LIFE CYCLE COST ANALYSES –AN INTEGRAL PART OF PAVEMENT REHABILITATION DESIGN.

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Abstract

Over the last two decades available funds for road rehabilitation became more acute and road authorities opted more for "holding actions" instead of rehabilitation. These actions are all but impossible to analyse using conventional design methods. Decisions were often taken without considering the total effect and long-term implications of such actions. SABITA recognised this problem and commissioned the writing of a software package (REACT) to assist design engineers with the Life Cycle Cost Analyses of any rehabilitation or holding action, based on decision theory (Bayesian Analysis). This paper highlights the principles in the Windows based REACT software package. Special reference is given to the Decision Support System developed to assist with the determination of the probability of distress.

1. INTRODUCTION

Since the earliest publication in South Africa of the Technical Recommendations for Highways Nr12 (TRH12): "Bituminous Pavement Rehabilitation Design" published in 1983 (CASRA, 1983), a life cycle cost analysis has formed part of the Pavement Rehabilitation Design process. The Rehabilitation and Investigation and Design Process have been identified to consist of four distinctly different phases, i.e. the Initial Assessment, Detailed Assessment, Rehabilitation Design and Economic Analysis. The Economic Analysis was defined to incorporate the comparison of applicable rehabilitation options on the basis of the Present Worth of Cost (PWOC) of each option over the design period of the pavement under investigation. More than one rehabilitation option and/or strategy is usually applicable to any specific road. Hence, a final recommendation should be based on a life cycle cost comparison of appropriate options and/or strategies.

The recommended life cycle cost analysis procedure recommended in the TRH12 is based on the decision theory (Bayesian Analysis). This approach allows engineers to incorporate local knowledge and experience about the behaviour of the road structure into the analysis process. The probability of distress is determined to establish intervention times for appropriate periodic maintenance actions, such as seals, etc in order to prevent structural damage due to environmental factors (water ingress into the pavement structure). At these intervention times allowance is made to consider the effect of any number of options (e.g. different types of seals, etc) over the rest of the design period (Jordaan, 1985).

In the early 1990s available funds for road rehabilitation became more acute and more and more road authorities opted for "holding actions" instead of rehabilitation. These actions are all but impossible to analyse using conventional design methods. Consequently, these decisions were often taken without considering the total effect and long-term implications (cost as well as pavement behaviour) of such actions. SABITA recognised this problem and commissioned the writing of a software package to assist design engineers with the Life Cycle Cost Analyses of rehabilitation/holding projects, enabling the comparison of various actions and to determine future needs in terms of the time for and type of intervention actions. This software package named REACT (for: <u>RE</u>habilitation <u>ACT</u>ion) (SABITA, 1998) was introduced through two papers during CAPSA 1994 (Jordaan et al, 1994 and Olwagen et al, 1994). Unfortunately, this original programme was written in DOS and soon became obsolete.

With maintenance becoming a rarity over the last decade on many of our rural roads, the need for the Life Cycle Cost analysis of any action taken on roads became even more important. As a basic minimum, such analyses should enable any road authority to identify and plan intervention actions as early as the design phase of any action taken on a road. In this way, funds for periodic maintenance could be earmarked at appropriate times for any road in their network. This is ideally provided for through the implementation of the recommended procedure contained in the TRH12. Consequently, SABITA funded a project in 2006 to rewrite the original REACT DOS programme into a Windows environment and to make it user-friendly. It was also agreed that the programme be published as part of the new TRH12 (to be published) and that SABITA will not publish the software as a separate entity.

This paper highlights the process contained in the new REACT software package. Special reference is given to the Decision Support System built into the programme to assist with the determination of the probability of distress developing during the analysis period. The probability of distress is directly used to determine the Agency and Road User Costs of doing nothing vs any number of possible intervention actions.

2 BASIC PRINCIPLES OF CALCULATIONS

2.1 Present Worth of Cost

Money has a time-dependant value. Normally, more than one rehabilitation option and/or strategy could be applicable to any one road. To compare the costs of one option or strategy with another, these costs have to be discounted over the same time period to the same point in time, often referred to as the Base Year of Costs, and the discounted costs is referred to as the Present Worth of Costs (PWOC). Costs in time are discounted to the base year by means of a discount rate. The discount rate recommended for the analysis of long term capital projects, including road projects, is usually in the order of 8 per cent. This portrays the principle of profit made by investing the money at an effective fixed interest rate of 8 per cent (after inflation has been taken into account). The REACT package is based on the calculation of the PWOC to compare various options and/or strategies.

2.2 Probable cost

The REACT programme allows for the consideration of various possible pavement conditions which could develop after the application of a short-term rehabilitation action. The calculation of the costs of any action takes into account the probability of occurrence, after a number of years, of various possible pavement conditions, each of which may again require different rehabilitation/holding or periodic maintenance actions to repair. Hence the calculated cost will not be an indication of actual costs, but rather the probable cost of the initial action over the analysis period.

Probable cost consists of a cost resulting from the occurrence of an event and the probability that the event will occur. The basic relationship used to calculate the probability of occurrence is:

$$P_i = {}^{m_i}\!/_{n} \qquad \text{(Eq.1)}$$

where

P_i = probability of event i occurring.

m_i = number of times event i occurs.
n = number of trials or experiments.

If an action leads to only one possible end condition, the probability of occurrence of that end condition is 1 (or 100 per cent). If an action has more than one possible end condition, the sum of the probabilities of these conditions must be 1 (or 100 per cent).

When the probabilities of the occurrence of a set of conditions and the costs resulting from those conditions are known, the probable cost of the action can be calculated as follows:

$$PC = \sum_{i=1}^{n} Pi \times Costi \qquad \text{(Eq.2)}$$

where

PC = probable cost of action.
n = number of possible conditions resulting from the action.
P_i = probability of condition i occurring.
$Cost_i$ = cost resulting from condition i.

As shown, the probable cost of an action is the sum of the probable costs of all the possible conditions resulting from that action.

The concepts of present worth of cost and probable cost are combined to calculate the probable present worth of costs, by using the present worth of cost in the calculation of probable cost.

2.3 Economic costs

Economic costs as calculated in the REACT program include the following:

- Construction costs (including traffic accommodation during construction),
- Pavement maintenance costs,
- Road user costs (vehicle operating costs and time costs – calculated according to the methodologies in CB-Roads – no updating of methodologies were provided for in the rewriting of REACT)) and extra road user costs during construction,
- Residual value cost – to compare pavements with different end conditions at the end of the analysis period on an economical level, the REACT program calculates the amount of money required to rehabilitate the pavement from its expected condition to the condition of a new pavement for all possible end conditions, and
- Extraneous costs and benefits allow the user to input other costs or benefits resulting from a specific action, for example a reduction in accident costs.

3. BAYESION DECISION TREES

3.1 Methodology of decision trees

Uncertainty in the future behaviour of a pavement can be accommodated by considering the possibility of occurrence of more than one pavement end condition after a number of years. The knowledge and experience of the pavement engineer are used to:

- identify the possible pavement conditions which could occur after a number of years for the specific pavement, and
- assign probabilities of occurrence to the various possible pavement end conditions.

The possible pavement conditions are identified and their probabilities of occurrence assessed by considering all possible variables, such as the pavement situation (Jordaan, 1988), including the pavement condition, the environment, as well as the characteristics of the rehabilitation action which is being considered. Following this procedure the accuracy of any prediction will be determined by the extent of the knowledge and experience of the engineer.

The procedure for the incorporation of uncertainty and the knowledge and experience of the engineer in the assessment of pavement condition is illustrated in Figure 1.

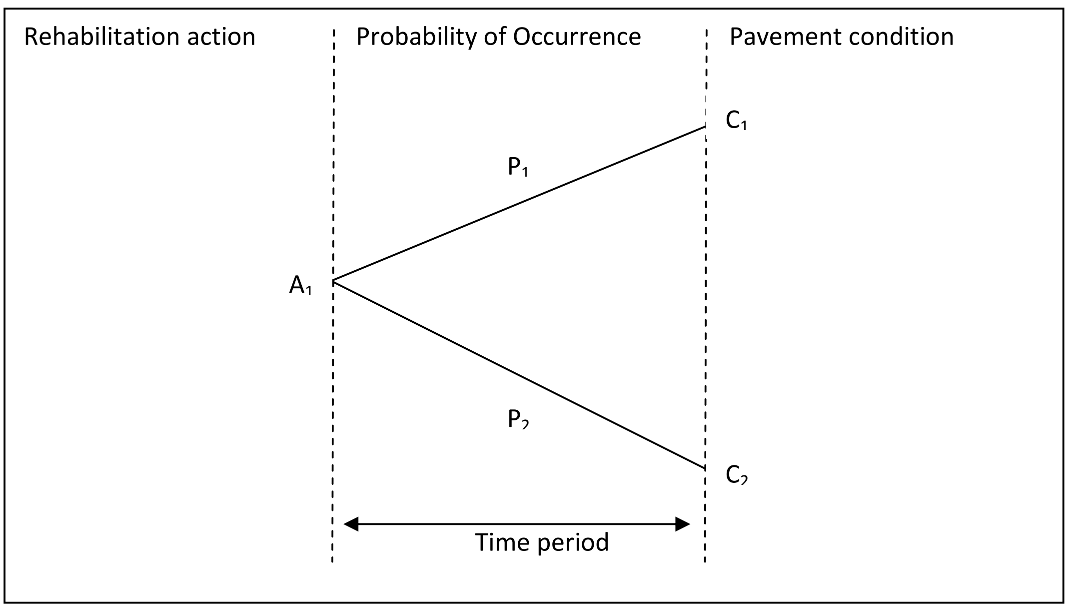


Figure 1: Demonstration of the incorporation of the uncertainty of pavement behaviour by considering probable different pavement end conditions

Figure 1 shows the application of a rehabilitation/holding action (A_1) which, could lead after a time period (t), to two possible pavement conditions (C_1 and C_2). Pavement condition C_{11} will most probably occur with a probability of P_1, while the probability of occurrence of pavement condition C_2 is P_2.

Following the procedure as described above, a “tree” with various “branches” can be constructed for each rehabilitation action to be considered. These “trees” are known as decision trees. The concept of decision trees is ideally suited to incorporate uncertainty and individual experience and knowledge into a formal procedure of analysis.

The concept of uncertainty is incorporated in the economic analysis by considering all possible pavement end conditions, and adding the costs of rehabilitating each of these end conditions into the calculation of the PWOC of the initial action. The introduction of uncertainty in the calculation of the most "probable" cost of an action leads to the determination of the cost referred to as the Probable Present Worth of Cost (PPWOC). Hence, the cost of an Action A_1 (in Figure 1), is determined as follows:

$$PPWOC = \text{Cost of } A_1 + \sum_{i=1}^{n} P_i \text{ Cost } C_i \qquad \text{(Eq. 3)}$$

where

PPWOC	= Probable Present Worth of Cost of action $A_{1.}$
Cost of A_1	= Initial cost of rehabilitation of a holding action.
i	= Number of possible pavement conditions after a time (t).
P_i	= Probability of occurrence of pavement condition i.
Cost C_i	= Cost of rehabilitating the pavement at time t at condition i .

The cost determined using the concept of decision trees will result in the "most probable" cost of an action which is to be distinguished from the true or real cost as determined when considering only one pavement condition.

A decision tree is a tool that can be used to analyse divergent courses of action where the end conditions are dependent on the preceding actions and the next actions are again dependent on the preceding end conditions. A decision tree enables the engineer to determine the best probable course of action, depending on the criteria for calculation. Where the calculation criterion is economic costs, as is the case with the REACT program, the results of the calculations will give the course of action that is probably the most economical. The interpretation of the results of the calculations will be discussed in more detail in the following sections.

3.2 Development of a decision tree in REACT

In the REACT program a decision tree is simply a progression of actions applied to the pavement, which could result in different possible pavement conditions, which in turn would require more actions. As discussed, a given action can have more than one end condition, each with one or more actions following them. For example, after a seal has been applied to a pavement which is cracked and deformed, the engineer may estimate that after 5 years there will be a 10 per cent probability that the pavement will only be deformed and a 90 per cent probability that it will again be cracked and deformed. If the pavement is just deformed, the engineer decides that he can either apply a corrective overlay or partially reconstruct the pavement. If the pavement is cracked and deformed, it can only be partially reconstructed. The end condition in the case of partial reconstruction will then be sound and in the case of an overlay either sound or deformed. The decision tree for this example is given in Figure 2.

3.3 Calculating the values of the decision tree nodes

Economic costs are calculated for each year during the duration of a given action and the year in which a following action occurs (Year x in Figure 2), or the end of the analysis period, as applicable. As these costs may differ for each condition due to differences in road roughness (which influences road user costs and road maintenance costs) these calculations are performed separately for each possible condition resulting from the action. The probable present worth of costs for the action is then the sum of the present worth of each cost component for each year on a given progression line to the condition, multiplied with the probability of the condition occurring.

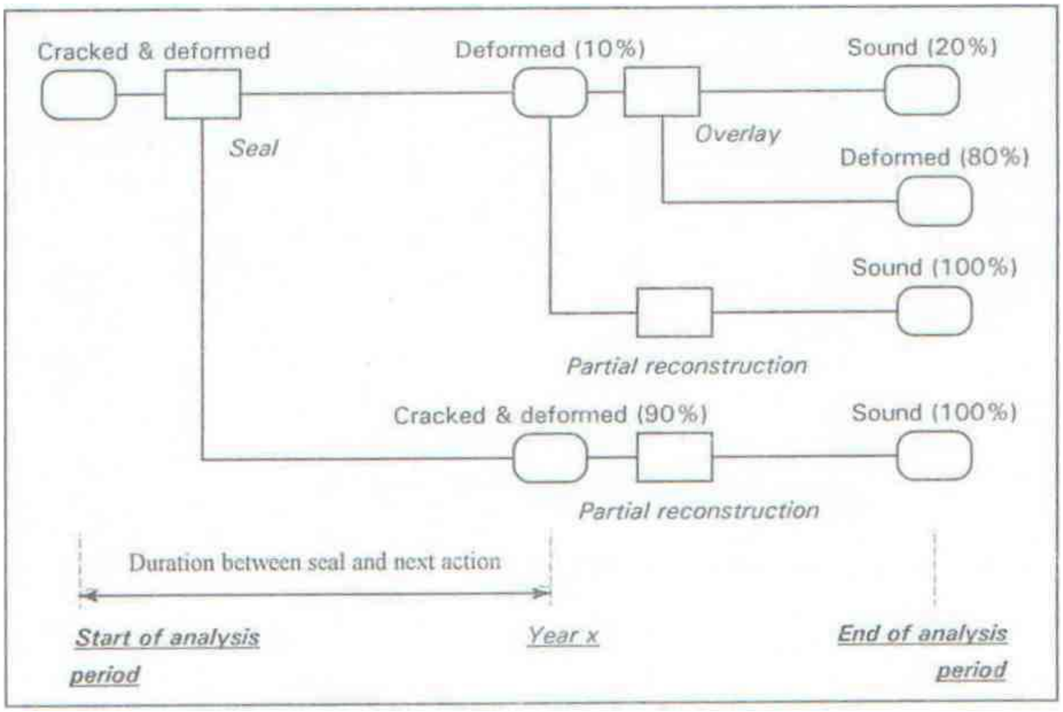


Figure 2: Graphical view of a simple decision tree

If the condition is followed by one or more actions (e.g. the deformed condition is followed by either an overlay or partial reconstruction) the costs of these actions are calculated in a similar manner and the cost of the action with the lowest total probable costs are added to the cost resulting from that condition. Thus the cost of an action or condition includes the probable cost of all actions and conditions branching from it.

4. THE PAVEMENT DETERIORATION MODEL

The program incorporates a pavement deterioration model that is dependent on the cumulative traffic loading that the pavement has carried in terms of E80's. This model is incremental, which means that it calculates the PSI for each year independently of any previous PSI's of the pavement. The basic relationship describing the model is as follows:

$$PSI_t = PSI_{new} - (PSI_{new} - PSI_{war}) \left[\frac{E80_t}{E80_{design}} \right]^n \qquad \text{(Eq. 4)}$$

where

PSI_t = PSI of the road at time t.

PSI_{new} = PSI of a road in a new condition.
PSI_{war} = PSI of a road in a warning condition.
(The definitions of the new, warning and severe PSI levels are dependent on the class and type of road as defined in TRH12)(CASRA, 1997)
$E80_t$ = the cumulative loading of the pavement in E80's up to time t
$E80_{design}$ = the design E80's of the pavement
n = the pavement load equivalency exponent, dependant on the base type and condition of the pavement

The user gives as input the original design E80's and the current PSI of the pavement to the programme. Using the given information the program calculates the effective cumulative E80's the pavement has carried to date to reach the current condition. Hence, in effect the pavement deterioration curve is adjusted to fit between a given start condition and a given end condition. The same principle is followed for the calculation of pavement deterioration over the duration of the analysis period. This enables the user to input different PSI's for different possible end conditions resulting from a given rehabilitation action. The program automatically adjusts the pavement deterioration curve to fit to the values specified by the user.

The concept of effective cumulative E80's is also used in the case where a short-term rehabilitation action is applied to the pavement. In this case the user specifies an improvement in riding quality in terms of an increase in the PSI of the pavement, which reflects the added structural capacity resulting from improvements to the pavement. In these cases the program adjusts the effective cumulative E80's the pavement has carried up to the point of application of the short-term rehabilitation action to take into account the increase in PSI. An effective increase in pavement life will result.

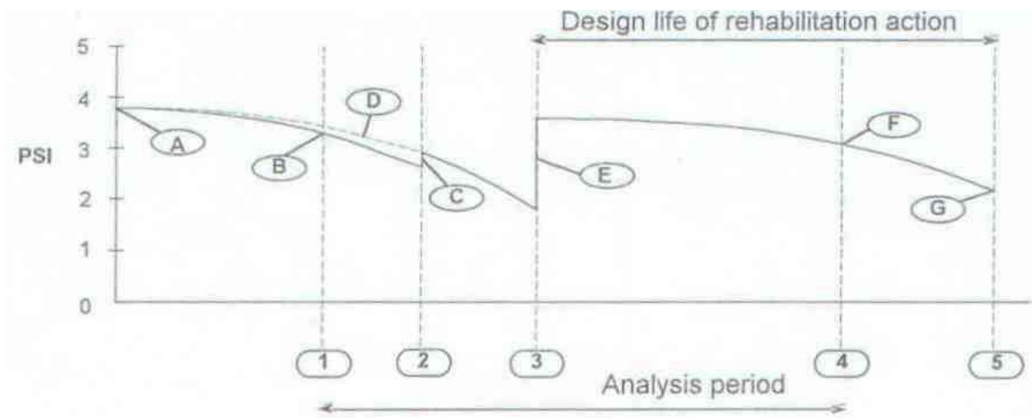
The effective cumulative E80's are set to zero when a pavement is rehabilitated, and the pavement deteriorates in a manner similar to the deterioration of a new pavement over the design period. These concepts are illustrated in Figure 3.

5. THE PROBABILITY OF THE OCCURRENCE OF A PAVEMENT END CONDITION

5.1 Development of a Decision Support System

The preceding sections examined the basic methodology for the economic appraisal of various rehabilitation options, incorporating the concepts of uncertainty through the use of decision trees. Fundamental to the implementation and use of the decision tree concept in the appraisal of future pavement performance, is the identification of the possible pavement end conditions and the assessment of the probability of occurrence of these conditions. The results of the analysis depend heavily on the experience and knowledge of the user. In order to assist the user in the assessment of future pavement conditions a prototype "Decision Support System" was developed for incorporation into the REACT software.

It is anticipated that, in time, through feedback from and interaction with experts in pavement behaviour, the Decision Support System will be improved. Currently, the output from the Decision Support System, in terms of the probability of occurrence of a pavement condition, should only be seen as a first order indication and should be treated as such by the user.



1. Start of analysis period
2. Application of short-term rehabilitation action
3. Rehabilitation of the pavement
4. End of analysis period
5. End of design life of rehabilitation action

A. PSI of new pavement
B. PSI of pavement at start of analysis period
C. Increase in PSI due to short-term rehabilitation action
D. Adjustment of pavement deterioration curve to take account of the short-term rehabilitation action
E. Increase in PSI due to the rehabilitation of the pavement
F. PSI at end of analysis period
G. PSI at end of the rehabilitation design life

Figure 3: Illustration of the calculation of the pavement deterioration curves using the concept of effective cumulative traffic loading

5.2 Effective life of a rehabilitation action

The Decision Support System developed for the determination of the probability of occurrence of a certain pavement condition is based on the expected life of the rehabilitation/holding action which is applied to the pavement. The average expected life (N_a) of the rehabilitation/holding action is adjusted by taking into account the:

- pavement condition before the rehabilitation/holding action is applied to the pavement,
- traffic loading that will be applied to the pavement,
- pavement type,
- any non-surfacing improvements applied to the pavement (e.g. drainage improvements), and
- environmental conditions.

The average life of a rehabilitation/holding action (N_a) is adjusted to determine the effective life (N_e) of the action for the specific situation. For example, the average life of a Cape seal is considered to be 13 years. Hence, after 13 years under "normal conditions" there is a 50 per cent probability that the road will be in a sound (good) condition. However, if the road is in a cracked condition when the seal is applied, the probability of a sound condition is reduced. This is accommodated through a reduction in the effective life of the Cape seal, taking the current pavement condition into account.

The most commonly used distress modes to describe pavement conditions are cracking and rut depth (deformation). Hence, the Decision Support System has been developed to take into account the following pavement conditions:

- sound,
- cracked,
- deformed,
- cracked and deformed (C+D), and
- even worse, (deformation, severe cracking, spalling and potholing).

A pavement is considered to be cracked or deformed or both when the "warning" levels of distress applicable to the specific category of pavement, as defined in the draft TRH12 (CSRA, 3) has been exceeded. The "even worse" condition refers to the disintegration of the pavement surfacing with spalling and the formation of potholes.

The effective life of a rehabilitation/holding action is determined as follows:

$$N_e(AS_i) = (N_a(AS_i) + N_c(AS_i) \times (f_{nr}(AN)_i) \times f_t \times f_p \times f_m \qquad \text{(Eq. 5)}$$

where

N_e = effective life in years of a rehabilitation/holding action (AS_i) with $N_e \geq 0$.
N_a = average life in years of action AS_i.
N_c = adjustment of average life of action ASi for pavement condition c.
f_{nr} = adjustment factor for the effect of non-road surface improvement (AN_i) applied to the pavement.
f_t = adjustment factor for the traffic loading conditions on the pavement.
f_p = adjustment factor for the type of pavement.
f_m = climate factor.

Table 1 gives a list of a number of short-term rehabilitation/holding actions (AS_i) with average expected lives (N_a) and the adjustments currently recommended taking into account the condition of the pavement when these actions are applied.

Similarly, <u>preliminary</u> adjustment factors for any non-road surface actions are recommended as shown in Table 2, for traffic loading conditions in Table 3, for the type of pavement in Table 4 and the adjustment factors for climate are given in Table 5. In time, with input from experienced users, all the factors recommended in Tables 1 to 5 should be improved to give generally accepted outputs.

Table 1: Average lives of short term rehabilitation actions and adjustments based on current pavement condition

Short-term rehabilitation/holding action (AS_i)	**Expected increase in PSI after action**	**Average life in years (N_a)**	**Adjustment in life for current pavement conditions (N_c)**			
			Def	**Cracked**	**C + D**	**Worse**
			N_{cd}	N_{cc}	N_{ccd}	N_{cw}
1. Pothole filling	+0,0	5	-5	-2	-5	-5
2. Crack sealing	+0,0	5	-5	-1	-5	-5
3. Fog spray	+0,0	2	-2	-2	-2	-2
4. Bitumen sand seal	+0,1	5	-5	-2	-5	-5
5. Slurry seal (fine)	+0,2	5	-1	-2	-2	-3
6. Slurry seal (coarse)	+0,3	7	-2	-3	-3	-4
7.Rut filling (Modified binder emulsions)	+0,4	6	-0	-1	-1	-2
8. PVC or single surface treatment	+0,2	6	-4	-2	-4	-5
9. Bitumen single surface treatment	+0,2	10	-6	-4	-6	-7
10. Double seal	+0,3	11	-8	-6	-8	-9
11. Cape seal	+0,3	13	-8	-6	-8	-9
12. Modified binder seal	+0,2	13	-8	-3	-8	-8
13. Open graded asphalt (25mm)	+0,9	10	-2	-5	-5	-7
14.Continuously graded asphalt(25mm)	+1,1	14	-3	-6	-6	-8
15. Gap graded asphalt (25mm)	+1,0	14	-5	-3	-5	-8
16. Thin SAMI (25 mm)	+1,1	16	-7	-2	-7	-8

5.3 Prediction of pavement condition

The Decision Support System gives an estimate of the expected pavement condition after a number of years (t), based on the effective life (N_e) of the rehabilitation/holding action and the current pavement condition. The expected pavement condition is expressed in probability of occurrence which is a number between 0 and 100 per cent.

The effective life (N_e) of a rehabilitation/holding action indicates the number of years (t) after which there is a 50 per cent probability that the pavement will be in a sound condition.

Table 2: Preliminary recommendations for the adjustment of the expected life of a rehabilitation/holding action for non-surface improvements

Non-road surface action (AN_i)	**Adjustment factor (f_{nr})**
Do nothing	1,0
Surface drainage improvements	1,05
Sub-surface drainage improvements	1,15
Shoulder improvements	1,1
Sealing the shoulder	1,2

Table 3: Preliminary recommendations for the adjustment of the expected life of a rehabilitation action taking into account the traffic loading conditions

Pavement category	**Traffic loading over 20 years (E80's*)**	**Adjustment factor (f_t)**
C	E1 (0,2 – 0,8)	1,2
	E2 (0,8 – 3,0)	1,0
B	E2 (0,8 – 3,0)	0,95
	E3 (3,0 – 12,0)	0,8
A	E3 (3,0 – 12,0)	0,7
	E4 (12,0 – 50,0)	0,5

* in 10^6 equivalent 80 kN single axle double wheel loads (E80's)

Table 4: Preliminary recommendations for the adjustment of the expected life of a rehabilitation action taking into account the type of pavement

Pavement type (material in base)	**Adjustment factor (f_p)**
Granular	1,0
Bituminous	0,8
Lightly cemented	0,8
Cemented	0,6

Table 5: Preliminary recommendations for the adjustment of the expected life of a rehabilitation action taking into account the climate

Climate	**Factor (f_m)**
Dry	1,2
Moderate	1,0
Wet	0,8

If the pavement has to last longer than the period t before a following rehabilitation/holding action will be considered, the probability of a sound condition will be less than 50 per cent. Similarly, the probability of a sound condition will be more than 50 per cent if the period is less than t. The probability of the pavement being in a sound condition after t years is calculated as follows:

$$P_s = 50 + \left(N_e - \frac{d}{f_t} \right) \times 10 \qquad \text{(Eq. 6)}$$

where

P_s = probability of the pavement being in a sound condition ($0 \le P_s \le 100$).
N_e = effective life of the rehabilitation/holding action.
d = time before a next action is to be considered (years).
f_t = adjustment factor for the category of the pavement.

It is assumed that the current mode of distress of the pavement will most likely re-occur with the application of a rehabilitation/holding action. For example, if the pavement is in a cracked condition, the pavement will most likely be either in a sound or a cracked condition after a number of years.

The Decision Support System estimates the following probabilities of occurrence:

P_c = probability of a pavement being cracked.
P_d = probability of a pavement being deformed.
$P_{c\&d}$ = probability of a pavement being cracked and deformed.
P_w = probability of a pavement in a worse condition than cracked and deformed (potholes forming).

The simplified procedure is used in the Decision Support System to estimate the probabilities as follows:

Pavement condition before applying a rehabilitation/holding action: Cracked

P_c = 100 - P_s
P_d = 0
$P_{c\&d}$ = 0
P_w = 0

Pavement condition before applying a rehabilitation/holding: Deformed

P_d = 100 - P_s
P_c = 0
$P_{c\&d}$ = 0
P_w = 0

Pavement condition before applying a rehabilitation/holding action:

- Cracked and deformed; or
- Worse than cracked and deformed (potholes forming).

Determining the total probability that the pavement will be cracked:

$$P_{cr} = 50 - \left(N_{cr} - \frac{d}{f_t} \right) \times 10 \qquad \text{(Eq. 7)}$$

where

P_{cr} = probability that the pavement is cracked including cracked and deformed.
N_{cr} = effective life if the current condition of the pavement is cracked.
f_t = adjustment factor for the category of pavement.
d = time period in years before a following rehabilitation action will be applied.

Determining the total probability that the pavement will be deformed:

$$P_{def} = 50 - \left(N_{def} - \frac{d}{f_t d} \right) \times 10 \qquad \text{(Eq. 8)}$$

where

P_{def} = probability that a pavement is deformed (including cracked and deformed) ($0 \leq P_{def} \leq 100$).
N_{def} = effective life in years if the current condition of the pavement is deformed.
f_t = adjustment factor for the category of pavement.
d = time period in years before a following rehabilitation action will be applied.

In this case the probabilities are calculated as follows:

If $P_{cr} > P_{def}$ then: $P_c = P_{cr} - P_{def}$
$P_d = 0$
$P_{c\&d} = P_{def}$
$P_w = 100 - P_s - Pc - P_d - P_{c\&d}$

If $P_{def} > P_{cr}$ then: $P_c = 0$
$P_d = P_{def} - P_{cr}$
$P_{c\&d} = P_{cr}$
$P_w = 100 - P_s - P_c - P_d - P_{c\&d}$

If $P_{def} = P_{cr}$ then:

$$
\begin{aligned}
P_c &= 0 \\
P_d &= 0 \\
P_{c\&d} &= P_{def} = P_{cr} \\
P_w &= 100 - P_s - P_c - P_d - P_{c\&d}
\end{aligned}
$$

There is room for improvement of the Decision Support System for the calculation of the probabilities of occurrence of the expected pavement condition. However, the foundation for such a system has been established. It is believed that, through future input from experts in the field of pavement engineering (more specific, pavement behaviour), the approach can be improved to give improved outputs.

6. CONCLUSIONS

The REACT software package has been rewritten in a Windows environment. This package is available to assist road pavement engineers to compare the most probable Life Cycle Costs of applicable rehabilitation/holding options and/or strategies for any number of uniform pavement sections as applicable to any project level road project. The programme is based on the decision theory (Bayesian analysis). The decision theory allows the user to take into account different pavement condition outcomes by considering the probability that the road will be in a certain condition. A Decision Support System is incorporated into the REACT software which assists the user in determining the probability of a certain pavement condition after any number of years. Scope exists to further develop the Decision Support System, incorporating experience of known experts into the system. At the same time the REACT software can be improved to give warnings when the probability of any defined pavement condition is exceeding pre-defined maximum limits (eg when the probability of pothole forming exceeds a value of say 5 per cent).

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KEY WORDS

Life Cycle Cost analysis, decision theory, pavement condition, pavement rehabilitation.