



INCORPORATING ASSET VALUE IN LIFE CYCLE COST ANALYSIS FOR TRANSPORTATION INFRASTRUCTURE ASSETS

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Abstract: Asset valuation is an essential component of effective asset management. It is an important method to demonstrate proper management of public assets and effective utilization of tax payers' money. Asset valuation is used in standard reporting, depreciation schedules, auditor requirements and condition assessments. As such, it allows agencies to demonstrate funding needs for asset preservation. On the other hand, Life Cycle Cost Analysis (LCCA) is used in asset management to evaluate different maintenance and rehabilitation strategies. In addition to maintenance and rehabilitation costs, agencies started to include other factors such as salvage value and user costs and environmental costs in the LCCA. However, to date, the impact of asset value on LCCA is not considered. Incorporating asset value in LCCA as a means of evaluating the return on investment is imperative. The paper presents a methodology to incorporate asset value as a component of LCCA. The proposed method is illustrated through an example using data from the Ministry of Transportation (MTO) Pavement Management System (PMS2).

1 Background

Asset management has gained movement over the last two decades. Asset Management in basic terms is a systematic business process that employs strategic, engineering and economical means to provide holistic approach to manage infrastructure assets to meet specified performance measures' Level of Services (LOS). There are many definitions of Asset Management in the literature; however, a widely used definition is that of the Federal Highway Administration (FHWA) US department of Transportation also adopted by Transportation Association Canada (TAC) (FHWA 1999; TAC 2013):

“Asset management is a systematic process of maintaining, upgrading and operating physical assets cost-effectively. It combines sound business practices and economic theory, and it provides tools to facilitate a more organized logical approach to decision making. Thus, asset management provides a framework for handling both short- and long-range planning.”

From the definition, it can be noted that implementing asset management necessitates implementing sound business practices and economic theory. It is a decision making tool or a framework that spans over an extended time horizon (FHWA 1999). In other words, implementing asset management is the development of business plans and programs of maintaining, upgrading and operating infrastructure assets over a specified time horizon. Therefore, as in any business practice, it is important to understand the value of the assets being managed.

On the other hand, with the implementation of asset management, several government regulatory bodies mandate agencies to report their Tangible Capital Assets' (TCA) values within their annual statement. For example, the Canadian Public Sector Accounting Board (PSAB), the Governmental Accounting Standard Board (GASB) and the New Zealand International Financial Reporting Standards (NZ IFRS) to name a few (Alyami and Tighe 2016).

Asset valuation is an essential component of effective asset management (TAC 2013). It is an important method to demonstrate proper management of public assets and effective utilization of tax payers' money. Asset valuation is used in standard reporting, depreciation schedules, auditor requirements and condition assessments (Byrne 1994). As such, it allows agencies to demonstrate funding needs for asset preservation (Lugg 2005).

Life Cycle Cost Analysis (LCCA) is used in asset management to evaluate different maintenance and rehabilitation strategies. In addition to maintenance and rehabilitation costs, agencies started to include other factors such as salvage value and user costs and environmental costs in the LCCA (Bryce et al. 2014; Mallela et al. 2011; Ozbay et al. 2004; Smith and Fung 2006; TAC 2013; Torres-Machí et al. 2015). However, to date, the impact of asset value on LCCA is not considered. Incorporating asset value in LCCA as a means of evaluating the return on investment is imperative.

2 Scope and Objective

This paper presents a methodology to incorporate asset value in LCCA for transportation infrastructure assets. The proposed method is illustrated through a pavement example based on data obtained from MTO PMS2. However, the method can be applied to other infrastructure assets.

3 Asset Valuation

In transportation infrastructure context, asset valuation- or asset management in general, are implemented to fixed and unfixed tangible assets within or out of the right of way (ROW) (TAC 2001, 2013). Example of fixed assets within the ROW include: pavements, bridges, signs, signals, etc. Fixed and unfixed assets out of the ROW include: maintenance depots (Ex. salt sheds, fuel tanks, etc.), material stockpiles, laboratories, communication equipment, computer hardware, etc. In addition, Haas and Raymond identified other non-tangible assets such as intellectual property, land, etc. (Haas and Raymond 1999).

The American Institute of Real Estate Appraisers (AIREA) defines asset valuation as the process of estimating the value of a specific asset at a given date, and it measures the relative value or wealth of asset over time (AIREA 1987). Marston et al. defined asset valuation in the context of engineering as "the art of estimating the fair monetary measure of the desirability of ownership of specific properties for specific purpose...engineering valuation is the art of estimating the value of specific properties where professional engineering knowledge and judgment are essential. ... based fundamentally upon [the asset's] ability to produce some kind of useful service during its expected future life in service...." (Marston et al. 1963).

There are various valuation methods that can be utilized to estimate infrastructure asset values such as book value, replacement cost, and written down replacement cost. Table 1 presents examples of asset valuation methods and basic definitions. It is recognized that there is no universally accepted method by the international community. However, it is noted that the book value, the replacement cost and the written down replacement cost methods are commonly used in highway infrastructure valuation (Cowe Falls et al. 2004; Dewan and Smith 2005; McNeil et al. 2000; OECD 2000).

Table 1: Asset valuation methods and basic definition (Adapted from (Amekudzi et al. 2002; TAC 2001)

Asset Valuation Method	Overview
Book Value	Present value based on historical costs depreciated to the present (commonly used for financial accounting purposes)
Replacement Cost	Present value based on cost of replacing/rebuilding the asset

Written Down Replacement Costs	Present value based on current replacement cost depreciated to asset current condition (commonly used for management accounting purposes)
Equivalent Present Worth in Place	The worth "as is". The book Value adjusted for inflation, depreciation, depletion and wear; i.e., the (accounts for changes in prices and usage; applicable to comparing with other investments)
Productivity Realized Value	The value in use. Net present value of benefit stream for remaining service life (provides a reflection of relative importance of the asset)
Market Value	Price buyer is willing to pay
Net Salvage Value	Cost to replace the facility less the cost of returning it to 'new condition' Cost of materials
Salvage Value	Present worth of the amount obtainable from disposing or recycling Facility
Option Value	Value of asset in specific circumstances (Used by private sector)

4 Life Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) refers to the direct financial costs associated with a project (TAC 2013). LCCA evaluates competing alternatives by evaluating costs incurred along the project life cycle including initial construction costs, maintenance and rehabilitation costs to maintain functional condition along the service life. This process is widely applied because it can evaluate differences between design options such as pavement type and various feasible design cross sections. Agencies of all levels have used LCCA to evaluate new technologies, develop alternatives, and to provide defensible decisions for alternative financing and procurement of projects (Smith and Fung 2006). LCCA is used by agencies to assist with long-term planning asset management plans and budget estimates.

In LCCA, it is important to account for the change of the time value of money (FHWA 2002; Markow 2012; TAC 2013). In other words, costs at different times must be converted to their value at a common point in time using a discount rate. To evaluate competing alternatives, infrastructure investments are converted to a single variable, the Net Present Cost (NPC). The NPC allows for comparing the total costs of the alternatives in today's dollars. The NPW is calculated as follows:

$$[1] \text{ NPC} = IC + \sum_{j=1}^k (M\&R_j \times \left(\frac{1}{1+i}\right)^{n_j})$$

Where

NPC= Net Present Cost (\$)

IC= Initial Cost (\$)

K = Number of future maintenance, preservation and rehabilitation

$M\&R_j$ = Cost of j^{th} future maintenance, preservation and rehabilitation activity (\$)

i = Discount rate

n_j = Number of years from the present to the j^{th} future maintenance, preservation and rehabilitation treatment

5 Proposed Methodology

5.1 Asset Value Loss: An Integration Mechanism

In the context of asset management, it is paramount to establish a value of an asset and be able to manage it, maintain and enhance its value. The following desired characteristics are identified in incorporating asset value in asset management decision making: 1) The asset valuation method selected

should be readily and easily calculated. 2) The valuation method directly relates to the asset condition, reflecting the needs and returns on investments for assets' preservation. 3) Capturing the value to the various stakeholders. 4) Addressing the challenges in predicting future asset values due to the instability of economic forces and the difficulty to predict future unit prices. In other words, due to the change in unit prices due to market forces, asset values may increase or decrease regardless of any asset management stewardship.

To address the challenges identified above to provide a stable measure that can be used in asset management decision making, the Asset Value Loss (AVL) is introduced as a ratio of the depreciated asset value to that of a new asset value, expressed as follows:

$$[2] \text{ Asset Value Loss (AVL) } = \frac{RC - WDRC}{RC}$$

Where; AVL is the Asset Value Loss ratio, WDRC is Written Down Replacement Cost, and RC is the Replacement Cost

The RC and WDRC methods are straightforward methods and easily calculated, understood and communicated. Using the ratio eliminates the impact of changes to unit prices and inflation or discount rate, as the percentage loss will remain constant regardless of any changes to unit prices.

To illustrate, consider a pavement section with 15 years analysis period based on MTO PMS2 data presented in Table 2. The section received rehabilitation at year 13. The section attributes, condition, replacement unit cost, and interest rate are provided in Table 2.

Table 1: Asset value loss illustration example

Year	PCI	RC (1)	WDRC (2)	Value Loss (\$) (1-2)	VL (%) (1-2)/(1)
1	97	\$ 4,140,281	\$ 4,006,964	\$ 133,317	3%
2	96	\$ 3,755,357	\$ 3,617,160	\$ 138,197	4%
3	95	\$ 3,406,219	\$ 3,236,930	\$ 169,289	5%
4	94	\$ 3,089,541	\$ 2,901,388	\$ 188,153	6%
5	88	\$ 2,802,305	\$ 2,463,506	\$ 338,799	12%
6	87	\$ 2,541,773	\$ 2,200,921	\$ 340,852	13%
7	86	\$ 2,305,463	\$ 1,974,168	\$ 331,295	14%
8	80	\$ 2,091,123	\$ 1,664,743	\$ 426,380	20%
9	79	\$ 1,896,710	\$ 1,499,919	\$ 396,792	21%
10	76	\$ 1,720,372	\$ 1,313,676	\$ 406,696	24%
11	73	\$ 1,560,428	\$ 1,135,524	\$ 424,905	27%
12	69	\$ 1,415,354	\$ 975,179	\$ 440,175	31%
13	92	\$ 1,283,768	\$ 1,181,067	\$ 102,701	8%
14	90	\$ 1,164,416	\$ 1,047,974	\$ 116,442	10%
15	87	\$ 912,350	\$ 793,745	\$ 118,606	13%

*Pavement Section Information: Pavement Type AC, Area: 52250 m2, Replacement Unit Cost: \$ 91.73, interest rate= 5%

The ratio indicates the total loss of asset replacement cost considering its current condition to that of a new asset. In other words, the ratio shows the loss of value due to the asset deterioration. If a preservation or rehabilitation is applied, the WDRC value increases as the condition improves and therefore reducing the loss ratio. The ratio allows for incorporating future values while addressing the challenges associated with economic fluctuations of unit costs. In addition, in the context of asset management decision making, the concept addresses the variation of value between sections due to the

different area. Figure 1 graphically illustrates the value loss ratio over the analysis period. The proposed AV_L is a function of the WDRC valuation methods; which incorporate asset condition to write down the replacement cost. To establish the threshold for AV_L , equation 2 is rearranged and the $AV_{L, \text{threshold}}$ is calculated as follows:

$$[3] AV_{L, \text{threshold}} = 1 - \frac{\text{Asset Condition minimum LOS}}{\text{Asset Condition (New)}}$$

Where,

$AV_{L, \text{threshold}}$: The maximum Asset Value Loss acceptable for the specified Level of Service (LOS)

Asset Condition Minimum LOS: Established LOS or threshold in place for asset condition

Asset Condition (New): The asset condition if newly constructed

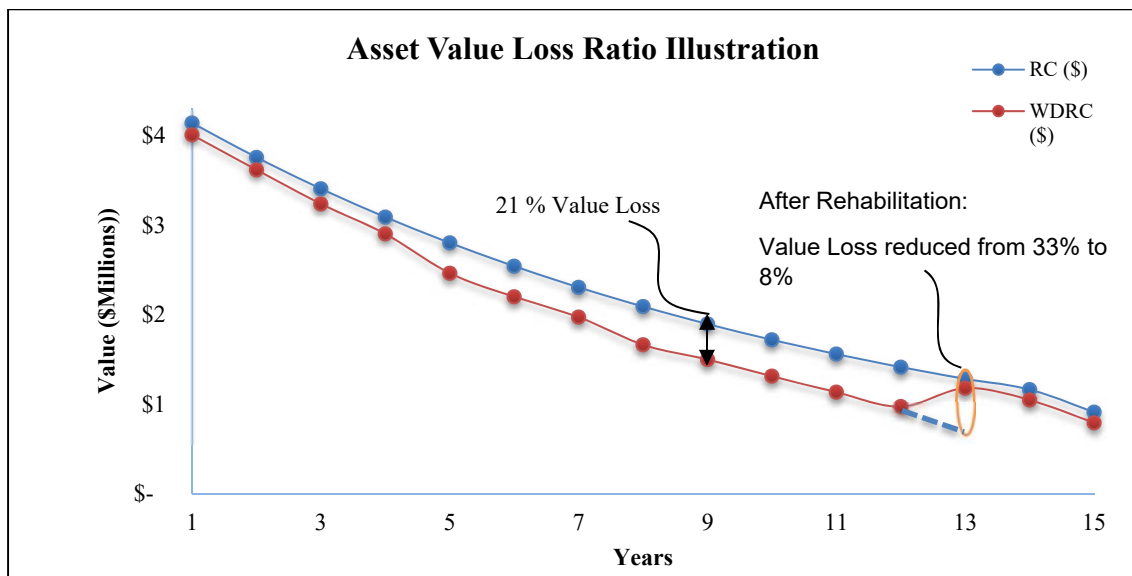


Figure 1: Graphical representation of value loss ratio over analysis period

As discussed earlier, one of the key challenges in reporting asset value using the current methods is predicting future asset values due to the instability of economic forces and the difficulty to predict future unit prices. Therefore, it is recommended that the AV_L is used to report the value as a percentage of the replacement cost (fixed to the analysis year unit cost) over the analysis period. The ratio can be presented to convey an increase of value loss due to lack of proper funding and asset management stewardship or vice versa. As presented earlier, the RC and WDRC methods are straightforward methods and easily understood and communicated. Using the ratio eliminates the impact changes to unit prices and inflation or discount rate as the percentage loss will remain constant regardless of any changes to unit prices. Figure 2 Figure presents a systematic framework to establish the current and future AV_L for infrastructure assets.

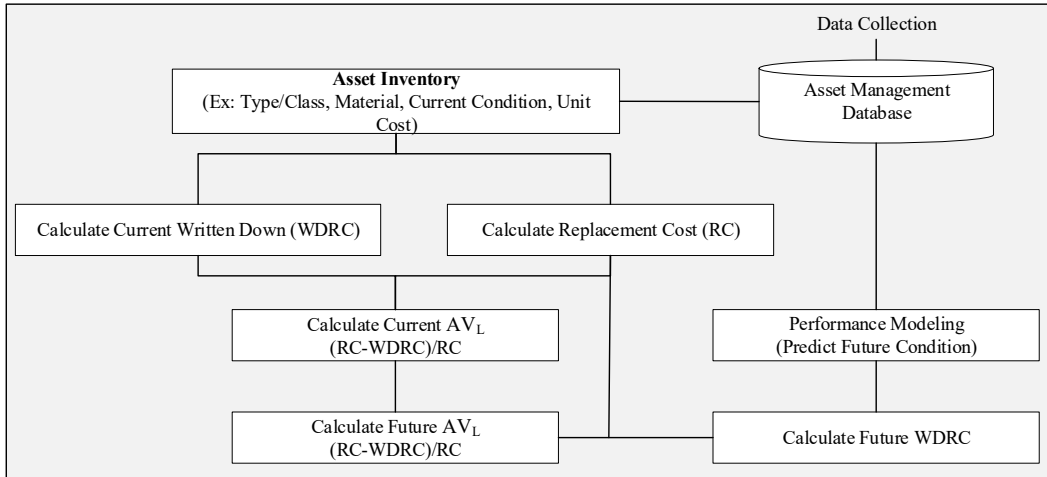


Figure 2: Asset value loss framework

5.2 Value-Based Life-Cycle Cost Analysis

As noted, the LCCA is used in asset management to evaluate different maintenance and rehabilitation strategies. In addition to maintenance and rehabilitation costs, agencies started to include other factors such as salvage value and user costs and environmental costs in the LCCA (Bryce et al. 2014; Mallela et al. 2011; Ozbay et al. 2004; Smith and Fung 2006; TAC 2013; Torres-Machí et al. 2015). However, to date, the impact of asset value on LCCA is not considered. Incorporating asset value in LCCA as a means of evaluating the return on investment is imperative. For example, the Transportation Research Board (TRB) issued a research needs statement with the objective to develop standard calculation methodologies to characterize the asset value of pavements for use in funding allocation, life cycle cost analysis and engineering evaluation.

The method proposed in the previous section can also be used in LCCA to evaluate different designs or the impact of different maintenance and rehabilitation strategies over the life cycle of the project on its value. The AV_L can be used to calculate the total loss of asset value over the analysis period and added as an incurred cost. Figure 3 shows an illustration of the proposed methods.

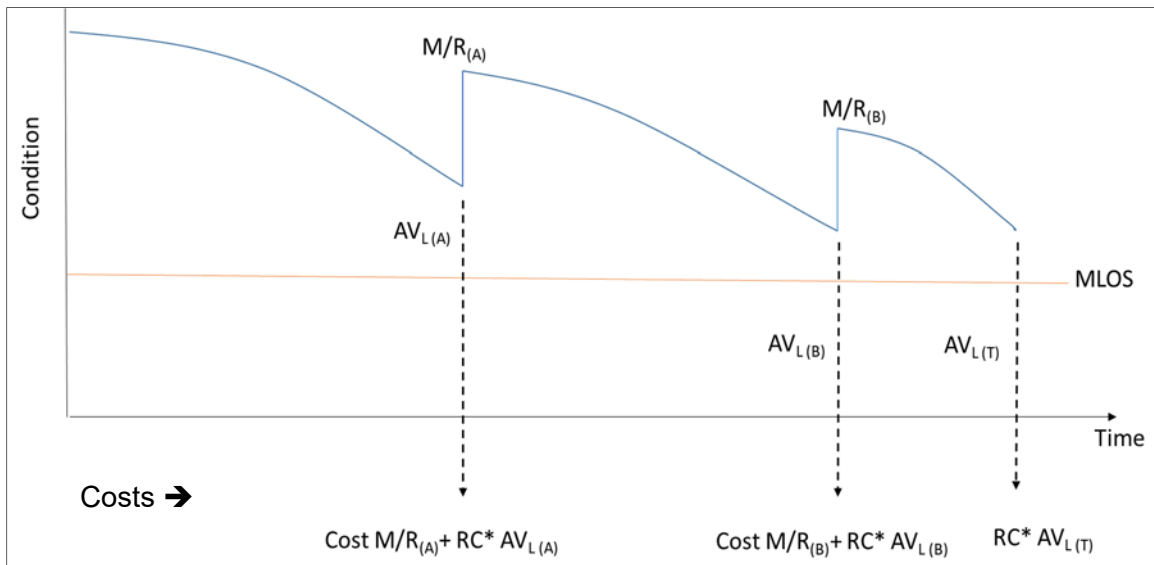


Figure 3: Incorporating asset value loss in LCCA illustration

As shown in Figure 3, the AV_L up to the time maintenance or rehabilitation is applied and at the end of the analysis period is used to calculate the loss in value up to that point. Mathematically, the calculation shown in Equation 4.2 can be modified to include asset value loss as follows:

$$[3] \text{ NPC} = IC + \sum_{i=1}^k (M\&R_j \times (\frac{1}{1+i})^{n_j}) + \sum_{t=1}^T (AV_{Lj} \times RC)$$

Where:

AV_{Lj} is the Asset Value Loss ratio before the j^{th} R&M $_j$ treatment is applied, and at the end of the analysis period (Year T)

RC is the present Replacement Cost (\$)

t = Year t of T years analysis period

Incorporating asset value loss allows for quantifying the opportunity loss in investment to preserve the asset and the impact of delay in maintaining assets.

5.3 Example

To further illustrate the proposed methodology, consider the pavement rehabilitation strategies example shown in Table 5.1.2. The pavement performance over the analysis period is illustrated in Figure 4.

Table 5.1.2: Pavement rehabilitation strategies example

	Option A	Option B
Rehabilitation 1	Hot Mix Overlay, Year 9	Year 12: Hot Mix Overlay
Rehabilitation 2	Mill + Hot Mix Overlay, Year 18	Year 20: Mill + Hot Mix Overlay

*Area = 21,491m², Replacement Unit Cost = \$91.73, Rehabilitation Unit Costs = \$19.16/m², Mill + Hot Mix Overlay = \$19.5/m², Analysis Year = 2010, Analysis Period = 20 years, Discount Rate = 5%
Following Equation 3, the NPW of the alternatives are calculated as follows:

Option A:

$$[(\$ 19.16 / \text{m}^2) * (21,491 \text{ m}^2) * (1/1.05^9)] + [(\$ 19.5 / \text{m}^2) * (21,491 \text{ m}^2) * (1/1.05^{18})] + [(0.25+0.28+0.012) * (\$ 91.73 / \text{m}^2) * (21,491 \text{ m}^2)] = \$ 1,508,257.53$$

Option B:

$$[(\$ 19.16 / \text{m}^2) * (21,491 \text{ m}^2) * (1/1.05^{12})] + [(\$ 19.5 / \text{m}^2) * (21,491 \text{ m}^2) * (1/1.05^{20})] + [(0.3+0.26+0.1) * (\$ 91.73 / \text{m}^2) * (21,491 \text{ m}^2)] = \$ 1,688,525.61$$

Based on the calculation above, option A is preferred. It is worth noting that without taking asset value loss into consideration, option B is more preferred as the NPW is \$387,421 while the NPW for option A is \$ 439,775. Therefore, by taking into account the asset value loss due to the delay in maintaining the asset allows for a justifiable and quantifiable need for funding and opportunity loss in investment.

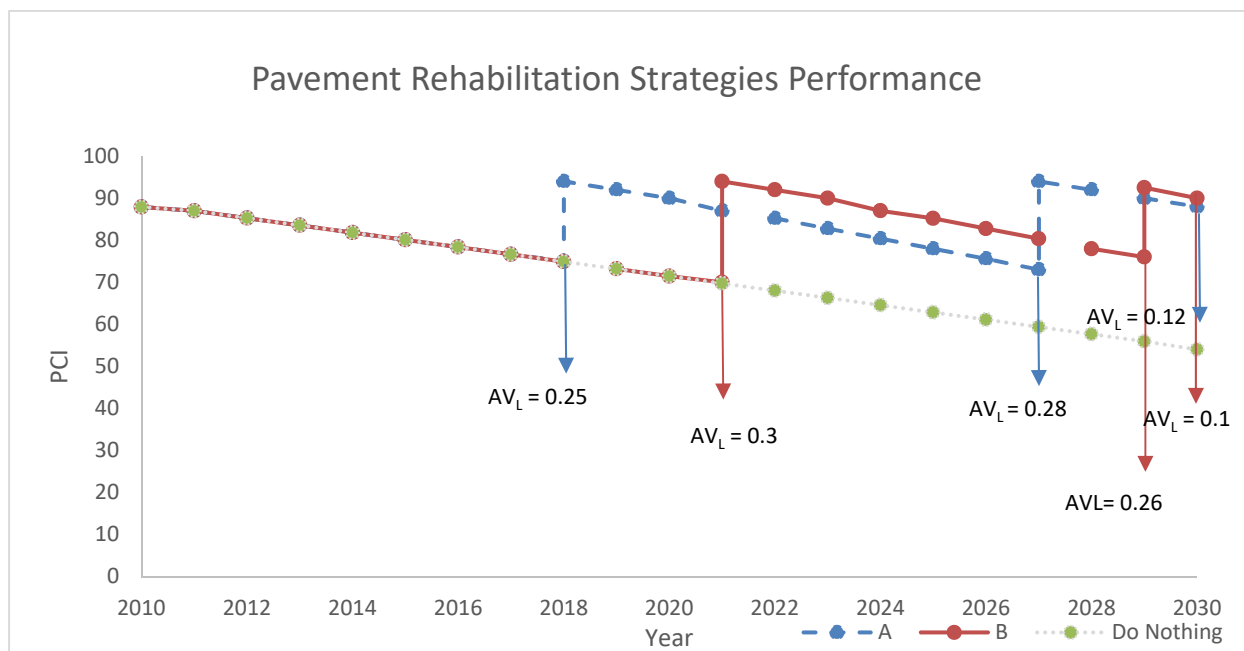


Figure 5.1: Value based life cycle cost analysis example for rehabilitation strategies

5.4 Summary and Conclusions

LCCA is used in asset management to evaluate different maintenance and rehabilitation strategies. In addition to maintenance and rehabilitation costs, agencies are using other factors such as salvage value and user costs and environmental costs in the LCCA. The paper presents a methodology to incorporate asset value as a component of LCCA as a means of evaluating the return on investment. The paper presented a methodology to establish asset value loss ratio that can be incorporated as a factor in LCCA. Incorporating asset value provides a tool for decision makers to evaluate different alternatives while taking into account the loss or add of value for a more justifiable and quantifiable need for funding and opportunity loss in investment.

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