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PAVEMENT LIFE CYCLE COST ANALYSIS: REVIEW AND ANALYSIS BY META COMPUTING TECHNIQUES

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Abstract

The cost of construction of roads consists of design expenses, material extraction, construction equipment, maintenance and rehabilitation strategies and operations over the complete service life. An economic analysis process called Life-Cycle analysis (LCCA) is employed to judge the cost-efficiency of alternatives supported Net Present Value (NPV) concept. it's essential to judge the above-mentioned cost aspects to get optimum pavement life-cycle costs. However, pavement managers are often unable to contemplate each important element that will be required for performing future maintenance tasks. Over the previous few decades, several approaches are developed by agencies and institutions for pavement Life-Cycle Cost Analysis (LCCA). While the transportation community has progressively been utilizing LCCA as an important practice, several organizations have even designed computer programs for estimating LCCA approaches to help with the analysis. Current LCCA methods are analyzed and LCCA software is announced during this article. Subsequently, an inventory of economic indicators is provided together with their substantial components. Previous literature will help highlight and study the weakest characteristics so on mitigate the shortcomings of existing LCCA methods and processes. LCCA research will become more vigorous if improvements are made, facilitating private industries and government agencies to accomplish their economic aims.
Keywords: ***Life-Cycle Cost Analysis (LCCA); Pavement management; LCCA software; Net Present Value (NPV)***

I. INTRODUCTION

Now a day, road pavement construction, maintenance and rehabilitation costs are rising dramatically. Highway agencies need to utilize tools and approaches that facilitate proper judgment making by applying economics and research like Life-Cycle Cost Analysis (LCCA) to attain economically reasonable long-run investments. LCCA may be a method supported by the ethics of economic analysis. It improves the estimation of the overall long-term economic viability of different investment options.This scheme finds a significant application in pavement design and management. A variety of agencies employ the LCCA approach to estimate the economic feasibility of pavement designs over the long run. Thus, it's important for activities to realistically evaluate pavement economics to supply suitable input to the

LCCA.

As a concept, it absolutely was within 1950 that benefit-cost analysis (BCA) was primarily applied as a range factor for various pavement design options. Then within 1970, LCCA principles started actuality applied in some key projects at the local and national state levels for pavement design and pavement type selection. "As presented in Fig. 1, the aim of LCCA represents the extent and details of the following steps"[20]. "All leaders and stakeholders should completely collaborate so that full effectiveness is achieved" [3].

Considering the mostly inadequate funding under normal circumstances, road specialists are consistently challenged with funding projects thanks to resource insufficiency. Moreover, with the growing demand for brand new road infrastructure, the demand for efficient management of old and new roads is on the increase also, together with safety demands, accessibility and also the implementation of advanced traffic management systems for decreasing socio-economic costs by modifying maintenance-related environmental effects, traffic issues, and losses. Maintenance backlogs nonetheless increase too. "Road authorities thus emphasize more on better efficiency and lower expenses thanks to limited funds. Since maintenance overheads normally comprise half the annual road infrastructure funds, it's vital to rearrange efficiency in road maintenance"[5&6]. Thus, with relation to road objects, life-cycle costs (LCCs) are considered as having a higher priority than simply investments. Hence, road authorities are expected to appreciate the importance of LCCA and maintain a calculation system. LCCs are deemed to be a restraint in road design selection or the assessment of tenders. When calculating LCCs, both road authority costs and costs of socio-economic nature should be taken into consideration. Road agency (authority) costs comprise expenses for planning, construction, design, maintenance, and rehabilitation. of these costs are usually the government's accountability to hide using tax earnings. Socio-economic costs comprise agency costs, user costs (e.g. delay costs, accident costs and automobile operation costs), and environmental costs.

II. LITERATURE REVIEW

2.1 Historical background

The American Association of Highway Officials (AASHO) introduced the concept of life-cycle cost-benefit analysis in its "Red Book" in 1960. The LCCA was introduced for highway investment decisions, and intrinsically, formed the notion of the economic evaluation of highway upgrades during the look stage. The subsequent progress step was made by Winfrey [2] who combined data available on the price of auto operations in an exceeding system to be utilized when highway planners are developing life-cycle costing processes. Moreover, two projects within 1960 introduced the use of LCC principles for pavement type selection and pavement design. within the first project, the Centre for Highway Transportation Research and therefore the Texas Transportation Institute (TTI) developed the Flexible Pavement System (FPS), a computer-based approach for analyzing and rating alternative flexible pavement designs through the life-cycle cost. The second project was by the National Cooperative Highway Research Program (NCHRP), which examined the promotion of the LCCA concept. Subsequently, the Rigid Pavement System (RPS) was developed by Texas DOT, which is the image of FPS concerning how Life-Cycle analysis of rigid pavements is administered. RPS also ranks alternative designs per their total life-cycle costs

Fig.1 The core process of LCCA

The use of the LCC concept is supported in the different AASHTO Pavement Design Guide editions, which also include detailed discussions regarding costs that should be considered in LCCA. The current study presents an overview of the basic life-cycle costing theories, with explanations of the various user and agency costs associated with highway pavement projects, as well as the discount rates and economic feasibility of systems.

2.2 Obligations and legislative requirements

In 1991, LCC application during the planning and construction of tunnels, bridges or pavements was mandated by the Intermodal Surface Transportation Efficiency Act. The FHWA stimulated state departments of transportation to hold out LCCA of all pavement projects having costs above US$25 million as per the designation Act of 1995, motorway agencies are speculated to perform an LCCA of each "high-cost usable project segment". It's legislatively presented the designation Act that LCCA is an approach for evaluating the overall amount of a feasible project segment by evaluating the initial costs and discounted future costs like maintenance, rehabilitation, reconstruction, resurfacing, and restoring costs, over the complete lifetime of the project.

Although LCCA is formally required in certain situations, the FHWA consistently encourages its implementation when evaluating all key investment decisions. This is often because such analysis could improve the efficiency and effectives of investment decisions regardless of whether particular LCCA-mandated requirements are satisfied or not. the necessity for highway agencies to perform LCCA was removed by the 1998 Transportation Equity Act for the 21st century. Nonetheless, utilizing LCCA as a call support tool remains advocated within the FHWA policy, stressing that the outcomes aren't exactly final decisions. this implies that the logical analytical framework of this type of research is as significant because the LCCA results themselves. "It's the target of TEA-21 to extend knowledge of LCCA by applying certain notions, as presented in Fig. 2"[20].

Walls and Smith presented technical instructions and suggestions within the FHWA Interim Technical Bulletin regarding the foremost suitable method of performing LCCA in pavement design. The Bulletin is geared toward throughway agency personnel who perform and evaluate pavement design LCCA. it's specifically associated with the technical aspects of continuous economic efficiency possibilities of other prospective pavement designs. Risk analysis is additionally included as a probabilistic method for understanding unpredictability within the design process.

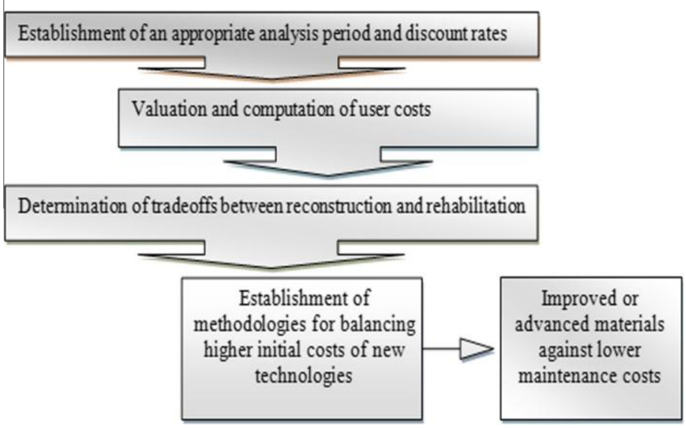

Fig. 2 Process of LCCA by TEA-21

2.3 LCCA models

Huvstig [21] analyzed different LCCA calculation models implemented by road authorities. The models were QUEWZ (Australia), Highway Design and Management (HDM I to IV) developed by the planet Bank, COMPARE (Great Britain) and Whole Life Costing System (USA). These models are basically implemented for the look and construction of roads and pavement types. LCC has been suggested as an element to think about during road design selection or alternatives assessment. However, since it's difficult to calculate LCC for road objects with the dearth of reliable information and calculation approaches, the LCC has less critical importance when assessing alternatives. The inadequacy of investment and maintenance related data is caused by road authorities' failure to own organized and systematic processes for data collection or follow-up throughout the stages of coming up with, design, construction and maintenance. These deficiencies are ultimate because of the scarcity of consensus and comprehensive LCC approaches to properly compute the user costs and environmental costs as precise as agency costs. In some circumstances, LCC even end in rising investment costs. The bases of current deterioration models are experience and empirical models. Nevertheless, these models could produce satisfactory results on the condition that past and future situations would remain identical. this can be quite a rare situation considering building, because a variety of things just like the use of heavier vehicles, traffic development and new varieties of tires impact road conditions. The outcomes of the SRA study are signified rising investment costs that cause negative budgetary implications. Also, it's indicated that this could result in the exploitation of situations by contractors who emphasize on costly resolutions with speculative guarantees that can't be verified or rectified until it's too late. It should be understood that LCC models are mainly for structural road design as tools for choosing the foremost economically reasonable solutions within the context of investment and maintenance. Many of the models don't consider geometrical road design, although such a design method provides road alignment and road restraint systems that affect costs during road life-cycle.

2.4 LCCA effectiveness in pavement design, maintenance and rehabilitation

The Federal Highway Administration (FHWA) guidelines are published to look at the varied cost effectiveness of pavement rehabilitation design approaches. The model framework applied in Anderson's study contained four stages: a pavement condition and analysis module, suitable maintenance and rehabilitation approaches, computing the prices and benefits of all approaches and selecting approaches on a network basis. The study incorporated relationships that link maintenance costs with the pavement serviceability index (PSI) and user cost with the PSI in keeping with road classification.

Lampty et al. [2] presented beneficial tips regarding the event and assessment of maintenance approaches. Their study report indicated that the model was basically developed for rehabilitation strategy analysis, but it are often changed to deal with preventive maintenance practices further more.

Gorvetti and OwusuAbabio [22] utilized LCCA principles in an exceedingly study that examined possible pavement design alternatives. The LCCA principles served to assess the benefits and costs of 1 particular design for flexible and rigid pavements separately over their respective life cycles. They indicated that current LCCA processes could comprise some pavement designs not taken under consideration within the initial LCCA development. In 1984, the long-term pavement programme (LTPP) and strategic highway research programme (SHRP-related) were initiated. the aim was to supply tools to higher understand pavement behavior and to aim for efficient management of highway infrastructure without large increases in funds. The research involved an intensive and detailed study of diverse real pavement and field conditions to find out about maintenance practices, the impact of climate, construction practices, material variations and long-term load effects. One segment of the LTPP study included specific pavement studies #4 (SPS-4) experiments, which were particularly developed to investigate the success of common preventive maintenance treatments of rigid pavements. it absolutely was anticipated that quantifying the power of varied maintenance treatments to prolong the service life or decrease distress rates would be facilitated by analyzing the pavement performance data achieved from the sites or the family sites. The aim of the experiment was also to research how different environmental regions, traffic rates, pavement types (plain or reinforced), sub grade types (course-grained or finegrained) and base types (stabilized or dense granular) impact the preventive maintenance of rigid pavements.

According to the FHWA, as per a recent survey of state practices, some form of LCCA is employed by 28 of 38 responding states in their pavement investment decision-making. it had been also indicated that but 1/2 these 28 states included user costs in their LCCA. In comparing the survey outcomes with an analogous attempt made within the past, Peterson showed that the states are gradually accepting and implementing LCCA concepts during pavement design.

Road authorities are required to specialize in decreasing costs and improving efficiency, since maintenance costs constitute an oversized portion of annual road infrastructure expenditure. Universally, road authorities can only perform new road projects and adequately maintain current roads by lowering costs and enhancing efficiency, as funds for road infrastructure are continually declining.

2.5 **LCCA effectiveness in preservation treatments**

In LCCA, the effectiveness of pavement maintenance or restoration is a major input. Short-term analysis of treat- ment effectiveness may be done, for instance the decline in deterioration rate or performance improvement, or there could be long-term assessments. "Such calculations of preservation effectiveness are more pertinent to LCCA. OneofthethreeapproachespresentedinFig.3 is mainly used for the long-term evaluation"[20] of the effectiveness of preservation treatment (usually over the entire treatment duration).

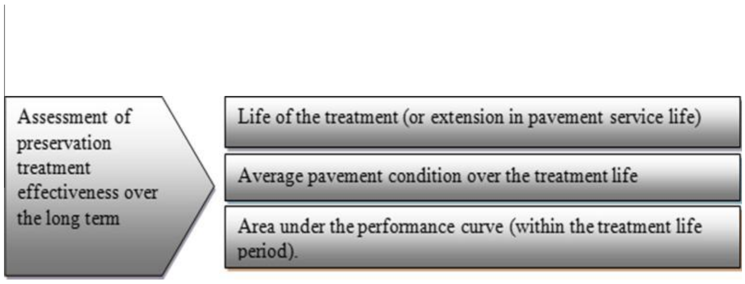

Fig.3 Three different methods to measure assessment of preservation treatment effectiveness

Effectiveness are often measured by forecasting what proportion extension is out there within the remaining service life through the preservation treatment. this implies the time remaining till the pavement weakens to a specific intensity, which is additionally stated because of the treatment service life or treatment life. Treatment life will be measured through performance curves (made from past data), or by using expert opinion and a treatment performance threshold. Compared to those two methods, the area-under-the-curve method is way more data-intensive but relies on simple logic. There are numerous benefits of a well-kept pavement; how- ever, it's quite difficult to quantify the benefits in monetary terms. the realm under the performance curve can function a substitute for user benefits.

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Kher [16] employed the realm under the performance curve for the Ontario Ministry of Transportation and Communications Program Analysis of Rehabilitation System as a substitute for user benefits. Also, the world under the condition-time curve was utilized as a measure of performance when developing budget optimization methods for PAVER (U.S Army Corps of Engineers' Pavement Management System)

Joseph also applied this curve together with road section length and average annual daily traffic (AADT) so as to match the cost-effectiveness of preventive maintenance strategies. the realm under the pavement performance curve was employed by the big apple State Department of Transportation for comparing the cost-effectiveness of different preventive maintenance approaches. within the PSI-ESAL loss concept (where the performance measure is Pavement Surface Index (PSI) and also the ''time'' scale is signified by cumulative loadings applied to the pavement), benefits are denoted by the world under the PSI-load curve. A funding allocation process for the point of entry Bay Area Metropolitan Transportation Commission was developed using the world under the performance-time curve concept.

III. EVALUATING THE BENEFIT AND COST-EFFECTIVENESS

Cost-effectiveness evaluation could be a method of economic evaluation. It involves comparing what's sacrificed (i.e. the cost) to what has been gained (effectiveness) that the alternatives are often evaluated. Measuring cost- effectiveness is also in deep trouble the short or long run. Between long-term and short-term evaluation, the cost- effectiveness concept can be considered more suitable for long-term evaluation. From the view of the economist, effectiveness evaluation may be performed in two ways: first, to realize maximum benefits from a particular level of investment (the maximum benefit approach), and second, to work out the minimum cost for the effective treatment of problems (least cost approach). The first method is applied very frequently in capital investment decision- making, while the second method is more suitable for maintenance cost assessment.

3.1 Maximum ''BENEFIT''approach

This method is often applied for the assessment of capital investment projects, since these activities usually comprise one big investment that's linked with considerable unexpectedness and where each alternative's cost is that the same. Hence, it's quite difficult to guage the precise benefits. it's also usually hard to work out measures of effectiveness for such projects and quite complex to explain thanks to the long duration of the activities and spillover effects. Many research works are conducted over the past twenty years to explain the measures for assessing capital improvement benefits. Several benefits include: tort liability, decrease in period, improved motorist comfort and safety, decreased or deferred capital expenditures through capital preservation, vehicle operating and maintenance costs, and reduced pavement deterioration rate.

3.2 Least Life-Cycle Cost approach

Pavement maintenance investments normally have lower values and take comparatively less time to complete capital improvements. Moreover, their effects are observed soon after

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completion. The least-cost method can be regarded as the most adequate when short-term assessment of corrective maintenance "investments" is to be carried out, because all alternatives are believed to lead to the same benefits.

3.3 Combination of cost and benefit approaches

When assessing pavement preservation, maintenance and reconstruction, using a combination of least cost and maximum benefit is advocated. According to the study, a benefit-cost analysis could be done when the costs and benefits are quantifiable in monetary terms. Among the best tools for measuring the effectiveness of different maintenance activities are the LCC and benefit analysis, whereby all factors are converted into economically measurable units. It is claimed that cost reduction is the benefit, which is implied in the term ''Life-Cycle Cost Analysis."

In pavement management, LCCA has been applied either as the least annualized life-cycle return that is calculated in perpetuity, or as the least present worth of the life-cycle cost and benefit. To evaluate the cost-effectiveness of network-level maintenance and rehabilitation processes, a basic type of LCCA approach was used.

IV. LCCA APPROACHES

LCCA entails two approaches that will be used, which are the probabilistic and deterministic approaches. Input variables are considered discrete fixed variables within the deterministic approach (for instance, design life = 20 years). However, it's observed that a particular level of uncertainty lies within the input values of any LCCA. If prediction is present with engineering analysis, there'll be some level of uncertainty, which is especially thanks to four reasons:

- First, uncertainty is caused by randomness, meaning that the measured or observed values would have different frequencies of occurrence and variation.
- Regional construction variation is the second reason for uncertainty. For instance, the data collected for location ''A" cannot be used to assess any condition in location ''B."
- Uncertainty across human factors is another reason for uncertainty. Factors include imperfect estimation or modelling.
- Finally, a lack of data may be a reason behind uncer-tainty, whereby it is possible to omit a variable due to limited data.

Uncertainties will be managed with various methods, including risk analysis (the probabilistic approach) or sen-sitivity analysis. Sensitivity analysis is employed during model development, when the effects of several input parameters must be analyzed. Several areas of uncertainty must be known during the decision-making process, which cannot be referred to as a part of this sort of research. The probabilistic approach is used with input variables and model for the characterization of risk with the result within the case of risk analysis. If all inputs are analyzed probabilistically, the LCCA system is deemed far more powerful and valid.

4.1 Sensitivity analysis

In order to know the variables affecting the final outcome at the biggest level, the sensitivity analysis method is employed.

Christensen et al. [23] reported that by using this process, the model variables are identified and also the ranking of the considered options is often changed by determining the breakeven points. Rehabilitation timing, discount rate and cost of materials are a number of the factors that have significant influence.

If a change occurs in a model variable like the discount rate, it would have an effect on the ranking of feasible design options, but no dominant alternative design options would emerge. Also, the effect of one model variable on the analysis out- comes are often judged through sensitivity analysis, but it's unattainable for engineers to realize the simultaneous and combined influence of several model variables on LCC results and rankings. Lastly, there's no exploration of the presence of particular values, as probability distributions aren't assigned to variables. Hence, risk analysis facilitates addressing these issues.

4.2 Risk analysis

Probability values are wont to describe variables rather than point values, ensuring that no variables are left unexplored. A simultaneous effect of several model vari- ables on the result is additionally observed, because the sampling techniques take under consideration the variability effect present within the input parameters. Lastly, it's still possible that a dominant outcome might not be observed. A descriptive and clearer image of the associated outcome is presented by assigning a probabilistic distribution to the variables. Many sources have presented information regarding risk analysis introduction, sampling concepts, relevant probability and comparison-related measures. It is feasible for the analyst to assign probability distributions to specific input variables when using risk analysis. to test how close the info set distribution is to the hypothesized theoretical distribution, the goodness-of-fit test are often performed once sufficient data is present. the development variables can best be described by the log- statistical distribution as compared to the widely presumed distribution. The lognormal distribution is followed by pavement thickness and pavement material costs. The results could also be altered if Gaussian distribution is employed rather than lognormal distribution. as an example, a price difference of □62,000/km was observed when distribution was applied instead of lognormal.

V. LCCA ASSESSMENT AND METHODOLOGY

"In the long run, the economic viability of pavement designs is calculated with LCCA. This method is employed by several agencies because it's essential to realistically analyze pavement economics so as to state an objective input to the LCCA. the excellent LCCA methodology is shown in Fig. 4"[20].

For the economic evaluation of projects, many economic indices are available. the inner rate of return (IRR), equivalent uniform annual cost (EUAC), benefit/cost ratio (B/C) and Net Present Value (NPV) are the foremost commonly used indices. Within the

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analysis environment, the amount and context of research determine the sort of indicator to be utilized by a transportation agency. In developing nations, the IRR is that the preferred economic indicator because the discount rate is incredibly uncertain.

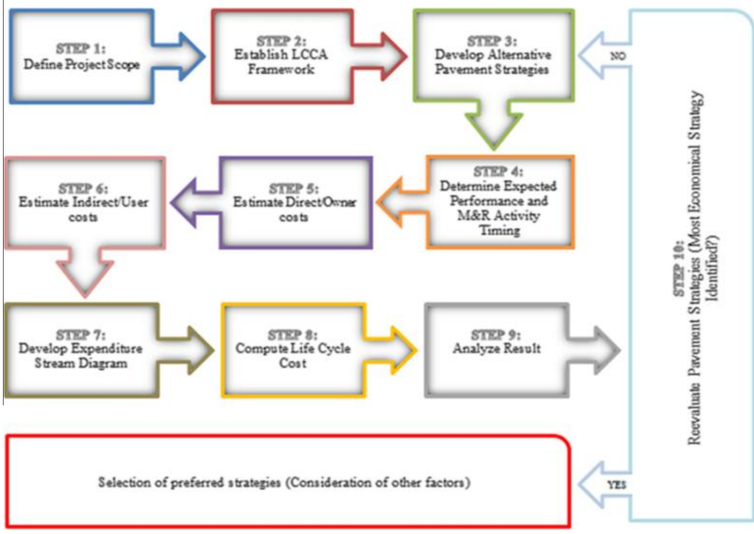

Fig.4 Methodology for conducting airport/highway pavement LCCA

The selected analysis period needs to be compared in terms of performance period establishment, costs of each alternative and activity timing. The equivalent uniform annual costs (EUAC) or the Net Present Value (NPV) is used for this purpose. NPV and EUAC are the most common indicators used today."The projected value in terms of the present value of money is used for the initial costs, maintenance and rehabilitation costs and salvage value is used, as shown by the expenditure stream diagram in Fig. 5"[20]. The discount rate factor is then applied to calculate the time value of money.

Eq. (1) can be applied for a pavement case, as NPV is considered a popular economic computation

$$NPV = Initial\ Cons.Cost + \sum_{K=1}^{N} Future\ Cost_K \left[\frac{1}{(1+i)^{n_k}}\right] - Salvage\ Value\left[\frac{1}{(1+i)^{n_e}}\right] \quad (1)$$

where:

N= number of future costs incurred over the analysis period,

i = discount rate in percent,

nK = number of years from the initial construction to the K^{th}expenditure,

ne= analysis period in years

Present and future expenditures are converted to a uniform annual cost in order to present the equivalent uniform annual costs (EUAC). When budgeting is carried out annually, this is a preferred indicator. Eq. (2) states the formula for EUAC

$$EUAC = NPV\left[\frac{(1+i)^n}{(1+i)^n - 1}\right] \quad (2)$$

Where:

i=discount rate,

n=years of expenditure.

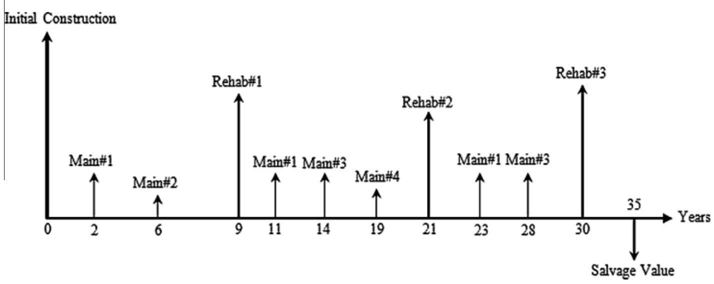

Fig. 5. Example of expenditure stream diagram

"As shown in Fig. 6, costs are divided into two basic categories: direct/owner costs and indirect/user costs, both of which are subdivided again"[20]

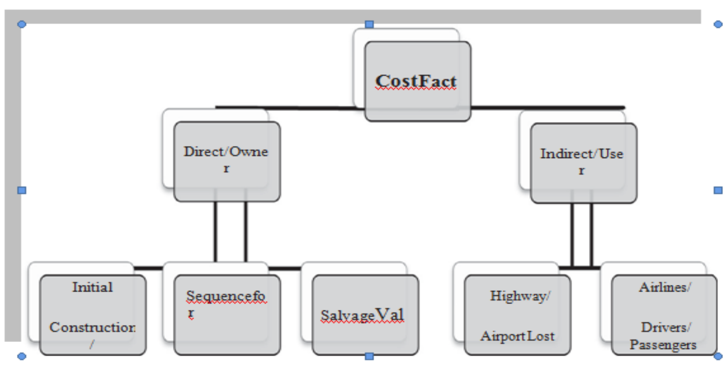

Fig. 6. LCCA cost factors in highway/airport

5.1 Initial cost

The initial construction cost is presented in unit price from bid records of projects constructed in previous years and only representative prices must be used. Unit prices is also taken out of the cost of previous projects if the representative costs aren't available. The start-up cost is often taken into consideration additionally as a part of the LCCA. Hence, the annual budget limits workplace and there's a necessity to analyze the expenditures short-term implications and therefore the long-term influence of pavement type decision.

5. 2 Determining the performance periods and activity timing

LCCA outcomes are much affected by activity timing and performance period. Both user and agency costs are impacted. Historical experience and analysis of pavement management systems (PMS) help present pavement performance design-life. The performance must be recorded at regular intervals from initial construction until reconstruction. By applying the concept of Perpetual Pavement, it's observed that reconstruction takes place longer (30–50 years) than a normal period. The analysis period proposed by the Asphalt Pavement Alliance (APA) is 40 years or more and it also requires for every pavement choice to have a minimum of 1 rehabilitation activity. The Alliance follows the 35-year minimum policy brought for-ward by the FHWA. Judgement or actual construction and pavement management data set must be utilized in fore- casting the magnitude of the first rehabilitation. in keeping with the APA, information was collected from various state highway agencies and also the result clearly showed that the first overlay was required after 15 years from initial construction and through the performance period. the common observed period for the identical interval was 15.7 years. the common performance period observed from the first to the second overlay was another 12 years. Hence, the typical time from the first construction to the second overlay was 27.7 years. The figures were extracted for asphalt overlay performance from a long-term pavement performance study by the FHWA. It indicated that the overlays lasted 15 years and a few lasted 15 years until significant distress signs were noted. within 1990 Super pave was implemented and within the 1990 a number of the agencies were using the Stone Mastic Asphalt (SMA), which is why variety of performance enhancements haven't been completely realized.

5.3 Maintenance and rehabilitation costs

Maintenance and Rehabilitation (M&R) is another matter that needs attention. Preventive maintenance strategies appear to be way more cost effective compared to conventional maintenance strategies. It's difficult to see maintenance costs because there's usually an absence of efficient record keeping and differentiation between maintenance actions can't be achieved. Hence, tools to assist users define the effects of preventive maintenance are required. Compared to the initial construction and rehabilitation costs, the upkeep cost of an LCCA has limited effect. Historical records of the particular pavement costs and activities must be utilized if these costs are present within the LCCA procedure. An artificial increase in LCC would happen if there have been unsuitable and frequent maintenance activities like rehabilitation.

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5.4 Salvage value

Beyond the analysis period, some pavement structure can still be serviced; however, if the condition is beyond maintenance, action must be taken. If the assets still have a useful life at the tip of the life analysis period, the salvage value or residual value must be determined. There are two components to the salvage value. One part is that the residual value, which refers to the web value from pavement recycling. The second part is that the serviceable life, which is that the pavement alternative remaining life when the analysis period expires. During LCCA, salvage value is that the term normally used, but within the case of FHWA, the term ''remaining service life" (RSL) is preferred. This helps differentiate the very fact that the pavement will remain in commission after the analysis period has expired. The salvage value may be taken because the percentage of initial pavement construction cost.

5.5 Discount rate

When long term public investments are being analyzed ,costs are compared at several points of time for which dis-count is necessary .A rupees pent in the future is considered of lesser worth than a rupees pent today ,which is why it is said that time, has money value. Hence, it is essential to convert the costs and benefits stated at different points of time to the costs and benefits that would happen at a common time. Discount rate is the rough difference between the interest and inflation rates and it indicates the real value of money over time. The mathematical relationships between interest rate, inflation rate and PW are presented in Eqs. (3) and (4).

$$PW = C \times \left[\frac{(1 + i_{inf})}{(1 + i_{int})}\right]^n \qquad (3)$$

Or:

$$PW = C \times \left[\frac{1}{(1 + i_{dis})}\right]^n \qquad (4)$$

Where:

PW = present-worth cost,

C = future cost in present-day terms,

i_{inf} = annual inflation rate (decimal),

i_{int} = annual interest rate (decimal),

n = time until cost C is incurred (years),

i_{dis} = annual discount rate (decimal)

Research has shown that if data are collected over a long period of time, the real-timevalueofmoneywouldonlybe2–4%. To determine the LCCA and the mean value of probabilistic normal- distribution LCCA, the most current annual real discount rate based on a long-term (10, 20 or 30 years) treasury rate must be used.

VI. PAVEMENT LCCA TOOLS AND PROGRAMMER

6.1 Existing LCCA packages

"Approaches for pavement Life-Cycle analysis are developed within the previous couple of decades by various organizations, agencies and other intuitions. Some have even developed computer programs for his or her LCCA approaches so as to further extend the analysis. This section includes an outline of the nominated LCCA software for pavement design and management (Table1)"[20]. Other pavement companies use different LCCA computer software and methodologies, including methods for Alabama, Pennsylvania, and non-automated methodologies. Highway work zone lane closures are evaluated using the QUEWZ model (Queue and User Cost Evaluation of labor Zones).

6.2 Merits and limitation of LCCA methodologies and software packages

LCCA models are subject to certain limitations. User cost exclusion is one of the limitations in analysis. Highway users incur these costs, which include delay costs, vehicle operating costs (such as fuel, tires, engine oil, and vehicle maintenance) and any other accident costs. User cost is excluded in several LCCA methods and software as quantification is difficult and there is disputed values treatment within strategy formulation. LCCA researchers and practitioners argue that preventive maintenance may be a new preservation strategy for pavements and data on long-term benefits still must be collected. Presently, only certain models are ready to quantify the long-term effective-ness of preventive maintenance treatment. this can be wiped out the shape of service life extension or a performance jump. Hence, it's seemingly challenging to incorporate preventive maintenance in LCCA. it's also observed that users find the accounting of LCCA input parameters complicated, which is why they are doing not consider it during the method. The LCCA models treat the input variables discretely and also the single deterministic results computed through the best-guess process of the fixed values for every input parameter. The assorted input parameters affect the model results, which is why evaluation is finished with sensitivity analysis. The uncertain areas that will be crucially affecting the choice making process don't seem to be shown as a part of the sensitivity analysis. Hence, it's difficult to look at which option consists of very cheap true LCC. The uncertainty problem is often managed by LCCA through the chance analysis procedure. This is able to allow decision makers to weigh the probability of any potential outcome. In contrast to most LCCA packages, this FHWA package includes LCCA probabilistic approaches.

Table1: Comprehensive LCCA packages.

SoftwarePackage	Year	Producer	Life-cycleCosts				Descriptions
			Initial Construction	Rehabilitation	User Cost	Salvage Value	
DARWin	N/A	AASHTO	√	√		√	Project level valuation
TEXAS DOTRPS/FPS	1968	Centre of Highway Research of Texas Transportation	√	√		√	Latest version consists of user cost
HDM	1977	World Bank	√	√	√		The HDM updated new versions
LCCP/LCCPR[1]	1987	University of Maryland			√		The programs comprise of user operating costs associated with pavement roughness
EXPEAR	1989	University ofIllinois[2]	√	√			Project level assessment
PRLEAM	1991	University of Waterloo	√	√	√	√	Most focus on cost-effective rehabilitation improvement approach
LCCOST	1991	Asphalt Institute	√	√	√	√	Routine maintenance (optional) is also considered
Micro BENCOST	1993	Texas Transportation Institute	√	√			Under the NCHRP Project7-12
ACPA LCCA[3]	1993	ACPA	√	√	√	√	Risk analysis is used to make sure a 90% confidence level
CAL-B/C	2000	California Department of Transportation	√	√	√		A first spreadsheet format (MS Excel)
REALCOST	2004	FHWA	√	√	√	√	First Probabilistic and comprehensive software
D-TIMS	2006	Indiana Department of Transportation	√	√	√		Provides the recommendations for the treatment for the specific distresses
IDAHO DOTLCCA	2008	Idaho Transportation Department	√	√			Units across the English and metric system can also be converted
APALCCA	2011	APA	√	√	√	√	The software using the work zone duration and the hourly traffic distribution

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1 "The rigid and flexible pavements were analyzed through the programs" [20].

2"The EXPEAR computer program was developed by the University of Illino is under a FHWAproject"[20].

3"The Winfrey's Economic Analysis for Highways (1969) and NCHRP Report 133 are used by the ACPA spread sheet to extract the user costs employing values"[20].

VII. CONCLUSIONS

"Use of LCCA must be allotted appropriately and data utilized must be from existing records that are accurate in terms of initial costs, salvage value, rehabilitation timing and costs further as discount rates"[20]. Data are available for some aspects, but other data must be analyzed and documented by the agencies themselves. It's essential to know that LCCA is simply a tool and also the results must not be taken as decisions. Several other factors but LCCA must be taken into consideration when deciding which type of pavement should be considered. The LCCA process comprises several assessments, predictions and assumptions. Differences in inputs can considerably impact analyst's confidence with the LCCA results. Input accuracy is crucial for all aspects. The precise estimation of pavement performance, traffic for quite 30 years within the long run and future costs by analysts determines the reliability of LCCA results. In managing forecast uncertainties, the probabilistic risk analysis approach is gaining popularity. It allows to quantitatively capturing input parameters, helping to supply LCCA results. an outsized an element of literature also states that LCCA implementation is as complicated as selecting the correct discount rate and agency costs, quantifying non-agency costs as user costs, securing credible supporting data including traffic data, estimating the salvage value and useful life, modelling asset deterioration, and estimating maintenance costs, effectiveness and travel demand throughout the analysis period. During major rehabilitation and construction activities, the overwhelming majority of LCCA only use delay costs as part of user costs.

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