Life Cycle Cost Analysis of Highway Project

by

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CERTIFICATION OF APPROVAL

Life Cycle Cost Analysis (LCCA) On Highway Project

By

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A project dissertation submitted to

Universiti Teknologi PETRONAS

in partial fulfillment of requirement for the

Bachelor of Engineering (Honours)

Civil

Approved by,

____

(AP Dr. Madzlan Napiah)

UNIVERSITI TEKNOLOGI PETRONAS

SEPTEMBER 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

(AHMAD IZZAT ASYRAF BIN MAZUKI)

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ABSTRACT

Every responsible engineer will care about the quality and cost of a project. An engineer need to make sure every structure that he made will not collapse. In the same time, he need to make sure the cost of the project will not be wasted. So, to get an optimum cost of a project, there must be a way to get a high precision of estimation.

The main objective of this study is to identify the alternative proposals and to verify alternatives those can be analyzed by using Life Cycle Cost Analysis (LCCA). The scope of study is focus on highway project. Activities involved are gathering data from highway contractor, calculating the total cost until the highway is finished constructed including all the accessories items, data collection from literature review, compiling data in order to analyze using LCCA rigorous methods for feasible material selection and analyzing data using Microsoft Excel software.

Many systems of LCCA have been proposed. Clearly the techniques are not totally same because of contrasts among the framework dissected. However, these are the methodology for this study’s LCCA; defining the problem, developing the cost breakdown structure, selecting cost model, gathering cost estimation, development of cost profile and evaluation by present worth analysis.

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CHAPTER 1

INTRODUCTION

1.1 Background of the Project

In this era, flexible pavement and rigid pavement are conventional used for highway. Flexible pavement yields "elastically" to traffic loading. Flexible pavement consists of asphaltic concrete wearing course, asphaltic concrete binder course, crushed aggregate road-base and subbase. The most common material used in the construction of rigid pavement slabs is Ordinary Portland Cement (OPC). Rigid pavements are generally formed in three layers - a prepared subgrade (bottom), base or subbase (middle), and concrete slabs (top). In addition, due to the development in research field, geopolymer concrete was introduced to the world. Geopolymer concrete is one type of concrete that is made by reacting aluminate and silicate bearing materials with a caustic activator. Usually, waste materials such as slag from iron and metal production or fly ash is used in order to keep a cleaner environment. Then, geopolymer concrete also can be used as one type of concrete in the rigid pavement.

However, highway project is not only consisted of pavement, there are many other accessories that need to be considered in order to follow the specification of a country. This specification is not created to waste the money, but it is created for the safety and comfortability of the highway users themselves.

The works' description of highway can be categorized to site clearance, demolition works, earthworks, drainage works, pavement works, road furniture, geotechnical works, traffic management, environment protection works, routine maintenance works, occupational safety and water relocation. These items are the major things that need to be considered in costing.

Since majority of Malaysians' transportation is private vehicle such as car and motorbike, the development of highway is compulsory to accommodate the increase in population of people in Malaysia. Besides, most Malaysian only using car to travel between one state to another state beside because the total time travel is similar with taking commercial airline. Example, from Kuala Terengganu (Terengganu) to Kuantan (Pahang), the total travel time with vehicle is only 2 hours. If there is a package of commercial airline with the same destination, waiting during boarding time and arrival time has taken 1 hour minimum, the minimum time for airplane taking and landing has taken half hour, and the total time travel in the air is half hour, then the total time will be 2 hours. That's why, there is no package offered by the airlines company between one state to another state beside. Other than that, travel with private car is cheaper than other alternatives transportation. Due to this factors, I decided to make a Life Cycle Cost Analysis (LCCA) to estimate the cost of constructing a 1 km highway. LCCA will be used as a decision tool for synchronizing the divisional conflicts by focusing on facts, money and time. LCCA is an economic tool which combines both engineering art and science to make logical business decision. There are three alternatives using Life Cycle Cost Analysis for this study: -

- Alternative 1: Constructing highway using asphaltic concrete pavement.
- Alternative 2: Constructing highway using Ordinary Portland Concrete pavement.
- Alternative 3: Constructing highway using geopolymer concrete pavement.

LCCA will be used to apply and evaluate which option is the best for highway project. Life cycle cost will involve cost owing that asset, operation, maintenance until disposal cost.

1.2 Problem Statement

Every responsible engineer will care about the quality and cost of a project. An engineer need to make sure every structure that he made will not collapse. In the same time, he need to make sure the cost of the project will not be wasted. So, to get an optimum cost of a project, a program must be developed to make sure the calculation getting a high precision of estimation. Since highway project is developed by the government, costing of a project must be reasonable because the source of money comes from the taxes which is being paid by the Malaysians. The major item of a highway project which generate a huge different in cost is the type of pavement used. There must be an analysis for asphaltic concrete, Ordinary Portland Cement concrete and geopolymer concrete.

1.3 Objective of Study

The Main objective of this study is: -

- To identify the alternative proposals.
- To verify those alternatives can be analyzed by using Life Cycle Cost Analysis.

1.4 Scope of Study

The scope of study is focus on highway project. Activity will involve to the following scope:

- Gathering data from highway contractor.
- It involves the total cost until the highway is finished constructed, including all the accessories items.
- Data collection from literature review, journal and other reference.
- Compiling data in order to analyze using LCCA rigorous methods for feasible material selection.
- Analyze data using Microsoft Excel software.

1.5 Relevancy of Study

- The rationality of choosing this study is to ease the highway designer in estimating the highway costing in the most precise method.
- This study is also the most effective solution for the problem for cost estimation in order to decide the most profitable solution.
- This study will also ease the clients so that they will not be cheated with the unreasonable costing.

1.6 Feasibility of Study

- Since the time constraint is 8 months, this study topic is appropriate with the time, the scope covered is definitely sufficient with time given.
- All the data gathering is copyright, belonged to the data's owner and permitted to be used for this study. This study only use that data for another calculation, this is the principal of ethic that is implement for this study.
- This study is also supported by an infrastructure expertise (construction company) that willing to give the data for our own benefits. MBAJ Construction & Development Sdn Bhd is currently constructing a highway without toll in Kuala Terengganu.
- This study uses Microsoft Excel for the calculation, which is feasible enough for me to accept this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Pavements

2.1.1 Asphaltic Concrete Pavement

Asphaltic concrete is a conventional composite material which can forecast of its condition under complex traffic loads that requires the utilization of theory of visco-elasticity. There are three noteworthy things happened in the asphaltic concrete which are damage impact because of traffic flow, stresses relaxation in the system and chemical recuperating crosswise over micro-crack and major-crack interfaces. The level of weariness damage maintained under loads relies on the wellness of the material relaxation and additionally relaxation happens at the same time in a harmed asphalt concrete pavement during rest periods. (Kim, Lee, & Lee, 1995)

2.1.2 Ordinary Portland Cement Concrete Pavement

Concrete pavement redirect a great deal less because of the utilization of vehicular loading than flexible pavement. Rigid pavements are worked by compacting the sub-grade before adding the sub-base that is all mostly picked. There are three sorts of rigid pavements: unreinforced concrete pavement, reinforced concrete pavement and continuously concrete pavement. These sorts of concrete pavement give a solid working stage and help conveying the vehicular loading when connected at the surface of the base. (Hadi & Arfiadi, 2001)

2.1.3 Geopolymer Concrete Pavement

Different scientists are concentrating on the usage of mechanical waste items as another option to common Portland Cement (OPC) to take care of issues like pollution and also a dangerous atmospheric warming. The utilization of waste items, for example, fly ash, metakolin, silica fume, and so on in concrete have observed to be helpful. In any case, these wastes can be utilized as incomplete substitution of OPC and can't absolutely supplant it. In such manner, Davidovits (1991) presented the idea of geopolymers which can created by the response of silica and alumina with the alkali-activating solutions. The instruments of geopolymers includes the response of silica and alumina, freed by hydroxides and silicates of sodium or potassium as the alkali-activating solution which brings about the development of solid alumina-silicate polymeric structures. (Mehta & Siddique, 2017)

2.2 Life Cycle Cost Analysis

Life Cycle Cost Analysis was initially intended for procurement purposes in the US Department of Defense (White and Ostwald, 1976) and is as yet utilized most usually in the military division and also in the development business (Woodward, 1997). The selection of life cycle thinking has been moderate in different businesses (Lindholm and Suomala, 2004). According to Woodward (1997), open area has likewise been an important promoter for life cycle cost estimations (Korpi & Ala-Risku, 2008). The utilization of life cycle cost analysis to bolster decision making raises the attention to proprietors, customers and general society of the aggregate cost of activities and in this way advances quality and extensive building arrangements ((ASCE), 2015-2016).

Life Cycle Cost Analysis (LCCA) was considered amidst 1960s and now productions as hotspots for an assortment of LCCA, for example, Systems Engineering and Analysis, Life-Cycle Cost and Economic Analysis (Fabrycky and Blanchard, 1991); Handbook of Industrial Engineering Logistics Engineering and Management Maintainability (Blanchard et al. 1995); The National Institute of Standards and Technology (NIST) Handbook 135, 1995 version, and so on. NIST characterizes LCCA as "the aggregate marked down dollar cost of owning, operating, maintaining, and discarding a building or a building framework" over some undefined time frame.

Additionally, British Standard International characterizes LCCA as a significant strategy which is utilized for anticipating and evaluating the cost execution of built resources. (Sinisuka, Cui, & Nugraha, 2013)

Another viable reference of LCCA was clarified by Barringer at his few papers and his site (www.barringer1.com). He clarified that LCCA is the aggregate cost of possession including the cost of the venture or resource obtaining, operation, maintenance and disposal. LCCA incorporates both deterministic costs, (for example, procurement costs, improvement expenses and disposal expenses) and probabilistic, (for example, the cost of failure, repairs, spare parts, downtime, losses net edge). The greater part of the probabilistic expenses related specifically with the dependability and attributes maintenances of the framework. As per Barringer (2003), the target of the LCCA is to pick the savviest way to deal with deciding the least long-term cost of proprietorship. (Sinisuka et al., 2013)

Life cycle economic examination ought to be done right on time in the system or product life cycle, in light of the fact that the result of the engineering system preparation can't be impacted especially when the design is finished. Utilization of procurement expenses is a simple rule for deciding of procurement, yet it might bring about terrible financial choices as the real expenses may show up amid system operation and support. Along these lines, LCCA includes assessment of all future cost identified with plan, development or creation, distribution, operation, maintenance, support, retirement and material disposal; that implies every one of the expressions in the system life cycle. (Utne, 2009)

2.3 Terminology of Life Cycle Cost Analysis

2.3.1 Present Worth (PW)

The Present Worth (PW) is a time series of cash flows, both incoming and outgoing, which is defined as the sum of the present values (PWs) of the individual cash flows of the same entity. (Nurul Sa'adah, 2013)

$$\mathbf{PW = S\ F_k\,(1+\mathit{i})^{-k}}$$

- i = effective interest rate, or MARR per compounding period
- k = index for each compounding period
- F_k = future cash flow at the end of period k
- N = number of compounding periods in study period
- Interest rate is assumed constant through project
- The higher the interest rate and further into future of a cash flow, the lower the PW

2.3.2 Future Worth Method (FW)

FW is based on the equivalent worth of all cash inflows and outflows at the end of the planning horizon at an interest rate that is generally MARR. (Nurul Sa'adah, 2013)

$$\mathbf{FW = PW\ (F/P,\ \mathit{i}\%,\ N)}$$

- if FW $\geq$ 0, it is economically justified

$$\mathbf{FW\ (\mathit{i}\%) = S\ F_k\ (1+\mathit{i})^{N-k}}$$

- i = effective interest rate
- k = index for each compounding period
- F_k = future cash flow at the end of period k
- N = number of compounding periods in study period

2.3.3 Annual Worth Method (AW)

Annual worth is an equal series of dollar amounts, over a stated period (N), equivalent to the cash inflows and outflows at interest rate that is generally MARR. (Nurul Sa'adah, 2013)

$$\textbf{AW}\ (\boldsymbol{i}\%) = \textbf{R} - \textbf{E} - \textbf{CR}\ (\boldsymbol{i}\%)$$

- AW = PW (A/P, *i*%, N)
- AW = FW (A/F, *i*%, N)
- If AW $\geq$ 0, project is economically attractive
- AW = 0: annual return = MARR earned

2.3.4 Capital Recovery (CR)

CR is the equivalent uniform annual cost of the capital invested that covers loss in value of assets and interest on invested capital. (Nurul Sa'adah, 2013)

$$\textbf{CR}\ (\boldsymbol{i}\%) = \textbf{I}\ (\textbf{A/P}, \boldsymbol{i}\%, \textbf{N}) - \textbf{S}\ (\textbf{A/F}, \boldsymbol{i}\%, \textbf{N})$$

- I = initial investment for the project
- S = salvage (market) value at the end of the study period
- N = project study period

CR is also calculated by adding sinking fund amount (i.e. deposit) to interest on original investment.

$$\textbf{CR}\ (\boldsymbol{i}\%) = (\textbf{I-S})\ (\textbf{A/F}, \boldsymbol{i}\%, \textbf{N}) + \textbf{I}\ (\boldsymbol{i}\%)$$

CR is also calculated by adding the equivalent annual cost of the uniform loss in value of the investment to the interest on the salvage value.

$$\textbf{CR}\ (\boldsymbol{i}\%) = (\textbf{I-S})\ (\textbf{A/P}, \boldsymbol{i}\%, \textbf{N}) + \textbf{S}\ (\boldsymbol{i}\%)$$

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

A research methodology characterizes what the movement of research is, the manner by which to continue, how to quantify advancement and what constitutes achievement. Some work resembles science; you take a gander at how individuals learn math, how the mind works, how kangaroos bounce, that attempt to make sense of them before making a testable hypothesis. Some work resembles engineering; you attempt to fabricate a great problem solver. Some work resembles arithmetic; you play with equation, attempt to comprehend its property before demonstrate things about them. Some work is illustration-driven, attempting to clarify particular phenomena. The best work consolidates all these and that's just the beginning.

Overall of research system characterizes as the procedure used to gather data and information with the end goal of settling on business choices. The philosophy may incorporate distributed research, interviews, overviews, surveys and other research strategies which could incorporate both present and authentic data.

3.2 Life Cycle Cost Analysis Steps

Below (Figure 1) is the process of methodology for Life Cycle Cost Analysis on Highway Project:

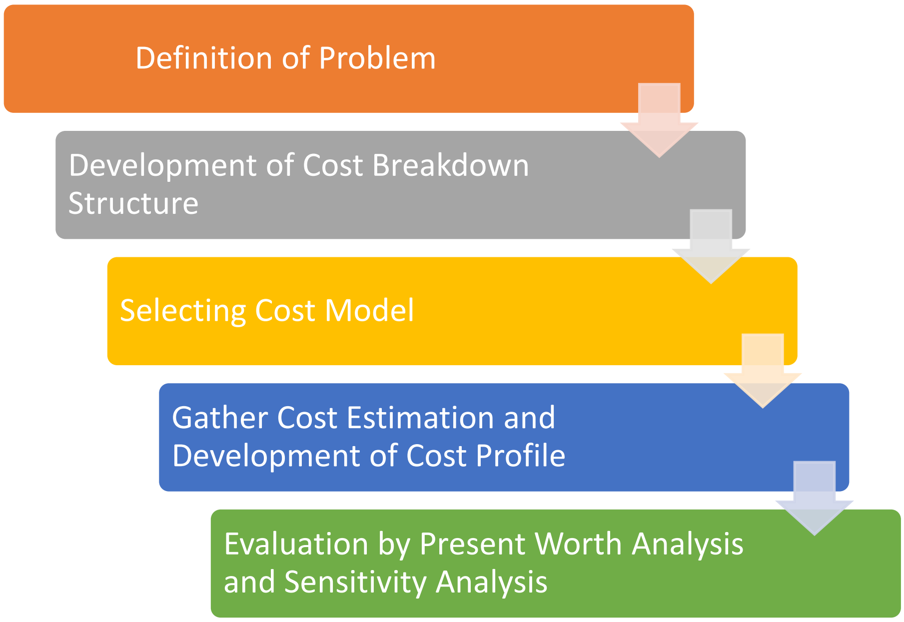

Figure 1: A Life Cycle Cost Analysis Process.

Numerous systems of LCC analysis have been proposed. Figure 1 show life cycle cost handle for this review. Clearly the techniques are not totally same because of contrasts among the framework dissected. Life cycle cost process had been resolved for this review and compressed as: -

Process 1	-	Definition of problem
Process 2	-	Development of cost breakdown structure
Process 3	-	Selecting cost model
Process 4	-	Gather cost estimation and development of cost profile
Process 5	-	Evaluation by present worth analysis

From all procedures, three principle forms had been resolved as a primary stage to break down in this review. To start with stage included process 1 and process 2 called initial phase. Second phase included process 3 and 4 where framework will model and information will be gathered. Last phase is process 5 and 6 used to create cost profile and assess result investigation for this venture.

CHAPTER 4

RESULT FOR LCCA ON HIGHWAY PROJECT

4.1 Introduction

There are three alternatives for life cycle cost analysis to be implemented on highway project. To provide a set of data that reliable and accurate for decision making process, this analysis need to be conducted. LCC can act as a decision tool for synchronizing the divisional conflicts by focusing on facts, money and time which is the economic tool that combines both engineering t and science to make logical business decision. Three alternatives for Life Cycle Cost Analysis (LCCA) for this study:

Constructing highway using asphaltic concrete pavement.
Asphaltic Concrete (AC) is the most conventional pavement in Malaysia which can be categorized as the majority pavement used.

Constructing highway using Ordinary Portland Concrete pavement.
Instead of using AC pavement, OPC pavement also need to be calculated to determine which one is more profitable in a long-term duration.

Constructing highway using geopolymer concrete pavement.
New technology nowadays, which are not implemented yet in Malaysia, also is one of the alternative that can be considered which LCCA calculation.

This study involves 25-year life cycle time for current system and new system. His study also involves 6% minimum acceptable rate of return (MARR) to accommodate the government requirement.

4.2 Background of The Pavements

4.2.1 Background of Asphaltic Concrete Pavement

Specifications

Below (Figure 2 & Figure 3) is the examples of Asphaltic Concrete Pavement:

Figure 2: Asphaltic Concrete Highway.

Figure 3: Asphaltic Concrete Cube.

Several categories of paving material in accordance to their intended function within the pavement structure. The categories include (from top of the pavement downwards):

- Bituminous wearing and binder courses.
- Bituminous road base.
- Unbound granular road base.
- Unbound granular sub-base.

Recycled asphalt pavement (RAP) shall be used instead of unbound granular road base, or up to 30% of RAP shall be included in bituminous road base. In the new JKR Standard Specifications for Road Works, there are descriptions of all paving materials used.

Bituminous Wearing and Binder Courses

In the JKR Standard Specifications for Road Works, specifications for bituminous mixtures are contained. The Poisson's ratio and elastic modulus are the two most important properties of bituminous mixtures for the purpose of pavement design. Elastic modulus of bituminous mixtures is a major function of its composition and density, while the temperature and loading time to which a bituminous mixture exposed in a pavement is the other function. Elastic modulus and the Poisson's ratio pronounce he effect of temperature. Elastic modulus values will vary from a few hundred Mega Pascals at high pavement temperatures to 3000 Mega Pascals at the low end of pavement temperatures within the range of temperatures that can occur in road pavements in Malaysia. Over the same temperature range, the Poisson's ratio varies from about 0.35 to 0.45.

The following average pavement temperatures are adopted for the design of pavement structures:

- Bituminous Road Base: 25°C
- Bituminous Wearing and Binder Courses: 35°C

4.2.2 Background of Ordinary Portland Cement Concrete Pavement

Fly Ash and Cement

The contractor shall propose the brand and source of the cement when submitting details of the proposed mix in accordance with Clause 5.3.3. The contractor shall use only the proposed cement in the work after the approval of the proposed mix by the superintendent. If the contractor nominates to use cement which has been stored longer than three months from the time of manufacture, a re-test shall be run to ensure the cement still complies with AS 3972 before the cement can be used. The cost of re-testing the cement shall be supported by the contractor then forward the results to the superintendent.

Aggregates

(i) General

The maximum soluble sulphate salt content of aggregates, expressed as percentage SO_3 by mass, shall not exceed 0.1 %, referring to properties specified in AS 2758.1. Aggregates containing more than the maximum permissible amount of sulphate or with visible encrustations of salts shall be washed and drained before being used in concrete. The superintendent may prevent the work continued until he is satisfied that harmful quantities of salts are not present after washing or rewashing of the aggregates.

At least 40 per cent by mass of the total aggregates in the concrete mix shall be quartz sand which having a nominal size of less than 5mm and shall contain at least 70 per cent quartz, by mass. Coarse and fine aggregates shall be washed optimally to achieve the specified drying shrinkage.

(ii) Fine Aggregates

Fine aggregate shall consist of clean, hard, tough, durable, uncoated grains uniform in quality. Fine aggregate shall comply with AS 2758.1 in respect of bulk density (1200 kg/m3 minimum), water absorption (maximum 5 per cent), material finer than 2 micrometers, and impurities and reactive materials.

Figure 4: Fine Aggregates.

(iii) Course Aggregates

Clean, crushed, hard durable rock, metallurgical furnace slag or gravel are the characteristics of a good coarse aggregate. Coarse aggregate shall comply with AS 2758.1 in respect of particle density, bulk density, water absorption (maximum 2.5 per cent), material finer than 75 micrometers, weak particles, light particles, impurities and reactive materials, iron unsoundness and falling or dusting unsoundness. If required, coarse aggregate shall be washed until reaching these requirements. When submitting details of the proposed mix, the contractor shall submit the certified laboratory test report on the quality and grading of the coarse aggregate proposed to the superintendent. The grading shall be known as the “nominated coarse aggregate grading”.

Figure 5: Coarse Aggregates.

4.2.3 Background of Geopolymer Concrete Pavement

The geopolymer concrete mix used is produced and handled in a similar manner to conventional concrete. The mix must be developed for the heavy-duty pavements to suit placement with a slip form paving machine. Key criteria of the mix included:

- Workability, slump and slump retention suitable for transport in tippers and slip form pavement construction.
- Achieve specified flexural strength of 4.8 MPa

The summary mix parameters were:

- Total alumina-silicate binder comprising GGBS + Fly ash, 415 kg/m3
- Water: binder ratio 0.41
- Nominal 40 mm maximum aggregate size, conforming with 28 mm to AS 2758.1 (3)
- Chemical activator, 37 kg/m3 solids content
- Proprietary water reducing admixture

Figure 6: Geopolymer Concrete Paver Machine.

4.3 Cost Models

Present Worth (PW) will be generated using excel spread sheet. Highest value of PW will be the most favorable alternative whether to be chose or not.

4.3.1 Summary of Sources Inputs Used In LCCA

INPUT	DESCRIPTION
Material Price	Estimation cost by manufacturer and contractor, as appropriate for construction.
Construction Cost	Estimation cost by contractor as available known data.
Maintenance Cost	Uses company data from previous maintenance history.
Operation Cost	Uses company data from previous maintenance history.
Labor and Overhead Cost	Included in Maintenance and Operation Cost.
Lifetime “n”	Lifetime will start from current year to net 25 years.
Interest Rate “i”, MARR	Assumption made 6% for current and future.
Tax Provision	No tax, due to classification as government asset.

Table 1: Summary of Sources Inputs Used.

4.3.2 Breakdown for Each Cost

Three alternatives will be analyzed and one of them will be chose as the best alternative to implement as the best alternative. All these three is 2 lanes 2 ways type.

Alternative 1: Constructing highway using asphaltic concrete pavement.

Asphaltic Concrete (AC) is the most conventional pavement in Malaysia which can be categorized as the majority pavement used.

Description	**Cost per kilometer (RM)**
Construction Works	
General Items	491,120
Site Clearance	52,000
Earthworks	463,500
Drainage Works	1,631,790
Pavement Works	1,664,040
Road Furniture	386,435
Geotechnical Works	629,305
Traffic Management & Control	233,200
Environmental Protection Works	231,490
Occupational Safety & Health	114,700
Water Pipe Relocation	346,020
Provisional Sum	756,400
TOTAL	7,000,000
Maintenance Works	
Annual Maintenance	20,000
Each 10 Years Maintenance (Design Life = 10 Years)	4,000,000

Table 2: Cost Breakdown of Asphaltic Concrete Pavement.

Below is the Pareto chart for Asphaltic Concrete to know the work descriptions those affect around 70% of the project:

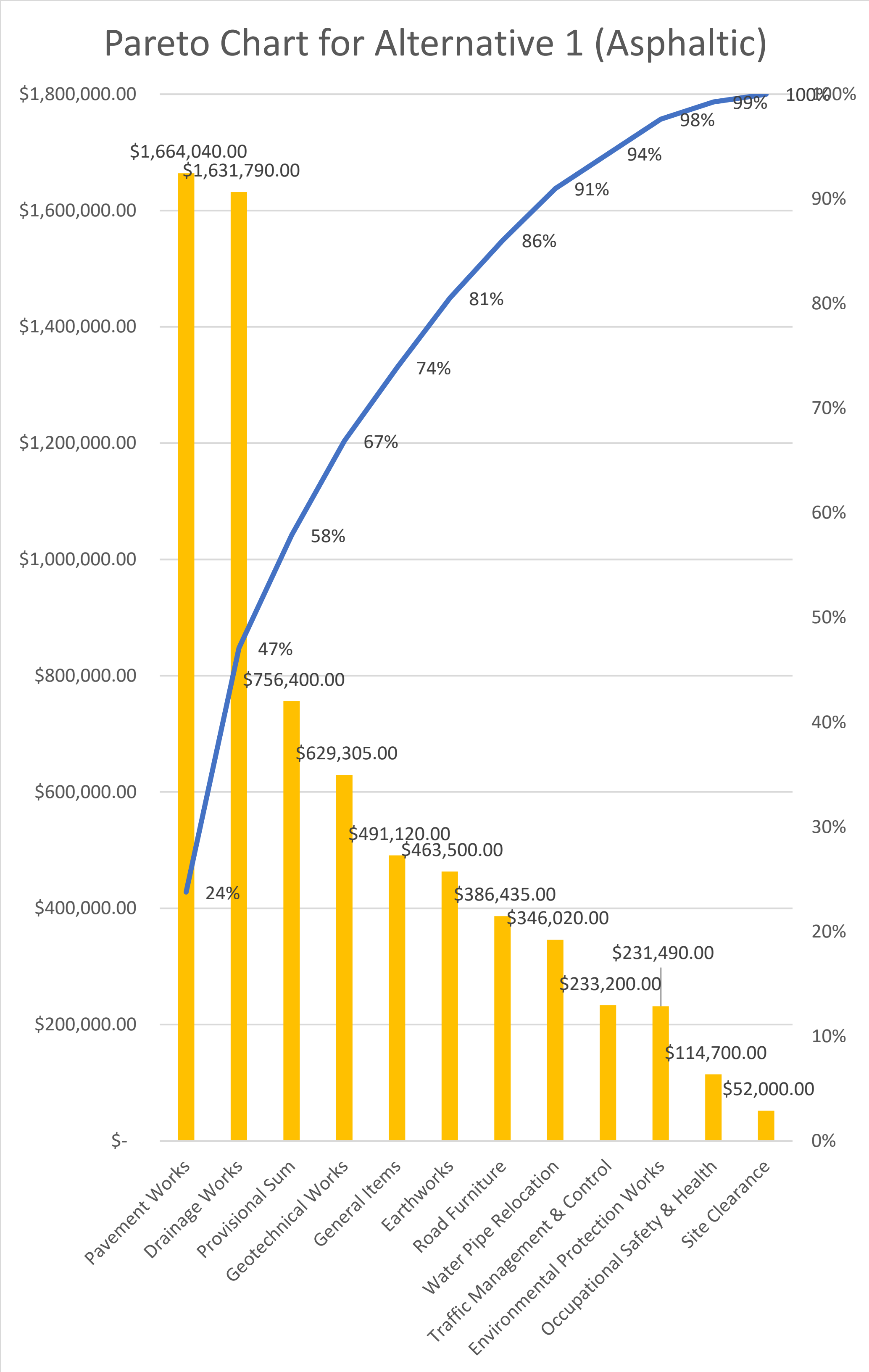

Figure 7: Pareto Chart for Alternative 1.

Alternative 2: Constructing highway using Ordinary Portland Concrete pavement.

Instead of using AC pavement, OPC pavement also need to be calculated to determine which one is more profitable in a long-term duration.

Description	Cost per kilometer (RM)
Construction Works	
General Items	491,120
Site Clearance	52,000
Earthworks	463,500
Drainage Works	1,631,790
Steel Reinforcement Works	1,040,025
Concrete Works	3,120,075
Road Furniture	386,435
Geotechnical Works	629,305
Traffic Management & Control	233,200
Environmental Protection Works	231,490
Occupational Safety & Health	114,700
Water Pipe Relocation	346,020
Provisional Sum	756,400
TOTAL	9,496,060
Maintenance Works	
Annual Maintenance	15,000
Each 30 Years Maintenance (Design Life = 30 Years)	10,000,000

Table 3: Cost Breakdown of Ordinary Portland Cement Concrete Pavement.

Below is the Pareto chart for Ordinary Portland Cement Concrete to know the work descriptions those affect around 70% of the project:

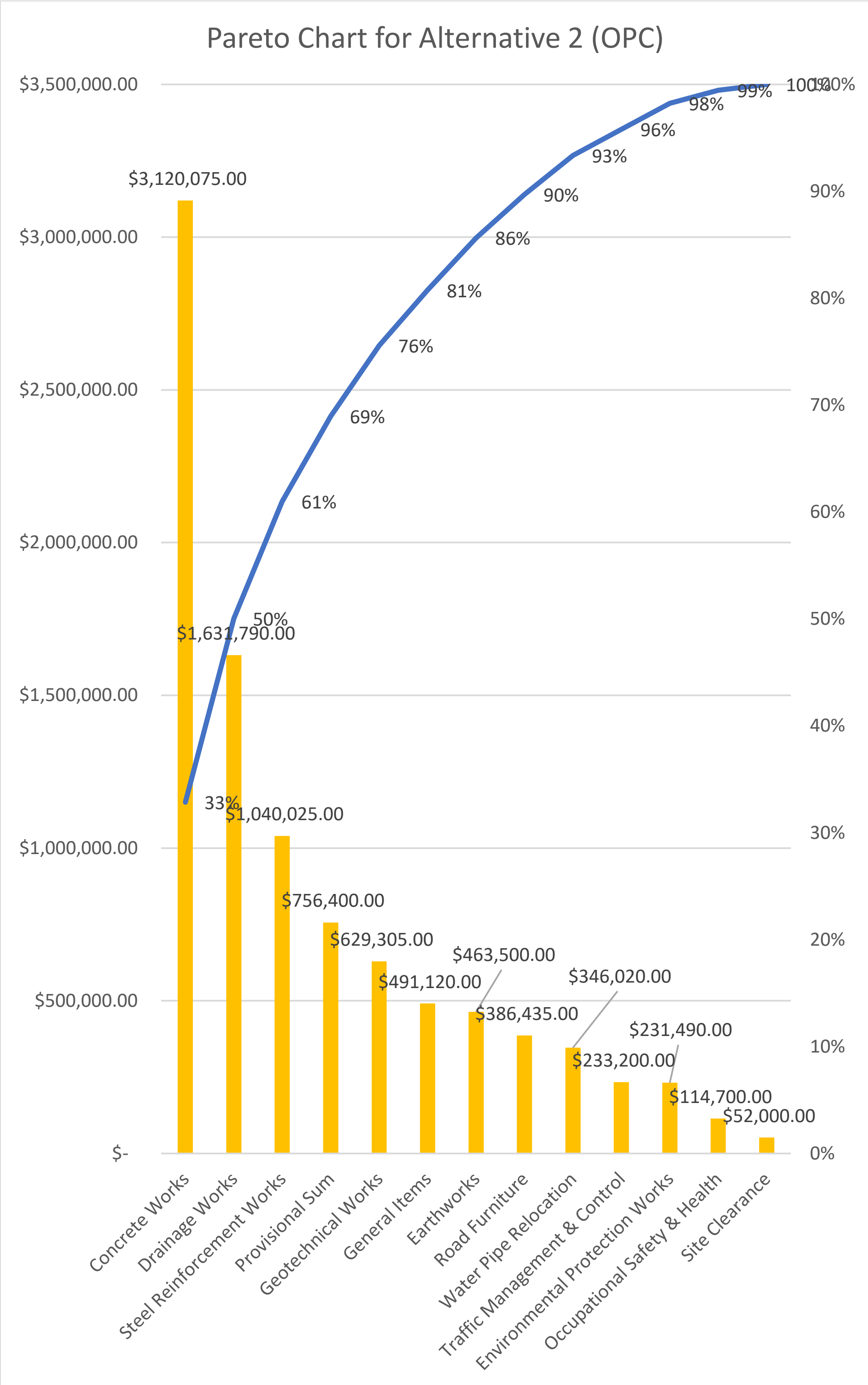

Figure 8: Pareto Chart for Alternative 2.

Alternative 3: Constructing highway using geopolymer concrete pavement.

New technology nowadays, which are not implemented yet in Malaysia, also is one of the alternative that can be considered which LCCA calculation.

Description	Cost per kilometer (RM)
Construction Works	
General Items	491,120
Site Clearance	52,000
Earthworks	463,500
Drainage Works	1,631,790
Steel Reinforcement Works	1,040,025
Concrete Works	3,900,094
Road Furniture	386,435
Geotechnical Works	629,305
Traffic Management & Control	233,200
Environmental Protection Works	231,490
Occupational Safety & Health	114,700
Water Pipe Relocation	346,020
Provisional Sum	756,400
TOTAL	10,276,079
Maintenance Works	
Annual Maintenance	15,000
Each 30 Years Maintenance (Design Life = 30 Years)	12,500,000

Table 4: Cost Breakdown of Geopolymer Concrete Pavement.

Below is the Pareto chart for Geopolymer Concrete to know the work descriptions those affect around 70% of the project:

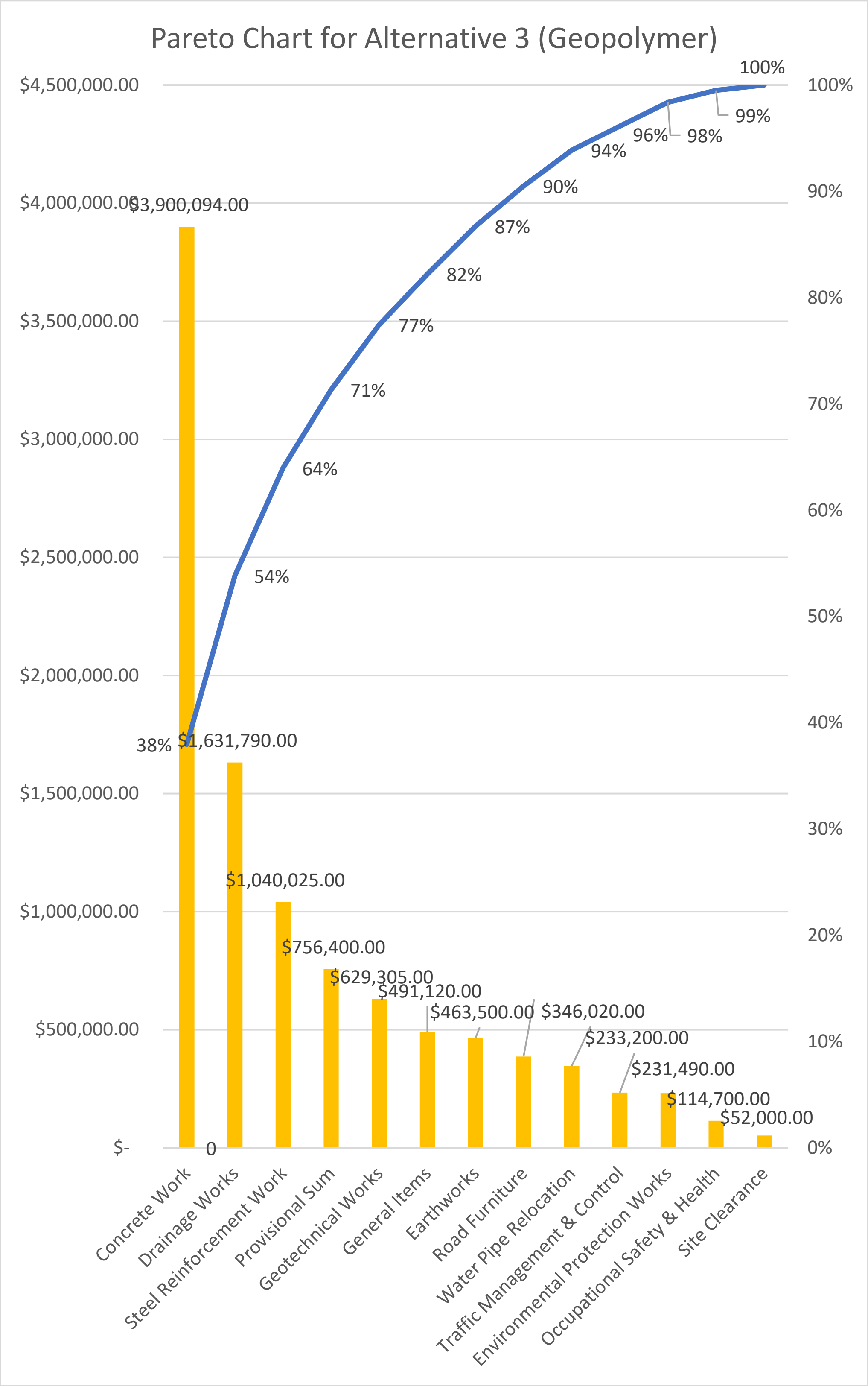

Figure 9: Pareto Chart for Alternative 3.

4.3.3 Analysis and Discussion

This part presents the result from calculation generated from excel data sheet. Interest rate used in this study is 3%. I will show the cost of the project for every two years of design life. In those graphs, will cover all the three alternatives. The costs are for 4 lane 2 ways highway and 1 km in length.

Two pages below are the excel spread sheet that is used to calculate Net Present Value (NPV) per design life. In the green cell is the input data that required by the user. The result (Net Present Value/Design Life) will be showed at the bottom of the pages.

LIFE CYCLE COST ANALYSIS OF HIGHWAY PROJECT			Interest Rate:	3%
Input(Green)→→→→→→	Total Number of Lanes :	4	Length of Highway (km):	1

<Only from 0 to 40>	
Highway Life (years):	2

Asphaltic Concrete		
Description		
Construction Works		
General Items		$ (491,120.00)
Site Clearance		$ (52,000.00)
Earthworks		$ (463,500.00)
Drainage Works		$ (1,631,790.00)
Pavement Works		$ (1,664,040.00)
Road Furniture		$ (386,435.00)
Geotechnical Works		$ (629,305.00)
Traffic Management & Control		$ (233,200.00)
Environmental Protection Works		$ (231,490.00)
Occupational Safety & Health		$ (114,700.00)
Water Pipe Relocation		$ (346,020.00)
Provisional Sum		$ (756,400.00)
	TOTAL	$ (7,000,000.00)
Maintenance Works		
Annual Maintenance		$ (50,000.00)
Each 10 Years Maintenance (Max Design Life = 10 years)		$ (4,000,000.00)

Figure 10: Excel Spreadsheet Page 1.

Ordinary Portland Cement Concrete		Geopolymer Concrete	
Description		Description	
Construction Works		Construction Works	
General Items	$ (491,120.00)	General Items	$ (491,120.00)
Site Clearance	$ (52,000.00)	Site Clearance	$ (52,000.00)
Earthworks	$ (463,500.00)	Earthworks	$ (463,500.00)
Drainage Works	$ (1,631,790.00)	Drainage Works	$ (1,631,790.00)
Steel Reinforcement Works	$ (1,040,025.00)	Steel Reinforcement Works	$ (1,040,025.00)
Concrete Works	$ (3,120,075.00)	Concrete Works	$ (3,900,094.00)
Road Furniture	$ (386,435.00)	Road Furniture	$ (386,435.00)
Geotechnical Works	$ (629,305.00)	Geotechnical Works	$ (629,305.00)
Traffic Management & Control	$ (233,200.00)	Traffic Management & Control	$ (233,200.00)
Environmental Protection Works	$ (231,490.00)	Environmental Protection Works	$ (231,490.00)
Occupational Safety & Health	$ (114,700.00)	Occupational Safety & Health	$ (114,700.00)
Water Pipe Relocation	$ (346,020.00)	Water Pipe Relocation	$ (346,020.00)
Provisional Sum	$ (756,400.00)	Provisional Sum	$ (756,400.00)
TOTAL	$ (9,496,060.00)	**TOTAL**	$ (10,276,079.00)
Maintenance Works		Maintenance Works	
Annual Maintenance	$ (10,000.00)	Annual Maintenance	$ (15,000.00)
Each 30 Years Maintenance (Max Design Life = 30 years)	$ (6,000,000.00)	Each 30 Years Maintenance (Max Design Life = 30 years)	$ (7,000,000.00)

	Asphaltic Concrete	O. Portland Cement Concrete	Geopolymer Concrete
Net Present Value/Design Life=	$ (14,209,090.00)	$ (19,033,938.00)	$ (20,614,885.00)

Figure 11: Excel Spreadsheet Page 2.

Net Present Value / Design Life

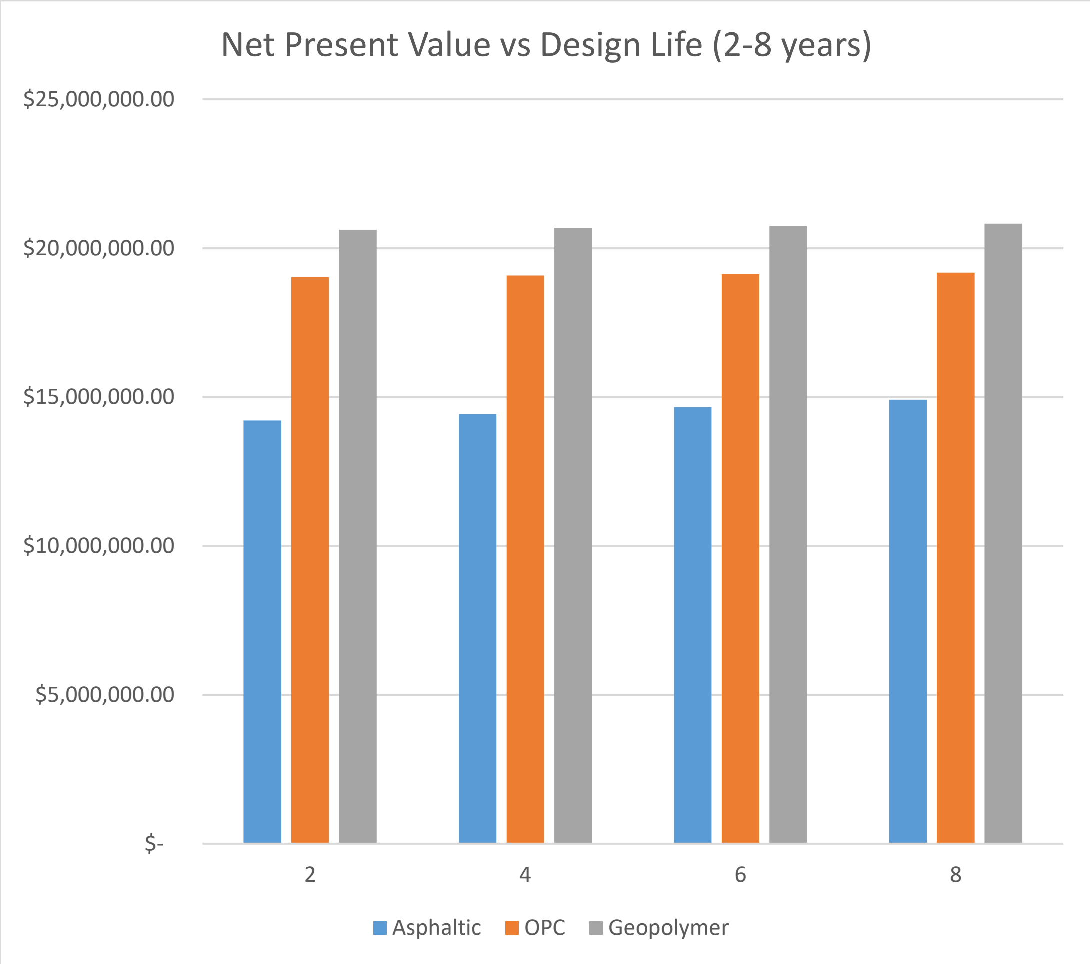

Figure 12: Cost Comparison for 2-8 Years Design Life.

From the Life Cycle Cost Comparison, in Figure 12, the distribution pattern is almost equal. Figure 12 covers from 2-year design life to 8 years' design life. So, during these years, the asphaltic concrete is the minimum cost while geopolymer concrete is the highest in cost. Ordinary Portland Cement Concrete's cost is in the middle between asphaltic and geopolymer concrete. So, for the designers who need to design highway for 8 years to 10 years of design life, the best choice in term of minimum cost is the asphaltic concrete highway.

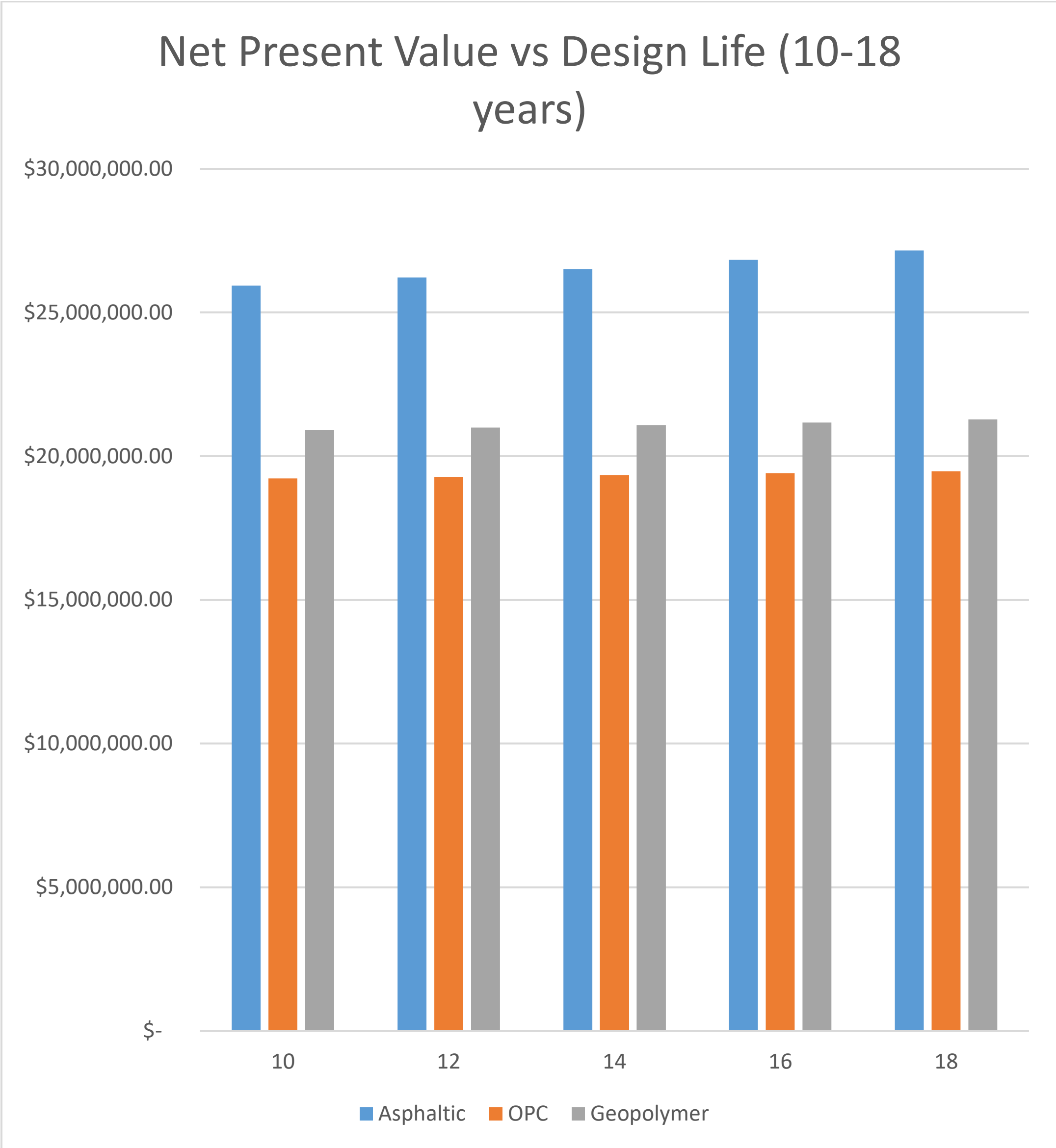

Figure 13: Cost Comparison for 10-18 Years Design Life.

From the Life Cycle Cost Comparison, in Figure 13, the distribution pattern is not equal. Figure 13 covers from 10-year design life to 18 years' design life. So, during these years, the asphaltic concrete is the highest cost while OPC concrete is the lowest in cost. Geopolymer concrete's cost is in the middle between asphaltic and Ordinary Portland Cement Concrete. So, for the designers who need to design highway for 10 years to 18 years of design life, the best choice in term of minimum cost is the OPC concrete.

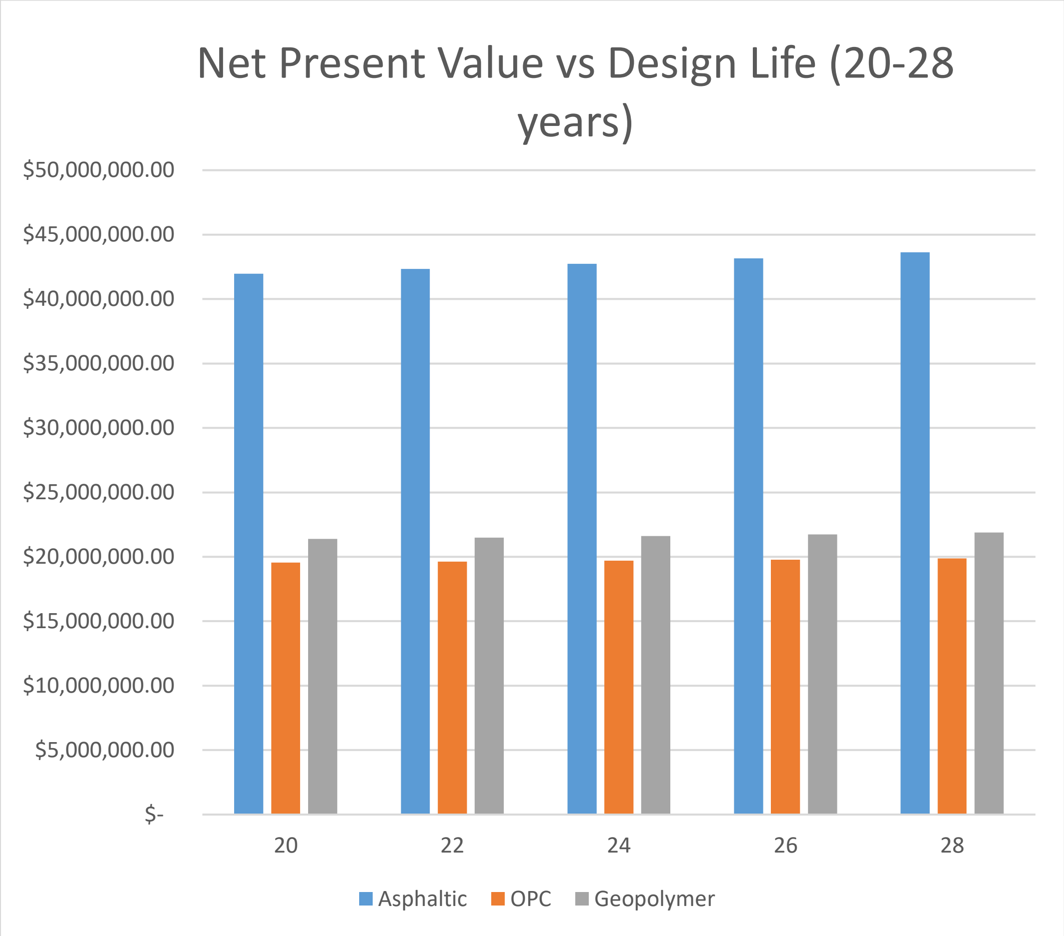

Figure 14: Cost Comparison for 20-28 Years of Design Life.

From the Life Cycle Cost Comparison, in Figure 14, the distribution pattern is also not equal. Figure 14 covers from 20-year design life to 28 years' design life. So, during these years, the asphaltic concrete is the highest cost while OPC concrete is the lowest in cost. OPC cost is about two times higher than OPC/Geopolymer during these years. Geopolymer concrete's cost is in the middle between asphaltic and Ordinary Portland Cement Concrete. So, for the designers who need to design highway for 20 years to 28 years of design life, the best choice in term of minimum cost is the OPC concrete.

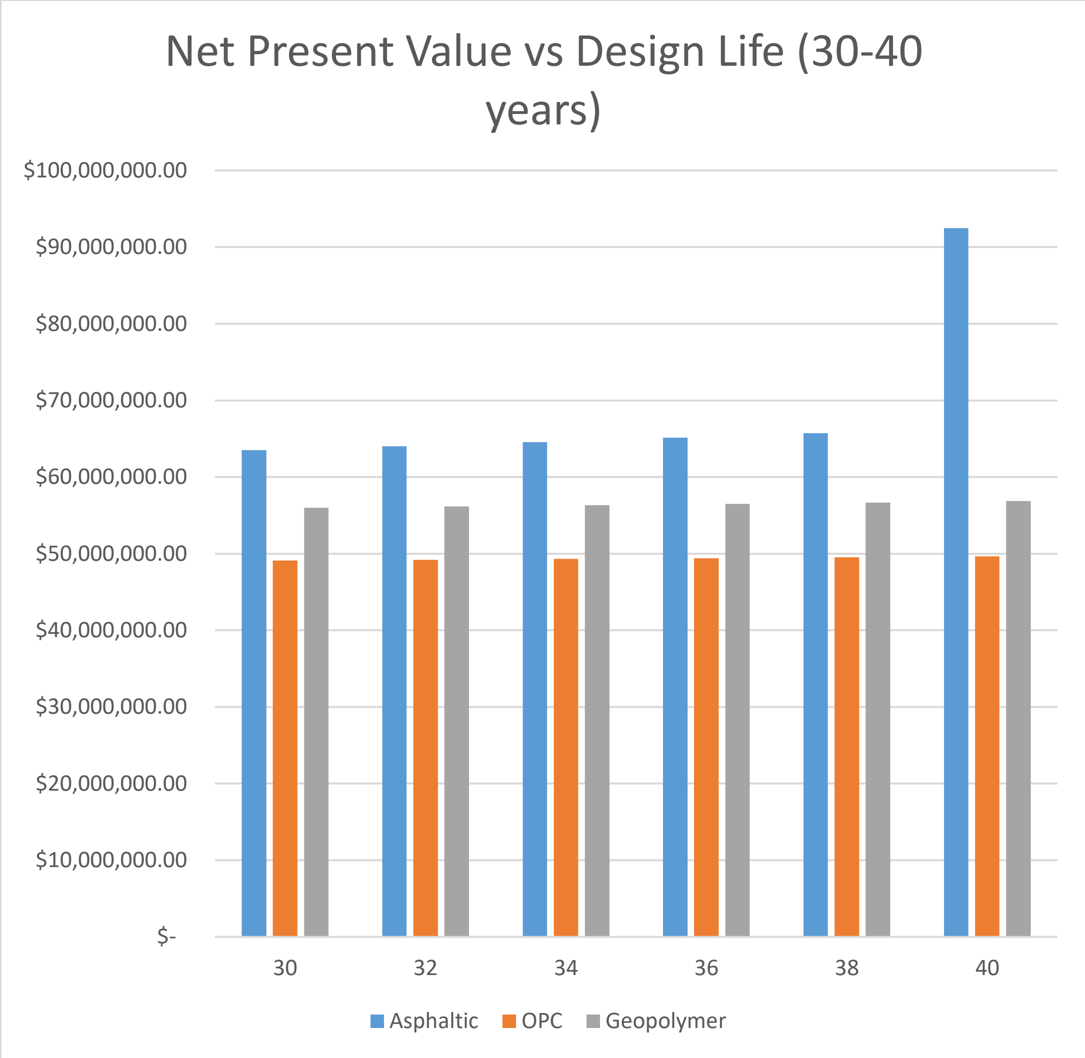

Figure 15: Cost Comparison for 40 Years Design Life.

From the Life Cycle Cost Comparison, in Figure 15, the distribution pattern is also not equal. Figure 15 covers from 20-year design life to 28 years' design life. So, during these years, the asphaltic concrete is the highest cost while OPC concrete is the lowest in cost. OPC cost is about two times higher than OPC/Geopolymer during these years. Geopolymer concrete's cost is in the middle between asphaltic and Ordinary Portland Cement Concrete. So, for the designers who need to design highway for 30 years to 40 years of design life, the best choice in term of minimum cost is the OPC concrete.

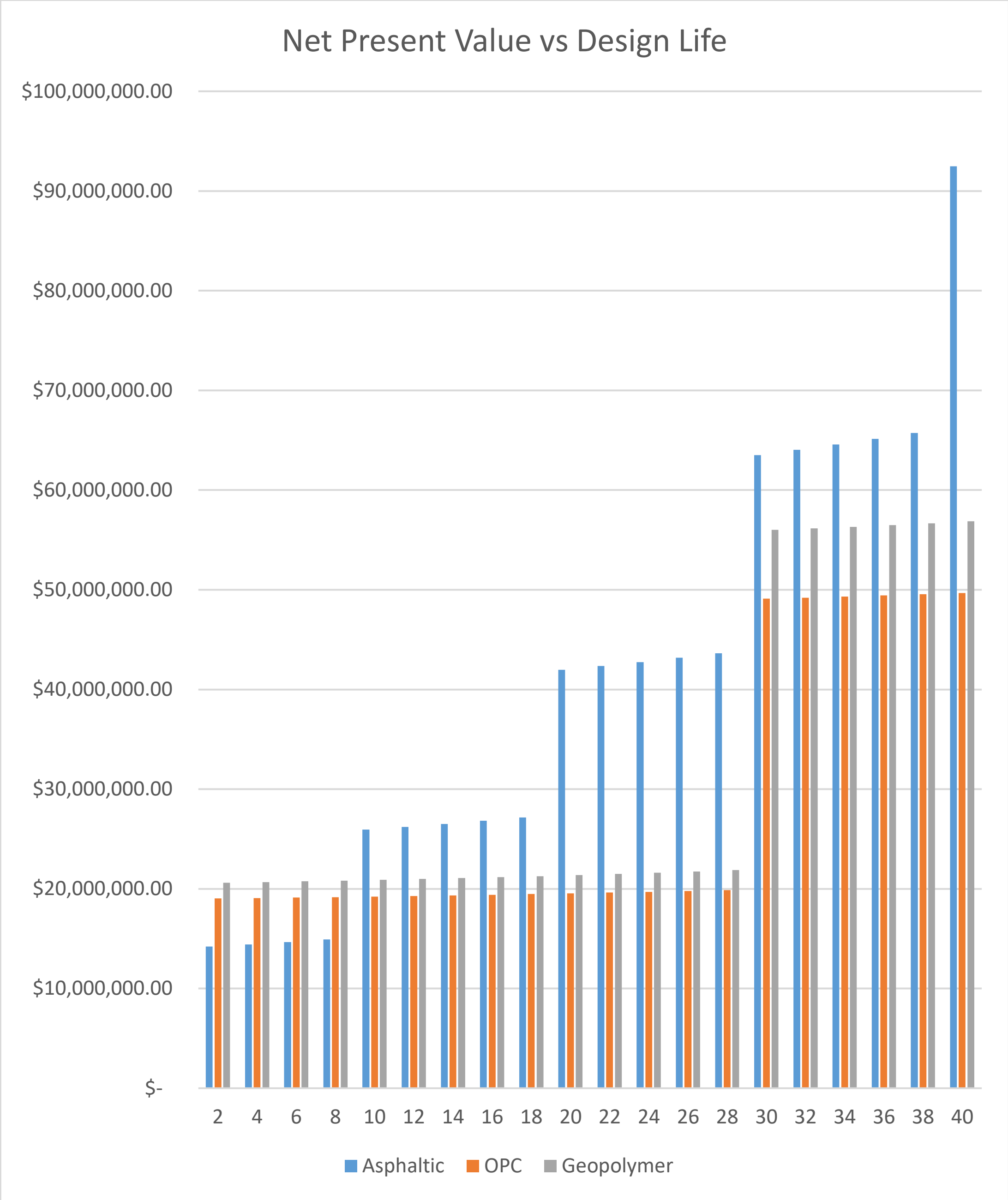

Figure 16: Overall NPV vs Design Life.

Figure 16 shows Life Cycle Cost distribution for overall years from year 2 to year 40. Asphaltic Concrete can be said as the most unreasonable cost to be chose as the main pavement for long term design. However, if the designer want to design the pavement less than 10 years, it is the most affordable one.

4.3.4 Summary of Present Worth (PW)

From excel spread sheet, Present Worth calculates for all alternatives, the value of Present Worth can be determined from the graphs before. From the three alternatives, the best alternative to be proposed is asphaltic concrete for less than 10 years' design, but for 10 years' design life and higher, better use OPC Concrete Pavement. However, since one ton of cement produced is equal to one ton of carbon dioxide released, better use geopolymer concrete to protect our earth from global warming, since geopolymer concrete is the middle price between asphaltic concrete and OPC concrete.

4.3.5 Sensitivity Analysis

By adding percentage from -20% up to 20%, that is the sensitivity analysis. Due to the flexible design life that can be chosen by the designer, sensitivity analysis will be focus on those 3 alternatives. Highest contribution cost for alternative 1 (asphaltic) that contribute about 70% involving pavement works, drainage works, provisional sum and geotechnical works. For alternative 2, highest contribution cost for alternative 2 (OPC) that contribute about 70% involving concrete works, drainage works, steel reinforcement works and provisional sum. For alternative 3, highest contribution cost for alternative 3 (Geopolymer) that contribute about 70% involving concrete works, drainage works, steel reinforcement works, provisional sum and geotechnical works.

4.3.5.1 Alternative 1: Asphaltic Concrete

Cost Models	Amount
Pavement Works	$(1,664,040.00)
Drainage Works	$(1,631,790.00)
Provisional Sum	$(756,400.00)
Geotechnical Works	$(629,305.00)

Table 5: Cost Models of Asphaltic Concrete.

	Total Cost			
% Change	Pavement Works	Drainage Works	Provisional Sum	Geotechnical Works
-20%	$ (6,667,192.00)	$ (6,673,642.00)	$ (6,848,720.00)	$ (6,874,139.00)
-15%	$ (6,750,394.00)	$ (6,755,231.50)	$ (6,886,540.00)	$ (6,905,604.25)
-10%	$ (6,833,596.00)	$ (6,836,821.00)	$ (6,924,360.00)	$ (6,937,069.50)
-5%	$ (6,916,798.00)	$ (6,918,410.50)	$ (6,962,180.00)	$ (6,968,534.75)
0%	$ (7,000,000.00)	$ (7,000,000.00)	$ (7,000,000.00)	$ (7,000,000.00)
5%	$ (7,083,202.00)	$ (7,081,589.50)	$ (7,037,820.00)	$ (7,031,465.25)
10%	$ (7,166,404.00)	$ (7,163,179.00)	$ (7,075,640.00)	$ (7,062,930.50)
15%	$ (7,249,606.00)	$ (7,244,768.50)	$ (7,113,460.00)	$ (7,094,395.75)
20%	$ (7,332,808.00)	$ (7,326,358.00)	$ (7,151,280.00)	$ (7,125,861.00)

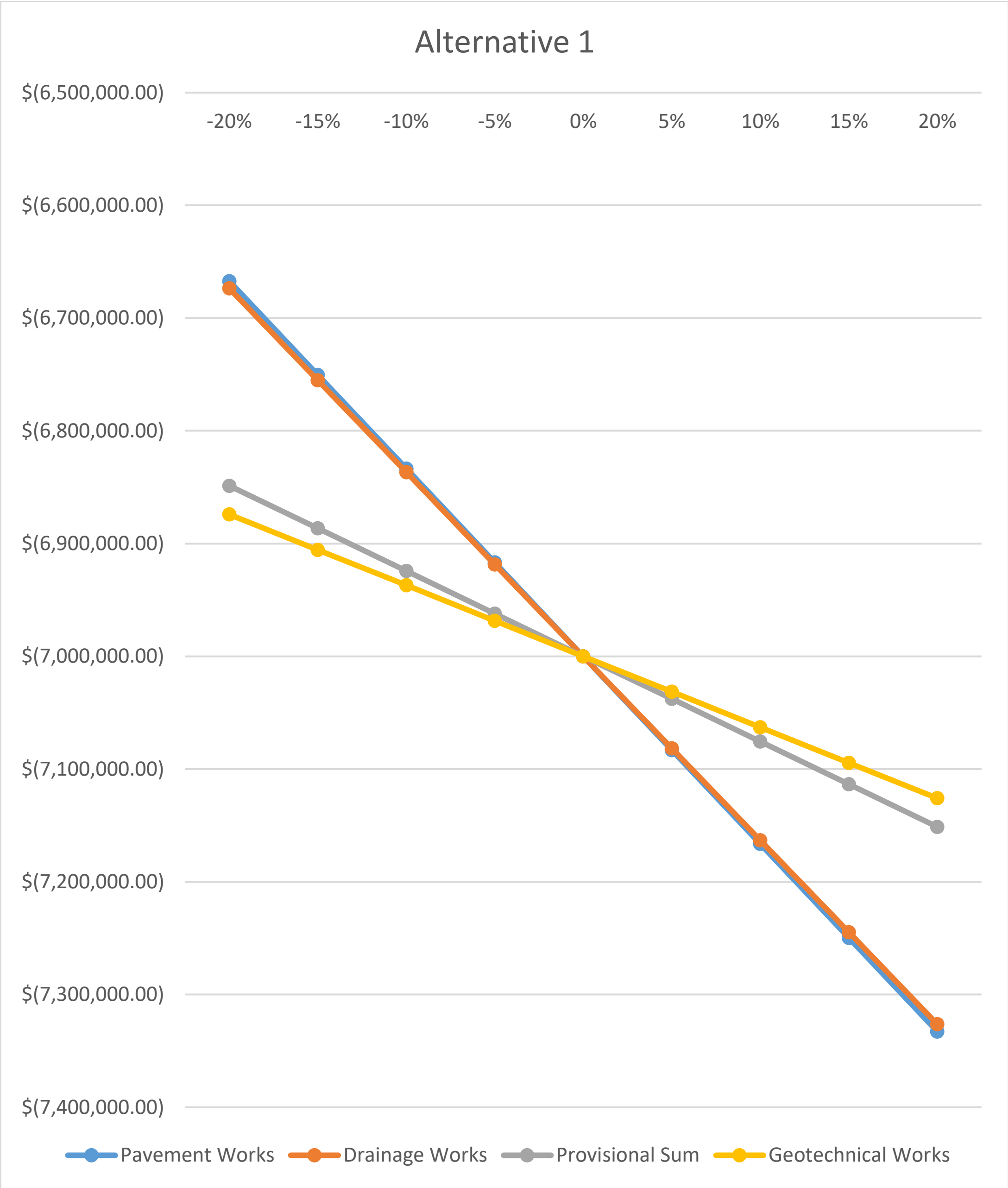

Figure 17: Spider Plot for Alternative 1.

4.3.5.2 Alternative 2: OPC Concrete

Cost Models	Amount
Concrete Works	$3,120,075.00
Drainage Works	$1,631,790.00
Steel Reinforcement Works	$1,040,025.00
Provisional Sum	$756,400.00

Table 6: Cost Models of OPC Concrete Pavement.

	Total Cost			
% Change	Concrete Works	Drainage Works	S. Reinforce	Provisional Sum
-20%	$ (8,872,045.00)	$ (9,169,702.00)	$ (9,288,055.00)	$ (9,344,780.00)
-15%	$ (9,028,048.75)	$ (9,251,291.50)	$ (9,340,056.25)	$ (9,382,600.00)
-10%	$ (9,184,052.50)	$ (9,332,881.00)	$ (9,392,057.50)	$ (9,420,420.00)
-5%	$ (9,340,056.25)	$ (9,414,470.50)	$ (9,444,058.75)	$ (9,458,240.00)
0%	$ (9,496,060.00)	$ (9,496,060.00)	$ (9,496,060.00)	$ (9,496,060.00)
5%	$ (9,652,063.75)	$ (9,577,649.50)	$ (9,548,061.25)	$ (9,533,880.00)
10%	$ (9,808,067.50)	$ (9,659,239.00)	$ (9,600,062.50)	$ (9,571,700.00)
15%	$ (9,964,071.25)	$ (9,740,828.50)	$ (9,652,063.75)	$ (9,609,520.00)
20%	$ (10,120,075.00)	$ (9,822,418.00)	$ (9,704,065.00)	$ (9,647,340.00)

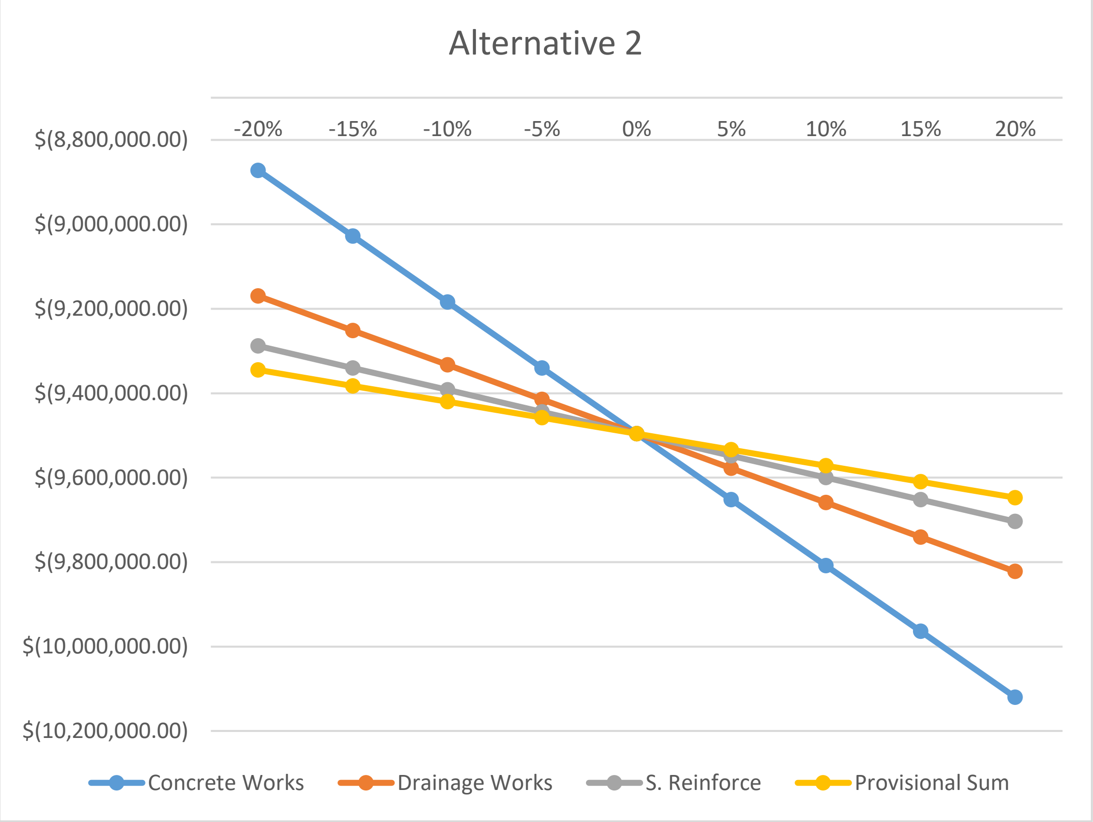

Figure 18: Spider Plot for Alternative 2.

4.3.5.2 Alternative 3: Geopolymer Concrete

Cost Models	Amount
Concrete Works	$3,900,094.00
Drainage Works	$1,631,790.00
Steel Reinforcement Works	$1,040,025.00
Provisional Sum	$756,400.00

Table 7: Cost Models of Geopolymer Concrete.

	Total Cost			
% Change	Concrete Works	Drainage Works	S. Reinforce	Provisional Sum
-20%	$ (9,496,060.20)	$ (9,949,721.00)	$ (10,068,074.00)	$ (10,124,799.00)
-15%	$ (9,691,064.90)	$ (10,031,310.50)	$ (10,120,075.25)	$ (10,162,619.00)
-10%	$ (9,886,069.60)	$ (10,112,900.00)	$ (10,172,076.50)	$ (10,200,439.00)
-5%	$ (10,081,074.30)	$ (10,194,489.50)	$ (10,224,077.75)	$ (10,238,259.00)
0%	$ (10,276,079.00)	$ (10,276,079.00)	$ (10,276,079.00)	$ (10,276,079.00)
5%	$ (10,471,083.70)	$ (10,357,668.50)	$ (10,328,080.25)	$ (10,313,899.00)
10%	$ (10,666,088.40)	$ (10,439,258.00)	$ (10,380,081.50)	$ (10,351,719.00)
15%	$ (10,861,093.10)	$ (10,520,847.50)	$ (10,432,082.75)	$ (10,389,539.00)
20%	$ (11,056,097.80)	$ (10,602,437.00)	$ (10,484,084.00)	$ (10,427,359.00)

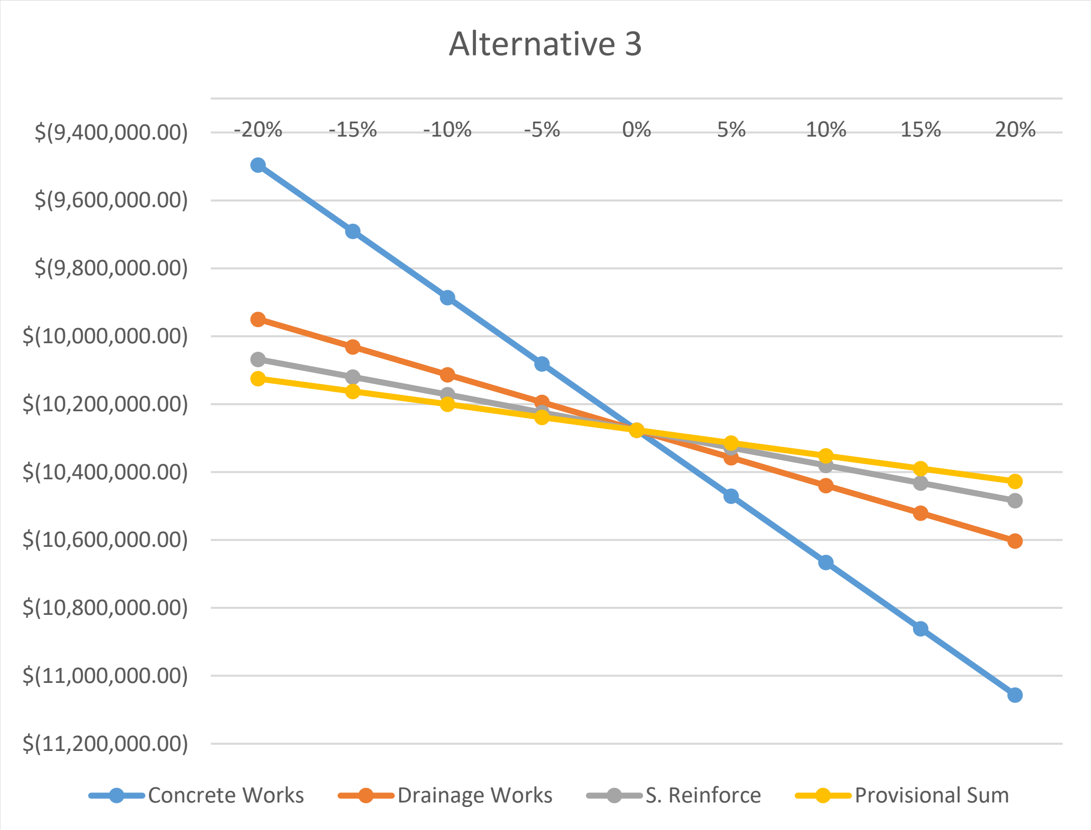

Figure 19: Spider Plot for Alternative 3.

4.3.6 Summary of Result and Discussion

Every increasing and decreasing of percentage in factor will affect slope line in this study as show in Figure 17, Figure 18 and Figure 19. Negative slope will consider as a positive slope due all cost in this study related to expenses and no cost generated to become revenue. Based on sensitivity analysis, the best alternative to choose is alternative 1 due to the most less amount changes when the price fluctuate. In a short range that is below 10 years' range, sensitivity analysis will be the best method for the decision making.

However, for a long term, example, for the design life of 30 years and above, the best alternative will be alternative 2. According to the data calculated, Present Worth of Ordinary Portland Cement Concrete Highway for 30 years' design life is RM -49,099,323.22 which was the lowest in cost among other two alternatives. Present worth compare the value of Ringgit today to the value of that same Ringgit in the future.

The last one, for a designer who wants the low and environmental friendly, alternative 3 will be the best alternative. For 30 years of design life, the Present Worth for Geopolymer Concrete Highway is RM -56,003,912.94 which is a little higher compare to OPC Highway but still much more lesser than Asphaltic Concrete. One ton of cement produced is equal to one ton of Carbon Dioxide emitted. Since global warming is in serious level currently, choosing Geopolymer concrete is considered as a good choice to protect the earth for the future generation.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

In a nutshell, the objectives of this extended proposal which is identifying the alternative proposals. The alternatives are case study on Asphaltic Concrete, case study on Ordinary Portland Cement Concrete and case study on Geopolymer Concrete.

Verifying alternatives using Life Cycle Cost Analysis (LCCA) are achived. I had used LCCA on those three alternatives; LCCA for constructing highway using asphaltic concrete pavement, LCCA for constructing highway using Ordinary Portland Concrete pavement and LCCA for constructing highway using geopolymer concrete pavement. After that, based on literature review and methodology, the alternatives can be analysed by using Life Cycle Cost Analysis.

5.2 Recommendations

1. This research should be studied abroad since many designer wants to know about it by including the facilities, e.g R&R beside the highway.
2. LCCA for two ways – six lanes highway should be carried on since our road two ways – 4 lanes already have traffic jam.
3. The design of the Highway should be stronger at the slow lane since most heavy vehicles are using slow lane compare to fast lane.

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