PAVEMENT CONDITION DESCRIPTION USING A DEDUCT POINT APPROACH

GD VAN ZYL and A VAN DER GRYP*

Mycube Asset Management Systems, PO Box 6937, Welgemoed, 7530
Tel: +2783 656-7187; E-mail: gerriev@mycube.co.za
*Department of Transport and Public Works, Western Cape Government, P.O. Box 2603, Cape Town, 8000
Tel: +2721 483-2222; E-mail: andre.vandergryp@westerncape.gov.za

ABSTRACT

The method to describe pavement condition, as documented in the existing TRH22 document, has specific shortcomings when several defects of slight degree, or when only major defects e.g. potholes exist on a road segment.
Following the testing of several alternative techniques, a deduct-point method was implemented and calibrated to calculate different condition and need indices in the Pavement Management System of the Western Cape Provincial Government.
This paper describes the background to the deduct-point approach, the processes followed to determine appropriate deduct values for any combination of defect degree and extent, as well as the aggregation of individual deduct values to describe, for example a pavement condition and a reseal need index.

1 INTRODUCTION

Pavement Management Systems (PMS) and Unsealed/Gravel Road Management Systems (GRMS), to a large extent, rely on the regular visual assessment of road segments for strategic and tactical planning purposes. The recommended assessment methodologies are well described in TMH9 (DOT, 1992) and TMH12 (DOT, 2000).

The purpose of the mentioned management systems is, amongst others, to:

- Determine the optimum unconstrained funding requirement
- Optimise the allocation of available funds
- Describe the current condition of each road and the road network
- Monitor the change in condition over time
- Identify and prioritise maintenance and remedial measures

The recommended method describing the condition of flexible pavements, as documented in TRH22 (DOT,1994), provided acceptable results up to a point in time, when road networks started to deteriorate rapidly as a result of insufficient maintenance.

The purpose of the paper is to summarise some of the shortcomings of the TRH22 models and to describe an alternative approach, namely the Deduct Point Approach, to quantify a road condition or to develop a need index e.g. Reseal Need Index, which could assist in the prioritisation of scheduled maintenance projects at the tactical network level.

The concept of using deduct values is not new and has been used world-wide for condition description and performance modelling (Shahin, 2005). However, the detail of application differs dramatically.

Confidence gained through application of a particular methodology, as described in this paper, the ease of adjustment and the simplicity to follow the logic for training purposes resulted in the decision to implement the approach in the PMS and GRMS of Western Cape Provincial Government.

2 CONDITION DESCRIPTION AND NEED INDICES

The description of road condition in simple categories provides an excellent way to communicate information to non-technical people involved with the management and/or funding of road networks. Applying standard procedures of description each year further highlights the trend of deterioration or improvement as shown in Figure 1 and Figure 2.

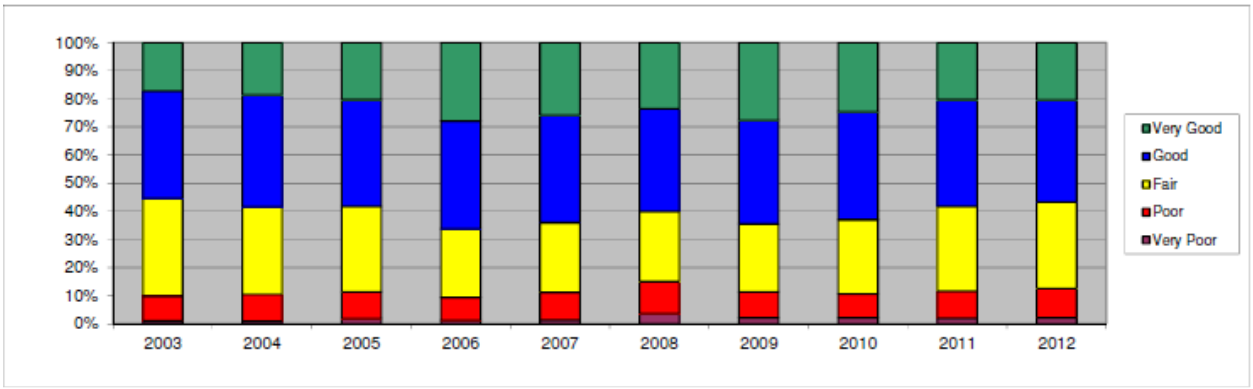

Figure 1 Condition of surfaced roads in the Western Cape

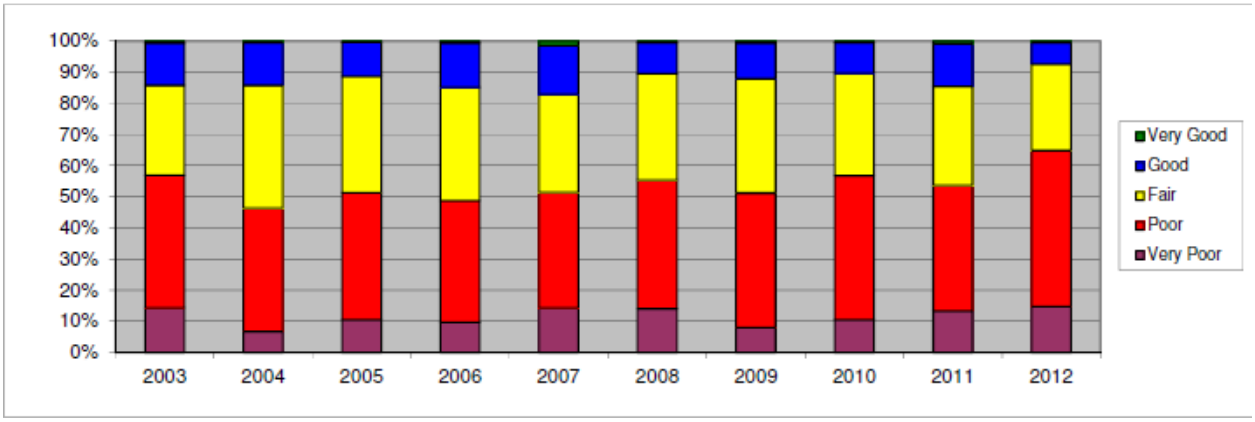

Figure 2 Condition of the unsealed roads in the Western Cape

Calculating need indices e.g. Reseal Need Index provides excellent input in the preliminary prioritisation of reseal projects at the tactical level.

3 SHORTCOMINGGS OF CURRENT TRH22 CONDITION INDEX CALCULATIONS

The Visual Condition Index (VCI) determination, as described in TRH22 (DOT, 1994), is based on principles applied in the former Transvaal Roads Department and Western Cape Provincial Government and further adjusted by the committee responsible for the compilation of the guideline document.

The contribution of each defect is determined by the Degree and Extent of each defect and a weight factor, defining the importance of the specific defect. The results obtained were considered acceptable for the road networks at that particular stage (road networks being reasonably well maintained). However, implementing Pavement Management Systems for numerous local road authorities since 1994 and critically evaluating the results highlighted specific shortcomings of the TRH22 models e.g.:

- The occurrence of many defects of lessor importance e.g. high degree but isolated and/or smaller degree and of larger extent, often result in a VCI of less than 50, indicating a "Poor" condition.
  Note: Incorporation of a "Small degree factor", as described in TRH22, does not improve the VCI value sufficiently

- The occurrence of single serious defects of high degree and large extent resulting in a VCI of more than 50, indicating still a "Fair" condition. A typical example found on several occasions was significant potholes/failures over a reasonable extent e.g. Degree 5, Extent 3, resulting in a "Fair" description.
  In these cases no other defects could be recorded

4 SELECTION OF AN ALTERNATIVE CONDITION DESCRIPTION METHOD

Different alternatives investigated to describe a general Visual Condition Index and a Reseal need Index included Fuzzy Logic, Artificial Neural Network and Deduct Point approaches. Although good results could be obtained through the first two mentioned approaches, the ability to easily pinpoint on site which defect/s should contribute the most to a particular index, ease in making adjustments, and transparency of logic for training purposes forced the decision towards the Deduct Point approach.

5 DEDUCT POINT APPROACH

5.1 Principles

For purposes of standardisation in South Africa all index values are:

- Presented on a percentage basis, therefore between 0 and 100
- 50% defines the cut-off value between acceptable and not-acceptable or between "warning/ Fair" and "Poor"
- In order to display information in five categories, the following ranges are typically used namely
  - 85 – 100 (Very Good)
  - 70 – 85 (Good)
  - 50 – 70 (Warning/ Fair)
  - 30 – 50 (Poor)
  - 0 – 30 (very Poor)
- Even if only one defect is visible and serious enough to define an unacceptable condition, the resultant condition index should be less than 50%
- A panel of experienced practitioners is used throughout the process

- Each defect, according to the standard guidelines for visual assessment in South Africa, is described in terms of a Degree and an Extent, or in some cases, just as a general degree over the assessment segment
- The Degree and Extent are typically rated on a scale of 1 to 5 (zero noted when the defect does not occur)

5.2 Process

5.2.1 Categorisation

For each index required (e.g. VCI, RNI), a matrix is drawn up defining each possible "Degree" and "Extent "combination.
Using an "Expert" panel, areas are defined within the matrix highlighting different condition categories/ need categories

Example (Table 1):

- For describing the general VCI, a situation where Degree 5 crocodile cracking occurs over an Extent 4 or Extent 5 defines in itself a "Very Poor" general condition.
- A situation where only Degree 2 crocodile cracking occurs isolated (Extent 1) still defines a "Very Good" condition.

Table 1 Categorisation

	Cracks-crocodile				
	Few		<-- Extent -->		Many
Degree	1	2	3	4	5
1	VG	VG	G	G	G
2	VG	G	G	F	F
3	G	F	F	P	P
4	G	F	P	P	VP
5	G	P	P	VP	VP

5.2.2 Assigning deduct values

Based on the ranges per category defined in Section 5.1 and shown in Table 2, a "Deduct value" is assigned to each Degree/Extent combination to represent the condition category (See Table 3).

Table 2 Deduct Point range per category

Condition category	Minimum	Maximum
VG	0	14
G	15	29
F	30	49
P	50	69
VP	70	99

Table 3 Assigned Deduct Points

	Cracks-crocodile				
	Few		<-- Extent -->		Many
Degree	1	2	3	4	5
1	4	10	16	21	27
2	12	21	27	35	42
3	16	33	42	50	58
4	21	45	55	63	70
5	25	50	62	70	75

A graphical display of the assigned “Deduct Points” (Refer Figure 3) assists in minimising errors.

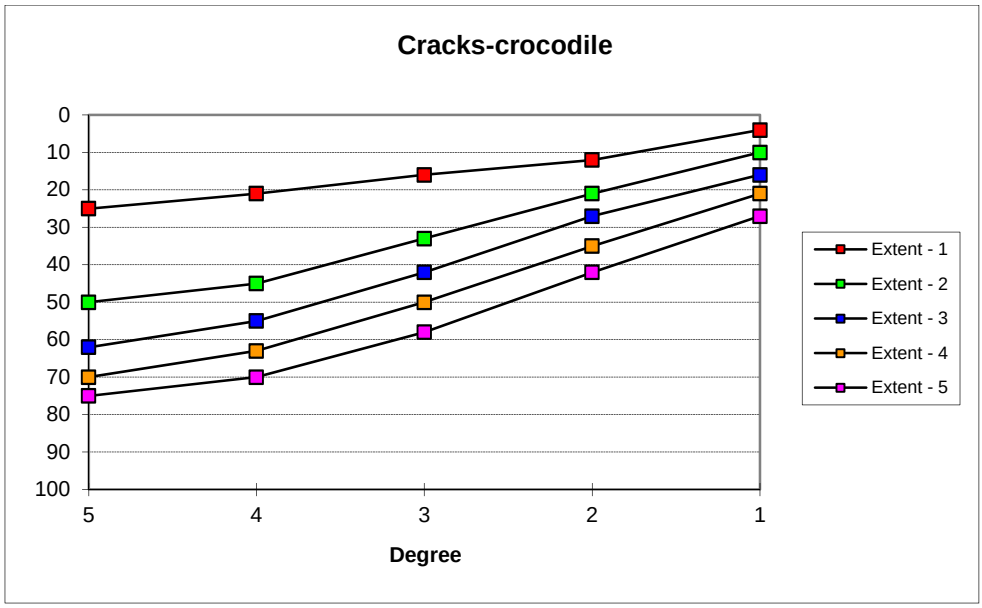

Figure 3 Graphical display of deduct values

Note:

The contribution of a defect to a particular index could be different to the contribution of the same defect to another index. For example the occurrence of structural potholes does not contribute to the Reseal Need Index, but has a major contribution to the pavement condition (VCI).

5.2.3 Comparing scenarios

Following the assignment of deduct values to all Degree/Extent combinations, the defect combinations are ranked according to the assigned deduct values, as shown in Table 4.

Table 4 Defect combinations ranked for comparison

Potholes (Degree 5/ Extent 5)	90
Potholes (Degree 5/ Extent 4)	83
Cracks-crocodile (Degree 5/ Extent 5)	75
Undulations (Degree 5/ Extent 5)	75
Potholes (Degree 5/Extent 3)	75
Potholes (Degree 4/ Extent 5)	72
Cracks-crocodile (Degree 4/ Extent 5)	70
Rutting (Degree 5/ Extent 5)	70
Undulations (Degree 5/ Extent 4)	70
Riding Quality (Degree 5/ Extent 4)	70
Cracks-crocodile (Degree 5/ Extent 4)	70
Potholes (Degree 3/Extent 5)	69
Potholes (Degree 4/ Extent 4)	65
Surfacing Failures/Patching (Degree 5/ Extent 5)	65
Undulations (Degree 5/ Extent 3)	65
Cracks-crocodile (Degree 4/ Extent 4)	63
Cracks-crocodile (Degree 5/ Extent 3)	62
Rutting (Degree 5/ Extent 4)	61
Surfacing Failures/Patching (Degree 4/ Extent 5)	60
Surfacing Failures/Patching (Degree 5/ Extent 4)	60
Rutting (Degree 4/ Extent 5)	60
Potholes (Degree 3/ Extent 4)	60
Undulations (Degree 4/ Extent 5)	60
Potholes (Degree 4/ Extent 3)	58
Cracks-crocodile (Degree 3/ Extent 5)	58
Potholes (Degree 5/ Extent 2)	56
Patching (Degree 5/ Extent 5)	55
Cracks-Block medium spacing (Degree 5/ Extent 5)	55
Surfacing Failures/Patching (Degree 3/ Extent 5)	55
Surfacing Failures/Patching (Degree 4/ Extent 4)	55

Note: It is essential to continuously refer to the exact descriptions of “Degree” and “Extent” for each defect, as described in the assessment guidelines.

Using the opinions of the “Expert panel”, the deduct value of each defect Degree/Extent combination is compared to the deduct value of the Degree/Extent combination for other defects above and below. If for example, the general opinion is held that a particular defect combination deduct value is too conservative, it is moved down the ranking to where it should fit and a revised “Deduct point” assigned to the combination. The relevant matrix for this particular defect (refer Table 3) is then adjusted and all the Defect combinations’ deduct points re-ranked.
The process continues until the panel is confident that the ranking represents the correct contribution to the specific condition/need index.

5.2.4 Aggregation

The need for a particular remedial action or to describe a condition, mostly depends on more than one defect. Therefore, the need exists to aggregate the contribution of different defects to a "Total Deduct Point" (Maximum 100).

Experience in evaluating feedback from practitioners and panel inspections on site, indicates that:

- The need for a particular action/or to describe a condition, seldom incorporates more than 3 defects. However, provision is currently made to incorporate 6 defects
- The contribution of the primary defect i.e. highest deduct point ($DP1_{Prim}$) should be taken as the full value
- The contribution of the secondary defect ($DP2_{Sec}$)should be in the order of 20% to 30% of the assigned deduct value
- The contribution of the tertiary defect ($DP3_{Tert}$) should be in the order of 10% of its deduct value
- Contribution of additional defects should not be more than 5%

The Total Deduct Point (TDP) is then typically defined as:

$TDP = (a)*DP1_{Prim} + (b)*DP2_{Sec}+(c)* DP3_{Tert}+(d)*DP4_{other}+(d)*DP5_{other}+(d)*DP6_{other}$

where:

(a) = 1
(b) = 0.2
(c) = 0.1
(d) = 0.05

5.2.5 Additional rule-sets

Dependent on the purpose (Index/need type), and condition of the road, it might be necessary to incorporate additional rule sets e.g.:

- Limiting the TDP to 100 in order not to obtain negative values
- Specifying that certain defects cannot act as Primary defects. Pumping of fines is one such an example

5.2.6 Initial field verification and adjustment

The following process was applied for both sealed and unsealed roads in the Western Cape:

- Selection of 100 road segments ranging from "Very Good" to "Very Poor"
- Using 3 experienced assessors to assess each segment individually
- Comparing the three sets of assessments
- On segments with poor comparison, reassessment by all three assessors as a team
- Panel inspection using practitioners, experienced with road rehabilitation and maintenance, categorising each segment in a condition/need category and estimating a final condition/need index value
    - Defining at least the Primary and Secondary defects
- Calculating the condition/need indices per road segment, using the "consensus" degree and extent ratings from the experienced assessors
    - Obtaining the deduct value per assessed defect (as shown in Table 5)
    - Sorting the defects according to descending deduct values
    - Calculating the contribution of each defect, the total deduct point and then the relevant condition/need index

- Comparing results with the “panel” decisions (refer Table 6)
- Pinpointing reasons for differences (Assessments, panel decision, deduct points, aggregation)
- Adjustment to deduct point and aggregation formulae where necessary

Table 5 Distress ratings and deduct values for a specific road section

DEFECT	Degree	Extent	Deduct value
SURFACING: FAILURE/PATCHING	5	1	20
SURFACING CRACKS	0	0	0
AGGREGATE LOSS	3	2	15
BINDER CONDITION	3	5	24
BLEEDING/FLUSHING	3	3	18
BLOCK/STAB. CRACKS	0	0	0
LONGITUDINAL/SLIP CRACKS	3	2	18
TRANSVERSE CRACKS	3	2	18
CROCODILE CRACKS	4	4	63
PUMPING	3	4	32
RUTTING	4	3	41
UNDULATION/SETTLEMENT	2	1	0
PATCHING	3	3	28
STRUCTURAL:FAILURE/POTHOLES	5	1	38
RIDING QUALITY	2	4	36
SKID RESISTANCE	2	4	16
SURFACE DRAINAGE	4	4	0
UNPAVED SHOULDERS	0	4	0
EDGE BREAKING	5	1	18

Table 6 Calculating VCI and comparison with panel rating

Road 1			Sorted		VCI
DEFECT	Degree	Extent	Deduct value		Index contribution
CROCODILE CRACKS	4	4	63		63
RUTTING	4	3	41		8.2
STRUCTURAL:FAILURE/POTHOLES	5	1	38		3.8
RIDING QUALITY	2	4	36		1.8
PUMPING	3	4	32		1.6
PATCHING	3	3	28		1.4
BINDER CONDITION	3	5	24		0
SURFACING: FAILURE/PATCHING	5	1	20		0
BLEEDING/FLUSHING	3	3	18		0
LONGITUDINAL/SLIP CRACKS	3	2	18		0
TRANSVERSE CRACKS	3	2	18		0
EDGE BREAKING	5	1	18		0
SKID RESISTANCE	2	4	16		0
AGGREGATE LOSS	3	2	15		0
SURFACING CRACKS	0	0	0		0
BLOCK/STAB. CRACKS	0	0	0		0
UNDULATION/SETTLEMENT	2	1	0		0
SURFACE DRAINAGE	4	4	0		0
UNPAVED SHOULDERS	0	4	0		0

Calculated	TDP	79.8
	VCI	20.2
	Condition	**Very Poor**

Panel Rating	Estimated VCI	25
	Condition rating	**Very Poor**

5.2.7 Comparison between TRH22 and Deduct point results

In general, when several defects are present over a large extent, the “Deduct VCI” and the “THR22 VCI” give similar results. However, for particular situations, as highlighted in Table 7, the “Deduct VCI” provides much better results, matching the “Expert Panel” opinion in all cases.

Table 7 Comparison between VCI results (Deduct Point versus TRH22)

DEFECT	RATING (Degree/Extent)	METHOD	VCI	CONDITION (Calculated)	CONDITION (Expert Opinion)
Potholes only	5/5	Deduct	9	Very Poor	Very Poor
		TRH 22	53	Fair	
Crocodile cracks only	5/5	Deduct	24	Very Poor	Very Poor
		TRH 22	64	Fair	
Rutting only	5/5	Deduct	29	Very Poor	Very Poor
		TRH 22	68	Fair	
All defects	1/2	Deduct	76	Good	Good
		TRH 22	64	Fair	
All defects	2/2	Deduct	55	Fair	Fair
		TRH 22	44	Poor	
All defects	2/1	Deduct	57	Fair	Fair
		TRH 22	58	Fair	

5.2.8 Continuous verification

The Pavement management System and Gravel Road Management System of the Western Cape Provincial Government provide, at the tactical level:

- Appropriate remedial actions categorised in terms of rehabilitation, upgrading, reseal and regravel
- Provisional priorities

Condition and need indices for both the surfaced and gravel roads are calculated using the calibrated deduct point system as discussed in the previous section.

Potential projects are inspected and verified or adjusted by a panel consisting of:

- Road Management System representative
- Materials Engineer or his representative
- District Roads Engineer
- Chief of Roads of the District Municipal Council
- Representative/s of the community

Confirmed rehabilitation and upgrading projects are referred for “detailed investigation and design” whereas scheduled maintenance projects i.e. reseal and regravel projects are reprioritised, if necessary, and scheduled for action according to the available funds.

Final priorities are annually compared with provisional priorities as calculated from the different indices. Although some changes to the appropriate remedial action and priorities are related to information not contained within the Road Management Systems, critical evaluation of the initial recommendations (based on calculated index values) is necessary to refine the models.

6 CONCLUSIONS

Condition indices calculated according to TRH22 (DOT, 1994) provided unsatisfactory results on several roads, resulting in an investigation into alternative calculation methods, and eventually in selecting the “Deduct Point” approach for this purpose.

The methodology is easy to understand, allows quick adjustments, provides transparency of logic for training purposes and above all, provides very good results.

The paper describes the systematic process and methodology for using the Deduct-Point approach within the PMS and URMS of the Western Cape Provincial Government, which could be of value to other road authorities.

7 REFERENCES

1. DEPARTMENT OF TRANSPORT (DOT), 1992, Pavement management systems: standard visual assessment manual for flexible pavements (TMH 9), Department of Transport, Pretoria.
2. DEPARTMENT OF TRANSPORT (DOT), 2000, Flexible pavement rehabilitation investigation and design (Draft TMH 12), Department of Transport, Pretoria.
3. DEPARTMENT OF TRANSPORT (DOT), 1994, Pavement Management Systems (TRH 22), Department of Transport, Pretoria.
4. SHAHIN, M.Y., 2005, Pavement management for airports, roads and parking lots, Second edition, Springer Science + Business Media, New York.