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THE IMPACT OF ECONOMIC ANALYSIS METHODS ON PROJECT DECISION-MAKING IN AIRPORT PAVEMENT MANAGEMENT

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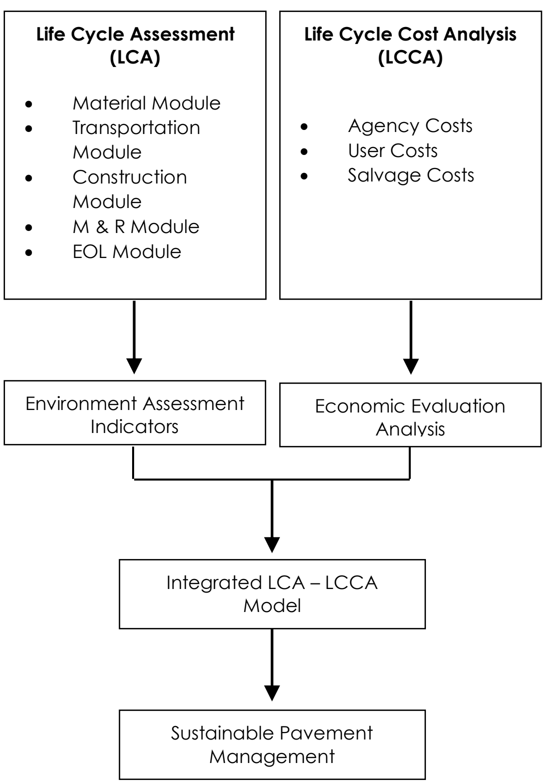
Graphical abstract



Abstract

Airports are a part of the world transportation network. Huge investments are made annually for airport pavement construction, maintenances and rehabilitations. The idea of integrating life-cycle cost analysis (LCCA) and life cycle assessment (LCA) is the latest approach to develop a method for assessing pavement sustainability. In this regard, research on economic evaluation analysis methods has resulted in the development and improvement of pavement management systems (PMS). This paper compares two main economic evaluations which mainly could use in LCCA namely net future value (NFV) and net present Value (NPV). To indicate the effect of economic evaluation a case study is examined. In this research LCCA comprises three main components which are direct costs, indirect costs, and salvage value. Airport Revenue Reduction Cost (ARRC) and Airline Delay Cost (ADC) considered as two specific indirect/user costs. The results show the impact of different economic analysis method on project decision-making where the use of crack sealing overlay (CSOL) is 35.8% and 28.3% more cost-effective than Portland cement concrete (PCC) and hot-mix asphalt (HMA), respectively.

Keywords: Airport pavement management, life-cycle cost analysis, net future value, net present value

Abstrak

Lapangan terbang adalah sebahagian daripada rangkaian pengangkutan dunia. Sejumlah besar wang dibelanjakan setiap tahun untuk pembinaan, penyelenggaraan dan pemuliharaan turapan lapangan terbang. Idea untuk menggabungkan penilaian kitaran hidup (LCA) dan analisis kos kitaran hayat (LCCA) adalah pendekatan terbaru untuk membangunkan kaedah penilaian turapan lestari. Dalam hal ini, kajian tentang kaedah analisis penilaian ekonomi telah menghasilkan pembangunan dan penambahbaikan di dalam sistem pengurusan turapan (PMS). Kertas ini membandingkan dua analisis ekonomi dalam LCCA iaitu nilai masa depan bersih (NFV) dan nilai masa sekarang bersih (NPV). Satu kajian kes telah diperiksa untuk menunjukkan kesan penilaian ekonomi ini. Dalam kajian ini, LCCA mengandungi tiga komponen utama iaitu kos secara langsung, kos secara tidak langsung, dan nilai sisaan. Dalam penyelidikan ini LCCA merangkumi tiga komponen utama iaitu kos langsung, kos tidak langsung, dan nilai penyelamatan. Kos Pengurangan Hasil Lapangan Terbang (ARRC) dan Kos Kelewatan Syarikat Penerbangan (ADC) dianggap sebagai dua kos tidak langsung/ pengguna. Hasil menunjukkan bahawa kesan kaedah analisis ekonomi yang berbeza terhadap pembuatan keputusan projek di mana penggunaan lapisan tindihan tampal retakan (CSOL) masing-masing adalah 35.8% dan 28.3% lebih jimat berbanding dengan simen konkrit Portland (PCC) dan asfalt campuran panas (HMA).

Kata kunci: Pengurusan turapan lapangan terbang, analisis kos kitar hayat, nilai masa depan bersih, nilai masa sekarang bersih

1.0 INTRODUCTION

Airports are one of the valued component of the world transportation network. They enable efficient movement of people and goods across vast distances, strengthen ties between communities, regions, and countries and promote economic growth. Huge investments are made annually for airport pavement maintenance and rehabilitation and sustaining the method on existing pavement. Airport stakeholders are looking for ways to achieve sustainability to increase operational effectiveness [1].

According to Hudson *et al*. [2], additional maintenance and rehabilitation of dilapidated pavements is a viable option from an economic point of view. Research on pavement management methods has resulted in pavement management systems (PMS) that provides a consistent, objective and systematic procedure for determining priorities, scheduling, allocating resources, and budgeting for pavement maintenance and rehabilitation [3]. Most PMS seek to maximize pavement maintenance and rehabilitation effectiveness by ensuring maximum benefits from the available fund. PMS provides the basis for an informed understanding of the possible consequences of alternative policies. The detailed analysis and design of pavement rehabilitation strategies in the project-level phase is performed by pavement engineering specialists [4].

Life-cycle assessment (LCA) is a comparatively recent environmental analysis method. Even though developed in the 1970s, LCA became popular at the end of the 1990s [5]. LCA is a method for quantifying the environmental impact associated with a product over its lifetime by considering the acquisition, transportation, construction, usage, maintenance and rehabilitation, and final disposal stages. Environmental problems such as climate change, stratospheric ozone depletion, tropospheric ozone formation, eutrophication, acidification and harmful impacts on human health and the ecosystems [6]. There is currently no standard LCA model specific for airport pavement usage [7]. In the LCA of highways, different methods are employed to evaluate the environmental impact. Each method has significant, unique benefits and drawbacks. According to Treloar *et al*. [8], the major drawback of most available methods is they encourage environmental responsibility in the construction industry instead of promoting environmental sustainability. More recently, several methods, such as those proposed by Stripple and Erlandsson [9], Santero *et al*. [10], and Bin Yu *et al*. [11], were developed to use LCA in environmental assessment.

Life-cycle cost analysis (LCCA) is an analysis technique that builds on the well-founded economic analysis principles to evaluate the overall long-term economic efficiency between competing alternative investment options. It identifies the best value (the lowest long-term cost that satisfies the desired performance objective) for investment expenditures [12]. In pavement design, LCCA is carried out in the project design stage. The LCCA analysis period should be sufficient to reflect long-term cost differences associated with reasonable design strategies. The Federal Highway Administration (FHWA) LCCA Policy Statement recommends an analysis period of at least 35 years for all pavement projects [13].

LCCA is suitable for many investment-related decisions to evaluate the economic worth of various designs, projects, alternatives, or system investment strategies to get the best return on the currency used [14]. The economic analysis helps decision-makers to make better choices regarding the alternative uses of scarce funds. LCCA provides the means to include the total cost to both airport management and user in the investment decision. However, the lowest LCC option may not necessarily be implemented when other factors such as risk, available budgets, and political and environmental concerns are considered. LCCA provides critical information to the overall decision-making process but is not the final answer [15]. Ozbay *et al*. [16] stated that LCCA would be used more often if the public and policymakers demand better resource management. The most common economic analyses are Benefit/Cost (B/C) Ratio, Internal Rate of Return (IRR), Net Present Value (NPV), Equivalent

Uniform Annual Cost (EUAC), Equivalent Uniform Annual Benefit, and Net Future Value (NFV).

The LCCA approach is preferred over the deterministic approach because it allows risk evaluation from the outputs. LCCA calculates the probabilities of each outcome represented by the parameter distributions. FHWA [17] developed the most recent program, RealCost, as a mechanism for probabilistic LCCA. Chen and Flintsch [18] proposed a logic-based model that aim to structure the mechanisms for decoding various intrinsically unclear inputs. The model assists in the further development of the probabilistic LCCA approach.

The integration of the two approaches provides a way to assess pavement sustainability. The integrated LCCA and LCA model is used to assess two bridge deck designs, conventional concrete bridge deck, and ECC link slab design in terms of total life-cycle costs, including direct costs, indirect costs, and environmental damage costs (EDC)by Kendall [19].

Airport pavements are critical for the taking off and landing of an aircraft. An immediate repair of the damaged pavement is necessary to ensure safety. This is a difficult task because of the limited funds and deterioration of pavement structures over time due to environmental factors and increasing traffic loads. This research describes the concept of NFV as an economic analysis in LCCA for the airport management system. This research presents the impact of different economic analysis method in project decision-making, especially concerning airport pavement management.

2.0 METHODOLOGY

This study aims to emphasis the effect of economic evaluation method in LCCA for assessing and improving the sustainability of airport pavements. The different economic analysis can be selected by pavement managers/engineers to evaluate the best pavement option. Nowadays, the use of LCCA is more established in highway pavement management rather than airports. The previous and only standard airport pavement management employed a simple Excel program, AirCost [20], which required much improvement. Babashamsi *et al*. [21] adopted the same approach to develop specific elements such as direct costs, indirect costs and salvage value and moreover considered uncertainty by using a risk assessment approach. His latest integrated method for airport pavement management (APMS) based on integrated LCCA and LCA appears in Figure 1. The proposed method makes a comprehensive and detailed environmental evaluation of airport pavements. The goal is to allow pavement practitioners with little specialized LCCA and LCA knowledge or resources to conduct a pavement sustainable development and obtain acceptable results using the inputs available to them within a reasonable timeframe.

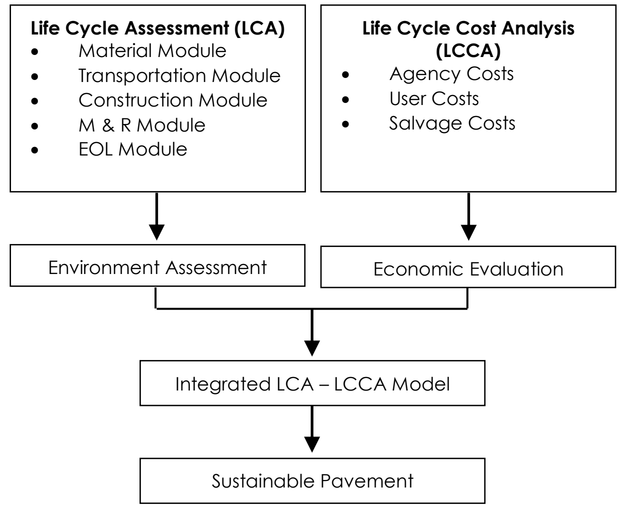


Figure 1 Flowchart for integrated LCA-LCCA model

LCCA comprises three main components, direct costs, indirect costs, and salvage value. An accurate LCCA approach relies on choosing an appropriate contracting model (alternate vs traditional contract) designed and prepared for agreement, the reliability of data to bolster the assessment, and the level of detail that can be managed for the analysis. The LCCA for airport pavement management incorporates the following steps that it is shown in Figure 2.

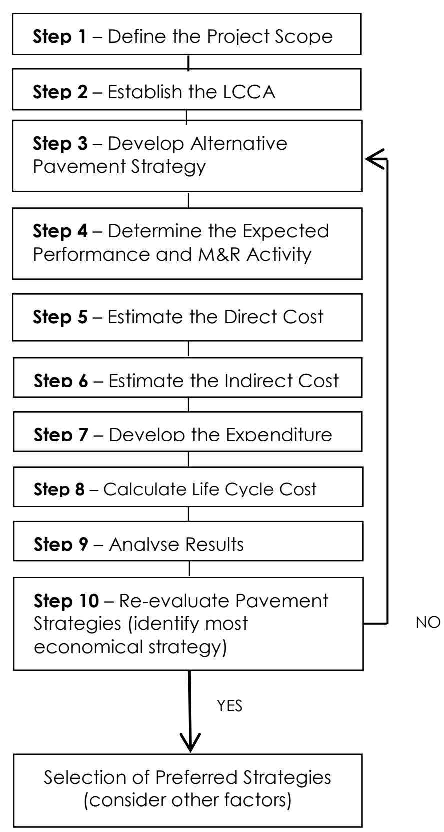


Figure 2 Process for conducting airport pavement LCCA

After defining the project scope, the basic pavement LCCA process requires that the analyst defines the schedule of first and future activities involved in implementing a particular alternative (whether new construction or rehabilitation), after that the costs of each of these activities are estimated. The predicted schedule of activities and their associated costs comprise the projected life-cycle cost stream. Using an economic analysis technique known as "discounting," all projected costs are either converted into present dollars and summed to produce a net present value (NPV), or calculated into future cost price and summed to produce a net future value (NFV). Discounting approach is standard practice among government agencies and is suggested by the FHWA [22]. LCCA should establish based on project budget, allocation and resources. FAA direction on utilizing NPV is sufficient. The NPV should be connected utilizing constant/real dollars and a discount [20]. As an alternative to NPV, NFV can be used. The advantage of NFV is that the analysis can show the real amount of costs that should be spent during the analysis period, while the NPV just indicates the project value. However, both of the economic analysis techniques are sufficient when comparing alternatives.

The mathematical relationship between present value (PV), future value (FV) the discount rate can be determined by Equation 1:

$$PV = FV \times [1/(1+i_{dis})]^n \qquad \text{(Eq.1)}$$

PV = Present-worth cost, ($)
FV= Future cost in present-day terms, ($)
n = Time until cost C is incurred, years.
i_{dis}= Annual discount rate, decimal

The main section in LCCA is estimating unit costs of constructing, maintaining and rehabilitating for each alternative strategy. The best way to evaluate physical costs is to recognize adequate and trustworthy unit cost data for pay items that contribute to the initial construction and all M&R treatments. The source of these data could be the historical bid records of construction projects in current years (ideally, the previous 7 years) [23]. Although experience-based estimates can quantify many LCCA inputs, it is suggested to be done using all available, applicable, and reliable data.

In 2007, Schumer reported that airport delays cost the economy approximately 40.7 billion dollars [24]. In this section, two specific user costs are considered.

- Airport Revenue Reduction Cost (ARRC)
- Airline Delay Cost (ADC)

Each alternative uses different constructional activities (initial construction/rehabilitation and future M&R) in the life-cycle period and affects the airport daily revenue reduction during execution. Key perspectives incorporated are characterizing by duration of each pavement event construction, reduction in airplane operations, and loss of daily operating revenue.

The EU report specifies that delays can be classified into two categories [25]:

- Gate-to-gate delays (single flight)
- Network-level delays.

This study considers only direct costs to the individual flight of such delays. Future work can investigate on the network-level delays and, in addition, subsequent economics costs to different industries and usinesses.

Current FAA guidance suggested calculating salvage value is based only on serviceable life [20].

The implementation and maintenance of APMS require a large investment and time and resources commitment. Larger airports may opt for training in the APMS process and implement and maintain APMS using internal staff. It is critical to identify all potential users of the system and determine their individual needs in the initial design stage of APMS to ensure everyone is satisfied with the end product. The potential users of an APMS differ depending on the implementing agency, whether it is an airport, state, regional planning agency, or branch of the military. APMS is implemented at the state or regional level, regional planning commission, individual airport, and FAA. The APMS implemented by military agencies is used by the military bases and at the federal level.

3.0 RESULTS AND DISCUSSION

NFV and NPV are analysis methods which help a company to prepare for the coming budgets over the life span of the highway. The NFV benefits the companies with the limited budgets. The NFV is the value for the current asset on a specific date in the future based on an assumed growth rate. NFV calculates the LCCA of the project from the start of the project (reconstruction, maintenance, rehabilitation, and salvage value) until the end of life. The NPV is the total amount required to implement the project, including reconstruction, maintenance, rehabilitation, and salvage value. Because the value of money changes over time, the private and public sectors with limited budget will have difficulties carrying out maintenance and rehabilitation after half of the project life span.

3.1 Case Study

The Rocky Mountain Metropolitan Airport was constructed in 1967 in Jefferson County, Denver, Colorado, USA. The airport has received large budgets for improvement and M&R for the past decades. Table 1 shows the specifications of the existing runway at the airport. The airport PCC pavement is at the end of its service life and has to be reconstructed to restore its serviceability. The existing base course is assumed to perform well and can function without intensive maintenance activities. Three replacement options are considered.

i. Remove and replace existing pavement with PCC (henceforth the PCC option). Remove existing PCC, keep the existing base and subgrade in place, and repave with a 300 mm (12 in.) PCC layer.
ii. Remove and replace existing pavement with HMA (henceforth the HMA option). Remove existing PCC, retain existing base and subgrade and repave with up to 250 mm (10 in.) HMA. Use a mill-and-fill (removal of the HMA surface and replace with new HMA) as a periodic rehabilitation strategy.
iii. Crack, seat, and overlay (henceforth the CSOL option). Crack and seat existing PCC pavement and overlay it with 150 mm (6 in.) HMA. Use mill-and-fill as a periodic rehabilitation strategy.

Table 1 Specification of the existing runway

Runway Information	Description
Runway length	1000 m
Runway width	61 m
Existing pavement	Concrete
Existing surface	25 cm
Existing base	25 cm
Distance from depot to plant	50 km
Distance from plant to site	50 km

3.2 LCCA Input Data

The three pavement overlay design followed the AASHTO pavement design guide. The standard designs are structural design, and the estimation for other necessary parameters such as equipment and transportation were based on general practice and reasonable assumptions. For example, the HMA mix was 5% asphalt, 85% crushed aggregate, and 10% natural aggregate by weight and the PCC mix design was 10% cement, 75% crushed aggregate, 10% natural aggregate, and 5% water. The transport distance for all materials from the depot to plant to site and vice versa was 50 km. Table 2 lists the structural design of the three overlay system options.

Table 2 Structural design for the three alternatives

PCC	HMA	CSOL
300 mm Existing crushed aggregate	250 mm Existing crushed aggregate	150 mm HMA 250 mm existing PCC Existing crushed aggregate

According to the Airport Cooperative Research Program (ACRP) [26], concrete slab rehabilitation is usually carried out every 18-20 years, and according to California Department of Transportation (Caltrans), the average life of a diamond-grind surface is 16-20 years [27]. Therefore, PCC rehabilitation for the PCC option is carried out every 20 years. For the other two options, the HMA mill-and-fill plan of every 15 years used in previous research [28–29] is employed in this study. Figure 3 shows the maintenance and rehabilitation schedule for regular preventive maintenance activities adopted by the airport in Jefferson country (Colorado), and Table 3 shows the types of maintenance and rehabilitation.

Table 3 LCA Deterministic results of alternatives ($1,000a), NFV

PCC Reconstruction	HMA Reconstruction	CSOL Reconstruction
Main#1: Crack & Joint sealing	**Main#1**: Crack sealing **Main#2:** Crack sealing **Main#3:** Seal coat **Main#4:** Crack sealing	**Main#1**: Crack sealing **Main#2:** Crack sealing **Main#3:** Seal coat **Main#4:** Crack sealing
Rehab#1: Crack & Joint sealing + Spall Repair + 50 % slab replacement	**Rehab#1:** 150mm mill and new AC	**Rehab#1:** Full-depth mill and new AC
Main#1: Crack & Joint sealing	**Main#1**: Crack sealing **Main#2:** Crack sealing **Main#3:** Seal coat **Main#5:** Crack sealing	**Main#1**: Crack sealing **Main#2:** Crack sealing **Main#3:** Seal coat **Main#5:** Crack sealing
	Rehab#1: 150mm mill and new AC	**Rehab#1:** Full-depth mill and new AC
	Main#1: Crack sealing **Main#2:** Crack sealing **Main#3:** Seal coat	**Main#1**: Crack sealing **Main#2:** Crack sealing **Main#3:** Seal coat

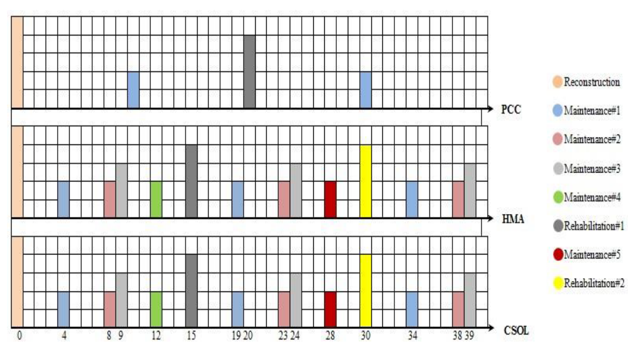


Figure 3 Reconstruction and M&R schedules for the three options

The LCCA model is employed to assess the optimal option for pavement overlay systems. This method comprises three components, direct costs, indirect costs, and salvage value.

a. Indirect/User Costs Input Data

These assumptions are adopted to analyse the user cost of each alternative.

i. An accurate annual revenue value is confidential information and is dependent on airport size and number flights and passengers. The value ranges between 10-15 million USD for medium international airports. This study assumed total annual revenue of 12 million USD (48 million MYR).
ii. The revenue growth is 5% in compound mode. A project is worth implementing if the revenue growth is higher than (or equal to) the discount rate.
iii. The number of flights at medium international airports is 300 flights per day, and each flight has 155 seats.
iv. The aeroplane crew cost differs with the level of responsibility. The assumed mean of crew cost is 0.3 dollars (30 cents) per minute, and each flight has ten crew members
v. The aeroplane maintenance cost is automatically filled after the type of airplane (mean number of seat) was selected. The analysis can change the value.

Table 4 shows the user costs for revenue reduction, duration, and airplane delay time for each event of the three alternatives.

Table 4 User costs input data for the three alternatives

Altern-atives	Event	Revenue Reduction	Duration of Construction Day	Airplane Delay Time (min)
PCC	Reconstruction	25	7	15
	Maintenance#1	0	1	0
	Maintenance#2	0	1	0
	Rehabilitation#1	10	3	10
HMA	Reconstruction	15	4	10
	Maintenance#1	0	1	0
	Maintenance#2	0	1	0
	Maintenance#3	0	1	0
	Maintenance#4	0	1	0
	Rehabilitation#1	10	3	10
	Maintenance#5	0	1	0
	Rehabilitation#2	10	3	10
CSOL	Reconstruction	10	3	10
	Maintenance#1	0	1	0
	Maintenance#2	0	1	0
	Maintenance#3	0	1	0
	Maintenance#4	0	1	0
	Rehabilitation#1	10	3	10
	Maintenance#5	0	1	0
	Rehabilitation#2	10	3	10

b. Direct Cost Input Data

The analysis period of this study is 40 years, and a discount rate of 4% is the customary value for recent years in deterministic LCCA projects. The mean discount rate and standard deviation for probabilistic LCCA are 4% and 1%, respectively. Table 5 shows the mean for pay item costs and maintenance and rehabilitation timetable for all options. For the probabilistic method, the cost variation for each item has a standard deviation of 10%. Unit Cost values are based on the mean cost of pay items in the Jefferson country airport system bid tabs from 2006 to 2016. The PCC does not have a salvage value because the analysis period and design life are 40 years.

Table 5 Initial and Maintenance and Rehabilitation unit costs for the three alternatives

PCC	HMA	CSOL
Initial Construction Costs		
PCC Removal, $11.00/m^2 PCC Paving, $190.00/m^3 Electrical, $320000.00/km Restripe, $12000.00/km	PCC Removal, $11.00/m^2 HMA Paving, $140.00/m^3 41640 litre Tack Coat, $0.25/L* Geotextile, $1.80/m^2 Electrical, $320000.00/km	Crack and seat, $2.00/m^2 Prepare surface, $1.00/m^2 HMA Paving, $140.00/m^3 41640 litre Tack Coat, $0.25/L Electrical, $320000/km Restripe, $12000/km
Maintenance Activity Costs		
Crack and Joint sealing, $3.00/m^2	Crack sealing, $2.00/m^2 Seal coat, $1.00/m^2	Crack sealing, $2.00/m^2 Seal coat, $1.00/m^2
Rehabilitation Activity Costs		
Spall repair, $5.00/m^2 Slab replacement, $200/m^3 Restripe, $12000/km	HMA Removal, $5.00/m^2 HMA Paving, $140.00/m^3 41640 litre Tack Coat, $0.25/L	HMA Removal, $5.00/m^2 HMA Paving, $140.00/m^2 41640 litre Tack Coat, $0.25/L

* 41640 litre Tack Coat, $0.25/L is equal to 11000-gal Tack Coat, $1.00/gal
* All prices are in USD and 1 USD = 4 MYR

3.3 LCCA Deterministic Output

In the conventional deterministic approach, the best option is based on a single value, the mean of results. Table 6 shows that the direct cost of PCC is $5,553,558 (22 million MYR), while the costs for HMA and CSOL are $5,055,028 (20 million MYR) and $3,645,643 (14.25 million MYR), respectively. The direct costs for HMA and CSOL after deducting salvage values are $4,972,093 and $3,562,708, respectively. In terms of NPV, the cost for CSOL is lower than those of PCC and HMA by 35.8% and 28.3%, respectively. Also Table 6 shows the ARRC and ADC of the CSOL option are lower than for other alternatives. In all three options, ADC assigned a higher indirect cost than to ARRC. The ADC is higher in rehabilitation with HMA and CSOL, while in PCC, the initial construction is higher than that of ADC. Table 7 shows the detailed direct costs and salvage values of the activities.

Table 6 LCCA Deterministic results of the alternatives ($1,000a), NFV

Option	Activity	Direct Cost	Indirect Costs		Salvage Value
			ARRC	ADC	
PCC	Initial	4838.4	63.3	1090.2	0.0
	Maintenance	933.3	0.0	0.0	
	Rehabilitation	2324.0	28.8	68.2	
	Total	8500.5	92.1	1158.4	
HMA	Initial	3519.5	21.8	414.5	2012.5
	Maintenance	3178.5	0.0	0.0	
	Rehabilitation	8752.0	59.0	129.1	
	Total	16222	80.8	543.6	

Option	Activity	Direct Cost	Indirect Costs		Salvage Value
			ARRC	ADC	
CSOL	Initial	1951.5	11.0	310.8	2012.5
	Maintenance	3178.5	0.00	0.0	
	Rehabilitation	8752.0	59.0	129.1	
	Total	14576.1	70.0	439.9	

*1 USD = 4 MYR
*5% supplemental costs are added to total direct costs

Table 7 LCCA Deterministic results for the alternatives ($1,000a), NFV

Alternative	Activity	Years	$(1+i_{dis})^n$	Cost	NFV
PCC	Reconstruction	2	71.08	4480.0	4845.4
	Maintenance#1	12	1.60	183.0	292.8
	Rehabilitation	22	2.37	2324.0	5507.0
	Maintenance#1	32	3.50	183.0	640.5
	Salvage Value	42	5.19	0.0	0.0
HMA	Reconstruction	2	1.08	3258.8	3519.5
	Maintenance#1	6	1.26	122.0	153.7
	Maintenance#2	10	1.48	122.0	180.65
	Maintenance#3	11	1.54	61.0	93.9
	Maintenance#4	14	1.73	122.0	211.0
	Rehabilitation#1	17	1.94	1609.0	3121.4
	Maintenance#1	21	2.27	122.0	276.9
	Maintenance#2	25	2.66	122.0	324.5
	Maintenance#3	26	2.77	61.0	168.9
	Maintenance#4	29	3.11	122.0	379.4
	Rehabilitation#2	32	3.50	1609.0	5631.5
	Maintenance#1	36	4.10	122.0	500.2
	Maintenance#2	40	4.80	122.0	585.6
	Maintenance#3	41	4.99	61.0	304.5
	Salvage Value	42	5.19	-1292.0	-2012.5
CSOL	Reconstruction	2	1.08	1807.0	1951.5
	Maintenance#1	6	1.26	122.0	153.7
	Maintenance#2	10	1.48	122.0	180.5
	Maintenance#3	11	1.54	61.0	93.9
	Maintenance#4	14	1.73	122.0	324.5
	Rehabilitation#1	17	1.94	1609.0	3121.4
	Maintenance#1	21	2.27	122.0	276.9
	Maintenance#2	25	2.66	122.0	324.5
	Maintenance#3	26	2.77	61.0	168.9
	Maintenance#4	29	3.11	122.0	379.4
	Rehabilitation#2	32	3.50	1609.0	5631.5
	Maintenance#1	36	4.10	122.0	500.2
	Maintenance#2	40	4.80	122.0	585.6
	Maintenance#3	41	4.99	61.0	304.5
	Salvage Value	42	5.19	-1292.0	-2012.5

Previous research seldom focuses on maintenance because routine maintenance is believed to contribute a small percentage in LCCA. However, Table 7 shows that the cost for maintenance is 10.2% of the total cost in HMA and 14.2% of the total cost in CSOL. The rehabilitation costs in PCC, HMA, and CSOL are 16.3%, 25.4%, and 35.2% of the total costs. This shows that routine maintenance is a critical part of pavement airport management. The maintenance values in HMA and CSOL did not affect user costs because the annual revenue and aeroplane delay costs are not affected. In other words, maintenance has no validity effect on user costs because of the short construction duration.

3.4 Analysis of Direct, Indirect, and Salvage Values Using NPV and NFV

Each analysis method gives a different direct cost, ARRC, ADC or salvage value. The same data was employed for NPV and NFV with a 4% discount rate. The present value of an annuity is the sum that has to be invested now to guarantee a desired payment in the future; the future value of an annuity is the amount the current investments will grow over time. Both the present and future value calculations assume a regular annuity with a fixed growth rate. Table 8 shows the deterministic results from NPV for all options.

The present annuity value is the current value of all the income generated by that investment in the future, or, in more practical terms, the amount of money that has to be invested today to generate a consistent income in the future. The present value calculation considers the interest rate, the desired payment amount, and the number of payments and discounts the value of future payments to determine the contribution necessary to achieve and maintain fixed payments for a specific time period.

Table 8 LCCA Deterministic results of alternatives ($1,000a), NFV

Options	Activity	Direct Cost	ARRC	ADC	Salvage Value
PCC	Initial	4142.0	58.6	89.2	0.0
	Maintenance	166.5	0.0	0.0	
	Rehabilitation	980.6	12.2	114.6	
	Total	5553.6	70.8	203.8	
HMA	Initial	3012.9	20.1	334.9	82.9
	Maintenance	516.7	0.0	0.0	
	Rehabilitation	1284.7	25.0	217.0	
	Total	5055.0	45.1	551.9	
CSOL	Initial	1670.0	10.0	251.2	82.9
	Maintenance	516.7	0.0	0.0	
	Rehabilitation	1284.7	25.0	217.0	
	Total	3645.6	35.0	468.2	

*$1 USD = RM 4 Malaysia
*5% supplemental costs are added to total direct costs

Table 9 shows a comparison of the direct cost, ARRC, ADC, salvage values for NPV and NFV. NFV values are higher because they give the value of money at a specific future time. The values for NPV are lower because these values are the present value of money. The value is the same as the total values of (Initial, Maintenance, and Rehabilitation) (Table 10).

Table 9 Total costs of the alternatives using NPV and NFV ($1,000)

	NPV	NFV
Direct Cost	14254.2	39298.5
ARRC	150.9	242.9
ADC	2013.9	2141.9
Salvage Value	165.8	4025.0

Table 10 Detailed direct costs of the alternatives using NPV and NFV ($1,000)

	NPV	NFV
Initial	8824.9	10309.4
Maintenance	1199.9	7290.3
Rehabilitation	3550.0	19828.0

The future value of an annuity is the amount of money that will be accrued by making consistent investments over a specific period, assuming compound interest. Instead of planning for a guaranteed amount of future income by calculating the amount that has to be invested now, this formula estimates the growth of savings for a fixed investment rate for a specific period.

4.0 CONCLUSION

LCCA should establish based on project budget, allocation and resources. Various economic evaluation analyses same as are Benefit/Cost (B/C) Ratio, Internal Rate of Return (IRR), Net Present Value (NPV), Equivalent Uniform Annual Cost (EUAC), Equivalent Uniform Annual Benefit, and Net Future Value (NFV)are used in different LCCA. NFV calculates the LCCA of the project from the start of the project (reconstruction, maintenance, rehabilitation, and salvage value) until the end of life. The NPV is the total amount required to implement the project, including reconstruction, maintenance, rehabilitation, and salvage value.

CSOL is 35.8% and 28.3% more cost-effective than PCC and HMA, respectively. Relative to PCC, the cost of the HMA option is lower with the highest uncertainty. PCC has higher indirect costs in terms of ARRC and ADC. The maintenance costs in HMA and CSOL are10.2% HMA and 14.2% of the total cost, respectively. The rehabilitation costs for PCC, HMA, and CSOL are 16.3%, 25.4%, and 35.2% of total costs. As it shows in results the decision-making of selecting a right economic analysis base on budget, allocation and contracts could increase up the cost to more than hundred present during the life-cycle.

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