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# A Rational Methodology for Resources Allocation for Highway Maintenance in India

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**Abstract** — *Roads are deteriorating fast due to lack of timely maintenance, leading to higher vehicle operating costs, increasing number of accidents. Highway agencies around the world have changed their attention from design and construction of new pavements (roadways/highways) to maintenance of already existing ones. Satisfactory maintenance of its highway network is essential for any nation's economic growth. Pavements must be selected for maintenance when they are still effective, before the need is apparent to the casual observers in order to avoid the rapid deterioration after a certain limit. This is because once pavements start to deteriorate; they deteriorate rapidly beyond the point where maintenance is effective. However, increasing traffic loading, deteriorating road conditions, and shrinking resources have presented a complex situation in maintenance aspect. Huge resources are being spent on the maintenance and development of existing roadways in India to ensure the mobility of people and goods.*

*In this thesis a rational methodology for allocation of resources for different maintenance activities to be carried out on different sections in a road network is proposed. This methodology is based on importance of the road sections, present road conditions, and future road conditions. A methodology for maintenance prioritization of road network is developed considering the critical road condition ascertain by various distress parameters categorized under the road failures of fractured, distorted and disintegrated surface. The methodology proposed in this study is illustrated with the help of an example of a small hypothetical highway network consisting of 4 sections.*

***Keywords*- Design;** *Highway; Pavements; design; Maintenance Priority; Resource Allocation*

## I. INTRODUCTION

The road transportation occupies a very dominant position in the over all transportation system. With increase in traffic load due to increased in economic and development activities, the road network is overstressed. Without adequate and timely maintenance, road deteriorate excessively. India has a large road network and roads are not in good condition so there is need for maintenance work. Roads are deteriorating fast due to lack of timely maintenance, leading to higher vehicle operating costs, increasing number of accidents. It has therefore become necessary to prioritize components for maintenance so as to ensure higher reliability while still operating within the allocated budget. Highway agencies around the world have changed their attention from design and construction of new pavements (roadways/highways) to maintenance of already existing ones. Maintenance of road or highway network is essential for economic growth of any country.

By 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 roads. If timely maintenance is not provided, the reconstruction will become unavoidable. Therefore road maintenance is one of the most important components of the entire road system. The maintenance process involves the assessment of present conditions of road, judgment of the problem and adopting the most relevant maintenance. In a road network it is so difficult to select the roads in a order of priority for their maintenance because resources are limited. So there is need to develop a rational methodology for resources allocation for Highway Maintenance. Prioritization and resources allocation may be depends on several factors such as present condition of road i.e. quantity and quality of deterioration, increasing rate of deterioration, importance of the selected road, traffic load on the selected road etc. In this study resources allocation depends on overall road conditions and importance of the road sections.

A resources allocation for maintenance system formulated according to specific needs and resources of a particular highway maintenance agency would assure satisfactory pavement performance with the minimum maintenance cost. There are different type of failures can occur on the roads like cracks, rutting, potholes, shallow depressions, hungry surfaces etc. Road deterioration causes for accidents on roads and which will increase the loss of life and properties. Scope of this study is to review literature, to develop a methodology and illustration of this methodology. This chapter introduces to problem identification, need of the study, objective and scope of this study and report organization.

## II. LITERATURE REVIEW

**Shahin, M.Y.**, "Pavement Management for Airports, Roads, and Parking Lots" the required maintenance strategies are determined based on the distresses data from the previous inspection data and the user-specified distress maintenance policy like- stop-gap policy.

As per IRC 82-1982 the type of distresses are broadly divided into four categories:

1) Surface defects- it includes fatty surfaces, smooth surfaces, streaking, and hungry surfaces;
2) Cracks – under which hair-line cracks, alligator cracks, longitudinal cracks, edge cracks, shrinkage cracks and reflection cracks;
3) Deformation- under this are grouped rutting, slippage, corrugation, shoving, shallow depressions, settlements and upheavals
4) Disintegration- covering potholes, stripping, loss of aggregates, raveling and edge breaking

Symptoms and causes of distresses are described below and treatments are given as follows:

1) **Hair-line crack:** - These appear as short and fine cracks at close intervals on the surface, Figure2.1.

These cracks are caused by:

– Insufficient bitumen content
– Excessive filler at the surface
– Improper compaction

2) **Alligator crack**: - These appear as interconnected cracks forming a series of small blocks which resemble the skin of an alligator.

These cracks are due to the following factors:

– Excessive deflection of the surface over unstable sub grade, sub base, base of the pavement, particularly in the wheel tracks.
– Excessive overloads by heavy vehicles or inadequate pavement thickness or both.
– Brittleness of the binder or initial over heating

3) **Shrinkage Cracks:** - These are cracks appearing in the transverse direction, or as inter connected cracks forming a series of large blocks.

Cause of shrinkage cracks is described below:

The primary cause for such cracks is the shrinkage of the bituminous layer itself with age. The bituminous binder loses its ductility as it ages and become brittle.

## III. PROPOSED METHODOLOGY

The main objective of this study is to develop a Methodology for recourse allocation for highway maintenance on the basis of priority of various activities of highway maintenance and importance of road section. A large number of factors such as present highway condition (present functional and structural condition), future highway condition (future functional and future structural condition )and the highway importance (highway class ,importance to the community ,and its political importance )influencing the priority of the highway sections for maintenance. Various methods had been developed for recourse allocation for highway maintenance based on different factors. Basic objective of recourse allocation for highway maintenance based on prioritization and important of sections are to manage maintenance work properly as per the aviability of resources and requirement. A rational methodology is proposed to be developed an efficient and effective methodology based on three factors namely present distress condition of roads, future distress condition roads and importance of highways to determine Priority Index and allocate the recourses for highway maintenances. This methodology for recourse allocation is developed considering the critical road condition ascertain by various distress parameters categorized under the road failures of fractured, distorted and disintegrated surface and structural condition . A practical methodology for prioritizing road works should be based on low-volume and very low-volume roads in the rural areas of developing countries. The methodology should be based on a system for estimating future traffic on improved roads on the basis of readily available data. Moreover, the method accommodates the need to consider the opening of roads that may be currently impassable to traffic. This procedure which is proposed here is simple and transparent, and therefore it is well suited to implementation of road conditions. It allows for certain basic parameters, such as present distress condition of roads, future distress condition roads and importance of highways.

### A. Methodology proposed for recourse allocation for highway maintenance

The main objective of this study is to develop a Methodology to allocate recourses for highway maintenance on the basis of maintenance Priority. .Priority analysis is a multi-criteria process for best ranking list of the sections for maintenance based on several factors. Priority setting approach must consider the relative importance of functional and structural condition of the section. Aim of this study is to determine Priority Index $(PI)_{as.}$

$(PI)_{as}$ depends on the following factors:

1 Present Distress Condition (PDC)
2 Future Distress Condition
3 Importance of Section

Normally three types of failure occurred in roads are as follows:

- Fractured surface (Alligator cracks, hair-line cracks, longitudinal cracks, edge cracks, shrinkage cracks and reflection cracks)
- Distorted surface (rutting, slippage, corrugation, shoving, shallow depressions, settlements and upheavals)
- Disintegrated surface (potholes, stripping, loss of aggregates, raveling and edge breaking)

It can be determined by the following equation,

$$PI_{as} = [(PDCI)_s\, W_{adc}\, W_{dc}\, W_s] + [(FDCI)_s\, W_{adc}\, W_{dc}\, W_s]$$

Where,

**$PI_{as}$** = Priority Index at a section for any one identified activity

**a** = Activity

**s** = Section

**PDCI** = Present Distress Condition Index

**FDCI** = Future Distress Condition Index

**$W_{adc}$** = Weightage of activity distress condition

**$W_{dc}$** = Weightage of distress condition

**$W_S$** = Weightage of section

PDCI consists of three indices are Present Fractured Surface Index (PFSI), Present Distorted Surface Index (PDTSI), Present Disintegrated Surface Index (PDISI).

Now the previous equation will be,

$$PI_{as} = [\{(PFSI)_s\, W_{adc}\, W_{dc}\, W_S\} + \{(PDTSI)_s\, W_{adc}\, W_{dc}\, W_S\} + \{(PDISI)_s\, W_{adc}\, W_{dc}\, W_S\} + \{(PSCI)_s\, W_{aDC}\, W_{DC}\, W_S\}] + [\{(FFSI)_s\, W_{aDC}\, W_{DC}\, W_S\} + \{(FDTSI)_s\, W_{aDC}\, W_{DC}\, W_S\} + \{(FDISI)_s\, W_{aDC}\, W_{DC}\, W_S\} + \{(FSCI)_s\, W_{aDC}\, W_{DC}\, W_S\}]$$

Evaluation of all parameters,

$$PFSI = \frac{Present\ fractured\ area\ (in\ percentage\ of\ total\ area)\ on\ the\ section}{Maximum\ fractured\ area\ (in\ percent\ of\ total\ area)\ on\ any\ section\ in\ the\ network}$$

$$PDTSI = \frac{Present\ distorted\ area\ (in\ percentage\ of\ total\ area)\ on\ the\ section}{Maximum\ distorted\ area\ (in\ percent\ of\ total\ area)\ on\ any\ section\ in\ the\ network}$$

FFSI

$$= \frac{Future\ fractured\ area\ (in\ percentage\ of\ total\ area)\ on\ the\ section}{Maximum\ fractured\ area\ (in\ percent\ of\ total\ area)\ on\ any\ section\ in\ the\ network}$$

$$= \frac{Present\ disintegrated\ area\ (in\ percentage\ of\ total\ area)\ on\ the\ section}{Maximum\ disintegrated\ area\ (in\ percent\ of\ total\ area)\ on\ any\ section\ in\ the\ network}$$

$$FDTSI = \frac{Future\ distorted\ area\ (in\ percentage\ of\ total\ area)\ on\ the\ section}{Maximum\ distorted\ area\ (in\ percent\ of\ total\ area)\ on\ any\ section\ in\ the\ network}$$

$$FDISI = \frac{Future\ disintegrated\ area\ (in\ percentage\ of\ total\ area)\ on\ the\ section}{Maximum\ disintegrated\ area\ (in\ percent\ of\ total\ area)\ on\ any\ section\ in\ the\ network}$$

PSCI = Structurally Adequate (0) or Structurally Inadequate (1)

FSCI = Structurally Adequate (0) or Structurally Inadequate (1)

$W_{adc}$ = user defined (0 or 1)

$W_{dc}$ = by opinion survey

$W_S$ = user defined (0 - 2)

**Evaluation of $W_{dC}$ (Weightage of distress condition) :**

 

Here values of $W_{dc}$ for all conditions considered for evaluation of $W_{dc}$ we have to give priority to the two most important factors those are over all highway condition and highway importance. These factors are also considered other factors like present and future condition and others. Weightage are decided as per Agarwal, P.K., Das, Animesh and Chakroborty, Partha," A Rational Approach for prioritization of Highway Sections for Maintenance", IIT Kanpur department of Civil Engineering. The rational weights was captured from a group of experts in India, who have knowledge and experience in the field of highway engineering, using a survey design based on Analytic Hierarchy Process (AHP). To obtain the relative importance (weight) of all these factors in a hierarchical structure, a specially designed questionnaire with a different set of questions (various aspects of highway maintenance) was prepared. The form consists of the following five main aspects,

1) Maintenance priority
2) Overall road condition
3) Functional condition
4) Riding quality and
5) Overall highway importance

The hierarchical structure and the method of pair wise comparison using Analytic Hierarchy Process improves and streamlines the process to obtain the relative importance (weight) of various factors influencing the priority in a more rational and systematic manner. The local weights of various levels in hierarchical structure are aggregated in order to compute the global weights which serve as their relative influence in maintenance priority. The global weights are interpreted as measures of their relative influence on a ratio scale according to their overall impact on the maintenance priority of the road sections. These global weights form the basis to determine the priority of the road sections. derived for each level in the hierarchical structure make it possible to tailor approach to suit the needs of highway agencies. For example, riding quality may be measured by any equipment such as ride meter, bump indicator etc. instead of measuring distress area as proposed in this approach. Yet the approach can still be used by considering the global weight of riding quality.

## IV. ANALYSIS & RESULTS

The main objective of this study is to develop a Methodology to determine recourse allocation for highway maintenance. To illustrate the methodology and to illustrate how methodology works, the following two cases were analyzed.

CASE I: Resource allocation based on priority Index i.e on the basis of the methodology proposed in this study

CASE II: Resource allocation based on present practice i.e based on the overall importance of the section. Overall importance of the section is determined on the basis of highway class, political importance of the section and importance of the section to community etc.

### A. Analysis and Results:

**Case I:** Resource allocation based on priority Index.

***"Table 4.1: Input data: Details of the Road Sections (Case I)"***

| Section No. | Designation | Length (m) | Width (m) | Road Classification | Important places connected | Political Importance |
|---|---|---|---|---|---|---|
| 1 | $S_1$ | 2400 | 7 | Major Arterial Road | Airport, Market | High |
| 2 | $S_2$ | 2160 | 7 | Local Street | Residential | Low |
| 3 | $S_3$ | 1800 | 7 | Major Arterial Road | Airport, Market | High |
| 4 | $S_4$ | 1200 | 7 | Local Street | Residential | Low |

***"Table 4.2: Input data: Details of the Distress Conditions present and Maintenance Activities required on the various sections (Case I)"***

| Section | Distresses | Required Activities | Designation |
|---|---|---|---|
| $S_1$ | Fractured Surface(Cracks)<br>Disintegrated Surface (Pot holes)<br>Distorted surface(Rutting) Structural defect | Crack filling<br>Patching<br>Patching<br>Overlay | $A_{11}$<br>$A_{12}$<br>$A_{13}$<br>$A_{14}$ |

| | | | |
|---|---|---|---|
| | | | |
| $S_2$ | Fractured Surface (Cracks)<br>Disintegrated Surface (Pot holes)<br>Distorted surface(Rutting)<br>Structural defect | Crack filling<br>Patching<br>Patching<br>Overlay | $A_{21}$<br>$A_{22}$<br>$A_{23}$<br>$A_{24}$ |
| $S_3$ | Fractured Surface(Cracks)<br>Disintegrated Surface (Pot holes)<br>Distorted surface(Rutting) Structural defect | Crack filling<br>Patching<br>Patching<br>Overlay | $A_{31}$<br>$A_{32}$<br>$A_{33}$<br>$A_{34}$ |
| $S_4$ | Fractured Surface (Cracks)<br>Distorted surface(Rutting)<br>Disintegrated Surface (Pot holes)<br>Structural defect | Crack filling<br>Patching<br>Patching<br>Overlay | $A_{41}$<br>$A_{42}$<br>$A_{43}$<br>$A_{44}$ |

***"Table 4.3: Input data: Details of Distresses of various Road Sections"***

| **Activities** | **PFS** | **PDTS** | **PDIS** | **PSC** | **FFS** | **FDTS** | **FDIS** | **FSC** |
|---|---|---|---|---|---|---|---|---|
| | **A $m^2$** | **A $m^2$** | **A $m^2$** | **A $m^2$** | **A $m^2$** | **A $m^2$** | **A $m^2$** | **A $m^2$** |
| $S_1$ | 336.00 | 168.00 | 505.00 | 3120.00 | 880.00 | 325.00 | 815.00 | 4212.00 |
| $S_2$ | 300.00 | 226.00 | 605.00 | 2000.00 | 931.00 | 282.00 | 1125.00 | 3140.00 |
| $S_3$ | 1890.00 | 1120.00 | 2015.00 | 1850.00 | 3210.00 | 110.00 | 4850.00 | 3665.00 |
| $S_4$ | 1428.00 | 1512.00 | 1580.00 | 1710.00 | 3350.00 | 3010 | 3820.00 | 2850.00 |

***"Table 4.4: Summarized Analysis results: Details of Distresses Indices of various Road Sections"***

 

| **Distress Indices** | **Values** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $A_{11}$ | $A_{12}$ | $A_{13}$ | $A_{14}$ | $A_{21}$ | $A_{22}$ | $A_{23}$ | $A_{24}$ | $A_{31}$ | $A_{32}$ | $A_{33}$ | $A_{41}$ | $A_{42}$ | $A_{43}$ | $A_{44}$ |
| PFSI | **1** | **0** | **0** | **0** | **1** | **0** | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **0** |
| PDTSI | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **0** | **0** | **1** | **1** | **0** | **1** | **0** | **0** |
| PDISI | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **1** | **1** | **1** | **1** | **0** | **0** | **1** |
| PSCI | **0** | **0** | **0** | **1** | **0** | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **0** | **1** |
| FFSI | **1** | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** |
| FDTSI | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **1** | **0** | **0** | **1** | **0** | **1** |
| FDISI | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **1** | **0** | **0** | **0** |
| FSCI | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** |

***"Table4.5: Result: PIas & Ranking based on the calculated value of PIas"'***

| **Sections** | **Activities** | **Calculated PIas** | | **Rank** |
|---|---|---|---|---|
| $S_1$ | $A_{11}$ | $PI_{11}$ | 0.0215 | 13 |
| | $A_{12}$ | $PI_{21}$ | 0.0478 | 8 |
| | $A_{13}$ | $PI_{31}$ | 0.056 | 7 |
| | $A_{14}$ | $PI_{41}$ | 0.182 | 5 |
| $S_2$ | $A_{21}$ | $PI_{12}$ | 0.004 | 16 |
| | $A_{22}$ | $PI_{22}$ | 0.009 | 15 |
| | $A_{23}$ | $PI_{32}$ | 0.023 | 11 |
| | $A_{24}$ | $PI_{42}$ | 0.200 | 4 |
| $S_3$ | $A_{31}$ | $PI_{13}$ | 0.047 | 9 |
| | $A_{32}$ | $PI_{23}$ | 0.215 | 2 |
| | $A_{33}$ | $PI_{33}$ | 0.455 | 1 |
| | $A_{43}$ | $PI_{43}$ | 0.110 | 6 |
| $S_4$ | $A_{41}$ | $PI_{14}$ | 0.0096 | 14 |
| | $A_{42}$ | $PI_{24}$ | 0.0224 | 12 |
| | $A_{43}$ | $PI_{34}$ | 0.042 | 10 |
| | $A_{44}$ | $PI_{44}$ | 0.214 | 3 |

Determination of resources required

The various resources required to carry out various maintenance activities are funds, equipment (like paver, roller, hot mix plant etc.), manpower (i.e labour, supervisor etc.), material (i.e aggregates, bitumen, emulsion, cement etc.). However, availability of the fund is the most important resources. Hence, in this study only funds constraints is considered.

The amount required for various maintenance activities are calculated on the basis of quantity of the work required and that is multiplied by the rate of the item. The rates are taken on the basis schedule of rate of MPPRRDA, March, 2009.

The various maintenance activities considered and their rates are given in Table 4.6

***"Table4.6: Result: Details of resource (fund) required for various maintenance activiites"***

 

| Sections | Activities | Calculated PIas | | Rank | Maintenance cost(rates) |
|---|---|---|---|---|---|
| $S_1$ | $A_{11}$ | $PI_{11}$ | 0.0215 | 13 | 67872.00 |
| | $A_{12}$ | $PI_{21}$ | 0.0478 | 8 | 141120.00 |
| | $A_{13}$ | $PI_{31}$ | 0.056 | 7 | 424200.00 |
| | $A_{14}$ | $PI_{41}$ | 0.182 | 5 | 1700400.00 |
| $S_2$ | $A_{21}$ | $PI_{12}$ | 0.004 | 16 | 60600.00 |
| | $A_{22}$ | $PI_{22}$ | 0.009 | 15 | 189840.00 |
| | $A_{23}$ | $PI_{32}$ | 0.023 | 11 | 508200.00 |
| | $A_{24}$ | $PI_{42}$ | 0.200 | 4 | 1090000.00 |
| $S_3$ | $A_{31}$ | $PI_{13}$ | 0.047 | 9 | 381780.00 |
| | $A_{32}$ | $PI_{23}$ | 0.215 | 2 | 940800.00 |
| | $A_{33}$ | $PI_{33}$ | 0.455 | 1 | 1692600.00 |
| | $A_{43}$ | $PI_{43}$ | 0.110 | 6 | 1008250.00 |
| $S_4$ | $A_{41}$ | $PI_{14}$ | 0.0096 | 14 | 288456.00 |
| | $A_{42}$ | $PI_{24}$ | 0.0224 | 12 | 1270080.00 |
| | $A_{43}$ | $PI_{34}$ | 0.042 | 10 | 1327200.00 |
| | $A_{44}$ | $PI_{44}$ | 0.214 | 3 | 931950.00 |
| | | | | | **Total maintenance cost= Rs.12023348.00** |

***"Table4.7: Result: Details of section (in the order of their importance) and maintenance activities to be carried out"***

| Sections | Activities | Rank | Maintenance cost(rates) |
|---|---|---|---|
| $S_1$ (overall importance of the section Ws= 0.87) | $A_{11}$ | 13 | 67872.00 |
| | $A_{12}$ | 8 | 141120.00 |
| | $A_{13}$ | 7 | 424200.00 |
| | $A_{14}$ | 5 | 1700400.00 |
| $S_2$ (overall importance of the section Ws= 0.17) | $A_{21}$ | 16 | 60600.00 |
| | $A_{22}$ | 15 | 189840.00 |
| | $A_{23}$ | 11 | 508200.00 |
| | $A_{24}$ | 4 | 1090000 |
| $S_3$ (overall importance of the section Ws= 0.86) | $A_{31}$ | 9 | 381780.00 |
| | $A_{32}$ | 2 | 940800.00 |
| | $A_{33}$ | 1 | 1692600.00 |
| | $A_{34}$ | 6 | 1008250.00 |
| $S_4$ (overall importance of the section Ws= 0.16) | $A_{41}$ | 14 | 288456.00 |
| | $A_{42}$ | 12 | 1270080.00 |
| | $A_{43}$ | 10 | 1327200.00 |
| | $A_{44}$ | 3 | 931950.00 |
| | | | **Total cost= 12023348.00** |

**Comparison of the proposed Methodology**

 

The methodology proposed in this study is illustrated with the help of an example of a small hypothetical highway network consisting of 4 sections. Three different level of funds available i.e 25 %, 50 % and 75 % is considered and results were compared to assess the suitability of the proposed methodology. The results obtained using proposed methodology is compared with the practice of resource allocation on ad-hoc basis (i.e. resources are allocated to more important sections first ). The comparison clearly illustrates that the methodology proposed in this study allocates the limited resources more rationally.

The following three different cases are considered

Case-I A = 25 %funds available

Case-I B = 50%funds available

Case-I C = 75 %funds available

The results obtained for resource allocation for case IA (When 25 ٪ Budget Available) is presented in Table 4,.8

***"Table No.4.8 Analysis and Result for Resources Allocation (Case – I A)"***

**Case-I A = When 25 ٪ Budget Available**

| S.no. | Resources Allocation Based On Proposed Methodology (Priority Index) | | | | Resources Allocation Based On Present Practices (Importance Of Section) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Section** | **Activity** | **Designation** | **Resources Allocated** | **Section** | **Activity** | **Designation** | **Resources Allocated** |
| **1** | $S_3$ | Patching (Pothole) | A32 | 940800.00 | $S_1$ | Crack filling | A11 | 67872.00 |
| **2** | $S_1$ | Patching (rutting) | A13 | 424200.00 | $S_1$ | Patching | A12 | 141120.00 |
| **3** | $S_1$ | Patching (Pothole) | A12 | 141120.00 | $S_1$ | Patching | A13 | 424200.00 |
| **4** | $S_3$ | Crack filling | A31 | 381780.00 | $S_3$ | Crack filling | A31 | 381780.00 |
| **5** | $S_2$ | Patching (rutting) | **A23** | 508200.00 | $S_3$ | Patching | A32 | 940800.00 |
| **6** | $S_1$ | Crack filling | **A11** | 67872.00.00 | $S_2$ | Crack filling | A21 | 60600.00 |
| **7** | $S_4$ | Crack filling | **A41** | 288456.00 | $S_2$ | Patching | A22 | 189840.00 |
| **8** | $S_2$ | Patching (Pothole) | **A22** | 189840.00 | $S_2$ | Patching | A23 | 508200.00 |
| **9** | $S_2$ | Crack filling | **A21** | 60600.00 | $S_4$ | Crack filling | A41 | 288456.00 |

The results obtained for resource allocation for case IB (When 50 ٪ Budget Available) is presented in Table 4,.9

***"Table No. 4.9 Analysis and Result for Resources Allocation (Case – I B)"***

**Case-I B= When 50٪ Budget Available**

| S.no. | Resources Allocation Based On Proposed Methodology (Priority Index) | | | | Resources Allocation Based On Present Practices (Importance Of Section) | | | |
|---|---|---|---|---|---|---|---|---|
| | **Section** | **Activity** | **Designation** | **Resources Allocated** | **Section** | **Activity** | **Designation** | **Resources Allocated** |
| **1** | $S_3$ | Patching (Pothole) | A32 | 940800.00 | $S_1$ | Crack Filling | A11 | 67872.00 |
| **2** | $S_1$ | Overlay | A14 | 1700400.00 | $S_1$ | Patching | A12 | 141120.00 |
| **3** | $S_1$ | Patching (Rutting) | A13 | 424200.00 | $S_1$ | Patching | A13 | 424200.00 |
| **4** | $S_1$ | Patching (Pothole) | A12 | 141120.00 | $S_1$ | Overlay | A14 | 1700400.00 |
| **5** | $S_3$ | Crack Filling | A31 | 381780.00 | $S_3$ | Crack Filling | A31 | 381780.00 |
| **6** | $S_2$ | Patching | **A23** | 508200.00 | $S_3$ | Patching | A32 | 940800.00 |

 

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | (Rutting) | | | | | | |
| **7** | $S_4$ | Patching (Pothole) | **A42** | 1270080.00 | $S_2$ | Crack Filling | A21 | 60600.00 |
| **8** | $S_1$ | Crack Filling | **A11** | 67872.00.00 | $S_2$ | Patching | A22 | 189840.00 |
| **9** | $S_4$ | Crack Filling | **A41** | 288456.00 | $S_2$ | Patching | A23 | 508200.00 |
| **10** | $S_2$ | Patching (Pothole) | **A22** | 189840.00 | $S_4$ | Crack Filling | A41 | 288456.00 |
| **11** | $S_2$ | Crack Filling | **A21** | 60600.00 | $S_4$ | Patching (Pothole) | A42 | 1270080.00 |

The results obtained for resource allocation for case IC (When 75 % Budget Available) is presented in Table 4.10

***"Table No. 4.10 Analysis and Result for Resources Allocation (Case – I C)"***

**Case-I C = When 75% Budget Available**

| **S.no.** | **Resources Allocation Based On Proposed Methodology (Priority Index)** | | | | **Resources Allocation Based On Present Practices (Importance Of Section)** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Section** | **Activity** | **Designation** | **Resources Allocated** | **Section** | **Activity** | **Designation** | **Resources Allocated** |
| **1** | $S_3$ | Patching (Rutting) | A33 | 1692600.00 | $S_1$ | Crack Filling | A11 | 67872.00 |
| **2** | $S_3$ | Patching (Pothole) | A32 | 940800.00 | $S_1$ | Patching | A12 | 141120.00 |
| **3** | $S_1$ | Overlay | A14 | 1700400.00 | $S_1$ | Patching | A13 | 424200.00 |
| **4** | $S_1$ | Patching (Rutting) | A13 | 424200.00 | $S_1$ | Overlay | A14 | 1700400.00 |
| **5** | $S_1$ | Patching (Pothole) | A12 | 141120.00 | $S_3$ | Crack Filling | A31 | 381780.00 |
| **6** | $S_3$ | Crack Filling | A31 | 381780.00 | $S_3$ | Patching | A32 | 940800.00 |
| **7** | $S_4$ | Patching (Rutting) | A43 | 1327200.00 | $S_3$ | Patching (Rutting) | A33 | 1692600.00 |
| **8** | $S_2$ | Patching (Rutting) | **A23** | 508200.00 | $S_2$ | Crack Filling | A21 | 60600.00 |
| **9** | $S_4$ | Patching (Pothole) | **A42** | 1270080.00 | $S_2$ | Patching | A22 | 189840.00 |
| **10** | $S_1$ | Crack Filling | **A11** | 67872.00.00 | $S_2$ | Patching | A23 | 508200.00 |
| **11** | $S_4$ | Crack Filling | **A41** | 288456.00 | $S_4$ | Crack Filling | A41 | 288456.00 |
| **12** | $S_2$ | Patching (Pothole) | **A22** | 189840.00 | $S_4$ | Patching (Pothole) | A42 | 1270080.00 |
| **13** | $S_2$ | Crack Filling | **A21** | 60600.00 | $S_4$ | Patching | A43 | 211470.00 |
| **12** | $S_4$ | Patching (Pothole) | A43 | 211470.00 | $S_4$ | Patching (Rutting) | A43 | 1327200.00 |

The results obtained using proposed methodology is compared with the practice of resource allocation on ad-hoc basis (i.e. resources are allocated to more important sections first ) and results are given From the Table 4.8 to Table 4.10. The comparison clearly illustrates that the methodology proposed in this study allocates the limited resources more rationally on the basis of the following facts:

- The proposed methodology allocates resources first to activity A33 i.e Rutting (Patching) on section 3 while based on present practice resources are first allocated to to activity A11 i.e maintenance of crack filling on section 1. Further note that overall importance of the section (Ws) of section S1 is 0.87 and for section S3 is 0.86. Section 1 is most important, however the proposed methodology allocates resources to Rutting (Patching) on section 3 which is nearly equal important to section 1 and also maintenance in form of Rutting (Patching) is more important/urgent as compare to filling of cracks and so on. Hence it may be concluded that proposed methodology allocates resources more rationally considering the following:

- Present distress condition of the section
- Future distress condition of the section
- Importance/urgency of a particular type of distress to be maintained
- Importance of highway class of the section
- Political importance as well as importance to community of the section (i.e importance of the places connected by the section)

## V. CONCLUSIONS AND RECOMMENDATIONS

The basic objective of this study was to develop a methodology for allocation of limited resources available for maintenance of a highway network. Some of the important conclusions drawn from this study can be summarized as follows:

- There is an urgent need to develop an appropriate methodology for allocation of limited resources available for maintenance of a highway network so that the limited resources available for highway maintenance can be utilized optimally.
- It is more rational that limited resources needs to be allocated based on the maintenance priority of various activities needs to be carried out on different highway sections
- maintenance priority of various activities can be determined on the basis of:
  - Present distress condition of the section
  - Future distress condition of the section
  - Importance/urgency of a particular type of distress to be maintained
  - Importance of highway class of the section
  - Political importance as well as importance to community of the section (i.e importance of the places connected by the section)
- The methodology proposed in this study is illustrated with the help of an example of a small hypothetical highway network consisting of 4 sections. Three different level of funds available i.e 25 %, 50 % and 75 % is considered and results were compared to assess the suitability of the proposed methodology. The results obtained using proposed methodology is compared with the practice of resource allocation on ad-hoc basis (i.e. resources are allocated to more important sections first). The comparison clearly illustrates that the methodology proposed in this study allocates the limited resources more rationally.
- Methodology allocates resources in the order of their maintenance priority which is determined considering the distress conditions as well as the importance of the section where maintenance activities needs to be carried out. Therefore, the resources are allocated where they are more urgently needed and also considering the importance of the section.
- For example, The proposed methodology allocates resources first to activity A33 i.e Rutting (Patching) on section 3 while based on present practice resources are first allocated to to activity A11 i.e maintenance of crack filling on section 1. Further note that overall importance of the section (Ws) of section S1 is 0.87 and for section S3 is 0.86. Section 1 is most important, however the proposed methodology allocates resources to Rutting (Patching) on section 3 which is nearly equal important to section 1 and also maintenance in form of Rutting (Patching) is more important/urgent as compare to filling of cracks and so on. Hence it may be concluded that proposed methodology allocates resources more rationally considering the following:
  - Present distress condition of the section
  - Future distress condition of the section
  - Importance/urgency of a particular type of distress to be maintained
  - Importance of highway class of the section
  - Political importance as well as importance to community of the section (i.e importance of the places connected by the section)

Based on the example considered in this study, it may be concluded that the methodology presented in this study allocates resources to different maintenance activities considering the condition of distresses, urgency of that distresses to improve that will be maintained by that activity, highway class where that activity to be carried out, political importance as well as importance to community of the section that is to be maintained.

## REFERENCES

[1] Agarwal, P.K.,"Road Condition, Prioritization and optimal resource allocation for Highway Maintenance at Network Level", Ph. D. thesis, Department of Civil Engineering, IIT Kanpur, Kanpur, 2006.
[2] IRC82-1982 code of practice for maintenance of bituminous surfaces of highway New Delh.

 