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Application of Life Cycle Cost Analysis for Road Construction Project

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Abstract - Life Cycle Cost (LCC) idea is significant in numerous fields. The assessment of life cycle cost examinations assumes a significant part in concluding if to secure to get a resource. The board investigations the expense of buying and activity of the resource, and for the most part considers a resource that costs the least. Methodologies for asphalt Life-Cycle Cost Analysis have been developed by associations and organizations over the last few years (LCCA). Although LCCA is increasingly being used as a mode of transportation in the local area, a significant practice. Current LCCA techniques are broke down and presented in this review article. In this review article rundown of monetary factors is furnished alongside there after parts. Exploring past writing will assist with featuring and examine most fragile angles to fix the shortcomings in current LCCA techniques, if private companies and government agencies work together, the LCCA examination can become more useful. Organizations begin to utilize this technique for their financial development then and only then LCCA will come in existence and would be made mandatory.

Key Words: Life-Cycle Cost analysis (LCCA); Pavement management; Sensitivity analysis; Net Present Value (NPV)

1.INTRODUCTION

In present days, construction industry is essentially zeroing in on the underlying development costs instead of future running expenses [1]. Expressway asphalt development, upkeep and cost of recovery is increasing rapidly. It is important for highway offices to employ instruments and methods that assist in the creation of an effective dynamic by analyzing financial aspects and activities. For instance, Life-cycle Cost Analysis (LCCA) can be used to make financially sound long-distance investments. LCCA is a methodology focused on monetary inquiry criteria. It improves the overall long-term evaluation of haul monetary ability of various venture alternatives [6]. Yet the way that it considers a plan time of 25 years for adaptable asphalts, the Portuguese manual of asphalt structures (JAE 1995) states the need of making a daily existence cycle cost investigation (LCCA) for a time of no under 40 years, called project examination period, to look at changed asphalt arrangements regarding worldwide expenses for the last decision of the asphalt structure for a public street or an interstate [8]. The significance of adopting a daily existence cycle strategy toward transportation ventures keeps on developing as arranging offices look for successful approaches to keep a maturing framework network that traverses more than 8.3 million path miles and supports over 122.9 million vehicle miles each year in India [10]. LCCA programs have been used by highway associations to favor the selection of one asphalt plan over the others. Much of the techniques have been heavily archived by roadway organizations portraying the point-by-point execution of asphalt LCCA, consider distinctive expense input esteems related with the asphalt over its administration life [12]. Life-cycle cost examination (LCCA) is the ordinary strategy for the assessment of the monetary advantages and gets back from any speculation by breaking down its future uses alongside the underlying expenses. While the utilization of LCCA in street development has been given impressive consideration during the previous many years, just restricted viable application has been accomplished so far [13].

2.RESEARCH METHODOLOGY

2.1 Literature search and selection

For the motive of this study, systematic research approach has been carried out and also many researches as well as review articles has been done. Keywords such as life cycle cost analysis, pavement management, net present value, sensitivity analysis and risk analysis were used for searching the research and review articles for study purpose. The articles reviewed in this paper have been collected from some reputed journals – International Journal of Project management, Journal of Construction Engineering and Management, Taylor and Francis, American Society of Civil Engineers, Multidisciplinary Digital Publishing Institute and others. This provided and initial head start to begin the review paper. After reviewing this article other literatures were found which were cited within these articles. While more than fifty articles were referred in this study and some papers were short-listed among these articles used for review and analysis. Table 1 provides the details of literature reviewed by source and time period of publication.

Table -1: Literature reviewed by source and time period

Description	Literature referred in the study					L
Research period	**2000 - 2004**	**2005 - 2009**	**2010-2014**	**2015 - 2019**	**2020 - 2021**	**2 - 2**
Journal articles		1	9	24	13	
Conference Proceedings			1			
Web publications	2			1		2
	2	**1**	**10**	**25**	**13**	**2**
Total	**51**					**35**

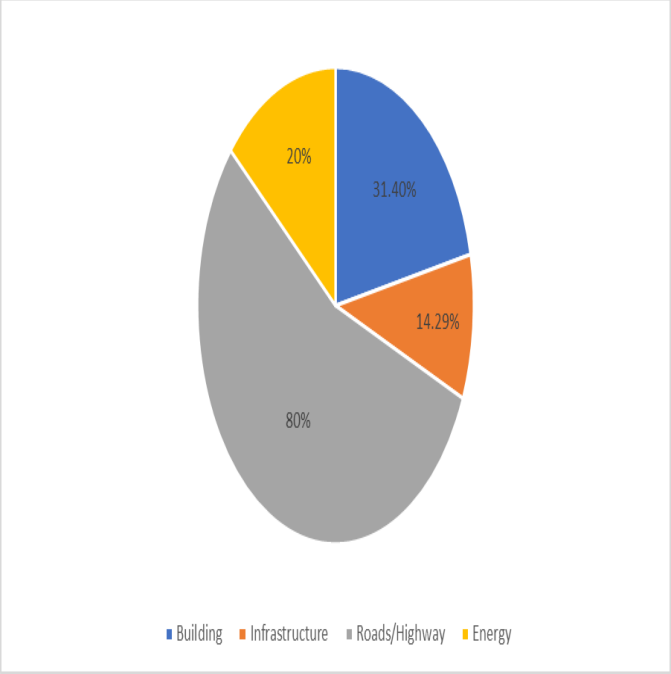

Fig -2: Break up of literature reviewed by type of projects

2.2 Literature classification

Further, the referred articles were divided in different countries in which the study was done, to check the trend of life cycle cost analysis in particular countries. In the next step, the studies were divided into types of project investigated by the authors in their study. Figure 1 & 2 represent the details of literature reviewed in this article by country and project type.

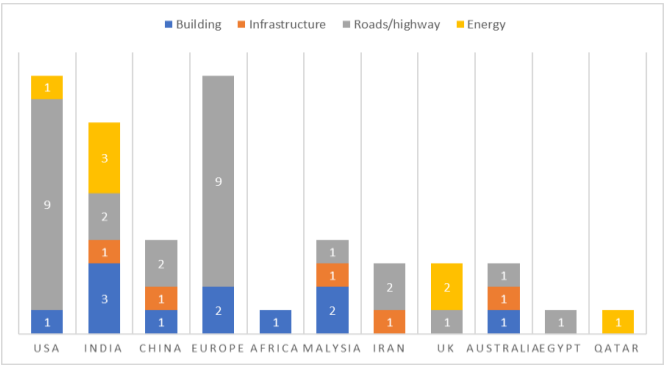

Fig -1: Literature reviewed – by country and project type

3.LITERATURE REVIEW

3.1 Historical background

Life cycle cost (LCC) assessment was initially acted in mid-1960s with the guide of U.S Department of Defense for speculation purposes. LCC performed for the U.S Department of protection was demonstrated by the way that the operational costs with respect to the weapon frameworks, used to be 75% of the total life cycle costs [1]. As an idea, it was during the 1950s that benefit-cost analysis (BCA) was first and foremost applied as a determination factor for different asphalt plan alternatives. At that point during the 1970s, LCCA standards began being execute in some vital tasks at the neighborhood and public state levels in numerous nations for asphalt plan and asphalt type choice [6]. LCCA is viewed as a significant apparatus by a few creators for the plan and upkeep of foundations, for example, spans, interstates, asphalts, and so forth Peterson (1985) clarifies how LCCA can be utilized by asphalt architects and support specialists to choose an asphalt structure that is the most affordable after some time [8]. It was guided into the transportation space during the 1960s through crafted by designing financial expert Winfrey and the American Association of State Highway and Transportation Officials (AASHTO) "Red Book". In the 1980's the central government uphold the utilization of LCCA as a method for monetary assessment and introduced LCCA condition of-

rehearses in transportation organizations [11]. The concept of LCCA evaluating is fraught with dangers and ambiguity, both of which have an effect on the unwavering accuracy and precision of its outcomes. In general, early efforts have been focused on how to deal with such dangers and eccentrics. For example, Flanagan et al. (1987) coordinated danger the executives and LCCA to address various wellsprings of dangers and eccentrics, for example, markdown rate, beginning capital expense and running expenses [12].

3.2 Functions and Legislative Requirements

The Intermodal Surface Transportation Efficiency Act of 1991 mandated the use of LCC during the planning and construction of passages, scaffolds, and asphalts [33]. The Federal Highway Administration (FHWA) aided state transportation departments in completing LCCAs for all asphalt projects costing more than $30 million. According to the National Highway System (NHS) Designation Act of 1995, each NHS "major cost functional venture fragment" should be subjected to a life cycle assessment [6]. LCCA is a technique for breaking down the complete monetary estimate of a realistic task fragment by evaluating the underlying expenses and restricted potential costs including assistance, recovery, remaking, remerging, and re-establishing costs over the entire life of the undertaking, as stated in section 303 of the NHS Designation Act. Despite the fact that LCCA is only needed in certain situations, the FHWA consistently promotes its use when evaluating extremely important speculation options. This is because, regardless of whether specific LCCA-approved requirements are met, such research may enhance the quality and efficiency of speculation options [34]. The 1998 Transportation Equity Act for the Twenty-First Century differentiated the obligation for expressway offices to conduct LCCA. However, using LCCA as a decision-making aid is still recommended in the FHWA technique, with the exception that the findings are not final decisions. This implies that the straight-thinking logical system of this sort of examination is just about as remarkable as the LCCA results themselves [35]. In the FHWA Interim Technical Bulletin, Dividers and Smith presented specialised headings and recommendations about the most reasonable technique for performing LCCA in asphalt plan [35]. The Bulletin is intended for employees of public interstate offices who conduct and evaluate asphalt plan LCCAs. It is particularly linked to the specific highlights of resourceful financial effectiveness prospects of other possible asphalt plans. Danger investigation is also included as a probabilistic method for understanding plan interaction vulnerabilities [6].

3.3 LCCA Models

Huvstig [6] explored a number of LCCA figuring models used by street experts. QUEWZ (Australia), HDM I to IV (extended by The World Bank), COMPARE (Great Britain), and Whole Life Costing System were the models used (USA). LCC has been suggested as a consideration to consider when deciding on a street plan or evaluating options. These models are primarily used to design and build streets and various asphalt forms [6]. Tradable merchandise, for example, raw petroleum, fuel oil, transportation fuel and in some cases, power have a worldwide market, and their future costs can be autonomous of the country financial pointers, for example, swelling rate. Hence, in this system, the expenses are isolated into energy-and time-related expenses. Time-related expenses are those influenced by the public economy, for example, work/gear and street client costs [17]. A model created to conjecture asphalt scraped spot because of studded tires was utilized to gauge the scraped spot's commitment to the rutting (Jacobson and Wagberg 2007) [18]. Weariness breaking models utilized in this examination were received from Mechanistic-Empirical Pavement Design Guide (MEPDG). Notwithstanding, it ought to be noticed that MEPDG longitudinal (top-down breaking) breaking models were not utilized for re-enactments in light of the fact that the precision of these models was resolved to be low [21]. Rutting in the black-top and unbound layers are independently anticipated in MEPDG. Absolute surface rutting is determined by adding the anticipated rutting altogether layers [21]. The age substitution model shows two circumstances: finishing and beginning a cycle with a preventive substitution. From this point forward, a devoted numerical recipe that incorporates limiting of expenses throughout a boundless time skyline is introduced. A common-sense model is utilized to contrast the numerical condition and the LCC procedures [23]. Other model is Total cost of ownership (TCO), in this model securing cost, possession cost and removal cost are added to get the complete expense of possession. Furthermore, this model attempts to limit the complete expense of possession [31]. Treatment expenses and decay cycles could impact treatment activity decisions and treatment timing, individually, in a LCCA. Henceforth, these two boundaries ought to be anticipated for every year. Thinking about vulnerabilities, probabilistic forecast models of treatment cost and asphalt disintegration were consolidated in LCCA model [7].

3.4 LCCA Effectiveness in Pavement Design, Maintenance and Rehabilitation

The rules of the Federal Highway Administration (FHWA) are spread to understand the various cost feasibility of asphalt recovery configuration approaches [6]. Anderson's model framework had four phases: an asphalt condition and investigation module, acceptable upkeep and repair approaches, registering the costs and benefits, and selecting approaches on an organizational premise. As indicated by street order, the investigation included links that interface support costs with the pavement serviceability index (PSI) and client costs with the asphalt functionality log [6]. It coordinates beginning and limited future organization, client

and other significant expenses over the lifetime of various ventures. It assists with perceiving the best worth (the least long-haul cost that fulfils the presentation objective being looked for) for venture spending (Walls and Smith 1998) [8]. LCCA is viewed as a significant device by a few creators for the plan and support of foundations, for example, spans, interstates, asphalts, and so forth Peterson (1985) clarifies how LCCA can be utilized by asphalt architects and support designers to choose an asphalt structure that is the most affordable over the long haul [8]. As indicated by ISO norms, LCA comprises of four stages: objective and extension, stock investigation, sway appraisal, and clarification (ISO, 2006a) [14]. In conventional LCC investigations, the expectation of the expenses in an undertaking is done through the assessment of current or future expenses by foreseeing the impact on expenses from likely patterns in financing cost and swelling (Chan, Keoleian, and Gabler, 2008; Eisenberger and Remer, 1977; Federal Highway Administration [FHWA], 2003; Mandapaka et al., 2012; Santos and Ferreira, 2013; Walls and Smith, 1998; Zhang, Keoleian, and Lepech, 2008) [17]. Life cycle costing is a monetary calculation approach that examines a project's total costs over an indefinite period of time by comparing costs for the venture today with operation and support costs later on (ISO 2008) [18]. Cost sources occurring at different times become the same by restricting all costs to a net present value (NPV), normally the hour of financing option. By splitting the subsequent LCCs between at least two other alternatives, the most cost-effective long-haul financing alternative can be identified (Walls and Smith 1998) [18]. The LCIA tries to build up a linkage between the framework and the possibility to cause human and ecological harm. In the understanding, the outcomes from the past stages are assessed according to the objective and extension to recognize examination refinements and upgrades, arrive at resolutions and suggestions, and, by and large, guide in the dynamic interaction (Finnveden et al., 2009) [22].

4.LCCA APPROACHES

The probabilistic and deterministic methodologies are the two methodologies that LCCA forces to be used. Information factors are viewed as particular fixed factors in the deterministic methodology (for example, plan life = 30 years). All things considered; it is noticed that a specific degree of flightiness exists in the info estimations of any LCCA. Whenever gauge is available with designing examination, there will be some degree of vulnerability, which is principally because of following reasons [6]:

- First, flightiness causes unusualness, meaning that the intentional or noticeable qualities will have different rates of occurrence and substitutes.
- The second reason for unconventionality in regional growth is variety. For example, the data collected in area"1" cannot be used to evaluate any condition in area "2."
- Another reason for arbitrariness is uncertainty among human elements. Imperfect estimation or explaining are examples of variables.
- Finally, an absence of information might be a purpose for eccentrics, for-which it is conceivable to leave out a variable because of restricted information.

Vulnerabilities can be controlled with different strategies, including hazard investigation (the probabilistic methodology) or affectability examination [7]. Affectability examination is utilized during model turn of events, when the impacts of a few info boundaries should be breaking down. Over the complex period, different territories of unconventionality should be known, which may not be known as a function of this type of investigation [8]. For the representation of risk, the probabilistic approach is used with input factors and PC replication, with the outcome based on the risk test. If all sources of data are probabilistically separated, the LCCA system is seen as significantly more impressive and valid [9].

4.1 Sensitivity Analysis

The affectability examination technique is used to understand the variances affecting the final outcome at the most fundamental stage. According to Christensen et al. [34], the model variables can be identified using this interaction, and the positioning of the considered options can be modified by controlling the breakeven focuses. It is discovered that the consequences of LCCA are influenced by various eccentrics and dangers related with various factors, for example, markdown rate and treatment timing [12]. Accordingly, an affectability examination is figured out how to test the impact of changing various factors on an official choice [12]. Normally, an affectability investigation is valuable for testing the effect of elective presumptions and decisions made in directing the LCA study. The target of such an examination is to give further experiences that can, thusly, improve the general blend plan while diminishing its ecological effect [15]. Affectability investigation is performed to evaluate meaning of different variables on the client costs such traffic, action timing, culmination rate, IRI movement rate, and rebate rate [19]. In the wake of getting ideal qualities for the plan boundaries, affectability examination can be performed to evaluate the impact of changes in plan boundaries (segment and framework dependability, viability and framework arrangement) and upkeep plan boundaries on the LCC and other execution pointers [31]. If a model variable, such as the rebate rate, were to shift, it would influence the placement of useful plan options, but no governing elective plan alternatives would emerge. Similarly, affectability testing may be used to determine the influence of a single model variable on investigation outcomes, but it is not possible for experts to determine the simultaneous and combined impact of many model variables on LCC results and rankings [34].

4.2 Risk Analysis

Likelihood esteems have been used to depict boundaries rather than point esteems, guaranteeing that no boundaries are unexposed. Simultaneously impact of a few model boundaries on the result is likewise seen, as the testing procedures consider the changeability impact present in the information factors. At last, it is as yet conceivable that an administering result may not be taken note. An illustrative

and clearer picture of the connected result is introduced by designating a probabilistic appropriation to the boundaries [6]. Numerous sources have demonstrated data concerning hazard investigation presentation, inspecting ideas, pertinent likelihood and correlation related advances. It is reasonable for the investigator to designate likelihood dispersions to specific information factors while utilizing hazard examination [24]. To test how close the data set appropriation is to the conjecture hypothetical circulation, the honesty of fit test is oftentimes performed once adequate information is available. The improvement boundaries can best be depicted by the log-measurable conveyance when contrasted with the generally expected appropriation. Asphalt thickness and asphalt content costs follow the log-typical circulation. Finally, if Gaussian appropriation is used instead of lognormal circulation, the results may be altered [34].

5. LCCA ASSESSMENT AND METHODOLOGY

LCCA is a financial methodology which is utilized to assess the total expense related with the structure plan and development, building activity, building activity and building deconstruction cost [6]. LCCA is done to extend future expenses over the long haul with the drawn-out speculation of proprietorship by utilizing present worth. The normal expansion rate in India according to World Bank information is 4.9% [13]. Change in expense by utilizing swelling rate can be determined by utilizing the underneath equation (1):

FV=PV*(1+i) n..... (1)

Where,

FV = Future value

PV = Present value

i = Inflation rate

n = Number of years

For the monetary appraisal of activities, numerous financial lists are available. Lists such as the internal rate of return (IRR), equivalent uniform annual cost (EUAC), benefit/cost proportion (B/C), and net present value (NPV) are widely used. The type of pointer to be used by a transportation company is defined by the degree and setting of inquiry within the examination context. In agricultural countries, the internal rate of return (IRR) is supported financial pointer as the markdown rate is truly capricious [6]. The broad LCCA technique is appeared in Figure 3.

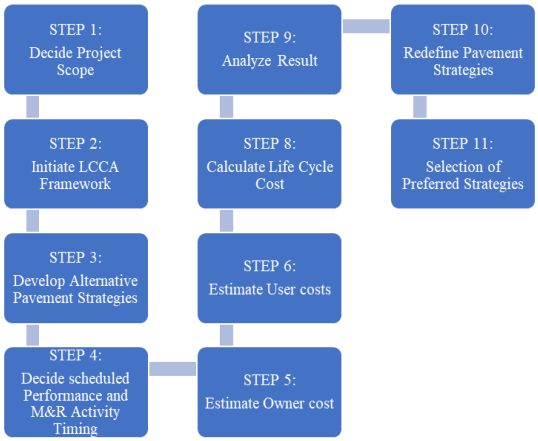

Fig -3: Methodology for conducting highway pavement LCCA

The chosen examination period should be analyzed as far as execution period foundation, expenses of each various other options and furthermore action timing. The same equivalent unit annual cost (EUAC) or the net present value (NPV) is utilized for this thought process. Net present worth and identical uniform yearly expense are the most widely recognized markers utilized these days. The extended an incentive as far as the current estimation of cash is used for the underlying expenses, support and recovery expenses and rescue esteem [6].

Since net present value is a common monetary figure, Equation (2) can be polished for an asphalt state. [34].

NPV = Initial Cons.Cost +∑(K=1)^NFuture Cost K [1/(1+i)nk]–Salvage Value[1/(1+i)ne] (2)

Where,

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

i = discount rate in present,

nk = number of years from the initial construction to the Kth expenditure,

ne = analysis period in years.

To present the corresponding uniform annual costs, the present and future costs are changed to an equivalent uniform annual rate (EUAC). This is a valuable measure as budgeting is done annually. Equation (3) states the formula for EUAC [34]:

EUAC = NPV[(1+i)n / (1+i)n – 1] (3)

Where,

i = discount rate,

n = years of expenditure.

As demonstrated in Figure 4, costs are ordered into two fundamental classes: direct expenses and backhanded expenses, the two of which are subcategorized again [6].

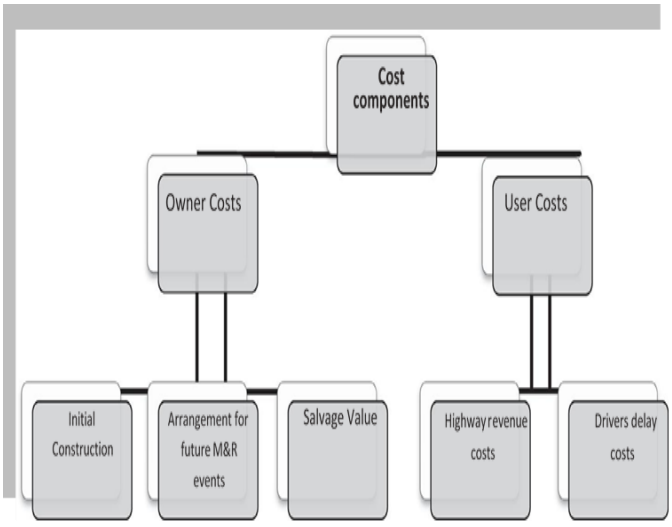

Fig -4: LCCA cost factors in highway project

5.1 Initial Cost

Only delegate costs can be used because the underlying implementation cost is presented in unit costs from bid records of tasks built in previous years. If the agent costs are not open, unit costs could be deducted from the general expense of previous tasks. The underlying cost should be taken into consideration as part of the LCCA. Along these lines, an office's annual budget limits it, and there is a need to look into the short-term and long-term effects of asphalt type selection [6].

5.2 Determining the performance periods and activity timing

Action timing and execution duration have a huge effect on LCCA outcomes. The expenses of both the customer and the office are affected. Past experience and a study of the pavement management system (PMS) will help prolong the life of the existing asphalt execution plan [6]. From the start of construction to the rest, the exhibition should be projected at regular intervals. As the concept of Continuous Pavement is applied, it is discovered that leisure takes place over a longer period of time (30 to 45 years) than is typical. The Asphalt Pavement Alliance (APA) proposes a 40-year or longer investigation cycle, as well as requiring any asphalt option to have at least one recovery action [34]. The Alliance (APA) follows the 35-year least strategy presented by the FHWA. Judgment or real development and asphalt the board data should be utilized in foreseeing the monstrosity of the main recovery. As indicated by the APA, data was gathered from 48 public parkway organizations and the result plainly demonstrated that the primary overlay was needed following a long time from fire up development and during the exhibition time frame. For a comparable time span, the average noticed length was 15.6 years. The standard exhibition cycle for 48 US states was an additional 12 years from the first to the second overlay. As a result, the average time between the main production and the overlay was 27.6 years. The figures for black-top overlay execution were taken from a lengthy FHWA asphalt execution report. It was discovered that the overlays lasted 15 years on average, with some lasting up to 20 years before notable trouble signs were detected [33]. During the 1990s, Superpave was implemented, and a portion of the offices used Stone Mastic Asphalt (SMA), which is why multiple execution upgrades have not been fully implemented [28].

5.3 Maintenance & Rehabilitation Cost

Another condition that needs attention is maintenance and rehabilitation (M&R). When compared to conventional support techniques, preventive maintenance systems tend to be much more capable [6]. It is hard to choose support costs on the grounds that there is for the most part a nonattendance of effective record keeping and qualification between upkeep activities can't be reached. In this manner, devices to assist clients with deciding the impacts of preventive upkeep are required [2]. In comparison to the underlying production and recovery costs, the LCCA support expense has a minor impact. If these expenses are available in the LCCA technique, past reports of actual asphalt expenses and exercises should be used [7]. If there were incorrect and revisited upkeep exercises including rehab, LCC would extend in a controlled manner [34].

5.4 Salvage Value

Regardless of the inspection time period, some asphalt construction may be overhauled; but, if the condition is beyond repair, action should be taken. If the resources are still useful near the end of life (EOL) examination period, the rescue value or lingering esteem should be chosen [6]. The rescue esteem is made up of two sections. One portion is the lingering esteem, which relates to the net profit of reusing asphalt [18]. The next section is the usable life, which is the asphalt's second life after the investigation period has ended. When conducting LCCA, the term "rescue esteem" is commonly used, but the term "remaining service life" (RSL) is sponsored by FHWA. This aids in altering the way the asphalt remains in place after the inspection period has ended. The rescue value can also be used to determine the initial asphalt construction expense [34].

5.5 Discount Rate

At the point when long haul public ventures are being inspected, costs are thought about at a few purposes of time for which markdown is required [6]. In this way, it's important to translate the costs and benefits reflected at different points in time to the costs and benefits that will arise at a normal time. The refund rate is the unpredictable distinction between the premium and swelling rates, and it measures the true worth of money over time [33]. The numerical connections between loan cost, expansion rate and present worth are introduced in conditions (4) and (5).

PW = C * [(1 + Iinf)/ (1 + Iint)]n (4)

Or:

PW = C * [1/ (1 + Idis)]n (5)

Where,

PW = present worth cost (₹),

C = future cost in present day terms (₹),

Iinf = annual inflation rate,

Iint = annual interest rate,

n = time until cost C is incurred,

Idis = annual discount rate.

According to research, if data is collected over a long period of time, the continuous estimate of money is only 2 to 4% [6]. The most recent annual genuine rebate rate based on a long haul (10, 20 or 30 years) deposit - taking rate should be used to determine the LCCA and the mean calculation of probabilistic ordinary appropriation LCCA [34].

6. DATA ANALYSIS

6.1 Future Value

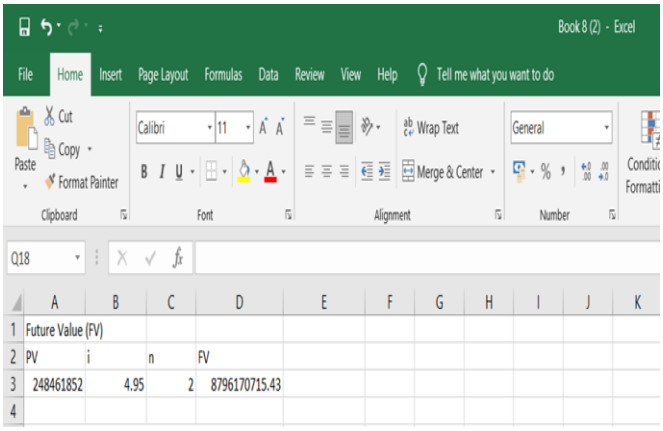

Fig -5: Calculation for future value

Where,

PV = Present Value,

FV = Future Value,

i = Inflation rate,

n = Number of years.

6.2 Net Present Value

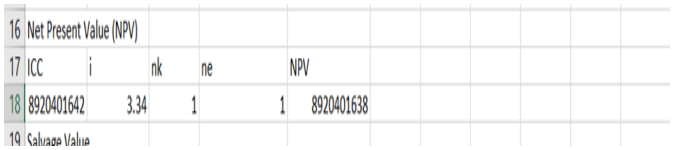

Fig -5: Calculation for net present value

Where,

ICC = Total of all cost

i = Discount Rate

nk = Number of years from initial construction to the Kth expenditure

ne= Analysis period

6.3 Salvage Value

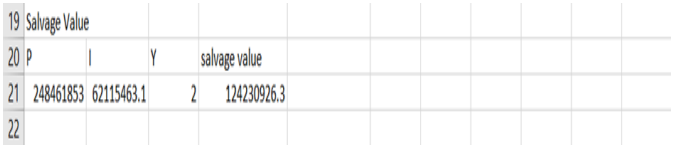

Fig -6: Calculation for salvage value

Where,

P = Present value

I = Depreciation value

Y = Number of years

6.4 Equivalent Uniform Annual Cost

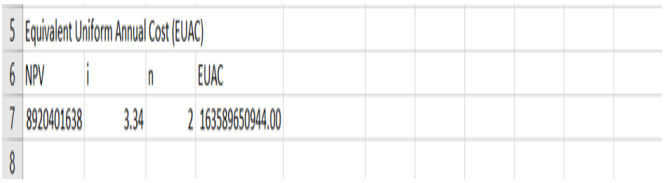

Fig -7: Calculation for equivalent uniform annual cost

Where,

NPV = Net present value

i = Discount rate

n = Years of expenditure

6.5 Present Worth

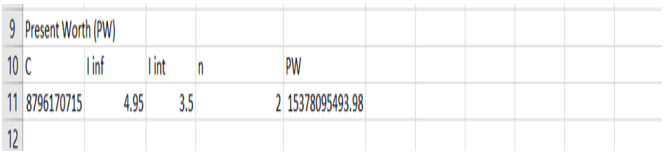

Fig -8: Calculation for present worth

Where,

C = Future cost in present day term

Iinf = Annual inflation rate

Iint = Annual interest rate

n = Time until cost C is incurred

7. CONCLUSIONS

The use of LCCA should be performed correctly, and the data should come from existing reports that are accurate in terms of starting costs, rescue esteem, recovery timing and expenditures, as well as rebate rates. It's important to remember that the LCCA is merely a tool, and the results will not be used to make decisions. Some different parts other than LCCA should be thought about when choosing which sort of asphalt ought to be explored. The LCCA interaction contains a few assessments, anticipating and suspicions. For all focuses, accuracy of information is critical. The sincerity of LCCA results is determined by experts' precise assessment of asphalt execution, traffic for over 25 years later, and potential expenses. The probabilistic danger examination method is growing popularity in organizing conjecture capriciousness. It allows for the determination of catchable knowledge limits, which helps in the processing of LCCA data. A substantial body of work also demonstrates that LCCA execution is as perplexing as selecting the right rebate rate and company costs, measuring non-office costs as client costs, integrating reliable supporting data such as traffic data, estimating rescue esteem and valuable life, demonstrating resource dissatisfaction, and estimating upkeep expenses, viability. Throughout the investigation time, there was a clear desire to travel the vast majority of LCCA only use postpone costs in combination with client costs during important recovery and growth exercises.

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