Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 3, March -2017

A REVIEW ON GIS-BASED PAVEMENT MAINTENANCE MANAGEMENT SYSTEM FOR URBAN CORRIDORS

Milaa Murshan[1], Monicaba Vala[2]

PG Student[1] Assistant Professor[2]
Department of Transportation Engineering at MarwadiEducation Foundation Rajkot[1]
Department of Civil Engineering at MarwadiEducation Foundation, Rajkot[2]

Abstract – *Maintaining of the roadway infrastructure takes great amount of time and money, big amount of money is invested in road maintenance to ensure the mobility of people and goods. However, deteriorations of road condition affect the quality of surface riding and can also represent an increased safety hazard to the users, leading to more accidents, with their associated human and property costs. Thus identify maintenance needs will result in control costs. Maintenance is essential to preserve and enhance economic and social benefits. The researches focused on the basic science of GIS and tried to use it for road networks maintenance. Indeed before adopting road maintenance programs to ensure these roads are in good condition all the times, good GIS database is essential to ensure maintenance is done in effective manner. Therefore, set of Spatial and attribute information of road network such as road name, road length, road geometry, classification of road whether it is local, residential collector or arterial, number of lanes, pavement width, rating and type of pavement, maintenance status and history and current condition of road should collect to develop such relational database. This database will be useful for ease of analyses and ease of visual and graphical displays of results. Integration of using GIS with pavement and other roadway maintenance and with improving highway safety lead to enhance decision making process and save time and money in future, so it is recommended that use a GIS in every transportation agencies.*

Keywords – *GIS, Pavement maintenance, pavement management, and database.*

I. INTRODUCTION

Preventive maintenance programs like Road rehabilitation reduce road repairs and expenditures and by help of GIS we can control cost, allocated funds, utilize the available budget in effective manner, priority maintenance, support decision making and maintain more number of roads with limited funds. Many researchers have been attempted to use the GIS in planning of road maintenance for showing the graphical conditions of pavement and predicting the future pavement condition.

II. STEPS FOR MANAGING ROADS

Managing the roads requires three procedures i) inventories of existing condition ii) Rating and evaluation of pavement conditions iii) using these evaluations to set maintenance prioritization.

i) Inventories of Existing Condition: include classification of road (local, residential, collector and arterial), length of road, pavement width, and geometry of road, pavement type (flexible, rigid or composite), construction, maintenance, rehabilitation history and current condition of the road.

ii) Rating and Evaluation of Pavement Conditions: there are many methods for rating the pavement condition one of them is pavement condition rating PCI which is numerical value from 0 to 100 where 0 indicates to the worst condition and 100 indicates to the best condition. As shown in table (1):

TABLE 1
PAVEMENT CONDITION INDEX VALUE

PCI Range	Pavement Condition	General Treatments
90-100	Excellent	Do Nothing
80-90	Very Good	Corrective Maintenance
75-80	Good	Preventive Maintenance
60-75	Fair	Resurfacing
40-60	Poor	Rehabilitation
20-40	Very Poor	Rehabilitation
0-20	Failed	Reconstruction

PCI can be calculate from the following formula:

PCI = 100 – Total Deduct

Total Deduct = Sum of Deduct Points

Where,

PCI= Pavement Condition Index

DP = Deduct Point

DP= N * S * E

N= (distress weight) Number of distresses of same type

S= Defect's Severity

E = Extent of Defect along the section

i) Set Maintenance Prioritization:

Simple Ranking Technique SRT for rating pavement condition depending on **Priority Index**

PI = DL / (TF * DF)

Where;

DL: Defect Length is the sum of defects for one distress type for entire section.

TF: Traffic Factor is the constant based on the traffic level prevailing on the section or arterial.

TABLE 2
Traffic Factor Value

ADT, VPD	TF
2500	0.1
2500-10000	0.5
>10000	1

Defect Factor (DF): is a numerical value that is allocated for every section depends on the type of defect and the required treatment as shown in Table 3:

TABLE 3
DEFECT FACTOR VALUE

Defect	Treatment	Defect Factor
Open Potholes	Rehabilitation	0.10
Alligator Cracking	Rehabilitation	0.15
Reflection Cracking	Rehabilitation	0.20
Rutting	Reshape & overlap	0.30
Old Patching	Overlay	0.50
Lean Surface texture	Surface dressing	0.70
Edge Fretting	Edge Patching	1.00
Low Shoulder	Shoulder Work	1.00

The following equation may be use to compute the priority index for all deteriorated sections on road network:

$$PI = \left(\frac{\text{ADT}}{\text{ADTavg}}.\right) * 10/[\left(\frac{\text{PSR}}{\text{PSRavg}}.\right) * \left(\frac{\text{R}}{\text{Ravg}}.\right)]$$

Every variable in every section has weight this weight can be computed from the following formula:

$$W_{ij} = \left[\frac{\frac{1}{R_{ij}}}{\sum(\frac{1}{R_{ij}})}\right] * (100\%)$$

Where W_{ij} and R_{ij} are weights and ranks of section i for variable j, respectively. Then the weight, that is a measure for priority, would be:

$$PI_i = W_{i1} + W_{i2} + W_{i3}$$

Where PI_i is PI for section i, W_{i1} is weight of section i for (ADT), W_{i2} is weight of section i for (PSR), and W_{i3} is weight of section i for (R). It was concluded that an automated system that integrate GIS, GPS and CVS is very useful for data collection, analysis, operation, display and classification of pavement damage data. The development of the system is a step in real-time disaster classification.

III. LITERATURE REVIEWS

(**Howard J. Simkowitz, 1998) [1]** Introduced the transportation applications of geographic information systems. He explained why GIS technology is important to transportation professionals, described how a number of transportation agencies are using GIS and provided insight on how to participate in this technology and he concluded with a more details and discussion of hardware and software requirements, topology, overlay processing, and special issues involved in design a GIS for transportation.

(Debbie A. Niemeier et al. 1993) [2] evaluated the differences between the GIS and non- GIS model computations and an analysis of how the differences in the two models alter travel demand estimation and quantify the improvements of GIS model and concluded that these differences were due human errors and inconsistent consideration of environmental and geographical constraints.

(Adel S.Aldosary et al, 1996) [3] Carried out an endeavored study to develop an application mechanism for a GIS-based maintenance system based on a study KFUPM. In this context, geographic information systems (GIS) have evolved as an effective tool to improve efficiency in the daily affairs of the maintenance, demonstrated cost-benefit analysis of the use of geographic information systems in the application of the mechanism maintenance system they concluded that GIS can be used instead of the current manual technique used in most large establishments to handle spatial data which is inefficient, time consuming, difficult to use.

(C. M. Thong et al. 1997) [4] used GIS to design a traffic information database for urban transport planning and he concluded that the treatment in the future implementation of geographic information systems, and will be many unexpected issues which are highly important in the implementation of GIS in transportation planning coverage.

(Jean-Claude Thill, 2000) [5] Conducted a study to place the concept of transportation GIS in the broader perspective of research in GIS and Geographic Information Science. Emphasis was placed on the specific needs of transport from the application of this technology is the emerging information. The paper concluded with a synopsis of dominant themes in current research in GIS for transportation. For this program successful quest should solidify the position of GIS as an integrated system for transportation research and management.

(Shih-L.S. et al. 2003) [6] introduces a temporal geographic information systems (GIS) design that offers Exploratory data for the study of interactive land use and transportation interaction in the user SPECI spatial fi ed and timetables analysis capabilities and concluded that the framework of spatial-temporal interaction used in this study provides a general structure for the leadership of analysts methodology for the exploration and use of land and interact in a manner which.

(Manoj K. Jha et al. 2004) [7] Developed a model for highway alignment optimization that integrates a GIS with genetic algorithms to examine the effects of various costs on alignment optimization that explores optimization in constrained spaces that realistically reflect the limits on road improvement projects and concluded that the model can optimize alignments in mountainous terrain or regions with very complex geography.

(Mohammed T.O. et al. 2006) [8] These research activities have been carried out to examine the potential of the integration of the Geographical Information System (GIS), the Global Positioning System (GPS) and the Computer Vision System (CVS) to enable flexible allocation of road and maintenance priorities. The classification process included distress type, distress severity level and options for repair. In this study, a system scheme that integrates the above-mentioned systems was developed. The system utilized data collected by GPS and a PC-based vision system in a GIS environment. GIS Are-view software was used for the purpose of data display, query, manipulation and analysis. The equipment which used in their work are Canon digital camera power shot, off-the shelf vision system, GPS 48 personal navigator system and GIS Arc-View software. In this study given classification of distresses based on measurement methods and units.

(Bhoj R.P. et al. 2010) [9] Developed a Geographic Information Systems (GIS)-based maintenance model considering pavement and roadside slope stability conditions. They have prepared a pavement maintenance priority map based on pavement condition. Researchers had used International Roughness Index (IRI) as the pavement condition index. Similarly, a roadside slope maintenance priority map is produced through analysis of slope stability conditions. combining the road and road slope maintenance priority maps, taking into account the weighting of each maintenance component, a comprehensive maintenance priority map is generated and concluded that GIS can manage and visualize different types of data together or separately and can aid in the decision making process Himalaya Regional road maintenance planning.

(B.t .Hassan et al. 2010) [10] A typical model of roads in Penang, Malaysia was used as a case study to further clarify the application of GIS in road maintenance. It was concluded that the adoption of GIS will lead to a more organized management of digital data especially those related to road data. Particularly, these system applications will also increase work productivity in managing road maintenance. The authors also showed GIS capability improving data accuracy reduce data duplication and increase work productivity. Thereby GIS will lead to more organized management of digital data of roads.

(Asma T.I. et al. 2012) [11] Authors study the suitability of applying Geographic Information System (GIS) for Maintenance Strategy Selection. A GIS based system that provides information for use was built as a platform on which all aspects of the Pavement Maintenance and Management System (PMMS) process can be built. The resulting system, GPMMS, can represent a significant enhancement of all aspects of the PMMS process. In this paper, Along the road of Nahrian University has chosen 23 parts, all of these parts are due to different reasons, such as weathering, aging, traffic load, and poor maintenance and so on. The range of PSI of these sections was between 1 to 4 and most of these sections in the low range were between 1 to 2. It was concluded that various spatial synthesis data are important for pavement management decisions. GIS technology has proven to be the most logical way to relate these diverse but relevant data.

(Karwan G. F. et al. 2014) [12] had developed an approach to produce a GIS database for road surface monitoring. In their paper, they had proposed a system for establishing the GIS database includes geo-tagged photographs, and local authorities automatically record and report road surface distress in the process. The method used fast and flexible interface to create a database from the field collected data, including geo-tagged photos. Further, the method provides a flexible data collection option, where only handheld GPS receivers and digital cameras are used in the field. Personal computer or cable connections were required. It was concluded that the developed method has significant benefits and proven performance using an easy and cost-effective technique in road surface monitoring.

(Lucia R. et al. 2015) [13] The authors had presented a holistic platform for pavement monitoring and maintenance management (PMMP) centered on RMS features, which is a web-based solution based on PMMS requirements and recommendation made in EU programs: RIMES and PAV-ECO. They had tried to exploit new technologies in order to design, Integration and implementation of automated and portable visual road inspection systems for distress monitoring and analysis of traffic speed pavements that can be installed in non-specialized vehicles. The PAV3M solution is based on PMMS requirements and is recommended in the EU program as a modular decomposition based on business process analysis. Automatic image and video analysis of pavements is based on ESRI (Environmental Systems Research Institute) products as ArcGIS, GIS as low-cost solutions for vehicles, cameras and other sensors.

(Adeleke O. O et al. 2015) [14] Developed rational database of spatial and non-spatial information based on digital map of the road, coordinates of location of defect, type of defect and its size. They evaluated and rated pavement surface on the road using pavement condition rating PCR form and scale**.** They concluded that GIS can be used successfully to build up PMS as a support tool for pavement maintenance strategy selection. This study recommended that road maintenance agencies should use GIS as support tool for pavement management and similar geospatial assets because of its ability to analysis the data, query capability and its capability of visual and graphical representation.

(Nihat M. et al. 2016) [15] Developed a performance models for pavement management systems application with geographic information system (GIS) method. They had use software in visual basic programming language for the developed model. It was found that using the software, both the present condition of the pavement can be examined and future performance based on expected traffic values can be predicted. The software can be used at both network and project level. In this study, the cost and benefit values were taken from the literature of determining the cost-benefit ratio. Using this model developed, a five-year maintenance and rehabilitation program can be planed for a given database considering the budget restraints. It was concluded that the developed software permit the data transfer to database, analyses and different scenario applications for showing results for GIS.

CONCLUSION

Based on the previous researchers' attempts, there is a growing need to use GIS in transportation planning, operation and maintenance and to use GIS to improve highway safety and give safety classification and to use GIS in decision-making process to define priority road interventions and to use GIS to design a traffic information database for urban transport planning and to use GIS exploratory data analysis approach and to use GIS for environmental modeling system for transportation planners and to use GIS for highway alignment optimization model and to use GIS in pavement distress classification, managing road maintenance and road surface monitoring and to use GIS in highway maintenance prioritization model and maintenance strategy selection and to use GIS for giving solutions for pavement management and monitoring systems. However, there are challenges in the field of GIS-T such as technical issues of representation , the social issues of economics, unambiguous communication of location , dealing with standards, the economic modeling of GIS-T, data creation and use, economic models, and response to new technologies, and application of knowledge gained from GIS-T and ITS research to other fields.

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