----------------------------------|----------------------|----------------------|---------------------|----------------------|---------------------------------|
| Applicability                     |                      |                      |                     |                      |                                 |
| Pavement type                     | Flexible, rigid, composite | Flexible, rigid, composite, gravel | Flexible, rigid, composite | Flexible, rigid, composite | Flexible, rigid |
| Road category                     | All                  | Freeway, arterial, collector, local | County, rural, urban | All                  | All |
| Equipment complexity              | Low                  | Moderate             | Minimum             | Minimum             | Maximum                         |
| Staff training requirements       | Moderate             | Minimum              | Maximum             |                      |                                 |
| Algorithm                         |                      |                      |                     |                      |                                 |
| Degree of completeness            | Limited distress types | Surface conditions only | Surface conditions only | Surface conditions, traffic | Data map (holistic approach) |
| Blind areas                       | Underlying problems  | Underlying problems  | Underlying problems | Fairly no            |                                 |
| Too explicit                      | No                   | No                   | Mainly subjective   | Yes                 | Mainly objective |
| Objective measurements (O) vs subjective personal assessments (S) | No Minor/major | No | Mainly subjective |                      |                                 |
| Impact level                      | Worldwide            | USA                  | Wisconsin, Michigan | Worldwide            | Australia mainly |
| Recording                         |                      |                      |                     |                      |                                 |
| Segmentation                      | Non available        | Unclear              | √                   | √                   | Determined by condition data (e.g. by using deflection results), 100 m for rutting |
| Representative segments           | 5,000 square feet    | ½ mile – 1 mile for rural, 1-4 blocks for urban | 500 m for damage index in PMS |                     |                                 |
| Results                           |                      |                      |                     |                      |                                 |
| Concluding scheme                 | Pavement surface condition rating | PCI decision matrix | Pavement surface condition rating | Pavement quality rating | Selection of alternative rehabilitation options |
| Next step                         | No suggestions       | Maintenance activity | Safety, future traffic | General maintenance | Explicit maintenance |

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Moreover, to conclude to the best pavement evaluation method, the analytical hierarchy process (AHP) technique [23] is followed hereafter. The evaluation criteria used are: a) cost, b) completeness, c) reliability and d) simplicity. The AHP hierarchy for this decision is shown in Fig. 7. The priorities are derived from a series of pairwise comparisons involving all the nodes, meaning each box in the hierarchy diagram. The nodes at each level will be compared, two by two, with respect to their contribution to the nodes above them. The results of these comparisons will be entered into a matrix which is processed mathematically to derive the priorities for all the nodes on the level, according to the methodology of the AHP technique [24]. The AHP fundamental scale in assigning the weights is shown in Tab. 4. The appraisal is conducted considering evaluation outcomes from Tab. 2 and Tab. 3, and begins by comparing the alternative evaluation methods with respect to their strengths in meeting each of the appraisal criteria, namely cost, completeness, reliability and simplicity, as shown in Tab. 5. In sequence, comparison of the criteria with respect to their importance to reaching the goal, meaning the best alternative, takes place as shown in Tab. 6. The calculations for the alternative pavement evaluation methods with respect to the criteria set, concluding to attributed weights to each criterion, are shown in Tab. 7.

![Fig. 6. Required resources and simplicity of pavement evaluation methods](image)

**Fig. 6.** Required resources and simplicity of pavement evaluation methods

| Hierarchization or recommended actions | Not strictly defined | Yes | Not strictly defined | Not strictly defined | Not strictly defined |
|---------------------------------------|----------------------|-----|----------------------|----------------------|----------------------|
| Correlation with the previous measurement | No | Yes (annual database) | No | No | Yes (historical data) |
| Measurements repetition | Not strictly defined | Annually | Not strictly defined | Not strictly defined | Annually |

| Table 5. Pairwise comparison matrix for appraisal criteria |
|----------------------------------------------------------|
| Cost | AUSTRALIAN | PASER | PCI | PSI | VIZIR | Priority |
| AUSTRALIAN | 1 | 1/9 | 1/3 | 1/5 | 1/7 | 0.033 |
| PASER | 9 | 1 | 1 | 7 | 5 | 3 | 0.513 |
| PCI | 3 | 1/7 | 1 | 1/3 | 1/5 | 0.063 |
| PSI | 5 | 1/5 | 3 | 1 | 1/3 | 0.129 |
| VIZIR | 7 | 1/3 | 5 | 3 | 1 | 0.262 |

| Table 6. | AUSTRALIAN | PASER | PCI | PSI | VIZIR | Priority |
|----------------------------------------------------------|
| Cost | AUSTRALIAN | PASER | PCI | PSI | VIZIR | Priority |
| AUSTRALIAN | 1 | 5 | 3 | 5 | 5 | 0.501 |

| Intensity of Importance | Definition | Explanation |
|-------------------------|------------|-------------|
| 1 | Equal importance | Two elements contribute equally to the objective |
| 3 | Moderate importance | Experience and judgment moderately favor one element over another |
| 5 | Strong importance | Experience and judgment strongly favor one element over another |
| 7 | Very strong importance | One element is favored very strongly over another, its dominance is demonstrated in practice |
| 9 | Extreme importance | The evidence favoring one element over another is of the highest possible order of affirmation |

*Intermediate values to reflect compromises: 2, 4, 6, 8
**Values for inverse comparison: 1/3, 1/5, 1/7, 1/9
Table 6. Pairwise comparison matrix with respect to reaching the goal

| Criteria       | Cost    | Completeness | Reliability | Simplicity | Priority |
|----------------|---------|--------------|-------------|------------|----------|
| AUSTRALIAN     | 1/5     | 1/5          | 1/5         | 1/5        | 0.088    |
| PASER          | 1/3     | 1/3          | 1/3         | 1/3        | 0.236    |
| PSI            | 1/5     | 1/5          | 1/5         | 1/5        | 0.088    |
| VIZIR          | 1/5     | 1/5          | 1/5         | 1/5        | 0.088    |
| AUSTRALIAN     | 1/9     | 1/5          | 1/5         | 1/5        | 0.575    |
| PASER          | 1/5     | 1/5          | 1/5         | 1/5        | 0.036    |
| PCI            | 1/5     | 1/5          | 1/5         | 1/5        | 0.159    |
| PSI            | 1/5     | 1/5          | 1/5         | 1/5        | 0.071    |
| VIZIR          | 1/5     | 1/5          | 1/5         | 1/5        | 0.159    |

Table 7. Weights of criteria according to pavement evaluation method used

| Criteria       | Pavement evaluation method | Cost    | Completeness | Reliability | Simplicity | Priority |
|----------------|---------------------------|---------|--------------|-------------|------------|----------|
| AUSTRALIAN     | 0.033                     | 0.513   | 0.063        | 0.129       | 0.262      | 0.001518 |
| PASER          | 0.063                     | 0.033   | 0.088        | 0.019       | 0.088      | 0.0023598|
| PCI            | 0.063                     | 0.033   | 0.088        | 0.019       | 0.088      | 0.0023598|
| PSI            | 0.063                     | 0.033   | 0.088        | 0.019       | 0.088      | 0.0023598|
| VIZIR          | 0.063                     | 0.033   | 0.088        | 0.019       | 0.088      | 0.0023598|

* Column A shows the priority of this alternative with respect to each criterion. Column B shows the priority of each criterion with respect to the goal. Column C shows the product of the two, which is the global priority of each alternative with respect to the goal.

Finally, overall priorities/weights for the pavement evaluation methods are shown in Tab. 8.

Table 8. Overall weights of pavement evaluation methods (no budget constraints)

| Evaluation method | Cost    | Completeness | Reliability | Simplicity | Goal     |
|-------------------|---------|--------------|-------------|------------|----------|
| AUSTRALIAN        | 0.001518| 0.101703     | 0.377775    | 0.003008   | 0.484004 |
| PASER             | 0.023598| 0.017864     | 0.023652    | 0.047376   | 0.11249  |
| PCI               | 0.002898| 0.047908     | 0.104463    | 0.046647   | 0.165421 |
| PSI               | 0.005934| 0.046647     | 0.010152    | 0.023312   | 0.080597 |
| VIZIR             | 0.012052| 0.017864     | 0.104463    | 0.023312   | 0.157691 |
| Totals:           | 0.046   | 0.203        | 0.657       | 0.094      | 1        |

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Based on the choice of decision criteria, on assigned experts’ judgments about the relative importance of each, and on their judgments about each pavement evaluation method with respect to each of the criteria, Australian method, with a priority of 0.484, is the most suitable. PCI and VIZIR, with a priority of 0.165 and 0.158 accordingly, are a step below, and PASER, PCI complete the appraisal list.

It is strongly noted that the relative importance of each criterion, as well as the judgment about each pavement evaluation method with respect to each of the criteria, should be set by specialized engineering personnel considering each case’s special features along with available budget and other potential constraints. In case there is need for specific findings to be extracted from the implementation of pavement priority of 0.242, indicating strong features reflected to the evaluation criteria, and the other ones follow in sequence.

Table 9 Overall weights of pavement evaluation methods (very strict budget constraints)

| Evaluation method | Cost | Completeness | Reliability | Simplicity | Goal |
|-------------------|------|--------------|-------------|------------|------|
| AUSTRALIAN        | 0.018414 | 0.047595 | 0.174225 | 0.001376 | 0.24161 |
| PASER             | 0.286254 | 0.00836 | 0.010908 | 0.021672 | 0.327194 |
| PCI               | 0.035154 | 0.02242 | 0.048177 | 0.004644 | 0.110395 |
| PSI               | 0.071982 | 0.00836 | 0.021513 | 0.004644 | 0.106499 |
| VIZIR             | 0.146196 | 0.00836 | 0.048177 | 0.010664 | 0.213397 |
| Totals:           | 0.558 | 0.095 | 0.303 | 0.043 | 1 |

4. Conclusions

As it easily perceptible from the previous analysis, considering no budget limitations, the most preferable method is the Australian, due to its strong reliability and completeness. On the other hand, whether resources constraints show up, the most suitable is the PASER method.

The usual practice followed by road authorities, that stands for implementing the same pavement evaluation method over the years, ignoring any flaws or lack of resources, may very likely lead to false output due to insufficient implementation issues as regards the evaluation procedure. For example, the Australian evaluation method can not deliver concise and safe results whether the staff has not been trained adequately, due to lack of relative resources.

The aim of this appraisal stands for pointing out the holistic frame that available methods should be evaluated into and is meant to be a comprehensive tool for road experts, to complete the task of pavement assessment whilst, in parallel, take into account the available resources.

To sum up, all methods show up advantages and handicaps, depended on required results and budget limitations. In order to select safely the most suitable method for pavement evaluation, the authorized staff has to carefully weigh the aforementioned parameters that take place in each case examined.

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Appendix

Fig. A. IRI roughness scale for evaluation

Fig. B. Individual PSR evaluation form

Fig. C. Example of a defect mapping sheet for a flexible pavement, from Austroads Guide to Pavement Technology: Pavement Evaluation and Treatment Design (AGTPT Part 5)

Fig. D. PASER rating system for evaluation

Fig. E. PCI flexible pavement condition survey data sheet