A Review on Pavement Maintenance System for Low Volume Roads

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Abstract: Road network serves as backbone of country as it provides support for development and growth of nation. If road condition is good and network is adequate it enables quick, safe and comfortable movement for goods and passengers between two places. Pavement maintenance plays quite important role in upkeeping service life of any road. After the introduction of PradhanMantri Gram SadakYojna significant improvement is there in village road development. There is need for maintenance system for these PMGSY roads as no systematical maintenance practices are followed by concerned agencies for these low volume roads. Pavement maintenance system comprises of inspecting pavement condition, rating pavement condition, prioritizing road network and optimizing various pavement maintenance strategies in systematic manner. First of all, data is collected from field by conducting various experiments regarding pavement condition and entered into database. This collected data is analyzed according to codal guidelines and based on that various maintenance strategies are optimized. Soft computing-based Pavement maintenance system would be more beneficial rather than conventional pavement maintenance system due to budgetary constraints of various government road agencies. Pavement maintenance system would be helpful in achieving maximum benefits under allocated budget. Road network prioritization and optimization of alternative maintenance strategies would be helpful in awarding contracts and arranging labors, materials, equipments for small scale pavement maintenance projects.

Keywords: Low volume road, Maintenance, Pavement condition, Economy

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I. INTRODUCTION

Road network plays an important role in economic development of any nation as it links industries and service sector with consumers. For holistic development, it is most important to connect rural areas with nearby trade centers and urban areas. Rural road connectivity plays important role in economic and social development of region as well as of nation. According to Economical Survey 2022 – 2023 around 65 percent population of total population lives in villages in India. For livelihood, 47 percent population of total population is dependent on agriculture and activities allied to agriculture. As two third population residing in rural areas it is most important to provide road connectivity amongst villages and towns. Only road network provision is not sufficient but to maintain road network in good condition for improvement in livelihood of villages is also needs to be considered. PradhanMantri Gram SadakYojna (PMGSY) is the scheme of Government of India which focuses on development of road network in rural area.

For the maintenance of road assets in longer run, timely maintenance is very beneficial. Pavement maintenance reduces the deterioration rate of pavement which ultimately improves service life of pavement. Timely maintenance of pavement not only not only improves service life but also reduces number of accidents and also reduces operating cost of vehicles.

Maintenace plan of road network must follow some principles having scientific basis. In first step condition of pavement and strength of pavement needs to be evaluated. To identify the type of distress, location of distress and severity of distress pavement condition surveys needs to be conducted. In depth reviews to determine the causes of distresses are done after the visual inspection and conduction of pavement condition surveys. Based on distress analysis decision needs to be taken that whether to initiate maintenance work or needs to investigate more for evaluation of maintenance requirements. After that maintenance plan should be formed for all the roads which comes under jurisdiction of concerned road agency.

II. NEED FOR PAVEMENT MAINTENANCE SYSTEM

Having road connectivity is not only enough, but it is also essential to maintain this road network and to keep these roads in good condition. Normally, Village roads are maintained by state agencies in India. There are no any systematic maintenance practices adopted by concerned road agencies for maintenance of pavement. As construction of Village roads accelerated after 2000 and continuing, in current time allocated budget for maintenance activities to concerned agencies is very limited. There is a need to develop for Pavement Maintenace System for village roads so that maximum roads can be maintained in limited budgetary constraints.

In current practice, selection of maintenance treatment for pavements having distresses by concerned state agencies does not follow any systematic process with scientific basis. Road agencies have budgetary limitations for maintenance of low volume village roads. Pavement maintenance system would be helpful in achieving maximum benefits with limited budget. Timely maintenance of pavement would be helpful in minimizing maintenance cost and maintaining service life of pavement. As the maintenance gets delayed, many times pavement can not treated and complete rebuilt of pavement requires in that case. According to World bank document Selecting Road Maintenance Systems (1997) depending upon the category of road and number of vehicles, due to timely maintenance of pavement the rate of return can be as high as 15% to 20%
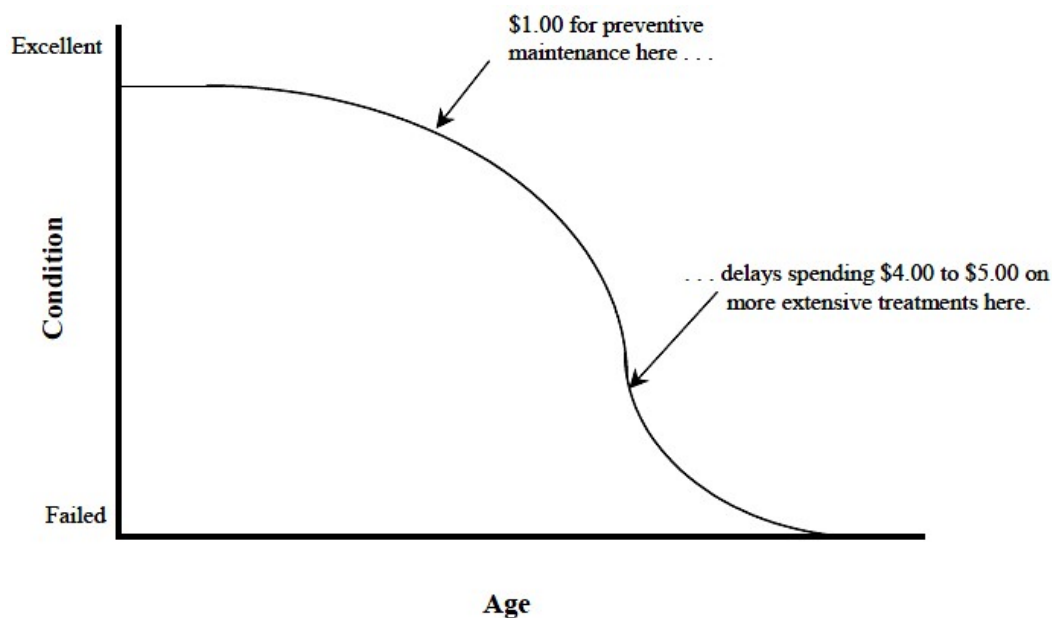

Fig. 1 Effects of delays in maintenance on cost of maintenance (World Bank Document, 1997)

III. LEVELS OF PAVEMENT MAINTENANCE SYSTEM

Pavement maintenance system can be implemented at two levels:

1) Network level
2) Project level

In network level pavement maintenance system, all roads under jurisdiction of concerned agency are evaluated at same time. Aim of network level pavement maintenance system is to develop a maintenance program by prioritizing maintenance requirement such that under total budget agency can yield maximum benefit. Network level pavement maintenance system can work on more approximate data as compared to project level management. In network level system, short term budget needs and long-term budget needs as well as present condition and future condition of overall network are having main concerns. Network level management is helpful in prioritizing the maintenance work. In network level maintenance system, roads are mainly evaluated through visual inspection and no complex methods are adopted to collect the pavement condition data.

Project level pavement system is focused on particular location under the jurisdiction of concerned agency rather than overall network in network level system. When the agency analyzes total road network under its jurisdiction, after that particular location for project level pavement maintenance system can be identified. As in network level pavement maintenance system no

detailed data had been collected, to propose maintenance strategy for particular location detailed investigations needs to be carried out. So, in project level maintenance once the location is identified than detailed data collection and data analysis is carried out for project level maintenance planning. Project level maintenance planning would be more economical and more beneficial rather than network level maintenance planning. Project level maintenance planning can be done for multiple locations at single time after network level identification.

IV. FRAMEWORK OF PAVEMENT MAINTENANCE SYSTEM

Pavement maintenance system is a sequential process which is useful to agencies associated with road maintenance works starting from evaluation of existing conditions to selection of maintenance strategies so that the pavement can be serviceable up to its design life. Data collected would be first stored into database and analysis would be performed. Based on information revealed from analysis various strategies would be optimized.
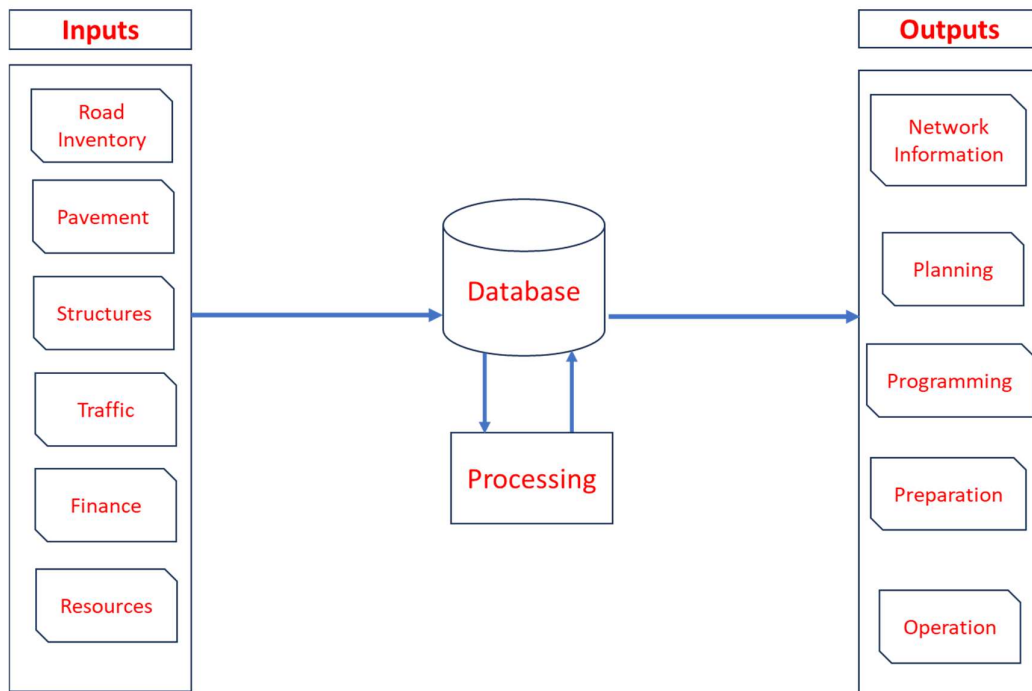

Fig.2 Framework of Pavement Maintenance System (Proceedings of the Highway Policy Seminar for Countries of the Former Soviet Union, 207 – 216 p.)

For national highways, state highways and urban roads system with automated monitoring is essential whereas for village roads system with visual inspection may be appropriate. In Pavement Maintenance System as huge data is collected, it is essential to have strong database mechanism. Data is analyzed and information revealed based on data analysis would be further uses for decision making process.
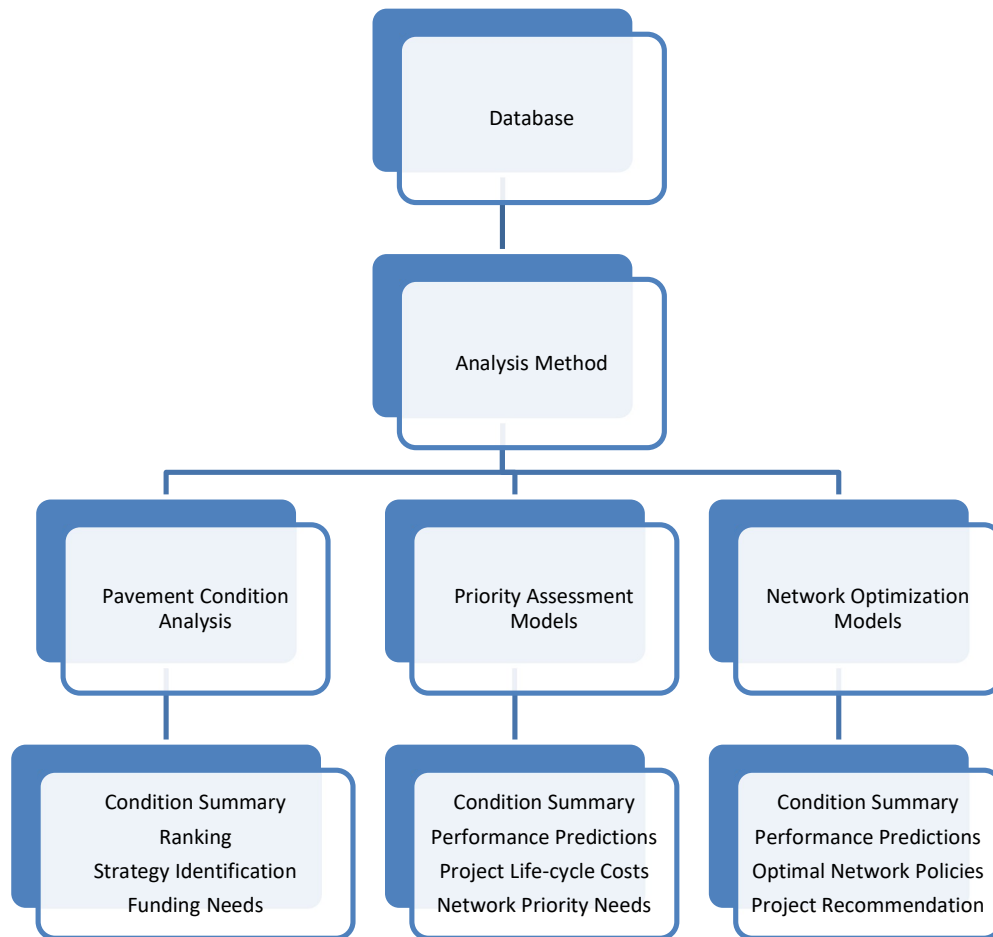
Fig. 3 Modules of Pavement Maintenance System, (Al-Kheder, 2005)

V. METHODOLOGY

A. Selection of road network

Due to limited budget for pavement maintenance, there is a need for prioritizing roads having basis of scientific methodology. To prioritize roads multiple factors like distresses in pavement, vehicle volume, nearby places having socio – economical importance is very important. Rutting, Raveling, Patching, Pothole, Cracking are considered as distresses in pavement. Total traffic, Total commercial traffic, Total truck traffic are various factors which being considered for vehicular factors. Medical facilities, educational facilities, Demographics are considered as socio – economic factors.

Pavement distress can be defined as deficiency in current condition of pavement as compared to its original condition. Pavement distresses having similar characteristics needs to be grouped. According to IRC 30, pavement distresses can be classified as below:-
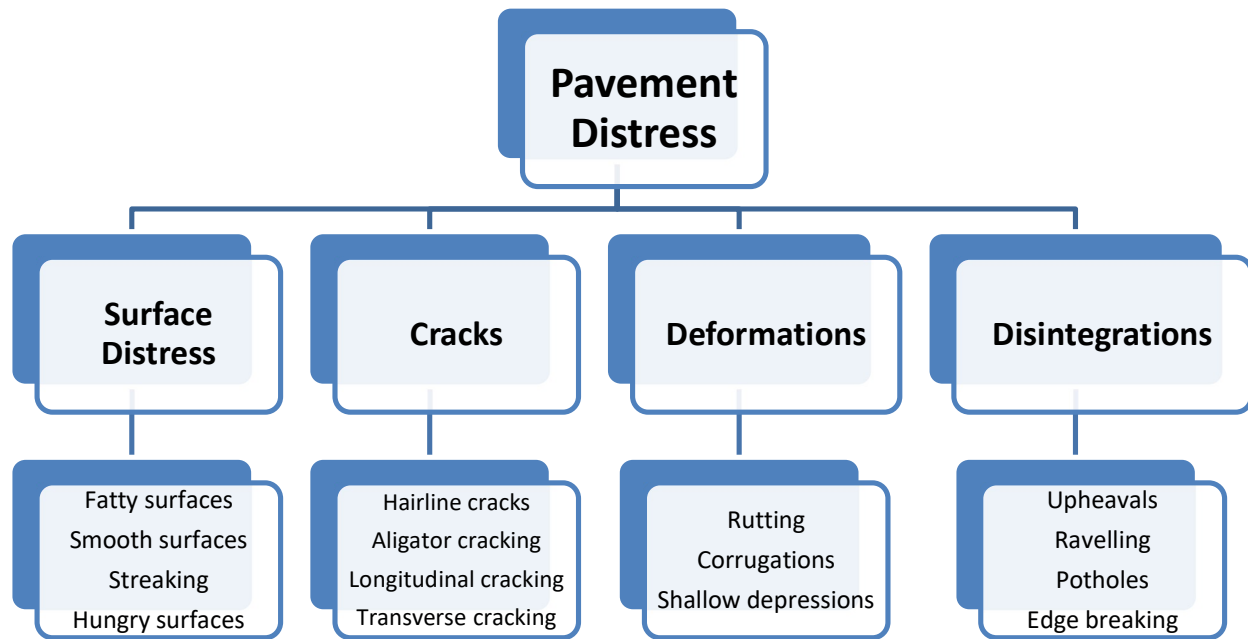
Fig. 4 Classification of Distresses according to IRC 82 - 2015

Due to insufficient quality and quantity surface distresses occurs. Normally, surface distresses are limited to the surface only. Cracks occurs in bituminous pavement with passing time. Based on severity, cracks are classified into various groups. When changes occur in original shape of pavement surface, it is known as deformation. Deformation in pavement is not limited to single layer. Normally, it extends to multiple layers. Defects which in initial stage if not corrected than leads towards completely reconstruction of pavement are considered as Disintegration.

Abhayet. al. (2016) developed Pavement Performance Index (PPI). Formula of PPI developed is based on rating criterion and severity weightage. Saranyaet. al. (2013) considered cracking area, pothole area, Roughness, Ravelling and vehicle damage factor for their study of pavement deterioration modeling. They had developed cracking, pothole, roughness progression model and developed Riding Comfort Index (RCI) model. Mathew et. al. (2008) used Artificial Neural Network and Regression Analysis for development of Pavement Deterioration Model. They had considered ravelling, pothole, roughness and edge failure for modeling purpose. Reddy et. al. (2005) developed Riding Comfort Index (RCI) for pavement maintenance needs. Moazamiet. al. (2011) considered total 19 distresses having different types for their study. To make easier evaluation all 19 distresses had been converted into Pavement Condition Index (PCI).

Traffic had been considered as important factor by many researchers for network level pavement maintenance system. L. Janani. et. al. (2018) considered traffic as important factor for prioritization of pavement maintenance sections. They had developed Maintenance Priority Index (MPI). Qaseemet. al. (2023) conducted study to establish relationship between Pavement Condition Index and Traffic Characteristics. Socio – Economic factors are considered in many studies of pavement maintenance system. As there are many factors IRC SP 20 – 2002 can be referred to convert all facilities value into road utility value.

B. Prioritization of Pavement

If one considers network of roads within cluster, all roads are not having same amount of deterioration and does not require maintenance at one moment. The roads having more damage and more importance are the one which should be prioritize first for maintenance. First of all, damage in roads is first assessed and then on basis of traffic and socio – economic factors, roads are selected. Ranking system needs to be implemented for maintenance works. There are various methods available for ranking like empirical methods, expert opinion etc. Empirical models need lots of data and are costly. If collected data is not accurate or less in quantity, reliability of model is not up to mark. Hence, opinion from experts having expertise in pavement maintenance are taken for ranking purpose. Experts having good skills, experience, knowledge are interviewed and various sets of questions are asked to them related to various types of failures in pavement. Based on opinion of experts ranking is done for prioritizing maintenance. Expert opinion method is very economical and gives better results as compared to empirical models.

Delphi technique is interactive technique which is used for ranking priority by interviewing experts. At least two rounds are organised in forms of written question answer in Delphi technique. At the end of first round interviewer gives summary of the opinions and judgements by all respondents. Based on this all respondents are asked to reconsider their opinion based on other's

opinions. In next round, attempts are made to achieve unique solution. Dhamaniyaet. al. (2014) calculated the utility values of roads for network level planning of maintenance works for roads developed under PMGSY by Delphi technique.

When boundary of dataset or information is not clear cut at that time Fuzzy set theory founds to be very effective for decision making process. From Fuzzy set theory Fuzzy logic can be derived. Chandranet. al. (2007) conducted study for eight pavement sections to develop Pavement Maintenance System. They had formulated Fuzzy membership functions. Based on that for each pavement section Fuzzy Condition Index was determined. For prioritization of pavement sections Fuzzy rankings were used.

Thomas L. Saaty developed Analytical Hierarchy Process for decision making based on Mathematics and Psychology. In AHP multilevel hierarchical structure of goals, objectives, criteria, sub criteria and alternatives is involved. Questions are designed and respondents compares expert opinions to determine the importance of factors through pair – wise comparisons. Chiraget. al. (2019) used Analytical Hierarchy Process for Pavement Maintenance Prioritization. They had considered traffic characteristics and distress data. Consistency ratio was calculated by dividing consistency index with random index to check consistency in judgements. Sarfarazet. al. (2017) used objective based Analytical Hierarchy Process for prioritization of pavement maintenance works. Total 28 road sections from Mumbai city were selected for study. While interviewing experts for pavement maintenance works, opinions given by experts are based on their skill, knowledge and experience, it does not consider the actual quantitative physical conditions of roads. Solutions based on Analytical Hierarchy Process were compared with Road Condition Index.

C. *Optimization*

Quality of maintenance treatment and its cost both plays significant role in pavement maintenance prioritization. Basically, there are two types of pavement maintenance optimization model.

1) Linear Optimization Model
2) Multi Objective Optimization Model

In linear optimization model aim is to maximize quality of maintenance with limited costs. In multi objective optimization model aim is to minimise cost of maintenance and improving maintenance quality. Bosurgi&Trifiro (2007) developed model for pavement maintenance management which were based on Artificial Neural Networks and Genetic Algorithms. Over a short period, Artificial Neural Network provided one optimal solution among many others. Mathew & Isaac (2007) used three models to determine future performance of pavements. Models were developed by Artificial Neural Network, Deterministic Regression Analysis and Multivariate Adaptive Splines. They had concluded that artificial neural network model is best amongst three for future pavement condition prediction.

VI. IMPLEMENTATION PROBLEM

Many developing countries may face problem in adopting and implementing pavement maintenance system due to: -

- Attitude of users; To implement Pavement maintenance system genuine commitment is essential
- Resistance to modifications also affects the implementation
- Issues related to work culture; No incentives for adopting modified practices
- Financial problems at local level
- Vacant positions of key staff or staff lacking adequate experience
- Training issues; Less time for staff to attend training due to operational reasons, Less time for practice and revision
- Old versions of hardware and software and lack of resources

VII. FINDINGS FROM THE STUDY

- Pavement maintenance system at local agency level which are associated with PMGSY roads will enable concerned decision makers to utilise maintenance budget for maximising benefits and effective use of resources.
- Asit depends on stronger political will, it is quite essential to have commitment for change from political side and strong support to implement the change
- There is a scope for utilization of HDM – 4 cost modelling for optimization purpose
- Delphi technique would be useful for expert selection which may in later stage would be used for rating by Analytical Hierarchy Process

REFERENCES

[1]   Moazami, H. Behbahani, and R. Muniandy, " *Pavement rehabilitation and maintenance prioritization of urban roads using fuzzy logic,*" Expert Syst.Appl., vol. 38, no. 10, pp. 12869–12879, Sep. 2011, doi:10.1016/J.ESWA.2011.04.079

[2]   S. Chandran, K. P. Isaac, and A. Veeraragavan, *"Prioritization of low-volume pavement sections for maintenance by using fuzzy logic",* Transp. Res. Rec., vol. 1, no. 1989, pp. 53–60, 2007, doi: 10.3141/1989-06.

[3]   Brown B.B., *Delphi process: "A methodology used for the elicitation of opinions of experts*" Santa Monica, California: RAND corporation, 1968. Accessed: Apr.29, 2022. [Online]. Available: https://apps.dtic.mil/sti/citations/AD0675981

[4]   T. L. Saaty, *"Fundamentals of decision making and priority theory with the analytic hierarchy process",* RWS publications, 1994.

[5]   The Word bank*, Selecting road management systems,* DOC1101 Issue, March 1997.

[6]   *Proceedings of the Highway Policy Seminar for Countries of the Former Soviet Union*, Moscow, 15-19 May 1995. Washington DC: International Bank for Reconstruction and Development/World Bank, 207–216p.

[7]   SaranyaUllas, Sreelatha T, B.G Sreedevi, "*Pavement Distresses And Roughness Modeling – A Case Study*", International Journal of Innovative Research in Science, Engineering and Technology, 2013

[8]   Mathew, B.S., Reshmy, D.S., and Issac, K.P., 2008*. "Performance Modelling of Rural Road Pavements Using Artificial Neural Network"*, Indian Highways, Indian Roads Congress, 36(1), January, pp.31-39.

[9]   Reddy, B.B, Sharma, R.S., and Veeraragavan, A., 2005. *"Development of flexible pavement preservation framework for an integrated Asset management."*, Journal of Indian Roads Congress, 66(1) ,April , pp.383-418

[10] AbhayTawalare, K. VasudevaRaju, "*Pavement Performance Index for Indian rural roads*", Recent Trends in Engineering & Material Sciences, 2016

[11] L. Janani, Raunak Kumar Dixit, V. Sunitha & Samson Mathew, "*Prioritisation of pavement maintenance sections deploying functional characteristics of pavements*", International Journal of Pavement Engineering, 2019

[12] MaenQaseemGhadi, Hesham Ahmad and Ismael Jannoud, "*Influence of Traffic Characteristics on Pavement Performance of Parking Lots"*, Infrastructures 2023, 8, 65, DOI: 10.3390/infrastructures8040065

[13] Chirag R. Bhuva, Prof. Bindiya Patel, Prof. Mayank Kanani, "*Pavement maintenance and prioritization using AHP: A case study of Rajkot city*", Journal of Emerging Technologies and Innovative Research, 2019

[14] Sarfaraz Ahmed , P. Vedagiri , K.V. Krishna Rao, "*Prioritization of pavement maintenance sections using objective based Analytic Hierarchy Process"*, International Journal of Pavement Research and Technology, 2017

[15] IRC:82-2015, *Indian Roads Congress Code of Practice for Maintenance of Bituminous Road Surface*, First revision. New Delhi, India: Indian RoadCongress, 2015

[16] IRC: SP:20-2002*, Rural Road Manual,* SpecialEdition20 ed. New Delhi India, Indian Road Congress, 2002