Transportation asset valuation

Dixhant Acharya

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A Thesis

Entitled

Transportation Asset Valuation

By

Dixhant Acharya

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Science Degree in Civil Engineering

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College of Graduate Studies

The University of Toledo
December 2014
Asset valuation is a part of Transportation Asset Management Planning (TAMP). This thesis deals with valuing different assets in transportation sector like pavements, bridges, traffic lights, signs and etc. The Ohio Department of Transportation database for pavement is the main focus for asset valuation in this research. The main objective of this thesis is to use different types of asset valuation approaches/ method to determine the value of transportation assets. The importance of asset valuation is highlighted by the significant role it plays in determining priorities for future investment. The main purpose of this thesis is to review different valuation method that includes depreciation and also compare the valuation method to get a general idea on what each valuation method represents. The results obtained further serves the purpose to come up with a valuation method that could be used by Ohio Department of Transportation. The research into various valuation method resulted in selection of primarily three valuation method Replacement Cost, Book Value, and Written down Replacement Cost method. The Written down replacement cost method incorporates the pavement condition rating so; it could be further adjusted for best and worst condition for the pavement to get asset value.
Replacement cost method gave a measure on the cost to replace the existing asset with a new one. Book value method incorporated historical construction cost depreciated to current time; the depreciation function selected was straight line depreciation. The major issue faced during the research was unavailability of historical cost and construction year data so; the use of Construction price index and replacement cost for 2014 was done to calculate historical cost for the year 2012. The record for historical data needs to be kept properly in order for any transportation agency to know how well it has been retaining its asset value. The conclusion that has been derived is to add Written down Replacement Cost method to Replacement Cost method in practice by Ohio Department of Transportation for valuing its asset.
I dedicate this dissertation to my family, especially my mother, Vijay Laxmi Acharya and my father Lal Prasad Acharya for giving me love and support in each step of my life; to my sister, Dikshya Acharya and my roommates in Toledo for their unconditional love and support.
Acknowledgments

First of all, I would like to thank my advisor Dr. Eddie Y. Chou for giving me the opportunity to work with him, for providing me proper guidance, monitoring and financial support.

Next, I would like to thank my Master’s advisory committee: Dr. Liangbo Hu and Dr. Bhuiyan Alam for their suggestion and time. In addition, I would like to thank Dr. Ashok Kumar for his help.

At last, not the least, I would like to thank my family and friends for their help and support during my graduate studies. Thanks and gratitude goes out to my roommates Deepesh Bista, Tilak Poudel, Nischal Rimal, Gopal Dahal, and Dipesh Niraula for their unflinching support and belief in me. To my lab mates Dr. Shou Wang and Pawan Sigdel for their help and support.

Thank you all.
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Chapter 1

Introduction

1.1 Summary of Thesis

The topic of the thesis is “Asset Valuation for Transportation Asset”. The thesis deals with fundamental concepts of asset valuation and how it can help government, private agencies in defining their asset management goals. Asset valuation is a part of Transportation Asset Management Planning (TAMP), this thesis deals with valuing different assets in transportation sector like pavements, bridges, traffic lights, signs and etc. The main focus is on pavement as it is the major asset for transportation agencies.

The importance of asset valuation is outlined by the significant role it plays in determining priorities for future investment. In this thesis an effort has been made in valuing different pavements for Ohio, as well as sub-dividing the pavements in Ohio to include three highway routes, three county, and one district using different approaches and comparing the pros and cons of each approach and coming up with a valuation method suitable for ODOT. Though the results are purely based on mathematical
analysis, further simulation using different software can be done namely ARGUS, dTIMS etc. Also, the results can be further made readily available to public using GIS so the government agencies could prioritize further steps depending upon the usage of the pavement and importance to the public.

1.2 Objectives

The main objective of this research can be summarized as:

1. To review and compare different valuation methods for pavements in Ohio.
2. Creating GIS maps for different cases within Ohio, which includes three highway routes, three counties, and one district.
3. To compare the results from different approaches and come up with pros and cons for each approach and suggest suitable method usable to ODOT.
4. To outline how the results can be used for further asset management practices.
Chapter 2

Literature Review

2.1 Asset Management (Valuation): A basic Concept

Transportation agencies all around the world are changing toward a corporate type business strategy which, in turn leads to shifts in federal, state, and local policies, relative to infrastructure management and expansion, budgeting decisions, and staff resource allocations over the past 20 to 30 years. This change in outlook for transportation agencies have affected transportation investment decisions and are likely to play a key role in the future. First, federal transportation policy and legislation have shifted significantly in response to constrained budgets and changing priorities at all levels (McNeil & Switzer, 2004). Although many agencies practice some elements of asset management, few, if any, have fully implemented the “systematic process” into their day-to-day operations for two primary reasons which can be iterated as there is considerable knowledge gap that is widening between agency understanding of current and emerging needs and priorities and the available practices and technologies that can inform and streamline decision making processes and also, the other reason could be that the
potential benefits from changing the decision-making processes within the transportation industry remain uncertain (McNeil & Switzer, 2004).

Why is asset valuation important; what is the driving force behind highway and other related transportation agencies now becoming concerned about asset valuation? The basic reason is that with a move to asset management, agencies are establishing and implementing business plans, and, as for private industry, this requires knowledge of what their assets are and are worth (originally and current, and desirably an estimate of future worth or value) (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001). While the well-established component systems (pavements, bridges, etc.) have provided an invaluable springboard for extending to asset management they have not generally focused directly on asset valuation as a key element (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001).

The overall context for asset valuation and performance measures should be the mission and/or vision statements of highway agencies in order to fully implement the systematic process for asset management. Accordingly, a representative set of Canadian and U.S. agencies (web sites) were sampled and the essential finding was that almost all were directed to providing “safe, reliable, efficient” transportation. Other terms or goals were “desirable driving standards”, performance standards involving “pavement smoothness and riding comfort”, “foster a competitive business environment supported by a safe, efficient and accessible transportation network”, ensure “appropriate levels of quality and accessibility”, and “minimize the long term costs of preserving the highway system” (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001).
There are several definitions for Asset Management in circulation; however, they are all similar in the requirement of providing a systematic combination of the planning and financial processes. Within these vast definitions, an overall asset management framework, as shown in Figure 1, has been developed (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001). This framework is generic in nature and allows flexibility to accommodate individual agency needs, resources and policies.
Figure 1 gives a comprehensive understanding of the asset management system that
should include the capability of looking at the future in terms of identifying future under-performers (which requires forecasting models or estimates), identifying alternative programs, costs and returns on investments, and calculating future asset values for these alternatives.

The two most commonly referred methods or bases for asset valuations are (historical cost based) book value and written down replacement cost (WDRC). However, there are other methods which should be identified and which can be quite relevant in certain situations and/or for certain asset items (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001).

With regards to different asset valuation methods a recommended framework has been presented in Figure 2. Figure 2 provides a recommended framework for asset valuation which is applicable to any method (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001). This framework follows the asset management framework of Figure 1 and includes the basic notion that in order to establish current asset value, there are three essential questions which need to be answered:

What assets do we have?

What is their condition or status?

What valuation method should be used and what is their value?
The framework for highway asset valuation is shown by:

Existing data

Existing data

Condition Measurements

Remaining life estimates

Application of appropriate valuation method

Data Base

Executive Information System

Approval or Modification

Inventory of Assets by:

- Types/Classes
- Amounts/Extent
- Locations

Acquisition of new data

Assessment of current condition or status of each asset; network distributions

Calculation of current asset values

Estimate of future asset values, based on:

- Future deficiencies
- Alternative programs and assessment of outcomes
- Selection of optimal programs for program period
- Condition or status of assets for (c)

Fig 2-2: Framework for highway asset valuation (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001)
2.2 Asset Valuation

Asset management for Transport Sector is for managing of different administration involved in transport sector’s resources more like a business. This approach requires valuation or capitalization of infrastructure assets, as this plays a significant role in determining priorities for future investment (Haas & Zaniewski, Modern Pavement Management, 1994).

Asset valuation is defined by Marston (1970) as,

“The art of estimating the fair monetary measure of the desirability of ownership of specific properties for specific purpose…”

He furthers refines the definition in terms of engineering valuation as,

“…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. . . . ”

Within these definitions are several important points. First, the process of valuation is an estimation of monetary value using engineering judgment and knowledge. In engineering, estimation is a common practice that indicates computation of some quantity, whose magnitude cannot be exactly determined, usually because of a lack of real data and/or the reality that the data is better represented as a statistical range of values. The estimate, therefore, is a close representation of the true magnitude based upon values selected with engineering judgment and knowledge of the asset being valued. Second, a measure of desirability is required, that is, the asset must provide value to someone or something and that value is relative depending upon the desirability of
ownership and productivity of the asset (Falls & Haas. R.C.G.. Tighe, A Comparison of Asset Valuation Methods for Civil Infrastructure, 2004).

Several authors (Amekudzi, 2002) (Falls & Haas. R.C.G.. Tighe, A Comparison of Asset Valuation Methods for Civil Infrastructure, 2004) are working to understand the implications of valuing assets using a variety of valuation methods, which is important for the calculation of current value; however, in order to calculate the future value, the valuation method must be predictive and this requires an understanding of both the asset valuation method and the engineering based performance models. In other words, there is an accounting / financial dimension and a technical / engineering dimension. In pavement or bridge management systems, where there are engineering models, it is possible to provide answers to the question “what will the condition of my network be in year x as a result of expenditure y?” However, it is not possible to answer the question ‘what expenditure do I need to have “x” probability of achieving value (or level of service) “y” in year(s) “z”? ’ (Falls & Haas. R.C.G.. Tighe, A Comparison of Asset Valuation Methods for Civil Infrastructure, 2004).

Asset valuation is a part of broad Asset Management System. The valuation process shifts the thinking from traditional engineering perspective to economics or finance, in order to provide an approach for transport program development. Shifts in federal, state, and local policies, relative to infrastructure management and expansion, budgeting decisions, and staff resource allocations over the past 20 to 30 years, have affected
transportation investment decisions and are likely to play a key role in the future (McNeil & Switzer, 2004).

The management of the roads and transportation assets needs to evolve as budgets and the economy change. Past practices have been restrictive, which has caused the physical activities to be reactive rather than proactive. Asset valuation can form the basis for the development of maintenance and forward work programs (Falls & Haas. R.C.G.. Tighe, A Comparison of Asset Valuation Methods for Civil Infrastructure, 2004).

There are many different definitions of asset management which all holds a common element related to decision making for physical assets and the use of business principles commonly used in the private sector. Asset management has received broad acceptance in the private sector and as well as in different transportation agencies all across the world these practices has been briefly summarized by OECD. In North America, most state departments of transportation are still struggling to determine what asset management means to them and are tentative as to whether this is an approach they want to adopt (OECD, Asset Managements for the road sector, 2001).
2.3 Valuing the Transport Infrastructure assets

Asset values can be expressed in variety of ways:

1) Each asset has an intrinsic economic value to the transport network as a whole, that is, the value of efficient movement of people and goods. (OECD, Asset Managements for the road sector, 2001)

2) Or, each asset has a capital value either calculated from the cost of repairing the asset to an “as built” condition or of replacing the asset in kind. (OECD, Asset Managements for the road sector, 2001)

An asset value in such accounting term is a key element in developing the common language between financial managers and overseeing bodies (OECD, Asset Managements for the road sector, 2001). Valuation of asset is an important aspect as it enables the reporting of the asset in monetary terms to reflect the physical condition of the transport network; this assists the asset managers and the overseeing body of the effects of different financing strategies.

There are many different methods for determining the value of an asset that can be summarized as (McNeil S., 2000):

Book value: current value based on historical cost adjusted for depreciation,
Replacement Cost: current value based on cost of replacing/rebuilding the asset

Written down replacement cost: current value based on replacement cost depreciated to current condition,

Market value: price buyer is willing to pay,

Equivalent present worth in place: historic cost adjusted for inflation and wear,

Productivity realized value: net present value of benefit stream for remaining service life.

The above mentioned methods can be amalgamated as three basic approaches. These approaches prescribed to value infrastructure assets, and no single approach is universally accepted. Commonly used approaches to value transportation infrastructure assets include: (OECD, Asset Managements for the road sector, 2001)

• *Economic value*: derived from the value of the asset to the whole community in terms of the value of the efficient movement of people and goods.

• *Historical cost*: the base acquisition accounting cost, or the initial cost to build the facility in the year it was constructed (usually taken from the original construction cost records).
• **Current replacement cost:** the engineering cost estimate to replace the facility under current market conditions with one of equivalent capacity, taking into account cost efficiencies arising from improvements in technology.

The value of an asset depends on whether you are interested in the financial or the economic value.

Some features, pros, and cons of different asset valuation methods is shown in the table below:

<table>
<thead>
<tr>
<th>Method (1)</th>
<th>Features (2)</th>
<th>Pros (3)</th>
<th>Cons (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Book Value (Historical Cost depreciated to current time) (Falls &amp; Tighe, A Comparison of Asset Valuation Methods For Civil Infrastructure, 2004)</td>
<td>Based on historical construction cost depreciated to current time</td>
<td>Relatively simple to calculate upon availability of data. Uses straight line depreciation function to depreciate asset</td>
<td>Does not take into account the condition of the asset, usage of the asset. Changes in the price is not accounted for. Results can be misleading for older assets with higher condition rating.</td>
</tr>
<tr>
<td>Replacement Cost (Cost to construct new pavement) (Ralph Haas, 2005)</td>
<td>Cost to replace old asset with new one</td>
<td>Calculated from construction price per lane mile. Data readily available. Easily understandable.</td>
<td>Valuation of asset with good condition from this method unsuitable. Construction price depends upon external market forces.</td>
</tr>
<tr>
<td>Written Down Replacement Cost (Historical Cost adjusted to pavement condition)</td>
<td>Based on historical cost of asset adjusted to pavement condition rating to get current</td>
<td>Asset condition governs the valuation. Easily Understandable.</td>
<td>Harder to calculate if historical cost not present. Different condition measure gives</td>
</tr>
<tr>
<td>Method</td>
<td>Description</td>
<td>的优点</td>
<td>Disadvantages</td>
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<td>---------------------------------------------</td>
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<tr>
<td>Equivalent Present Worth</td>
<td>Based on historical cost adjusted to account for inflation, depletion, and wear</td>
<td>Accounts for changes in prices and usage. Useful for comparing rates of return with other investment.</td>
<td>Neglects changes in technology and service standards. Many conjectural assumption needed for valuation.</td>
</tr>
<tr>
<td>Productivity Realized Value</td>
<td>Based on productivity of remaining service life of asset</td>
<td>Reflects realistic importance of asset. Basis for budgeting.</td>
<td>Requires various assumptions and non-market estimates. Market force affects the valuation particularly if parallel service exists.</td>
</tr>
<tr>
<td>Market Value</td>
<td>Based on price buyer is willing to buy</td>
<td>Simple concept. Applicable when public agency sells of its assets.</td>
<td>Volatile as it is based on market values. Little use as rarely public agency sell their assets.</td>
</tr>
</tbody>
</table>

### 2.4 Depreciation in Transport Sector

Another important factor in determining asset value is identification of the deterioration and/or depreciation functions appropriate to each asset item. As in case of different
approaches to asset valuation there are number established depreciation methods in use. The most common methods are: (OECD, Asset Managements for the road sector, 2001)

- **Straight-line depreciation**: the value of an asset depreciates at a constant rate over time.

- **Condition-based depreciation**: where the value of an asset depreciates according to its condition.

Many road administrations use a combination of these two methods, the choice of depreciation method generally depends on the type of asset. For example, it may be appropriate to apply straight-line depreciation to assets that are not subject to vehicle loading, such as traffic signal systems and highway lighting, whereas condition-based depreciation may be more appropriate for assets such as pavements and bridges.

The figure below shows how the asset depreciates over time using different depreciation methods. The asset values and period shown in the graph below are generic in nature and initial asset value was $10,000 and depreciated over a period of 10 years, also the graph below gives us the nature of each depreciation and how it affects the asset value over a period of time. The depreciation methods used in the graph below are:

1) Straight Line Depreciation (SLN)

2) Sum of Year Digits (SYD)

3) Declining Balance (DB)

4) Double Declining Balance (DDB)
2.5 Government Accounting Standards Board (GASB) Section 34

This Statement establishes new financial reporting requirements for state and local governments throughout the United States. The mission of the GASB is to establish and improve standards of state and local governmental accounting and financial reporting that will result in useful information for users of financial reports and guide and educate the public, including issuers, auditors, and users of those financial reports (USDOT, 1999).

GASB 34 is a past based approach that estimates the historical cost using construction cost trends. The estimated historical cost can be calculated, under the GASB34 guidelines, as deflated replacement cost adjusted for the remaining service life and useful
life. This method is different to written-down replacement costing that the replacement cost is deflated using a price index (such as the Construction Price Index), rather than a deterioration model. The calculation is the same as Book Value, with the estimated deflated historical cost being used. Due to the combined effect of inflation and discount factors assets older than 25 years have zero value. GASB 34 effectively adjusts the replacement cost for age of the asset. If historical costs are not available, the historical cost of the section is determined by deflating current replacement costs per square foot (differentiated by functional classification) to the construction/rehabilitation year using the FHWA Highway price index. This is referred to a “Deflated GASB” (Falls & Haas. R.C.G., Tighe, A Comparison of Asset Valuation Methods for Civil Infrastructure, 2004).

2.6 Data needs for different valuation methods

The valuation of assets can be performed in various different ways, each method requires certain parameters or different sets of data for example book value method requires the asset to have historical cost i.e. the cost during which it was built, the salvage value and life of the asset. The different sets of data required for various method has been tabulated in the following table.
Table 2-2 Data Requirements for different valuation method (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001)

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<td>Deflated GASB</td>
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2.7 Approaches for Valuing and Depreciation of Assets used by different Countries according to OECD

**Australia**

Road assets are initially recorded at their cost, as required by the AASB, and a replacement cost approach is generally used when road infrastructure assets must be revalued. Replacement cost is most often used for valuing timber bridges, and is based on the cost of an equivalent concrete structure with the same capacity (Austroads, 1997).

As for depreciation, Australia appears to be furthest along with implementation. For instance, the State and Territory governments are already using one of two approaches to depreciate their highway infrastructure assets: straight-line depreciation or condition-based depreciation.

The governments of New South Wales, Western Australia and Tasmania use condition assessments to depreciate their roads and bridges, although each uses a straight-line approach to depreciate their traffic signal systems and highway lighting (Austroads, 1997). Conversely, the governments of Victoria, South Australia, the Northern Territory and Queensland use straight-line depreciation method for all their highway asset categories (roads, bridges, traffic signals and lighting). Additionally, the useful lives established for each asset category vary substantially among the States and Territories.
Belgium

In Belgium, a replacement cost approach is recommended for valuing infrastructure assets (OECD, Performance Indicators for the Road Sector, 1997).

As for the case of depreciation the CSPSA recommends the use of a condition-based method to depreciate infrastructure assets and highlights the many advantages of condition-based depreciation. However, straight-line depreciation appears to be permitted under the guidelines (OECD, Asset Managements for the road sector, 2001).

Canada (Canada, 1998)

In Canada, the CICA recommends the use of historical cost, where possible, for road infrastructure asset valuation (OECD, Asset Managements for the road sector, 2001). At the present time, many Canadian road administrations have limited experience with capital asset valuation using historical cost.

Interestingly, many road administrations expressed a desire to use measures that determine how well they are managing their roadway assets. As such, several Canadian jurisdictions have indicated that valuation of highway assets using replacement cost is one alternative measure that can provide useful information for asset management purposes over historical cost approach. This provides a real scenario of how the asset condition is rather to the time when the asset was constructed.
Although Canada’s effort appears to be just getting underway, in terms of asset valuation information provided in the OECD indicates that a condition-based depreciation method is being used (OECD, Asset Managements for the road sector, 2001).

**Finland**

The road infrastructure asset value is an important factor at the national level. The Ministry of Transport and Communications (MTC) takes care of all modes of traffic (road, railway, air, water and telecommunications), and is responsible for the allocation of the budget between these traffic modes, this budget is allotted for new construction to maintenance and management of the asset.

The asset value of the entire infrastructure is monitored by the MTC, although different administrations are responsible for data collection and the estimation of the asset value. The asset value is currently used in political discussions at the ministerial level and on the balance sheets of the road administration (OECD, Asset Managements for the road sector, 2001).

External accounting systems have been modified and standardized in the whole state from the beginning of 1998, since when all the state agencies and ministries have had similar accounting systems providing balancing of the accounts. The country-wide accounting system is rather similar to business accounting and there are statements of revenues and expenditures and balance sheets in use in all the agencies. A simple
spreadsheet program (POKLA) has been developed for asset value calculations and valuation (OECD, Asset Managements for the road sector, 2001).

Road network or engineering structures were categorized into four groups (roads structures, pavements, bridges, and other structures) due to the different nature of investments and depreciation parameters. Moreover, the road management of Finnra has been distributed as follows (OECD, Asset Managements for the road sector, 2001):

- Routine maintenance.
- Periodic maintenance.
- Planning.
- Road investments.
- Traffic information and services.
- Land acquisition.
- Administration.

Road investments have been further categorized into rehabilitation, improvement and new investments. Routine maintenance and other similar costs that do not preserve or increase the asset value are excluded. Data for asset value calculations has been collected since 1950, and the method of calculation is similar to that used in standard investment calculations (Virtala, 1996).

In Finland, the most important parameters in asset value calculations are the depreciation parameters. The main depreciation parameters are the holding times of different
structures, type of depreciation function (linear, regressive or progressive), and the salvage value.

The depreciation parameters have been determined in such a way that deprecations are equal to the reparation needs. This results in a more accurate estimate of the road infrastructure asset value. The holding times and depreciation values finally used are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Holding time (years)</th>
<th>Depreciation Values (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road structures</td>
<td>50</td>
<td>2.00</td>
</tr>
<tr>
<td>Pavements</td>
<td>10</td>
<td>10.00</td>
</tr>
<tr>
<td>Bridges</td>
<td>85</td>
<td>1.18</td>
</tr>
<tr>
<td>Other structures</td>
<td>10</td>
<td>10.00</td>
</tr>
</tbody>
</table>
United Kingdom

In the United Kingdom, it is recommended that the road network should be valued on the basis of the current replacement cost depreciated to reflect the overall condition of the network (Her Majesty’s Treasury, 1999b). This is deemed to be a more appropriate valuation approach for basing decisions on resource allocation.

On the introduction of resource accounting, an initial valuation and condition assessment will be made for the network. Thereafter, a variant of renewals accounting supplemented by annual condition surveys may be used as a method of approximate depreciation (Treasury, Resource Accounting and Budgeting – A Short Guide to the Financial Reforms, 1996a).

The UK Government recommends that a variant of renewals accounting is used to calculate the depreciation charge this in turn leads to, a consistent annual condition survey being undertaken of a significant and representative proportion of the road network in order to assess whether the condition of the network has improved or deteriorated in the year.

The financial impact of the improvement/deterioration can then be evaluated. If the survey reveals that the network has maintained a steady state during the year then the renewals expenditure is an acceptable proxy for the depreciation charge (OECD, Asset Managements for the road sector, 2001). However, if the condition of the network has deteriorated/improved between surveys, the value of the impairment/improvement, if
material, should be charged/credited to the operating cost statement (Treasury, Resource Accounting Manual, 1996b). If the road network is not expanding or contracting, the total charge to the operating cost statement should be broadly similar from year to year (Treasury, Resource Accounting and Budgeting – A Short Guide to the Financial Reforms, 1996a).

United States (USDOT, 1999)

The GASB recommends that state, city and county government agencies, in reporting capital assets as part of their modified financial statements, use a historical cost approach (e.g. the construction cost in the year the asset was built) in establishing transportation infrastructure values (OECD, Asset Managements for the road sector, 2001). If historical cost information is not available, GASB provides guidance for a proxy estimate using the current replacement cost. The current replacement costs should then be deflated to the year of the asset’s original year of construction using a number of general price-level indices available from the US Government or other generally accepted and available price indices, these general price indices can be Construction price index, NHCCl index or others.

If historical cost information was not available, such a procedure would need to be performed for any major infrastructure asset acquired, significantly reconstructed, or significantly improved, in fiscal years ending after 30 June 1980 (OECD, Asset
Managements for the road sector, 2001). It must be noted that the aforementioned procedures are merely suggestions, and GASB allows governments to use any valuation approach that complies with the intent of the statement.

The GASB indicates that governments may use any established depreciation method, and identifies both straight-line depreciation and condition-based depreciation as acceptable (OECD, Asset Managements for the road sector, 2001). The GASB requirements also provide maximum flexibility to agencies in establishing the “useful life” of each asset group. No specific guidelines on this are included in the Statement (GASB, n.d.). The Statement does indicate that a single depreciation rate may be applied to (OECD, Asset Managements for the road sector, 2001)

a) A class of assets;
b) A network of assets;
c) A sub-system of a network; or
d) An individual asset.

The GASB requirements indicate that infrastructure assets which are part of a network or sub-system of a network do not have to be depreciated if two distinct criteria are met. First, the government manages the infrastructure assets using an asset management system that has the characteristics set forth below. Second, the government documents that the infrastructure assets are being preserved at, or above, a condition level originally
established for the assets (OECD, Asset Managements for the road sector, 2001). To meet the first requirement, the AMS should have (GASB, n.d.):

- Have an up-to-date inventory of the assets.
- Perform condition assessments of the infrastructure assets at least once every three years, and summarize the results using a measurement scale.
- Estimate each year the annual amount required to maintain and preserve the infrastructure assets at the condition level originally established for those assets.

Such an exemption to the required depreciation exercise may spur state and local governments to implement comprehensive asset management systems, although it is too early to determine the potential effect of such an incentive.

2.8 Asset Type

Tangible assets are a term used in accounting procedure (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001). As well, there are other (non-tangible) assets which in the highway setting can be classified into fixed assets (within right-of-way), unfixed and fixed assets (outside the right-of-way), and other non-physical assets, as shown in Table 3 and 4 (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001)

A necessary complement to the framework of Fig. 2 is identification of the appropriate
valuation method for each asset item as shown in Figure 4 for agency owned assets (some changes would likely be needed if these assets were owned or managed by the private sector) (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001). For some of the items, more than one method is shown as appropriate. While it is realized that, the use of one method for consistency, the diversity of highway assets suggest that it may well be reasonable to adopt more than one such method, particularly for management accounting purposes (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001).

Another necessary complement to the framework of Figure 2 is identification of the deterioration and/or depreciation functions appropriate to each asset item (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001). For some assets (e.g. Pavements) deterioration and depreciation can be coincident. For others they are not likely to be coincident (e.g. Signs may be kept essentially in their original state by periodic maintenance but may also be depreciated over a period of time to establish a book value). Figure 4 and 5 also suggests deterioration functions (different depreciation method) applicable to the various tangible asset items. In some cases, there are several possible alternative functions (e.g., pavements, bridges, and drainage structures) and which one applies is site specific. While figure 4 and 5 presents suggested valuation methods to quantify asset value, the selection and use of any method and depreciation functions are highly dependent upon the availability of accurate data, both current and historical (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001).
2.9 Types of Transportation assets

2.9.1 Tangible assets

Tangible assets are a term used in accounting procedures, Assets that have a physical form. Tangible assets include both fixed assets, such as machinery, buildings and land, and current assets, such as inventory (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001).

In the Transportation setting tangible assets can be classified into fixed assets (within right-of-way), unfixed and fixed assets (outside the right-of-way).

2.9.2 Non- Tangible assets

Nonphysical assets, such as patents, trademarks, copyrights, goodwill and brand recognition, are all examples of non- tangible assets (Falls & Hosang, Asset Valuation as a Key Element of Pavement Management, 2001).
Table 2-4 Appropriate Asset Valuation Method(s) and Suggested Deterioration Functions for tangible Asset (Fixed Assets) (Haas & Raymond, Long Term Performance Specified Contract Framework for Road, 1999)

<table>
<thead>
<tr>
<th>Type (1)</th>
<th>Asset Item (2)</th>
<th>Valuation Method (3)</th>
<th>Depreciation/ Deterioration function (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pavements</td>
<td>BV, RC, WDRC</td>
<td>Concave up or down, straight line, or sigmoidal</td>
</tr>
<tr>
<td></td>
<td>Bridges</td>
<td>BV, RC, WDRC</td>
<td>Function varies with component element</td>
</tr>
<tr>
<td></td>
<td>Signs</td>
<td>BV, RC</td>
<td>Step function applies to sudden breakage or disappearance of sign kept in good condition i.e. replacement cost, curve function concave down applies to lack of maintenance</td>
</tr>
<tr>
<td>Fixed Assets (within the right of way)</td>
<td>Signals and loop detectors</td>
<td>BV, RC</td>
<td>Step function applies to sudden breakage or disappearance of sign kept in good condition i.e. replacement cost, straight line applied for properly maintained items</td>
</tr>
<tr>
<td></td>
<td>Guiderails and barrier walls</td>
<td>BV, RC, WDRC</td>
<td>Concave down generally used; step function if sudden damage occurs</td>
</tr>
<tr>
<td></td>
<td>Culverts</td>
<td>BV, RC, WDRC</td>
<td>Concave down generally used for material and structural deterioration; step function for blockage</td>
</tr>
<tr>
<td></td>
<td>Pavement Markings</td>
<td>BV, RC</td>
<td>Straight line or concave down</td>
</tr>
<tr>
<td></td>
<td>Lighting</td>
<td>BV, RC, WDRC</td>
<td>Same as for signals and loop detectors</td>
</tr>
<tr>
<td></td>
<td>Sidewalks and Bike paths</td>
<td>BV, RC, WDRC</td>
<td>Same as for pavements</td>
</tr>
</tbody>
</table>
Table 2-5: Appropriate Asset Valuation Method(s) and Suggested Deterioration Functions for tangible Asset (Unfixed Assets) (Haas & Raymond, Long Term Performance Specified Contract Framework for Road, 1999)

<table>
<thead>
<tr>
<th>Type (1)</th>
<th>Asset Item (2)</th>
<th>Valuation Method (3)</th>
<th>Depreciation/ Deterioration function (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfixed Assets (Outside of the right of way)</td>
<td>Quarries &amp; pits, Material Stockpiles</td>
<td>BV, RC, WDRC, EPV, MV</td>
<td>Straight line</td>
</tr>
<tr>
<td></td>
<td>Yards (buildings, sheds, fuel tanks etc.)</td>
<td>BV, RC, WDRC, MV</td>
<td>Straight line for most items</td>
</tr>
<tr>
<td></td>
<td>Mobile offices, laboratories</td>
<td>BV, RC, WDRC, MV</td>
<td>Straight line</td>
</tr>
<tr>
<td></td>
<td>Communication Equipment</td>
<td>BV, RC, WDRC, MV</td>
<td>Straight line</td>
</tr>
<tr>
<td></td>
<td>Computer hardware, software</td>
<td>BV, RC, WDRC, EPV, MV</td>
<td>Straight line</td>
</tr>
<tr>
<td></td>
<td>Vehicles, equipment and parts inventory</td>
<td>BV, RC, WDRC, MV</td>
<td>Straight line</td>
</tr>
</tbody>
</table>
Chapter 3

Data and Methodology

3.1 Data

The data was obtained from ODOT database, for the purpose of this thesis Ohio’s Pavement data was extracted for the complete data set. The Ohio data was further subdivided into three highway routes: I-75, US-20, and I-71, three county: Lucas, Fayette, and Delaware, and also one district: District 1. Different valuation methods were used in all the cases to review and compare the pavement value. The valuation for complete Ohio data was done also further dividing the pavements in Ohio according to priority: General, Urban, and priority networks. This showed how the pavement asset in Ohio is distributed to urban network, or highway network. The database used in this thesis contained the PCR data for each section length of pavements in Ohio. The historical cost for each section of pavements has not been recorded or kept by ODOT this required that the historical cost was calculated from current replacement cost and construction price index for base year of 2012 for all the cases considered in this thesis.
The data contained information on pavements from Key Id, District and county in which the pavement was located, route, section length, number of lanes, priority, mile class, surface type, surface width, route type, pavement type, PCR value and the date, IRI.

The data for PCR was further classified into 5 classes as shown in Table 6. The data for construction price index was obtained separately from FHWA.

3.2 Methodology

3.2.1 Basic flowchart of Valuation Methods

This section shows a brief description on the valuation methods as a process flowchart, their features, data required, formulas, problem faced and usability as a viable valuation method. The selection and description for depreciation used has been discussed in sections later on.

Fig 3-1: Process Flowchart for Book Value method of valuation
Fig 3-2: Process Flowchart for Replacement Cost method of valuation

Replacement Cost
- Based on current construction cost

Data Required
- Construction Cost per lane mile: $1,250,000
- Lane mile

Calculation Process
- RC = $1,250,000 * lanemile

Problem faced
- Construction cost per lane mile changes according to external forces so, cost of $1,250,000 used from ODOT

Fig 3-3: Process Flowchart for Written down Replacement cost method including ADJUSTED. WDRC method of valuation

Written Down Replacement Cost
- Based on historical cost adjusted to pavement condition

Data Required
- Historical Cost
- Pavement Condition Rating

Calculation Process
- $\bar{V}_t = HC \left( \frac{Pt}{P_{best}} \right)$
- Also to incorporate best and worst condition ADJUSTED WDRC calculated
- $\bar{V}_t = HC \left( \frac{Pt-P_{worst}}{P_{best}-P_{worst}} \right)$

Problem faced
- Unavailability of actual historical data so, deflated GASB used to calculate Historical cost from replacement cost and CPI
Fig 3- 4: Process Flowchart for Equivalent Present Worth method of valuation

Equivalent Present Worth

Data Required

Calculation Process

- Based on historical cost adjusted to account inflation, depletion and wear
- Historical Cost
- Inflation rate
- Not used as inflation fluctuates on a day to day basis so the valuation unreliable

Fig 3- 5: Process Flowchart for Productivity Realized Value method of valuation

Productivity realized Value

Data Required

Calculation Process

- Based on productivity of remaining service life of asset
- Remaining service life of asset
- Non-market estimates to value productivity
- Not used as true construction date for all pavement section not available so, calculating remaining service life not possible
- Affected highly by different definitions for productivity

Fig 3- 6: Process Flowchart for Market Value method of valuation

Market Value

Data Required

Calculation Process

- Based on price buyer willing to pay
- Selling price for the asset
- Not used as market price to volatile to predict

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3.2.2 Selection of Suitable Valuation Methods

In this thesis, not all valuation and depreciation method was used to get the value of pavements in Ohio. From the previous section we could see the valuation that would suitable to calculate the pavement value. Based on it the valuation method, the functions or methods selected are namely:

1. Book Value 
2. Replacement Cost 
3. Written Down Replacement Cost 
4. Adjusted WDRC 

Deflated GASB approach was used to get the historical costs of the pavements using replacement cost and Construction price index for the base year of 2012.

3.2.3 Replacement Cost

Replacement Cost is construction cost which, takes into consideration that an existing asset will be replaced by new one of same quality for calculating the construction cost there are three main components that needs to be considered material cost, transportation cost, and operation cost.

The total replacement cost for each type of asset is considered differently. For pavement the total replacement cost is the summation of different construction cost for different pavement layers (D. & Parth A. Makwana, 2012).
The GASB provides us with the construction cost for pavement according to the year in which they are to be constructed this value can be used as replacement cost (AUDITOR, 2002).

In case of this thesis a generic value for the construction cost of pavement per lane per mile of $1,250,000 was used. This value was used because of unreliability of material and construction cost as this depends on the bids received by state transportation agencies for different projects.

3.2.4 Written Down Replacement Cost Approach

Written down Replacement Cost is the price, at current market value, required to return an asset to new condition, adjusted for the deteriorated condition of the asset at the time of replacement (D. & Parth A. Makwana, 2012). The condition of the asset is used to adjust the replacement cost as a means of acknowledging that some assets are in better or worse condition at the time of replacement and therefore not all replacement costs will be the same on a unit cost basis. As with replacement cost, this is a difficult method to use for future predictions, due to the difficulty in estimating future replacement costs. However, good performance modeling can predict future asset condition and it is for this reason, that some highway agencies use WDRC (D. & Parth A. Makwana, 2012).
In the “written-down replacement cost method,” the asset is calculated as the product of its historical (original) construction cost and a condition ratio (D. & Parth A. Makwana, 2012). The condition ratio is the ratio of the current condition to the best condition. Thus, this method utilizes performance models that predict asset condition at any time. In this thesis, PCR is used as performance model.

Unlike the “adjusted value with respect to condition threshold” method, this method does not consider a failure condition threshold and therefore could overestimate or underestimate asset value (D. & Parth A. Makwana, 2012). Using the written-down replacement method, the value of an asset at any time \( t \), \( V_t \) is calculated as follows:

\[
V_t = HC \times \left( \frac{P_t}{P_{best}} \right) 
\]

(1)

Where, \( HC \) is the historical (original) construction cost; \( P_t \) is the condition at time \( t \); and \( P_{best} \) is the best possible condition of the asset.

For incorporating the condition threshold the written down replacement cost is adjusted. The “adjusted value with respect to condition threshold” method utilizes both current and past data to determine asset values (D. & Parth A. Makwana, 2012). The following equation presents the calculation and the key variables associated with this method.

\[
V_t = HC \times \left( \frac{P_t - P_{worst}}{P_{best} - P_{worst}} \right) 
\]

(2)
Where, \( V_t \) is the asset value at year \( t \); HC is the historical (original) construction cost; \( P_t \) is the expected condition at year \( t \) (from the deterioration model); \( P_{worst} \) is the worst possible condition of the asset; and \( P_{best} \) is the best possible condition of the asset.

The PCR data was classified into 5 different classes to expedite and give uniformity to the calculation of written down replacement cost as well as facilitate for finding adjusted written down replacement cost.

<table>
<thead>
<tr>
<th>PCR</th>
<th>Expression</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>100-90</td>
<td>Very Good</td>
<td>5</td>
</tr>
<tr>
<td>90-75</td>
<td>Good</td>
<td>4</td>
</tr>
<tr>
<td>75-55</td>
<td>Fair to Poor</td>
<td>3</td>
</tr>
<tr>
<td>55-40</td>
<td>Poor</td>
<td>2</td>
</tr>
<tr>
<td>40-0</td>
<td>Very Poor</td>
<td>1</td>
</tr>
</tbody>
</table>

### 3.2.5 Book Value Approach

Book value is defined as the value of an asset based upon historical costs less any allowance for depreciation, this valuation approach can also be considered as a backward
looking approach to asset value as it includes the cost to build (or acquire) the asset, adjusted for consumption of that asset and in that sense is actually book cost. In the case of civil infrastructure, consumption is based upon the condition of the asset (which is equated to depreciation of the asset) to adjust the historical costs to current value (D. & Parth A. Makwana, 2012). Depending on the age of the asset, actual cost data may be available, or the historical value is calculated by adjusting current replacement cost by historical price factors (D. & Parth A. Makwana, 2012). That is, for recently built or acquired assets, the actual cost data is used, while older assets for which actual costs are not readily available, the historical cost is an estimated cost calculated (D. & Parth A. Makwana, 2012). The construction cost data can be estimated using current replacement costs which can be adjusted to yield their construction cost from Construction Price Index (CPI) or similar inflation indices (D. & Parth A. Makwana, 2012). Book value can be calculated using the following equation.

\[
BV_t = P - \frac{P - S}{t_s - t_p} * (t - t_p) \quad (3)
\]

Where, P is historical (original) construction cost; S is salvage value; \( t_s \) is the year of the salvage; \( t_p \) is the year of construction; thus \( t_s \) to \( t_p \) is the analysis period, and \( t \) is the current year. This method uses straight line depreciation. The useful lives for asset as well as salvage value have been tabulated below:
### Table 3- 2 Useful Lives of different assets (AUDITOR, 2002)

<table>
<thead>
<tr>
<th>Assets</th>
<th>Useful Lives (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Computer Equipment &amp; Peripherals</td>
<td>3</td>
</tr>
<tr>
<td>Vehicles and Equipment</td>
<td>5</td>
</tr>
<tr>
<td>Heavy Equipment</td>
<td>10</td>
</tr>
<tr>
<td>Furniture and Fixtures</td>
<td>7</td>
</tr>
<tr>
<td>Improvements other than Buildings</td>
<td>20</td>
</tr>
<tr>
<td>Buildings</td>
<td>40</td>
</tr>
<tr>
<td>Roads</td>
<td>20</td>
</tr>
<tr>
<td>Concrete bridges</td>
<td>50</td>
</tr>
<tr>
<td>Timber bridges</td>
<td>30</td>
</tr>
</tbody>
</table>

### Table 3- 3 Salvage Values for different assets (AUDITOR, 2002)

<table>
<thead>
<tr>
<th>Asset</th>
<th>Salvage Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Computer Equipment</td>
<td>1</td>
</tr>
<tr>
<td>Furniture</td>
<td>10</td>
</tr>
<tr>
<td>Vehicles and heavy equipment</td>
<td>10</td>
</tr>
<tr>
<td>Improvement other than buildings</td>
<td>20</td>
</tr>
<tr>
<td>Buildings</td>
<td>20</td>
</tr>
<tr>
<td>Roads</td>
<td>30</td>
</tr>
</tbody>
</table>
The useful lives of different assets and the salvage values for different assets and infrastructure are given by the data above.

### 3.2.6 Deflated GASB approach

GASB 34 effectively adjusts the replacement cost for age of the asset. If historical costs are not available, the historical cost of the section is determined by deflating current replacement costs per square foot (differentiated by functional classification) to the construction/rehabilitation year using the FHWA Highway price index (USDOT, 1999). This is referred to a “Deflated GASB” (GASB, n.d.).

The cost of replacing an asset differs from year to year, due to inflation. The Federal Highway Administration (FHWA) provides annual Construction Price Indices (CPI) to facilitate conversion of monetary values to account for inflation. The following equation can be used to determine the replacement cost of an asset at any time $t$.

$$ RC_t = HC \times \left( \frac{CPI_t}{CPI_{year\ built}} \right) ... (4) $$

Where, $HC$ is the historical (original) construction cost; $CPI_t$ is the construction price index in year $t$; $CPI_{year\ built}$ is the construction price index in the year it was built; and $RC$ is the replacement cost in year $t$. 
In this thesis the Deflated GASB was used to get the historical cost of assets for the base year of 2012, using the valuation obtained from Replacement Costs per lane per mile and Construction Price Index.

The Construction Price Index obtained from FHWA is shown below (Nguyen, 2014):

<table>
<thead>
<tr>
<th>Year</th>
<th>Construction Price Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>39.7</td>
</tr>
<tr>
<td>1988</td>
<td>40.5</td>
</tr>
<tr>
<td>1989</td>
<td>43.9</td>
</tr>
<tr>
<td>1990</td>
<td>44.1</td>
</tr>
<tr>
<td>1991</td>
<td>40.4</td>
</tr>
<tr>
<td>1992</td>
<td>40.4</td>
</tr>
<tr>
<td>1993</td>
<td>42.2</td>
</tr>
<tr>
<td>1994</td>
<td>46.2</td>
</tr>
<tr>
<td>1995</td>
<td>45.0</td>
</tr>
<tr>
<td>1996</td>
<td>45.6</td>
</tr>
<tr>
<td>1997</td>
<td>47.6</td>
</tr>
<tr>
<td>1998</td>
<td>49.9</td>
</tr>
<tr>
<td>1999</td>
<td>52.9</td>
</tr>
<tr>
<td>2000</td>
<td>53.5</td>
</tr>
<tr>
<td>2001</td>
<td>58.7</td>
</tr>
<tr>
<td>2002</td>
<td>53.1</td>
</tr>
<tr>
<td>2003</td>
<td>56.6</td>
</tr>
<tr>
<td>2004</td>
<td>79.9</td>
</tr>
<tr>
<td>2005</td>
<td>98.1</td>
</tr>
<tr>
<td>2006</td>
<td>104.1</td>
</tr>
<tr>
<td>2007</td>
<td>100.0</td>
</tr>
<tr>
<td>2008</td>
<td>95.0</td>
</tr>
<tr>
<td>2009</td>
<td>78.4</td>
</tr>
<tr>
<td>2010</td>
<td>76.8</td>
</tr>
<tr>
<td>2011</td>
<td>84.0</td>
</tr>
<tr>
<td>2012</td>
<td>79.2</td>
</tr>
</tbody>
</table>
3.3 Depreciation in Assets

Depreciation is a loss of value from the original cost of the asset. Based on the cost technique, a generic equation to determine accrued depreciation is expressed as follows (SIRIRANGSI & HERABAT, 2001):

\[ D_t = f(X_1, X_2, X_3, \ldots, X_n) \ldots \ldots \ldots \ldots \ldots \ldots (5) \]

Where \( D_t \) is depreciation at time \( t \) and \( X_1, X_2, X_3, \ldots, X_n \) are the attributes. The attributes of accrued depreciation are, for example, traffic volume, service life, socioeconomic and technology (SIRIRANGSI & HERABAT, 2001). The relationship between depreciation and deterioration is suggested by AIREA (Appraisal, 1987).

Accrued depreciation is a loss of value from historical cost. There are three main components of accrued depreciation physical depreciation, functional obsolescence, and external obsolescence (SIRIRANGSI & HERABAT, 2001):

\[ D_t = (d_t + f_t + e_t) \ldots \ldots \ldots \ldots \ldots \ldots (6) \]

Where,

\( D_t \) is accrued depreciation at time \( t \),

\begin{tabular}{|c|c|}
\hline
2013 & 97.1 \\
\hline
2014 & 96.9 \\
\hline
\end{tabular}
\( d_t \) is physical deterioration at time \( t \),

\( f_t \) is functional obsolescence at time \( t \), and

\( e_t \) is external obsolescence at time \( t \)

### 3.3.1 Physical Deterioration (Depreciation)

Physical deterioration is the loss in serviceability, which is caused by damage or decay in the components of a particular asset (SIRIRANGSI & HERABAT, 2001). The change of performance indices should be reflected in the asset value. When a maintenance or rehabilitation is applied, the condition of an asset is improved and the corresponding asset value should increase. AIREA (1987) defines the physical deterioration as the item of deferred maintenance. It can be measured by determining the cost of repairing the asset to an acceptable condition (SIRIRANGSI & HERABAT, 2001).

### 3.3.2 Functional Obsolescence

Functional obsolescence is a loss of value due to the defects of material or design which may be caused by current standards or laws (AIREA, 1987). This is measured by the difference between the costs of additions or modification of an element meets the new standards and the cost of an element that was installed at the time of original construction (SIRIRANGSI & HERABAT, 2001). The functional obsolescence is constant over the life cycle of pavement (SIRIRANGSI & HERABAT, 2001).
External obsolescence is a loss of value according to the change of external factors such as social, technological, economic, governmental, and environmental factors (AIREA, 1987). The change in expectation for the use-of a particular infrastructure causes external obsolescence. Usually the external obsolescence is not considered when depreciating assets as it varies from user to user (SIRIRANGSI & HERABAT, 2001).

Considering all the components for depreciation it can be expressed in terms of only physical depreciation:

\[
D_t = (d_t) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)
\]

Where,

\( D_t \) is depreciation at time \( t \),

\( d_t \) is physical deterioration at time \( t \),

The depreciation approach uses various functions that relate asset value to asset age to determine asset value at any specific year. The pattern of asset depreciation may follow any one of several forms, including straight line, declining balance, double-declining balance, and sum-of-years digits, concave, convex, or sigmoidal (D. & Parth A. Makwana, 2012). The increasing accumulated depreciation of the asset over the years causes the asset value to decrease gradually from its original value at the time of construction. Depreciation methods thus begin with the historical cost of asset
construction and then make adjustments for deterioration (D. & Parth A. Makwana, 2012).

3.3.3 Straight line Depreciation

In straight-line depreciation, it is assumed that the asset loses a fixed value every year. This annual loss in value, or constant depreciation rate, is simply calculated as the historical cost less salvage value, divided by the asset service life. The rate of straight-line depreciation (SLD) is given by:

\[
SLD = \frac{(P - S)}{(t_s - t_p)}
\]  

Where, P is historical (original) construction cost; S is salvage value; t_s is the year of the salvage; t_p is the year of construction; thus t_s to t_p is the analysis period, which is often equal to the asset service life.

3.3.4 Sum of Years Digits Depreciation

The sum-of-years-digits depreciation (SOYD) method depreciates the value of an asset over time by computing a different fractional depreciation rate for each year. For SOYD, instead of dividing by the total number of years that the asset has been in service (as is the case for SLD), the difference between historical cost and the salvage value is multiplied by a ratio that is related to the remaining life. This depreciation at the end of
the study period can be very large causing the replacement cost to zero as it is cumulative in nature so in case of roads it is not used.

\[ SOYDt = \frac{(N - t + 1)}{(\frac{N}{2})(N + 1)} * (P - s) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9) \]

Where, \( N - t + 1 \) is the useful remaining life at the beginning of year \( t \); \( N \) is the analysis period or service life; \( t \) is the given year; \( P \) is the historical (original) construction cost; and \( S \) is the salvage value.

### 3.3.5 Declining Balance Depreciation

The declining balance (DB) depreciation method uses a constant fraction (depreciation factor) of the End of the Previous Year (EOPY) book value to determine the extent to which an asset depreciates in each year.

\[ DBt = \left( \frac{1}{N} \right) * BV_{t-1} - 1 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (10) \]

Where, \( DB_t \) is the declining balance depreciation; \( 1/N \) is the depreciation factor; \( N \) is the analysis period or service life; and \( BV_{t-1} \) is the asset value at the end of the previous year.
3.3.6 Double Declining Balance Depreciation

The double-declining balance depreciation, a special case of the declining balance depreciation, calculates depreciation as a constant fraction of the EOPY book value. The fraction is 2/N, where N, the analysis period, is typically taken as the asset life. The double-declining balance method yields a larger depreciation in the early years of an asset and the book value never reaches zero.

\[ DDB_t = \left( \frac{2}{N} \right) \times BV_t - 1 \]  
\[ \text{Equation (11)} \]

Where, DDBt is the double-declining balance depreciation at year t; (2/N) is the depreciation factor; N is the analysis period or service life; and BV_{t-1} is the asset value at the end of the previous year.

3.3.7 Sigmoidal Depreciation

The other depreciation methods like straight line, sum of Years digits, declining balance and double declining balance are common in financial accounting. There are other depreciation methods to describe the trend of depreciation specific assets as Reverse sum of Years Digits, sigmoidal Depreciation, and inverse sigmoidal depreciation (D. & Parth A. Makwana, 2012).
The sigmoidal depreciation (s-curve) is a less common mathematical function for depreciation. In this method the asset considered has a slow depreciation at the beginning of its service life, a fast depreciation during its middle life, and then deteriorates rapidly at the end of its service life (D. & Parth A. Makwana, 2012).

The inverse sigmoidal form has a reverse order where the asset depreciates rapidly in its early life, slowly during its middle years, and rapidly again near the end of its service life.

\[
V_t = E - \frac{A}{(B + C \times t)^D} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (12)
\]

Where, \( V_t \) is the asset value at year \( t \); \( E \) is the original (historical) construction cost; \( A, B, C, D \) are coefficients, calibrated for a specific asset, which are also called shape parameters and dictate the shape of these curves; and \( t \) is the asset age.

### 3.3.8 Selection of Depreciation Method

In order to select proper depreciation method to be used for the valuation of pavements the figure below gives us a good example of how the SR-295 road network in Lucas county depreciates using SLD, DBT, DDBT, and SOYDT. From the figure below we can see that SLD gives a uniform depreciation, while the other depreciation method shows higher initial depreciation and slows over time. This is contradictory in nature to pavements as in new condition the depreciation is low and then it accelerates at the end of service life. Thus, the best depreciation method is the SLD and can be used to calculate
Book Value of the asset. The major drawback of the other depreciation method is that after certain time the book value calculated from these method results in negative asset value which, in turn means that the asset is unusable this may not be true. For this reason other methods of depreciation are not considered for valuing of assets.

Fig 3- 7: Depreciation in Asset Value for SR- 295: Construction Year 1987
Chapter 4

Results and Discussion

4.1 Results

4.1.1 Case I (I-75)

This case involved valuation of I-75 highway network in Ohio using Replacement Cost (RC), Historical Cost (HC), Written Down Replacement Cost (WDRC), Adjusted WDRC (Adj. WDRC), and Book value (BV).

In this case the first step was to extract I-75 data from ODOT database. Then, the section length was calculated which lead to calculation of replacement cost. The historical cost was calculated from replacement cost and Construction Price Index, the historical cost calculated was for the base year of 2012. After finding the historical cost the valuation from WDRC, Adj. WDRC and Book Value was carried out. The figure below shows I-75 highway network in Ohio and the valuation of the asset found from the different method used.
OHIO: I-75 Highway Network

Legend

Fig 4-1: I-75 highway network in Ohio
4.1.2 Case II (US- 20)

This case involved valuation of US- 20 highway network in Ohio using Replacement Cost (RC), Historical Cost (HC), Written Down Replacement Cost (WDRC), Adjusted WDRC (Adj. WDRC), and Book value (BV).

In this case the first step was to extract US- 20 data from ODOT database. Then, the section length was calculated which lead to calculation of replacement cost. The historical cost was calculated from replacement cost and Construction Price Index, the historical cost calculated was for the base year of 2012. After finding the historical cost the valuation from WDRC, Adj. WDRC and Book Value was carried out. The figure
below shows US- 20 highway network in Ohio and the valuation of the asset found from
the different method used.
4.1.3 Case III (I-71)

This case involved valuation of I-71 highway network in Ohio using Replacement Cost (RC), Historical Cost (HC), Written Down Replacement Cost (WDRC), Adjusted WDRC (Adj. WDRC), and Book value (BV).

In this case the first step was to extract I-71 data from ODOT database. Then, the section length was calculated which lead to calculation of replacement cost. The historical cost was calculated from replacement cost and Construction Price Index, the historical cost calculated was for the base year of 2012. After finding the historical cost the valuation from WDRC, Adj. WDRC and Book Value was carried out. The figure...
below shows I- 71 highway network in Ohio and the valuation of the asset found from the different method used.

Fig 4- 5: I- 71 Highway Network in Ohio
4.1.4 Case IV (Lucas, Fayette, and Delaware County)

This case involved valuation of Lucas, Fayette, Delaware County in Ohio using Replacement Cost (RC), Historical Cost (HC), Written Down Replacement Cost (WDRC), Adjusted WDRC (Adj. WDRC), and Book value (BV).

In this case the first step was to extract the county data from ODOT database. Then, the section length was calculated which lead to calculation of replacement cost. The historical cost was calculated from replacement cost and Construction Price Index, the historical cost calculated was for the base year of 2012. After finding the historical cost
the valuation from WDRC, Adj. WDRC and Book Value was carried out. The figure below shows the counties road network in Ohio and the valuation of the asset found from the different method used.

The separate valuation of I-75 and US- 20 in Lucas County, I- 71 in Delaware County and I- 71 in Fayette County are also shown below. This gives us idea on how much of the asset value for the county is contributed by major highway network passing through it.
Fig 4-7: Road Network in Lucas, Delaware, and Fayette County in Ohio
Fig 4-8: Road Network in Lucas County in Ohio

OHIO: Lucas County Road Network Asset Value
(921.67 Lane mile)

Asset Value (Millions)

<table>
<thead>
<tr>
<th>RC</th>
<th>HC</th>
<th>WDRC</th>
<th>ADJ_WDRC</th>
<th>BV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1,152.09</td>
<td>$941.84</td>
<td>$718.28</td>
<td>$662.61</td>
<td>$875.91</td>
</tr>
</tbody>
</table>
OHIO: Fayette County Road Network Asset Value (454.3 Lane mile)

Fig 4-9: Road Network in Fayette County in Ohio
Fig 4-10: Road Network in Delaware County in Ohio

OHIO: Delaware County Road Network Asset Value
(552 Lane mile)
Lucas County: I- 75 Highway Network Value
(68.08 Lane mile)

Fig 4-11: I- 75 Highway Network in Lucas County
Lucas County: US- 20 Highway Network Value (66.18 Lane mile)

Fig 4- 12: US- 20 Highway Network in Lucas County
Fayette County: I- 71 Highway Network Value
(77.56 Lane mile)

Fig 4- 13: I- 71 Highway Network in Fayette County
4.1.5 Case V (District 1 of OHIO)

This case involved valuation of District 1 in Ohio using Replacement Cost (RC), Historical Cost (HC), Written down Replacement Cost (WDRC), Adjusted WDRC (Adj. WDRC), and Book value (BV).

In this case the first step was to extract the District 1 data from ODOT database. Then, the section length was calculated which lead to calculation of replacement cost. The historical cost was calculated from replacement cost and Construction Price Index, the historical cost calculated was for the base year of 2012. After finding the historical cost the valuation from WDRC, Adj. WDRC and Book Value was carried out. The figure
below shows the District 1 road network in Ohio and the valuation of the asset found from the different method used.

The separate valuation of I-75 passing through in District 1 is also shown below. This gives us idea on how much of the asset value for the district is contributed by major highway network passing through it.

![OHIO: DISTRICT 1 Road Network](image)

**Fig 4-15: Road Network in District 1 in Ohio**
Fig 4-16: District 1 Road Network Asset Value

OHIO: District 1 Road Network Value
(3,467.5 Lane mile)
4.1.6 Case VI (OHIO)

This case involved valuation of all road networks in Ohio using Replacement Cost (RC), Historical Cost (HC), Written down Replacement Cost (WDRC), Adjusted WDRC (Adj. WDRC), and Book value (BV).

The data for all Ohio road network was obtained from ODOT database. Then, the section length was calculated which lead to calculation of replacement cost. The historical cost was calculated from replacement cost and Construction Price Index, the historical cost calculated was for the base year of 2012. After finding the historical cost the valuation from WDRC, Adj. WDRC and Book Value was carried out. The figure below shows the valuation of the complete road network asset found from the different method used.
The road network for Ohio was separated into three branches depending on the priority namely G (General), P (Priority), and U (Urban).

Fig 4-18: Total Road Network Asset Value in Ohio

<table>
<thead>
<tr>
<th>Asset Value (Billions)</th>
<th>RC</th>
<th>HC</th>
<th>WDRC</th>
<th>ADJ_WDRC</th>
<th>BV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$62.95</td>
<td>$51.46</td>
<td>$43.05</td>
<td>$40.25</td>
<td>$47.86</td>
</tr>
</tbody>
</table>

OHIO Total Road Network Value
(50,357.26 Lane mile)
Fig 4-19: Total General Priority Road Network Asset Value in Ohio
OHIO: Value for Priority Road Network
(13,502.09 Lane mile)

Fig 4-20: Total Priority Road Network Asset Value in Ohio
4.2 Discussion

The results gave the numerical value obtained from each valuation method for all six cases. The value from replacement cost is for highway network for good condition i.e. best condition rating this value could be compared to valuation obtained from other methods in terms of percentages to get how much of the total asset value is retained from other methods. The table below shows the comparison between the three interstate highway routes.
Table 4-1 Comparison of Replacement cost to other methods: Highway network

<table>
<thead>
<tr>
<th>Methods</th>
<th>I-75 Value (millions)</th>
<th>%</th>
<th>I-71 Value (millions)</th>
<th>%</th>
<th>US-20 Value (millions)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement Cost</td>
<td>1,357.29</td>
<td>100</td>
<td>1,676.90</td>
<td>100</td>
<td>971.86</td>
<td>100</td>
</tr>
<tr>
<td>WDRC</td>
<td>965.63</td>
<td>71.14</td>
<td>1,188.74</td>
<td>70.88</td>
<td>643.92</td>
<td>66.25</td>
</tr>
<tr>
<td>Adj. WDRC</td>
<td>934.95</td>
<td>68.88</td>
<td>1,121.29</td>
<td>66.86</td>
<td>580.94</td>
<td>59.77</td>
</tr>
<tr>
<td>Book Value</td>
<td>1,031.92</td>
<td>76.02</td>
<td>1,274.91</td>
<td>76.02</td>
<td>738.89</td>
<td>76.02</td>
</tr>
</tbody>
</table>

From the table we can see that the value given by replacement cost has 100% good pavement condition rating. The WDRC method for I-75 shows that it is 71.14% of the replacement cost this could mean that that 71.14% of the road way is in good condition. The same could be said for other valuation methods and highway network. The value obtained from book value is 76.02% for all the highway network.

In all case studies the asset value calculated from different method showed different values. The highest values were obtained from Replacement Cost in all cases this was due to the fact; replacement cost gives asset value or pavement value in this thesis as to replace them with a new one. This statement should not hold true as the Book value approach always gives us the highest value as not only the historical cost is depreciated to current time but all the maintenance and preservation cost is depreciated to current time.
to give a higher asset value as more money has been invested into the project or pavement.

Due to unavailability of actual historical construction cost for all sections of pavements in all the cases, the historical cost calculated in all cases were for base year 2012, so these values are based on replacement cost and construction price index obtained for FHWA. This gives uniformity to the historical cost as all the pavements are considered to be constructed in 2012 and from this historical cost the book value using straight line depreciation was found. As for, WDRC and Adjusted. WDRC the historical cost in conjecture with PCR values and rating the assets valuation were done.

The values from WDRC and Adjusted WDRC give a measure of asset value based on the condition of the pavement. The adjusted. WDRC was lower than WDRC as it includes the best and worst condition for the pavement.

ODOT uses replacement cost to value the pavements so; the replacement cost calculated has been compared to the value from tamds database in the following table.
## Table 4-2 Comparison of Replacement Cost used by ODOT to the cost calculated

<table>
<thead>
<tr>
<th>Route/Road Network</th>
<th>Lane mile ODOT (1)</th>
<th>Replacement Cost from ODOT Database (millions) (3)</th>
<th>Calculated lane mile (4)</th>
<th>Calculated Replacement cost (millions) (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-75</td>
<td>1088.94</td>
<td>$1,361.71</td>
<td>1085.83</td>
<td>$1,357.29</td>
</tr>
<tr>
<td>US-20</td>
<td>777.45</td>
<td>$971.81</td>
<td>777.49</td>
<td>$971.86</td>
</tr>
<tr>
<td>I-71</td>
<td>1344.56</td>
<td>$1,680.70</td>
<td>1341.52</td>
<td>$1,676.90</td>
</tr>
<tr>
<td>Lucas</td>
<td>856.36</td>
<td>$1,070.45</td>
<td>921.67</td>
<td>$1,152.09</td>
</tr>
<tr>
<td>I-75 Luc</td>
<td>68.80</td>
<td>$86.00</td>
<td>68.08</td>
<td>$85.10</td>
</tr>
<tr>
<td>US-20 Luc</td>
<td>66.18</td>
<td>$82.72</td>
<td>66.18</td>
<td>$82.73</td>
</tr>
<tr>
<td>Fayette</td>
<td>455.60</td>
<td>$569.50</td>
<td>454.30</td>
<td>$567.88</td>
</tr>
<tr>
<td>I-71 Fay</td>
<td>77.58</td>
<td>$96.97</td>
<td>77.56</td>
<td>$96.95</td>
</tr>
<tr>
<td>Delaware</td>
<td>554.32</td>
<td>$692.90</td>
<td>552.00</td>
<td>$690.04</td>
</tr>
<tr>
<td>I-71 Del</td>
<td>93.68</td>
<td>$117.10</td>
<td>94.00</td>
<td>$116.91</td>
</tr>
<tr>
<td>District 1</td>
<td>3466.01</td>
<td>$4,332.51</td>
<td>3467.50</td>
<td>$4,334.38</td>
</tr>
<tr>
<td>I-75 District 1</td>
<td>194.00</td>
<td>$242.50</td>
<td>193.56</td>
<td>$241.95</td>
</tr>
<tr>
<td>Ohio Total</td>
<td>50660.00</td>
<td>$63,325.00</td>
<td>50357.26</td>
<td>$62,950.00</td>
</tr>
<tr>
<td>G priority</td>
<td>29547.27</td>
<td>$36,934.09</td>
<td>29981.74</td>
<td>$37,480.00</td>
</tr>
<tr>
<td>Priority</td>
<td>13732.94</td>
<td>$17,166.18</td>
<td>13502.09</td>
<td>$16,880.00</td>
</tr>
<tr>
<td>U priority</td>
<td>6116.52</td>
<td>$7,645.65</td>
<td>6079.76</td>
<td>$7,600.00</td>
</tr>
</tbody>
</table>
Chapter 5

Conclusion and Future Works

5.1 Conclusion

The main conclusion that could be drawn from this thesis would be that ODOT should not only use replacement cost method for valuing its asset but also incorporate Written down replacement cost method. This method gives a proper value on how well ODOT is retaining its asset value than replacement cost which just gives ODOT the value to replace the asset. The WDRC gives an idea on how well the different management and preservation strategy used by ODOT is helping in retaining the asset value.

From this thesis and the different case study considered, it could be concluded that if transportation agencies are in the process of developing asset values. They should also recognize that despite the variability in the different valuation method, the important thing is the change over time of the asset being valued as valuation is a measure or indicator of how well the agency is retaining its asset value using different management and maintenance techniques.
Replacement Cost calculated in this thesis gives us the general idea of the cost required to replace the existing pavements with a new one irrespective of the condition of the pavement. This increases the overall road network value for the cases mentioned in this thesis. Thus, replacement cost is just the indicator of the value of the asset which needs to be replaced and this would result in both good and bad pavement condition being considered as the same.

Deflated GASB is being used because of a dearth of accurate historical data as the failure of transportation agencies across the state to keep record of historical construction cost. The concept of asset valuation is fairly new this provides further incentive for transportation agencies to keep historical records. This fact resulted in using deflated GASB method to back track from current replacement cost to historical cost for the base year 2012 using Construction Price Index provided by FHWA. WDRC incorporated engineering performance models and in turn giving actual valuation close to the pavement condition.

The need for asset valuation is placing a new emphasis on retaining historical cost data. What this means is that as agencies move forward, deflated GASB will be replaced with historically based GASB and WDRC calculated will be based on the actual historical cost, while the Adjusted. WDRC not only incorporated pavement condition but also the threshold for the condition rating being used.
Asset Valuation could be further used in asset management work as valuation is an important part of management of assets. From the values calculated one could come up with management or preservation strategy for pavements.

Regardless of which valuation method is used, the important point is to select a valuation method that can be easily sustained and managed, is not data and/or analytically burdensome and that proper asset management should result in retention of asset value.

### 5.2 Future Works

This thesis can be further improved in ways by incorporating other performance measure to get asset values like IRI (International Roughness Index). Furthermore, use of valuation software dTims, ARGUS could improve and quicken asset valuation procedure for transportation agencies across the country.
References


