THE STUDY OF SUSTAINABLE CONSTRUCTION PRACTICES IN INFRASTRUCTURE PROJECTS

By

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DISSERTATION

Submitted to the
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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

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PERAK DARUL RIDZUAN

MAY 2013

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, and that original work contained herein have not been undertaken or done by unspecified sources or persons.

YEO CHIN YAP

ABSTRACT

Sustainable construction is the kind of construction aiming to reduce the environmental impacts of a building over its entire lifetime while optimizing the economic viability, safety and comfort of its occupants. In different types of infrastructure projects, sustainability is important in ensuring the efficiency of the particular infrastructure in the long term while reducing pollution and waste to the environment. The purpose of this research is to study the sustainable construction practices in all types of infrastructure projects and how it affects the environment, social and economy. Besides that, problems of ineffective construction in infrastructure projects are discussed. Solutions to solving these ineffective constructions are deliberated. All the data obtained is analysed into different forms using selected methodology namely research, data collection and analysis. Relative importance index (RII) is calculated for each cause and effect of unsustainable infrastructures and we can determine the top 3 causes and effects. SPSS software is used to the analyse the data where the mean and standard deviation is calculated and standard deviation is used to determine the higher ranking of causes and effects to unsustainable infrastructures if there are any factors with the same value of relative importance index. The top three causes of unsustainable infrastructures are lack of communication, inadequacy of standards and regulations and high initial cost of the infrastructures. The top three effects of unsustainable infrastructures are annihilation of natural habitats, increase of logging activities or replacement of old buildings and high energy consumption in buildings. Levels of success of proposed solutions are determined and the top 5 solutions are maintaining the biodiversity and ecology near the site location, use of renewable energy with least environmental effects, use of recycled building components that are bio-degradable, design infrastructures for adaptability and disassembly and optimizing the infrastructure configuration for optical performance. These causes and effects of unsustainable infrastructures are important for us to determine the solutions from the top ranked factors and to successfully apply sustainable construction practices into infrastructure projects to preserve the environment, securing the economy and promoting social development.

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CHAPTER 1: INTRODUCTION

1.1. Background

Sustainable construction is where the construction is concerned with environmental, social and economy impact of creating a usable structure. The constructed building or infrastructure must be energy efficient, to be safe for the people who work or live in them and to reduce pollution and waste to the environment.

Sustainable construction may be linked to the concept of sustainable development where sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Close operation is needed between engineers, design group, architects and contractors at all project stages. (Yan Ji and Stellios Plainiotis,2006).

Engineers generally limit the use of the term “infrastructure” to describe fixed assets that are in the form of a large network. One such efforts defines infrastructure as the network of assets “where the system as a whole is intended to be maintained indefinitely at a specified standard of service by the continuing replacement and refurbishment of its components.

There are a lot of aspects to look into to achieve sustainable construction. The examples are environmental impacts, materials used, cost estimate, economic development and social impacts. These important attributes may create an infrastructure that needs minimum maintenance and cost-saving. The introduction of the roads and railways in that certain area may improve the economic development. Infrastructure yields indirect benefits through supply chain, property values, minor business progression, purchaser sales and social benefits of community development.

While infrastructure development may initially be damaging to the natural environment, justifying the need to assess environmental impacts , it may contribute in mitigating the "perfect storm" of environmental and energy sustainability, particularly in the role transportation plays in modern society. The creation of high-speed rail may be causing noise pollution to the rural communities but have helped other nations to deal with concurrent issues of economic competitiveness, climate change and energy use.

Cost is one of the critical issues in making the particular infrastructure sustainable. Modern technologies tend to cost more money than the usual design of infrastructure. The stigma is knowledge of upfront cost verses the life-cycle cost. The savings in money come from reusing of waste materials, resource minimization and the efficient use of utilities which results in decreased energy bill.

1.2. Problem Statement

1.2.1. Problem Identification

Buildings and infrastructures use a large amount of energy: according to the US Department of Energy, about 18% of all energy used in the US is consumed by commercial buildings. The European Commission estimates that 35% of all of Europe's greenhouse emissions come from buildings. They use a lot of space and take up a lot of resources during construction and when they are in use.

The construction industry is directly and indirectly responsible for about half the total UK emissions of carbon dioxide, 90% of all surface mineral extraction and over a quarter of all waste sent to landfill. These statistics include new and present buildings and new buildings are more energy and resource efficient than older ones.

Buildings account for more than 40% of total energy consumption and the construction sector as a whole is responsible for approximately 40% of all human-produced wastes. So, the facility of adequate housing and infrastructure for transport, communication, water supply and energy supply, sanitation and commercial and industrial activities poses a major challenge.

Energy consumption is a serious problem found in sustainable construction as the wastes produced may pose an amount of risk to the environment. An infrastructure such as an airport or public school needs to be energy efficient in order to reduce waste while producing its own energy or heat. Location or orientation of a building can make it make it more environmental friendly. Example, a public school set far away from the areas where people are most likely to live will have more of an impact on the environment because students will have to travel a greater distance to get there.

Using materials bought from other places may cause an increase in the cost used in construction of infrastructure. Transportation costs will increase because materials have to be sent a far distance to reach the construction site. Some materials used may be hard to install and maintenance may cost more if the material used is hard to find.

1.3. Significant Of the Project

The importance of sustainable construction shall be made known to all the engineers and architects as they are the one designing the infrastructures and they shall take sustainability as a main priority in the design process. This research will also show how sustainable construction producing positive effects to the environment, social development and economy growth.

Methods on how to enhance sustainable construction will be provided specifically in infrastructure projects. Increase in quality of sustainable construction enabling the project to achieve energy efficiency and stimulate implementation and actual application of tools and technologies while promoting awareness among countries.

This research project will also present the requirement or criteria of a sustainable construction in infrastructure projects. Some of the criteria may not fit into different situation, example: building of roads and construction process of an airport.

1.4. Objectives

The objectives of this research are:

- To identify the causes of unsustainable construction in infrastructure projects.
- To recognise the effects of unsustainable construction to social development, economy and environment.
- To find the innovative solutions in producing sustainable construction in infrastructure projects.

1.5. Scope of Study

This research will be focusing on factors to unsustainable construction in infrastructure projects. It also helps to understand the technique in improving sustainable construction and a case study regarding sustainable construction will be discussed in this research. Data collected will be analysed using simple index formulas such as the relative importance index and also SSPI. Questionnaire and different types of survey will be done to further support the research and getting the accurate results.

1.6. The Relevancy of the Project

It is estimated that the construction and demolition of buildings is responsible for around 40% of the waste in our landfills, few of which is toxic and hazardous. When it comes to electricity use and greenhouse gas productions, it is assessed that the construction industry is responsible for around 30%-40%. This includes extraction, production, and carriage of raw materials, through to the heating, lighting, construction and cooling of our homes.

Sustainable construction in infrastructure projects is about places where sustainable communities can thrive – places where people work and use in life while meeting the diverse needs of existing and future's needs contributing to a high quality life.

The construction of buildings not only produces more waste but also requires more transport and electricity, often results in landscape damage, habitat destruction, ecological disruption, and deforestation. That is why important to perform intensive research in finding innovative solutions to sustainable construction in infrastructure projects and environmental responsibility.

1.7. Background of Case Study

A main project that has been selected for this case study is the construction of Berapit Tunnel Concrete Slab Track in Electrified Double Track Project from Ipoh to Padang Besar.

Figure 1: Brapit tunnel

The Berapit Tunnel is located in section N6 S26 between Taiping and Padang Rengas. The tunnel for the down track extends between chainages 107.200 and 110.061 and for the Up track between chainages 107.170 and 110.061.The design of the slab track is under the contractual responsibility of Emrail who have appointed URS Scott Wilson to carry out the design.The pre-final design submission was approved by MGJV/SCG and KSET and Emrail have made a Final design re-submission taking into account all comments previously received.

The scope of works under the Berapit tunnel slab track includes for the design of the slab and the track fastening system, supply of track fastenings, construction of the slab track complete with track fastenings, commissioning of the track and maintenance of the slab track.

Figure 2: Stretch between Taiping portal and Padang Rengas Portal

Figure 3: Construction of top slab in Berapit Tunnel

Figure 4: Construction of Transition Slab (excavation work + formwork)

Figure 5: Completion of Concrete Slab Track For Berapit Tunnel

CHAPTER 2: LITERATURE REVIEW AND THEORY

2.1 Introduction

While the terms ‘green building’,’ecological building’ and ‘sustainable construction’ have been in use for some time, the first definition sustainable construction was proposed by Charles Kibert during the First International Conference on Sustainable Construction in Tampa,1994: ‘Sustainable construction is the creation and responsible management of a healthy built environment based on resource efficient and ecological principles’ (cited in Bourdeau,1999,p.41).

The International Council for Research and Innovation in Building and Construction (CIB) defined sustainable construction as ‘the sustainable manufacturing, maintenance, use, demolition and reuse of buildings and construction or their components, while sustainable buildings and built environment are seen as ‘the contributions by buildings and the built environment to achieving components of – sustainable development’ (CIB,2004,p.02)

The concept of sustainability in building and construction has evolved over numerous years. The initial emphasis was on how to deal with the issue of inadequate resources, especially energy and on how to reduce impacts on natural environment. Prominence was placed on practical issues such as materials building constituents, construction expertise and energy related design ideas. More recently, an thankfulness of the significance of non-technical issues has developed. It is now acknowledged that economic and social sustainability are important as the cultural heritage aspects of the built environment.

None of these descriptions is solely satisfactory but they do serve to outline three aspects of sustainable construction:

1) It requires a broad interpretation of construction as a cradle to grave process, involving many more role players than just those traditionally identified as making up the construction industry.
2) It emphasises both environmental protection and value addition to the quality of individuals and communities.

3) It embraces not just scientific responses but also the non-technical aspects related to social and economic sustainability.

2.2 Principles of Sustainable Construction

There are six principles for the sustainable construction, proposed by Charles J.Kibert, University of Florida. The principles are:

1) Maximization of resource use;
2) Maximization of resource use;
3) Protect the natural environment;
4) Use renewable and recyclable resources;
5) Pursue quality in creating the built environment.

There are 3 ways by which civil engineering and construction industry can act to realise sustainable construction:

- Creating built environment;
- Restoring impaired and/or contaminated environments;
- Improving arid environments.

Everybody has to realise now that in order to achieve sustainable construction, the industry must change the process of creating the built environment. This could be coined as bringing changes from linear process to cyclic process within the construction industry. The industry is using energy, material and other resources to create buildings and other civil engineering projects and the end result of all these activities is huge volume of discharge waste during and at the end of the facility's life. Therefore, changing this process will bring increased use of recycle, renewed and reused resources and significant decrease in use of energy and other natural resources.

As an engineer, creating better-built environments for human is one of our missions. We need to be serious in paying attention about the sustainability principles. Government has been paying attention to this issue where they focus on sustainable concepts by building a sustainable community including sustainable transport methods, reuse of materials and less usage of natural resources.

Sustainable construction in infrastructure projects also involved the life cycle of the infrastructure, the environmental quality, functionality and future values. Besides that, sustainable construction also involved creating buildings that allow user to enjoy the standards available and at the same time ensuring that future generations will have access to the services needed for their survival. (Rayna Luther, 2005). Sustainable construction also promotes efficient use of resources in the design, construction and use of infrastructures by recycling, reuse and application of ecology materials. It focuses on minimizing waste production, energy consumption , enhancing the biodiversity, conserving natural resources and taking care of the environment. (Rayna Luther, 2005).

2.3 Components for sustainable construction

2.3.1 Natural Resources Consumption

As infrastructure development continues and maintenance of existing infrastructure is required, the demand for more aggregates will continue to rise. The Federal Highway Management reports that natural aggregates used for road base and mixed in with concrete and asphalt account for 94% of the material used in highway construction (USGS, 2006). The demand for natural aggregates is expected to grow to 2.6 billion metric tons by the year 2020 (USGS 1997). Since natural aggregates are a finite resource, the availability of aggregates where they are needed most, in developing areas is also decreasing due to improved demand, zoning procedures and alternative land uses restricting mining. The use of energy efficient systems can be energy saving and reduce use of natural resources.

2.3.2 Waste Production

Solid wastes are divided into two groups depending on their origins and characteristics: industrial and municipal wastes. Wastes from minor businesses involving in commercial activity, for example, airports, railways, housing units as well as single units are classified MSW (municipal solid waste). Governments now is encouraging recycling, reducing wasteful, packaging and introducing products that are more environmentally sound. Another method that can be used to achieve sustainable construction is by designing building for adaptability and disassembly and deisgn with less material use. To cut the generation of leftover, design should use salvage and recycle demolition waste

. For example in a highway infrastructure, reuse highway construction materials such as used concrete is a suitable replacement for natural aggregates as base material in highway construction. Renajendran and Gambatese (2007) found that for every 1% replacement of natural aggregate with recycled aggregate, there was reduction of 8 tons in the total waste. Christensen (2004) estimated in Canada that 63% of all construction and demolition waste is generated from road and bridge construction. A similar study conducted in the US concluded that road and bridge construction and demolition waste were the primary contributor to the 123 million tons of building related waste generated.(USEPA, 1998).

Although the popularity of recycling on infrastructure construction projects has increased in recent years, the frequency that it is applied is still limited. In 2009, the amount of materials reported to be recycled increased by 45% compared to previous year (USGS 2010). The environmental impacts from mining and manufacturing natural aggregate and transportation for material are reduced when recycling material is chosen over disposal. Impacts of the End of Life stage of a life cycle assessment reduced from this method after life cycle assessment reported to be the largest contributor to the environmental impact of infrastructure construction. (Ranajendran & Gambatese, 2007).

2.3.3 Transportation

Transportation is a fundamental activity that can be developed in a sustainable manner or can have detrimental environmental effects. Environmentally, transport systems have significant effects upon air and water quality. Transportation will causes environmental concerns with any form of development but the key issue is that there are transit system designs that minimise the harmful effects – air and water pollution, habitat loss and hydrologic conditions. Another transportation methods and systems provide a large opportunity to reduce environmental degradation. Societies must grasp the chance to create alternative, more sustainable systems.

Transportation resulting from construction activity has a significant impact on the overall sustainability of infrastructure construction. The transportation sector consumes 13 million barrels of petroleum each day, of which heavy trucks used in construction account for approximately 380,000 barrels each day (David, Diegel &

Boundry, 2010). Concrete mixer trucks alone travelled 1.2 billion miles, averaging 15600 miles per truck annually.(US Census Bureau, 2004).

Transport of concrete to the site and return of concrete truck is one of the largest environmental impacts of highway construction projects. A case study of an batch plant at the site recorded the reduction of the environmental impact when compared to hauling concrete from an offsite batch plant. The study documented a saving og 7.9 million lbs of carbon dioxide over the course of the project that resulted only from the reduced need to transport the concrete (Edwardsen, 2010). Depending on the site, a batchplant at site can be a strategy to significantly reduce the environmental impact of highway construction.

Reduction in miles of paved roads improves environmental quality. Annihilating cemented roads and changing them with green space or vegetation is a sustainable training. However, the more possible situation is the destruction of a road for expansion. Although exchanging pavement with another form of impervious surface cover means that watershed health and biodiversity will still suffer, it is a more maintainable answer than evolving an intact natural area.

2.3.4 Land Use

In some new communities, elements of urban infrastructure system are moving much closer to and even inside the buildings themselves. Recently, there is a distorting of the traditional boundaries that separate buildings from their civil infrastructure. In some societies, big distribution grids and remote treatment and generation facilities are giving way to a network of distributed or ‘on-site’ structure systems, with shared fundamentals incorporated into the fabric of the built atmosphere. Additional varied land use and building types can complement these on-site infrastructure systems, creating self-reliant, mixed development of housing, commercial space and industry. In these societies, each different housing growth is seen simultaneously as a centre of occupation, transportations and food production as well as a facility for power generation, stormwater treatment, water management and leftover management.

Designers and engineers are faced with an increasing range of choices. The life cycle impacts and material and energy flow need to be assessed for very diverse expertise, and for a greater variety of measures and sites. Decision makers need wide-ranging prototypes in order to combine flow from different stocks (i.e.,buildings ,roads ,pipes ,etc) and allow meaningful comparisons between integrated and less integrated systems.

The location of the infrastructure is very crucial in this stage as it determines how the city develops in terms of economy and social development. A sustainable transport system in the middle of the city promotes economic growth as people can use these transport to reach destination in a short duration. A wastewater treatment plant near to the city may causes some odour problem to the nearby community but saves a lot of cost and time for wastewater to travel and treated efficiently.

2.4 Factors affecting sustainable construction in Infrastructure projects(Design Phase)

2.4.1 Site location

A proper site location is very important in infrastructure projects as it may affect the environment around it thus making the project unsustainable. Reusing or refurbishing an existing developed location may be beneficial because the project is not planned at a new location where clearing the area is needed. Strategies should be put in to make sure that the infrastructure is not damaging the environment and conservation of the biodiversity nearby is compulsory.

2.4.2 Energy Efficient

Being energy efficient in infrastructure projects as it can saves a lot of cost while deal minimum damage to the environment. Maximising the energy efficiency of buildings and infrastructure operations through the use of renewable sources, decentralised co-generation and energy cascading techniques in a manner which optimises integrated energy flows and minimises potential global environmental impacts such as GHG emissions.

2.4.3 Materials

Building design and infrastructure construction use significant quantities of natural resources and materials. The building industry consumes 3 billion tons of raw materials annually – 40% of total material flow in global economy.(Bakens, 2003). In order to achieve sustainable construction, selecting the usable materials is important. Salvaging used materials or using organic materials will help reducing material consumption.

2.4.4 Waste

Waste produced during construction process can be recycled or reuse as throwing tons of waste materials will only polluting the environment and causing unsustainable construction. Environmental practices in selecting the waste products for reuse in other field are a way of conserving the environment. Integrated on-site waste treatment system is also another way of treating waste materials in reducing pollution and source reduction practices.

2.4.5 Sustainable Design

Sustainable design can be defined as thoughtful integration of architecture with electrical works, mechanical works and structural works. According to the C-SanD paper work (Malik et al, 2002), they define sustainable design as an innovative solution to technical problems. These solutions should always take into account the impact upon the environment. Innovative solutions means solutions that can minimize the cost, conserving energy and natural resources while reducing pollution.

Sustainable design also means the conception and realization of environmentally sensitive and responsible expression as part of involving matrix of nature.(William McDonough and partners, 2000). Design for sustainability means a combination and broadening of three fields; energy consumption in buildings, waste as a cost and environmental conservation.

Sustainable design is more of a philosophy of infrastructure than a prescriptive style. Sustainable infrastructure may be different in appearance and there is no specific look or style. Integrated design is the design where each component is considered part of a greater whole and is critical to successful sustainable design.

2.5 Causes of Infrastructure Unsustainability

2.5.1 Lack of Knowledge

Engineers, Planners and architects may lack the necessary knowledge in design of energy efficient infrastructure concepts or in new technologies. They may also lack the knowledge of best practices in this sustainable design of infrastructures.

2.5.2 Lack of awareness

Not many citizens in specific regions knew about sustainable construction and its concepts. This sustainability issue may not be obvious enough in the eyes of the world that there is no public awareness on this issue.

2.5.3 High Initial Costs

The developer and the contractor may not want to participate in this sustainable construction as it involves high initial costs in constructing sustainable infrastructures.

2.5.4 High Maintenance Costs

For some energy efficient systems or treatment plants, they may require regular maintenance to upkeep the performance and its efficiency.

2.5.5 Lack of Communication

There may be lack of communication between engineers, planners and designers due to indifference in opinions: Engineers on sustainability, planners on aesthetic value while designers on appearance.

2.5.6 Long Payback Periods

Important as the developer is not the end user in this construction project. Occupants may not live in the same place for a long period. Construction of infrastructure may not fit into ‘best investment or value’.

2.5.7 Inadequancy of Standards and Regulations

Insufficient information on standards about sustainable infrastructure around the world may cause the infrastructure not recognisable.

2.5.8 Different in Expectations and Demands

Buildings owners or government may not take in account of energy efficient principles or specific building criteria.

UNEP-SBCI focused on highest ranking core global issue of climate change and after 2 consecutive meetings, they came out with a solution of developing a common carbon metric for building sector in 2009. They also came out with the SB Index where it will provide a globally reliable framework to measure, understand, report and verify actual building performance on core sustainability issues, especially in developing countries. The index will include the categories below:

- Energy efficiency;
- Materials (scarcity, consumption, waste generation);
- Biodiversity;

- Economic considerations;
- Social development.

According to Brundtland Report, if deforestation were to continue in Amazonia at present rates until 2000, about 15% of plant species would be lost. Climatic changes would produce considerable stress for all ecosystems so it is important that natural diversity be maintained as a means of adaptation. The growth or energy demandin response to industrialization, urbanization and societal affluence has led to an extremely uneven global distribution of primary energy consumption. The consumption of energy per person in industrial market economics, for example, is more than 80 times greater than in sub-Saharan Africa. And about a quarter of the world's population consumes three-quarters of the world's primary energy.

The environmental risks and uncertainties of a high energy future are also disturbing and give rise to several reservations. Four stand out:

- The serious probability of climate change generated by the "greenhouse effect' of gases emitted to the atmosphere, the most important of which is carbon dioxide (CO2) produced from the combustion of fossil fuels [16];
- B.N. Lohani [15] said urban-industrial air pollution cause by atmospheric pollutants from the combustion of fossil fuels;
- Acidification of the environment from the same causes;
- The risks of nuclear reactor accidents, the problems of waste disposal and dismantling of reactors after their service life are over and the dangers of proliferation associated with the use of nuclear energy.

CHAPTER 3: METHODOLOGY AND PROJECT WORK

3.1 Research Methodology

This chapter explains about the method that have been use to carry out this research in order to achieve the objective of the research. This section is going to review the methods applied in collecting data to determine the real application of sustainable construction in infrastructure projects. Instead of gathering information through primary and secondary sources like textbook, journal, conference papers, report, a series of interview and questionnaires will be carried out. The data will then be analysed and presented in forms of table, graph and pie chart so that it is easy to understand.

3.2 Semi-Structure Interview

The purpose of this interview is to obtain more insight information from the staff and management on site. The interview aims to know more about ways or methods that can be taken to apply more sustainable construction in infrastructure projects. The interviewee themselves may have their own opinions in this sustainable construction that can be taken in as recommendations. Besides that, other questions that are related to the research topic can be asked during the interview.

3.3 Questionnaire Administration

To get the appropriate or sufficient responses from the management and staffs, a combination of open ended questions are provided so that the interviewees can give their own opinions in their own way. The questionnaire is given to management teams, engineers, planners and architects.

3.4 Data Analysis

The data collected will be arranged according to factors involved and tabulated. This factors that affects the application of sustainable construction is vital in helping the research thus promoting sustainable construction in infrastructure projects.

Data collected from the questionnaire will be analysed by using the relative importance index. The relative importance index is used to identify the role played by each predictor to know the number of occurrence and compared to local statistics.

SPSS software will be used in analysing the questionnaire results and producing the ideal analysis of this particular study. Relative importance index can be calculated by formula and can be obtained from SPSS software in a different way.

A total of 34 respondents are selected for this particular study and questionnaires are distributed. Relative importance index is calculated for each factor using the following formula (found from an online source: http://shodhganga.inflibnet.ac.in/bitstream/10603/2589/12/12_chapter%203.pdf) :

$$\frac{\varepsilon A_i X_i}{N X_i}$$

where:

A = the rate of significance / rate of success where i represent factor from 1 to 5 corresponding from “Very Low” to “Very High”

X_i = the total frequency of response for i=1,2,3,4 and 5 as illustrated as follow:

X_1 = frequency of the “Very Low” and corresponding to A=1; X_2 = frequency of the “Low” response and corresponding to A=2 and so on.

To establish the ratings for questionnaire forwarded to the respondents comprising of developers, engineers and consultants, an severity index is used to reflect the ratings of 5 different categories. They are illustrated as follows:

1 = Very low or extremely ineffective

2 = Low or ineffective

3 = Medium or moderately effective

4 = High or very effective

5 = Very high or extremely effective

The above ratings were mainly used for evaluating the severity in causes and effects of infrastructure unsustainability and to assess the solutions to infrastructure unsustainability with its success rate.

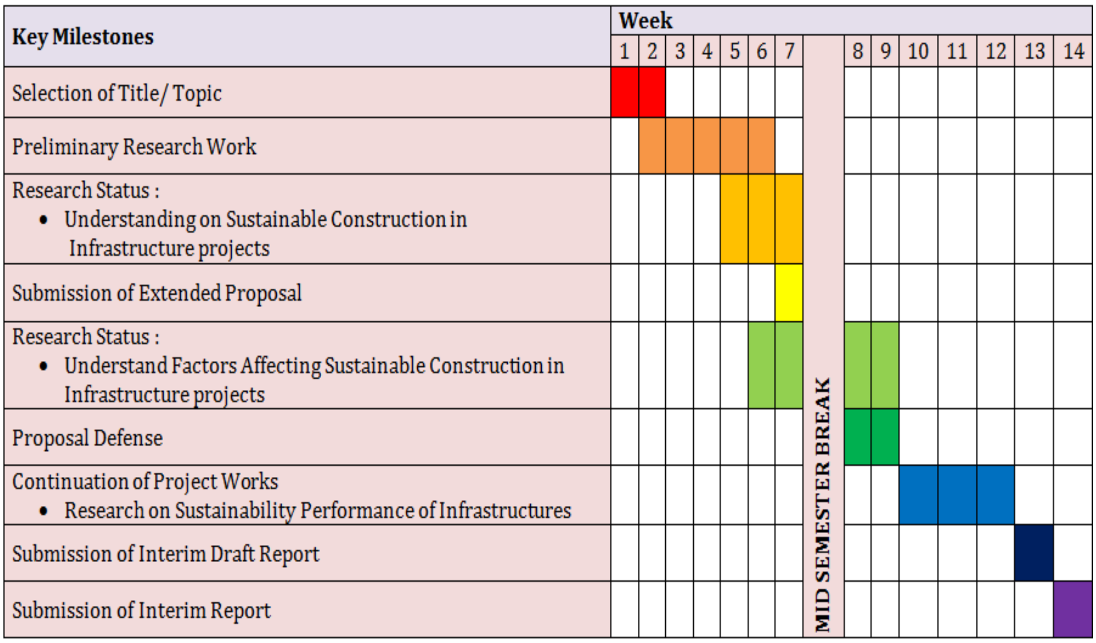

Figure 6: Project Activities and GANTT Chart for FYP 1

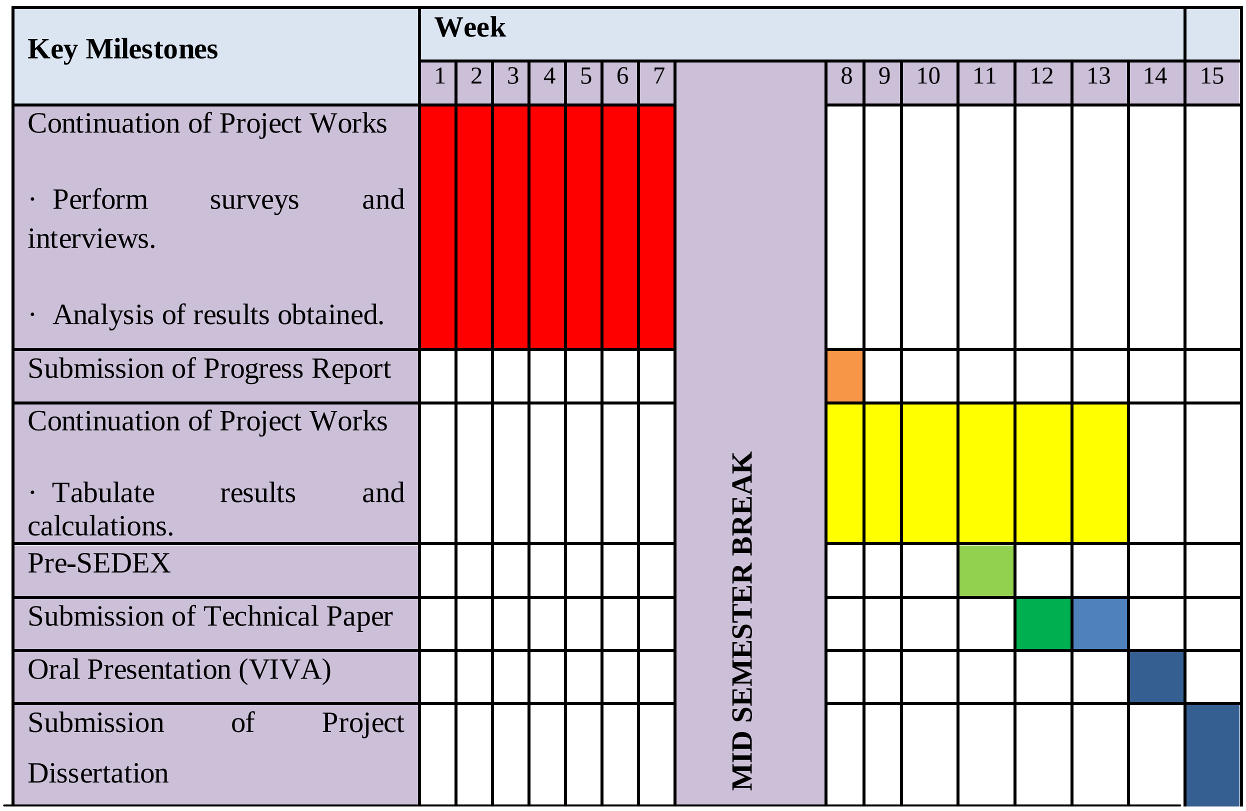

Figure 7: Project Activities and Key Milestones for FYP 2

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

The study focuses on the sustainable construction practices in infrastructure projects. The main location for all the respondents is in Kuala Lumpur where the infrastructure projects are blooming and being developed at a quick pace. The respondents are mainly contractors, consultants, developers and suppliers.

A sample size of thirty five employees who worked in infrastructure projects are identified as targets for this study. Twenty sets of the questionnaire is sent directly to the respondents while the other fifteen is send to several companies in Kuala Lumpur.

From the survey results, only thirty respondents gave feedback based on the questionnaire. Out of the thirty feedbacks, only twenty questionnaires came back with completed answers. The respondents who sent back incomplete forms may not fully understand some of the questions prepared and did not answer the questions in the form.

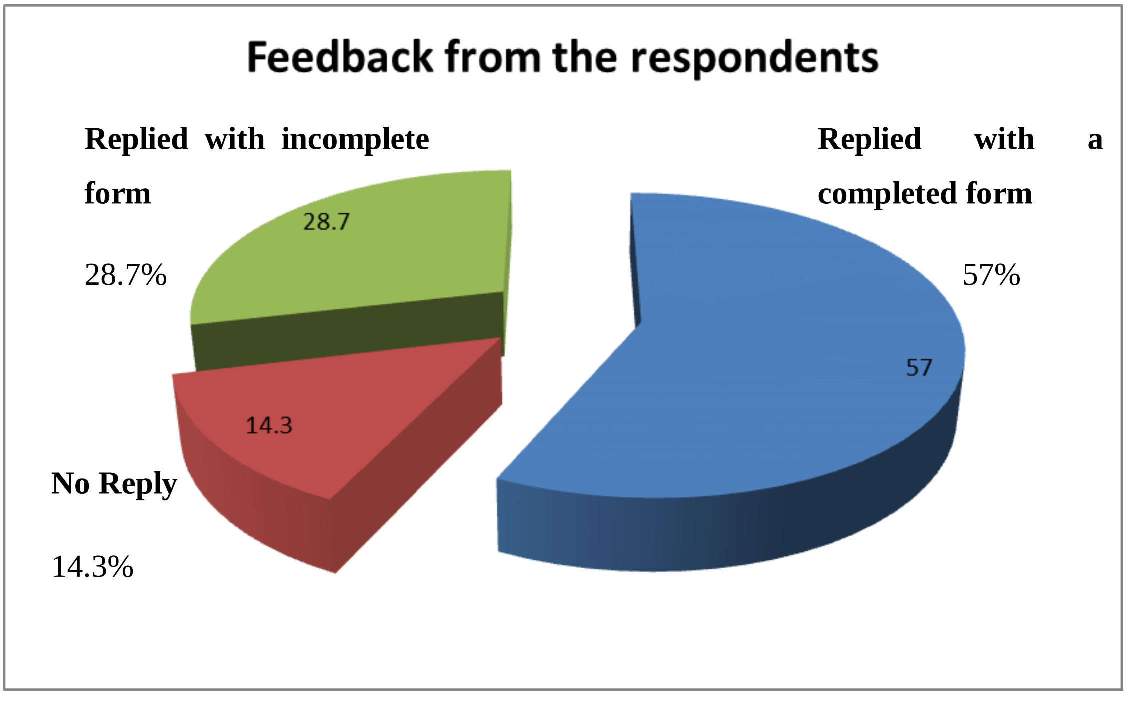

Figure 8: Feedback from respondents

Each set of questionnaire is divided into 5 different sections and these sections are shown below:

1. Background information of respondents and their companies.
2. Basic knowledge about Sustainable Development in infrastructure projects.
3. Significances of each causes of infrastructure unsustainability
4. Effects of unsustainable construction in infrastructure projects to economy, environment and social development.
5. To study the sustainable construction practices which are applicable based on their success rates.

Table 1: Location and Organization of Respondents

Location	No of respondents						Total
	Clients		Contractor		Consultant Firm		
	Frequency	%	Frequency	%	Frequency	%	
Kuala Lumpur	9	30	7	23.33	10	33.33	26
Ipoh	-	-	3	10	1	3.34	4
Total (number)	9		10		11		30
Total (%)		30		33.33		36.67	100%

Based on figure 9, 90% of the respondents were from Kuala Lumpur while the others were locating in Ipoh. The questionnaires are sent as e-mails to the respondents so that they have more time answering questions and results are more organized and manageable. Most of the e-mails are sent directly to the respondents in order to save time and skipping all the management levels.

A few interviews are done on the spot with some of the respondents to get more feedback and opinions from them on the issue. The reaction from them is encouraging and the opinions are recorded. Problem with interviews is that they consume a lot of time and may disrupt the work of respondents at that particular time.

For future research related to this topic, it is recommended for all to use face-to-face interview to increase number of feedbacks and useful opinions from the respondents. Besides that, interviewer can improve their skills on communicating with people and build up their confidence in their future career.

Table 2: Results of respondents' involvement in infrastructure projects.

Response	**Frequency**	**Percentage (%)**
No	7	23.3
Yes	23	76.7
Total	**30**	**100.0**

Based on the table above, we can conclude that more than 70% of the respondents have been involved in the infrastructure projects during their career. The other remaining 23% of respondents may be involving in other private projects or dealing with consultancy work that is not related to infrastructures.

The involvement of these respondents in infrastructure projects made it easier for them to answer the questions related to sustainable construction practices as they have experience in handling infrastructure projects and understand the general concept of sustainable construction.

4.2 Analysis data for Section A

As mentioned before, the questionnaire is divided into 3 sections. In section A, the respondents were asked about their experience and organizations they represented. From Table 3, we can see that there are nine clients, 33.33% of them are contractors, and 36.67% of them are from consultant firms. The respondents may be the engineer, project manager, director or even consultants of the companies.

Besides that, 20% of the respondents have experience in the construction industry for less than 2 years; 30% of them have experience of 2 to 5 years; 33% of the respondents have experience of 6 to 10 years and the remaining respondents have experience of more than 10 years. We can conclude that those with experience of 6 to 10 years may be the project manager or lead engineer of their company while those have experience of more than 10 years may be the director or the top manager in their company.

Table 3: Experience and Organizations of Respondents

Experience	Number of Respondents						Total
	Client		Contractor		Consultant firm		(Number)
	Frequency	%	Frequency	%	Frequency	%	
< 2 years	2	6.67	2	6.67	2	6.67	6
2 - 5 years	1	3.33	3	10	5	16.67	9
6 - 10 years	3	10	3	10	4	13.33	10
> 10 years	3	10	2	6.67	-	-	5
Total		30%		33.33%		36.67%	30

In the questionnaire, the respondents are asked about the types of projects that they usually deal with and the results are shown below.

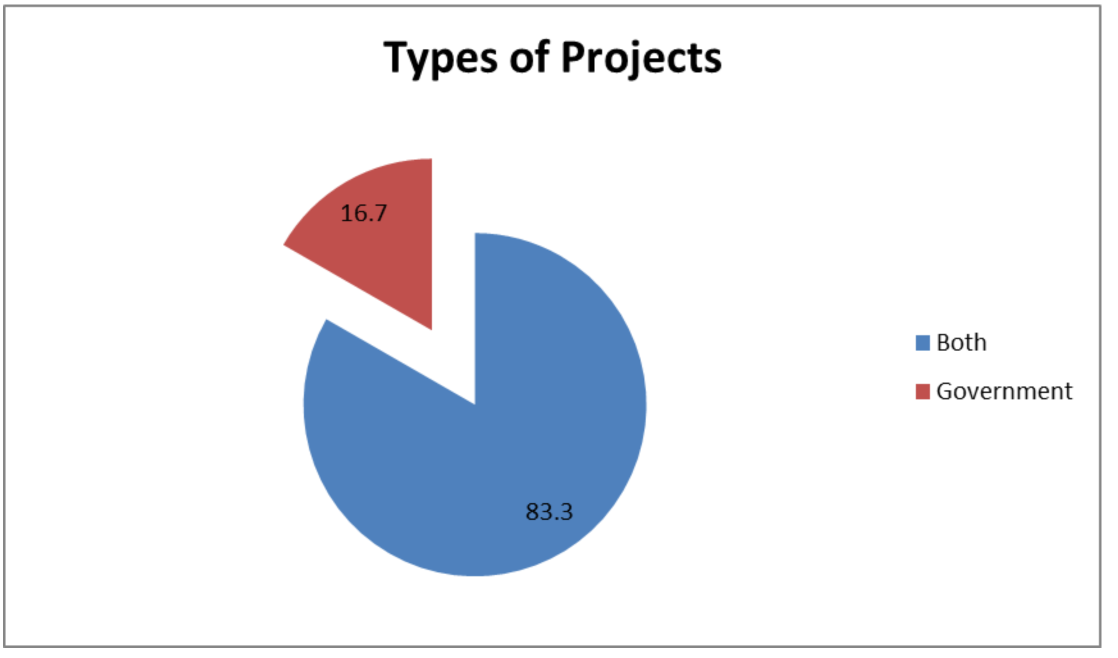

Figure 9: Types of Projects Respondents Involved in Construction Industry

From the survey, 83.3% of the respondents have involved in both types of projects during their career and 16.7% of them only deal with government projects. Most of the respondents are from consultant firms and they usually get involved in both types of projects as they tender for all kinds of projects.

4.3 Analysis data for Section B

In section B, the respondents are asked based on their general knowledge in sustainable development in infrastructure projects. From the survey, all of the respondents have heard about the term "Sustainable Construction". They mentioned that this term always appear on newspapers, books/magazines, internet and seminars. However, 20% of the respondents are not really interested in knowing more about the term. This may due to the fact that the issue of sustainability is not important enough in their opinion and in the eyes of the world. The other 80% of respondents are fairly interested in the topic and want to understand the effects of the term to our nation and to the world.

From the survey, we found out that 80% of the respondents agreed that those sustainable construction practices will aid in economic, environment and social development. We can say that sustainable construction practices are applicable in infrastructure projects to aid in that development thus improving our life and conserving the environment.

Table 4: Rate of Understanding of Respondents on Issues related to Sustainability in Infrastructure Projects based on Tertiary Education

Rate of Understanding	**Frequency**	**Percentage (%)**
1 (Very Low)	0	0
2	2	6.7
3	17	56.7
4	9	30.0
5 (Very High)	2	6.6
Total	**30**	**100.0**

Based on Table 4 above, we calculated that the average index is 3.367 where this indicated that the respondents have good understanding on issues related to sustainable construction in infrastructure projects based on their tertiary education. This showed that we need to continue educating the young generation on the matter regarding sustainability in infrastructure project to further explore on the importance of sustainability.

From the questionnaire, results indicated that 57% of the respondents agreed that the implementation of sustainable construction practices in infrastructure projects is feasible while the remaining 43% disagreed on the feasibility of sustainable construction practices in infrastructure projects. The disagreed party may not fully understand the importance of sustainable construction practices in infrastructure projects to the future generation.

4.4 Analysis data for Section C

To find the suitable and effective practices that are applicable and feasible in infrastructure projects, we must first determine the causes of unsustainable infrastructures. From literature review, we understand that the meaning of infrastructures is not limited to just bridges and roads because commercial buildings, airports, dams, schools, rail and public housing are also the critical components for an economy to function.

The infrastructures in the future shall adapt the practices derived from this questionnaire to be able to sustain the younger generation needs while preserving the environment and promoting social and economic development. There are 8 major causes of unsustainable infrastructures and this section is to determine the level of significance of each cause while understanding the reason for each causes in this issue.

The first cause for this unsustainable infrastructure is because the engineers lack the knowledge of best practices used in sustainable construction. The second cause due to this issue is due to lack of awareness among citizens and society as they are not aware of the severity of this matter. High initial cost in constructing sustainable infrastructures may be one of the causes of unsustainable infrastructures as it is the third indicator related to this matter.

High maintenance cost, lack of communication, long payback periods, inadequacy of standards and regulations, difference in expectations and demands are some of the other causes of unsustainable infrastructures. All these causes will be discussed further on in the following analysis of each cause.

It is important to analyse the significance of each causes in unsustainable infrastructures because we need to know the most severe cause and tackle the issue of unsustainable infrastructure to solve this issue of unsustainability that has been happening around us for some time.

Based on the questionnaire results on section C, we found out the relative importance index of each cause of unsustainable infrastructure using the formula given and other related results using descriptive statistics in SPSS software. The results are shown below for the first cause:

Table 5: Significance of Lacking in Knowledge to Unsustainable Infrastructures.

Rate of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	2	6.7	3.367	0.7184
2.0	19	63.3		
3.0	8	26.7		
4.0	1	3.3		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

Based on Table 5 above, we can conclude that lacking of knowledge is not really significant to unsustainable infrastructures as 63% of respondents rated low significance for this issue and only one respondent gave a high rating. This showed that our engineers do not lack the knowledge of which practices to use in promoting sustainability in infrastructure projects.

After a series of calculation, lack of knowledge produced the lowest relative importance index to unsustainable infrastructures and this indicated that our engineers, managers and even directors are aware of the practices used in sustainable construction and there may be other severe causes initiating unsustainable infrastructure.

For the second cause which is the lack of awareness, the result of the questionnaire is shown below:

Table 6: Significance of Lacking in Awareness to Unsustainable Infrastructures.

Rate of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.467	0.8193
2.0	1	3.3		
3.0	16	53.3		
4.0	11	36.7		
5.0 (Very High)	2	6.7		
Total	**30**	**100.0**		

From Table 6 we can observed that 53% of respondents rated medium and 36.7% rated high lacking of awareness among the public causing unsustainable infrastructures. We can said that lack of awareness among the public is the fairly concerned causes in this issue and government should promote sustainability to the public and raise the awareness so that we will be working together to a more sustainable future.

For the fourth cause which is the high initial cost, the rate of significance marked by respondents is shown in the Table below:

Table 7: Rate of Significance of High Initial Cost to Unsustainable Infrastructures.

Rate of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.467	0.6814
2.0	1	3.3		
3.0	13	43.3		
4.0	14	46.7		
5.0 (Very High)	2	6.7		
Total	**30**	**100.0**		

The table showed that 46.7% of respondents rated high and 43% of them rated medium for this particular cause in this questionnaire. This indicated that high initial cost is of the top ranked factor causing unsustainable infrastructures due to refusal of government to spend such big sum on these infrastructure projects and this might not guarantee the success of sustainable infrastructures as there may be problems during the project itself and causing more money into the project.

The rates of significance of few other causes are shown below:

Table 8: Rate of Significance of High Maintenance Cost to Unsustainable Infrastructures.

Rate of Significance	**Frequency**	**Percentage (%)**	**Mean**	**Standard Deviation**
1.0 (Very Low)	0	0.0	3.300	0.6513
2.0	3	10.0		
3.0	15	50.0		
4.0	12	40.0		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

Table 9: Rate of Significance of Lack of Communication to Unsustainable Infrastructures

Rate of Significance	**Frequency**	**Percentage (%)**	**Mean**	**Standard Deviation**
1.0 (Very Low)	0	0.0	4.100	0.6074
2.0	0	0.0		
3.0	4	13.3		
4.0	19	63.3		
5.0 (Very High)	7	23.3		
Total	**30**	**100.0**		

Table 10: Rate of Significance of Long Payback Periods to Unsustainable Infrastructures.

Rate of Significance	**Frequency**	**Percentage (%)**	**Mean**	**Standard Deviation**
1.0 (Very Low)	0	0.0	3.433	0.7279
2.0	3	10.0		
3.0	12	40.0		
4.0	14	46.7		
5.0 (Very High)	1	3.3		
Total	**30**	**100.0**		

Table 11: Rate of Significance of Inadequacy of Standards and Regulations to Unsustainable Infrastructures.

Rate of Significance	**Frequency**	**Percentage (%)**	**Mean**	**Standard Deviation**
1.0 (Very Low)	0	0.0	3.633	0.7649
2.0	1	3.3		
3.0	13	43.3		
4.0	12	40.0		
5.0 (Very High)	4	13.3		
Total	**30**	**100.0**		

Table 12: Rate of Significance of Difference in Expectations and Demands to Unsustainable Infrastructures.

Rate of Significance	**Frequency**	**Percentage (%)**	**Mean**	**Standard Deviation**
1.0 (Very Low)	0	0.0	3.167	0.6477
2.0	3	10.0		
3.0	20	66.7		
4.0	6	20.0		
5.0 (Very High)	1	3.3		
Total	**30**	**100.0**		

Table 13: Relative Importance Index of all the causes of unsustainable infrastructures.

Ranking	Causes of Unsustainable Infrastructure	Relative Importance Index
1	Lack of communication	0.82
2	Inadequancy in Standards and Regulations	0.73
3	High Initial Cost	0.71
4	Lack of awareness	0.69
5	Long Payback Periods	0.68
6	High Maintenance Cost	0.66
7	Different in Expectations and Demands	0.63
8	Lack of knowledge	0.45

From here we can said that the rate of significance is different for each causes to unsustainable infrastructures and the most critical factor here is lack of communication as lack of communication has the highest relative importance index following with inadequacy in standards and regulations and high initial cost. Lack of communication among engineers, planners and designers is the most critical and actions must be taken so that there will not be conflict among these professional services.

Besides knowing the RII for each factor causing unsustainable infrastructures, we can use the mean as the other way to determine the importance of each factor causing this phenomenon. The mean and standard deviation of each causes is shown below:

Table 14: Mean and Standard Deviation of Each Cause of Unsustainable Infrastructures.

No.	Causes of Unsustainable Infrastructures	Mean	Standard Deviation
1	Lack of Communication	4.100	0.6074
2	Inadequancy of Standards and Regulations	3.633	0.7649
3	High Initial Cost	3.467	0.6814
4	Lack of Awareness	3.467	0.8193
5	Long Payback Periods	3.433	0.7279
6	High Maintenance Cost	3.300	0.6513
7	Different Expectations and Demands	3.167	0.6477
8	Lack of Knowledge	2.267	0.6397

From Table 14, we can see that the ranking is the same as Table 13 but there is a problem: Causes no.3 and no.4 have the same mean. There is another way of solving this whereby we can calculate the standard deviation of both causes and the smaller number is the more crucial cause in this case. Standard deviation is another calculation to show that the data is closer to the mean and in this case the data for high initial cost has a smaller standard deviation indicating that the data is at a smaller range within the mean rather than the other one. If there are 2 data with the same mean, we can always use standard deviation to determine which of the data is closer to the mean and within a smaller range of numbers indicating its importance to the relevant effect.

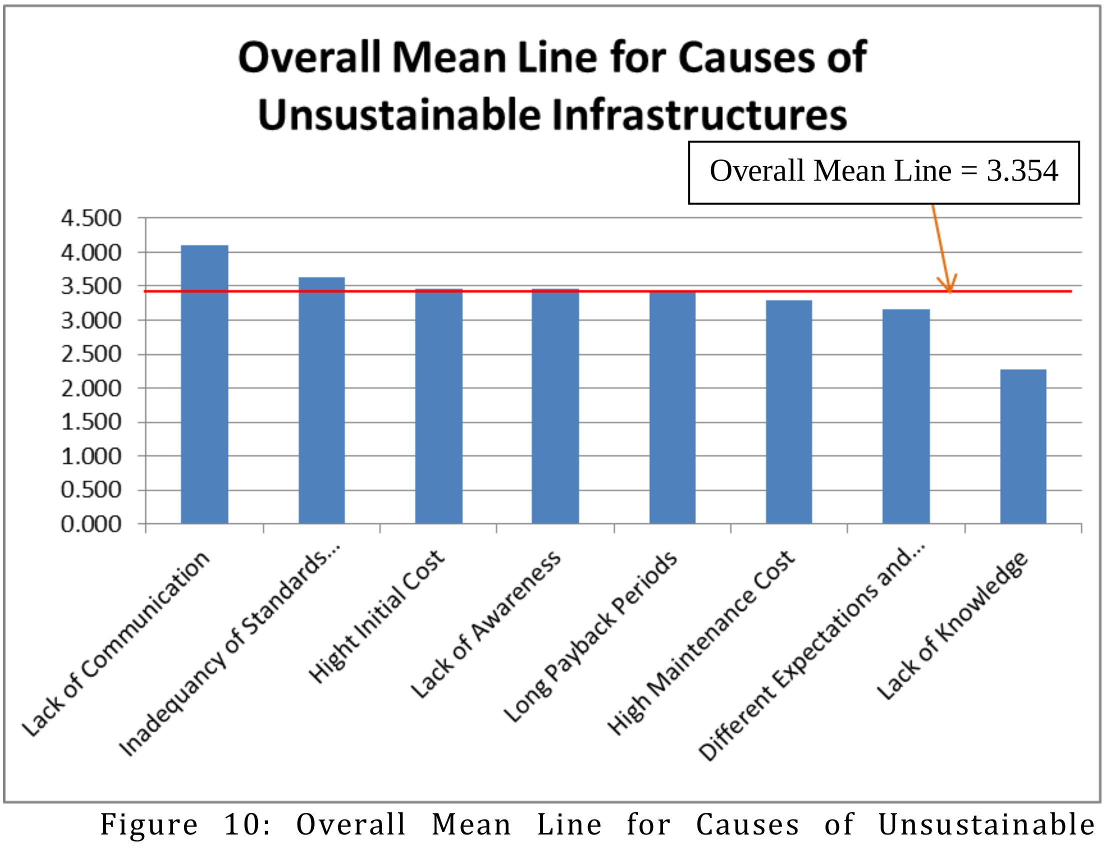

Figure 10: Overall Mean Line for Causes of Unsustainable Infrastructures.

Figure 10 showed the overall mean line for all the causes of unsustainable infrastructures. From here we understand that the few causes that we should focus on are lack of communication, inadequacy of standards and regulations, high initial cost, and lack of awareness. If we are able to come up with the right solutions, sustainable infrastructures can be achieved and the future generations can meet their own needs.

To overcome some of the issues occurred, developers, governments, engineers and other involved members should come together and take up the responsibility of solving the matter of unsustainability in infrastructure projects and to promote sustainable construction practices to the younger generations. Engineers, planners and designers should discuss properly on the issue of design work and other related works so that to compromise each other's ideas and put in the sustainable construction practices to every level of design work to maximise the potential of sustainability in infrastructure projects.

Developers and government should take the initiative to build more sustainable infrastructures and include more sustainable practices during construction to improve the lifespan of the infrastructure for future use without demolishing or replacing it. Besides that, they should understand the concept of lifecycle cost versus upfront cost as they will realise that they do not have to spend huge sum of money in the future to build new buildings except for some minor maintenance works if they succeed in constructing sustainable infrastructures and understanding the sustainable construction practices used in the industry.

Besides that, the government should introduce new regulations regarding sustainable infrastructures to the contractors and consultant firms to follow if they need to refer to any standards as their reference point. This will be helpful not only to companies but also to the engineers as they will be updating themselves with the new standards while abiding to the regulations imposed by the government to promote sustainability and constructing sustainable infrastructures.

4.5 Analysis data for Section D

The effects of unsustainable infrastructures can be quite destructive not only to the environment but also to the community living and working in a certain area. It is important to analyse the effects of unsustainable construction in infrastructure projects to identify the right solution for each effect. Without sustainable infrastructures, the old buildings need to be replaced and natural habitats destroyed for development of infrastructure such as bridges, roads and dams. This will be harming the wildlife and increasing the greenhouse emissions of carbon monoxide and other harmful gases.

The effects of unsustainable infrastructures are divided into 3 parts mainly the social effects, environmental effects and economic effects. All the respondents will be determining the level of significance of each effect and the results will be tabulated. There are 3 major social effects: High energy consumption in buildings, poverty and inequality among people and stress to community living and working in unsustainable infrastructures.

There are 4 economic effects which will be analysed here: Increase of transportation cost, old buildings need to be replaced by new buildings and more maintenance is needed compared to sustainable infrastructures. For environmental effects, there are mainly 4 aspects to be analysed that are increase of logging activities, natural habitats destroyed, emission of greenhouse gases and depletion of natural resources at a drastic rate.

Besides that, the environmental effects will be evaluated as it is important to determine the level of significance for each effect. There are 4 effects to be evaluated mainly increase of logging activities, natural habitats destroyed, increase in emission of greenhouse gases and depletion of natural resources at a drastic rate.

The results of social effects are shown as follow:

Table 15: Level of Significance on the Effect of High Consumption in Buildings to Unsustainable Infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.700	0.7022
2.0	0	0.0		
3.0	13	43.3		
4.0	13	43.3		
5.0 (Very High)	4	13.3		
Total	**30**	**100.0**		

Table 16: Effect of Poverty and Inequality among People.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	4	13.3	2.400	0.8550
2.0	13	43.3		
3.0	10	33.3		
4.0	3	10.0		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

Table 17: Level of Effect of Stress Community face while living and working in unsustainable infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.200	0.6644
2.0	4	13.3		
3.0	16	53.3		
4.0	10	33.3		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

From the results above, we can say that high energy consumption in buildings has more influence than other social effects due to unsustainable infrastructures. It is because unsustainable infrastructures may not have the efficient system to save energy and improve its overall system. Unsustainable infrastructures also causes community that live and work in it feeling stress because workers may not feel comfortable with the air-condition system or the quality of air is not good enough in that particular infrastructure.

For the economic effects of unsustainable infrastructures, there are 4 main effects that will be analysed here which are the increase in transportation cost, replacement of old buildings, more maintenance needed compared to sustainable infrastructures and increase price of building materials.

Table 18: Effect of Increase of Transportation Cost.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.3633	0.6687
2.0	1	3.3		
3.0	11	36.7		
4.0	16	53.3		
5.0 (Very High)	2	6.7		
Total	**30**	**100.0**		

Table 19: Effect of Replacement of Old Buildings.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.433	0.5683
2.0	0	0.0		
3.0	18	60.0		
4.0	11	36.7		
5.0 (Very High)	1	3.3		
Total	**30**	**100.0**		

Table 20: Level of effect for more maintenance compared to sustainable infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.100	0.7120
2.0	6	20.0		
3.0	15	50.0		
4.0	9	30.0		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

Table 21: Level of effect on increased price of building materials due to unsustainable infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.533	0.7303
2.0	2	6.7		
3.0	12	40.0		
4.0	14	46.7		
5.0 (Very High)	2	6.7		
Total	**30**	**100.0**		

From Table 18 to Table 21, we understand that unsustainable infrastructures may have a high influence on the economy and we cannot underestimate the economic effects that could cause massive losses to the nations around the world. If the infrastructure itself is unsustainable, it will eventually be replaced by new infrastructure and this causes building materials price hike due to the extensive demand for building materials.

To build a sustainable infrastructure successfully, the construction phase is vital in saving cost while ensuring the project is done in time. The transportation cost is a crucial factor here as it is not cheap to transport cement or building material from a place to the site. Building a cement production facility nearby is a smart solution as cost is reduced by more than half and the construction may be done in time and within budget. If the transportation of cement or building material is straining the budget, the infrastructure built is deemed unsustainable as the construction phase contributes to the whole project itself.

More maintenance is needed in unsustainable infrastructures as the system used is older than the ones in sustainable infrastructure so the maintenance team have to check on the system from time to time for hardware replacement. In sustainable infrastructures, most of the components are able to sustain themselves such as the auto-light system and the water circulation system. They are set on a cycle where they switch off automatically and trigger the maintenance only when there is a system failure.

For the environmental effects, the results are shown below in 4 different tables.

Table 22: Level of effect on increase of logging activities due to unsustainable infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.700	0.4661
2.0	0	0.0		
3.0	9	30.0		
4.0	21	70.0		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

Table 23: Level of effect in destroying natural habitats due to unsustainable infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.867	0.6814
2.0	0	0.0		
3.0	9	30.0		
4.0	16	53.3		
5.0 (Very High)	5	16.7		
Total	**30**	**100.0**		

Table 24: Level of effect on emission of greenhouse gases due to unsustainable infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.433	0.5561
2.0	2	6.7		
3.0	13	43.3		
4.0	15	50.0		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

Table 25: Level of effect on depletion of natural resources due to unsustainable infrastructures.

Level of Significance	Frequency	Percentage (%)	Mean	Standard Deviation
1.0 (Very Low)	0	0.0	3.067	0.5833
2.0	4	13.3		
3.0	20	66.7		
4.0	6	20.0		
5.0 (Very High)	0	0.0		
Total	**30**	**100.0**		

Based on the results given for environmental effects, we found out that natural habitats destroyed is one of the worst effect due to unsustainable infrastructures because the government have to find a new place to build up the new infrastructure if the old ones has run out of its usable life cycle. The government has no choice but to clear a new area for the new infrastructure and this will certainly destroy the natural habitats around that area thus endangering the life of wildlife.

To clear a new area for construction of an infrastructure project, logging activities have to be done to allow the construction work to begin. If the old infrastructure is abandoned and not demolished, government will have to increase logging activities at new locations for the construction of new infrastructure and this is devastating to the nature and to the younger generations. This also causes the sudden increase in emission of greenhouse gases which constitute to global warming. Besides that, natural resources such as wood and fuel will be depleting at a drastic rate if sustainable construction practices is not applied in infrastructure projects.

Table 26: Relative Importance Index of All the Effects of Unsustainable Infrastructures.

Ranking	Effects of Unsustainable Infrastructures	Relative Importance Index
1	Natural habitats destroyed.	0.773
2	Increase of logging activities for replacement of old buildings.	0.740
3	High energy consumption in buildings.	0.740
4	Increase of transportation cost.	0.727
5	Increased price of building materials due to limited resources.	0.693
6	Emission of greenhouse gases surges.	0.687
7	Old buildings need to be replaced by new buildings.	0.687
8	Stress to community living and working in unsustainable infrastructures.	0.640
9	More maintenance is needed compared to sustainable infrastructures.	0.620
10	Natural resources depleting at a drastic rate.	0.613
11	Poverty and inequality among people.	0.480

Based on the table above, we can find out the relative importance index for each effect of unsustainable infrastructures. Many of the respondents labelled 'natural habitats destroyed' as the most important effect of unsustainable infrastructures and this showed that the government have to come up with solutions to tackle this issue as soon as possible to save the nature and the wildlife.

We also noticed that there are a few effects in the table having same relative importance index and the standard deviation will be used to solve this issue.

Table 27: Mean and Standard Deviation of Effects having the same Relative Importance Index.

No.	Effects of Unsustainable Infrastructures	Mean	Standard Deviation
1	Increase of logging activities for replacement of old buildings.	3.700	0.4661
2	High energy consumption in buildings.	3.700	0.7022
3	Emission of greenhouse gases surges.	3.433	0.6261
4	Old buildings need to replaced by new buildings.	3.433	0.5683

Based on the information that we got from Table 26, effect that have a smaller standard deviation indicates that the effect is much more important compare to the effect having a bigger standard deviation. This means that the logging activities have more effects compare to high energy consumption in buildings.

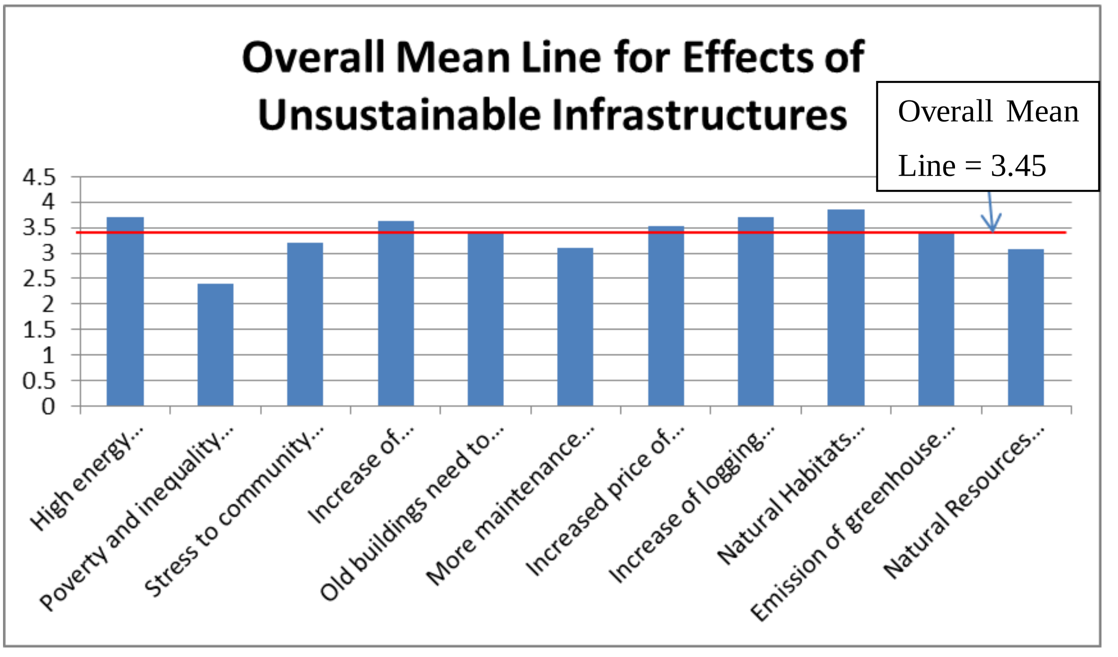

Figure 11: Overall Mean Line for All Effects of Unsustainable Infrastructures.

From Figure 11, we can see that the mean of all the effects are put in columns and the overall mean line is calculated from the total mean divided by number of effects. The calculated overall mean is 3.45 and showed on the chart. We can conclude that high energy consumption in buildings, increase of logging activities, increase of transportation cost and natural habitats destroyed are the effects that we should look into in making infrastructures more sustainable. This will further promote sustainable construction in infrastructure projects thus helping the economy and the community.

Each effect has its own implication to the society, nature and economy. This implies that unsustainable infrastructures can bring a significant impact to the world and to the younger generation. We must first reduce the effect of unsustainable infrastructures while applying sustainable construction practices in the new or upcoming infrastructure projects so that our economy would be stable, people living and working well and the environment preserved for the younger generations.

In order to verify the results obtained, I interviewed the project manager about this issue and asked him about the severity of unsustainable infrastructures. He did agreed on the fact that natural habitats are destroyed with the construction of new infrastructures but they cannot really do anything about it as the old infrastructures are better kept than being demolished as they can still perform easier tasks but needed more maintenance than the new infrastructures. He also mentioned that logging activities is a need for them to clear the land for the new infrastructure and the transportation cost increased vastly as the infrastructure is located far from the city itself and this increased the budget by almost 15%.

4.6 Analysis data for Section E

In this last section of data analysis, solutions are proposed for sustainable construction practices that can be applied into the real infrastructure projects. Solutions are proposed from different aspects such as water, construction site, energy, human factor, materials and waste. These aspects are important as they can promote sustainable construction while preserving the environment, stabilize the economy and help social development. The solutions that have good responses from the respondents can be frequently applied during the project while the other solutions can be further enhanced to improve its efficiency of their practicality.

The results of each solution are expressed in a table below with their respective means and standard deviations:

Table 28: Mean and Standard Deviation of Proposed Solutions for Sustainable Construction Practices in Infrastructure Projects.

No.	Proposed Solutions	Mean	Standard Deviation
1	Maintain the biodiversity and ecology near the site location	3.633	0.4156
2	Use renewable energy sources with least environmental effects	3.621	0.6254
3	Use recycled building components that are bio-degradable	3.620	0.6747
4	Design infrastructures for adaptability and disassembly	3.590	0.5127
5	Optimize infrastructure configuration for Energy Performance	3.584	0.7127
6	Use salvaged and remanufactured materials	3.546	0.5247
7	Use locally manufactured materials	3.540	0.7234
8	Use energy saving equipments and appliances	3.512	0.7303
9	Reduce and recycle Construction Waste	3.490	0.5674
10	Provide views and connection to natural environment	3.480	0.4932
11	Use native trees, shrubs and plants	3.433	0.4833
12	Development at Environmentally Appropriate Areas	3.417	0.6087
13	Provide a clean and healthy environment	3.395	0.5123
14	Salvage and reuse Demolition Waste	3.376	0.6747
15	Use On-site Biological Waste Treatment Systems	3.365	0.6087
16	Conserve Building Water & Water Consumption	3.348	0.5942
17	Manage site water	3.254	0.7626
18	Provide effective lighting	3.250	0.6237

Based on the table above, we have 18 proposed solutions from different aspects and the one with the highest rate of success is by maintaining the biodiversity and ecology near the site location follow by the use of renewable energy source with the least environmental effects. Using recycled building components and designing infrastructure for adaptability and disassembly are also the top 5 solutions proposed and agreed by the respondents.

In order to verify this results, interview were done on site regarding to the case study discussed earlier in Chapter 2. I interviewed the Project Manager, the Consulting Engineer and the Construction Manager on site. They agreed with the respondents that maintaining the biodiversity and ecology near to the site location is important but they also mentioned that renewable energy can be used in the future for the infrastructure projects and the use of recycled building components can reduce the cost of the project thus making the infrastructure sustainable. The construction manager also emphasized that using local manufactured materials can be really helpful at times to reduce the transportation cost.

The Consulting Engineer also commented that the design process is vital for the infrastructure to be able to adapt to the surrounding and making it easier for disassembly rather than demolishing it. The project manager hoped that the application of sustainable construction practices in infrastructure projects can reduce the total cost of the project and preserving the environment for future generations while promoting social development for the nearby communities.

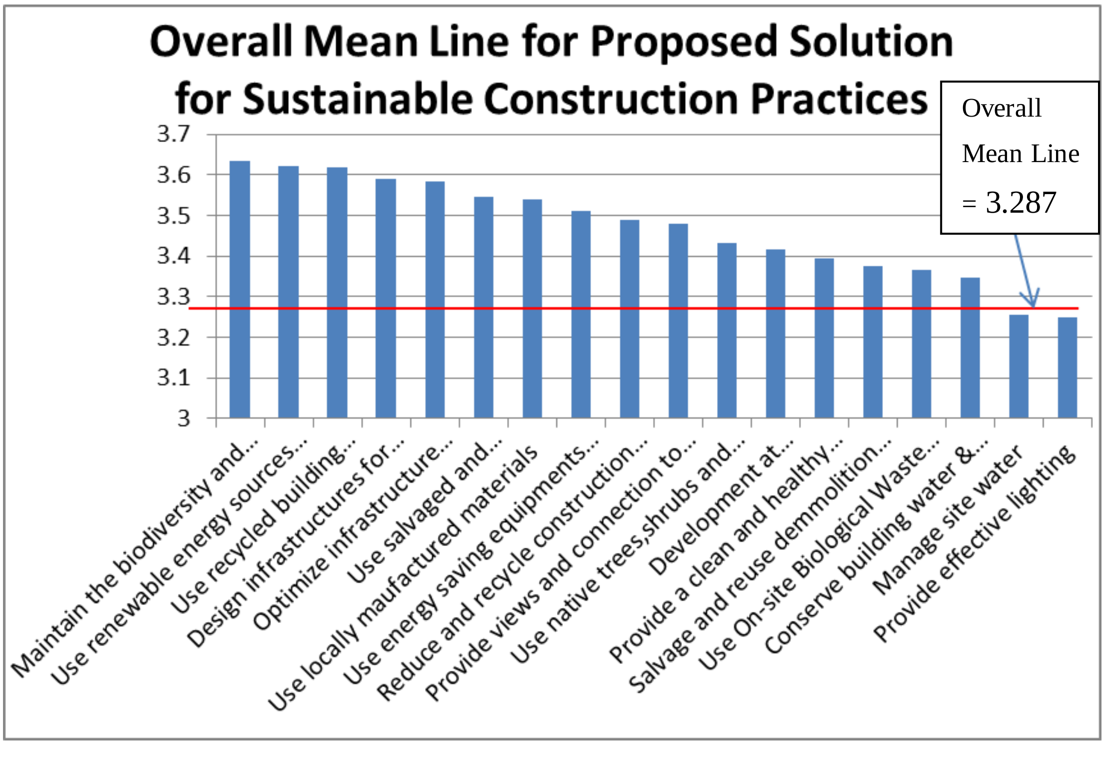

Figure 12: Overall Mean Line for Proposed Solutions for Sustainable construction in infrastructure projects.

From Figure 12, we can conclude that all the proposed solutions are above the overall mean line indicating that these solutions are acceptable and applicable to the construction in infrastructure projects. If most of the solutions are applied, sustainable infrastructures are achieved thus aiding the economy, society and preserving the environment. This overall mean line is for us to determine the higher importance solutions to be used or applied in sustainable construction in infrastructure projects.

By knowing the causes and effects of unsustainable construction, we can tackle the problem more effectively and coming out with the suitable yet practical solutions to make sustainable infrastructures a success. The solutions will further enhance the idea of sustainable infrastructures and bring it to the international level where countries combine innovative ideas to create the sustainable and magnificent infrastructures besides preserving the environment, promoting social development and moving the economy.

CHAPTER 5: CONCLUSION & FUTURE WORK

Sustainable construction in infrastructure projects may not be achieved in a short period of time but the awareness among societies is in the positive side as we realise the importance of sustainability for the future generation. The causes of ineffective construction should be tackled efficiently to improve the productivity and sustainability of the structure in the long term. Engineers, architects and planners should possess the required knowledge to design viable structure and the life-cycle cost should be taken into consideration before constructing. Nations around the world should be aware of the damage done to the environment by unsustainable construction in infrastructure projects and do something to minimize the negative effects by reducing the use of natural resources and managing the land usage effectively. All in all, innovative solutions shall be created to apply to infrastructure projects in order to make them self-sustainable while producing minimal destruction to the environment.

From the questionnaire results and interviews with respective personnel, sustainable infrastructures cannot be built in a day and those sustainable construction practices should be spread among the clients, consultants and contractors so that they know what is the best design or the choices they have to build a sustainable infrastructure where it can maintain itself with least maintenance. Besides that, they should also be wary of the effects of unsustainable infrastructures and what might happen in the future where there is nothing left in the nature for the younger generation to see, touch and experience. They should make the right choice in design and during construction not only to reduce cost but to reuse, recycle and take care of the environment even after the infrastructure is built.

For future work, further analysis should be done to discover more ways to sustainable construction practices and realizing the importance of sustainability in infrastructure projects by studying the efficiency of sustainable construction practices in infrastructure projects.

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APPENDIX

Questionnaire
Faculty of Civil Engineering
Universiti Teknologi PETRONAS
The Study of Sustainable Construction Practices in Infrastructure Projects

Section A: Personal Particulars

Name:

Position: Grade CIDB:

Please tick (√) at the answer you choose for the following questions:

1. How long have you served in the construction industry?
   - [ ] < 2years
   - [ ] 2-5 years
   - [ ] 6-10 years
   - [ ] >10 years

2. Have you ever been involved in infrastructure projects?
   - [ ] Yes
   - [ ] No

3. Which organizations/parties do you represent?
   - [ ] Client/Developer
   - [ ] Contractor
   - [ ] Consultant
   - [ ] Government bodies
   - [ ] Others: ______________

4. What is the type of project your company usually deals with:
   - [ ] Private
   - [ ] Government
   - [ ] Both

Section B: Basic Knowledge about Sustainable Development in Infrastructure Projects

1. Do you understand the term " Sustainable Construction " ?

   ☐ Yes ☐ No

2. Are you interested to know more about the concept of Sustainable Construction?

   ☐ Yes ☐ No

3. Does your company implement sustainable construction practices in their infrastructure projects?

   ☐ Yes ☐ No

4. Do you think that those practices could aid in economic, environment and social development?

   ☐ Yes ☐ No

5. How do you rate your understanding on issues related to sustainable construction in infrastructure projects based on tertiary education and related training programs?

   ☐ Very Low ☐ Low ☐ Medium ☐ High ☐ V.High

6. Do you think that the implementation of sustainable construction practices in infrastructure projects is feasible?

   ☐ Yes ☐ No

The study of sustainable construction practices in infrastructure projects

Section C: The objective of this section is to study the significance of each causes of infrastructure unsustainability.

Please tick (√) to identify the level of significance for each indicator.

Indicators	Description	Level of Significance				
		Very Low	Low	Medium	High	Very High
Lack of knowledge	Engineers lack the knowlegde of best practices used in sustainable construction.					
Lack of awareness	Sustainability issue is not obvious enough in the eyes of the public.					
High Initial Cost	High initial costs involved In constructing sustainable infrastructures.					
High Maintenance Cost	Regular maintenance needed for high effeciency systems.					
Lack of Communication	Lack of communication between engineers, planners and designers due to different opinions.					
Long Payback Periods	Construction of infrastructure may not fit into "best investment or value."					
Inadequancy of Standards and Regulations	Insufficient information on standards about sustainable infrastructures.					
Difference in Expectations and Demands	Developer or government may not take in account energy efficient principles during the design process.					

Section D: The objective of this section is to study the effects of unsustainable construction to economy, environment and social development.

Please tick (√) to classify the effects into its level of significance.

Indicators	Level of Significance				
	Very Low	Low	Medium	High	Very High
Social Effects					
High energy consumption in buildings.					
Poverty and inequality among people.					
Stress to community living and working in unsustainable infrastructures.					
Economic Effects					
Increase of transportation cost.					
Old buildings need to be replaced by new buildings.					
More maintenance is needed compared to sustainable infrastructures.					
Increased price of building materials due to limited resources.					
Environmental Effects					
Increase of logging activities for replacement of old buildings.					
Natural habitats destroyed.					
Emission of greenhouse gases surges.					
Natural resources depleting at a drastic rate.					

Section E: The objective of this section is to categorize the proposed solutions into its own level of success.

Please tick (√) at the right box for the level of success for each proposed solution.

Proposed Solution	Level of Success				
	Very Low	Low	Medium	High	Very High
SITE					
Development at Environmentally Appropriate Areas					
Maintain the biodiversity and ecology near the site location					
Use native trees, shrubs and plants					
WATER					
Manage site water					
Use On-site Biological Waste Treatment Systems					
Conserve Building Water & Water Consumption					
ENERGY					
Use energy saving equipments and appliances					
Optimize infrastructure configuration for Energy Performance					
Use renewable energy sources with least environmental effects					
HUMAN FACTOR					
Provide a clean and healthy environment					
Provide effective lighting					
Provide views and connection to natural environment					
MATERIALS					
Use salvaged and remanufactured materials					
Use recycled building components that are bio-degradable					
Use locally manufactured materials					
WASTE					
Design infrastructures for adaptability and disassembly					
Salvage and reuse Demolition Waste					
Reduce and recycle Construction Waste					