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RESEARCH ARTICLE

PAVEMENT TYPE SELECTION FOR DEVELOPING COUNTRIES APPLYING LIFE CYCLE COST ANALYSIS

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Abstract

Road network acts as a vein for the socio-economicdevelopment of a country. To maintain sustainable development,countries all over the world are investing heavily in road network infrastructure development. Bangladesh, an essential partner of the Asian Highway, is alsoinvesting heavily in road network development. But due to poorplanning, inefficient implementing agencies, inadequate pavementdesign, low-quality construction practices, lack of pavementmaintenance, rampant overloading & tropical climaticconditions, the investment is not yielding the desired result. In Bangladesh, the current trend of pavement construction is 95% flexible pavement [16]. Due to tropical climatic conditions & regular flash floods during the rainy season, water stagnation damages the flexible pavements severely. The rigid pavement has a high potential of survivability against the damage due to water stagnation. In Bangladesh, the transportation agencies emphasize on least initial construction cost rather thanthe least Life Cycle Costas the only tool for pavement type selection. Due to low initial construction cost, the flexible pavement always gets priority over the rigid pavement. In this research, Life Cycle Cost Analysisof flexible and rigid pavement had been done for Sylhet-Bholagajroad comprising of both rigid & flexible portions. The pavement design data & different Schedule of Rates collected from the Roads and Highways Departmenthad been used for this analysis. 12% discount rate was used to convert all estimated future costs to Net Present Value. After performing a life cycle cost analysis, it can be concluded that rigid pavement is the optimal choice of pavementfor developing countries like Bangladesh.

Introduction:-

Road infrastructure development and maintenance require significant capital investment. New road construction costs nearly 50% of the annual budget for transportation agencies in many developed countries. In comparison,Maintenance and Rehabilitation (M&R) of the existing road network costs the remaining 50% budget [12]. Bangladesh is a developing country, and around 15-20% of its annual budget for roads is spent onM&R programs [3]. A sustainable road transport infrastructure that requires the least possible M&R cost will boost the social, economic & cultural development of a country. Transportation agencies worldwide are involving themselves

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in finding the appropriate pavement type that requires fewer recurring costs but meets the ever-increasing demands of road users, including comfortability, speed & safety [11]. Whether the flexible pavements are economically superior to rigid pavements or not over a long time is a historical debate. Even experienced transportation agencies & experts have different opinions on this subject [19]. For suitable pavement type selection, transportation agencies globally have started using tools & techniques [4]. The Life Cycle Cost Analysis (LCCA) is one of the tested tools based on economic analysis principles for the suitability of different long-term rivalling investment options [13]. The sustainability of national highways can be achieved by reducing pavement life cycle cost to a minimum [8]. Developed countries are using LCCA as a reliable mechanism for the construction and maintenance of bridges and highways. But in developing countries, very little utilization of LCCA is found. Only a few research works have been performed on the application of LCCA in developing countries [9]. This research aims to select the economically viable pavement type for developing countries like Bangladesh.

Literature Review:-

In 1960, AASHTO "Red Book" first discussed the possible application of LCCA in pavement construction [21]. In the USA, state transportation agencies must conduct LCCA of any project to justify their planning & actions while using federal funds. The mandate for the application of LCCA for pavement, bridge, or tunnel construction projects at both metropolitan and state level was made by 1991, Intermodal Surface Transportation Efficiency Act (TEA) [20]. National Highway System Designation act of 1995 requiredLCCA evaluation of all national highway projects costing $25 million or moreundertaken by any state. The federal executive order 12893, signed in 1994, mandated federal agencies to apply a systematic evaluation of costs and benefits for taking any development action [14]. Though the 1998 TEA withdrew the requirement of LCCA for transportation, still Federal Highway Administration encourages highway projects to be evaluated by LCCA before its implementation. LCCA is currently being used as a supporting tool for taking decisionsat the projectlevel. But recently,the application of LCCA has been started atthe networklevel [6].

Research Methodology:-

Life Cycle Cost Analysis:-

Life Cycle Cost (LCC) can be defined as the summation of all one-time and reiterating costs during the life period of a project. Federal Highway Administration (FHWA) defines LCCA by:

"LCCA is an analysis tool based on the principles of economic analysis for evaluating long-term economic efficiency among rivalling investment options. This analysis incorporates costs of agency (initial costs and future M&R costs), user, and other related costs over the design life of alternative investment options. It emphasizes finding the best value investment option" [20].

LCCA is applied to select pavement type andselect rehabilitation strategies of existing pavements [18]. The application of LCCA ensures the selection of the most cost-effective solution and illustrates the factors that influence cost-effectiveness. Different types of costs incorporated in LCCA have been discussed in AASHTO Pavement Design Guidelines [1]. Pavement LCCA mainly focuses on agency costs, user costs &society costs [2]. The agency costs have been further subdivided into initial construction costs and M&R costs. The initial construction costs include the costs of pavement design, acquisition of land & construction of pavement.The M&R costs incorporate the costs of preservation, reconstruction, restoration & rehabilitation.User costs include the costs of vehicle operation, traffic delay & accidents. Social costs represent all the costs related to environmental degradation of the area surrounding the pavement. People living nearby have to bear social costs sometimes even without using the pavement facilities.

The LCCA period of both flexible and rigid pavement had been taken 20 years for this research. According to AASHTO Design Guidelines [1], flexible pavements require overlay after every 10 years. But flexible pavement in Bangladesh reaches its terminal serviceability within 05 years of construction due to overloading traffic stream & tropical climatic conditions. So, after every 05 years, an overlay is recommended for flexible pavements instead of 10 years [10]. For rigid pavement, there is no need for overlay during its 20 years design period. Due to poor record-keeping in Bangladesh, the determination of costs associated with pavement M&R activities is very complex. Even the transportation agencies find difficulty in differentiating maintenance activities. To overcome this information deficiency, the maintenance cost estimation for flexible & rigid pavements had been adopted from the "Maintenance and Rehabilitation Needs Report of 2019 - 2020 for RHD Paved Roads" by RHD, Bangladesh [17]. The estimated maintenancecosts have been presented in table 1 below:

Table-1:- Maintenance Costs of Pavements.

Pavement Type	Maintenance Work Type	Cost($)
Flexible Pavement	Routine Maintenance	$947/km/Year
	Periodic Maintenance	Overlay Cost at the end of 5^{th},10^{th}&15^{th}year
Rigid Pavement	Routine Maintenance	$947/km/Year
	Periodic Maintenance	No overlay is recommended during its 20-years Design Period

Theland acquisition costs, road user costs & environmental costs were considered the same for both types of pavements. They had not been included in the calculation due to their equal contribution to pavement LCC. FINNROAD Limited, a pavement consultant, has estimated different costs related tothe overlay of flexible pavements by studying various pavement projects undertaken by RHD [7]. The estimated costs have been presentedin table 2 below:

Table-2:- Different types of Costs associated with Overlay of Flexible Pavement (Finnroad Limited, 2008).

Serial No.	Description of Cost	Amount of Cost
1	Overlay/Resurfacing Cost	Overlay Cost
2	Engineering Overhead Cost	10% of Overlay Cost
3	Miscellaneous Cost	5% of Overlay Cost
4	Economic Loss Due to Delay & Discomfort	2% of Overlay Cost

Net Present Value (NPV)

For the economic evaluation, transportation agencies use different available indices. Among the available indices, the Internal Rate of Return (IRR), Benefit-Cost Ratio (B/C), Net Present Value (NPV), Equivalent Uniform Annual Cost (EUAC) are the most commonly used economic indices [4]. Because of simplicity and ease of use, NPV had been used in this research. The NPV is the present discounted monetary value of expected net benefits [20]. In NPV, all the associated costs are converted to a single time cost [15]. Equation 1 had been used for NPV calculation of future investments:

$$\text{NPVof future investment} = \sum\left[\text{Initial Cost} \times \frac{(1+i)^n}{(1+d)^n}\right] \quad \text{……………………………………………………….Equation (1)}$$

Where, i is the economic growth rate in percentage
d is the discount rate in percentage
& n is the year of expenditure

To convert all the futurecosts to NPV, a 7% growth rate & a 12% discount rate for the fiscal year 2019-2020 had been considered according to the Bangladesh Planning Commission's direction [5].

Site selection for Data collection

LCC comparison between flexible pavement and rigid pavement requires that both the roads should have the same geometric profile & same soil characteristics over which they are built. Both the pavements should also carry similar traffic loadings. Several roads under RHD had been observed to meet these requirements, and only theSylhet-Bholagajroad project had been chosen as the suitable site. The road is a 30 km Zilla road consisting of a 17km flexible pavement while the rest of 13 km is rigid pavement.

Data Collection

The detailed pavement design data of Sylhet-Bholagaj road was obtained from the Technical Services Wing of RHD. The pavement has a two-lane single carriageway, each having a lane width of 4.9m. The design traffic data was collected from Sylhet, RHD. The pavement was designed assuming a 7% traffic growth rate, and the design life for both flexible & rigid pavement was 20 years.The expected cumulative Equivalent Single Axle load was assumed to be 323.81 million for 20 years. The flexible & rigid pavement was designed following the "Pavement Design Guide for RHD" April 2005 & Design Specification of AASHTO 1993 [1]. The RHD specified cement concrete compressive strength, yield strength of reinforcement & different joints specificationwas followed during the rigid pavement construction. Different pavement layer thicknesses along with corresponding California Bearing Ration (CBR) values for flexible & rigid pavement have been presented in table 3 below:

Table-3:- Pavement Layer Thicknesses with Required CBR.

Flexible Pavement		
Pavement Layer	**Required CBR (%)**	**Layer Thickness (m)**
Subgrade	05	---
Improved Subgrade	>08	0.30
Sub-Base	>25	0.30
Aggregate Base Type-II	>50	0.30
Aggregate Base Type-I	>80	0.25
Bituminous Binder Course	---	0.07
Wearing Course	---	0.05

Rigid Pavement		
Pavement Layer	**ConcreteClass/ CBR (%)**	**Layer Thickness (m)**
Sub-Base	>25	0.25
Dry Lean Concrete	Concrete class-20	0.10
Cement Concrete Pavement	Concrete Class-35	0.35

Data Analysis & Results:-

The pavement design data & different RHD Schedule of Rates obtained from different RHD sections had been used for life cycle cost comparison between flexible and rigid pavement. Thevolume of work required for flexible & rigid pavement was found from the pavement design data containing detailed layer thickness information. The initial construction cost for both pavement typeswas found out by multiplying the differentwork volumes bytheir corresponding rates. Conversion of all associated future costs to NPV was done using a 12% discount rate. The initial construction cost of both types of pavement have been presented in tables 4 & 5 below:

Table-4:- Initial Construction Cost of Flexible Pavement per km.

RHD Item Code	**Item**	**Length(m)**	**Width(m)**	**Thickness (m)**	**Unit (m^3)**	**RHD Schedule of Rates 2019**		**RHD Schedule of Rates 2015**	
						Rate (\$/m^3)	**Amount (\$)**	**Rate (\$/m^3)**	**Amount (\$)**
02/08/01	300mm Improved Sub-Grade	1000	10.3	0.3	3090	12.35	38161	10.9	33681
02/11/01	Hard Shoulder	1000	3	0.05	150	67.4	10110	56.2	8430
03/02/01	300mm Sub-Base	1000	10.3	0.3	3090	64	197760	51.6	159444
03/03/02	300mm Aggregate Base Type-II	1000	10.3	0.3	3090	70.3	217227	56	173040
03/03/01	250mm AggregateBase Type-I	1000	10.3	0.25	2575	104.6	269345	77.8	200335
03/10/01(b)	Dense Bituminous Surfacing Base Course (Plant Method)(Bitumen Grade 60/70)	1000	10.3	0.07	721	274	197554	235.7	169939
03/10/02(b)	Dense Bituminous Surfacing Wearing Course (Plant Method) (Bitumen Grade 60/70)	1000	7.3	0.05	365	288	105120	238.2	86943
Initial Construction Cost (\$)/km							**1,035,277**		**831,812**

Table-5:- Initial Construction Cost of Rigid Pavementper km.

RHD	**Item**	**Le**	**W idt**	**T hi**	**Q ua**		**RHD Schedule of Rates 2019**	**RHD Schedule of Rates 2015**

Item Code						Unit	Rate ($/unit)	Amount ($)	Rate ($/unit)	Amount ($)
03/13/01 (b)	Brick on End Edging	01	----	----	1000	Lin. Meter	2.8	2800	1.2	1200
03/02/01	150mm Sub-Base	01	9.8	0.25	2450	m^3	64	156800	51.6	126420
03/14/02(c)	100mm Thick Dry Lean Concrete (Concrete Class-20)	01	9.8	0.1	980	m^3	184	180320	174.2	170716
----	Reinforcement	---	----	----	160	Ton	1127	180320	1077	172320
03/15/03(c)	300mm Cement Concrete Pavement (Concrete Class-35)	01	9.8	0.35	3430	m^3	227	778610	221	758030
Initial Construction Cost ($)/km								**1,298,850**		**1,228,686**

Fromtables 4 & 5 above, it is observed that when the 2019 Schedule of Rates had been used, the per kminitial construction cost of rigid pavement is $1,298,850 while the cost is $1,035,277 for flexible pavement. So, the rigid pavement has a 25% higher initial construction cost than flexible pavement. When the 2015 Schedule of Rateshad beenused, the per km initial construction cost of rigid pavement is $1,228,686, while the cost is $831,812 for flexible pavement. Here the rigid pavement has a 47% higher initial construction cost than flexible pavement.The life cycle cost calculation for both flexible & rigid pavement has been presented in tables 6 & 7 below:

Table-6:- Life Cycle Cost of Flexible Pavementper km.

Item Description	RHD Schedule of Rates 2019		RHD Schedule of Rates 2015	
	Cost ($)	NPV ($)	Cost ($)	NPV ($)
Investment Cost For 20 Years Design Period	1035277.5	1035277.5	831812.7	831812.7
Routine Maintenance Cost 947 $/Year	17996	11759	17996	11759
Total Overlay Cost During 5th, 10th& 15th year after Construction	908022	585154	770648.1	496627
Engineering Overhead Cost	90802	58515	77065	49663
Miscellaneous Cost	45401	29258	38532	24831
Traffic Delay Cost	18160	11703	15413	9933
Life Cycle Cost/km		**1,731,666**		**1,424,625**

Table-7:- Life Cycle Cost of Rigid Pavementper km.

Item Description	RHD Schedule of Rates2019		RHD Schedule of Rates 2015	
	Cost ($)	NPV ($)	Cost ($)	NPV ($)
Initial Construction Cost	1298850	1298850	1228686	1228686
Routine Maintenance Cost 947 $/Year	17996	11759	17996	11759
Life Cycle Cost/km		**1,310,609**		**1,240,445**

The life cycle cost analysis presented in tables 6 & 7 reveals that the rigid pavement is much cheaper to build & operate than flexible pavement. It is seen that per km life cycle cost of rigid pavement is $1,310,609, which is 32% cheaper than the flexible pavement having a cost of $1,731,666 when the 2019 Schedule of Rates had been used. It is also seen that per km life cycle cost of rigid pavement is $1,240,445, which is 14% cheaper than the flexible pavement having a cost of $1,424,625 when the 2015 Schedule of Rates had been used. For better visualization, the initial construction cost & summation of future M&R costs for both flexible & rigid pavements have been presented in figure 1 below using the RHD Schedule of Rates 2019:

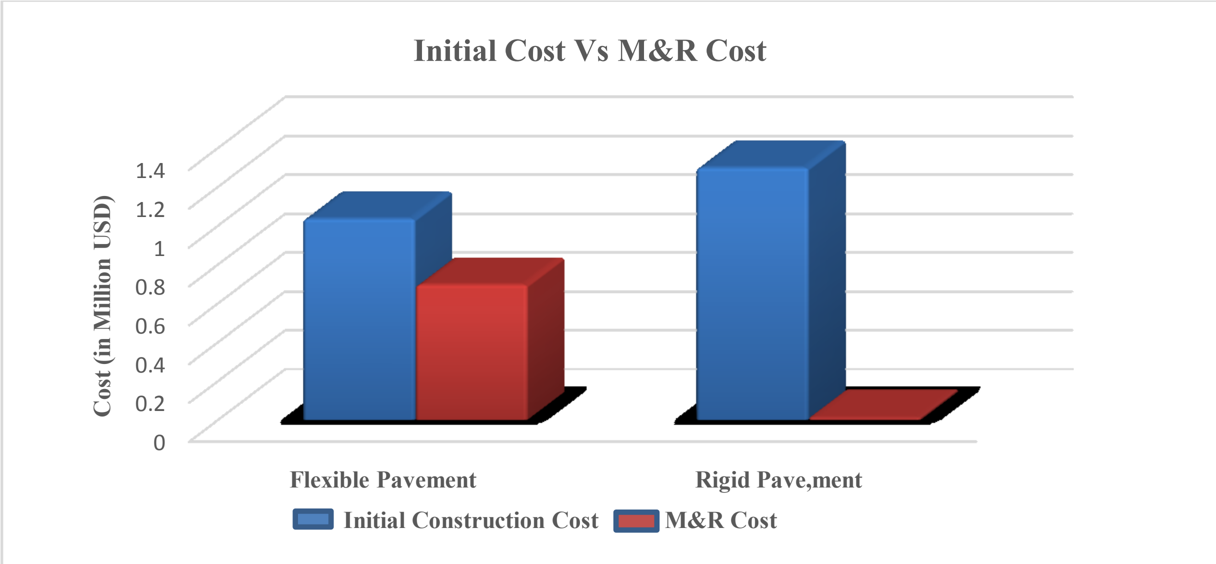

Fig1:- Life Cycle Cost of Pavement by Parts.

So, after life cycle cost analysis, it can easily be said that though the initial construction cost of rigid pavement is always higher than the flexible pavement irrespective of the Schedule of Rates used, due to low M&R cost, the LCC of rigid pavement is much lesser than flexible pavement throughout its 20 years design period. For a developing country like Bangladesh, due to resource scarcity, transportation agencies should find a cost-effective, sustainable solution, and rigid pavement meets both the requirement [10].

Conclusion:-

The initial construction cost comparison based on Schedule of Rates 2019 & 2015 has revealed that rigid pavement is 25 % and 47% more expensive to build than flexible pavement, respectively. Initial construction cost is primarily dependent on materials costs. As materials price varies on availability, one country's initial construction cost comparison result might be totally different from another country. Ironically, most of the time, transportation agencies in developing countries decide based on initial construction cost only. But the life cycle cost comparison based on Schedule of Rates 2019 & 2015 has revealed that rigid pavement is 32 % and 14% less expensivethan flexible pavementthroughout its design period, respectively. The flexible pavement needs costly overlay every 5 years, making it costlier than rigid pavement though the initial construction cost comparison result was completely reverse. Based on the output of life cycle cost comparison between flexible and rigid pavement presented in this research, it can be concluded that rigid pavement is the optimal choice of pavementfor developingcountries like Bangladesh with tropical climatic conditions.

References:-

1. AASHTO, 1993. Guide for Design of pavement Structures Part 1, Chapter 3, Life Cycle Cost Analysis for Pavements, American Association of State Highway and Transportation Officials, Washington, DC.
2. Amini, A.A., Mashayekhi, M., Ziari, H. and Nobakht, S., 2012. Life cycle cost comparison of highways with perpetual and conventional pavements. International Journal of Pavement Engineering, 13(6), pp.553568.
3. ArifuzzamanBhuyan, M., 2009. Evaluation of flexible and rigid pavements construction in Bangladesh.
4. Babashamsi, P., Yusoff, N.I.M., Ceylan, H., Nor, N.G.M. and Jenatabadi, H.S., 2016. Evaluation of pavement life cycle cost analysis: Review and analysis. International Journal of Pavement Research and Technology, 9(4), pp.241-254.
5. Bangladesh Planning Commission, 2015. Seventh Five Year Plan FY2016-FY2020. General Economic Division, Bangladesh Planning Commission. Accessed on: 28 March, 2020.
6. Flintsch, G.W. and Kuttesch, J., 2004, January. Application of engineering economic analysis tools for pavement management. In 83rd Annual TRB Meeting, Washington, DC.
7. FINNROAD Limited. 2008. A Technical Paper on Concrete Roads- for Better and Safer Roads in Bangladesh. FINNROAD Limited.

8. Gransberg, D.D. and Molenaar, K.R., 2004. Life-cycle cost award algorithms for design/build highway pavement projects. Journal of Infrastructure Systems, 10(4), pp.167-175.
9. Hamim, O.F., Hoque, M.S., 2019. 'Prediction of Pavement Life of Flexible Pavements under the Traffic Loading Conditions of Bangladesh', International Airfield and Highway Pavements Conference, Chicago, Illinois, USA, 21 -24 July, 2019.
10. Hamim, Omar Faruqe, Saidis Salekin Aninda, Md Shamsul Hoque, and Md Hadiuzzaman. "Suitability of pavement type for developing countries from an economic perspective using life cycle cost analysis." International Journal of Pavement Research and Technology 14, no. 3 (2021): 259-266.
11. Kale, P.B., Aher, M.C., Aher, P.D., 2016. Life Cycle Cost Analysis of Rigid and Flexible Pavements, International Journal of Advanced Technology in Engineering and Science, 4(12), 340-348.
12. Ketema, Y., Quezon, E.T. and Kebede, G., 2015. Cost and benefit analysis of rigid and flexible pavement: case study in chancho–derba-becho road project (Doctoral dissertation).
13. Lamptey, G., Labi, S. and Sinha, K.C., 2004. Development of Alternative Pavement Rehabilitation and Maintenance Strategies for Pavement Management. In 83rd Annual TRB Meeting, Washington, DC.
14. NCHRP (2003). "Bridge Life-Cycle Cost Analysis" NCHRP Report 483, TRB, Washington, DC.
15. Papagiannakis, A.T. and Masad, E.A., 2017. Pavement design and materials. John Wiley & Sons.
16. RRD (2006), Pavement Design Guide, Ministry of Communication, Roads and Railways Division.
17. Roads and Highways Department, 2018. Maintenance and Rehabilitation Needs Report of 2019 - 2020 for RHD Paved Roads. HDM Circle, Roads and Highways Department.
18. Reigle, J.A. and Zaniewski, J.P., 2002. Risk-based life-cycle cost analysis for project-level pavement management. Transportation Research Record, 1816(1), pp.34-42.
19. Villacres, J.N., 2005. Pavement Life-Cycle Cost Studies Using Actual Cost Data–A Synthesis.
20. Walls III, J. and Smith, M.R., 1998. Life cycle cost analysis in pavement design-interim technical bulletin (No. FHWA-SA-98-061). United States. Federal Highway Administration.
21. Wilde, W.J., Waalkes, S. and Harrison, R., 1999. Life cycle cost analysis of Portland cement concrete pavements (No. FHWA/TX-00/0-1739-1). University of Texas at Austin. Center for Transportation Research.