International Journal of Latest Trends in Engineering and Technology
Vol.(16)Issue(1), pp.026-032
DOI: http://dx.doi.org/10.21172/1.171.04
e-ISSN:2278-621X

COMPARISON OF ROUGHNESS PREDICTION MODEL DEVELOPED USING HDM-4 AND GENETIC PROGRAMMING (GP) FOR URBAN ROADS OF PATIALA

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Abstract- Road sections retrograde and results in disfiguring of the entire road section prior to its design life and this is due to the insufficient maintenance and rehabilitation activities. Maintenance activities plays major role in the stability of any particular level of serviceability (LOS). For determining maintenance strategies, Roughness prediction is most important. In this study, Roughness prediction was done for the urban road sections of city Patiala. Roughness was predicted with the help of two different techniques i.e. HDM-4 and Genetic Programming (GP). For this study road condition surveys along with different distresses measurement was done for 16 road sections. Data was collected for four consecutive years, from 2012 to 2015 period. Out of these four years data, first two years data was used to develop model of Roughness using genetic programming technique and the next two years data was used to validate the models developed. This study also includes the development of Pavement Maintenance Management System (PMMS) for all the 16 sections by using the calibrated HDM-4 models for the urban road network. It also includes determination of Remaining Service Life (RSL) and selection of Optimum Maintenance strategies.

Keywords- Urban Roads, Roughness, HDM-4, GP, RSL and PMMS.

I. INTRODUCTION

The pavement maintenance and management plays a very important role to keep the pavements within the serviceability levels both at the project level considering detailed maintenance management practices. PMMS at project level solve various maintenance management issues related to the selection of the optimal maintenance solutions and to determine the cost effectiveness of various maintenance alternatives. Application of HDM-4 software at project level for developing PMMS of Patiala road sections has been discussed in this study. Remaining serviceable life (RSL) notion has been around for decades and is well enrooted within pavement community. It is a traffic application from initial construction or reconstruction to first major rehabilitation as if changes in age with respect to time. Its prime purpose to provide a logical process that will create an event and timing of those events to bring out life-cycle analysis. It is necessary to develop some scientific approach to compute RSL of road sections and many researchers have been working on the development of accurate and efficient methods to calculate RSL of road sections. Aggarwal et al. [1] developed a critical appraisal of pavement management systems which helped to validate pavement conditions with provision of different strategies for improving. Aggarwal et al. [2],[3] developed pavement management system for Indian national highway network and its use in developing countries by calibrating models with respect to Indian conditions. They concluded that adoption of condition responsive gives more economical outcomes with increase in life of pavement. Gupta et al.[7] carried study about determining the remaining service life of urban flexible pavement. They prepared deterioration models for prediction of distresses and for maintenance management strategies for selected urban road network. Jain et al.[9] carried study by using HDM-4 for road management in India for uplifting present scenario of road networks by utilization of software to predict upcoming difficulties and their prevention measures for increasing life span with different maintenances and rehabilitation. Keraliet al.[10] discovered about the role of HDM-4 in highway management which acclaimed about the increase in

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infrastructure with emphasize on road constraint with development management. Pinenaaret al.[14]brought the comparison of HDM-4 with HDM-3 on case study in Swaziland in order to show the most effective software to give better results within a limited financial constraint in which accuracy and precision counts for forthcoming scenario. Highway Development and Manegement-4 tool acts as future decision making tool for road network management and is applied to predict road deterioration effects, work effects and user effects *etc.* Chopra et al.[4] developed pavement maintenance management system (PMMS) of urban road using HDM-4 model and also performed comparative analysis of scheduled type and condition responsive type M&R strategies. This present study aims to develop PMMS for 16 road sections of urban city Patiala using HDM-4, which is further used to predict roughness and also using two years dataset GP was used to develop roughness model, using which roughness of next two years was predicted and compared with actually observed values.

II. ANALYSIS USING HDM-4 MODELS

2.1 Road Network and Vehicle Fleet data input in HDM-4

The basic data input in HDM-4 are Road Network and Vehicle Fleet Data. Road Network refers to the network having number of road sections with their characteristics. Vehicle Fleet Data refers to representation of vehicles and their characteristics.

Road Network

For the present study, Road Network named as 'Patiala City Road Network' has been created. 16 road sections with Section ID UR01-UR016 have been entered in HDM-4. Each road section with its definition, geometry, pavement and condition data has been inputted. Prior to this, Traffic Flow patterns have been created in Configuration part. Climate Zone 'North India Plain' has been selected for the study. The traffic detail and road parameters, pavement type and condition of various road networks have been entered in HDM software. This road network has been further used to determine the objectives.

VEHICLE FLEET

For the study, Vehicle Fleet named as 'Patiala City Vehicle Fleet' has been created. Eight types of Motorized Vehicle (MT) *i.e.*, Two-wheeler, Car/Jeep/Van, Auto-Rickshaw, Bus (Medium), Mini-Bus, Truck, Mini-Truck and Tractor/Trolley and three types of Non-Motorized Vehicle (NMT) *i.e.*, Cycle, Man-Driven Rickshaw and Cart have been included in this vehicle fleet. All the vehicles with their basic characteristic data and economic unit costs were entered as inputs into vehicle attributes under vehicle fleet section in HDM-4 software as shown in Fig.1. This vehicle fleet has been used further for determining the objectives of the present study.

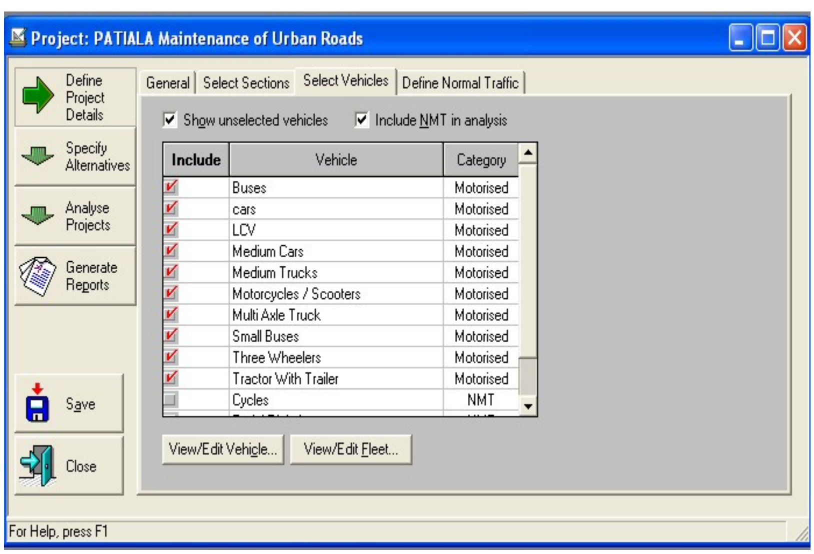

Fig. 1: Vehicle Fleet with all the Vehicles Defined

2.2 RSL of Road Sections

RSL of a road section means the time period in years after which the reconstruction of the pavement is to be carried out by the agencies, providing no Maintenance and Rehabilitation (M&R) works throughout the intervening period. 'Project Analysis' in HDM-4 has been selected for determining this parameter.

A new project named as 'Determination of RSL' was created which consisted of 'Patiala City Road Network' and 'Patiala City Vehicle Fleet' as inputs. The intervening period (analysis period) for the analysis of the project was taken as 10 years keeping in mind that all the selected road sections will require reconstruction work within next ten years when no maintenance work is provided during the intervening period. Analyse by project was chosen for analysis. Fig.2 shows general input data for Project: RSL of pavements.

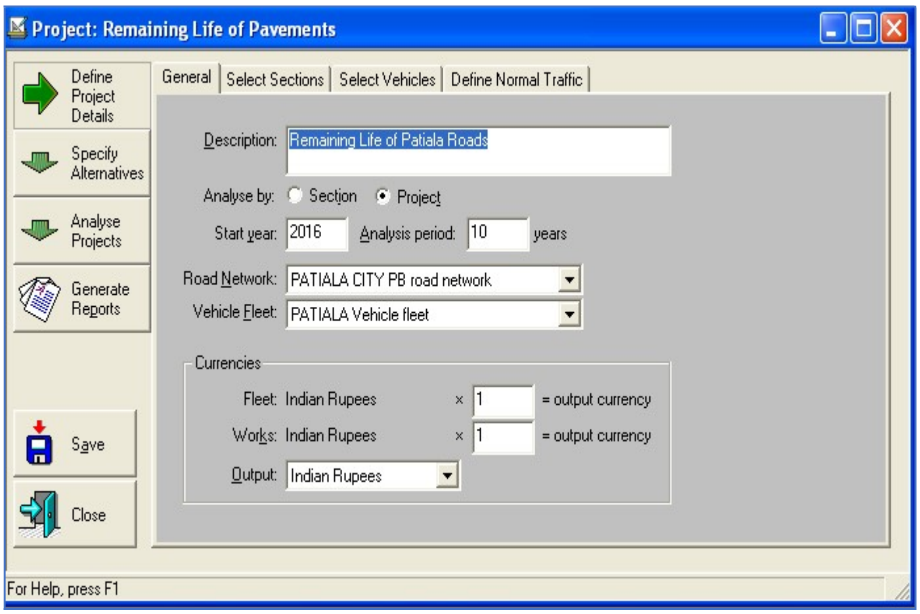

Fig. 2: General Input Data for Project: Determination of RSL

The condition responsive alternative named as 'No maintenance till Reconstruction' has been defined for the project in which 'Reconstruction' maintenance work standard was assigned along with intervention criteria to each road section. As road roughness plays a vital role in PMMS, Roughness >= 6 m/km IRI has been taken as intervention criteria for reconstruction work. The Roughness progresses with each year (start year - 2016). If it exceeds intervention value *i.e.,*> = 6 IRI in a certain year, Reconstruction alternative shall be triggered for that year. Fig. 3 show roughness progression graph for all the selected road sections. The sharp fall in average roughness values indicates the reconstruction work of the road section in that certain year. RSL of all the pavements is the network is determined in terms of the number of years left before the reconstruction of the road surface is required based upon the condition responsive intervention criteria of roughness in terms of IRI. Reconstruction will be initiated till the roughness value of the surface progress till the intervention criteria of roughness. RSL of all the road sections were computed from the above mentioned roughness progression graphs and road work summary report of the road sections. Fig.4 shows the computed RSL values of each road section. It can be observed from Fig.4 that all the road sections will require reconstruction work within 0 to 9 years if no M&R work is assigned to the road sections throughout the intervening period.

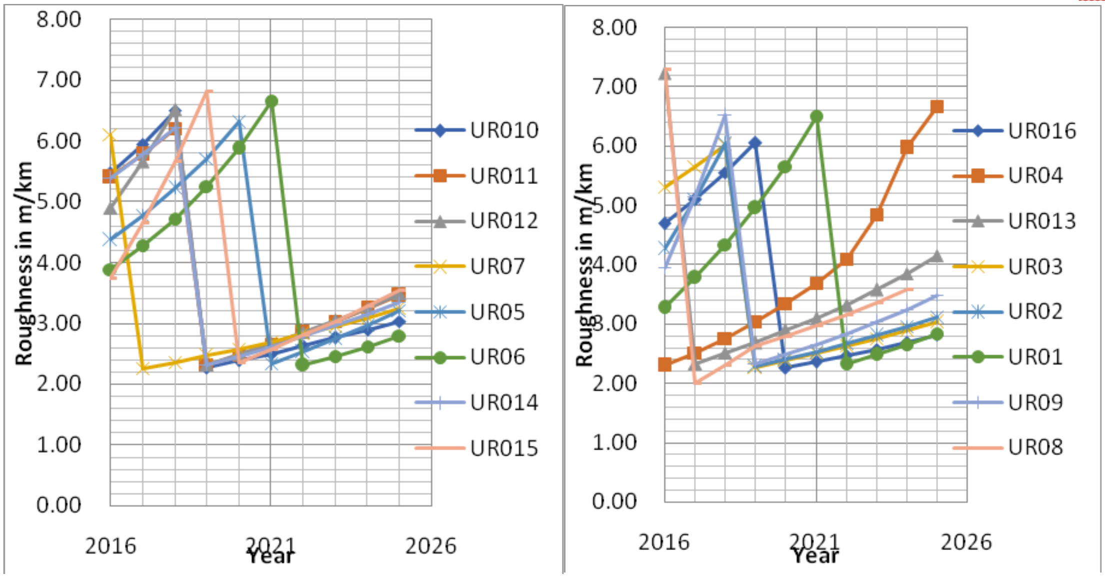

Fig. 3: Roughness Progression for all Road Sections

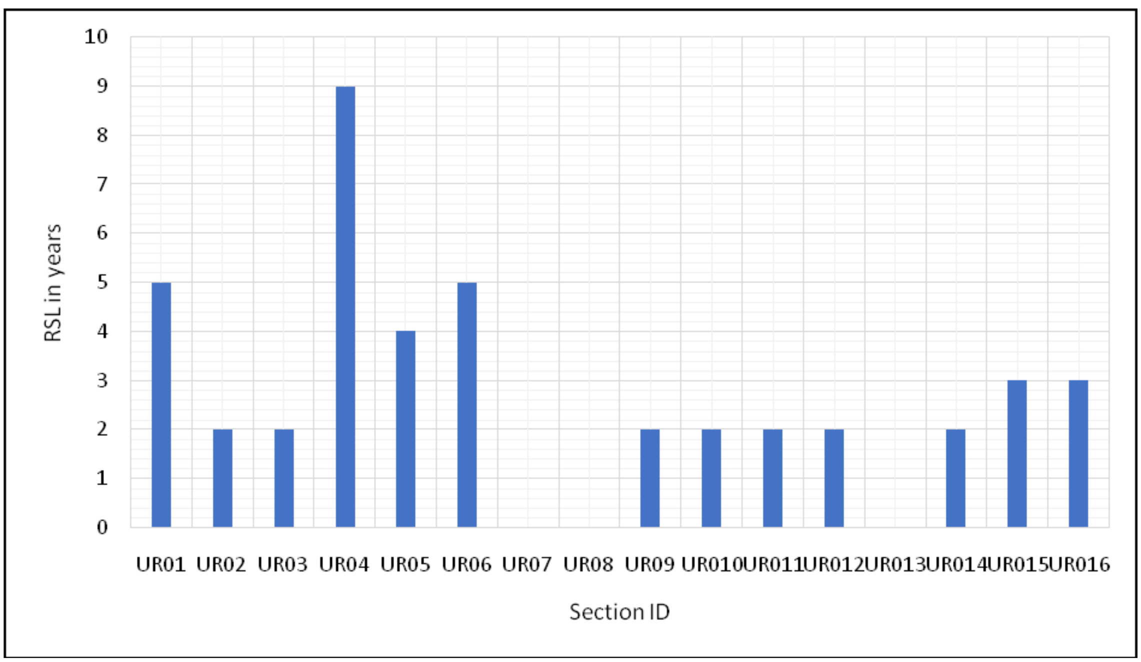

Fig. 4: RSL (in years) for various Road Sections

RSL value of the road section will help the road agency to know the imperative time for reconstruction work prior to the failure of entire road. Budgeting and funding for reconstruction work can be done accordingly. The Roughness progression graphs of all the alternatives for the road sections UR010 is shown in fig 5 with a calculated average calibration factor of 1.2 for the roughness progression. The intervention criteria for various alternatives have been successfully implemented as predicted from the roughness progression values and the drop in the roughness value as soon as the maintenance alternative has been provided. Alternative 1 to 5 corresponds to routine maintenance, resealing, thin overlay, thick overlay, resealing plus overlay and reconstruction respectively. Base alternative is considered as No maintenance given criteria.

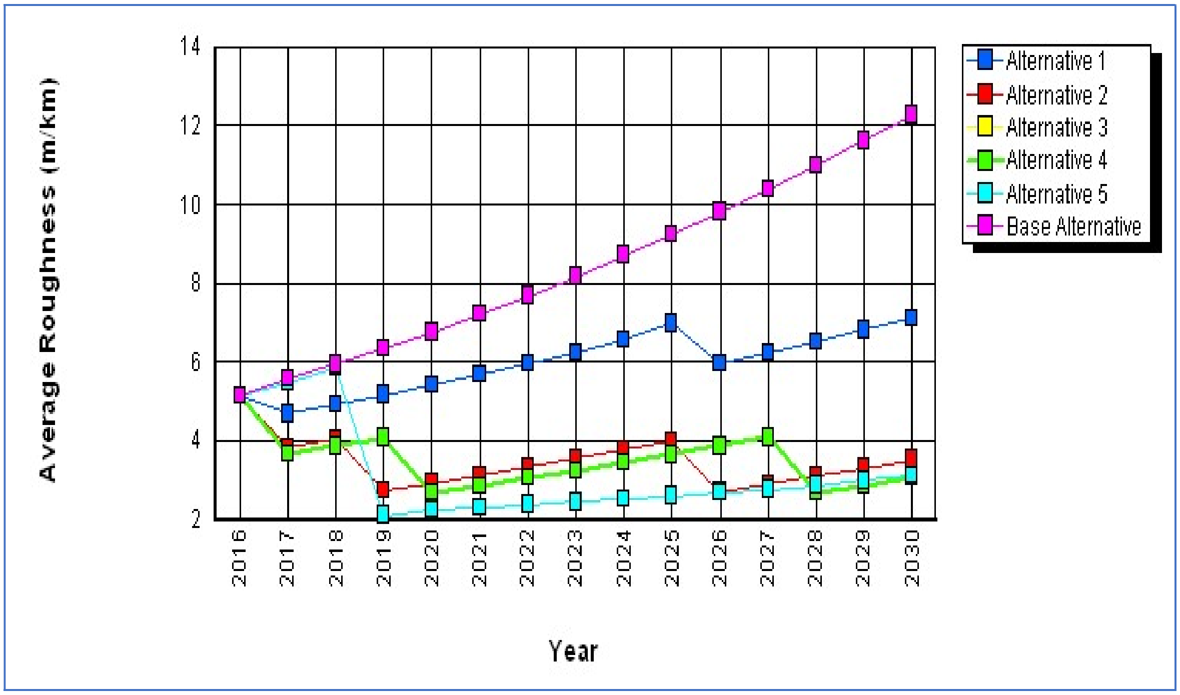

Fig 5: Roughness Progressions under All Alternatives for UR010

III. MODEL DEVELOPMENT USING GENETIC PROGRAMMING (GP)

3.1 Introduction to Genetic Programming (GP)

GP has commenced as an endeavour to discover how computers could be trained to solve problems without being explicitly programmed to do so. GP is an extension to genetic algorithms proposed by Koza (1992) who defines GP as a domain independent problem-solving approach in which computer programs are evolved to solve, or approximately solve, problems based on Darwinian principle of reproduction and analogy of naturally occurring genetic operations such as reproduction, crossover and mutation. The five major prelude steps for the basic version of GP require the user to specify: a) the set of terminals for each stem of the to-be-evolved program; b) the set of primitive functions for each stem of the to-be-evolved program; c) the fitness measure; d) certain parameters for controlling the run; e) the termination criterion and method for designating the result of the run.

3.2 Development of GP Model for Roughness

The dataset used for GP model development is same as used in the development of HDM-4 models. The control parameters as given in Koza (1992) have been investigated in this study. The data set gathered during the years 2012 and 2013 have been used for training models, *i.e.,* for the prediction of year 2013 pavement distress, the data set of year 2012 has been used. The GP model for progrssion of roughness has been developed for this study as shown in Table 1. The post-regression fits for the training data set model (Model R.1) is presented in Fig.6, respectively.

Table 1: GP Model for Progression of Roughness for Urban Roads

Model R.1 (Roughness Progression)	$IRI_j = 1.254\left(\frac{(ESA_i \times AGE_i \times IRI_i)}{(ESA_i \times RD_i \times dNPT \times AGE_i) + (12.048 \times IRI_i) + (ESA_i^{3} \times AGE_i)} + (IRI_i)\right.$ *Where, IRI_j is roughness of next year, IRI_i is roughness of previous year, ESA_i is the number of equivalent standard axle repetitions in the analysis year (in millions), AGE_i is age of pavement before the start of analysis year, dNPT is change in the number of potholes during analysis year, RD_i is rut depth in the previous year.*

It can be seen from Fig.6, it can be observed that for Model R.1*i.e.,* Roughness Progression as shown in Table 1, the value of R^2 is 79.4% with the value of RMSE of 0.04. It can be observed from Fig.6 that the deviation can be noticed between observed and predicted values because of modeling approach adopted. But, this variation is quite reasonable for the urban road section with different age and traffic loading conditions.

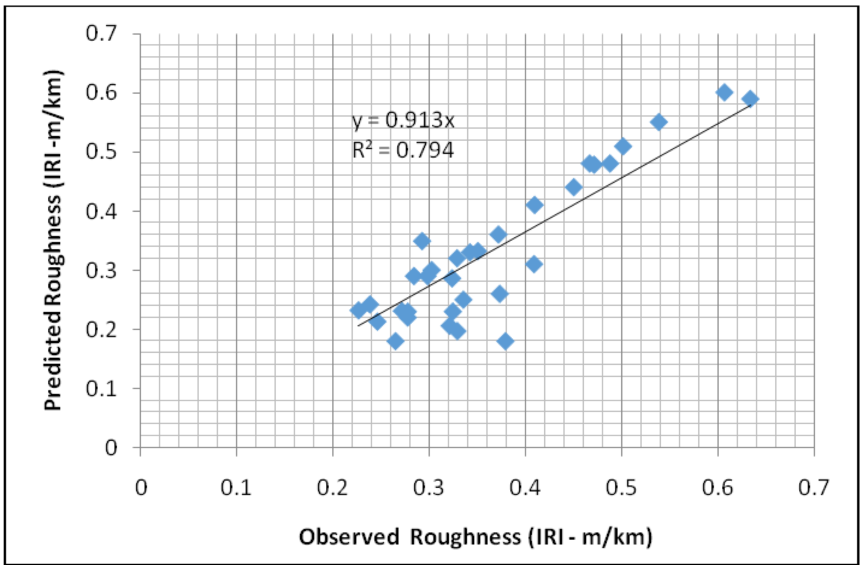

Fig.6: Scatter Plot between Observed vs Predicted Roughness for Training

3.4 Validation of GP Models

To further test the efficacy and reliability of the models, the data sets collected during the years 2014 and 2015 have been used for the validation purposes. For the prediction of pavement distress of year 2014, the data gathered during year 2013 has been used and for the prediction of pavement distress of year 2015, the data gathered during year 2014 has been used. The value of R^2 obtained using Model R.1 has been used to obtain the roughness progression and the values of R^2 obtained for year 2014 and year 2015 are 98.11% with RMSE 0.76 and 98.64% with RMSE 0.09, respectively. The GP model has been predicting with good competence for both the data sets (2014 and 2015). The results are revealing that these GP models can be applied successfully to the roads of Patiala City, Punjab, India.

IV. CONCLUSION

1. All the road sections taken in this study of Patiala city will be needing reconstruction work within 0 to 9 years if no maintenance and rehabilitation work is assigned to the road sections throughout the intervening period as predicted by using calibrated roughness model of HDM-4. The calibration factor of 1.2 has been calculated for the selected road network using window technique.

2. It can be said that developed GP model has a strong correlation between observed and predicted values of roughness progression in terms of IRI and it gives better distress prediction than the calibrated HDM4 model for the roughness. As an outcome, we can say that GP models provide good results for the prediction of pavement roughness and may serve as a predictive model for the prediction of pavement distress for the urban road network and will be useful to develop the pavement maintenance management system by providing optimal design of maintenance strategies for the urban road network.

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