DEVELOPMENT OF NETWORK LEVEL PAVEMENT MANAGEMENT SYSTEM FOR LOW VOLUME RURAL ROADS

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Degree of Master of Philosophy

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DECLARATION OF THE CANDIDATE & SUPERVISOR

I declare that this is my research proposal and this proposal does not incorporate without acknowledgment any material previously published submitted for a Degree or Diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

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R.M.K. Sandamal

I have read the proposal and it is in accordance with the approved university proposal outline. I am willing to supervise the research work of the above candidate in the proposed area.

Signature of the supervisor: …………………………. Date: ……………………………

Dr. H.R. Pasindu

DEDICATION

I dedicate this dissertation to Dr. H. R. Pasindu, my supervisor who encouraged me to conduct the study successfully, and to my parents, brother & wife who supported me throughout.

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ABSTRACT

In Sri Lanka, there is about 156,000 km length of roads and among those about 92% are considered as rural roads (LVRRs). These roads are playing a pivotal role in community development, transport of people, goods, and services in the rural areas by providing connectivity between residential, agricultural areas and the national road network. In the future, with rapid motorization takes place, it is expected the traffic volume on these roads will increase significantly. Limited funding, subjective and ad-hoc maintenance decision making has resulted in suboptimal maintenance level for these road networks. Moreover, the inability to collect extensive data which are needed to run most of the existing pavement management systems (PMSs) and the technical expertise required has resulted in the low usage of such systems by local road agencies. Therefore, there is a need to develop a cost-effective simplified approach for network-level decision-making to assist in pavement maintenance management.

The study explored the applicability of smartphone-based roughness data to assess the pavement condition of LVRRs as a novel pavement performance evaluating criteria by validating its accuracy compared with a Class III type roughness measurement equipment. The correlation value between the two measurements was high as 0.84. Even though, the relationship has shown that smartphone roughness slightly underestimates road roughness still it can apply to LVRRs as a cost-effective, accurate method. Moreover, it was assessed whether roughness results represent pavement distress conditions in the LVRRs. Regression models were developed to find the relationship between International Roughness Index (IRI) and key distress types. It was found that Raveling, Edge Breaking, Pothole, Edge Breaking, Edge Gap has shown a good correlation with IRI as 0.61, 0.56, 0.55, 0.52 respectively. Further, to evaluate the combined effect of distress on IRI progression, stepwise multiple regression analysis was conducted by considering the roadway width and the model for narrow roads had an R-squared of 0.89. For the wider roads the model accuracy is high as with R-squared of 0.86. Interestingly, pothole was identified as the key distress type in both models while edge breaking and edge gap only relevant in narrow roads. Finally, IRI progression was evaluated with the Pavement Condition Index (PCI) and a non-linear relationship was found with an R-squared of 0.75 from the sigmoidal function. Moreover, relationship between IRI with Pavement Serviceability Rating (PSR) was evaluated and found that a good relationship with R-squared of 0.76 for the model.

The relevant maintenance strategies used for LVRRs were identified by establishing threshold and trigger values based on the works of literature and current practice in the Sri Lankan context. To support the decision-making criteria, an analysis scheme was developed by using a defined decision tree. The objective function was established as the minimization of the average network IRI value which represents the maximum network condition. Two analysis systems were developed; one with Integer Programming and the other with a Genetic Algorithm (GA) based system. In addition to that, Engineer's judgment was compared with the two methods by using an illustrative example. From the results, it was found that GA is always provided the optimum work program while Integer Programming merged into a suboptimal level. Although Engineer's objective decision-making has shown significant variation when there is a budgetary constraint. However, when there is a sufficient amount of budget available most of the Engineer's judgments were also close to the optimum solution.

Further, in this study socio-economic importance was incorporated in the maintenance planning decision-making scheme by using the multi-objective optimization analysis. A socio-economic priority index was developed by using the priority factors namely traffic volume, land use, community importance & accessibility to the road network. In there, a network-level maintenance strategy budget estimation tool will also be introduced by considering different road surface conditions and maintenance strategies used in LVRRs. The set of optimal solutions for the multi-objective problem generated using the 'Pareto Optimality' concept. A case study was performed and found that the method would be useful in prioritizing the roads having socio-economic importance. Furthermore, another illustrative example was performed by incorporating safety performance in decision criteria using a predefined parameter called Cumulative Safety Index (CSI). The study has also shown that rather than spending money on optimizing a single objective, optimization of multiple objectives at a time would be a better option since the improvement of the existing network is higher in that case. Moreover, the multi-objective optimization approach would provide ability to include objective functions which cannot be incorporated in single objective optimization approach.

The core attributes of the proposed system are, reduced the data requirements, simplified the analytical tools and allowing users to customize considering the resource constraints in prioritization and optimization and that would allow road agencies to make objective decisions and optimize the road maintenance process. The finding from this research can be used for

maintenance planning for local road authorities in Sri Lanka as well as for other developing countries by adopting the parameter defining for their local context.

Keywords: Roughness; low volume rural roads; pavement management systems; smartphone-based roughness data; socio-economic importance; multi-objective optimization

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LIST OF ABBRIVIATIONS

Abbreviation	Description
LVRR	Low Volume Rural Road
PMS	Pavement Management System
PCI	Pavement Condition Index
PSR	Pavement Serviceability Rating
GA	Genetic Algorithm
CSI	Cumulative Safety Index
HV	Heavy Vehicle
RDA	Road Development Authority
ADT	Average Daily Traffic
MOO	Multi-Objective Optimization
PRDA	Provincial Road Development Authority
HDM	Highway Development and Management Model
ADB	Asian Development Bank
UN	United Nation
FHWA	Federal Highway Administration
M&R	Maintenance & Rehabilitation
DM	Decision Maker
LCC	Life Cycle Cost
DoT	Department of Transportation
GIS	Geographical Information System
AASHTO	American Association of State Highway & Transportation Officials
AADT	Average Annual Daily Traffic
ESAL	Equivalent Standard Axle Load
USA	United States of America

ASTM	American Standard of Testing & Materials
AHP	Analytical Hierarchy Process
ANN	Artificial Neural Network
M-E	Mechanistic & Empirical
GPS	Geographical Positioning System
RMS	Root Mean of Square
CV	Coefficient of Variation
AC	Asphalt Concrete
HMA	Hot Mix Asphalt
PCC	Portland Cement Concrete
WSM	Weighted Sum Method
SOO	Single Objective Optimization
eIRI	Estimated International Roughness Index
cIRI	Calculated International Roughness Index
ANOVA	Analysis of Variance
VIF	Variation Inflation Factor
LKR	Sri Lankan Rupees
PI	Priority Index