An Innovative Approach for Selection of Critical Activities for Maintenance of Rural Road Network

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Abstract— Roads play a very important role in the social and economic development of any country. The failures of low rural roads have been predominant in many developing countries like India, which affect both the road users and the road agencies. Thus, in order to reap the benefits of created assets it is essential to maintain the low volume rural road timely. Rural road network are deteriorating fast due to lack of timely maintenance, leading to higher vehicle operating costs, increasing number of accidents etc. Thus, providing appropriate maintenance treatment at appropriate time, the rate of deterioration can be deferred to a great extent and this will reduce the maintenance cost of huge low volume road network in developing countries like India. Selection of critical activities for maintenance depends on several distress condition such as, structural condition, traffic operational condition, traffic safety condition, road sight condition and drainage condition of the road. However, a critical review of the literature indicated that no such comprehensive methodology is available to select critical maintenance activity for maintenance of low volume road. Thus, the main objective of this study is to develop an innovative approach for identification of critical maintenance activity for sustainable maintenance of low volume road based on component condition index. The study proposes that first activity which are more critical for maintenance and which give maximum outcomes need to be selected first. The approach proposed in this study is illustrated with the help of example of rural roads. Analysis results indicated that the proposed approach is less time consuming simple and cost effective and can be executed with minimal data which can be obtained easily. It is expected that this study will be useful for the road engineers and researcher to identify of critical maintenance activity for sustainable maintenance of low volume road and effective utilization of resources.

Keywords: Low Volume Roads, Maintenance Activity, Rural Road Network, Road Maintenance

I. INTRODUCTION

Road connectivity has a catalytic effect on the economic and social development and poverty alleviation in rural areas. However, these benefits would reduce substantially due to poor maintenance of these created assets. Thus, in order to reap the benefits of created assets it is essential to maintain the rural rural road network timely. However, experiences have shown that these roads, although relatively cheap to construct, are often an unsustainable maintenance burden for many rural road authorities, and are rarely maintained in a serviceable conditions. Rural road network consists of the 58% road network percentage of total road network in India, and the second largest road network in the world hence required a great care and huge investment for construction and maintenance. Hence, maintenance activities of road depends on several factors such as condition of road i.e. quantity and quality of deterioration, increasing rate of deterioration, importance of the different sections etc. Hence, it is difficult to select appropriate section for maintenance in order of their ranking in a road network. Thus, there is an urgent need to develop an innovative approach for Selection of critical Activities for Maintenance of rural Road Network. Most of the methods for evaluation of section conditions are sophisticated, costly and need specialized equipment and men power thus, the use of such Approach on low volume road network practically becomes impossible. Hence, there is need to develop a rational methodology which is cost effective, quick and simply operated.

This paper consists of four sections of which this is the first. The second section presents an innovative approach for selection of critical activities for maintenance of rural road and the third section present the analysis and result using proposed approach. The last section presents the important conclusions drawn based on this study.

II. AN INNOVATIVE APPROACH FOR SELECTION OF CRITICAL MAINTENANCE ACTIVITIES

The main objective of this study is to develop the Methodology for Identification of critical maintenance activity. It is proposed to select maintenance activity based on the basis of the component condition and also developed a activity index to identify critical maintenance activity on road. Thus, the method propos that maintenance activity which are more critical for maintenance needs to be selected first. Thus, the methodology will be more economical as details studies needs not to be carried out on all sections.

A. Module-A: Development Of Hierarchical Structural For Identification Of Component Condition:

A hierarchical structure is developed for Identification of component condition affecting overall section condition of low volume road.

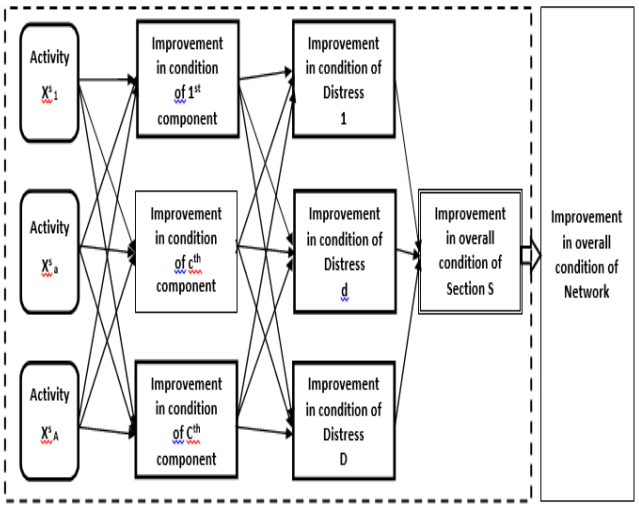

Fig. 1: A hierarchical structural for Identification of critical maintenance activity

In the given hierarchical structure 20 different types of activities are taken which affect the 25 component condition and further this component condition improve five distress condition these five distress condition improves overall condition of section s. section condition depends upon structural condition, traffic operation condition, traffic safety condition, drainage condition and section importance Figure 1 presents the hierarchical structure developed in module-A to evaluate section condition of road.

B. Module-B: Development of a methodology for evaluation of component condition index:

The main objective of the module-B is to develop methodology for evaluation of component condition Index for identification of critical maintenance activity. Activity index has the 25 component condition index in 5 distress category some of the example of component condition index are explain as follows

Determination of component Condition index at section s

1. $CCI_{s1} = \frac{\text{Quantity of distress at section s}}{\text{Maximum quantity of same distress at any section}}$

2. $CCI_{s2} = \frac{\text{Present distress area on section}}{\text{Total carriageway area of section s}}$

3. $CCI_{s3} = \frac{\text{Required condition as per IRC standard} - \text{Existing condition at section s}}{\text{Required condition as per IRC standrad}}$

For calculating different component condition identify the appropriate index given as above for example; component condition concluded distress area obtain by the CCIs1 , component condition belong to road Drainage calculated by CCIs3.

C. Module-C: Development of Activity Index for Identification of Critical Maintenance Activity:

Activity Index depends upon component condition index and its relative weight, Equation presents the section index developed to evaluate rural road section condition at project level.

$$AI_{as} = \sum_{\forall c}^{n=25} \{CCI_s\} \; x \; \{W_{DC}\} \, x \, SI_{sp}$$

Where

AIas = Activity Index of activity a at section s
CCIs = Component condition Index of section S
Wdc = relative weight of distress condition
SIsp = Section index of section S at project level
n = number of component condition

Now, the strategy to evaluate condition of different distress condition i.e. structural distress condition Traffic operational condition, Traffic safety condition, shoulder distress condition, drainage condition and section Importance index for section s. is developed and explained as follows:

AI_{as} = 0.33 [$CCIE_s$ + $RSIE_s$] + 0.11 [$CCIL_s$ + + STILs + $STIE_s$+ BSILs + RSlLs + $RSIS_s$ + +PCI_s+ $RCIW_s$ + $RCIC_s$ + USI_s + LMI_s] + 0.13 [$BBCI_s$+ $TBCI_s$ + BSIEs + CCI_s + RFI_s] + 0.06 [$SECI_s$ + SDI_s + VGI_s] + 0.07 [$ICCI_s$ + DSI_s+ $SSDI_s$ +$CDSI_s$] +0.3 SII_s

The component conditions which are not affected by application of the specific maintenance activity for improvement of distress condition is neglect and the component condition which directly affected by application of maintenance activity is taken with their relative weight which is obtain by AHP.

III. Analysis & Result for Identification of Critical Road Sections

As discussed in the above equation used to determine activity index which identify the critical maintenance activity on road sections based on component condition. To illustrate the methodology and to illustrate how the proposed methodology works, detailed analysis were carried out. Two different cases were analyzed given in Table-4. A network consists of 4 road sections were analyzed. Details of different cases considered, input data and analysis results for each case is presented in the following section.

Table 1: Different Case considered illustrating the Methodology

S. N.	Input DATA	Case- I				Case- II			
		S 1	S 2	S 3	S 4	S 1	S 2	S 3	S 4
3	Total carriageway Area m2	S	S	S	S	S	S	S	S
4	Length of carriageway (m)	S	S	S	S	S	S	S	S
5	No. of Breaches or blockages	S	S	S	S	S	S	S	S
6	Tree branches Less than 4.5m	S	S	S	S	S	S	S	S
7	Cracking without rutting (m2)	D	D	D	D	S	S	S	S
8	Stripping (m2)	S	S	S	S	S	S	S	S
9	Bleeding (m2)	S	S	S	S	D	D	D	D
10	Rutting (mm)	S	S	S	S	S	S	S	S
11	Potholes (m2)	S	S	S	S	S	S	S	S
12	Reflection crack (m2)	S	S	S	S	S	S	S	S
13	Area of Edge subsistence	S	S	S	S	S	S	S	S
14	Required camber in %	S	S	S	S	S	S	S	S

15	Undulations (mm/km)	S	S	S	S	S	S	S	S
16	Area of loss material	S	S	S	S	S	S	S	S
17	area of shoulder deformation	S	S	S	S	S	S	S	S
18	Length of drain silting (M)	S	S	S	S	S	S	S	S
19	Missing Road furniture	S	S	S	S	S	S	S	S
20	Required cross drainage	S	S	S	S	S	S	S	S
21	Potholes on cross drainage surface	S	S	S	S	S	S	S	S
22	Scouring length in side drains	S	S	S	S	S	S	S	S
23	bush and cut grass	S	S	S	S	S	S	S	S
24	Road furniture and signs dirty	S	S	S	S	S	S	S	S

S = component condition remains same on all the four section
D = variation in component condition with the change of sections

A. Case-I Effect of structure distress condition on identification of sections:

In this case it is assumed that the Total carriage way area and shoulder area are same in the four section and all the network parameter also same excluding only cracking without rutting (m2) (ASDs) of the section are different at various Selected Section,. Details of input data for case-I are given in Table 2

S. N.	Input DATA	Case- I			
		S1	S2	S3	S4
3	Total carriageway Area m2	3750	3750	3750	3750
4	Length of carriageway (m)	1000	1000	1000	1000
5	No. of Breaches or blockages	12	12	12	12
6	Tree branches Less than 4.5m	18	18	18	18
7	Cracking without rutting (m2)	**1040**	**1256**	**1532**	**1785**
8	Stripping (m2)	0	0	0 0	00
9	Bleeding (m2)	389	389	389	389
10	Rutting (mm)	40	40	40	40
11	Potholes (m2)	449	449	449	449
12	Reflection crack (m2)	144	144	144	144
13	Area of Edge subsistence and rutting	0	0	0	0
14	Required camber in %	3.2	3.2	3.2	3.2
15	Undulations (mm/km)	373	373	373	373
16	Area of loss material	0	0	0	0
17	area of shoulder deformation	323	323	323	323
18	Length of drain silting (M)	121	121	121	121
19	Missing Road furniture	23	23	23	23
20	Required cross drainage	3.1	3.1	3.1	3.1
21	Potholes on cross drainage surface	374	374	374	374
22	Scouring length in side drains	54	54	54	54
23	bush and cut grass	0	0	0	0
24	Road furniture and signs dirty	16	16	16	16

Table 2: Input data for the analysis of case-1 (variation of cracking)

Case-I The Activity index (AIas) for all the four sections was determined using AIas Equation and Indices value given in Table 3 which is used to determine critical maintenance activity of different section. Here cracking area more than 25% of the total section area considered as a part of structural distress and which belongs to AI3s (Local sealing or filling of cracks) as per the proposed approach component condition also affect indirectly to the other maintenance activity, High value of AIas indicates that higher rank should be given to that section following analysis done with the application of MS Xl. it will also valid on multiple number of sections.

activity Index	Case-IA	Case-IB	Case-IC	Case-ID
AI_{1s}	0.00578	0.00615	0.00662	0.00705
AI_{2s}	0.00815	0.00868	0.00935	0.00996
AI_{3s}	0.03133	0.03906	0.04999	0.06105
AI_{4s}	0.00000	0.00000	0.00000	0.00000
AI_{5s}	0.00000	0.00000	0.00000	0.00000
AI_{6s}	0.00338	0.00360	0.00387	0.00413
AI_{7s}	0.01303	0.01387	0.01494	0.01592
AI_{8s}	0.00000	0.00000	0.00000	0.00000
AI_{9s}	0.00390	0.00415	0.00447	0.00476
AI_{10s}	0.00000	0.00000	0.00000	0.00000
AI_{11s}	0.00415	0.00441	0.00475	0.00506
AI_{12s}	0.00405	0.00431	0.00464	0.00495
AI_{13s}	0.00000	0.00000	0.00000	0.00000
AI_{14s}	0.00153	0.00163	0.00175	0.00187
AI_{15s}	0.00251	0.00267	0.00288	0.00306
AI_{16s}	0.00000	0.00000	0.00000	0.00000
AI_{17s}	0.00467	0.00496	0.00535	0.00570
AI_{18s}	0.00207	0.00220	0.00237	0.00253
AI_{19s}	0.00000	0.00000	0.00000	0.00000
AI_{20s}	0.00616	0.00656	0.00706	0.00752

Table 3: Analysis and result for Case-I

Ranks obtained for different section are shown in the Figure 2. It is clear from the Figure 3 that forth section have critical condition whose activity index (AIas) is highest among the other sections shown graphically in Figure 2.

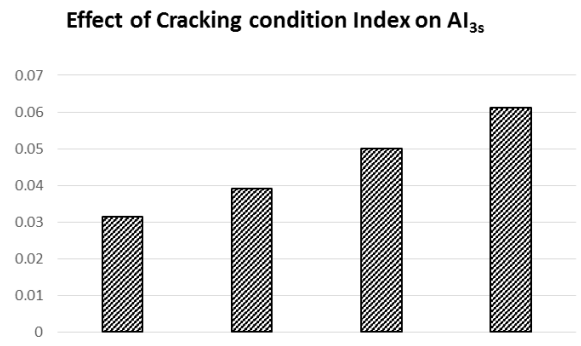

Fig. 2: analysis result of Case-I Effect of structure distress condition

B. Case-II: Effect of Traffic safety condition (Bleeding surface) in identification of sections:

In this case it is assumed that the Total carriage way area and shoulder area are same on four section and all the network parameter also same excluding only area of bleeding surface distress of the section are different at various Selected Section, A network consists of 4 road sections. Details of input data for case II-A are given in Table 4

S. N.	Input DATA	Case- I			
		S1	S2	S3	S4
3	Total carriageway Area m2	3750	3750	3750	3750
4	Length of carriageway (m)	1000	1000	1000	1000
5	No. of Breaches or blockages	12	12	12	12
6	Tree branches Less than 4.5m	18	18	18	18
7	Cracking without rutting (m2)	1040	1040	1040	1040
8	Stripping (m2)	0	0	0 0	00
9	Bleeding (m2)	389	542	742	912
10	Rutting (mm)	40	40	40	40
11	Potholes (m2)	449	449	449	449
12	Reflection crack (m2)	144	144	144	144
13	Area of Edge subsistence and rutting	0	0	0	0
14	Required camber in %	3.2	3.2	3.2	3.2
15	Undulations (mm/km)	373	373	373	373
16	Area of loss material	0	0	0	0
17	area of shoulder deformation	323	323	323	323
18	Length of drain silting (M)	121	121	121	121
19	Missing Road furniture	23	23	23	23
20	Required cross drainage	3.1	3.1	3.1	3.1
21	Potholes on cross drainage surface	374	374	374	374
22	Scouring length in side drains	54	54	54	54
23	bush and cut grass	0	0	0	0
24	Road furniture and signs dirty	16	16	16	16

Table 4: Input Data for analysis of Case-II (effect of bleeding surface distress condition)

Case II at includes evaluation of activity index of four different low volume rural road sections. The activity index (AIas) for four different sections was determined using AIas Equation and it is presented in Table 5.

activity Index	Case-1	Case-2	Case-3	Case-4
AI_{1s}	0.00585	0.00594	0.00605	0.00615
AI_{2s}	0.00826	0.00838	0.00854	0.00868
AI_{3s}	0.03168	0.03209	0.03263	0.03308
AI_{4s}	0.00000	0.00000	0.00000	0.00000
AI_{5s}	0.00000	0.00000	0.00000	0.00000
AI_{6s}	0.00342	0.00484	0.00675	0.00844
AI_{7s}	0.01320	0.01340	0.01365	0.01387
AI_{8s}	0.00000	0.00000	0.00000	0.00000
AI_{9s}	0.00395	0.00401	0.00409	0.00415
AI_{10s}	0.00000	0.00000	0.00000	0.00000
AI_{11s}	0.00420	0.00426	0.00434	0.00441
AI_{12s}	0.00410	0.00416	0.00424	0.00431
AI_{13s}	0.00000	0.00000	0.00000	0.00000
AI_{14s}	0.00155	0.00157	0.00160	0.00163
AI_{15s}	0.00254	0.00258	0.00263	0.00267
AI_{16s}	0.00113	0.00115	0.00117	0.00119
AI_{17s}	0.00472	0.00480	0.00489	0.00497
AI_{18s}	0.00209	0.00213	0.00217	0.00220
AI_{19s}	0.00000	0.00000	0.00000	0.00000
AI_{20s}	0.00624	0.00633	0.00645	0.00656

Table 5: Analysis results for Case-II (Selection of critical maintenance activity)

Indices value given in Table 5 was used to determine Activity index on different section. High value of AIas indicates that higher rank should be given to that section. Analysis and result for Case II shown graphically in Figure 4

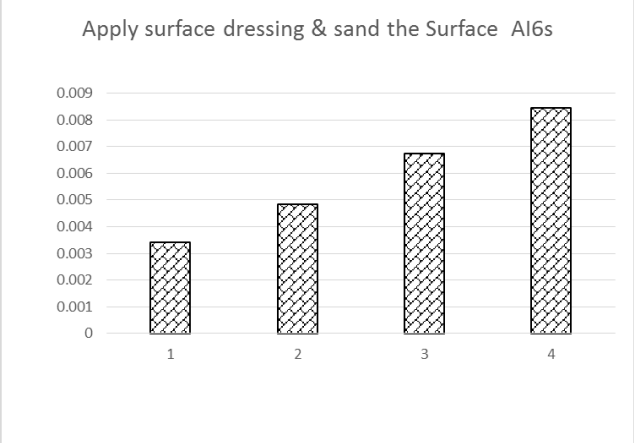

Fig. 3: analysis result of Case-II Effect of variation in bleeding surface distress area)

Ranks obtained for different section are shown in the Figure 3. It is clear from the Figure 3 that forth section have critical condition whose activity index (AIas) is highest among the other sections.

IV. CONCLUSIONS

Some important conclusions drawn from this study are as follows:-

- Selection of critical road maintenance activity on road network should be selected considering component condition index (Structural condition, Surface condition, Traffic Safety condition, Shoulder condition, Drainage condition of each road section in the road network. However a critical review of the literature indicated that no such comprehensive methodology available for Identification of Critical road maintenance for Sustainable Maintenance of Road network. Therefore there is an urgent need to develop An innovative approach for selection of critical activities for maintenance of rural road network considering component in a comprehensive way.
- This study presents the methodology which contains four modules to select the most appropriate sections of a low volume roads network considering their rank for maintenance based on importance, traffic operational condition, drainage condition, structural condition and traffic safety condition of road section etc.
- In "Module-A" A hierarchal structure is developed for Identification of component condition affecting overall section condition. In this structure 25 component condition index are also developed to identify the condition of different sections in the road network. In "Module-B" 25 indices are developed at project level for evaluation of affecting overall section condition to identify the condition of different sections in the road network. A activity index (AIas) is developed in Module-C" considering CCIs and their relative weight. The AIas can be used to select the critical sections of road network using minimal data.
- The methodology proposed in this study is also illustrated with the help of example of a low volume roads network. Analysis results indicated that the proposed methodology is less time consuming simple and cost effective and can be executed with minimal data which can be obtained easily and economically.
- It is expected that the approach proposed in this study can be used for selection of exact maintenance activity on appropriate section of road network so that the road maintenance can be utilized to achieve maximum improvement.

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