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A COST-BENEFIT OPTIMIZATION MODEL FOR MAINTENANCE AND REHABILITATION ACTIVITIES OF ROADS

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ABSTRACT: The support and recovery of existing, develop street offices are winding up slowly progressively noteworthy and essential parts of roadway action. A proficient upkeep and recovery arrangement is fundamental for a sheltered, agreeable and financially savvy transportation framework. Be that as it may, choices to keep up existing street offices include various conceivable alternatives in exercises going from routine upkeep to restoration or recreation, in decisions for assignment of assets all through a parkway arrange, and to choose ventures versus non-speculation choice. Additionally, any financial investigation ought consider the cost fact or as well as be intended to give greatest inclusion of advantages like changes in streetupkeep costs, changes in mishap rates, expanded travel or request, ecological impacts, change in estimation of merchandise moved, changes in agrarian yield, changes in administrations, changes in mechanical yield, changes in land esteems, and so forth. Because of these attributes building up a support and recovery strategy for streets is troublesome and new ideas and systematic methodologies should be acquainted with location this issue. Streamlining models is one such systematic methodology which helps in making a money saving advantage examination of upkeep and restoration exercises of streets and in contrasting the different conceivable choices with give out the best movement inside the financial backing designated, before being really done in down to earth.

In the present investigation it was meant to define a multi-target streamlining model considering all fundamental just as adequate elements mindful in 'upkeep and recovery exercises' of expressway offices in order to limit the absolute expense and increment the all out return in wording profits by enhanced street condition subject to the useful impediments looked by concerned organization and client because of decay in street condition. A non-overwhelmed arranging hereditary calculation II (NSGA-II) based C writing computer programs was contemplated and used toapprove the created model. In conclusion, the proposed streamlining model is contrasted and ongoing field information gathered from National Highway Division, Dhenkanal, Odisha in order to guarantee its usefulness and ease of use.

Keywords: Analytical Models, Multi-Objective Optimization Model, Road Maintenance and Rehabilitation, Pavement Management Systems (PMS), Model Validation, Genetic Algorithm.

I. INTRODUCTION

1.1. GENERAL

Street organize is basic to encourage exchange and transport, financial advancement and social incorporation. It is utilized for the smooth movement of the two individuals and merchandise. In addition size of the street organize, its quality and access has an immediate connection with transport costs. Transportation by street has the favorable position over different methods for transport due to its simple availability, adaptability of activities, way to-entryway administration and dependability because of which it is the favored method of transportation. Worldwide challenge has made the presence of productive street transport and coordinations frameworks in conveyance chain a flat out objective. Restoration and development of new streets are fundamental to give adequate, protected and productive transportation for traveler and merchandise and are imperative for making the economy focused and for continuing a high rate of development. The street improvement from various perspectives represents both the test and opportunity in foundation advancement.

1.2. REPAIR AND REHABILITATION OF ROADS

The upkeep and restoration of existing, develop street offices are ending up progressively vital segments of expressway movement. A productive upkeep the executives arrangement is basic for a safe and financially savvy transportation framework. Choices to keep up existing street offices includes various conceivable alternatives in exercises extending from routine upkeep to recovery or remaking, in the spatial and transient designation and dispersion of assets all through a roadway arrange, and in decisions between ventures versus non-interests in a specific street organize. In addition the arranging of support programs infers the capacity to assess life-cycle execution and expenses, with tradeoffs estimated in monetary just as specialized terms. Putting off street upkeep results in high immediate and roundabout expenses. In the event that street absconds are fixed expeditiously, the expense is generally unassuming. In the event that absconds are dismissed, a whole street area may flop totally, requiring full remaking at multiple times or more the expense, overall, of upkeep costs. Still then numerous nations will in general support new development, restoration, or reproduction of streets over upkeep. Because of these attributes, the advancement of fix and recovery arrangement is muddled, and new ideas and diagnostic methodologies should be acquainted with location this issue.
In any case, nearly little work has been committed to the advancement of systematic models as improvement models expected explicitly for support programs. These models

venture the future conditions and execution of streets by distinguishing inadequacies and utilize a money saving advantage investigation to choose financially supported enhancements for streets from among different choices accessible. Any monetary examination should consider the greatest inclusion of advantages like changes in street upkeep costs, changes in mishap rates, expanded travel and decline in vehicle working expense and travel time; and social advantages as natural impacts, change in estimation of products moved, increment in rural and mechanical yield, changes in administrations, changes in land esteems and so on. Assessing the advantage segment of a transportation framework is troublesome, and in some cases is preposterous to expect to evaluate benefits for a few segments like social advantages, future traffic circumstance and so on.

Recovery exercises, (for example, overlays, real piece substitutions, and so on.) create a considerable, quickly recognizable amendment of lacks, spoken to by prompt upgrades in the condition or disintegration bend and is done at distinct interims or frequencies, as proposed by Markow et al., 1987

II. LITERATURE REVIEW

As clarified in the past part, diagnostic models can best take care of the profoundly intricate issue of creating support and restoration programs for street systems. Not just we need to limit the expense brought about in actualizing the upkeep movement in streets yet in addition the advantages from the action must be assessed in kind which can be spoken to precisely by utilizing enhancement models.

In this section a survey is exhibited on past business related to streamlining of upkeep movement of streets and the different parameters watched are assembled together. From that point forward, the inspiration driving this proposal work is expressed trailed by issue proclamation.

2.1. Writing REVIEW:-

The motivation behind the writing survey is to examine and break down the elements which are consider as target capacities, choice factors and requirements in the detailing of a streamlining model which are thusly assembled by number of writers who utilized them. Exact portrayals of all the writing are introduced underneath.

Markow et al. (1987) demonstrated that the improvement of asphalt support and recovery arrangement is confounded by a few variables the executives choices should in this way be assessed based on life-cycle costs, with tradeoffs estimated in monetary just as specialized terms. They talked about a logical methodology, dynamic control hypothesis, which ended up being an exceptionally appealing streamlining technique for overseeing expressway framework including all the key factors of enthusiasm with in fact right designing

what's more, financial connections communicated inside the issue definition (e.g., conditions depicting changes in asphalt condition because of disintegration or fix, or varieties in rush hour gridlock levels because of development or redistribution) having certain components of the issue in their essential frame to maintain a strategic distance from scientific difficulties (e.g., traffic is thought to be consistent), and drives specifically and effectively to the arrangement of ideal support and restoration approach. It was expected to be connected in monetary investigations of asphalt the board options, to evaluate tradeoffs among asphalt structure, support and restoration, and to check the ideal planning of upkeep and recovery activities.

Ouyang and Madanat (2008) displayed a numerical programming model dependent on discrete control hypothesis for deciding the ideal restoration recurrence and force on an arrangement of asphalts which limits the life-cycle cost for a limited skyline by consolidating both nonlinear asphalt execution model and whole number choice factors into a blended number nonlinear programming (MINLP) to plan various recovery activities in an arrangement of asphalt offices under spending limitations. Two unique arrangements, a branch-and-bound calculation and an eager heuristic, are drawn closer and numerical investigation demonstrated that the heuristic methodology gave a decent estimate to the correct optima with much lower computational costs which is exceptionally helpful for vast scale useful issues.

Yin et al. (2014) displayed an incorporated and powerful methodology for assessing the venture important to keep up or enhance the future dimensions of administration and asphalt states of offices in an expressway organize at an altogether lower cost when contrasted and preservationist speculation designs. They accepted future travel requests and office conditions as dubious and the scientific program is understood by means of a cutting plane calculation. Numerical outcomes from the Sioux Falls arrange recommend that the methodology can conceivably address reasonable systems. Accepting the measure of limit extension and the reemerging thickness as consistent factors and the event of at most one upkeep and enhancement action amid the investigation time frame impedes the ability of the proposed model.

Lamptey et al. (2014) displayed a contextual investigation for upgrading choices on the best mix of preventive upkeep (PM) medicines dependent on Decision Support System and timings to be connected in the reemerging life-cycle (interim between reemerging occasions) utilizing affectability examination, for a given expressway asphalt area consolidating key framework the executives ideas of treatment-explicit triggers, execution hop models, and execution drift models. The examination results demonstrated that contrasted with office costs, client costs are progressively delicate to changes in the rebate rate which can impact the decision of ideal PM plan.

Durango-Cohen and Sarutipand (2017) displayed a computationally-engaging quadratic programming structure to address the issue of finding ideal support arrangements for multifacility transportation frameworks and to catch nonlinearities in cost terms, unequivocally catching the bidirectional connection among interest and disintegration In the plan, every office's crumbling and request/traffic are distinguished and spoke to as a direct framework, i.e., an autoregressive moving normal model with exogenous sources of info (ARMAX) model and after that connected as the condition of an office can affect request at different offices. A progression of numerical models spoke to that the

direct estimation is substantial for the single-birthplace, single-goal, and two-connect substitutable system by examining basic system topologies and traffic designs where it is ideal to arrange (synchronize or exchange) intercessions for bunches of offices in transportation frameworks.

Ng et al. (2018) exhibited a whole number programming-based choice to represent the vulnerabilities because of upkeep and restoration upgrades and weakening rates expecting that parameters are deterministically known. In the primary model, the main wellspring of vulnerability is given by the upgrades due to M&R activities. Second model considers both M&R enhancements just as decay rates to be questionable. A numerical contextual investigation utilizing true information from Rockwall County showed that the cost of vulnerability is a non-diminishing capacity of the dimension of vulnerability and it increments with the quantity of vulnerabilities considered. Be that as it may, high computational prerequisites and open-circle M&R strategies of whole number programming models makes it less attractive from an administrative point of view.

Santeroa et al. (2017) demonstrated the quickly developing enthusiasm for asphalt life-cycle appraisals (LCAs) in enhancing the maintainability of this basic interstate framework. The current writing builds up a fundamental system for evaluating ecological effect, yet can't convey worldwide ends with respect to materials decisions, support methodologies, structure lives, and other best practice arrangements for accomplishing manageability objectives. The asphalt LCA writing is assessed crosswise over four key methodological characteristics: (1) practical unit similarity; (2) framework limit likeness; (3) information quality and vulnerability; and (4) ecological measurements. These four properties are viewed as fundamental for contrasting and conglomerating the consequences of the diverse examinations, and for portrayal of general decisions about the ecological effects of various life-cycle stages, life-cycle parts, and asphalt types from the aggregate group of work and enhancing the inadequacies.

III. MODEL VALIDATION

The developed model must be calibrated and validated in order to prove its proximity to the real-world problem and to compare with the actual field data. Hence in this chapter, it is described about the region of data collection obtained from NH Division, Dhenkanal, Odisha and the data collected are tabulated under different heads of parameters used in the formulation of objective functions, decision variables and constraints. The model is then validated using a Non-dominated Sorting Genetic Algorithm (NSGA-II) code in C adapted from Indian Institute Of Technology, Kanpur's research laboratory "Kanpur Genetic Algorithms Laboratory" (KanGAL).

3.1. DATA COLLECTION

3.1.1. Overview of National Highways in India

National Highways (NH) are the arterial roads of the country for inter-state movements of passengers and goods. They criss-cross the length and breadth of the country connecting the National and State capitals, major ports and rail junctions and link up with border roads. The National Highways Authority of India (NHAI) is an autonomous agency of the Government of India, responsible for management of a network of over 70,000 km of National Highways in India. It is a nodal agency of the Ministry of Road Transport and Highways created through the promulgation of the National Highways Authority of India Act, 1988. In February 1995, the Authority was formally made an autonomous body. It is in charge of the development, maintenance, management and operation of National Highways, totalling over 71,772 km (44,597 mi) in length. construction and maintenance of National Highways (NHs), administration of Motor Vehicles Act, 1988 and Central Motor Vehicles Rules,1989,

formulation of broad policies relating to road transport, environmental issues, automotive norms, etc. besides making arrangements for movements of vehicular traffic with neighbouring countries.

The NHAI has the mandate to implement the National Highway Development Project (NHDP) in phases. Phase I includes the Golden Quadrilateral (GQ), portions of the NS-EW Corridors, and connectivity of major ports to National Highways, at an estimated cost of Rs.300 Billion, approved in December 2000. Phase II includes the completion of the NS-EW

corridors and another 486 km (302 mi) of highways, at an estimated cost of Rs.343 Billion, approved in December 2003. Phase IIIA and IIIB includes an upgrade to 4-lanes of 4,035 km (2,507 mi) and 8,074 km (5,017 mi) of National Highways , at an estimated cost of Rs.222 Billion and Rs.543 Billion, approved in March 2005 and April 2006 respectively. Phase V includes upgrades to 6-lanes for 6,500 km (4,000 mi), of which 5,700 km (3,500 mi) is on the GQ, entirely on a DBFO basis, approved in October 2006. Phase VI will develop 1,000 km (620 mi) of expressways at an estimated cost of Rs.167 Billion which has been approved in November 2006. Phase VII will develop ring-roads, bypasses and flyovers to avoid traffic bottlenecks on selected stretches at a cost of Rs.167 Billion which has been approved in December 2007.

3.1.2. Region of Data Collection

Data on various parameters of the model was collected from National Highway Division, Dhenkanal, Odisha. The general information about various maintenance activities carried out by the concerned department is as follows;

Rehabilitation or strengthening, termed as 'Improvement of Riding Quality (IRQP)' of National Highways (NH), is done in between 5 years to 8 years interval after the construction of new highway. This includes pavement overlays, slab replacements etc. Another part of this

maintenance work is called 'Periodic Renewal (PR)' which is carried out in between 3 years to 4 years interval after the construction of new highway which involves major repairs as maintenance of shoulders, potholes, depression, and road markings etc. Apart from all these, minor repair works are carried out every year after construction. All the maintenance work is carried out according to Ministry of Road Transport and Highways (MORTH) and Indian Roads Congress (IRC) specifications. Design period of National Highways are generally considered to be 10 years.

Maintenance work of National Highways involves some field tests to ascertain the extent of deterioration of the road and to find out the amount of maintenance necessary so that the road functions satisfactorily by using some standard instruments and methods given by MORTH and IRC. Generally roughness of the road before maintenance work is measured through Fifth Wheel Bump Integrator which gives results on average deflections with respect to the longitudinal profile/lane of the road measured in mm/km. Sometimes the roughness measurement is also carried out post maintenance to check whether the maintenance done
was able to correct the road deficiency or not. The strength of the road is ascertained through Benkelman Beam Deflection test and the standard procedure for finding the thickness and type of overlays to be provided is followed, using the data obtained from Benkelman Beam Deflection test. The cracks, potholes and depressions are measured in cubic meters and the total volume of the affected region in a particular stretch is found out. Data is collected for four stretches of NH-42 and NH-200.

National Highway 42 (or NH 42) is a National Highway of India entirely within the state of Odisha. It links NH 5 northeast of the city of Cuttack with NH 6 in Sambalpur connecting some primary locations as Dhenkanal and Angul. It runs for a total length of 261 km (162 mi). Average crust available is 425 mm and sandy sub-grade soil type. It is a two lane road, with traffic Intensity of 1413 commercial vehicles per day (CVD). It has been approved forfour laning with paved shoulders in Phase-IV of NHDP in 2011. IRQP data collected was obtained for the stretch from KM 161/0-176/0, i.e. from Boinda to Rairakhol of NH-42 for the year 2007-2008.

National Highway 200 (NH 200) is a National highway in India that connects Raipur, the state capital of Chhattisgarh to Chandikhole in Odisha linking Talcher, Keonjhar with Paradip Port via Chandikhol on NH-5A and some primary locations as Simga, Bilaspur, Sarangarh, Raigarh and Deogarh. It covers a distance of 740 km (460 mi).
it in Chhattisgarh and a major part of 440 km in Odisha. It is also a two lane road of intermediate width (5.50 meters) with traffic intensity of 1732 CVD. Traffic volume in this NH is increasing day by day owing to rapid industrial growth and also due to the mining traffic from mines in Talcher and Keonjhar to Paradip Port for shipping. The sub-grade soil type is of red earth. It has been approved for four laning with paved shoulders in Phase-III of NHDP. PR data was obtained for KM 301/893-309/0 and 319/0-332/0 of NH-200, i.e. from Pitiri to Kamakshanagar to Bhuban stretch for the year 2009-2010. Another set of PR data to stretches from KM 342/0-352/0 of NH-200, i.e. from Kamakshanagar-Bhuban, carried out in 2009-2010 was also obtained. PR data to stretches from KM 301/893-309/0 of NH-200, i.e. for the stretch from Pitiri-Kamakshanagar, carried out in the year 2002-2003 was also obtained.

3.2. DATA TABULATION

All the above data is collected from the above mentioned road stretches NH-42 and NH-200 are gathered and formulated as shown in the following tables. 64 data points are obtained according to chain age of the road stretch and formulated under different heads representing the various parameters used in the development of the objective functions, decision variables and constraints of the optimization model.

IV. CONCLUSION AND RECOMMENDATIONS

The multi-objective optimization model formulated for maintenance and rehabilitation activities of roads satisfied the research objectives described in this thesis to a reasonable level as both the cost as well as benefit in terms of improved road condition was considered in the optimization model. Moreover the constraints described in the model can be used to put a check on whether the previous maintenance activities carried out was effective to enhance the performance of the road or not. It also ensures that the future maintenance and rehabilitation activities are at least up to an acceptable condition enforced by introducing condition index for repair and rehabilitation separately.

The model validation done by using a Non-dominated Sorting Genetic Algorithm (NSGA-II) code in C adapted from Indian Institute Of Technology, Kanpur's research laboratory "Kanpur Genetic Algorithms Laboratory" (KanGAL) wit h GA parameter inputs as observed from the field data was seen to be giving satisfactory optimum values for two real-coded decision variables of repair and rehabilitation interval. Optimum repair interval of 4 years from the program matched with the field data by 32.81 % and the optimum rehabilitation interval of 8 years from the program matched with the field data by 54.35 %. With more data available, it can be expected that the Non-dominated Sorting Genetic Algorithm II (NSGA-II) can accurately predict the optimum solutions to the problem of developing a suitable maintenance and rehabilitation activities of roads.

Owing to the difficulties faced while formulating and validating the proposed model, this research work can be further extensive if the multi-objective optimization model developed can be reduced to a single-objective optimization model by assigning weights to the two objectives, reducing the complexity of the model. Also further if the parameters considered in the constraints can be made linear with fewer assumptions, then also the model can be solved easily to give good results in less time.

