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Sustainable Road Development and Management

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ABSTRACT

The aim of this project is to identify and evaluate the common sustainable development and management practices that are currently being utilised by the road industry. Furthermore determine if these practices are having an advantageous benefit acting upon the industry; and determine the barriers impeding the implementation of the identified sustainable development and management practices. To gather the data required the methodology best suited for this research project was to undertake a minimum of two site tours and one case study, this allowed adequate information to be gathered and processed. The research project calculated the benefits often experienced by organisations through undertaking two site tours on; Redbank Plains Road Upgrade and Moreton Bay Rail Project and analysing a case study on the Great Eastern Highway Project. From the site tours and case study it was revealed that certain sustainable management and development practices incorporated by the organisation did in fact have advantageous benefits in relation to social, economic and environmental aspects. From this conclusion the research project progressed to provide recommendations to combat the current barriers impeding the implementation of sustainable practices. These recommendation include; additional training and education to allow for a better understanding of the sustainable practice, additional planning in the design phase of the road construction to allow for adequate timing to implement the sustainable practice, and finally present motivational aspects to the client and/or contractor to gain momentum in the application of sustainable practices.

DISCLAIMER PAGE

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I certify that the ideas, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.
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Contents

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE AND ACRONYMS
(OR ABBRIVATIONS)

The following abbreviations have been used throughout the text and bibliography

IS	Infrastructure Sustainability
USQ	University of Southern Queensland
LC	Lean Construction
RS	Rating System
CS&ST	Case Study & Site Tour

LIST OF APPENDICIES

CHAPTER 1 – INTRODUCTION

1.1 Project topic

The research topic that was chosen to be analysed was sustainable road development and management. The research topic will be supervised and undertaken with the aid of Dr David Thorpe. The key words that can be analysed with the topic are sustainability, economic, social and environmental sustainability, road development and management.

1.2 Problem Statement

This research was conducted to evaluate the current sustainable practices and development utilised within the road development and management industry. Currently, implementation of sustainable management and development practices can take a considerable amount of resource and cost to develop. Therefore the problem is created for clients and contractors in determining the usefulness of sustainability.

1.3 Background

This research was conducted to determine the possible utilisation of sustainable practices and methodology which can have a positive impact on environmental, social and economic aspects of this specific industry. Therefore solving the issue that is present in the road industry; whether it is all worth it? Therefore the need to research and reveal to organisations these benefits can be seen to be substantial.

1.4 Objectives

1. Undertake detailed literature review into the current sustainable issues surrounding road development and management and how they can be combatted.
2. Undertake research into possible rating systems (RS) and lean construction (LC) and how it impacts road development and management sustainability.
3. Undertake research into the possibility of recycled aggregates and development methodologies and how they impact on road development and management sustainability.

4. Critically evaluate current barriers impeding on sustainable road development and management
5. Conduct up to the three site tours to observe, understand and document how sustainable road practices are being incorporated into road development and management.
6. Submit a high quality academic dissertation in the required format.

The first significant objective for this project involves researching into current theories and procedures incorporated in today's current road development and management approaches. This will demonstrate and reveal what companies and/organisations utilise to develop and manage sustainable roads.

Early research into sustainable practices employed by organisations reveals that a common sustainable practice is to incorporate a RS when developing and managing roads. This method of rating is essentially a list of sustainability best practices with each criteria being weighted to an acceptable level (Muench, S et al, 2011). It is deemed that this method is employed often due to two factors; its simplicity and, how it can provide guidance to any organisation wishing to develop a sustainable road as it essentially is a check-list (Muench et al, 2011). Another upcoming theory that many organisation are adopting to become sustainable is lean construction (LC). This terminology refers to minimising waste of materials, time and cost (Olatunji 2008). Even though typically LC refers to increasing maximum value for the client, it is believed this can be adapted to focus more on limiting waste of material in turn limiting the impact the road development has upon the environment (Olatunji 2008).

The third objective for this dissertation is to research into the possibility of recycled aggregates and materials and analyse their benefits in limiting their impact upon the environment. With this information it will be evaluated to determine if companies are currently incorporating these materials into their design and management of certain roads. Early research reveals even though many states around Australia have vast amounts of quality rock that can be exploited for road development it can be deduced that this isn't sustainable as you are depleting a finite resource (Department of Victoria Roads, 2011) Therefore over the past decade significant expansion into researching into new recycled and manufactured aggregates would be advantageous. A common recycled aggregate utilised in road development is crushed concrete (Department of Victoria Roads, 2011).

Often forged from demolition jobs early research reveals that this requires little screening to get a high graded aggregate, making it a favourable recycled aggregate among companies (Department of Victoria Roads, 2011). Further research reveals that currently the construction and demolition is responsible for approximately 40% of all Australian waste material; however it is believed that upwards of 50% is currently being recycled (Newson, 2011). With research revealing this information it made this objective to analyse the different recycled aggregates and materials utilised and evaluate how they limit the impact upon the environment paramount importance.

The fourth objective for this dissertation is to critically evaluate the current barriers impeding on more companies adopting sustainable road development and management. When researching into current barriers that could be hindering many companies deciding upon sustainable practices it revealed that many aspects are in fact impeding upon sustainability.

The final objective that this dissertation will explore is to conduct a minimum of three site visits and one case study, this will allow this research project to analyse current company's sustainable methods and procedures that are being employed and allow this dissertation to critically evaluate these methods compared to other conventional methods. Therefore creating a comparison and ideally revealing why certain companies don't opt for certain sustainable methods and/or practices. It is believed that this objective is important to achieve as three sites tours and a case study will provide significant information and knowledge in order to gain an understanding of the industry.

It has to be noted that certain objectives that are deemed to be important will be discussed in Chapter 2: Literature Review, however researched more thoroughly and discussed at greater lengths. A full list of project specifications can also be viewed in Appendix A

1.5 Potential consequential effects of this project

This dissertation is designed to provide extensive information on current sustainable practices when developing and managing roads. Even though the topic of sustainable road development and management have ample amount of literature, it was decided this research project will utilise this literature and compare it to certain roads and give an in-depth analysis on the current sustainability of the road. The main focus of this analysis is to collect information upon the application of sustainable development and management

practice and determine their impact and benefit in relation to the three spheres of sustainability; environmental, social and economic

Therefore it can be seen that this projects potential outcome may prove to be useful to certain companies in the road industry. It will also be beneficial to other parties, for example: any client/s that are currently in the planning phase of their project or requiring management of their assets and wish to have a sustainable approach, any future student and/or professional interested in furthering their knowledge in this project topic field.

CHAPTER 2 - LITERATURE REVIEW

2.1 Introduction to Literature Review

Over the years there has been a shift in the construction industry to now give significant importance to sustainable practices and construction. It has shifted considerably over the past decade so much so that often the clients will favour a contractor that has catered for sustainable practices and construction, even willing to award a winning tender over a cheaper competitor (USQ, 2014). The management of sustainability is becoming increasingly vital in a world that is focused on allowing the generations to have a similar lifestyle to the lifestyles we appreciate today.

The term sustainability can be explained in many different ways, however Smart and Sustainable Homes (2008) summarises sustainability as the development that increases the total quality of life, both currently and in the distant future, in a way that preserves the environmental processes on which life depends. From this definition it was deduced that the term sustainability for this research project will separate the term into three categories; social, economic and environmental. To better demonstrate how the three categories interrelate with each other; figure 1: Conceptual model of sustainable development can which capitulates this is seen below:

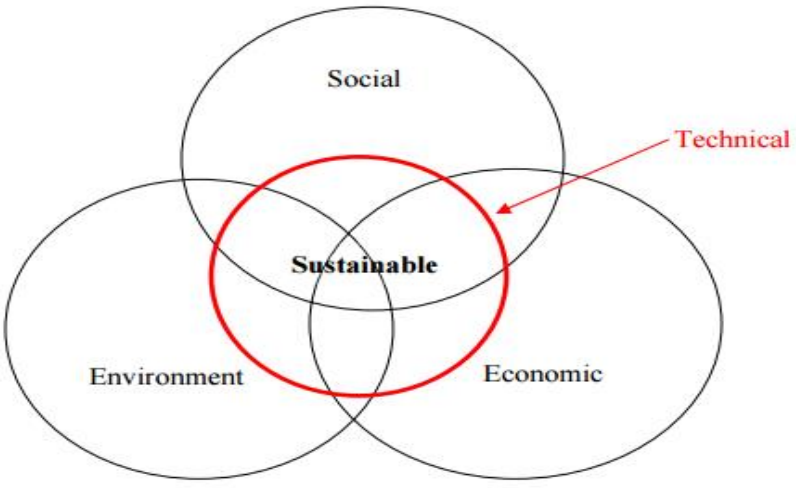

Figure 1: Conceptual model of sustainable development (Foth et al, 2011)

Therefore it can be seen that sustainability is not only limited to environmental but social and economic, all in which play an important role in order to improve sustainable road development and management.

The first component of sustainability is environmental; this simplified means limiting the impacts that the road development and management has upon the environment (Foth et al, 2011). The second section is social; this associates to how the community is affected by the development and management of the road (Foth et al, 2011). The last section is economic; briefly, means cost-effective over time in regards to development and management procedures (Foth et al, 2011). All aspects of sustainability will be studied and related back to the development and management of sustainable roads then analysed how improvements and alterations can be made to change procedures and methods in the future.

This section of the research project relates to critically investigating and analysing the current literature and published sources on the sustainable road development and management topic. Undertaking an in-depth literature review significantly aids and improves our understanding and knowledge within the topic allowing a higher quality dissertation that reflects the current information and literature. This research project will highlight certain published sources and/or literature to evaluate the following sub topics:

- Topic One: Common practices of sustainable road development and management.
- Topic Two: Possible recycled aggregates and methods that can be implemented to improve sustainable development.
- Topic Three: Investigate current barriers affecting the push for higher sustainable road development and management.

2.2 Common Practices of Sustainable Road Development and Management.

After extensive research was conducted on the current sustainable practices being incorporated into the road development and management industry, it was found that there is a vast range of practices that are being utilised by the industry to improve the sustainability of road development and management.

The two that this research project is particular interested in is:

- Rating systems
- Lean Construction

2.2.1 Rating System

Analysing the literature describes that a sustainable RS is in essence a list of sustainable best practices with weighting and criteria attached (Muench et al, 2011). The criteria in which the road development and management is marked on can be adapted and changed to suit the ethos of the organisation and/or company. A RS allows the organisation utilising it to qualify each sustainable practice, therefore giving a numerical or graded review (Alam, & Kumar, 2013). Often the RS is primarily based on three broad dimensions of sustainability – environmental, social wellbeing and economy, with environmental often being prioritised (Alam, & Kumar, 2013). The conventional sustainability problem areas of environmental often can be seen to be energy consumption, emissions during the different construction phases and the road impact such as slope, curve, and road footprint (Alam, & Kumar, 2013). Some other not so common environmental sustainability areas are: biodiversity, habitat protection, sound and light pollution, air and water quality, land use and visual amenity, climate change considerations, resource conservation, source of materials, waste management and future proofing (Griffiths, 2008). Therefore with this information for a sustainable RS to be effective it would have to analyse and incorporate these areas. To increase the efficiency incorporating other sustainable areas that may arise throughout the life cycle of the project is important. Literature reveals that many organisations within the road industry would benefit from a sustainable RS being incorporated into its project (Muench et al, 2011).

This is supported as literature states that the necessity of a RS in many organisations and projects can be simplified down to five main reasons:

- Encourage more sustainable practices in roadway design and construction
- Provide a standard quantitative means of roadway sustainability assessment
- Allow informed decisions and trade-offs regarding roadway sustainability
- Enable owner organizations to confer benefits on certified road projects
- Establish an implementable baseline requirement for roadway sustainability.

(Muench et al, 2011).

With this information provided it was believed that sustainable road RSs can have a positive influence on the project even though it is often thought otherwise. Analysing the previous literature reveals that there are numerous RSs utilised by organisations, it was decided that the main systems that will be analysed and revealed to be important are:

1. Green Roads (USA)
2. Institute for sustainable infrastructure (Envision) (USA)
3. Infrastructure Sustainability Council of Australia (ISCA) (AUS)

2.2.1.1 Green Roads Rating Systems

Analysing the literature reveals that a common RS utilised by many organisations is Green Roads. The success of Green Roads as a RS can be attributed to the fact that they offer guidance in the design phases, construction phases and maintenance and management phases. Another key factor to the success of Green Roads in the road industry is it specifically designed and created with road development and management in mind. This differs from the other common all-inclusive infrastructure RSs. The fact that Green Roads has analysed and developed sustainable practices for the entire lifecycle of the project allows a more accurate and sustainable project to be constructed. This has a positive influence as often construction projects only concentrate their thoughts about sustainable practices in the design and construction phases. This approach neglects later phases of the construction where many opportunities for sustainable practices to be implemented occur.

Green Road consists of 7 voluntary categories as seen in Appendix B: Green Roads RS, with each 7 voluntary categories having subsections to emphasize and investigate all

aspects of construction. These 7 categories can be seen to encompass all aspects of sustainability from environmental, social and economic. It is often stated that organisations cannot achieve all 7 voluntary credits points due to the nature of the construction industry; however they can strive to amass as many points as possible. This allows companies in the road industry to decide which sustainable practices would be best suited for their specific project, thus making sustainability more achievable and manageable for organisations. If an organisation adopts Green Roads RS approach it can be seen to have significant advantages and benefits that can be seen below: The information utilised in this section was sourced by Bevan, T et al (2010) and Muench et al (2011).

1. Environmental benefits
    a. Reduce emissions
        i. Reduce Air emissions
        ii. Reduce wastewater emissions
        iii. Reduce soil/solid waste emissions
    b. Reduce consumption
        i. Reduce water use
        ii. Reduce fossil energy use
        iii. Reduce raw material use
        iv. Create renewable energy
        v. Optimise habitat and land use
2. Human-Centric benefits
    a. User improvements
        i. Improve human health
        ii. Improve access and mobility
    b. Interaction improvements
        i. Increase awareness
        ii. Improve aesthetics
        iii. Create new information
3. Economic Benefits
        i. Improve business practice
        ii. Increase lifecycle saving
        iii. Increase lifecycle service

(Bevan, T 2010).

2.2.1.2 Envision Rating System

Another common RS that is often utilised by American based organisations is called Institute for Sustainable Infrastructure who is responsible for the creation of Envision. The literature reveals that the Envision RS is a holistic framework used for evaluating and rating the community, environmental and economic benefits of all types and sizes of infrastructure project (Clark, A 2014). The basis of the RS Envision is similar to Green Roads as both provide a simple approach to demonstrate to the organisation the possible sustainable avenues in which the organisation may take. This RS is broken down into five different categories; refer to Appendix C for the sub categories; however the main five are as followed:

- Quality of life
- Resource allocation
- Climate and risk
- Leadership
- Natural World

(Bertera, B 2012)

Though this specific RS does not solely specialise in road infrastructure compared to Green Roads, it does however look at the broader picture of infrastructure. However this study reveals that it can still be utilised effectively by organisation which are developing and/or managing roads. The five different levels that can be achieved by organisations implementing Envision RS are:

- Improved: Performance that is at or above conventional standards.
- Enhanced: Indications that superior performance is within reach.
- Superior: Sustainable performance is noteworthy.
- Conserving: Performance that has achieved essentially zero impact.
- Restorative: Performance that restores natural or social systems.

(Bertera, B 2012)

When analysing these levels that could potentially be achieved by organisation constructing or managing roads, a realistic but impressive goal would be organisation attaining a rating above superior. Evaluating the criteria that needs to be met in order to achieve a superior or higher rating as mentioned before can be seen to be in five categories.

2.2.1.2.1 Quality of life

Critically evaluating the quality of life category it reveals that the main focus behind this category are the purpose of the project, wellbeing and finally community, in which these three points are separated into 13 subcategories (Bertera, B 2012). This is an important aspect to consider as this category relates to the social and community aspect of sustainability. For any road organisations that decided to develop and/or managing any particular road it can be deduced that this category is upmost importance that needs to be incorporated into any sustainable discussions. Albeit this often is not the case as social sustainability get scant attention in mainstream discussion compared to the other two main spheres of sustainability; economic and environmental (Peduto B 2012). This is an issue that needs to be combatted if the goal of achieving a superior rating or above in the road industry.

2.2.1.2.2 Leadership

The second category within Envision RS is leadership; this was included in Envision as they believe that correct leadership would significantly improve sustainable construction, thus allowing organisations to achieve a higher score (Alam & Kumar 2013). Further research reveals that Envision has separated leadership into; collaboration, management and planning sub-sections (Bertera, 2012). Collaboration is concerned about unifying all parties involved in the project towards achieving and maintaining sustainable practices (Bertera, 2012). The unification of all parties, particularly the engagement of stakeholder is not just preferred but in fact a pivotal requirement of any project (Morse & Bell, 2012). Management sub-category of leadership is concerned specifically about establishing a sustainable management systems and improved infrastructure integration (Bertera, 2012). These aspects are important if it is wished that an increase into sustainability in road development and management.

The final aspect of leadership is planning, this particular Envision category analyses and rewards criteria points for organisations that encompasses and implements plans for maintenance and monitoring and addresses the possibility of extending the useful life of the road (Bertera, 2012). This is a significant sustainable practice that all road projects can implement on their project; this is true as any road project considering its sustainability impact would benefit by analysing its lifecycle perspective (Pears, 2004). Research reveals that most of the environmental, social and economic influences associated with roads are not directly owing to the construction phases, but in fact results from policy decisions concerning how to satisfy a need and how the road is utilised (Pears, 2004). This source suggests then that the subcategory planning carries significant weighting when it comes to achieving a sustainable development and management of a road (Pears, 2004).

2.2.1.2.3 Resource Allocation

The third category in the Envision RS is resource allocation. Envision believes that this category is significant in order for road development to achieve a superior and above sustainable rating (Bertera, 2012). This particular category has been separated into; materials, energy and water (Bertera, 2012). It is believed that the material section of resource allocation analyses the project use of recycled material, use of regional materials, divert waste from landfill, and reduce excavated material taken off site. The construction industry is one of the largest contributors to waste and pollution throughout its full life cycle (Horvath 2004). It is believed that the building and construction industry accounts for 39% of total energy use, 12% total water consumption, 68% of total electricity consumption, and 38% of carbon dioxide emissions. Furthermore, construction waste composes 40% of landfill material (Allen et all, 2008). Analysing the current literature and the above statistics reveals why Envision has incorporated material into its sustainable RS. These figures are significant and highlights just how unsustainable the current construction industry is. It is believed if road development and management wishes to become sustainable then the above statistics have to be combatted and improved, which can be aided in the utilisation of Envision RS.

Unfortunately a shortcoming of Envision RS has arisen when undertaking this literature review. It states if companies wish to get criteria points in the resource allocation category you are required to reduce certain aspects. However the guidance stops there, this can be

improved significantly by Envision by giving assistance and recommending practices that can be utilised by the road industry. Though Envision does have shortcomings, in general Envision RS if incorporated correctly incites discussion and critical thinking of ways to combat these statistics stated earlier, which may otherwise be lost in the road industry.

2.2.1.2.4 Natural World

The next category that Envisions RS incorporated is natural world. Analysing this category it can be deduced that this category encompasses three main aspects; siting, land and water, and biodiversity (Bertera, 2012). The first aspect is siting, which focuses on the footprint of the road, and the site that has been selected (Bertera, 2012). When developing and planning roads, companies that are utilising Envision RS receive criteria points if they, consider and preserve prime habitat, preserve and protect wetlands and surface water, preserve and protect farming land, avoid opposing geology, preserve and protect Greenfields sites (Bertera, 2012).

This category can be summarised as developing and constructing the road in accordance with the location selected. Whilst also taking into consideration important areas surrounding the footprint of the future road (Envision, 2012). This is an important aspect as not only does it tick the environmental sphere but by considering the surrounding area it also aids the economic and social sphere of sustainability.

The economic sphere is achieved as it is believed that brownfield sites are more economical due to the existing infrastructure and services. If the surrounding areas of the project is preserved it limits the disturbance to the community and increases the perception of the company. Therefore selecting and making decisions with sustainability in mind regarding siting can significantly reduce the impact the development and management of roads has on social, environment and economics.

The category natural world progresses to incorporate and incite thought into land and water, this relates to managing stormwater runoff that may occur during development of roads, reducing pesticide and foreign soils being implemented into the area, and finally prevent contamination of surrounding grounds and water (Envision, 2012). Biodiversity has been included into natural world category which incorporates, the project preserving local species sharing the space of the project and restore disturbed soils (Envision, 2012).

2.2.1.2.5 Climate and Risk

The final category incorporated into Envision is climate and risk. This particular category is interested in two main principles: Emissions, and Resilience (Envision 2012). Analysing the emission subcategory it becomes clear in order for road development and management to attain sustainability. A hurdle that needs to be overcome is reducing greenhouse gas emissions, air and dust pollutants (Bertera, 2012). These aspects have significant effects on all three spheres of sustainability; therefore require consideration by all parties of the project. The next main principle in climate and risk is resilience, this subcategory relates to the climate threat, preparing for long term adaptability and finally preparing for short term hazards (Envision 2012). In relation to road development and management the adaptability of the road in question is a significant factor to consider when evaluating sustainability. Due to the ever changing modern road infrastructure in many countries it has become paramount that roads must process the ability to be able be upgraded, renewed and adapted (Dell et al, 2014) This will allow roads to attain a higher sustainability rating as theoretically if you increase the adaptability of the road you simultaneously increase its life expectancy thus rendering future virgin roads redundant (Dell et al, 2014). It is stated that future roads will be constructed in a way to increase its adaptability to increased travel volumes and to accommodate fluctuations in demand for public transport, cycling and walking.

2.2.1.3 Infrastructure sustainability Rating System

Further investigation of the current literature reveals that another RS that will be analysed is the infrastructure sustainability rating scheme. Infrastructure sustainability or commonly referred to as IS was the original RS developed and utilised within Australia, it is a voluntary system that aims to measure the sustainability performance of projects (Walters & Lees, 2013). IS can be seen to be similar to the previous RSs in the way that both systems assess sustainability across the life of the project; design, construction and operation of infrastructure (IS Overview, 2014). It also evaluates the sustainability including environmental, social, economic and governance aspects of infrastructure project and assets (IS Overview, 2014). There are six main themes and 15 subcategories which carry 51 credits refer to appendix D for the detailed IS RS however themes and categories are listed below:

- Management and Governance
    - Management systems
    - Procurement and Purchasing
    - Climate Change Adaptation
- Use of resources
    - Energy and Carbon
    - Water
    - Materials
- Emission, pollutions and waste
    - Land
    - Discharge to Air, Land & Water
    - Waste
- Ecology
    - Ecology
- People and Place
    - Community Health, Well-being and Safety
    - Heritage
    - Stakeholders Participation
    - Urban & Landscape Design
- Innovation

(IS Overview, 2014)

The IS rating tool differs from the previous two sustainable RSs Green Roads and Envision; in the way that IS rating tool is a self-assessment tool. This can be seen as the user/project team nominate a performance that they deem they have achieved across each category and subcategory and provide supporting evidence (Hargroves, 2014). With the information and supporting evidence supplied it is then critically analysed and compared to predetermined weightings implemented into the IS rating tool, the overall rating is then estimated and compared to a likely level of achievement (Hargroves, 2014).

The possible levels of achievement are: Commending, Excellent and Leading. To achieve a commending achievement in sustainability you must receive a score between 25- 49. Excellent achievement requires the project to obtain a rating score between the figures 50- 75. Finally the Leading is the highest awarded achievement which requires a score

between 76- 100, this is the ideal achievement which many road projects can achieve. The above statics and figures were sourced at Infrastructure Structure overview (2014).

It can be deemed that the fact IS rating tool added a self-assessment aspect to their tool is significant for the future and success of sustainability. This self-assessment and the need for the project to provide and support evidence of sustainable practices allow further discussion and education into sustainable practices which are all critically important. This statement can be supported as education can be seen to be an essential tool for attaining sustainability within the road industry, and that public awareness, education and training is critical to moving the industry towards sustainability (Mckeown, 2012). The importance of discussion and education of sustainability can be carried over into the road industry in specific the development and management of roads due the significant and importance of roads.

It is stated that roads are the largest asset class of many local types of councils, with road management their largest operation activity (Walters & Lees, 2013). The literature review into IS rating tool revealed that there are some key benefits that can be seen if organisation utilise the rating tool:

- Provides a common national language for sustainability in infrastructure.
- Supports consistent application and evaluation of sustainability in tendering processes.
- Scopes whole of life sustainability risks for projects and assets, enabling smarter solution that reduces risks and control.
- Foster resources efficiency and waste reduction, reducing cost.
- Encourages innovation and continuous improvement in the road industry.
- Builds an organisation credentials and reputation in its approach to sustainability in infrastructure.

(IS overview, 2014).

This rating tool has been trialled in local council around Australia, with one trial being held at Redland City Council (Walters & Lees, 2013). This trial conducted at the end of 2013, which has revealed a number of issues and shortcomings of the rating tool. Such issues include:

- The relevance of certain subcategories was questioned in relation to the development and management of roads.
- Interpretation was required on certain subcategories in relation the operations context.
- Confusion around street lighting which typically resulted in the largest use of energy in road management are often not managed by the local council, but are paid for by the council.
- The trialled council believes that asset deconstruction/disassembly is meaningless in road development and management as often these assets are upgraded, re-used and renewed indefinitely.

(Walters & Lees, 2013)

Further literature reveals that Infrastructure Sustainability Council of Australia if wished to combat these issues that were raised modifications had to be made (Walters & Lees, 2013). This can be a significant aspect Infrastructure Sustainability Council of Australia requires change otherwise local councils and private organisation when developing and managing roads may discontinue using a sustainable RS due to these issued raised earlier. The first modification that might be made is removing potential credits that cannot be attained by the road industry; case in point the asset deconstruction/disassembly of roads is not achievable or realistic (Walters & Lees, 2013). Another modification the literature reveals is simplifying certain categories; this is a critical aspect that has to be modified by Infrastructure Sustainability Council of Australia if they wish for project to utilise their rating tool (Walters & Lees, 2013). This is seen to be significant as they whole point rating tool is to be a simple guidance tool that can be utilised by organisation to achieve and increase sustainability in the road development and management industry.

2.2.2 Lean Construction

The construction industry is one of the largest contributors to pollution and waste through its life cycle (Horvath 2004). It is believed that the building and construction industry is responsible for an estimated 39% of total energy use, responsible for 12% total water consumption, contributes to an approximately 68% of total electricity consumption, and 38% of carbon dioxide emissions. To add to these statics it is believed that construction waste is accountable for 40% of landfill material (Allen et all, 2008). These substantial statistics can be seen to be caused by construction activities as they impact the

environmental at every phase of the building process from: extraction of raw material, processing of the material, manufacturing, transportation, construction and finally demolition/disposal at the end of the building useful life (Edge Environment, 2012). These figures listed above especially the figure of construction waste contributes to 40% of the total landfill has significant impact upon the environment. The bi-product of landfill can be seen to be methane which contributes to global warming (Australian Bureru of Statistics, 2010).

Analysing the current literature and revealing statistic stated above it is common knowledge that a new practice needs be implemented across the construction industry. An upcoming practice that is creating significant change in the road and construction industry is lean construction (LC). This philosophy origin can be seen to be in the manufacturing industry, in specific Toyota production team (Koskela, 1992).Toyota was the first organisation to bring 'lean principles' into the spotlight, this primitive form of LC is structured around seven principles in its production manufacturing, with its core being preserving value with less work (Intergraph, 2012). This principle that was put forward by Toyota into the mainstream media required significant time to be adopted and accepted as an adequate principle (Intergraph, 2012). It wasn't for another two decades before lean principles utilised by the manufacturing industry would be deemed to synergise and embraced by the construction industry.

With the first literature recognition of the term LC in 1992 stating that the advantages of the new production philosophy in relation to productivity, quality, and indicators resulted enough in practice to decide to enhance the rapid distribution of the new principles (Koskela, 1992). Koskela (1992) introduced to the production industry the philosophy of productivity and quality to an unexpected construction industry.

Following on from Koskela new production philosophy it was stated that LC is much like the current practices that are utilised currently as the goal of better meeting clients' needs while using less of materials and resources (Howell, 1999). This was the first adaption of the often utilised production industry practice to be suggested as a practice that could utilised for the construction industry (Marhani, et al 2013). The refinement and adaptation of LC over the years has witnessed the definition to be developed and refined much like the principle itself (Marhani, M et al 2013). The definition that is best suited to common aspects of LC is about attaining an equilibrium in the use of people, materials and resources required to complete a task and/or project (Marhani, M et al 2013). This allows companies

to reduce cost while eliminating waste and delivering the projects on time, however it is not about eliminating everything and expecting to get more out of what is left (Kim, 2006).

Analysing the previous literature review this research project believes that LC philosophy of reducing waste to create higher profit can be adapted and modified to synergise with sustainability. This can be achieved as the fundamentals for LC principles is a proven way to reduce waste and increase productivity therefore attracting popularity within the road industry; thus in turn making sustainable roads viable for clients (Marhani, M et al 2013). Due to its inordinate potential in satisfying client's requirements in term of growing the value and productivity of a road project, LC is seen as an alternative approach that can be implemented to the road industry (Marhani, M et al 2013).

Due to the overwhelming literature supporting the advantages that are witnessed by the construction industry from the implementation of LC; cutting down the amount of material, labour and resources to the required level significantly impacts and alters the cost of the project positively. Another advantage that is associated with LC is; due to the increased planning that is required, a shorter project duration is experienced, all the while promoting sustainable construction (Marhani, M et al 2013). Analysing the literature reveals that there is seven key aspects impeding on companies utilising LC, such as:

- Managerial
- Technical
- Human Attitude
- Process of Lean Construction
- Educational
- Government
- Financial

(Marhani, M et al 2013).

2.2.2.1 Managerial

Managerial implementation barriers can be described to be a significant barriers many organisations have to overcome if they wish to implement LC on their project (Marhani, M et al 2013).This can be summarised to be a lack of support from top management (Abdullah et al, 2011). This is a difficult barrier to overcome as without commitment from top

management stakeholders may struggle and encounter numerous difficulties in the pursuit of sustainability.

2.2.2.2 Technical

The next barrier that needs to be countered is the aspect of technical; this refers to the constructability of the project (Abdullah et. al, 2011). It is believed if a road design is difficult to construct then often members of the organisation may wish to allow extra resources, materials and/or labour to ensure any delays or problems can be dealt with adequately. A method that is suggested is to engage all stakeholders early on in the construction design phase. This will allow any foreseeable problems to be dealt with before they become critical (Morse, S & Bell, S 2010).

2.2.2.3 Human Attitude

The next barrier can be deduced to be human attitude; literature reveals that human attitude is seen to be one of the main influences that slow down the implementation of LC in the industry, particularly during the physical application period (Howell, 1999). This barrier refers to the stakeholder's commitment, tenacity and will-power to persevere in the implementation of LC (Abdullah et. al, 2011). The success of the implementation of LC in the industry is determined by how hard the stakeholders wish for sustainability. An example can be seen to be the performance of a worker to strive for an accurate estimate of material amount instead of allowing a percentage of error in his estimate (Abdullah et. al, 2011).

2.2.2.4 Process of Lean Construction

The process to implement LC requires significant amount of meetings and communication between all parties (Abdullah et. al, 2011). If these meetings and/or communication lines are deemed to be poorly managed then additional work and effort in the design phase of the project is deemed necessary (Abdullah et. al, 2011). This therefore can be seen to be a significant barrier as many clients wish to accelerate the design phase not hinders this stage due to their desire to begin construction as soon as possible. However this does not need to be the case as additional planning and designing will have a positive impact on the budget and success of the project (Abdllah et. al, 2011).

2.2.2.5 Education

The barrier of education revolves around the stakeholder's involvement in the construction project, and them receiving ample training in order for them to implement LC principles (Marhani, M et al 2013). As stated earlier in the research project the literature reveals that education is an essential tool for attaining sustainability within the road industry, and that public awareness, education and training is critical to moving the industry towards sustainability (Mckeown, 2002).

2.2.2.6 Government

This can be adapted to relate to the statement that stakeholders require ample training in order to successfully implementing LC principles in road development and management (Mckeown, 2002). This training entails top management and equivalent members taking time and resources in order to educate the masses, this will allow a balanced approach for LC.

2.2.2.1 Financial

The final barrier is financial, which relates to the inflation due to risky uncertain market condition for construction, additional construction cost and poor salaries of professionals (Olatunji, 2008). This effects the implementation as often clients wish to go with the safe option when construction their project thus often denying funds for LC practices to be implemented (Marhani, et al 2013). The lack of financial and reward incentive often occurring in the construction projects hinder LC being implemented (Marhani, et al 2013). In the way that contractors are not given the funds to allow for additional staff in the design phase of the project to create and develop accurate plans and resource requirements. Thus rendering LC near impossible as lack of effort in estimation and design will result in the project requiring extra resources than expected.

Analysing the literature a case study of a construction project reveals that using the mentioned practice of LC resulted in a significant environmental effect by reducing material waste by an estimated 64% on this specific project (Nahmens et all, 2012). These figures can be estimated to be of similar when comparing to road development and management. With this information stated it is clear how and why organisations are adopting LC in order to increase profitability on projects while still increasing sustainability. This research

project believes the next challenge faced is to engage the road industry into LC, all the while synergise LC with the continued efforts of recycling and other sustainable practices, to eliminate significant amounts of landfill contributed by construction industry. From the literature review, it was found that LC has the ability to improve the performance of construction projects particularly in reducing site waste, construction time and overall construction cost, improving quality of the projects and reduce its environmental impact.

2.3 Recycled aggregates and methods to improve sustainable development.

With management practices and tools reviewed and the literature concluded, it is stated that both RSs and LC highlight that resources and materials is a significant aspect. It is believed that this aspect of resources and materials needs to be evaluated if sustainable road development and management is wished to be achieved.

2.3.1 Sustainable Aggregates and Methods

Initial research reveals that Australia's sustainable aggregates industry is increasing in popularity within the road industry, with many making the decision to select sustainable aggregates over other less sustainable options within the market (Newson, 2012). Newson (2012) goes on to state that in 2008-2009 approximately 9 million tonnes of recycled aggregate was used to replace virgin aggregates. These are important figures to consider as early research reveals that sustainable recycled aggregates are in fact getting utilised throughout Australia. Victoria roads (2011) states that the most used aggregate within road development and management is crushed rock. This raising the question whether this crushed rock often a raw material mined could be replaced by other sustainable aggregates.

The effect that virgin material has on the environment is no hidden secret. The nature of construction is not an environmentally friendly process, this is especially evident when virgin materials are utilised by the project. The obtainment of virgin materials for construction projects has a significant negative impact on the environment in that they are depleting a finite resource, while emitting substantial greenhouse gases while attaining the resource (Ramesh et al, 2012). Global statistics shows that the construction industry as discussed in the research project in section 2.2.2 Lean Construction are depleting a total of 40% of natural materials all the while emitting 40-50% of global

greenhouse gas emissions (Ramesh et. al, 2012). It is claimed that the selection of sustainable materials often is reliant on which phase the project is currently within (Pacheco-Torgal et al, 2014). Evaluating the characteristics and properties of sustainability materials in the road project becomes paramount to the design and development of sustainable roads (Pacheco-Torgal et al, 2014). If selection of the material is left too late or not enough allowed time in design phase of the project it was found that unsustainable materials were often chosen over sustainable materials (Pacheco-Torgal et al, 2014).

2.3.1.1 Crushed Concrete

Research reveals that the most common and readily available sustainable aggregate is crushed concrete, as seen in figure 2: Crushed Concrete (Department of Victoria Roads 2011)

Figure 2: Crushed Concrete (Department of Victoria Roads 2011)

This sustainable aggregate is reported to have a 65% lower greenhouse emission influence associated to that of similar products made from virgin mined rocked (Department of Victoria Roads 2011). This is a significant sustainable aggregate that road industry needs to invest in as research reveals that concrete debris often constitutes the largest single aspect of all solid waste that is emitted to landfill, and the largest fraction of this is recyclable concrete (Wangchuk, 2013). Re-utilising crushed concrete is a paramount material that needs to be utilised whenever possible due to it benefits such as:

- Conserving natural finite resources
- Reduce the amount of waste sent to landfill
- Reduce natural resource exploitation
- Reduce transport costs

(Wangchuk, 2013).

Alex Fraser Group has emerged as an industry leading innovative organisation in recycling construction materials, they specialise in recycling concrete into crushed concrete often utilised as an aggregate in the road base (Hargroves, 2012). A case study into Alex Fraser group reveals and supports the benefits listed above in the case of the newly designed and built Clem 7 tunnel in Brisbane, Australia (Hargroves, 2012). The benefits recorded on that specific large road development project are:

- A Saving of over 1, 000 tonnes of Carbon dioxide
- Diversion of 100,000 tonnes of waste from landfill sites
- 120,000 tonnes reduction in natural resource depletion
- A saving of 725 truck movements (45,000 km of road travel)
- 20% reduction in material costs from savings in transport and sourcing.

(Hargroves, 2012).

Another important aspect that is revealed about recycled concrete as an aggregate is to do with the often pre-existing limestone found in concrete (Hi-Way Stabilizers, 2015).

2.3.1.2 Lime Stabilisation

Often it is found that stabilisation is required on the subgrade soil due to the types of soils found in the area of the project (Hi-Way Stabilizers, 2015). Lime stabilisation is the most commonly used kind of subgrade stabilising; this is because numerous projects that have subgrade soils of which are clayey (Hi-Way Stabilizers, 2015).

A method of road stabilisation instead of using an expensive lime mixture that is often implemented is mixing the crusher dust concrete into the subgrade soil to allow for the lime to penetrate the soil. This is a significant benefit to road development as it has been researched that lime stabilised subgrade soils strength improvements of up to 20 times

are often attainable depending on the type and reactiveness of the soil (Hi-Way Stabilizers, 2015). Other commonly known sustainability benefits of a lime stabilised road include but not limited to:

- Subgrade stability
- Compaction anvil
- Reduced pavement depth
- Increased Strength and Stiffness

(Hi-Way Stabilizers, 2015)

The increased subgrade stability that is often achieved with the extra lime in the subgrade allows for a more stable and durable subgrade (Hargroves, 2012). This allows greater resistance to the volume and strength changes that commonly occur due to moisture and temperature variations (Hi-Way Stabilizers, 2015). This in turns extends the expected life of the road before renewal and/or upgrades are required. This increased subgrade stability creates an 'anvil' in which subsequent aggregate layers may be compacted upon (Hi-Way Stabilizers, 2015). This allows road development to achieve denser roads in less effort, thus decreasing the amount of required energy and materials to achieve the required density of layers (Hi-Way Stabilizers, 2015).

With the implementation of lime stabilisation, a road project can reduce the required pavement depth; this is achieved by stabilising the subgrade. The increase in designed CBR strength allows a reduction in the required pavement depth, consequently reducing the volume of aggregate needed for the road development (Hi-Way Stabilizers, 2015). This generates reduced transport costs, reduced aggregate costs and reduces the amount of aggregate needed, and finally reduces time and energy if further depths were required (Hi-Way Stabilizers, 2015).

Another common benefit of using recycled concrete that possess limestone content is increase strength and stiffness often achieved on the subgrade (Hi-Way Stabilizers, 2015). This simply put means a stronger stable subgrade that hinders deformation and failure that other road sub-grade encounter over their lifecycle (Hi-Way Stabilizers, 2015). In summary, the utilisation of recycled concrete as an aggregate can be seen to be an exceptionally sustainable aggregate due its limestone content, it's a recycled material therefore conserving the finite resources, and economical benefits to the project.

2.3.1.3 Recycled Glass

Another common sustainable aggregate that can persuade organisations away from the often chosen virgin crushed rock as an aggregate is post-consumer glass. This sustainable aggregate is different from normal materials as glass has the unique ability that it can be recycled numerous times without changing its chemical properties (Wangchuk et al, 2013). Often this sustainable material is sourced from pre-existing buildings, recycled glass bottles and glass factories (Wangchuk et al, 2013). Currently this sustainable aggregate is often implemented as an aggregate and/or binder for the asphalt pavement layer of modern roads, but it can also be used as part of the admissible foreign material component of road-base and sub-base (Hargroves, 2012).

Literature has indicated that this sustainable aggregate is not being utilised to its full potential in Australia, due to many states dictating that glass aggregate be categorised as a foreign material (Wangchuk et al, 2013). This lack of use for glass is due to governments enforcing that only 3% of foreign material can be present in asphalt pavements and road-bases (Wangchuk et al, 2013). One organisation, the municipal association of Victoria, is promoting the use of recycled materials in-particular recycled glass; they are recommending that the amount allowed by the governments be extended from 3% to 15-25% (municipal association of Victoria, 2015). This increase is supported by a trial conducted by Swinburne University which has proven that mixtures of up to 30% recycled glass are found to be achieving equal performance to, or exceeding that of blends using virgin rock as aggregate (Wangchuk et al, 2013). Another study that was conducted over in Fulton Hogan, New Zealand reveals that the trial conducted of utilising a higher content of glass displays no visual signs of rutting, distress or fracturing (Wangchuk et al, 2013)

Analysing the disadvantages of this sustainable material exposes that when glass is positioned and compacted often larger glass particles will bring into line with one another, therefore running parallel to the road surface, this affects the skid resistance of asphalt to be inferior to that of conventional asphalt (Clean Washington Centre, 1996). This is a significant issue that requires road development projects to analyse as safety for the commuter is paramount even over sustainability. In light of this fact often glass will not

be utilised in surface pavement on highways, due to the reduced skid resistance (Clean Washington Centre, 1996).

Another issue that has been witnessed by the road industry, in relation to recycled glass being utilised in the development stage relates to bonding. It is an ever occurring issue that all road development projects are required to understand and manage the bonding between aggregate and asphalt. In particular when under heavy volume and over a long duration of time it can be seen that these bonds weaken (Clean Washington Centre, 1996). This weakening of bonds will effect and cause the asphalt to strip and free itself from the aggregate, increasing the potential for early life failure (Clean Washington Centre, 1996). This can occur to any selected aggregate and asphalt, however due to the smooth surface of glass it can be analysed that the stripping potential is higher than that of natural rougher aggregates (Clean Washington Centre, 1996). This needs to be understood and corrected as a shorter life cycle is potentially increasing maintenance therefore can be seen to be unsustainable.

2.3.2.4 Recycled Tyres

It is estimated that within Australia approximately 20 million car and truck tyres are scraped annually throughout Australia, with the situation in Queensland contributing approximately 3.5 million (Queensland Transport, 2009). This statistic is further worsened by the figures that 60% of these tyres are sent and disposed to landfill, while its estimated that only 30% of tyres are recycled either by re-treading or other methods, the final 10% of these tyres are seen to be disposed and dumped illegally (Hargroves, 2012). This quantity of un-recycled tyres is an issue that needs to be combatted, as stockpiling up of tyres is not an ideal situation (Queensland Transport, 2009). This is the case as each tyre can be calculated to approximately consist of 1L of oil, therefore extremely flammable and in the case of a fire will incur catastrophic environmental, economic and social issues (Hargroves, 2012). The statistics that only 30% of all tyres are recycled within Australia may be caused due to that fact that there is estimated to be roughly 10 recycling outlets compared to 4,000 tyre retailers and 30 organisation licensed to dispose of tyres (Hargroves, 2012).

The use of these tyres within the road industry generally encompasses the tyres be shredded to produce a material called crumb rubber. This product is implemented as a

binder in the production of asphalt and has been seen to be successfully executed across Australia (ARPG, 1999). Due to the presence of rubber the asphalt improves numerous critical properties such as: increased durability; thus reducing the chance of road fractures and cracking due to limiting the fluctuations of thermal changes that are often present throughout Australia (ARPG, 1999). This allows a longer life cycle in many cases to be an achievable goal. This is supported by ARPB (1999) when they conducted tests that concluded rubber asphalts can produce both good rutting and fatigue performance simultaneously, compared to conventional asphalt (ARPB, 1999). Another benefit due to the presence of rubber in relation to asphalt production in the road industry is an increase in skid resistance (ARPG, 1999). This impacts the social aspect of sustainability as a safer road for the stakeholders that use the road is an important worth-while aspect. Another social and environmental sustainable benefit is the belief that crumbed rubber when present in the road pavement reduces the noise emitted by the traffic volume (Queensland Transport, 2009). This will have long-term beneficial impact upon the surrounding community adjacent to the particular road by limiting the disturbance that would be present. Not only is it be advantageous in limiting the disturbance to the surrounding human community it would also allow the surrounding wildlife less disturbance throughout the day and night.

Another useful utilisation of the recycled tyres in the road industry is being explored by an organisation called Ecoflex. This organisation sees the removal of the sidewall of used tyres to create a structural unit or container (Hargroves, 2012). The unit voids are then packed with crushed rock, gravel, sand/or soil, thus forming a structural building block that performs almost as an aggregate unit (Hargroves, 2012). Typically this engineered recycled unit can be adapted to aid in many construction situations; however the main use in relation to the road industry is using this unit to create a high strength sub-base (Hargroves, 2012). This is constructed from a single or double deposit of car and/or truck tyres, filled with this the different types of rocks and sands (Hargroves, 2012) With this unit implemented it is often revealed that this unique engineered system allows for a better dispersion of the typical load and pressure witnessed on a road (Hargroves, 2012). An example of the engineered recycled unit and its appropriateness to the road industry is being implemented by many haul roads in the Hunter Valley. The wet, soft-subgrade present in mines are often deemed to be susceptible to degradation under extreme heavy pressure emitted by equipment (Hargroves, 2012). The results from this trial demonstrate that the recycled tyres mitigate erosion and drainage problems better than other

construction methods (Hargroves, 2012). This method allows and permits water to naturally drain without impacting on the overall strength of the road and structure (Hargroves, 2012). The utilisation of this new recycled unit affects sustainability in a positive manner as it limits the environmental impact often associated with mining haul roads, all the while providing high quality durable roads that heavy equipment can rely upon.

These aspects are important if recycled material is wished to be widely implemented across Australia as they not only attract attention due to their environmental benefits, but often this recycled material reduces the total project cost (Foth et al, 2011). This can be seen in the case study investigated as it calculated the difference between conventional unsustainable roads developments would of cost compared to a recycled sustainable road development as seen in figure 3: Cost of conventional vs. recycled pavement structures (Foth et al, 2011). This specific case study was undertaken on an American built urban road that utilised numerous sustainable practices. The road design subgrades can be seen in figure 4 and 5. This is important as this shows another appealing aspect of sustainable road development aggregate that could be utilised, this advantageous aspect is value for money therefore attracting clients and/organisations.

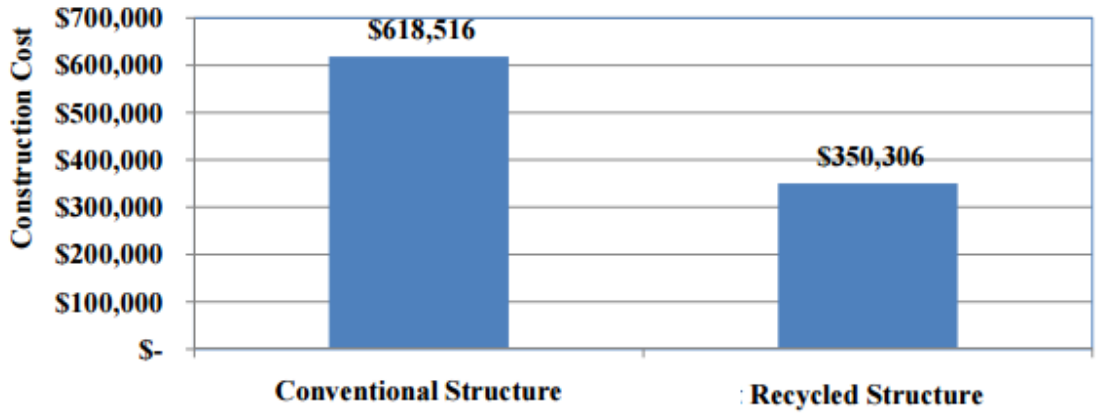

Figure 3: Cost of conventional vs. recycled pavement structures (Foth et al, 2011)

The difference between conventional road development structure and the recycled structure can be seen in figure 4 and 5.

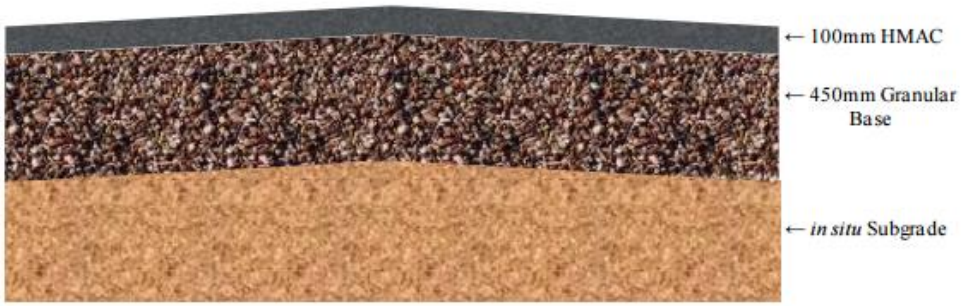

Figure 4: Conventional road structure (Foth et al, 2011)

Figure 5: Recycled Structure (Foth et. al, 2011)

Another methodology that can be implemented across the road industry is warm-mix asphalt. Simply put this methodology allows a reduction in the overall temperature of the asphalt in the production phase of approximately 20% (Politano, L 2012).

Typically it is seen that hot mix asphalt is produced at a temperature close to 150 Celsius or higher depending on the different types of binding agents utilised (Politano, L 2012). With the new technology and methodologies it is researched that asphalt can be produced at a cooler temperature; roughly 120 Celsius (Hurley, G & Prowell, B 2005). These reductions in temperature can be achieved by incorporating a variety of additives, foaming technology and chemically modified asphalt (Hurley, G & Prowell, B 2005). With this significant reduction of heat required in production of asphalt many benefits are associated with the new technology such as:

- Reduced Fuel consumption at the asphalt pant
- Reduced emissions at the asphalt plant
- Reduced asphalt fumes at paving site
- Reduced construction delays
- Potential for improving long-term pavement performance

(Politano, L 2012).

As mentioned earlier in the research project due to the temperature reduction in the production of warm mix asphalt compared to hot mix asphalt, it is claimed that this equates to a reduction in the required energy and fuel needed in the production process (Politano, L 2012). Studies indicate that a reported total energy saving ranging from 20-35% at the asphalt plant with an average fuel saving of 23% (Politano, L 2012). This equates to roughly 1 to 2 litres of fuel saving per tonne of asphalt produced; this extrapolated can result in substantial savings in road development (Politano, L 2012). Therefore this aspect is not only creating an environmentally sustainable benefit but also an economic benefit for the organisation and/or client.

Generally, the production of asphalt can be seen to emit large quantise of emissions, primarily Greenhouse Gas (Politano, L 2012). Analysing the difference in warm and hot asphalt production it reveals that due to the reduction in energy and fuel combustion necessary to get the required temperature, typically the emission are seen to be slightly lower (Hurley & Prowell, 2005). This reduction in emissions signifies an important cost savings, considering that it is estimated that 30-50% of the total overhead costs at an asphalt plant can be linked to emission control (Hurley & Prowell, 2005).

Often the reduction in emission means that plants meet specified air pollution regulations therefore can be built in ideal location in regards to projects, which can limit transport time and cost (Politano, L 2012). Similar to the previously mentioned benefits this falls into the two spheres of sustainability: economic and environmental. This aids in the decision to select the warm mix asphalt over conventional hot mix asphalt.

Utilising warm mix asphalt can be deemed to influence the volume of fumes and dust emitted when laying down at the paving site (Politano, L 2012). Lower temperatures also mean that any emissions, either visible or non-visible, that may contribute to health problems, odour problems, or greenhouse gas emissions, will also be reduced (Politano, L 2012). This encompasses social sustainability in that the surrounding community in relation to the location of the development road is limiting the interruption to the community. This reduction of dusts and fumes also provides better working conditions in which crew members operate in, thus creating a safer environmental for all stakeholders; which hopefully produces a more productive working environment (Politano, L 2012).. A comparison between hot mix asphalt and warm mix asphalt fumes being emitted can be seen in figure 6.

Figure 6: Comparison of Hot mix asphalt and warm mix asphalt (Politano, L 2012).

The use of warm mix asphalt in numerous situations shows a reduction in the duration of the laying of the asphalt (Politano, L 2012). This is a significant social and economic boost in favour of warm mix asphalt as reducing the interference to the surrounding community and stakeholders is paramount. An example of reducing the interference is in relation to the duration in which the road is closed. Simultaneously while reducing the annoyance to the community it can be seen that a cost saving can be deemed to be achievable as road closures and employment of adequate traffic staff is an expensive operation.

It is an important aspect that warm mix asphalts if to be sustainable has to achieve similar strength and durability standards to that of a high mix asphalt. Moisture susceptibility from incomplete aggregate drying and insufficient binder stiffness can lead to pavement deformation such as rutting and fracturing (Sullivan, E & Moss, A 2014). This is not an issue as it is believed that warm mix asphalts have comparable resistance to rutting relative to conventional hot mix asphalt (Politano, L 2012). The ability in which the asphalt resists thermal cracking is another important criteria as this type of deterioration can have calamitous effects (Sullivan, E & Moss, A 2014). In relation to warm mix asphalt when comparing to conventional asphalt has an increased thermal cracking resistance, thus increasing the life expectancy of the newly developed road (Sullivan, E & Moss, A 2014). Another factor to consider when deciding upon warm mix asphalt is the binder aging (Politano, L 2012). It is known that the lower temperature at which warm

mix asphalt is developed and poured will result in reduced asphalt binder oxidation, aging and hardening (Politano, L 2012).). Summarised this means an increased life expectancy when comparing to the conventional approach.

Analysing wet mix asphalt it is found that the most popular method of producing warm mix asphalt is in fact water based foaming (Sullivan, E & Moss, A 2014). Water based foaming is responsible for approximately 88% while additives make up 22% of the market (Sullivan, E & Moss, A 2014). Due to water-based foaming requiring no extra additives, therefore a cheaper option this is why such a significant portion of the market selected that specific technology (Sullivan, E & Moss, A 2014). The issue that arises with this selection compared to other method is the quantity of clean drinking water required to interact with the liquid binder to create a foaming effect (Sullivan, E & Moss, A 2014). Even though it has slightly lesser saving costs to the client it is believed that organic additives such as waxes are a preferred selection (Sullivan, E & Moss, A 2014). This requires significant reduced amounts of water, all the while reducing the temperature further during production.

2.4 Current barriers affecting implementation

It can be deduced that there are many factors hindering sustainable development and management in the road industry. Despite international acknowledgment that the construction industry needs to travel towards sustainability, current action has been mainly conceptual to date and has not adapted entirely by the road industry (Pryce, 2001). It can be deduced that certain factors can be attributed to hindering the implementation of sustainability in the road industry. These factors include:

- Inadequate resources.
- Lack of momentum and motivation from the client/contractor.
- Lack of knowledge and techniques within the company.

(Pryce 2001).

4.3.1 Inadequate Resources

The first barrier that can be seen to be encountered by many councils and/or companies is the issue of having inadequate resources. This term relates to the company and/or council having finite amount of resource such as cash and capital, employees and time,

to name a few examples. This is a difficult barrier to overcome with many aspects contributing to why companies struggle to achieve sustainability due to inadequate resources. As mentioned previously in the research project, this barrier could potentially be overcome by demonstrating and showing construction organisation about LC. This research project believes that LC eliminates the common five wastes often experience on construction projects as seen in table 1: Five types of wastes. These five common wastages can be seen to significantly impact the project negatively; this statement is supported by various studies revealing that:

- quality costs due to non-conformance can be up to 12% of total project costs
- Poor materials management can be unto 10-12% of total project costs
- Excess consumption of material (on sites) is on average up to 10% of total costs.
- Working time on non-value adding activities on sites can be up to 60% of total time

  (RIB Consultants 2013)

If LC eliminates these five common wastages it can be seen to significant increase resources such as cost and profit, time and client relationships. To further analyse these common wastages Ortiz (2009) suggests that there are five types of waste within the construction industry. Due to the barrier that many organisation face of inadequate resources to implement sustainable practices these five types of waste need to be combatted. As suggested previously LC may eliminate or mitigate certain types.

Table 1: Five types of wastes (Ortiz, 2009)

Type of Waste	**Description**
Defects	Quality errors that have become costly and were not prevented
Overproduction	The act of producing more than what is needed, before it is needed, and faster than is necessary. Overproduction is by far the most common type of waste in an organization, and it can breed other wastes.
Waiting	When manufacturing and operational process are out of synchronization, people and machines are idle.
Transportation	Movement of material (raw material, work in progress and finished goods).

Inventory	Excessive levels of raw material, work in progress and finished goods in correlation to throughput time and delivery requirements.

4.3.2 Lack of Motivation

The second barrier that can be seen as a factor that impacts on the ability to achieve sustainable road development and management is the client/contractor company aren't motivated or don't see its advantages. Certain advantages include reducing total cost of the project and reducing the overall time to develop and manage a sustainable road. (Ortiz, 2009). It can be deduced that the main way to combat this barrier is to increase the pressure put upon the company, client and contractor by tightening the standards and procedures that are enforced by law (Ortiz, 2009). Another method that could be seen to be easier would be the community applying pressure that as a stakeholder one of their needs and expectations is a sustainable road development and management.

4.3.3 Lack of Knowledge

The third barrier that impacts on companies and council ability to achieve sustainable road development and management is there lack of knowledge and techniques (Ortiz, 2009). This term relates to the company not processing the appropriate employees who have the required knowledge and skills to achieve a sustainable road development and management (Ortiz, 2009). This is usually the case as sustainable road development incorporates new materials and techniques of implementation, causing employees or companies difficulties to adjust (Ortiz, 2009). A method to combat this barrier would be implementing an expert figure into the company who has the required skills, knowledge and experience working with sustainable roads development. Another method can be seen to be training the pre-existing employees with the new procedures and practices associated to sustainable road development and management.

2.5 Conclusion of Literature Review

The literature reviewed validates that there is ample amount of sustainable practices that can be utilised in management and development of road industry, to have significant benefits and impacts to the three spheres of sustainability. From implementing LC, RSs,

recycled aggregates, lime stabilisation, sustainable development practices and overcoming barriers it is believed that sustainable road development and management is a worthwhile endeavour that should be implemented across the industry.

The literature reviewed reveals that management practices discussed earlier in the literature research has a substantial impact on environmental, economic and social sustainability. This is the case as implementation of management practices such as LC and RSs allow top management to influence the overall sustainability of the road project thus creating an environment for sustainable thinking. Even though the benefits of sustainability is clear in the road industry as mentioned earlier there are many barriers impeding on the adoption and implementation of sustainable practices and management. It is important to understand that sustainability is not merely a checklist that you incorporate into road projects just to satisfy the external community and regulations, if incorporated correctly and effectively sustainable practices can have significant benefits upon the road industry.

CHAPTER 3 - RESEARCH AND DESIGN METHODOLOGY

3.1 Methodology

The methodology utilised throughout this research project stayed consistent with all stages being completed. It was decided that this dissertation will be broken down into four distinct phases; they are as followed.

- Start-up phase: This phase involves gathering all the required information about sustainable road development and management.
- Applying Phase: This phase involves creating the formal letter requesting permission to undertake site visit and analysis on specific roads.
- Site visit Phase: This phase of the project involves commencing the site visit, gathering any information about the site like current sustainable practices etc.
- Write up Phase: This phase is presenting all the finding, recommendation and information in a formal written research project.

A more in-depth breakdown of the four methodology phases including individual descriptions of tasks can be seen in table 2: Descriptive project methodology

Table 2: Descriptive Project Methodology

Phase 1	**Start-up Phase**
1A	Brief research into the topic of sustainable road development and management
1B	Research conducted based on the brief research into the topic
1C	Review information and determine what is relevant and useful for this project.
1D	Determine common sustainable practices within the road industry, to

	create the criteria that will be utilised when site visit occurs.
Phase 2	**Applying Phase**
2A	Create and write a letter outlining my intentions of the site visit
2B	Undertake some research on specific roads this research project may be interested in visiting
2C	Apply and send out letters of my intentions to appropriate companies
Phase 3	**Site Visit Phase**
3A	Gather all responses to the sent out letters
3B	Determine which three site visits would be most advantageous
3C	Set up dates with the company when best suited to undertake the site visit
3D	Undertake the site visits
3E	Analyse each site visit and determine what sustainable practices they incorporate into their road projects.
Phase 4	**Write-up Phase**
4A	Incorporate site visit information and analyses.
4B	Compare site visit information and analyses to pre-existing research of common sustainable practices
4C	Complete draft dissertation for supervisor to review and receive feedback

4D	Finalise dissertation making sure to include any amendments offered from supervisor and any extra research or finding since draft.

When analysing this adapted methodology as to why it was decided to separate this study into four stages, it becomes clear that it allows easy understand of the sequences required to complete this dissertation. For the sake of this research project it can be deduced that all stages are important and contribute to the completion of this research project.

3.2 Site Tours and Case Study

The decision to undertake a case study and site tours (CS&ST) was selected over other methods as it is believed that this will allow a better representation of what current sustainable development and management practices are being utilised, and whether they are worthwhile additions to a project. It was decided that two site tours accompanied with one case study will allow an insight into the current road industry. In order to achieve high qualitative results it was decided that background research will be undertaken. From this initial research a potential list of organisations was created, this list was undertaken to see potential organisations that may be eligible to host a site tour. For the purpose of getting a fair portion of the road industry one private organisation; thesis was selected while one local council; Ipswich City Council was selected for the site tours. While the selection of the road in which the case study will be performed upon, research and selection was decided due to its reputable status within the road industry in being sustainable. The case study was conducted on the Great Eastern Highway. Once this selection of the CS&ST was selected it was then decided that a semi survey will be produced in order to receive like information across all three CS&ST. A copy of this questionary that was present in the CS&ST can be seen in appendix E.

The objective of undertaking three CS&ST was to collect qualitative results which will allow the primary researcher to analyse sustainable practices that are often used in the road industry, and reveal the benefits frequently present in sustainable decisions, and finally calculate whether it is worthwhile. It was also decided in order to receive adequate information and collective census of the road industry the decision of three minimum

CS&ST was chosen. The types of questions that were incorporated into the semi-survey were implemented in order to gain the required information that was wished to be explored.

3.2.1 Formation of letter of intention and survey's

The formation of the letter of intention was created in order to give my site tour request credibility and safety for the organisation that this is a genuine request. This allowed said organisations and people to quickly validate that this email is a genuine email supporting my request. The creation of letter of intention was done by a USQ staff upon request by the organisation that was selected to be approach for a site tour. A copy of the letter of intent can be seen in Appendix F.

The formation of the surveys was undertaken with the guidance of my supervisor through email correspondence. The questions that featured on the survey were formulated to collect information on: Current materials and aggregates that are being utilised on the road project, any management theories that are incorporated into the said organisation or project, barriers which are impeding on sustainability, their opinion on the state of sustainability in the road industry and whether sustainable practices implemented were a worthwhile endeavour. These selected questions have the intention to gather critical information in order to determine all aspects of sustainable road development and management. This survey was not distributed, however used to give the primary researcher a set of questions that may highlight what is needed from the site tours.

3.2.2 Research into potential organisations for CS&ST

The selection of potential roads and/organisations was based upon a few criteria that were required to be fulfilled before contact was made. The first criteria that had to be met were for the site tours to be within driving distance of Brisbane, Australia. This decision was implemented because of travel implications that were imposed due to the location of the primary researcher. The second criteria were that this research project wished to capture all sections of the road industry; therefore target both public and privately built roads. This would allow a greater insight and analyse of the entire road industry. The third criteria were to be that the organisation was a highly reputable within the road industry. This as well as it was wished that the specific organisation has undertaken numerous road

projects in and around Australia. This type of civil construction organisation was sought after as it was believed that these larger more reputable firms would tend to have greater capabilities of implementing sustainable development and managing practices upon their roads.

In order to meet these major criteria it was decided that a search will be conducted in order to create a potential list of organisation that may be targeted. This collected a significant portion of the road industry; however majority of these were seen to be involved in the private sector of the road industry. The google search involved researching into civil construction companies that may have potential road development and management projects ongoing, briefly researching into their philosophy about sustainability and if they have constructed any note-worth sustainable projects over the past years. The list of companies that made the shortlist to be contacted includes around ten civil construction companies. These ten companies were specifically picked due to having pre-existing road development and management projects undergoing. When researching into potential publically built roads undertaken by the council the approach into the selection was based on location proximity. Four councils; Logan City Council, Redland City Council, Brisbane City Council, and Ipswich City Council were all selected as mentioned earlier due to their proximity being in and around Brisbane, Australia.

The selection for the case study that will be analysed throughout this research project was chosen on its sustainability merit. This was undertaken by researching and evaluating the Infrastructure of Sustainability Council of Australia, and their projects that they rated. This selection process will allow this research project to analyse a highly rated Australian road project and evaluate its sustainability and determine whether it was worthwhile. This selection process does not have any location proximity issue, as majority of the information will be from online sources and literature. Another criteria that does not matter for this case study is the whether or not the project is publically built or private. It is believed that this will not affect the overall gathering of the census as a public and private built roads will still be analysed in the site tours. Therefore the only criterion can be seen to be is it must be highly rated with numerous sustainable practices being implemented.

3.2.3 Distribution

Once the list of potential organisation was created it was decided for private organisations all ten researched organisation would be contracted via email regarding the possibility of conducting a site tour, refer to Appendix G for a copy of the email. Once emailing these ten organisations it was revealed that often these emails were directed towards the organisations administrators. The email that was distributed can be seen in Appendix F, which was also attached with a letter of intentions provided by Dr David Thorpe by request of the organisation.

The distribution of my questionary once a site tour is selected will be on the day of the site tour if they wish they can witness the type and sort of information the Primary researcher is requesting and needing; this will allow adequate time to comprehend the questions and the information that is wished to be obtained throughout the site tours.

3.2.4 Selection of organisation

The first organisation that was selected to be evaluated from the participants was Thiess. This company fits all of the specific criteria that was wished, it is a reputable organisation, within proximity of the primary researcher. Therefore with these criteria met it was decided that this project will be selected and a site tour was commenced. The tour which Thiess gave permission to document was the Moreton Bay Rail Project with upgrades to the surrounding road network. The second organisation that responded to the letter of intention was Ipswich City Council. This certain council allowed this research project to gather information and practices that could be adopted by public organisations. The second tour that was undertaken is on the Redbank plains road upgrade in Redbank Plains, Queensland. The Redbank plains road upgrade sees flood mitigation works, road reconstruction, stormwater drainage. The third site tour that was selected and was analysed for this research project is the upgrade on the Great Eastern Highway. This specific project has a large scope which included; upgrading the existing road from four lanes to six, improved central medians, upgraded intersections, footpaths and bicycle paths.

3.3 Limitations

The following limitations have been identified that have impacted this research in significant way. These limitations have progressed and risen throughout the course of this research that required action in order to successfully complete this research project. The limitations for this research project included: Getting the required quantity of site tours and at a timely manner, getting the information that is required for this research project, receiving incorrect and/or false information about the site, documentation distribution and technical difficulties associated with documentation control, and finally the risk involved at certain construction phases in which the road is being developed may be at.

A limitation that has been identified to have impact this research project is the attainment of the required quantity of site tours at an adequate time; this was a limitation that was difficult to mitigate as it was affected by external factors that cannot be controlled. However it was decided that more organisations were targeted and corresponded in order to achieve an improved chance of attaining a site tour. This limitation is believed to have conveyed consequential effects upon this research report as the primary researcher underwent final site tours for Ipswich City Council later than expected.

Receiving the required relevant information was seen to be a limitation that had occurred throughout this research project. Due to confidential agreements in the private sector of the road industry discussion about aspects that was wished to be discussed upon did not occur to the extent that the primary researcher wished. This has impacted the quality of the research as the information that was deemed to be important was not allowed to be featured in this research project. It was deemed to be necessary that a questionary was created in hopes to mitigate and lessen the extent of this limitation occurring. With a survey in place it allowed supervisors and/or representatives of the organisation to understand what type of information was wished to be acquired from the site tours. Another situation where this limitation arose was one site tour did not incorporate sustainable development and management practices to a great deal, this limited the discussion and results that was obtained.

Linked to the previous limitation to an extent is receiving incorrect and/or false information from the site tour and/or literature. This is was an ever present limitation that is difficult to control and mitigate, due to the primary researcher may unintentionally

encounter bias literature, and/or the organisation with holding or presenting false information in order to portray the organisation in a different light. In relation to the literature and the presence of bias this was mitigated as the primary researcher has undertaken courses that highlight and aid in detection of bias into literature. Another tool that has aided in mitigating the limitation of biased literature is the utilisation of creditable peer-reviewed literature. Mitigation techniques however for false information provided upon the site tours is difficult to control as it can be seen to be external and challenging to identify false information.

Documentation control and distribution of documents was a limitation that occurred throughout this research project. This limitation included control of documents and literature; ensuring control and storage of important documents, documents that are required to be distributed; ensuring they are correctly attached in the correct format for the recipient to utilise. All these issues was addressed to an extent, however numerous times email correspondence and document control was not to a high enough level.

The final limitation that has currently been identified is the risk of injury when conducting the site tours. It can be seen that the construction industry is typically a risky environment that requires careful thought and adoption of safety practices. The nature of the construction industry may incur as a limitation as sites or parts of the sites may be deemed to be too risky to attend, thus limiting the amount of information available. This limitation has affected this research project in one scenario when the primary researcher wished to witness a sustainable practice, however due to construction activities being completed it was deemed to be inaccessible. This research project combats this limitation occurring other times by ensuring the primary researcher has an up to date white card and when conducting the site tours to ensure full personal protective equipment is worn when required.

CHAPTER 4 - RESULTS

As previously mentioned in chapter 3 methodology this research project deemed that it was necessary to undertake a total of two site tours and one case study. This decision was chosen as it will demonstrate specifically the industry examples of how sustainable road development and management have advantageous benefits if implemented successfully. The two site tour that was decided to be visited and analysed is Moreton Bay Rail Project in particular focusing upon the road network connecting the existing infrastructure and the Ipswich city council project, Redbank plains road, Redbank Plains. While the case study was selected via Infrastructure Sustainability Council of Australia, this decision was made to highlight an industry leading project that has adopted sustainability to a great extent.

4.1 Site tours

4.1.1 Redbank Plains Road upgrade

The first site that was undertaken to gather information and data from was the Redbank Plains Road upgrade in Redbank plains. The main contractor for this specific project is Ipswich City Council and BMD construction group, which is jointly funded by local, state and federal government. This project was approved as it is believed that this upgrade on the road network will cope for the ever expanding Redbank Plains and the surrounding areas. The scope of work that is associated with this project is upgrading the existing road from two lanes into four lanes, flood mitigations work, stormwater drainage, pedestrian and bikeways, signalisation of two intersections, a map of the project layout of work can be seen in figure 7 while the flood mitigation and drainage scope can be seen in figure 8: Water Retention Basin

Figure 7: Map of the project layout of work (Department of Infrastructure 2015)

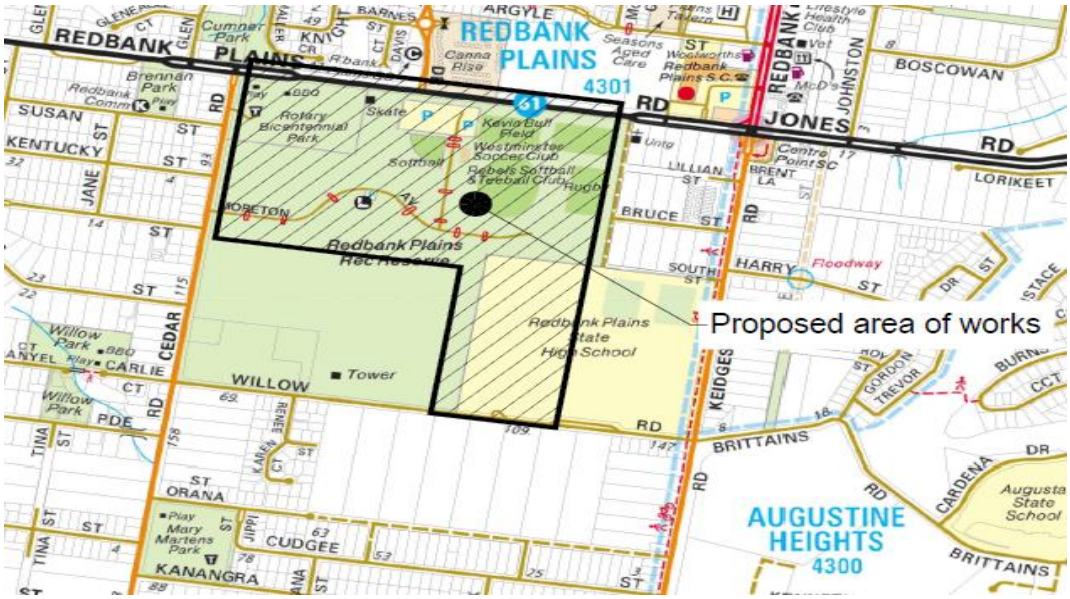

Figure 8: *Map of the proposed flood basin (Department of Infrastructure 2015)*

This extension and upgrade will allow for access and easing of traffic on targeted sections of the road network. It was calculated that the average vehicles per day utilising this stretch of road is approximately 20,000 vehicles, due to the recent and upcoming shopping centre extension situated on this road it is believed that this figure of 20,000 will increase to about 27,000 by 2025. This specific site tour revealed to the primary researcher that sustainability influenced both management and development aspect; therefore this research project will reveal the findings for both categories. All data discussed within this chapter 4.1.1 was provided by the Ipswich City Council on completion of the site tour.

4.1.1.1 Management sustainability

This section of the results for Redbank plains road sees numerous examples of where social, economic and environmental sustainability has been implemented to influence the project advantageously. This research project will briefly highlight these sustainable management practices implemented upon this project.

Stakeholder management was deemed to be a major issue that had to be understood and dealt with due to it being a council road; therefore they had to manage all stakeholders and the external community very careful throughout the life of the project. It can be seen that there were copious amounts of sustainable practices implemented in relation to social sustainability, therefore it was decided that these practices will be highlighted in order to better represent them and their influences. Firstly the term social sustainability can be summarised to be a process in which the construction project promotes wellbeing, liveability of the area, health equality and continuous community development (Palich & Edmonds 2013). The first example that will be highlighted is the expected vehicles per day as mentioned earlier are approximately 20,000. This is a significant statistic that required attention by Ipswich City Council in order to limit the disturbance to the surrounding community and external stakeholders. Results reveal that they throughout the project deemed it necessary to keep two lanes open consistently, while the developing and constructing on the other side of the road. Associated with this social sustainable practice was the need to limit the stoppage and disturbance of the traffic. Therefore Ipswich City Council implemented the idea that a timeframe of approximately five minutes was allowed for traffic coordinators to impede on the flow of the traffic. Another external stakeholder management example that was encountered was the layout of the drainage system, which ran directly through a community soccer field. This saw Ipswich City Council adapt and modify their project schedule to limit the impact it has upon the soccer teams season. This saw an increase to the liveability and impact the project has upon the surrounding community.

Another significant management practice implemented relates to the project requiring night time work during different stages of the project. This decision made by Ipswich City Council if not managed correctly will influence and impact the surrounding community negatively, thus decreasing the overall sustainability of the project. The issue

surrounding night-time work is the light and noise emissions from the project, therefore Ipswich City Council implemented the following practices to mitigate the disturbance:

- Face lights away from the residential buildings.
- Limit the amount of night time work required.
- Disable rear reversing alarms.
- Install mufflers on plant and equipment.
- Schedule noisy activities during the day time.

All these practices increased the social sustainability of the Redbank Plains Road project as these practices limit the disturbance to the surrounding community and stakeholders.

4.1.1.2 Development sustainability

This section of the research project is interested in the sustainable development methodology and practices utilised in the construction of Redbank plains road. Conducting the site tour on this project revealed significant and major sustainable practices that were implemented had substantial influences and benefitted numerous parties, such as the surrounding community, the client and finally the contractor. This research project will now briefly describe and highlight these practices to present how if implemented correctly sustainable development practices can impact the project.

The first incident that was revealed once undertaking the site tour was the stabilisation of the clayey ground in which the road is being built upon. It was decided that the implementation of lime stabilisation supplied by Stabilised Pavement of Australia was a sustainable practice that influenced the project significantly.

As mentioned previously in chapter 2: Literature Review lime stabilisation in essence allows the subgrade to increase in strength; acting like an ‘anvil’ for succeeding layers to build upon. Ipswich City Council were given the selection between two different types of roads, option 1 being unbound gravel replacement while option 2 is a lime stabilised road, both in which can be seen in figure 9 and figure 10.

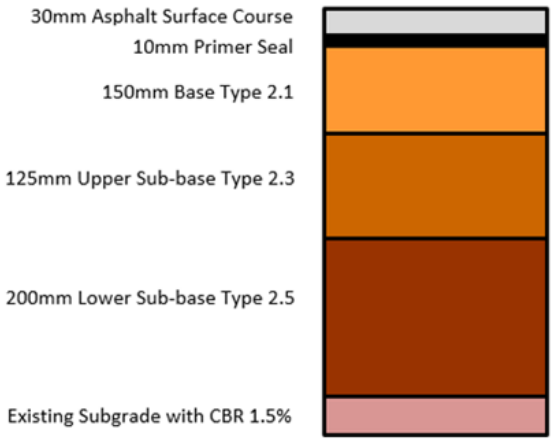

Figure 9: Option 1 Unbound Gravel Road

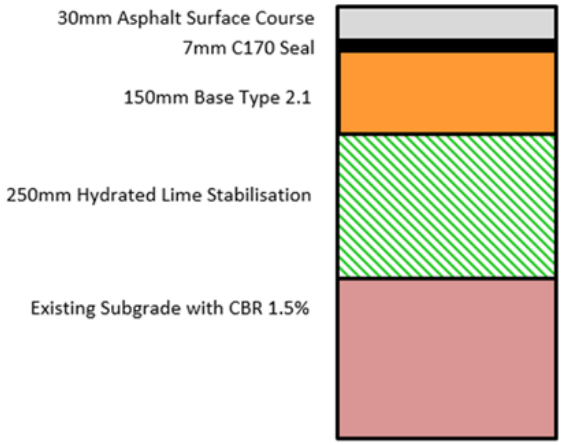

Figure 10: Option 2 Lime stabilised Road

The different type of road that could have been selected by Ipswich City Council can influence the overall project immensely in such ways as; direct cost, carbon emission, and resource efficiency and truck movements. The difference that can be witness is due to the altered layers and design each option has, the breakdown of depths of layers can be seen in Table 3 and 4.

Table 3: Unbound granular replacement design

Thickness (mm)	**Material**	**Depth (mm)**
30	Asphalt Surface Course	30
10	Primer Seal	40
150	Base Type 2.1	190
125	Upper Sub-base Type 2.3	315
200	Lower Sub-base Type 2.5	515
	Existing Subgrade (CBR 1.5%)	

Table 4: Lime stabilisation design

Thickness (mm)	Material	Depth (mm)
30	Asphalt Wearing Course	30
7	One Coat C170 Seal	37
150	Base Type 2.1	187
250	In Situ Hydrated Lime Stabilisation (5%)	437
	Existing Subgrade (CBR 1.5%)	

These results were calculated and provided by Ipswich City Council for comparison and discussion only. The first section that will be highlighted and calculated is the direct cost saving that both options have and the difference that is encountered. The option 1 road development methodology direct cost can be seen in the table 5 below while option 2 road development methodology can be seen in table 6.

Table 5: Costs and operation procedure for unbound granular replacement

Description of Work	Estimated Quantity	Unit	Rate Cost ($/m^2)	Extended Amount excl. GST ($)
Profile existing pavement up to 515mm thick and dispose as required	3,215	Tonnes		$18,072
Supply and place 475mm of gravel (Type 2.1, 2.3 and 2.5) at $45/tonne	2,965	Tonnes		$133,423
10mm primer seal	3,121	m^2		$15,605

Supply and place 30mm of asphalt at a rate of $140/t	225	Tonnes		$31,460
Total			**$64/m^2**	**$198,560**

Table 6: Costs and operations procedure for lime stabilisation

Description of Work	**Estimated Quantity**	**Unit**	**Rate Cost ($/m^2)**	**Extended Amount excl. GST ($)**
Establishment	1	Each		$1,200
To supply 2m profiler and cut to a depth of 187mm including loading into trucks supplied by the client. Price includes 2 operators, ute and fuel	1	Days		$2,410
To spread 5% Hydrated Lime and mix to a depth of up to 250mm using 2 passes of a large stabiliser with enclosed spreading centrally mounted mixing box whilst incorporating water	2	Days		$11,600
To supply bulk Hydrated Lime in full loads (min 24t loads)	78	Tonnes		$28,080
Supply and place 150mm of gravel (Type 2.1) at $35/tonne	936	Tonnes		$32,770
7mm C170 seal	3,121	m^2		$15,605
Supply and place 30mm of asphalt at a rate of $140/t	225	Tonnes		$31,460

Total	**$39/m^2**	**$123,125**

A brief summary and comparison between the two options can be seen in the table 7. This saving equates to approximately 75,000 dollars saving for Ipswich City Council which is calculated to be 40% cheaper, all the while still upholding the structural integrity of the road to a standard that is accepted and certified by the Main roads transport.

Table 7: Cost saving by using Lime Stabilisation

Option	Total Cost excl. GST
Unbound granular replacement	$198,560
Lime stabilisation	$123,125

The second benefit that will be highlighted and calculated is resource efficiency, that both options have and the difference that is encountered. This second benefit of resource efficiency encompasses numerous aspects such as, amount of new material required, amount of recycled material and finally amount of waste emitted to landfill. This is an important consideration that needs to be taken seriously as utilisation of a raw virgin material is commonly known to be an unsustainable practice.

The Figure 11: Resource Efficiency has been generated with the information provided by the Ipswich City Council while undertaking a site tour on their project.

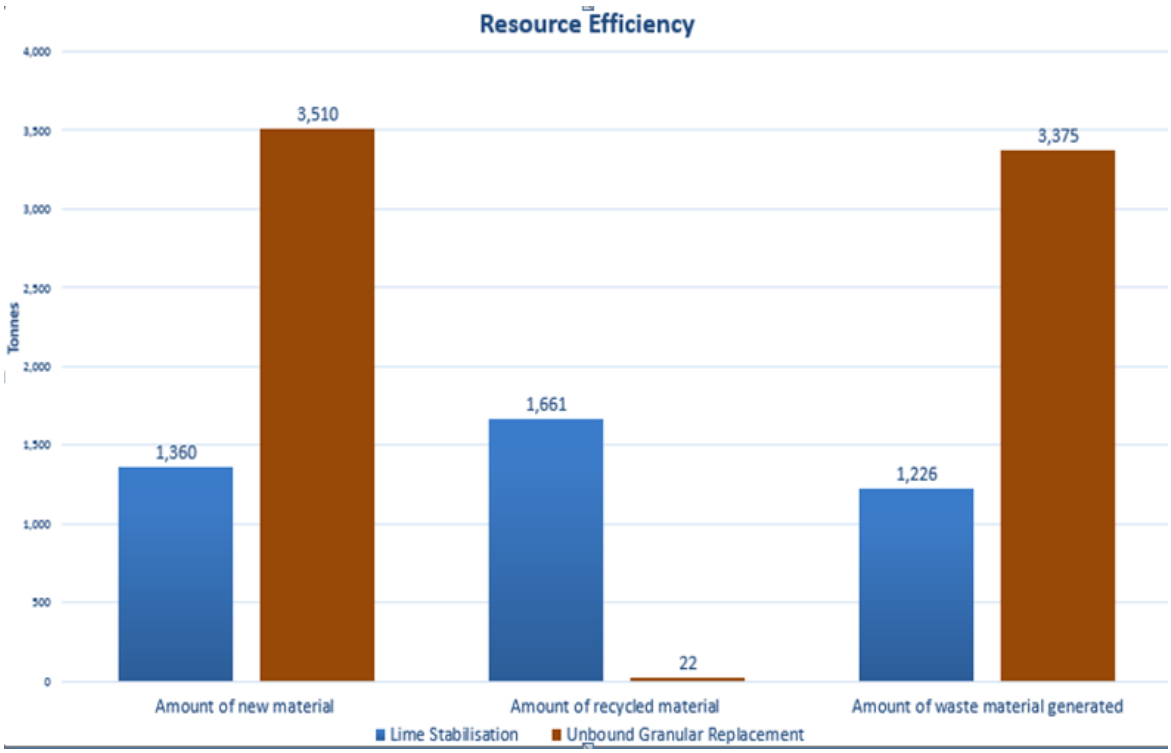

Figure 11: Resource Efficiency

These figures reveal the extent and impact lime stabilisation has when comparing to conventional road development. A reduction in approximately 1,200 tonnes of new raw material, increase of about 1,640 tonnes of recyclable material and finally reduction in waste diverted from landfill that equates to approximant 2,150 tonnes was witnessed by Ipswich City Council which is significant environmental aspect.

The final benefit that is associated with lime stabilisation is the reduced truck movements needed to complete the project. This specific aspect is significant but often overshadowed by the previous two benefits; direct cost and resource efficiency. The reduction in truck movements means; less damage upon the surrounding road network that may not have been designed to withstand high quantity of heavy haul trucks, secondly it means reduced amount of fuel required by transportation trucks and finally the disturbance to the greater surrounding community. For this specific project the two options differ significantly when calculating the required travel movement of trucks, refer to figure 12 to gauge the difference between the two road design options; lime stabilisation or unbound granular replacement. The amount of fuel required for the truck movements for option one was calculated to be 4,372L while lime stabilisation option 2 equates to be 3,199L this a difference of approximately 1,173L. Another factor to consider with the reduced truck movements is the schedule reduction that is often experienced, for the Redbank Plains

Road upgrade project this was calculated to be about five day reduction. This limits the disturbance to the surrounding community while reducing the required time of road closures and traffic coordination which this research project neglected to calculated.

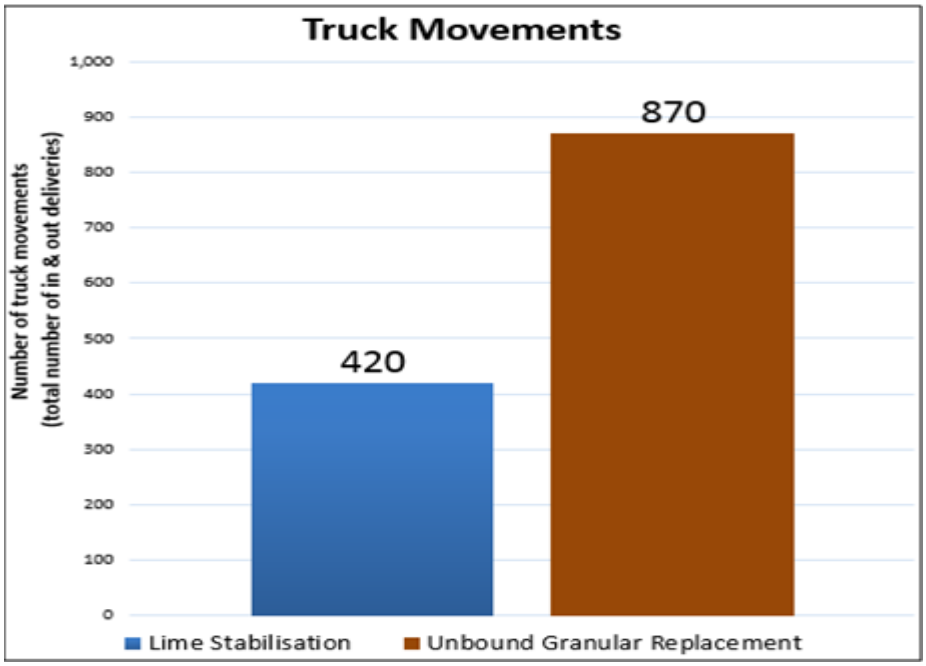

Figure 12: Number of truck movements the difference

With these benefits listed for lime stabilisation vs unbound granular replacement it became clear that the option selected by Ipswich City Council was in fact option two: Lime stabilisation due to the following summary of benefits:

- Saved $75,000 dollars in direct cost (40%).
- Saves 5days of disturbance to residents from road work activities.
- Recycles 1,661 tonnes of material.
- Save the manufacturing and importation of 2,150 tonnes of raw material from quarries.
- Prevent and eliminate 2,149 tonnes of waste being emitted to landfill.
- Reduced 450 of heavy truck movements which may impact the surrounding road networks and pavement.
- Save 1,173L by this reduction of truck movement.

Other sustainable practices that were witnessed when undertaking the site tour of Redbank plains road include but not limited to, erosion and sediment control,

implementation of a water basin and finally re-use of materials across the duration of the project. The first other sustainable practice relates to erosion and sediment control, these two sections if left unchecked can cause significant environmental issues for waterways and aquatic life that surrounds the area. This result in significant fines and reputation tarnish with adequate of erosion control and sediment control isn't implemented. Ipswich City Council for this project incorporated both sediment and erosion control by installing a geotextile sediment fence as seen in figure 13.

Figure 13: Geotextile sediment fence

Another sediment control measure that was required due to the project proximity to a water source and the stormwater run-off can be seen in figure 14 This specific stormwater run-off control measured implemented by Ipswich City Council affects environmental sphere of sustainability tremendously as similar to the geotextile fence it limits the impact the construction road site has upon the surrounding water sources and the wildlife inhabiting the water source.

Figure 14: Sediment control wall

Part of the project scope that Ipswich City Council had to construct was flood mitigation techniques in order to keep the upgraded road from being inundated with water at any point in the future. It was decided that a water basin will be implemented which will control the flow of the stormwater and flooding when needed, the planned area of the water basin can be seen in figure 15. The sustainability aspect of this flood mitigation technique was implemented by Ipswich City Council where they re-utilised the cut soil from the basin and transported it for fill across the construction site and future planned fields in close proximity. This is calculated to be a saving of approximately 145,000 dollars in new virgin soil, transport costs and finally reduction in cost associated with emitting waste to landfill. All these significantly impact on the sustainability of the project in particular environmental and economic.

4.1.2 Moreton Bay Rail Project

Thiess is the primary contractor undertaking and completing this landmark project, which is funded jointly by both Australia and Queensland Government. This project undertaken is set to increase growth into the surrounding infrastructure and transport network in the region of Redcliffe, Queensland. The scope for the Moreton Bay Rail Project is to extend the surrounding roads to connect with the newly constructed rail station and lines. This extension will allow for access and easing of traffic on targeted sections of the road

network. The major finding that was seen to have risen from this site tour is the soil that the road network infrastructure was planned and constructed upon. The geology of which the corridor is built upon created a problematic issue in that the soil is acidic sulphate soil; a sample of this soil is seen in figure 15. All data discussed within this chapter 4.1.2 was provided by the Thiess Construction on completion of the site tour

Figure 15: Acidic Sulphate Soil Redcliffe, Queensland.

Evidence reveals that particular areas of the project have different amounts of acidic soil and toxicity levels which were deemed to have been a difficult issue as a site wide soil testing and extensive geotechnical reporting were necessary. These 'hot spots' of acidic sulphate soil can be seen in Appendix H,I,J,K. Thiess were presented with this problematic issue, which requires significant input in order to mitigate the impact the soil has upon the surrounding environment and community and the feasibility of the project. From the site tour conducted it was found that they mitigated this significant aspect by implementing crushed concrete into the base of the exposed soil as seen in figure 16.

Figure 16: Crushed Concrete Stockpile

This implementation of crushed concrete reduced the overall PH level of the exposed acidic sulphate soil to a level that is acceptable and safe. With this decision it was found that not only did it limit the need for conventional less sustainable methods but in fact reduced the pre-existing concrete across the project that would have been emitted to landfill. This was achieved as an agreement between Thiess and Alex Fraser was met, this agreement sees Alex Fraser processing the pre-existing concrete then refining it to produce crushed concrete. Alex Fraser supplied a total of 60,000 tonnes of crusher dust, which is a significant aspect as it reduces the amount of pre-existing concrete being emitted to landfill. Calculating the cost shown that per cubic meter of concrete emitted to landfill equates to about $35 per cubic meter as discussed between the primary researcher and Chris Keeler on the 14th of August 2015. The decision to select sustainable crushed concrete allowed a saving of approximately 11,000 tonnes of virgin material being extracted and utilised. Further calculations reveal that this sustainable unconventional method reduces the carbon emission approximately by 460 tonnes of carbon that would be required to produce alternative methods. Further advantageous benefits relates to the truck movements required to import and execute the conventional lime stabilisation methods. This reduction in truck movements equates to about 380 truck movements across Queensland. This problem effects the surrounding environment, social community, and the economic feasibility of the project. These implications will be discussed further in Chapter 5: Discussion.

4.1.2 Great Eastern Highway

The next sustainable road that will be analysed and highlighted is the Great Eastern Highway built in Perth, Australia by Main Roads Western Australia. This specific project includes upgrading and renewing a 4.2km section of road between Kooyong Road and Tonkin Highway, with this section being widened from four lanes to six lanes (Great Eastern Highway Upgrade 2014). Numerous other subsidiary tasks related to this project include, constructing a central median, upgrading and improving pre-existing intersections, bus priority lanes and pedestrian and bicycle lanes for the surrounding community. (Great Eastern Highway Upgrade 2014).

The results reveal that the first sustainable practice implemented to have a benefit upon the project is that implementation and utilisation of a RS. The specific rating tool that was utilised by Main Roads Western Australia was the IS RS. The surrounding literature was

discussed and analysed previously in Chapter Three: Literature Review; briefly put this RS in essence a set of best sustainable practice. The Great Eastern High way achieved a rating of 'commending' this is calculated to be a score of approximately 25-49. To put that score in context refer to Figure18

Score	Rating Level
< 25	Not eligible to apply for a certified rating
25 - 49	Commended
50 - 74	Excellent
75 - 100	Leading

Figure 18: Rating Levels (Great Eastern Highway Upgrade 2014).

Analysing the Great Eastern Highway upgrade reveals numerous sustainable findings which Main Roads Western Australia implemented in order to achieve the score commending; these findings can be seen in the table 8: Great Eastern Highway result. The categories that this project deemed to be necessary include; management, water, materials, previous land use, heritage and finally innovation. Each category will have a score and a brief description of the practices implemented in order to achieve the score that it did. This will highlight the sustainable practices utilised and implemented throughout the duration of the project.

Table 8: Great Eastern Highway Results (Great Eastern Highway Upgrade 2014).

Category	**Score**	**Practices implemented**
Management	6.3 out of 10.5	• Strong environmental, health and safety plans and systems implemented • Knowledge sharing
Water	2.9 out of 7	• Opportunities to reduce water was identified but not implemented greatly • Utilised groundwater bores

		• Constructed a weir in order to capture stormwater runoff
Materials	6.2 out of 7	• Extensive recycled materials utilised instead of conventional methods
Previous Land Use	3.3 out of 3.3	• Greater than 75% of land used was disturbed land.
Heritage	2.5 out of 5	• Implemented a heritage/artefact management plan
Innovation	1.7 out of 5	• Utilisation of warm-mix asphalt when possible

Some further findings and results associated with this project that is significant and industry leading are the categories of materials and previous land use. The materials for this specific project can be seen to industry leading in the way that a total of 43 per cent of imported materials were deemed to be recycled (Great Eastern Highway Upgrade 2014). This amount of recycled material being used by Main Roads Western Australia is the highest ever recorded for a single project (Markham 2012). It is calculated that recovery of recyclable materials from previous pre-existing structures equates about 80% of this scrap construction waste has been diverted from landfill (Markham, D 2012). It was calculated this equates to approximately 300 dollars per semi tipper (Markham, D 2012). The process in which recyclable material is gathered, processed, refined, implemented can be seen in figure 17 to figure 20.

Figure 17: Extraction and Recovery (Markham, D 2012)

Figure 18: Recycle depot (Markham, D 2012)

Figure 19: Processing (Markham, D 2012)

Figure 20: Implementing (Markham, D 2012)

The major issue that is deemed to influence the selection of sustainable materials over conventional materials is whether they match up characteristically. For this case study it was revealed that the recycled product used performed to a great outcome in relation to sustainability. This was supported by Taljaard the construction manager of the great eastern highway where he states that they were happy to see that the material achieved and passed the required level of quality and strength in order to sustain the heavy loads and requirements of a motorway (Markham, D 2012)

CHAPTER 5 - DISCUSSION

5.1 Site Tours

The objective that was wished to be achieved was obtaining a minimum of two site tours and a case study to gather a census of the road development and management industry. When evaluating this objective this research project successfully achieved this goal as the minimum was achieved. Another objective to gain a true census of the industry was to target a public and privately built road. The focus of these site tours and case studies were to collect information upon application of sustainable development and management practices and see their impact in relation to the three spheres of sustainability; environmental, social and economic. As mentioned previously the two site tours that was decided to be visited and analysed was Moreton Bay Rail Project and Redbank plains road upgrade, while the case study was conducted on the Great Eastern Highway project. The obtainment of these three sites was deemed to be more difficult than first expected, this may be due to the lack of time that is often witnessed and experienced within the construction industry. However even due to the late response on one of the site tours the primary researcher believes that adequate time and information was provided to influence this research project positively. It was decided that fortnightly communication correspondence with the potential organisations would allow the primary researcher to undertake a site tour was deemed necessary. This decision was believed to be a main contributor as to why the final site tour of Ipswich City Council road was achieved.

The decision to incorporate both a privately built and publically built road into the discussion is believed to influence and adapt this research project to accurately make conclusions on the whole of the sustainable road development and management industry. This statement of each site tour validates any conclusion that is made as it is believed that a true census of the road industry was gathered, as both have different focuses. For example council/public built roads are more concerned and interested in social and surrounding communities whereas it can be seen that the private organisation are

concerned with their reputation and economic aspects of the development and management of roads.

As mentioned previously in this section the main focus of the site tours was to determine possible advantageous benefit that may have been experienced when developing and managing a road. Therefore this chapter will concentrate its efforts to answer the question: is it all worth the time, cost and effort to implement sustainable road development and management.

5.1.1 Redbank Plains Road

This specific site tour that was conducted on the 23rd of October 2015, revealed significant findings that was discussed in chapter 4: Results. These results will now be discussed in conjunction with the undertaken literature review in an effort to answer the question was the implemented sustainable practices worth it? This particular project was constructed by Ipswich City Council within the area of Redbank Plains, Queensland. Due to its proximity to residential housing and community facilities it was seen that significant external stakeholder management was necessary in relation to the management of project. The consensus that was gathered from this public built road was its strong focus on the two spheres of sustainability; social and environmental. Though the literature revealed that social sustainability gets scant attention in comparison to the other two spheres of sustainability, this was found not to be the case for this particular project (Peduto B 2012). The attention and time that was spent mitigating the disturbance this project has upon the surrounding community such as noise mitigation techniques, community meetings, and returning the site/area to its original state has seen Ipswich City Council commended by the community and residents. This approach implemented by Ipswich City Council to concentrate on social sustainability when managing this road upgrade project has seen that the surrounding community has been managed well. An example of this can be seen to be the community soccer field requiring to be excavated in order to install drainage and piping. This example revealed that Ipswich City Council planned this scope of work to be conducted when the soccer season is concluded which sees the fields currently not being occupied and utilised. Another example of social sustainable practice being incorporated relates to traffic flow management and sequence of activities for the project. This particular example sees that the methodology of the project adapted in order to mitigate the disturbance to the surrounding community, in that the pre-existing road

stayed functional while the upgrade was being constructed. Another practice associated to this was traffic flow management, was a requirement instated by Ipswich City Council that a maximum of five minutes traffic stoppage was allowed on the pre-existing road. This was a social sustainability as the liveability and community disturbance both altered for the greater good for the duration of the project. Though these are only two examples this reveals the lengths of which Ipswich City Council has taken in order to increase the liveability and limit the disturbance this project has upon the surrounding community.

With the question of whether the decision to focus time and effort upon social sustainability was worth-while becomes difficult to answer as these examples do not return a quantitative measure. However literature reveals that external stakeholder management helps formulate and contribute a vital part in the success of a project (Haughey, 2015). In-conjunction with this literature the primary researcher conducted a conversation on the 23rd of October 2015 with the Ipswich City Council Project Manager, Pedro Baraza who believes if Ipswich City Council neglected or reduced its effort it inputted to management of the road development, this project would not be as successful as it has been to date. This supports what the primary researcher believes that social sustainability practices incorporated by Ipswich City Council had an advantageous benefit to the project thus answering the question it was worth-while to have such extensive social sustainability practices implemented.

This research project will now discuss the decisions and practices implemented when developing the Redbank Plains Road project. As the results show in Chapter 4 the major development practice was that of lime stabilisation. This particular decision resulted in numerous advantageous benefits when comparing to the conventional method. The two options that were presented towards Ipswich City Council were a lime stabilised sub-base or higher quantity of gravel sub-base which can be referred to in figures 9 and 10. This particular development decision to adopt a lime stabilised sub-base saw significant advantageous benefits such as reduced overall direct cost, increased resource efficiency, and finally reduced truck movements. These benefits offered quantitative data such as; 40% different in cost, reduced overall construction of road sub-base by five days, recycled 1,661 tonnes of materials, eliminated 2,150 tonnes of raw material, reduced 450 truck movement and finally eliminated 2,149 tonnes of waste emitted to landfill.

The literature review undertaken in Chapter 2 reveals some other common benefits of a lime stabilised road that could have been experience are:

- Subgrade stability
- Compaction anvil
- Increased Strength and Stiffness.
- Reduced pavement depth.

(Hi-Way Stabilizers, 2015)

With these figures and benefits listed it becomes clear why Ipswich City Council opted for a lime stabilised sub-base instead of a conventional built sub-base. By critically analysing this sustainable practice it reveals the reason why this particular practice was incorporated could be due to these figures acting as a motivator for the client. The literature review that was conducted in chapter 2 of this research project states that a barrier to the implementation of sustainable practice can be a lack of motivation (Ortiz, 2009). This site tour revealed that a lack of motivation can be a barrier however if significant motivation is gathered it inadvertently has a polar opposite effect as in it can aid the implementation of the practice.

Other significant sustainable development practices witnessed on this site tour was the stormwater flood mitigation and the re-use of certain materials. The decision to integrate a water retention basin into the scope of the project was made, due to the fact that it is a tool to mitigate flood damage to the road and the surrounding community. This is deduced to be a significant sustainable practice that Ipswich City Council implemented which encompasses both environmental and social sustainability in the way it allows control of high volumes of stormwater. There is no denying the advantageous benefit of this particular sustainable development practice; such benefits include but not limited to:

- Reducing and mitigating the level and frequency of stormwater-run off on the surrounding community that may constitute a health issue.
- Reducing/eliminate stormwater- run off that could adversely affect and cause nuisance and/or damage upon pre-existing infrastructure.
- Reducing the potential erosion resulting environmental impact on creeks, rivers and water sources.

(Brisbane City Council, 2015)

Associated with the decision to implement a water retention basin was the idea to re-use the cut soil from the planned area and utilise it for future planned work in and around the construction site, thus limiting the need for future new topsoil. This resulted in a cost saving of approximately 145,000 dollars from re-utilising pre-existing site soil on areas that require extra filling in, reduced truck movement distance and finally the amount of soil emitted as waste is reduced.

Relating back to the question of whether these development sustainable practices were deemed to be beneficial and worth-while. The primary researcher believes that the practices integrated into the project are deemed to be advantageous in nature regarding the three spheres of sustainability. This is believed as lime stabilisation saw significant environmental, economic and social sustainability which is supported by the literature Review undertaken in Chapter 2 of this research Project. While the water retention basin is less economically driven, but motivated by the environmental impact it will have. Therefore with these benefits listed and discussed it becomes clear that these practices are a good example of sustainable ideologies incorporated into a project can impact it positively.

5.1.2 Moreton Bay Rail Project

The second site tour that was conducted on the 14th of August 2015 was the Moreton Bay Rail Project upgrade. This site tour revealed significant results in regards to sustainable practise which were discussed and presented in Chapter 4: Results. Similarly to the previously discussed site tour of the Redbank plains road project these results will be discussed in conjunction with the in-depth literature review in an effort to answer the question that has arose: is the sustainable practices often implemented by the road industry worth-while? This specific construction project as mentioned previously in this research project was undertaken by the organisation Thiess Construction who was the primary contractor to complete the scope of work, in which the major work front was upgrades to the rail line. The minor scope of work was upgrading and constructing roads that connect the existing network to these newly built train stations and train lines; this is where the research project will focus its efforts and attention.

Due to the project being constructed in Redcliffe, Queensland this saw a major issue arise that required input and management by Thiess or significant consequences will occur if left unchecked. This issue relates to the acidic sulphate soil that was present throughout the planned construction site; location of this acidic sulphate soil can be seen in appendix H, I, J and K, this reveals that acidic sulphate soil was a site wide issue. Literature reveals that the presence of metal sulfides in the soil is the main contributor as to why acidic sulphate soil is seen to be such an environmental hazard (Australian Government, 2015). The literature goes on to state that if left undisturbed the soil has little to no impact upon the environment (Australian Government, 2015). However this is not the case for Thiess as they were required to unearth and expose the sulphate soil due to road development upgrade. If Thiess neglected this exposed acidic sulphate soil, literature states that catastrophic consequences on the environment would occur. The main consequence often present when dealing with acidic sulphate soil is once the exposed soil reacts with oxygen and sediment run off may affect the following areas:

- Aquatic ecosystem
- Primary industries
- Recreation and aesthetics
- Drinking water
- Industrial water
- Cultural and spiritual values

(Australian Government, 2015)

With the information provided within this chapter it becomes clear that Thiess construction cannot neglect any exposed acidic sulphate soil.

When neutralising and mitigating the acidic sulphate soil the conventional method is installing and implementing virgin lime into the soil, this process lowers the overall PH level to an acceptable standard which doesn't affect the areas listed above. It was revealed while undertaking the site tour that this conventional method though it is adequate Thiess selected a more sustainable method. This method involves pre-existing concrete being processed and refined into crushed concrete by Alex Fraser organisation. With this new material then added and mixed into the exposed acidic sulphate soil which similar to the

conventional method lowers the overall PH levels due to the pre-existing concrete containing high amounts of lime.

Analysing the sustainability aspect of this decision opted by Thiess can be seen to be a major example of where if sustainability is implemented and thought out correctly can have a successful impact upon the project. Not only does this decision mitigate the environmental aspect of the exposed acidic sulphate but it also has significant economic sustainable aspect associated. This is believed as lime by itself though is useful it can be seen to be an expensive method and material. Whereas because Thiess had significant pre-existing concrete from the project that was deemed to be surpluses to requirements it allowed them to receive 60,000 tonnes of crushed concrete at a cheaper rate, while eliminating 11,000 tonnes of lime that would been required. The benefits of this decision does not stop there however because this decision to re-utilise the concrete that would have been emitted to the landfill has now be recycled. This has economic and environmental aspects of sustainability attached as mentioned previously it equates to approximately 35 dollars per cubic meter of concrete. Due to confidential agreement not being approved between the primary researcher and Thiess Construction it becomes difficult to gather quantitative data associated with this particular sustainable decision. However it becomes clear that this option selected by Thiess demonstrates that certain sustainable practices can be deemed to impact the construction project significantly in relation to economic, environmental and social aspects. Therefore answering the question previously asked whether this unconventional method of controlling acidic sulphate soil was beneficial and worth it, due to the previously mentioned sustainable method this primary researcher believe it was. This is supported by the conversation that was held on the 14th of August 2015 with Chris Keeler whose role is a civil site engineer that accompanied the primary researcher mentioned that this particular practice completed by Thiess was the most noteworthy, beneficial practice that they undertook on the project.

5.1.3 Great Eastern Highway

This particular project differs from the previous two site tours as this project was not visited by the primary researcher, but instead analysed online via the Infrastructure Sustainability Council of Australia. The primary contractor for this highway upgrade within Perth, Western Australia was Main Roads Western Australia. The scope of work that this particular project is interested in is upgrading and renewing a 4.2km section of

highway between Kooyong Road and Tomkins Highway, with many other subsidiary works such as, median strips, drainage and barriers. Similarly to the previously discussed site tours these results will be discussed in conjunction with the in-depth literature review in an effort to answer the question that has arose: is the sustainable practices often implemented by the road industry worth-while?

This particular project was selected to be analysed by this research project due to the main factor that they utilised a RS to guide and assist the project for sustainable development and management. Infrastructure Sustainability rating tool was the selected rating tool that was adopted and incorporated into this project by Main Roads Western Australia. Referring back to the literature reveals that RSs are an upcoming management tool being adopted by the road and construction industry as they in essence give guidance to organisation that aren't particularly fluent and confident in sustainable construction (Muench et al, 2011). This is a significant management tool that was adopted for this project, however it is difficult to see its quantitative measure and benefit due to information not being readily available. Nevertheless analysing the score that this project achieved can be assumed that reference and ideas where gathered from the Infrastructure Sustainability RSs. Therefore the benefit and level of usefulness can only be assumed to be positive and in fact influential in relation to sustainability of the Great Eastern Highway.

Going further in-detail of the sustainable development the major sustainable practice implemented was the utilisation of recycled material on the project. It was calculated that Main Roads Western Australia achieved a record setting 43% of total imported material was in fact recycled material. An example of where recycled material was witnessed with positive affect was the re-use of crushed concrete in the sub-base of the highway. Though no quantitative direct cost analyse could be undertaken due to lack of information, it was found that typically a reduction of upwards of 65% in greenhouse gases are witnessed (Department of Victoria Roads 2011), while still conserving natural finite resources, reducing the amount of waste sent to landfill, reducing natural resource exploitation and finally reducing transport costs (Wangchuk, 2013). Analysing whether the decision to incorporate such a significant amount of recycled material on the site was beneficial and worthwhile can be answered by the Riaan Theron the principle pavement engineer for this project who stated that not only did Main Roads Western Australia believe that the recycled material offer a superior performance but also reduced delivery time and transport times which the project to be completed in a shorter timeframe (Demolition

Perth 2015). Another example of where sustainable development practice that was implemented influenced the overall project is the decision to build the planned highway road on pre-existing brownfield sites. It was calculated that a total of 75% of the land that was constructed and utilised was already being utilised or registered as a developed land. This reduces the environmental impact the project has on the surrounding environment. With all these examples of sustainable practices concluding the similar results of that these practice influence the overall project positively it can be concluded that for this specific site and project it was deemed to be impactful and successful of Main Roads Western Australia to implement a proven RS, recycled material and finally utilisation of brown sites.

5.2 Summary

The available literature for the site tour and case study of; Moreton Bay Rail Project and Great Eastern Highway project both returned with a reduced amount of quantitative data to support the claim that sustainable road development and management has a beneficial impact making it worth-while. However the primary researcher believes that there is still enough qualitative data and expert opinion supporting certain sustainable practices that were incorporated into the project. Analysing the Redbank plains road upgrade project highlighted the preferred amount and type of data that was wished to be gathered. This research project will now summarise the information provided by all the projects in order to adequately answer the question that arose at the beginning of this chapter; whether or not sustainable practices have enough advantageous benefit to warrant focus and resources being delegated by the road industry. Due to the extensive amount of sustainable practices in the industry and the limited case and site studies that were investigated by this research project not all practices are analysed. However the primary researcher believes enough practices have been evaluated and highlighted to give a preliminary conclusion and opinion to whether sustainable road development and management it worth the time, cost and resources.

It is believed that sustainable road development and management within the road industry is achievable and a worthwhile endeavour that all organisation can strive to incorporate into their project. Why this statement is believed to be true is due to the results gathered and evaluated on the case study and site tours conducted by the primary researcher revealing significant advantageous benefits. The census that was gathered from these site

tours and case study revealed that these benefits impact all aspects of sustainability. Environmental sustainability for example can be witnessed with Thiess implementing lime stabilisation to neutralise the acidic sulphate soil, social sustainability is seen to be achieved by Ipswich City Council continued efforts of stakeholder management of the surrounding community and finally economic aspect from Main Roads Western Australia re-utilising 43% of the recycled material on-site allowed for a reduction in direct material costs. Overall this chapter's main focus and intentions were to highlight the sustainable practices adopted and incorporated by the projects. Then analyse and reveal their positive impacts that they had upon their project, with this information and analyse completed it becomes clear that the road industry should strive to incorporate sustainable practices into their current or future projects that they make undertake.

CHAPTER 6 - CONCLUSION

The research that was conducted in Chapter 2 sought to identify the current common sustainability management and development tools and practices that are being incorporated into the industry. The aim to identify these tools and practices were to evaluate their advantageous benefit and impact they have upon social, economic and environmental sustainability. The research conducted hoped to evaluate what barriers are impeding these sustainable tools and practices being implemented on more regular bases by the road industry. The literature reviewed and site tours undertaken all focused on the main question of whether sustainability has enough substantial benefits to warrant focus and resources being allocated in order to strive for sustainability. Furthermore if it is deemed that sustainability is viable and worthwhile then what barriers are impeding upon implementation. The main findings and discussion are observed in Chapter 5 – sections 5.1 and 5.2. This conclusion will collate the findings and literature review in order to answer the main question, suggest recommendations that can enhance implementation of sustainable practices and finally identify future works that others can undertake to build upon this research project.

Does sustainability warrant extensive focus and resources provided by the road industry? This was the questions that was formulated and required to be answered if sustainability is wished to be implemented industry wide. From the completion of this research project it becomes clear that sustainable practices do impact positively on social, economic and environmental sustainability in numerous ways. Due to the vast amount of sustainable practices evaluated and analysed in this research project, it was decided that critical examples will be put forward to demonstrate why the primary researcher believes that extensive focus and resources are warranted to be provided in order to implement these practices effectively. These practices similar to the literature review will be structured and separated into development and management sustainable practices and tools. It was decided in order to answer this question thoroughly site tours and case studies was the selected methodology for this research project.

6.1 Development practices

The first example that supports the primary researcher is lime stabilisation; this particular sustainable practice was seen to be implemented on both site tours with substantial affects upon sustainability. Moreton Bay Rail Project saw Thiess combat a significant environmental hazard by implemented crusher dust that created a lime stabilised soil which resulted in noteworthy advantageous benefit. Redbank Plains Road Project also saw a lime stabilised sub-base utilised which had economic-reduced overall cost of the project, environmental-reduced the amount of extra depth and layers of sub-base and gravel required which resulted in an overall positive impact. An issue that was seen even though both these two sites saw significant benefits, when analysing the case study the Great Eastern Highway project they neglected this sustainable practice and opted for a conventional straightforward road design. Overall in summary lime stabilisation as a sustainable development practice for the future is believed to be necessary for the road industry as the impact witnessed on two site tours is too substantial too ignore by the industry. The second critical example of development sustainable practice that had an overall positive impact is the utilisation of recycled material. This particular development practice is more common when compared to lime stabilisation, however this does not mean it cannot be incorporated to a greater extent on projects. The fact that Great Eastern Highway currently holds the record of most recycled material utilised on a project, and that only equates to 43% of the total import material is an alarming figure. With the significant benefits often witnessed by project that utilise recycled material such as literature example of the Clem 7 tunnel, Brisbane that utilised crushed concrete as an aggregate saw benefits such as:

- A Saving of over 1, 000 tonnes of Carbon dioxide
- Diversion of 100,000 tonnes of waste from landfill sites
- 120,000 tonnes reduction in natural resource depletion
- A saving of 725 truck movements (45,000 km of road travel)
- 20% reduction in material costs from savings in transport and sourcing.

(Hargroves, 2012).

These were only two critical examples, that highlight and support the primary researcher's belief that sustainable practices that can be adopted by the road industry has significant advantageous benefits, however these types of benefits were seen across the field of

development sustainability practices. Therefore to conclude it is most certainly worthwhile endeavour that the road industry allocates time and resources to possible sustainable development practices.

6.2 Management Practice

The first significant example that supports the claim that sustainability can impact and alter the success of the project is seen when undertaking the site tour on Redbank Plains Road. The particular sustainable practice that was witnessed was external stakeholder management in particular the surrounding community. Ipswich City Council incorporated additional resources and time to manage the surrounding community to an inordinate success. Literature reveals that social sustainability in relation to the other two spheres receives scant attention, so it was interesting to see the impact that was witnessed by Ipswich City Council. Literature states that external stakeholder management helps formulate and contribute a vital part in the success of a project (Haughey, 2015). This was also supported by the conversation held between the primary researcher and the project manager of this project, who believes if Ipswich City Council neglected or reduced its effort it inputted to management of the road development, this project would not be as successful as it has been to date. The second management tool that was proposed to be of interest to this research project was RSs. This particular sustainable management tool is seen to be gaining popularity in the road industry, as seen by a significant project; Great Eastern Highway upgrade utilisation of this tool. Concluding whether this rating tool was seen to be effective and worthwhile was difficult as quantitative data was not received, however in principle the guidance that this tool offers organisations can be seen to be viable and would be impactful upon any project. The example of Great Eastern Highway achieving a 'commending' result from the infrastructure sustainable rating tool is testimony to its importance and supports the claim that it is in fact a worthwhile effective sustainable management tool that can be adopted. The final sustainable management tool that this research proposed to be analysed and evaluated was LC. Unfortunately for this research project no case or site tour implemented this specific tool, however the principle of LC; about attaining equilibrium in the use of people, materials and resources required to complete a task and/or project is of sustainable nature. (Marhani, M et al 2013). With the state of the road industry in general emitting significant landfill waste, carbon dioxide and utilising substantial raw virgin material it becomes clear reducing this would impact the overall sustainability of road management and

development. Therefore concluding this management practice it is believed that this particular tool would be a worthwhile addition that organisation can adopt and modify to increase sustainability of the road industry.

6.3 Recommendations

From the drawn conclusion that sustainable practices are deemed to be worthwhile the issue arises as to why they have not been implemented to a great extent. This research project has evaluated these barriers that impede on implementation and will now draw recommendations that the primary researcher believes that has to be incorporated in order for sustainability to gain motion and popularity in the road industry. The barriers that were mentioned from the literature review in Chapter 2 include:

- Lack of momentum and motivation from the client/contractor.
- Inadequate resources.
- Lack of knowledge and techniques within the company.

The primary researcher believes if these three barriers are dispensed then the road industry will be more inclined to adopted certain sustainable practices, therefore recommendation will be drawn from combatting these three barriers. The first recommendation that will be given relates to the lack of momentum and motivation. The primary researcher believes this particular barrier is simply misunderstood by the industry. As been argued throughout this research project the motivation for the organisation to adopt sustainable road development and management practices are vast, varying from environmental, social and economic benefits. To combat the primary researcher believes further research and information should be provided to the client/ contractor that highlight the benefits associated with the certain sustainable practice. This will hopefully pursued and allow clients and contractors to opt for the sustainable practices over conventional unsustainable ones.

Inadequate resources is the next barrier that requires attention if sustainable practices are wished to be adopted. A recommendation that was developed throughout completing the research project was additional planning and designing.This will allow the client and/or contractor to have greater time to understand what resources are required in order to implement the sustainable management and development practices. This

recommendation can be worked in conjunction with LC as that also recommends additional planning and better estimations in order to eliminate the typical over estimation due to contingency.

The final barrier that can be seen to impede on sustainable road development and management is lack of knowledge and techniques. This particular barrier should not influence the industry due to the fact that additional training and education would solve this aspect. The primary researcher believes that additional training would be beneficial for the industry and for sustainability, which is supported as Mckeown (2012) states that training and education is an essential tool for attaining sustainability within the road industry.

6.4 Future Studies

With the conclusion of this research project, the possibility of future and furtherer studies within the area of sustainable road development and management are evident. Due to the fact that there are vast amounts of sustainable practices that could be analysed and evaluated, the major aspect of further studies the primary researcher believes could be evaluating the less common sustainable practices. Other furtherer studies include but not limited to:

- Undertaking more site tours that have utilised sustainable practices.
- Undertake greater analysis of direct cost saving potentials of sustainable development and management practices.
- Determine disadvantages associated with certain sustainable practices that aren't discussed within this research project.
- Develop a rating system specifically designed for the road industry within Australia.
- Further research into the critical sustainable practices that the primary researcher has highlighted; LC and lime stabilisation.
- And finally further research into the recommendations provided by the primary researcher to reveal if adopted would they actually impact and influence the industry to select sustainable practices.

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Appendix A:

University of Southern Queensland

Faculty of Engineering and Surveying

ENG 4111/4112 Research Project

Project Specifications

For: David Price

Topic: Project 66: Sustainable road development and management

Supervisor: Dr David Thorpe

Enrolment: ENG 4111 – S1 2015

ENG 4112 – S2 2015

Project Aim: The project aim is to analyse current road development and management theories and methodologies and to research possibilities of improvements.

Programme

1. Undertake detailed literature review into the current sustainable management practices, such as rating tools and lean construction.
2. Undertake research into current sustainable development practices, such as warm-mix asphalt and recycled aggregates and binders that will aid in improving the sustainability of roads.
3. Undertake research into the possibility of recycled aggregates and materials and what impact they have on sustainability.
4. Critically evaluate current barriers impeding on sustainable road development and management
5. Conduct up to the three site tours to observe, understand and document how sustainable road practices are being incorporated into road development and management and their advantageous benefits that are associated with these practices.
6. Submit a high quality academic dissertation in the required format.

If time permits:

1. Undertake research into the future technologies that may assist in improving the sustainability of road development and management.

Appendix B

Table 1. Greenroads Listing by Category.

No.	Title	Pts.	Description
Project Requirements (PR)			
PR-1	Environmental Review Process	Req	Complete an Environmental Review Process.
PR-2	Lifecycle Cost Analysis (LCCA)	Req	Perform LCCA for Pavement Section.
PR-3	Lifecycle Inventory (LCI)	Req	Perform LCI of Pavement Section with Software tool.
PR-4	Quality Control Plan	Req	Have a Formal Contractor Quality Control Plan.
PR-5	Noise Mitigation Plan	Req	Have a Construction Noise Mitigation Plan.
PR-6	Waste Management Plan	Req	Have a Plan to Divert C&D* Waste from Landfill.
PR-7	Pollution Prevention Plan	Req	Have a Stormwater Pollution Prevention Plan.
PR-8	Low-Impact Development (LID)	Req	Study Feasibility of LID Techniques for Stormwater.
PR-9	Pavement Management System	Req	Have a Pavement Management System.
PR-10	Site Maintenance Plan	Req	Have a Maintenance Plan for Environment, Utilities.
PR-11	Educational Outreach	Req	Publicize Sustainability inFormation for Project.

Table 1. Greenroads Listing by Category. (Continued)

No.	Title	Pts.	Description
Voluntary Credits			
Environment & Water (EW)			
EW-1	Environmental Management System	2	Have ISO 14001 Certification for General Contractor.
EW-2	Runoff Flow Control	3	Reduce Runoff Quantity.
EW-3	Runoff Quality	3	Treat Stormwater on-site.
EW-4	Stormwater Cost Analysis	1	Conduct a LCCA for Stormwater BMP*/LID Selection.
EW-5	Site Vegetation	3	Use Native Low/no Water Vegetation.
EW-6	Habitat Restoration	3	Create New Habitat Beyond what is Required.
EW-7	Ecological Connectivity	3	Connect Habitat Across Roadways.
EW-8	Light Pollution	3	Discourage Light Pollution.
	EW Subtotal:	21	
Access & Equity (AE)			
AE-1	Safety Audit	2	Perform Roadway Safety Audit.
AE-2	Intelligent Transportation Systems (ITS)	5	Implement ITS Solutions.
AE-3	Context Sensitive Solutions	5	Plan for Context Sensitive Solutions.
AE-4	Traffic Emissions Reduction	5	Reduce air Emissions Systematically.
AE-5	Pedestrian Access	2	Provide/improve Pedestrian Accessibility.
AE-6	Bicycle Access	2	Provide/improve Bicycle Accessibility.
AE-7	Transit & HOV* Access	5	Provide/improve Transit/HOV Accessibility.
AE-8	Scenic Views	2	Provide Views of Scenery or Vistas.
AE-9	Cultural Outreach	2	Promote Art/Culture/Community Values on Roadway
	AE Subtotal:	30	
Construction Activities (CA)			
CA-1	Quality Process Management	2	Have ISO 9001 Certification for General Contractor.
CA-2	Environmental Training	1	Provide Environmental Training.
CA-3	Site Recycling Plan	1	Provide Plan for on-site Recycling and Trash.
CA-4	Fossil Fuel Reduction	2	Use Alternative Fuels in Construction Equipment.
CA-5	Equipment Emission Reduction	2	Meet EPA* Tier 4 Standards for Non-road Equip.
CA-6	Paving Emission Reduction	1	Use Pavers that Meet NIOSH* Requirements.
CA-7	Water Use Monitoring	2	Develop Data on Water use in Construction.
CA-8	Contractor Warranty	3	Offer an Extended Warranty on Pavement.
	CA Subtotal:	14	

Materials & Resources (MR)			
MR-1	Lifecycle Assessment (LCA)	2	Conduct a Detailed LCA of the Entire Project.
MR-2	Pavement Reuse	5	Reuse Existing Pavement Sections.
MR-3	Earthwork Balance	1	Balance Cut/Fill Quantities.
MR-4	Recycled Materials	5	Use recycled materials for New Pavement.
MR-5	Regional Materials	5	Use Regional Materials to Reduce Emissions.
MR-6	Energy Efficiency	5	Improve Energy Efficiency of Operational Systems.
	MR Subtotal:	23	
Pavement Technologies (PT)			
PT-1	Long-Life Pavement	5	Design Pavements for Long-life.
PT-2	Permeable Pavement	3	Use Permeable Pavement as a LID Technique.
PT-3	Warm Mix Asphalt (WMA)	3	Use WMA in Place of HMA•.
PT-4	Cool Pavement	5	Use a Surface that Retains Less Heat.
PT-5	Quiet Pavement	3	Use a Quiet Pavement to Reduce Noise.
PT-6	Pavement Performance Monitoring	1	Relate Construction to Performance Data.
	PT Subtotal:	20	
	Voluntary Credit Total:	108	
Custom Credits (CC)			
CC-1	Custom Credits	10	Design your own Credit.
	CC Subtotal:	10	
	Greenroads Total:	118	

•C&D = construction and demolition; BMP = best management practice; HOV = high occupancy vehicle; EPA = U.S. Environmental Protection Agency; NIOSH = National Institute for Occupational Health and Safety; HMA = hot mix asphalt.

Appendix C:

QUALITY OF LIFE
13 Credits

1 PURPOSE
QL1.1 Improve Community Quality of Life
QL1.2 Stimulate Sustainable Growth & Development
QL1.3 Develop Local Skills & Capabilities

2 WELLBEING
QL2.1 Enhance Public Health & Safety
QL2.2 Minimize Noise and Vibration
QL2.3 Minimize Light Pollution
QL2.4 Improve Community Mobility & Access
QL2.5 Encourage Alternative Modes of Transportation
QL2.6 Improve Accessibility, Safety, & Wayfinding

3 COMMUNITY
QL3.1 Preserve Historic & Cultural Resources
QL3.2 Preserve Views & Local Character
QL3.3 Enhance Public Space

QL0.0 Innovate or Exceed Credit Requirements

LEADERSHIP
10 Credits

1 COLLABORATION
LD1.1 Provide Effective Leadership & Commitment
LD1.2 Establish A Sustainability Management System
LD1.3 Foster Collaboration & Teamwork
LD1.4 Provide for Stakeholder Involvement

2 MANAGEMENT
LD2.1 Pursue By-Product Synergy Opportunities
LD2.2 Improve Infrastructure Integration

3 PLANNING
LD3.1 Plan For Long-Term Monitoring & Maintenance
LD3.2 Address Conflicting Regulations & Policies
LD3.3 Extend Useful Life

LD0.0 Innovate or Exceed Credit Requirements

RESOURCE ALLOCATION
14 Credits

1 MATERIALS
RA1.1 Reduce Net Embodied Energy
RA1.2 Support Sustainable Procurement Practices
RA1.3 Use Recycled Materials
RA1.4 Use Regional Materials
RA1.5 Divert Waste From Landfills
RA1.6 Reduce Excavated Materials Taken Off Site
RA1.7 Provide For Deconstruction & Recycling

2 ENERGY
RA2.1 Reduce Energy Consumption
RA2.2 Use Renewable Energy
RA2.3 Commission & Monitor Energy Systems

3 WATER
RA3.1 Protect Fresh Water Availability
RA3.2 Reduce Potable Water Consumption
RA3.3 Monitor Water Systems

RA0.0 Innovate or Exceed Credit Requirements

NATURAL WORLD
15 Credits

1 SITING
NW1.1 Preserve Prime Habitat
NW1.2 Protect Wetlands & Surface Water
NW1.3 Preserve Prime Farmland
NW1.4 Avoid Adverse Geology
NW1.5 Preserve Floodplain Functions
NW1.6 Avoid Unsuitable Development on Steep Slopes
NW1.7 Preserve Greenfields

2 LAND+WATER
NW2.1 Manage Stormwater
NW2.2 Reduce Pesticide & Fertilizer Impacts
NW2.3 Prevent Surface & Groundwater Contamination

3 BIODIVERSITY
NW3.1 Preserve Species Biodiversity
NW3.2 Control Invasive Species
NW3.3 Restore Disturbed Soils
NW3.4 Maintain Wetland & Surface Water Functions

NW0.0 Innovate or Exceed Credit Requirements

CLIMA AND R
8 Credits

1 EMISSIONS
CR1.1 Reduce Greenhouse Gas
CR1.2 Reduce Air Pollutant Em

2 RESILIENCE
CR2.1 Assess Climate Threat
CR2.2 Avoid Traps & Vulnerabi
CR2.3 Prepare For Long-Term A
CR2.4 Prepare For Short-Term
CR2.5 Manage Heat Island Effe

CR0.0 Innovate or Exceed Cred

Appendix D

Themes	Categories
Management and Governance	Management Systems
	Procurement and Purchasing
	Climate Change Adaptation
Using Resources	Energy & Carbon
	Water
	Materials
Emissions, Pollution and Waste	Discharges to Air, Land & Water
	Land
	Waste
Ecology	Ecology
People and Place	Community Health, Well-being and Safety
	Heritage
	Stakeholder Participation
	Urban & Landscape Design
Innovation	Innovation

Appendix E:

Questions:

Topic: Sustainable Road Development and Management

So for development the main talking points are:

1. Material utilised and if it's recycled e.g re-used crushed rock.

2. Any development strategies or any new technology's that promote sustainability in the road industry e.g warm mix asphalt, foaming technology, insitu stabilisation.

3. Any waste management techniques utilised by your company.

And Management points are:

1. Does Thiess utilise any management tools that promote sustainability e.g rating systems (ISCA or another common rating systems)
2. Would you utilise lean construction to minimize waste?

3. In the planning stages of this project did you think about sustainability in mind? E.g using green space? Footprint of the road.

4. Erosion Control when laying out the footprint?

5. In your professional opinion what is limiting sustainability in the road industry.

Appendix F:

David Thorpe <David.Thorpe@usq.edu.au> Aug 6

to rraikunajones, me

Hello Ben

This email is to advise that David Price is a Construction of Construction (Honours) student with the University of Southern Queensland.

He is undertaking his Honours research on the topic of Sustainable Road Development and Management.

Please contact me if you have any queries.

Regards

David Thorpe

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Appendix G:

Dear Ben,

I am currently undertaking my final year of construction engineering at the University of Southern Queensland. I am conducting research for my thesis topic: Sustainable road development and management. I am emailing you regarding the possibility of a site tour and a few queries about any particular roads currently being designed and/or constructed with sustainable practices or methods being utilized by Thiess. I currently hold a white card and have experience in the construction industry. I have attached my resume and cover letter if any further information is required. Also as of the 6th of August I have requested a letter from the University of Southern Queensland to support my request and need to undertake the site tour however I am still waiting a response from them.

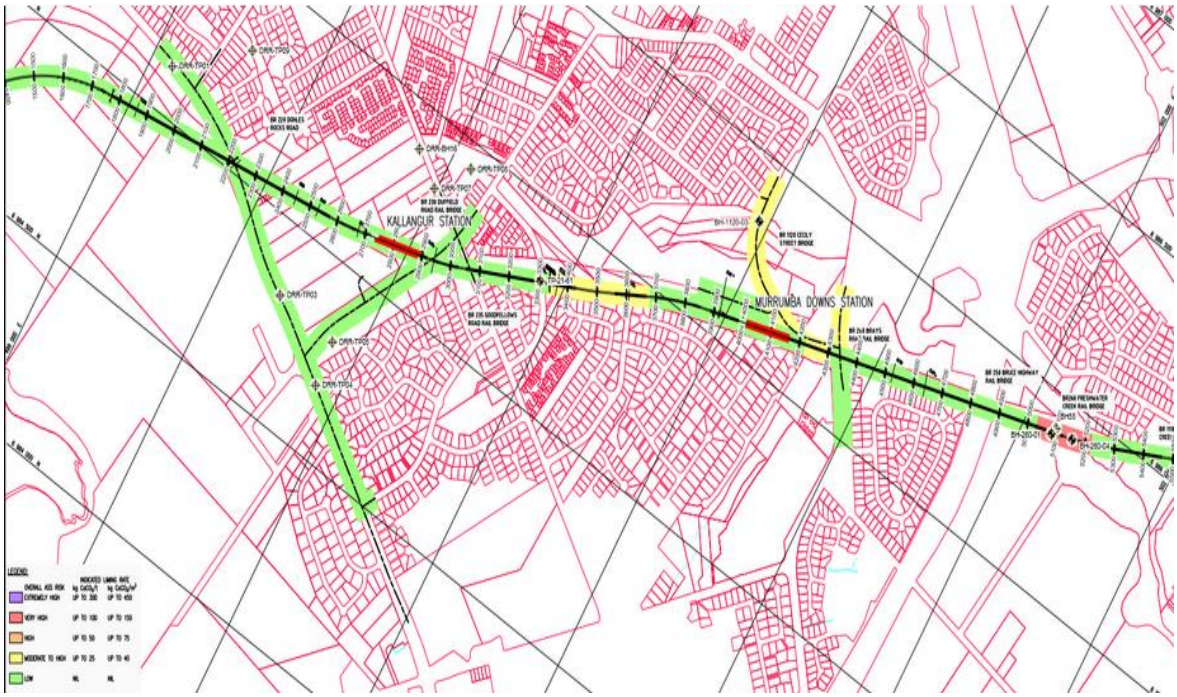
I look forward to hearing your response.

Kindest regards,
David Price.
0412 429 457

Appendix H:


PETRIE STATION
KALLANGUR STATION
LAWNTON STATION

Appendix I:


KALLANGUR STATION
MURRUMBA DOWNS STATION

Appendix J:


MANGO HILL EAST STATION
MANGO HILL STATION

Appendix K:


ROTHWELL STATION
ROTHWELL STATION
KIPPA-RING STATION