University of Southern Queensland

Faculty of Health, Engineering and Sciences

A Preliminary Feasibility Study For Transporting Surat Basin Export Coal Using Maglev Technology

A dissertation submitted by

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In fulfilment of the requirements of

Bachelor of Civil Engineering

November 2013

Abstract

Australia is one of the world's largest exporters of coal and many mining companies are interested in the coal rich Surat Basin. The problem is that this land is currently inaccessible as there is no feasible transportation infrastructure. Currently there is a joint venture by mining and rail companies to construct the Surat Basin Rail Link which will connect the Surat Basin to Gladstone Port. This proposal is restricted to exporting only 42 Mtpa as any increase in the volume of coal will drastically raise overall costs. The coal export volume from the Surat Basin could be drastically increased with a strong coal demand, as shown from the large amount of mining interest and planned coal mines. This report aims to complete a prefeasibility study for transporting Surat Basin export coal with Magnetically Levitated Trains (Maglev) as an alternative to Rail if higher export volumes are required. Maglev is considered an alternative proposal primarily as it has high potential for cost savings in the future for transporting high volumes over long distances. Currently there is no publically released documentation surrounding the transportation of coal using Maglev technologies. This provides an exciting opportunity to conduct investigations for the operational, technical and financial feasibility, giving future engineers guidance if this technology becomes feasible.

In both the technical and financial feasibility aspects, it is evident that Maglev is not currently feasible compared to conventional rail, as there are no designs of Maglev to transport coal. Preliminary designs completed explain how the primary design concerns are overcome, underlining that once detailed designs have been completed Maglev transporting coal can be technically feasible. While the German Transrapid Maglev is currently the most feasible model it is not financially viable. The expected release of the Japanese MLX in 2025 will have increased characteristics and properties, and lower operational costs. With projected future Maglev technology transporting 75 Mtpa of export coal from the Surat Basin to Gladstone Port, it will have a yearly saving of $532 million dollars. From these savings Maglev's high capital cost will only require 19 years of operation to breakeven to Rail's total cost. For these projected Maglev characteristics to occur, advancements such as improving superconductor technology is required. It is only after these technological advances, that Maglev will be a feasible alternative solution to Rail for transporting coal. In the near future Maglev may become a feasible alternative if the current delays continue to prevent the Surat Basin Rail Link from being approved.

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ENG4111/2 *Research Project*

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Acknowledgements

The writer would like to take this opportunity to gratefully acknowledge the assistance and contribution of all who have assisted in the development of this report.

I would like to thank Trevor Drysdale who was my supervisor. He gave me the freedom to carry out this Thesis proposal of my choosing while keeping me on track throughout the semester.

Also thanks to Mr Hill my year 12 physics teacher who introduced me to Maglev and Superconductors.

Also thanks to Ron Ayres for directing my vision on a practical and relevant problem.

Finally and most importantly I would like to thank my family and friends who have supported me over the course of the year giving me the motivation to keep achieving the best every day.

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Chapter 1: Introduction

"Every great new thought was opposed. Every great new invention was denounced. The first motor was considered foolish. The airplane was considered impossible. The power loom was considered vicious. Never disregard any idea for the sole reason that it doesn't appear in your vision of the future" from Ayn Rand, The Fountainhead

1.1 Background

Professional engineers have to be constantly looking into the future to find new designs or methods to implement to increase efficiency and introduce sustainable practices. With these new technologies it is our duty to mould designs to solve present day problems.

Australia is one of the world's largest coal exporters and many mining companies are eyeing of the coal rich Surat Basin. There are estimated up to four billion tonnes of coal reserve, which is currently untouchable due to the lack of an adequate rail system. Currently the Surat Basin is only serviced by the Western Rail line, which has export capacity problems being caused from both the rail line and the port capacity. By opening up this land to mining investment it has the potential to maintain and enhance the economic and social conditions in the region, state and national and ensure Australia remains a large contributor to the world's energy sector.

To solve this problem currently there is a combined effort by mining and rail companies to install a new railway to connect the Surat Basin coal mines to the Gladstone port. It is the role of an engineer to look at possible alternatives and access their feasibility for this project. Looking into the future the possibilities of engineering solutions is limitless but one alternative technology that can be analysed is Magnetically Levitated Trains (Maglev). It is the aim of this report is to complete a pre-feasibility study on transporting export coal from the Surat Basin using Maglev technology.

Maglev is a modification of the design of trains that use magnets as a method of propulsion and levitation removing the requirement for wheel on track contact. The carriage are levitated a short distance above the ground at a distance dependant on one of many models have been designed.

The primary reason Maglev is investigated to solve this problem is that the track alignment characteristics are perfect in making Maglev financial feasible. Normally the main selling point of Maglev is that it can reach higher speeds, but this is not of primary concern for this proposal. The advantage which makes Maglev a feasible alternative is that Maglev has lower operational costs than Rail. Lower operational costs are due to the existence of friction and minimal maintenance costs. The Surat Basin has a long haul distance with coal has to be transported, making it a viable location for Maglev due to its lower operating costs.

The current models of Maglev are not feasible due to its high capital costs, old technology and infrastructure, the public's unwilling to change to new technology where levitation is involved and there are only multiple commercially operating Maglevs'. There are plans for new models of Maglev to become commercially viable in 2025 which utilises recent technological advancements, to drastically increase efficiency and decrease operating costs. Superconductors are one of the prime areas for future research, and is currently restricting the financially feasibility of these Maglev technologies which utilise them.

Currently there has been no research or public acknowledgement into transporting coal using Maglev technology. This provides the perfect opportunity to research and complete preliminary designs to determine if Maglev technology is a feasible alternative in solving this local present day problem.

1.2 Research Objectives

A pre-feasibility study is a comprehensive but broad study of the viability of a proposal that has potential to become feasible in the future. It looks at the operational, technical, and financial feasibility to determine an overall verdict of feasibility. Finally, suggestions are recommended on how to precede with future feasibility studies.

The primary objectives of this report is to determine the feasibility of maglev transporting coal, but also to provide future guidance to engineers guidance there is currently no publically available information. To determine a verdict on the overall feasibility, there are a number of tasks which had to be completed as identified within the scope of the project.

1. Research and identify the background information related to the current state of Maglev technology and superconductors.

2. Complete a preliminary investigation to identify prominent current and future Maglev Transportation Systems.

3. Complete a preliminary investigation to identify the present status of the coal

industry within the Surat Basin to determine the operational feasibility.

4. Collect available financial data on the costs of Maglev technology and conventional coal trains.

5. Identify and discuss the required primarily future design requirements for Maglev technology to transport coal and provide preliminary designs.

6. Complete a preliminary financial feasibility model using collected data and information.

7. Determine the Operational, Technical and Financial feasibility of the proposal.

8. Present the overall feasibility verdict and provide future recommendations for this proposal.

The second aim was to have the document as an overall source of information regarding the feasibility of Maglev transporting coal. The reason for this is that future engineers may be considering this feasibility and there is no released documentation publically available. Along with explaining how the feasibility was determined, the report also has a number of topics which were not analysed in the impact of the feasibility for this report, but would have to be considered and analysed for future detailed feasibility designs. They are:

9. Identify and complete a detailed analysis of the advantages and disadvantages of Maglev technology and its ability to transporting coal.

10. Complete a preliminary probability and impact feasibility analysis for the transportation of export coal using Maglev technology.

11. Identify the design requirements needed for the alignment and make preliminary design proposals on possible track alignments from the Surat Basin to a local port.

Chapter 2: Literature Review - Maglev Transportation

There are also supporting discussion and summaries of Superconductors are and their impact on the future feasibility of Maglev. This chapter was not included the Literature Review as it is not required to understand Maglev or for the proposal for Maglev to transport coal. There are numerous times within the report where superconductors are mentioned to be capable of making the future MLX feasible. This appendix is for any engineers who are interested on how these conclusions are founded or overall superconductor's capabilities.

2.1 Introduction

As stated in the Introduction Magnetic Levitation Trains (Maglev) is a model of train which uses magnetic levitation to propel vehicles with magnets rather than through friction through wheels on a railroad. The Maglev carriage is levitated a short distance away from the guideway by magnets which also are used to create lift and thrust. A detailed description on how these systems work are described in this chapter.

Presently most of the Magnetic Levitation Trains (Maglev) design and research around the world have focused on the transportation passengers. The aim is for Maglev to become completive to other transportation modes such as High Speed Rail (HSR) and Air Travel. Chapter 2 discusses the prominent models of Maglev systems currently in operation and the technology involved. I will also look at Australia's involvement in planning for Maglev and what the future holds for Maglev.

When looking at the feasibility of Maglev, the primary concern is regarding cost. Currently most Maglev technology is not competitive for the transportation of people when comparing with other viable options. But there is a great deal of research and testing around the world to develop a cheaper and more competitive Maglev system.

Currently there has not been any substantial research been carried out regarding the movement of freight with Maglev. While the technology will be the same as transporting people, there will be different requirements such as the need for transporting heavy loads and loading and unloading coal. The aim of this Chapter in the literature review is to provide current Maglev technical information which will assist in the appreciation and understanding of the feasibility regarding the use of Maglev for the transportation of coal.

2.2 Prominent Maglev Trains

There are a number of different ways which superconductors can be applied to magnetically levitate trains. In theory powerful superconducting magnets both on the train and the ground with opposite polarity will effectively suspend the train in mid-air. Engineers have found a number of different methods to apply the property of magnetic levitation to create Maglev Trains. There are a large number of different models of Maglev trains but within this literature review only the two major designs will be discussed. Most Maglev trains and prototypes fall under one of two categories:

- Electromagnetic suspension (EMS)
- Electrodynamics suspension (EDS)

Another experimental and theoretical category include

- Inductrack

Figure 1 shows the global development of Maglev trains.

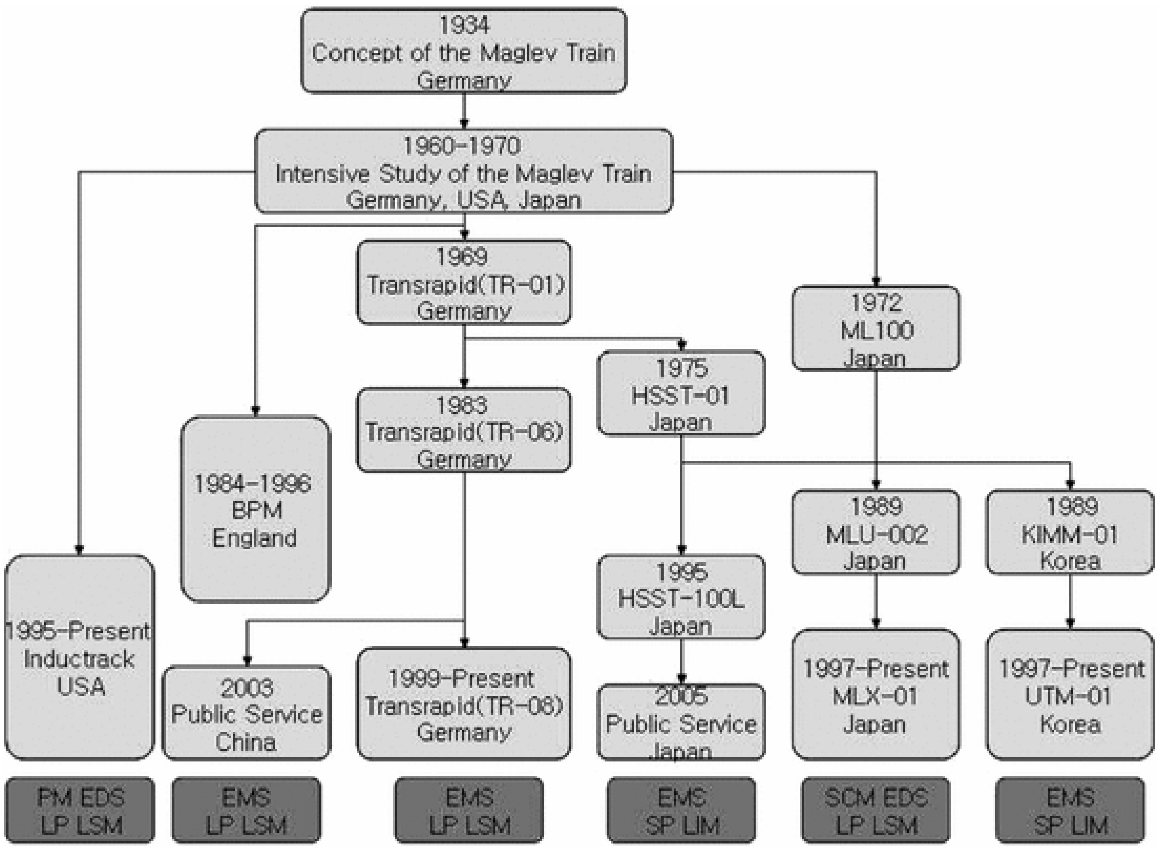


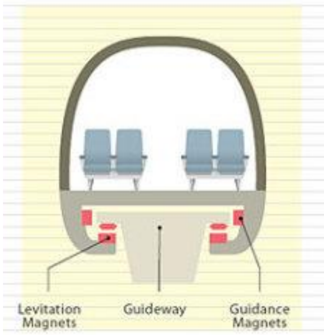
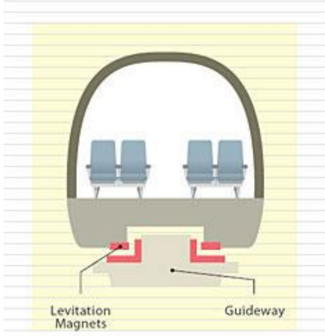
Figure 1: Development of global Maglev (Lee, 2006)

Legend for the above table is identified below and in the following Chapter.

- Electromagnetic Suspension (EMS)
- Electrodynamic suspension (EDS)
- Linear Induction motor (LIM) , (LP, SP = Long/Short Primary type)
- Linear Synchronous Motor (LSM), (LP, SP = Long/Short Primary type)
- SCM = Superconducting Magnet

The following table summarises the two current mainstream magnetic levitation trains which are operational. They are the German Transrapid and the Japanese MLX-01. All of the identified properties are discussed within this chapter.

Table 1: Description of the operational Maglev as identified within the Literature Review

Feature	German Transrapid	Japanese MTX-01
Picture of Train	 **Figure 2: German Transrapid (US Department of Electrical Engineers, 2005)**	 **Figure 3: Japanese MLX 01 (US Department of Transportation Federal Railroad Administration, 2005)**
Maglev Suspension System	Electromagnetic Suspension (EMS)	Electrodynamic Suspension (EDS)
Location of Magnets	 **Figure 4: EMS (Venus Project, 2013)**	 **Figure 5:EDS (Venus Project, 2013)**
Maglev Propulsion System	Linear Synchronous Motor (LSM), (Long Primary type)	Linear Synchronous Motor (LSM), (Long Primary type)
Levitation Force Type	Attractive Levitation	Repulsive Force
Stability	8-12mm gap, Highly reliable electronic control system to ensure correct levitation	10cm gap

Low Speed	Able to levitate	Not currently able to levitate, has wheels
Magnetic fields	Equals to the earth's magnetic field	Current design has high magnetic fields (enough for pacemakers to require magnetic shielding)
Power Failure	Emergency battery power to enable the train to stop, then rest on the track	Emergency battery provides power
Current Commercial use	Germany and China	Not currently in commercial use. Aiming for 2025 in Japan
Highest Speed	501km/hour	581km/hour
Weight Capacity	70 tonnes of Freight	Heavy load capacity

This table shows the different classifications of Maglev trains in operation. These tables are created from the information identified and discussed in the following chapter.

Table 2: Classification of Maglev trains (Lee, 2006)

Type	**In Operation**			**Ready to Use**		
System	HSST (Japan)	Transrapid (Germany)	MLU,MLX-01 (Japan)	UTM (Korea)	Swissmetro (Swiss)	Inductrack (USA)
Levitation	EMS	EMS	EDS	EMS	EMS	PM EDS
Propulsion	SP-LIM	LP-LSM	LP-LSM	SP_LIM	LP or SP - LSW	LP-LSM
Air gap	8-12mm	8-12mm	80-150mm	8-12mm	18-22mm	80-150mm
Maximum speed	100km/hr	501km/hr	581km/hr	110km/hr	500km/hr	500km/hr
Service	Low-med speed, short distance	High Speed, Long distance	High Speed, Long distance	Low-med speed, short distance	High Speed, Long distance	High Speed, Long distance
Characteristic	Levitation /Guide integrated	Levitation/ Guide separated	Cooling required for SCM	Levitation/ Guide integrated	Partial vacuum in tunnel	Halbach Magnet Array

2.2.1 Electromagnetic Suspension (EMS)

Figure 6: German Transrapid (US Department of Electrical Engineers, 2005)

Electromagnetic Suspension is used by the German Transrapid where the Maglev train wraps the carriage around a T-shaped guideway. Electromagnets on the track use alternating current to attract the train above the guide way. This method uses attractive levitation. The T shaped guideway is generally elevated and fabricated from steel, concrete or a hybrid design (Simon, 1988) (US Department of Transportation Federal Railroad Administration, 2005).

Electromagnetic suspension allows the train to levitate above a steel guideway while electromagnets on the train are being propelled by other electromagnets on the guideway. The Transrapid doesn't utilise the increased strength of superconductors are electromagnets as this technology is over 20s old. As can be seen by figure 7 the attractive force of the magnets attached to the vehicle lift the train carriage towards the guideway from osculating the magnets positive and negative to create an attraction (Simon, 1988) (US Department of Transportation Federal Railroad Administration, 2005) .

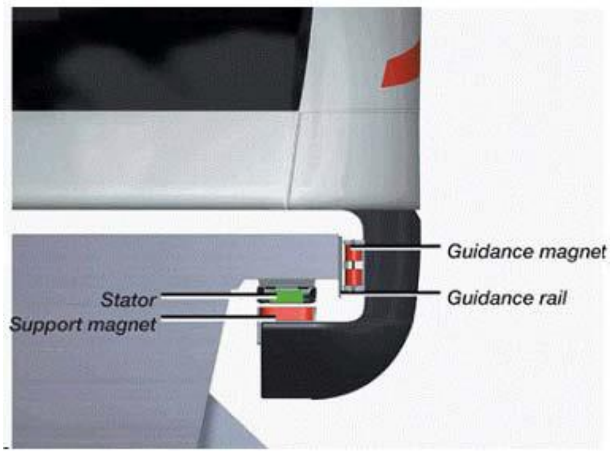


Figure 7: Transrapid Levitation/Guidance Magnet Arrangement (US Department of Transportation Federal Railroad Administration, 2005)

The Germans are leaders in this technology and have operational trains running since 1999. The Transrapid propulsion is from linear synchronous motors to reduce on-board weight. The current German Transrapid Maglev design vehicle is 25m long and 3.75m wide. This was designed to transport passengers which could hold about 100 in coach class. This German technology has been implemented with the distance travelled at approximately 1 million kilometres and transported over a million passengers. These trains have reached the speeds of 500 kilometres per hour in November of 2003. (Lee, 2006)

For the Transrapid Linear Synchronous motor the primary windings (Stator) are embedded in the guideway while secondary (rotor) consist of the levitation magnets on board the train. The frequency of the alternating current feeding the stator must be synchronized to the speed of the vehicle. Breaking is achieved by reversing the phasing of the primary current. As can be seen in the diagrams the vehicle chassis wraps around the guideway so that if delevitation occurs the vehicle will drop to the guideway and skid and coast to a rest. (Lee, 2006)

2.2.2 Electrodynamic suspension (EDS)

Figure 8: Japanese MLX 01 (US Department of Transportation Federal Railroad Administration, 2005)

Electrodynamic suspension uses the principal of repulsive levitation. This type of levitation relies on Lenz's law of electricity which describes how moving an ordinary loop of wire next to a large magnet causes a current to flow through the loop. The loop will create an electromagnet so it will attempt to resist any change in the magnetic field that penetrates it. This temporality produces its own magnetic field which acts opposite to the applied field. Engineers use this electrical principal to levitate the superconducting trains. This is applied by placing ordinary conducting wire loops in the path of the train. When the high speed train approaches, large currents will spontaneous begin to flow around the loop to create an opposing magnetic field that levitates the incoming train (Simon, 1988).

The MLX utilises superconductors which give large performance and efficiency properties to the Maglev system, but presently this one of the reasons why it is not presently feasible. Currently the superconductors have to be cooled which drastically increases the operational cost of the MLX. There is much development by the international community to improve the superconductors so that they will need less or no cooling. In Appendix B is a detailed description of superconductors and what is being done to improve the efficiency. In the last 10 years there have been major advancements with superconductors, and if these trends continue a cost effective MLX may be in the near future.

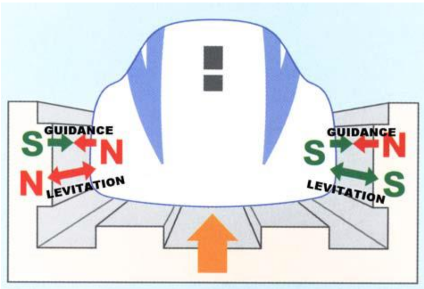


Figure 9: Levitation Principle in Japanese System (US Department of Transportation Federal Railroad Administration, 2005)

As seen in the figure 9 the train carriage is placed within the track with coils in the guideway to create a full coverage of required levitation. The minor disadvantage of this setup is that the levitation produced within the coils is lost rapidly due to resistance within the coil. At high speed this is not a problem since the train passes quicker than the magnetic field disappears. This is however a concern at low speeds since it causes reduced lift and can cause total delevitation. The train solves this problem by using wheels for take-off until it reaches a safe speed of 30 km/hr. This method of travel is not suited for low speed operations (Simon, 1988).

The Japanese are the leaders on this type of technology. They have created a number of different tracks, but most noticeably is the MLX01 high speed test rack. This has operated over 400 000 km and has achieved speeds around 600km/h. This can reach higher but at this speed there is a large aerodynamic drag. The vertical clearance between the guideway and the carriage is 10cm. Unlike the German Transrapid system the technology has not be deployed in a revenue service. The current developments which the Japanese are trying to achieve are to enhance performance and to reduce the high capital costs. (US Department of Transportation Federal Railroad Administration, 2005)

2.2.3 Inductrack and other systems

The Inductrack is a newer form of the Electrodynamic system which uses permanent room temperature magnets to produce the magnetic fields instead. The Inductrack arranged the magnets in a Halbach array to create the required levitating force. They are made from new materials which create high magnetic fields. Currently there is no commercial version of the Inductrack or a full scale system prototype. For this reason there is no estimated costing related to this system, but it highlights the efforts of engineers to find new methods to make Maglev technology a feasible future. (Venus Project, 2013)

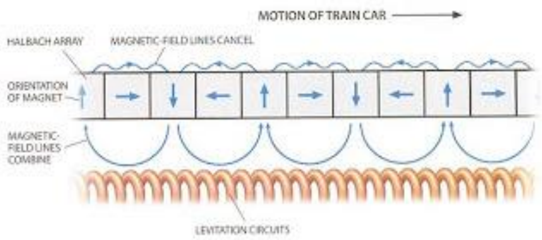


Figure 10: Inductrack (Venus Project, 2013)

As can be seen in figure 10 the track is an array of electrically shorted circuits containing insulating wire. One of their designs the circuit runs along the track like a ladder. Like the Electrodynamic suspension (EDS) it also repels the magnetic field created from magnets from the train carriage. The current design of a high speed Inductrack allows for an inch spacing between the carriage and the guideway removing the requirement for a sensor. (Venus Project, 2013)

Low speed Maglev Technology

There are a large amount of low speed Maglev train concepts throughout the world. The following is a list of different concepts

- American Maglev technology system at Old Dominion University in Norfolk, Virginia
- MagneMotion Maglev M^3 which involves using permanent magnets in attraction
- LevX which involves using permanent magnets in repulsion
- Japanese HSST (Research as Low-medium Maglev)
- Korean UTM

2.3 Key Features of Maglev Train Systems

2.3.1 Propulsion

Present Maglev trains currently use linear motors as the form of propulsion. It differs from the conventional rotary motor as it doesn't use mechanical components for movement.

Linear induction motor (LIM)

"What occurs within the linear induction motor is that the space-time variant magnetic fields are generated by the primary parts across the air gap and induce the electromagnetic force in the secondary part, a conducting sheet" (Lee, 2006). Electromagnetic fields which are generated create eddy currents which interacts with air gap flex to produce thrust known as Lorenz's force. (Lee, 2006)

There are two types of linear induction motors

Short Primary type

This includes stator coils on board the carriage and the conducting sheets of the guideway. It is very easy to lay this type which reduces construction costs. This however has low energy efficiency because of drag forces and leakage inductance. The short type has a maximum speed of 300 km/h. It is generally used for low-medium speed Maglev trains. (Lee, 2006)

Long Primary type

This includes having the stator coils on board the carriage and the conducting sheets are on the board. The construction cost of the long primary type is much higher than the short primary type. An advantage is that does not need any eddy current collector for operation. This is used for high speeds because the transfer of energy using a current collector is difficult. (Lee, 2006)

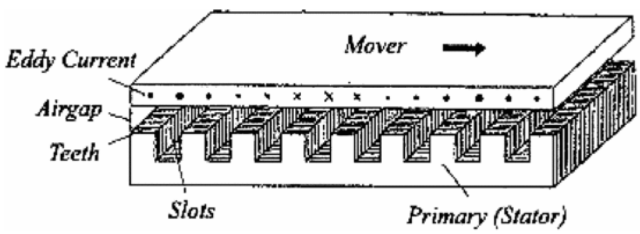


Figure 11: LP type Liner Induction motor (Lee, 2006)

Linear Synchronous Motor (LSM)

The thrust force is caused by the interaction between the magnetic field and armature currents. The speed of the carriage is controlled by the controller's frequency. Like the linear induction motor there are two types which have the same properties of short primary and long primary type. (Lee, 2006)

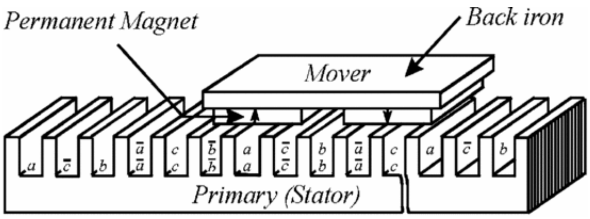


Figure 12: Linear Synchronous motor LP type (Lee, 2006)

Within Linear Synchronous Motors there is another option of two types according to the magnetic field.

Electromagnets with Iron Core used by the German Transrapid are shown in figures below:

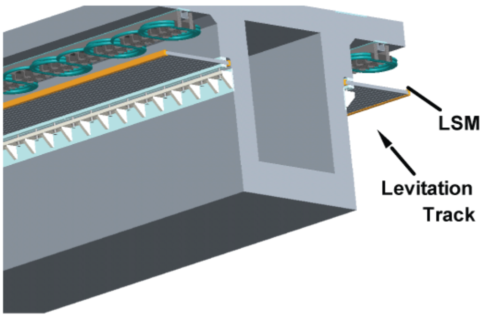


Figure 13: LSM for the German Transrapid (General Atomics, 2013)

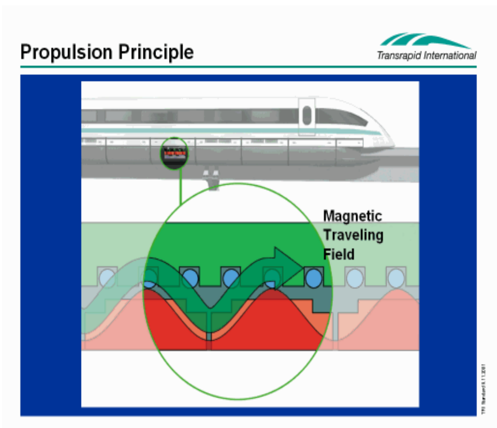


Figure 14: When a current is supplied to the windings, it creates a travelling alternating current that propels the train forward by pushing and pulling. (Transrapid A, 2013)

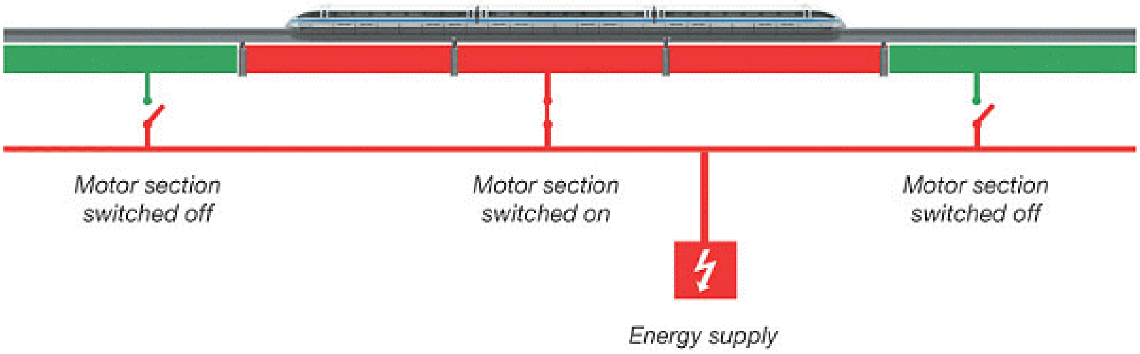


Figure 15: Propulsion only activated in sections of Track where the vehicle is (Transrapid B, 2013)

Superconducting Magnets used by the Japanese MLX are shown in figure below:

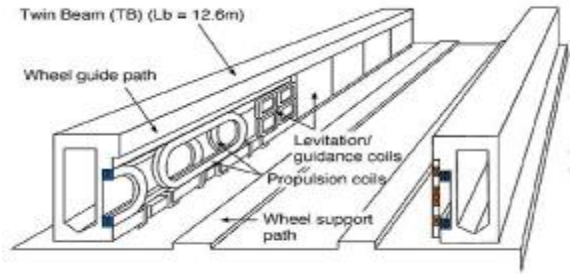


Figure 16: Beam method with propulsion coils (Florida Space Institute, 2000)

Comparison

The recent Maglev proposals prefer the linear Synchronous Motor (LSM) because of its higher efficiency and power factor compared to the Linear Induction Motor. The usage of the electric power consumption is a critical part to ensure feasibility for high speed operation.

Both do not require sensors and are similar in reliability and controllability. The main factors depend on the speed and construction cost.

2.3.2 Lateral Guidance

With the Maglev trains being a non-contact system the train requires guiding forces to prevent lateral displacement.

German Transrapid Magnetic Attraction Force

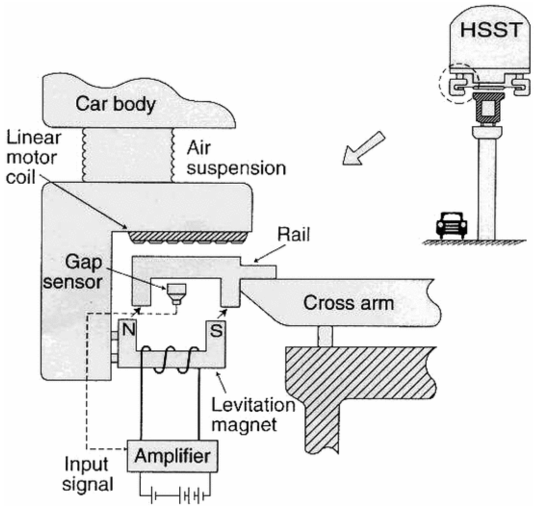


Figure 17: HSST (Lee, 2006)

"As can be seen in the figure 17 the magnetic attraction force is generated in the way to reduce the reluctance and increase the inductance when the vehicle displaces laterally. Because energy tends to flow towards the small reluctance, this guides the vehicle centred laterally." (Lee, 2006)

This has the advantage of integrating the guidance with the levitation but the interference between the two means it cannot run a very high speeds.

Japanese MTX Magnetic Repulsive Force

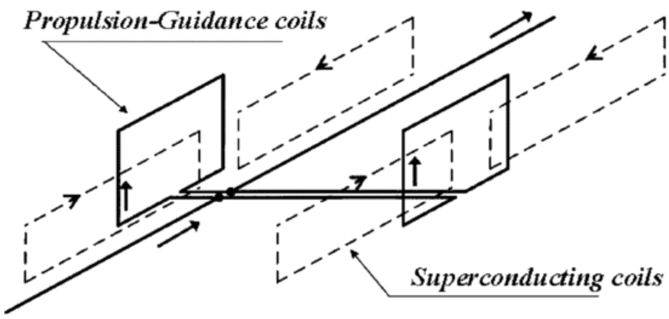


Figure 18: Propulsion and Guidance coils in the Japanese MLU-002 (Lee, 2006)

As seen from figure 18, the placements of propulsion coils are on the left and right side of the guideway. This induced electromotive force (EMF) cancels out when the train runs through the centre of the guideway. When the carriage moves closer to a sidewall the current flow's through the coil by the EMF induced by the distance difference. (Lee, 2006)

For the Japanese MTX they have the same setup as described above, whereas the German Transrapid the guidance electromagnets are attached on the extended undercarriage and the reaction rails on both sides of the guideway as can be seen in figure 18. (Lee, 2006)

2.3.3 Transfer of Energy to Vehicles

While all Maglev trains have batteries on the carriages, a power source is still required. The electric power supply is required for levitation, propulsion, on-board electrical equipment and battery recharging. The method to get this energy depends on the speed at which the train goes.

<u>Low Speed Operations</u>

Mechanical contact using a pantograph is used for low speeds up to 100km/h. It is for this reason Short Principal setups Maglev trains are only used for low-medium speeds. (Lee, 2006)

<u>High Speed Operations</u>

Power cannot be obtained from the ground at high speeds so the high speed Maglev trains cannot have to use another method.

- **German Transrapid**

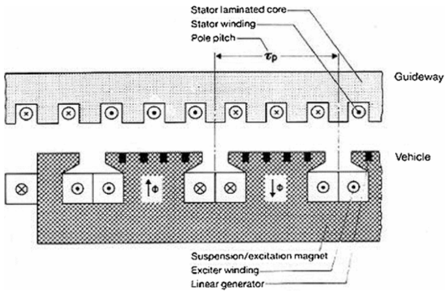


Figure 19: LSM design of Transrapid (Lee, 2006)

German Transrapid implements a linear generator that is combined with the levitation electromagnets as seen if figure 19. The linear generator derives its power from travelling through the magnetic fields when the carriage is in motion. While the generator is contact free, there are possible issues with the induced voltage due to unevenness of the air gap and small magnitude of induced voltage due to miniaturized inducting coils. (Lee, 2006)

- **Japanese MLX**

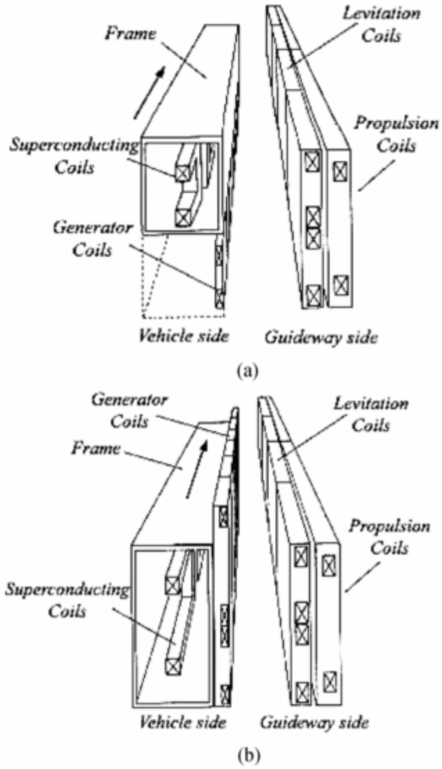


Figure 20: Two types of linear generator used in the MTX

The Japanese MLX uses a gas turbine generator and two linear generators. There are two orientations for the placement of the linear generators. a) Uses superconducting coils and generators at the upper and lower sides of the carriage. b) Uses one generator coil between the superconductor coils and the levitation propulsion coils. The placement of the type depends on the location of the carriage. These generate a dc flux which is transformed to ac flux. (Lee, 2006)

2.4 Identification of present advantages and disadvantages of Maglev

The following advantages and disadvantages are from a number of different sources, but primarily from US Report to Congress and Department of Electrical Engineers document. All of the figures are related to the design of the Transrapid in Germany. Below show the points of Advantages and Disadvantages and for an in-depth analysis of each point read Chapter 4.2.1 to Chapter 4.2.4

Advantages of Maglev Trains

- High Speeds
- High Turning Circle Capacity
- High Grade Capacity
- Shared Transport Corridors
- Reduced Maintenance costs
- Small land requirements
- Large number of prototypes and interest
- Potential of Superconductors
- Rate of Superconductor advancement.
- Society push to become more sustainable and greener
- Environmentally friendly compared to current methods of coal transportation
- High Safety focus
- Doesn't use petroleum products
- High Capacity
- Competitive against Air Travel and HSR alternatives for transportation of passengers
- Reliability
- Right of Way
- Low impact on national security
- Average Speed energy saving
- A number of socioeconomic effects

Disadvantage of Maglev Trains

- Not economic feasible
- Peak speed versus average speed
- Availability of lower cost less risky alternatives
- Energy consumption

- Guideway construction
- Currently not competitive.
- Mostly experimental phase
- Political parties and politicians
- No Maglev freight in operation
- No Maglev coal designs or analyses.
- Incompatible with Rail infrastructure
- A large number of socioeconomic effects

2.5 Australia’s Involvement

There have been a number of different proposals which looked at the implementation of Maglev technology within Australia. There have been proposals from Melbourne to Sydney, Sydney to Illawarra and around Melbourne. Two of the most recently discussed Maglev proposals are discussed below.

Melbourne Maglev Proposal

Figure 21: The Sydney to Illawarra Proposal (Windana Research, 2010)

In 2008 the Government of Victoria put forward a proposal to build a privately funded and operational Maglev line. The proposal was for Maglev to connect the city of Geelong to Melbourne’s outer suburbs and to Tullamarine and Avalon domestic and international terminals. The proposal costed $8 Billion but a $15 billion upgrade the road system was decided. (Windana Research, 2010)

The Sydney to Illawarra Proposal

In the mid-1990s there was call for a Maglev train between the largest commuter corridors in Australia between Sydney and Wollongong. While there are traditional Railway lines between the major cities, it would take 2 hours compared to the 20 minutes proposed by Maglev. Transrapid had a proposal which was capable of travelling at more than 400km/h. This proposal was $2 billion but was rejected due to not being feasible for the population which would service it. (Christodoulou, 2008)

2.6 Research areas for the improvement of Maglev Trains

Below are a number of points which highlights the key areas for research in the field of superconductors: (Inventors About.com, 2013)

- Magnetics
  - Developing High Temperature Superconductors, Cryogenics, low temperature refrigerators and improved superconducting magnet design and construction
  - Superconductors have the largest impact on the future feasibility because of its present high operating costs to have them cooled below critical temperature. Within Appendix B is a detailed discussion identifying what superconductors are and how they are being improved.
- Material
  - Fibre reinforced plastics for vehicles and structural concerts
- Electronics
  - Communication and high power solid-state controls
- Engineering
  - Vehicle Design, precision manufacturing, construction, fabrication of concrete structures, wheeled alternatives and operational consideration.
- Power Equipment
  - Equipment for transmission lines and the guideway must be developed.
- Vehicles
  - Construction materials (Aluminium or fibre reinforced plastic), hold required on-board equipment, communication modes, best aerodynamic design, minimising environmental impacts such as routing, magnetic exposure, noise and air pollution. Designed to transport Freight.

2.6.1 Development of modified superconducting magnets refrigeration system

The main source of mechanical loss for the coil unit is frictional heat load caused by micro sliding between the superconducting coil and the clamps. The micro sliding is caused from vibrations from the movement of the train. To meet this improvement there is currently development of a new on board GM refrigeration system. (Florida Space Institute, 2000, p. 13). In Appendix B.4 show the recent rapid increase in critical temperature over the last 10 years. If the superconductors operating temperature was only requiring economic refrigeration methods than the MLX will greatly improve its operational financial feasibility.

2.6.2 Electromagnetic coil design

Electrodynamics Maglev systems are characterised by having currents that provide yielding lift and the movement of the vehicle induce guidance forces. The current aim is to develop a reliable electromagnet coil track so that it can provide a stable and flexible to the threshold speed.

As stated within Magnetic Levitation Space Propulsion by Florida Space Institute on p17 the main issue is "The main issue is what are the forces on the coils are as the system function of system geometry due to passage of set of magnets past the coil." The Electrodynamic Maglev design approaches will allow for an assessment of entry and exit effects for the problem around transient eddy currents. This is dependent on the accuracy of the computation of the mutual coupling between the magnets (the number of discrete filaments and design on the coil) (Florida Space Institute, 2000, p. 17). For further reading on superconductors read Appendix B.

2.6.3 Development of Maglev superconducting magnet vibration characteristics

Currently high performance and reliability magnetically levitated superconducting magnets are being developed. The heat generation per time caused by the electromagnetic forces due to the magnetic fields from the levitation coils is under 2 W when vehicle levitated. The Superconducting magnets are subjected to a variation of electromagnetic forces which ripple through the magnetic fields which affects the behaviour of the Superconducting magnets. These magnetic forces are called spatially fifth ripples and induce a number of eddy currents to produce Lorentz forces and structural vibrations in the superconducting magnets. These vibrations lead to heat generation and evaporate the liquid helium. The heat load increase (heat generation per time) acceptable is dependent on the refrigeration method (Florida Space Institute, 2000, p. 22). For further reading on superconductors read Appendix B.

2.7 Future Potential of Maglev

Throughout the world there are a number of different countries which are aiming to provide a feasible and mass produced Maglev Transportation system.

The following list of countries has a Maglev train proposal and/or development programme to continue efforts in attempting to improve the technology.

- Denmark
- Germany
- Switzerland
- United Kingdom
- China
- India
- Japan
- Malaysia
- Pakistan
- North America

The US has invested $70 million dollars since 1998 (to 2005) in the "Maglev Deployment Program". This program's aim is to modify existing Maglev systems to demonstrate it in a revenue service in the US. (US Department of Transportation Federal Railroad Administration, 2005, p. 6)

The Japanese, US and Swiss are trying to develop Maglev high speed trains which travel at a speed approximately 1000 km/h. They are hoping to achieve this by travelling magnetic levitated trains through airless tubes underground. Japan says the technology may be available in a decade with smaller versions released sooner. The reason for the airless tube is to remove air friction which prevents high speeds of other Maglev trains on the surface. This train would be cost competitive due to smaller tunnels required meaning a smaller amount of boring. (Nusca, 2010)

Chapter 3: Methodology and Quantitative Data

3.1 Methodology

The aim of this Chapter is to explain to readers the method which was taken within this report to achieve the aim of the thesis as set out in the scope. The scope in Chapter 1.3 gives a detailed description of the aims of this pre-feasibility analyse.

A pre-feasibility study is a comprehensive study of a project that has the potential to become feasible in the future. It looks at the various factors of technical, legal, operating, economic, social and environmental factors to guide a decision to its likely feasibility and makes suggestions on how to precede with future feasibility studies. As stated the following is a list of the aims which a pre-feasibility study aim to explore

- Operating factors
- Technical factors
- Financial and Economic factors

The following is a description of the chapters in the report and their aim in completing the requirements of a pre-feasibility study.

Chapter 2: Literature Review

The aim of the literature review is to determine all of the technical information which is relevant to the project. Within this Chapter the only topic discussed is related to Maglev and it technical factors. There are also more technical factors discussed in Appendix B regarding Superconductor technology. It is not within the Literature review as it is not necessary to know, but gives the reader appreciation of the science that will allow this technology to become feasible in the future.

This Chapter collects information from a large number of sources to provide a clear vision to allow readers to fully understand the current state of this technology. The topics identified and discussed with the literature review provides the technical information to allow further analyse and discussion to occur in other Chapters.

Chapter 3: Quantitative Data

This chapter is the collection of all quantitative data relevant for analyse of the feasibility study. The information given is quantifiable data that have specific properties. The data which is collected relates to the Surat Basin, conventional coal train costing and Maglev costing. These three segments are the basis by providing values for the financial feasibility model. The chapter collecting the qualitative data with subjective properties impact this model by varying factors as assumed through different scenarios.

Chapter 4: Qualitative Data

Within this chapter is the identification and analyse of qualitative data relevant for the discussion on the projects feasibility. This data is information which has no values and is subjective dependant on the viewer and scenario. The chapter looks at the advantages and disadvantages of Maglev transporting Coal and what possible events could occur and their predicting there impacts will have on the projects feasibility.

The reason this information is not able to be quantified is that the future impact and resultant costs are unknown. The cost of this can only be determined through a detailed analyse and the impact on feasibility is so variable that it is impossible to determine due to no indication of research in this area. This chapter also identifies and discusses legal and social and environmental factors which are not analysed in the overall project feasibility.

Chapter 5: Design

The aim of this Chapter identifies and discusses two important design parameters making Maglev technically feasible to transport coal. The first is the design of the Maglev train itself and identifies design principles that will have to be considered. The second is the alignment for which a Maglev Train will be able to travel to best service the Surat Basin. While it provides basic estimated data, the information is used in the financial scenario model. This Chapter identifies and discusses operating and technical factors which is analysed in the overall project feasibility.

Chapter 6: Preliminary Financial Feasibility Model Results

The aim of this chapter is to provide results that have been collected from the financial feasibility model to allow analyse and discussions of these results in Chapter 7. The models aim is to provide an accurate representation on the financial feasibility of Maglev transporting coal compared to Rail. To determine an accurate verdict there has to be a large number of variables which have to be taken into account in the model. The results have to show a number of important outputs which are critical for the analyse of the financial feasibility. Within the chapter are the assumptions which are a part of the model and all the financial data which has been incorporated into the model. Also discussions on what scenarios are being analysed and how these differ.

The feasibility of Maglev transporting coal is primarily being analysed through a preliminary economic model. This model is developed from two sets of data.

- The Quantitative Data is the building block of the model as it is the present financial and situation/scenario values. This data has been collected and discussed within Chapter 3.
- The Qualitative Data is all of the values which are at the presently unknown or unable to be calculated. While this data is not directly impacting the analyses of the model, there are discussions on how this data will impact the financial feasibility through discussing various scenarios and social pushes.

The Quantitative values and Qualitative information are brought together and analysed in a number of different scenarios to determine what impacts different variable have on the financial feasibility. The three societal pushes which are discussed are the industrial push, combined push and the sustainability social push. These discussions will inform future designers on possible events may occur in the future and how they will affect the future financial feasibility.

Chapter 7: Viability Discussion and Recommendations

The viability is discussed under three sections; the Operational Feasibility, Technical Feasibility and the Financial Feasibility. The Operational Feasibility refers to information identified from a number of sections throughout the report but primarily Chapter 3. The Technical Feasibility refers to information identified from a number of sections throughout the report but primarily Literature Review and Chapter 3 and 5. The Financial and Economic Feasibility refers to information identified from a number of sections throughout the report but primarily Chapter 3 and 6

Each of these areas of feasibility will be discussed through asking a number of important questions that relate to the feasibility. After all relevant questions have been asked and discussed there will be an overall verdict on the feasibility of each factor. At the end of the report are the conclusions which bring all these verdicts together to provide an overall feasibility verdict. After the conclusion the recommendations will be presented.

3.2 Surat Basin Coal

The information and data collected within this chapter was from early 2013.

3.2.1 Australian and Queensland Coal Industry in the world market

Australia's production of coal within 2011-12 has been 223 million tonnes. Of this 164 million tonnes was exported overseas as part of the total seaborne trade of 871 million tonnes. All of these values are expected to rise from 5 to 11 precent in the next year. (Australian Government: Bureau of Resources and Energy Economics, 2012). Currently Australia exports coal to Japan, China, the Republic of Korea, India and Taiwan (Australian Coal, 2011).

There is a large potential to expand the output of export Coal from Australia. There are number of large projects planned and being constructed which is the reason for Australian rapid expected increase of saleable coal by 11% over the next five years. It is estimated by 2017 that Australia will export 271 million tonnes. (Australian Coal, 2011). For comparison the Indonesia are currently exporting 308 Mtpa. (Australian Government: Bureau of Resources and Energy Economics, 2012)

Globally the demand for energy will always increase due to population growth, improving living standards, industrialisation and modernisation. Despite major fluctuations in coal prices the coal mining industry is still a major force of employment and economic prosperity and growth. Currently there are two major forces which will shape the future of the Coal Industry. They are the requirement to supply secure, reliable and affordable energy to the population, and to move to a carbon-constrained, sustainable and environmentally friendly energy supply. Even with this push of green energies, coal will be expected to account for 80% of the world's primary energy mix in 2030 (Queensland Government b, 2012, pp. 4,5).

Figure 22 shows the cost of thermal coal. For any mining related feasibility study the current circumstances of the cost of thermal coal will have a major factor in mining projects feasibility.

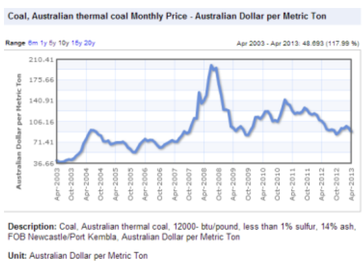


Figure 22: Australian Thermal Coal price per metric ton (Index, Mundi, 2013)

As of April 2013 the cost of thermal coal per tonne from Australia is $89.96 (Index, Mundi, 2013). It can be seen that the price for thermal coal in Australia is the nearly lowest for the first time in 5 years.

Queensland's coal industry is the largest within Australia with approximately 30 billion tonnes of high quality coal resources with 85% of coal extracted exported overseas. (Australian Coal, 2011). The Queensland Coal industry has identified future uncertainties that could impact on the feasibility of coal. These factors are coals impact on the environment and how the population will react with cleaner alternatives and competition due to other fuel sources such as Coal Seam Gas. Recently many jobs have been lost to remain competitive within the international market which has seen the price of coal drop. Figure 23 is a map which shows the different coal systems within Queensland and their transportation routes and ports.

Figure 23: Queensland Coal Systems (Queensland Government b, 2012)

3.2.2 Surat Basin

The Surat Basin is an area which is located 200-400 kilometres northwest of Brisbane. Presently there are only operational mines at the southern end of the Basin due to their ability to access Railways. In the future there are expected developments of new mines in the northern section due to substantial deposits being found.

Presently most of the coal mined in the Surat Basin is used for local energy supply with only a small amount being exported. This is due to the lack of Rail and port infrastructure around Brisbane. The Rail link is currently serving the lower Surat basin is full to capacity from mines from the Clearance Moreton Basin (Australian Bureau or Resources and Energy Economics, 2012).

The Surat Basin produces thermal coal and there are currently a number of different projects which are at the planning stage in the region. The future coal expansion in the Surat Basin requires at joint agreement between many mining related businesses to give the go ahead between all the businesses as every proposal is a key part of the overall coal chain.

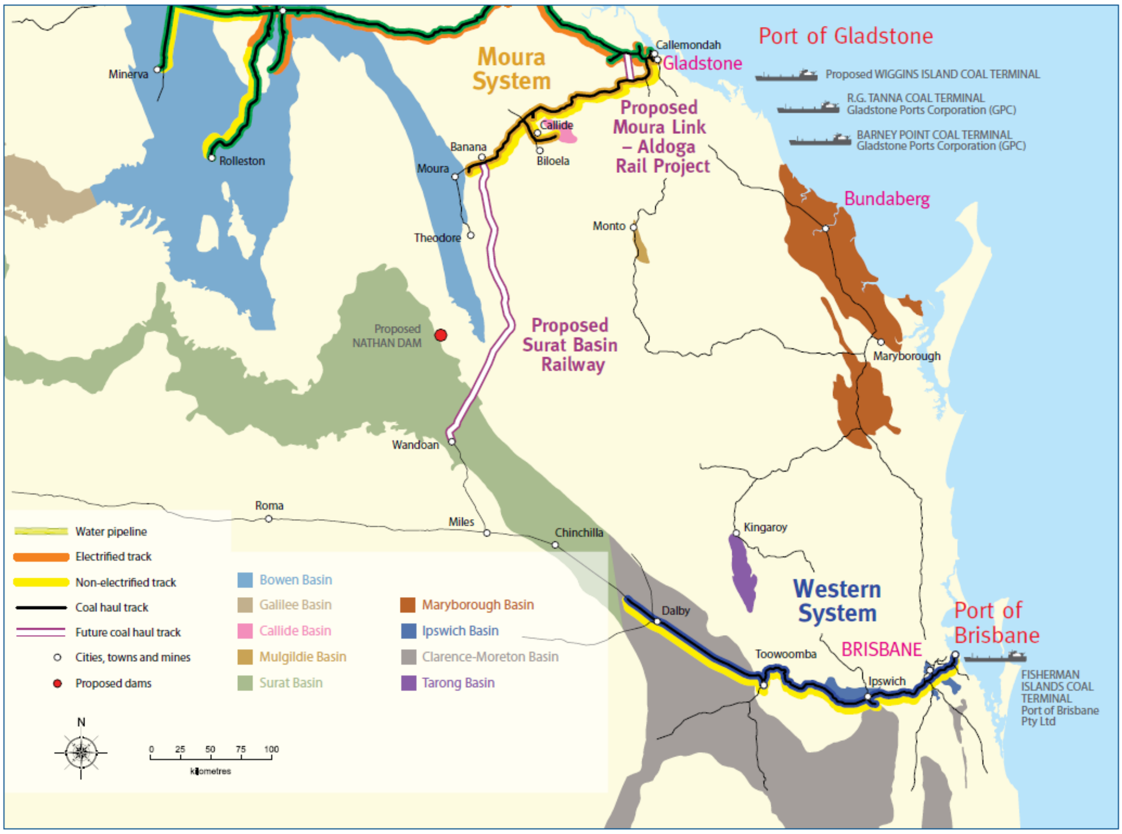


Figure 24: Surat Basin Map (Queensland Government b, 2012)

Present Coal Mines within the Surat Basin and Surrounding Area

The following table provides a detailed description of the coal mines within the Surat Basin

Table 3: Mines within the Surat Basin and the surrounding area

Name	**Company**	**Reserves Mt**	**Saleable 2011-2012(Mtpa)**	**Comments**
Cameby Downs	Yan Coal	100-500	1.4	OC - Expanding
Kogan Creek	CS Energy Ltd	Confidential	2	OC
Wilkie Creek	Peabody Energy Aus Pty Ltd	Confidential	1.4	OC - Expanding
New Acland	New Hope Corporation	500-1000	5.1	OC - Expanding to 10 Mtpa
New Oakleigh	New Hope Corporation	Confidential	0.3	OC
Jeebropilly	New Hope Corporation	Confidential	0.8	OC
Commodore	Cockatoo Limited	Confidential	2.9	OC
Meandu Mine	Stanwell	To 2031	4.5	OC - Supplies 45% states energy

The total saleable coal from operational mines is approximately 18.4 Mtpa.

Southern district					
Open-cut					
Callide & Boundary Hill	10 104 478	9 133 580	8 757 686	7 795 447	7 911 268
Cameby Downs	-	-	-	522 850	1 410 728
Commodore	3 886 916	3 507 834	3 324 889	3 391 141	2 926 960
Dawson	6 656 965	6 898 335	-	-	-
Jeebropilly	-	338 645	915 556	799 230	837 929
Kogan Creek	2 174 116	2 405 872	2 150 360	2 525 512	1 946 665
Meandu	3 556 657	4 982 037	4 449 789	4 218 130	4 580 987
Moura	-	-	7 010 516	6 486 005	9 302 882
New Acland	3 876 303	4 226 649	4 618 114	4 544 324	5 183 232
New Oakleigh	537 254	472 235	272 902	314 962	360 762
Rolleston	6 634 289	7 232 411	6 041 824	5 682 429	9 067 259
Wilkie Creek	2 184 251	2 319 843	1 797 063	1 142 797	1 481 445
Sub-total	**39 611 229**	**41 517 441**	**39 338 699**	**37 422 827**	**45 010 117**
District total	**39 611 229**	**41 517 441**	**39 338 699**	**37 422 827**	**45 010 117**

Figure 25: Mining quantities over last 5 years (Queensland Government, 2012)

Proposed Coal Mines within the Surat Basin and Surrounding Area

The following are the mines which either have the mining lease granted or under application.

Table 4: Proposed Coal mines with the Surat Basin

Name	**Company**	**Reserves Mt**	**Planned Capacity (Mtpa)**	**Comments**
Collingwood	Cockatoo Coal Limited	100-500	6-9	OC
Elimatta	Northern Energy	100-500	5	OC
Taroom	Cockatoo Coal Limited	100-500	8-12	OC
The Range	Stanmore Coal	100-500	5-7	OC
Wandoan	Xstrata Coal	>1000	30-90	OC
Woori	Cockatoo Coal Limited	10-100	4	OC

The total saleable coal from current proposals for mines is approximately 60 Mtpa.

Coal Deposits within the Surat Basin and Surrounding Area

The following is a list of coal exploration projects and coal development projects in the Surat Basin as of May 2013.

- Cattle Creek
- Cowandah
- Clifford
- Meeleebee
- Bottle Tree
- Bushranger
- Tin Hut Creek
- Columboola
- Kruger
- Davies Road
- Rywung
- Sefton Park
- Glen Wilga
- Haystack Road

- Norwood
- Bundi
- Elmatta
- Taroom
- The Range
- Horse Creek
- Collingwood
- Krugers
- Dalby West

The list shows the business interest for coal in the Surat Basin and the potential export capacity which has not yet been account for. Data for some of these mines have only just been released data provided changes constantly. For a detailed operational feasibility study all of these mining opportunities have to be analysed to determine what possible export capacity will the proposed coal transportation system has to meet.

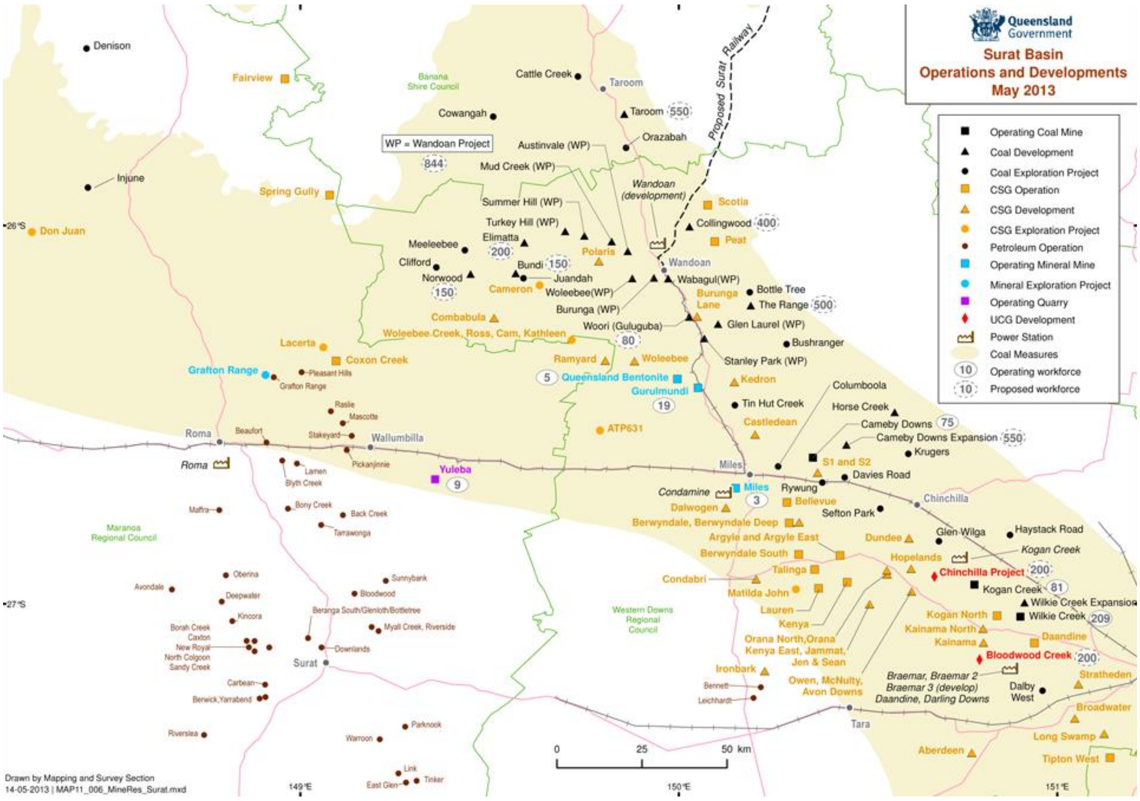


Figure 26: Surat Basin Operating Mines, planned development and exploration. (Surat Basin Homes, 2013)

3.2.3 Coal transportation methods in the Surat Basin

Offsite Road and Public Road Transport via Trucks

Road transport is used constantly within the daily operation of a mine. Normal operations for transporting coal with trucks are for shorter hauls to a local port or to nearby Rail facilities. This is only used for low volumes but has high flexibility. It is very expensive to transport coal long distance with truck. A financial analyse of trucks is not carried out as there is no possibility of it being more feasible than Rail in a long term plan to transport export coal long distances.

Presently there are coal trucks travelling from the Surat Basin mines to the ports because of the lack of Rail access. In Toowoomba 7 million tonnes of coal is carted to the city every year to the ports or south east Queensland power stations. This causes concern within the community due to the number of trucks on the roads, high vehicle emissions, noise and the amount of coal dust (Campbell, 2010). Currently there is CCTV to make sure coal trucks pass through the town with their loads properly covered. National guidelines exist which recommend transporting coal by trucks apply a wetting agent and use tarpaulins covers. (The Chronicle, 2011)

B double trucks along with other forms of trucks are used for transporting coal via the road system within Queensland. When comparing with Rail 1 train could equal 20 or 30 B-double trucks. The present Vehicle configuration can be +- 31 tonnes per load. Coal is loaded to these trucks from front end loaders as can be seen in the figure below.

Figure 27: B-Double being loaded with coal (Xstrata B, 2013)

Other options are

- Concept Vehicles within Legislation = +-38 tonnes per load
- PBS Vehicles (with concessions) = +- 48 tonnes per load
- Road Train (dedicated heavy haul roads) = 100-350 tonnes per load (Barnard, 2009)

West Moreton (Western) System Coal Railway

The West Moreton Railway presently services 4 mines and allows transportation of coal to local power plants and to the coast for export. The Railway is owned and operated by QR national. It operates under unique circumstances where coal trains run alongside city passenger services on the network. The coal is transported across the Darling Downs, down the Toowoomba Range, through the Lockyer Valley and through the suburban Rail system to the port of Brisbane. (Australian Bureau or Resources and Energy Economics, 2012)

The greatest channelling for these mines is to increase the number of trains to carry coal down the Toowoomba range and through Brisbane which can be congested with passenger Rail services. (Queensland Government b, 2012)

This system runs on non - electrified system where only diesel trains operate on the Rail network. The track axle load is 15.74 tonnes on a Narrow track gauge. The western System has limited potential for expansion due to the constraints of the Brisbane suburban Rail network. The restraints are 680m long trains and have a 1940 tonnage limit. This makes the current Rail capacity of 7 Mtpa. (Boyle, 2010)

The coal mines are under a lot of pressure by residents along the Rail track like Brisbane to have covered lids. They have agreed to start load profiling and veneering (spraying a chemical on top of coal to stop coal dust) to increase coal dust suppression measures.

Figure 28: Map of Brisbane (AustCoal Consulting Alliance Client Breifing, 2010)

Moura System Coal Railway

The Moura system presently services 5 mines and allows them to transport coal to local power plants and to the coast for export. The Moura Rail System and the Northern Blackwater Rail System combine to form the Capricornia Coal Chain which exports its coal through the ports of Gladstone.

The Moura system would be expanded if the Surat Basin Railway project was to go ahead to allow for the increased required capacity. The present Moura Rail system has a capacity of 17 Mtpa with 11.3 Mtpa being exported in 2009/2010. This Railway service is owned and operated by Queensland Rail. There are presently planned upgrades to increase the capacity to 27 Mtpa to meet future Surat Basin Rail capacity requirements. (Aurizon, 2013)

This system runs on non - electrified system where only diesel trains operate on the Rail network. The track axle load is 20 tonnes on a Narrow track gauge. This line is only a single track. (Boyle, 2010)

Figure 29: Map of Gladstone (AustCoal Consulting Alliance Client Breifing, 2010)

Ports in Queensland

The following is a table which shows the export quantities of coal from different coal terminals in Queensland.

Table 16 - Exports by port (tonnes)

Port	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
Abbot Point	12 544 738	14 443 487	16 927 920	15 063 943	13 602 137
Brisbane	5 501 207	6 243 182	6 302 866	6 614 664	8 836 197
Dalrymple Bay	42 966 648	47 997 846	63 502 782	54 714 400	51 011 208
Gladstone	53 940 679	56 131 950	60 096 075	53 035 260	59 400 656
Hay Point	37 129 868	35 156 454	36 292 312	33 066 248	32 010 349
State total	**152 083 140**	**159 972 919**	**183 121 955**	**162 494 515**	**164 860 547**

Figure 30: QLD Export by Port (Queensland Government a, 2012)

The Port of Brisbane

Within the Port of Brisbane the Queensland Bulk Handling Pty Ltd operates the Fisherman Island Coal Terminal. They currently operate at a 10 Mtpa handling capacity

The current Rail system which services the port of Brisbane is the West Moreton System. While small expansions can occur at the port the constricting factor is the Rail system unable to cope with the increased tonnage. This port is limited in its ability to expand due to space restrictions. (Boyle, 2010)

The Port of Gladstone - P.G Tanna Coal Terminal and Barney Point Coal Terminal

The Port of Gladstone handles over 30 products to 30 countries. Coal is 70% of the total cargo to go through the port. Currently GPC owns both terminals in the port which are the P.G Tanna Coal Terminal and the Barney Point Coal Terminal. Both terminals currently have a capacity of 75 Mtpa which plans are in place to increases one to 90-100 Mtpa in the future. (Gladstone Ports Corporation, 2011)

This port currently services the Blackwater coal system, the Bowen Basin and the Moura System. The port would also service the Surat Basin if the Surat Basin Railway was constructed. There are also coal terminals being analysed such as Wiggins Island Coal Export Terminal and Balaclava Island Coal Terminal. The Barney point terminal is ceasing coal exporting due to the coal dust effect on the town of Gladstone. When these are constructed the Barney terminal is ceasing operation. After these constructions and decommission the overall capacity will be 135 Mtpa. (AustCoal Consulting Alliance Client Breifing, 2010) The location of the Port can be seen in figure 24.

3.2.4 Methods of Unloading Coal from Rail Wagons

There are three primary methods for unloading coal from Rail wagons. These are described below.

<u>Bottom Rapid Discharge Coal Hopper Wagon</u>

The Bottom Discharge Wagon uses a door at the base of the wagon to open allowing the coal to fall through gravity. The base of the wagon is on a slope to allow all the coal to slide out. Figure 31 shows the wagons with the bottom doors open.

Figure 31: Bottom Discharge Coal Wagon (Titagarh Wagons Limited, 2013)

The following website shows a video of the bottom discharge coal wagon unloading coal at a power station. "http://www.youtube.com/watch?v=RTIHKJ3nXLk" (LNERGE, 2008).

<u>Side Tipping Coal Wagon</u>

The Side Tipping Coal Wagon uses the whole container to tip to the side allowing the coal roll out. The figure below is one of many different types of side tipping used in coal trains.

Figure 32: Side Tipper Coal Wagon (wolstenholm100, 2011)

The following website shows a video of the side tipper coal wagon unloading coal at a power station (at 3:45 minutes) “http://www.youtube.com/watch?v=p1s6cVlLBJE" (wolstenholm100, 2011).

Rotary Wagon Dumper

The Rotary Wagon Dumper is a mechanism used by the Rail industry to unload designed Railcars of their load. By holding the wagon to the section of track it rotates the track allowing the contents of the wagon to be unloaded through gravity. For this to occur there is a special swivel connection which allows the wagons being rotate while being connected to each other.

Figure 33: Rotary Wagon Dumper (Hey and Patterson, 2012)

The following website shows a video of the side tipper coal wagon unloading coal. "http://www.youtube.com/watch?v=pt8ffgVZbBY" (hreiv, 2009).

3.2.4 Future Surat Basin Infrastructure Projects and possibilities

Surat Basin Rail Joint Venture

The Surat Basin Rail joint venture is a proposed 204 kilometre Railway which will unlock 6 billion tonnes of coal for export within the Surat Basin. The multiuse Rail link is between Wandoan and Banana which will initially have a capacity of 42 million tonnes per year. The joint venture is between ATEC Rail Group, Xstrata Coal and Aurizon (Surat Basin Coal, 2013). The details of the Rail have been identified as of the start of 2013.

The following map shows the purposed Rail and how it connects the Surat Basin to the Wiggins Island Coal Export Terminal

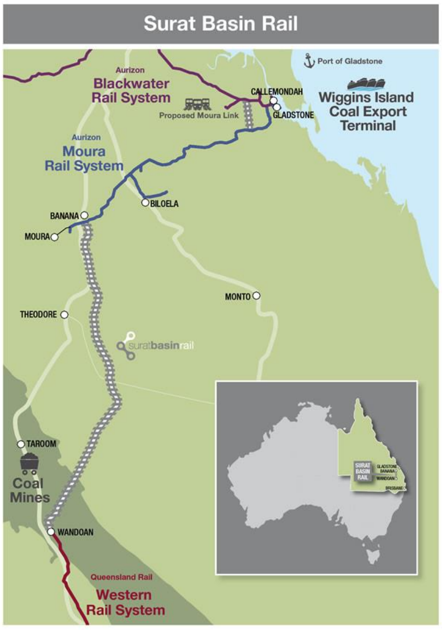


Figure 34: Path of the purposed Surat Basin Coal (Surat Basin Rail, 2013)

The reason for the proposal of 42 Mtpa is not larger is that it is what the rail line of Moura can handle this capacity without having major upgrades drastically increasing the cost. This is partly the reason for Wandoan to only have a low export volume when previously stating a possibility of 30 to 90 Mtpa (if good economic market) as it must share the Rail line with half a dozen other mining companies who are apart or wanting to join the joint venture.

The coal chain is referred to as all the parts of the export coal mining process which as mining, Rail network and port facilities. The coal chain development is critical for the Surat Basin Rail because the related development has to be achieved for feasibility. The projects which are integral for the success of the new Railway are:

- Expansions on the Aurizon Rail Network
- Wiggins Island Coal Export Terminal
- Coal Mine developments in the Surat Basin (Surat Basin Rail, 2013)

They have completed the following: (Surat Basin Rail, 2013)

- Completed an EIS
- Appointed Contractor
- State Development Area declared
- Material Change of Use approval
- Surat Basin Rail Bill Passed

Future Milestones are: (Surat Basin Coal, 2013)

- Communication with local Landowners
- Finalize key agreements with Queensland Government
- Finalise Agreements with customers
- Make final investment decision
- Process acquisition of land for the corridor
- Start construction

The Scope of the work include the following: (Surat Basin Coal, 2013)

- 204 km of single track
- 22-24 diesel powered train movements per day on trains up to 2.5 km in length.
- 8 passing loops
- Estimated cost of $1 billion (AustCoal Consulting Alliance Client Breifing, 2010, p. 14)
- 14 technical studies undertaken as a part of the EIS
- 60 meter wide corridor
- Estimated construction time is 3 years
- 48 major road and Rail bridges
- numerous large and small culverts
- A signalling and telecommunication systems
- Public and Private Railway crossings.
- Single narrow-gauge track

Wiggins Island Coal Terminal

The primary aim of this facility is to facilitate coal exports from the Surat Basin. The Initial Advice Statement was provided in 2005 regarding a new coal terminal at Gladstone port's Wiggin Island. The aim of this terminal is to service expanding development in the Queensland coal systems. (Boyle, 2010)

The completion of the first stage (32 Mtpa) has been pushed back to March 2015 due to poor market conditions and delayed project approvals. This is expected to have a cost of $2.5 Billion. The companies are still well placed and still have high desire to complete this project. (Swanpoel, 2012)

Also the Wiggins Island Coal Export Terminal is progressing with plans to expand beyond stage one plans and expressions of interest have been received for more than 175 Mtpa of coal export capacity. (Wiggins Island Coal Export Terminal, 2010)

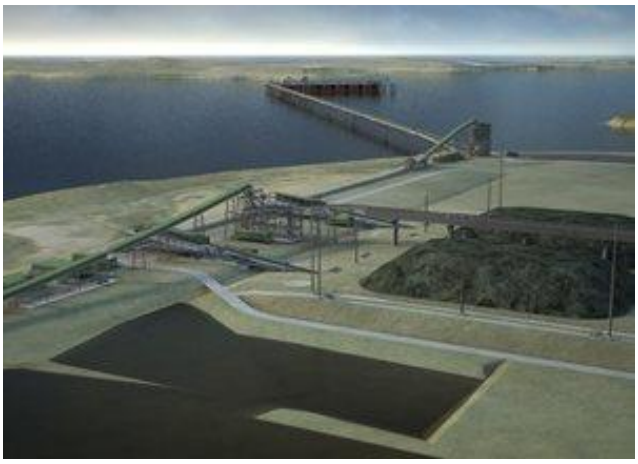


Figure 35: Wiggins Export Coal Terminal projected animated 3D model (Wiggins Island Coal Export Terminal, 2010)

Figure 36: Location of Terminal (Queensland Government Department of State Development, Infrastucture and Planning, 2013)

The main components of the terminal are (Wiggins Island Coal Export Terminal, 2010)

- A Rail receiving dump station can handle 7500 tonnes per hour
- Has the ability to upgrade to 70Mtpa in later stages.
- a 5.5km long overload conveyor
- Stockyard for 1.9 million tonnes of coal
- Single berth with a travelling ship loader to fill ships at 8250 tonnes per hour
- A number of channels and wharf to accept vessels with a dead weight tonnage of 40,000 to 220, 000

Balaclava Island Coal Terminal

There is currently a proposed Balaclava Island Export Terminal being investigated. They are currently completing the Environmental Impact Statement.

The location is on Balaclava Island is 40 km north of Gladstone. The map of the location is shown below.

Figure 37: Location of Balaclava Island Coal Terminal map (Queensland Government Department of State Development, Infrastucture and Planning, 2013)

The current characteristics of the project are (Queensland Government Department of State Development, Infrastucture and Planning, 2013)

- Coal export facility with a capacity of 35 Mtpa
- Construction cost $1 Billion
- The Rail will spur from the North Coast Line
- Use land conveyors to transport coal to the island and loaded on to ships.

Wandoan Coal Project

The Xstrata Wandoan Coal Project is a proposed open-cut thermal coal mine within the northern Surat Basin. As of July 2012 they are undergoing the final Queensland Government approvals which will allow for the development of the purposed mine.

At the present they have not been had Environmental Authority issued, Mining Lease issued or the Development Approvals issued. Once these have been approved there will be a final financial decision. The location of the town of Wandoan can be seen in figure 38 (Xstrata A, 2013).

The current characteristics of the project are:

- Mining lease application for 32000 hectares
- Have a construction period of four years
- Present plans are for 30 years producing approximately 30 Mtpa, but originally had higher ambitions if improved market conditions with a rail capable of transporting this amount of coal.
- Produced thermal coal which will be crushed, sized and washed before being transported.

Nathan Dam

Water is essential for coal production and presently there are not the required resources available within the Surat Basin to allow a large number of high capacity coal mines. This is being organised by Sun Water (a government owned corporation). (Department of State Development, Infrastucture and Planning, 2013)

The dam also provides contingency storage for the water supply in the region. The location is on the Dawson River with the pipeline through the Surat Basin to Dalby. This project is also integrated with the production and use of coal seam gas water.

Figure 38: Location of the proposed Nathan Dam (Queensland Government b, 2012)

The following characteristics of the project include (Department of State Development, Infrastucture and Planning, 2013)

- Holds 880 000 ML
- Annual yield of 66 000 ML
- 260 kilometre trunk pipeline
- An investment of $1.4 Billion
- If approved then completion could be around 2016-2017

<u>Future Cockatoo Coal Surat Basin projects</u>

Cockatoo Coal have mining and exploration rights to a large amount of land within the Surat Basin and have number of coal mine proposals ready. They have limited their exploration due to the lack of transportation methods for the coal to be exported. They are holding back on any major investments until there is clarity regarding the Surat Basin Railway. (Cockatoo Coal, 2013)

In the Surat Basin they have a total of 300 Mega Tonnes of Marketable Coal reserves. This includes a total of 1761 Mt of known coal reserves in their land. Figure 39 is a map of the land which Cockatoo Coal has 100% or joint interests in the Surat Basin.

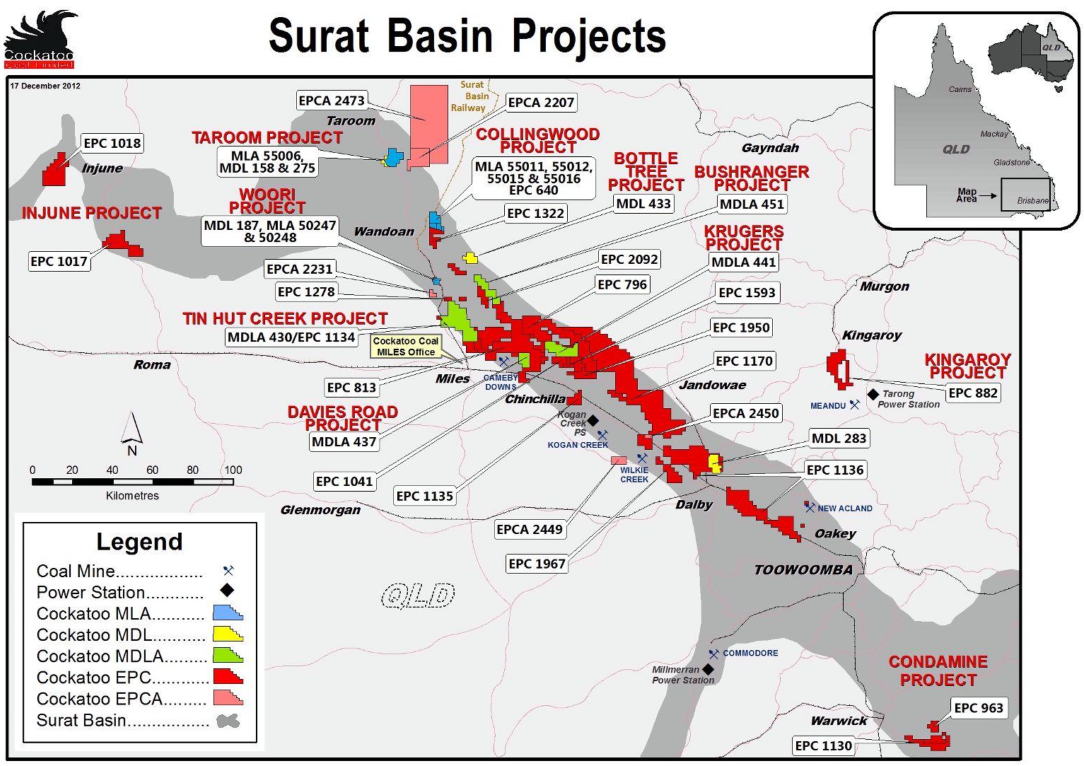


Figure 39: Surat Basin Projects (Cockatoo Coal, 2013)

Alternative Coal infrastructure design options

Slurry Pipelines

Slurry pipelines are when coal is mixed with water and then pumped over long distances to a port where it can be exported. At the end of the pipeline the coal is separated from the slurry through a filter where the water is then treated and discharged or returned to the mine. (Marrero, 1993)

Slurry has a number of economic advantages at smaller distances (5 -50 km) and makes less noise disturbance and impact on the environment then Railroads. The cost of feeding plant and discharge dewatering could be 30% of the final cost. The ratio of coal to water is 1 to 1. This can be increased by compressing the coal into a log with a diameter 5-10% less than the diameter than the pipe. This increases the ratio of coal from water to 3 or 4 to 1. The dry the coal it is evaporated or separated in a centrifuge. The advantages of coal logs are that it doesn't need much drying due to the compressed state. Coal logs use 1/3 to 1/4 less water and have a transporting cost -50% less of a conventional coal slurry pipelines (Marrero, 1993)

The largest coal slurry pipeline was 439km but stopped operation in 2005 and now is planned to be dismantled. The largest purposed slurry was over 1675km in South Australia to service mineral deposits which are a few hundred kilometres away from shipping ports. A 110km pipeline is purposed in the Northern Territory with a diameter of 457mm will be able to supply a capacity of 10 Mtpa of magnetite concentrate. (The Australian pipeliner, 2009)

Magpipes

Currently the uses of electromagnetic drives are improving the cost effectiveness of Magpipes compared to other modes of transport for certain circumstances. Currently they have designed a demonstration project which uses linear synchronous motors to move capsules of coal. It is said to be economical to carry 10 Mtpa over a distance of 2 to 50 kilometres. While previous pneumatic pipelines have not been feasible, the new electromagnetic drive achieves 4 times larger line fills and reduction in capital cost by half. It can achieve speeds of 18 m/s. The demonstration project has 275 meters of 610mm diameter cast fibreglass pipes. (Mongomery, et al., 2007)

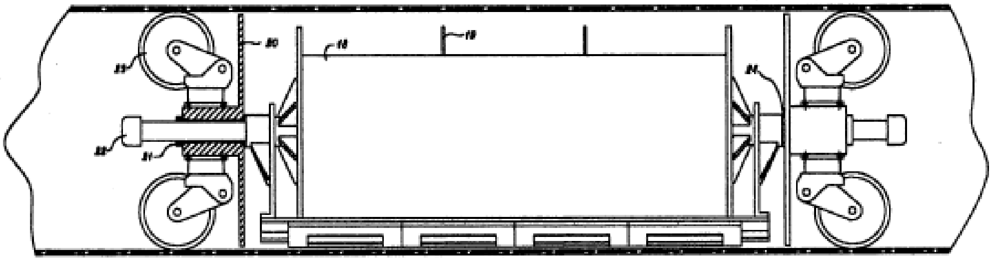


Figure 40: Elevation view of the pipe and capsule (Mongomery, et al., 2007)

The following pictures show the pipe carriages and the load and unload stations.

Figure 41: Capsule with 300kg of rock (Mongomery, et al., 2007)

Figure 42: Load and Unload station

The following table shows the cost of Magpipes for two different distances.

	Case 1	**Case 2**
Distance (miles)	3	30
Tonnage per year	2	10
Capital Cost ($M)	4.6	50.1
Annual Operating Cost ($M)	0.8	5.2
Competitive cost of truck transport ($/ton-mile)	0.35	0.08
Savings per year ($M)	1.3	18.1

Table 5: Comparative Costing to Truck (Mongomery, et al., 2007)

3.2.5 Possible positive future factors for Coal

There is much discussion on the future of coal within Australia and the World. The prediction from planners is that in the near future will be an increase in the requirement of coal as a power sources for the short to medium term future. There are also a large number of articles published which predicts a negative outlook on the future of Australia's Coal Industry. The following discussions and information is from an article written by Lisa Upton for the SBS on the future of Australia's Coal Industry (Upton, 2013)

<u>Trade</u>

The following is a list of statements discussing the positive aspects of trading Coal in the future:

- Coal demand is growing everywhere except the US
- Predictions by the International Energy Agency say that coal will equal with oil as the world's leading energy source by 2020.
- The International Energy Agency states in the Medium-Term Coal Market Report that Australia will recover its throne as the biggest coal exporter. While there are issues with rising labour costs and domestic currency rates making Australia uncompetitive to other countries like Indonesia, the report states that if Australian continues with plans for infrastructure projects and mine expansions it will become the world's largest exporter with an overall expected amount to be 356 Mtpa by 2017. (Internation Energy Board, 2012)

<u>Environmentally Issues</u>

With talk of only aiming to use coal for a short to medium term, the Australian Coal Association says this is unrealistic and is instead focusing on clean coal technology. The recent opening of a carbon capturing plant west of Gladstone is a step forward for this vision. This involves a $200 million project capturing greenhouse gas generated by the local power stations preventing it from being released into the atmosphere. (Upton, 2013)

<u>Research</u>

A positive future outcome is for the widespread application of extracting energy from coal emission free. There are researches in Ohio America who have been able to achieve this. They have extracted energy from coal while preventing 99% of the carbon dioxide from being released into the atmosphere. They use a technique called Coal-Direct Looping to collect the energy without actually burning it through chemical reactions. Currently there is a large scale application of the experiment being constructed. While there are cases of other researchers achieving this feasibility of widespread application is yet to be determined. (Grozdanic, 2013)

Another research development which would make coal powered power stations more environmentally friendly is to remove the carbon dioxide from the air. This has been achieved by engineers in America which have been able to suck carbon dioxide from the air and transform it into a fuel. While this design is very early on, the potential for research and applications are huge and may play an important impact on the future of coal emissions. (Parsons, 2009)

3.2.5 Possible negative future factors for Coal

Trade

There are a large number of articles published which paint a negative outlook on the future of Australia's Coal Industry. They discuss the following topics: (Upton, 2013) (Internation Energy Board, 2012) (Australian Coal, 2011)

- While currently there are enough investment planned but current uncertainties will cause delayed or cancelled projects. This is caused from the low prices and uncertainty about future economic growth. In the world there are 300Mtap of terminal capacity planned and 150-600 Mtpa mine expansion planed.
- People are trying to plan for a short to medium term reliance on coal energy.
- The Australian Coal Association is not positive about the countries future prospects due to falling commodity prices and strong competition.
- Other countries such as Mozambique, Colombia, Indonesia and the United States are providing coal at a lower cost.
- CEO of the Australian Coal Association states "Australia is at a terrible junction where not only has the international market come off in terms of price but our costs and productivity has gone to a terrible place.
- Australia was the cheapest place to produce coal but now it currently costs $176 per tonne compared to the lowest international cost of $106 per tonne.
- Queensland has had over 5.5 thousand job cuts in the last 6 months.
- Queensland has millions of tonnes locked up and unable to be exported

Environmental Issues

With the increase of production of coal in Queensland this always causes concern regarding to the general population about health impacts and environmental damage. This will always be a major concern within modern society. In Gladstone port the exports are expected to double within 15 years which will cause major problems with local environmental groups. The Gladstone Conservation Council says that the miners are like drug dealers who supply harmful products to the community without caring about its impact. (Upton, 2013)

3.3 Coal Transportation Financial Data

Queensland 70% of rail freight revenue is coal. Factors which have seen coal transport prices increase are:

- State government using Rail charges as a form of taxing the industry
- Productivity below best practice level due to restructuring.

Coal transportation prices can be difficult to compare due to variables such as traffic density, traffic mix, terrain, climate, and average haul lengths. When comparing Rail systems it is important to consider:

- Length of haul. Longer the haul has higher total cost by a lower cost per tonne kilometre.
- Traffic density. The higher the traffic coal density the cheaper the cost to haul per km.
- Coal needs more wagons and locomotives compared to other commodity as it is bulkier.
- The width of the gauge has a number of impacts on the capacity of coal
  - Lower weight and volume capacity due to lower maximum axle loads
  - Shorter train lengths

3.3.1 Difficulty in accessing accurate data

One of the key barriers which make the ability to find coal transportation cost difficult is that it is extremely confidential. In reports and inquiries there are discussions regarding the difficulty of accessing cost data. The following are quotes on this problem:

- "We find this data is extremely tightly held by agencies and if we ever see it, it is under strict confidentiality". (NSW Rail Costing document, p27)
- "It would be fair to say cost uncertainly within reports are driven by a lack of publicly available information, often because the costs associated with projects likes these are held tightly by the agencies concerned, sometimes for reasons of confidentiality"(NSW Rail Costing document, p27)

They also expand on how even on annual reports the breakdown of expenditure is not made publically available.

In the search for accurate data many documents where accessed online and at the local libraries for which this chapter identifies the limited findings. There were also a number of attempts to contact mining business including the Surat Basin Railway group and the only response was that they were not able to release any data requested as it is strictly confidential.

There have also been discussions with the general public and mining industry staff providing approximate values of different variables in the Queensland mining industry but these cannot be used as is unable to provide appropriate references and authenticity cannot be checked. Staff in the mining industry will not allow any exact values to be officially given as it breaks their strict confidentiality rules.

Another reason for this difficulty in accessing accurate data is due to the fact that the cost varies so much from project to project within Australia as can be seen within data identified within Chapter 3.3.2. There have been recommendations to transport departments to promote the use of a consistent work breakdown structure for the purpose of comparison, review and benchmarking of transport infrastructure costs. (NSW Rail Costing document, p32)

3.3.2 Conventional coal train financial data

Table 6 shows the financial data collected from this chapter

Table 6: Primary Rail Financial Data used within the model from Chapter 3.3

Item	**Cost**	**Comments**
Single Guideway Cost - Rural Region	$4 Million/km	Combines Surat Basin Railway estimations and other coal Railways
Single Guideway Cost - Urban Region	$ 5 Million/km	Combines Surat Basin Railway estimations and other coal Railways
Single Guideway Cost - Mountainous Region	$6 Million/km	Combines Surat Basin Railway estimations and other coal Railways
Freight Rates	$4 cents/tonne/km	Determined from a large number of mines as shown in figure 44
Total Coal Operational Cost	3.4 cents/tonnes/km	Discussed in chapter 3.3.2 using a 15% profit margin (conservative).
Cost of Carriages	$0.2 million	Determined in Chapter 3.3.2

The following chapter identifies the financial data publically available.

<u>Cost of Rail to install per kilometre</u>

The following table is of eight Railway costs per kilometre constructed prior to 2012. The costs did not also provide locations of these track locations due to confidentiality concerns. It is likely that these higher costs are in urbanised areas.

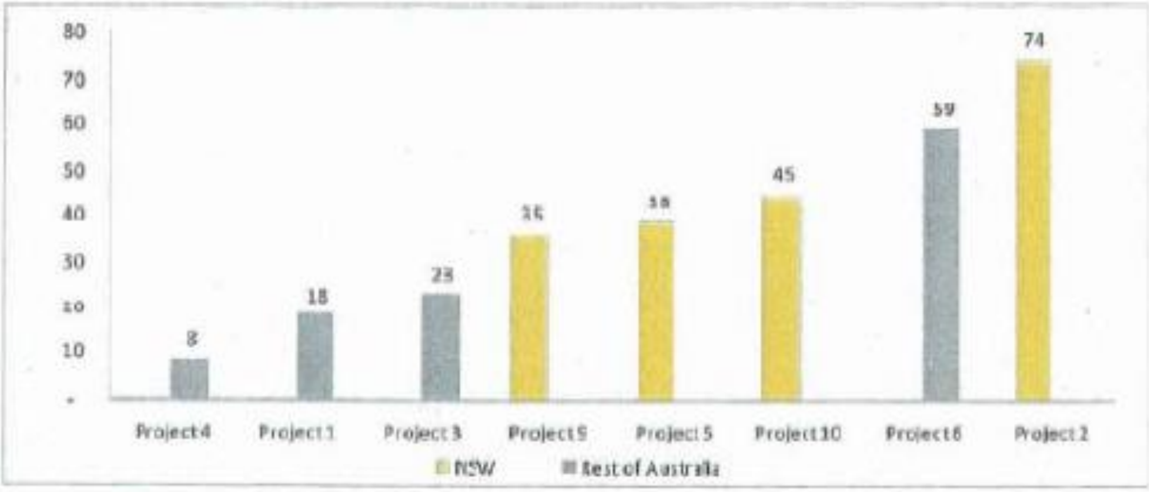


Figure 43: Total Cost of installing a Railroad ($million/km) (NSW Rail Costing document, p31)

The following table shows total track installation benchmarking data collected in 2008. Each of these routes has a number of special constraints which increased or decreased the price as briefly discussed in the report referenced.

Table 7: Track installation benchmarking data (ARTC Capital Works Costing, p9)

Name of Project	Year	Length (km)	Total Cost	Rate per km (million)
Alice Spring - Darwin	2001	1410	$1.1 billion	$0.78
Cloudbreak Mine to Port Headland	2006	285	$680 million	$2.39
Bauthinia Regional Rail line	2005	110	$240 million	$2.18
Coal connections	Outgoing	69	$217 million	$3.14
Surat Basin Railway	Design	200	$1 billion	$5
Minimbah Bank Third Track	Design	10.8	$100 million	$9.26

There were a number of considerations which have to be taken into account when developing track costing for rail for the different locations rural, urban and mountainous. There are discussed below.

1. The assumed rail alignment price for a rural region is $4 million. While this is less than the Surat Basin Rail Alignment of an average of $5 million, this estimate makes the figure more conservative realistic values. Firstly not all the Surat Basin Railway is in rural areas as the mountainous areas would increase the overall average price and secondly this number is closer to other coal tracks. As seen in table 7 the costs of other coal connections are in the $3 million mark. This data was not chosen as there was no location description present for these costs so it is unable to determine how relevant these figures are.

From figure 43 rail connections have identified the cost of installing a Rail system shows a range of 8 million to 74 million. While these figures are not for coal mine connections, it shows how costs can drastically increase for installing Railways. There was no reference to the locations due to confidentiality so this was not considered comparable.

Also the Surat Basin track cost is for only 43 Mtpa, which the cost should increase for the higher proposed capacity but is not estimated in this report.

2. Since both the West Moreton Brisbane Rail System only have a capacity of 7 Mtpa and (Chapter 3.2.3), entirely new Railway tracks will have to be installed to allow for the increased capacities analysed within the model.

3. The Moura Rail System only has a small capacity of 17 Mtpa at the moment. There are presently upgrades planned to increase the capacity to 27 Mtpa to service the Bowen Basin and allow for future upgrades for the proposed Surat Basin Line. For the Moura line to increase its capacity to meet 42Mtpa from the Surat Basin Rail and current Bowen Basin coal capacity there will have to be a large upgrade in the line capacity (Aurizon, 2013). It is assumed for this distance the total track will be replaced.

3. The financial difference in requiring purchasing land and using existing rail alignments but have not is considered within this report.

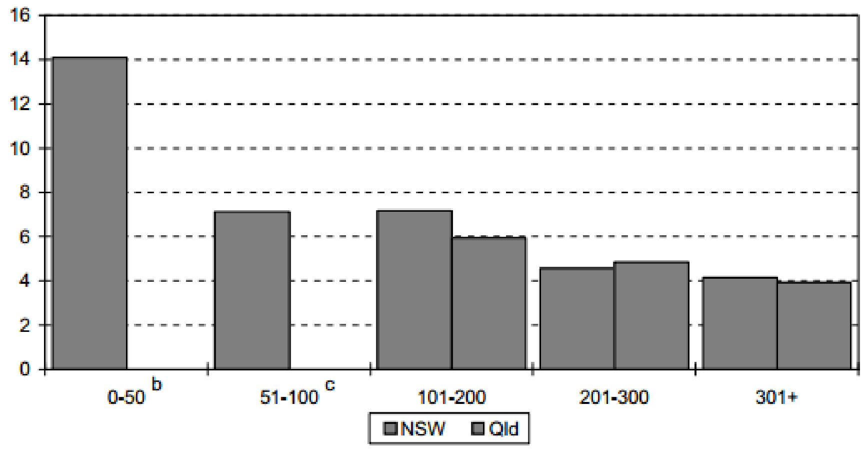
4. Using the basis of $4 million per km, it is known that the costs increase for mountainous areas. With the overall cost of the Surat Basin being $5 million on average, it is approximated that the average track cost is $6 million.

5. For the urban calculations it is assumed that they will be installed along existing rail corridors which would reduce the large price for land acquisition (as Maglev is assuming the same). It has been approximated that the value is approximately $5 million per km which is slightly higher than rural costs. This is a conservative estimate that can only be approved by rail company's financial data that is not released due to confidentiality reasons.

Cost of Operation and Maintenance

The following figure shows the Mining Freight Cost in QLD and NSW (cents/ net tonne/ kilometre). This is the data used in the financial model to determine the operational and maintenance cost of Rail transporting coal. The actual values take into account the profit margin as identified and presented in Chapter 6.1.3

Figure 7.1: **Weighted average freight rates for NSW and Queensland, 1996[a]** (cntk)



a Based on rail charges for 85 mines. Weighted average distance for each category similar except for 101–200 km category.

b There are no rail freight hauls between 0–50 km in Queensland.

c For confidentiality reasons, NSW and Queensland have been combined in the 51–100 km category.

Figure 44: Mining Freight Cost in QLD (cents/ net tonne/ kilometre) (The Australian Black Coal Industry, 1993, p. 182)

There have been a number of different financial data related to the operational and maintenance cost found but are not used as they either not comparable with Maglev data, data for passenger transport or they are from old sources from international sources. None of these would be considered acceptable information to use within the financial model. While the data collected is from 1996, it is in the data format which can be compared with Maglev, is from Queensland and New South Wales coal tracks and is considered accurate and legitimate. This was determined by far the best data available due to the strict limit of publically accessible information due to confidentiality.

There have been a number of considerations when determining what the overall operational cost of rail transporting coal. The approximations of relevant values were determined due to the lack of creditable information

1. A profit margin of 15% has been approximated to be the profit margin for rail at distances above 300 kilometres. With this profit margin the operational cost of Rail will be 3.4 cents/tonne/km and the saving of the Maglev system will be 0.2 cents/tonne/km.

Exact profit margins of business in Queensland are unknown due to strict confidentiality. An average of 16.1% profit margin has been determined for a number of large Railroad companies from the S&P 500 (Yahoo Finance, 2013). This number is higher than what realistically due to the increased length decreasing the profit margin would be paid. The advantage for this Surat Basin Rail proposal is that while it has a long length, the ratio of revenue to operating costs are low which means the rail company still make a large profit. With different track lengths they have a varied profit margin as per meeting the principal of scale of economics. It is assumed there is the same scale of economics for both alignments even though they are different with length.

2. From freight cost data provided in figure 44 it has been determined that a 300km 15% profit margin accurately predicts the profit margins for other distances assuming that the profit margin increases proportional to the distance.

For example in the 50km to 100 km range the freight cost of 7 cents and the operational cost of 3.296 cents would make a profit margin of 54 %. We are able to calculate that 100 kilometres is 3 times longer than 300 kilometres with a profit margin of 15%. 15% profit margin times the distance ratio of 3 calculates a proportional value of 45% profit margin if at 100kms. This number is the lower boundary as this value is for 100 kilometres where the highest boundary would be 50km. It can be seen in figure 45 that the actual profit margin from the provided freight costs are within the limits determined. This model is used to check that for 15% profit margin the new profit margin dependant on the length is within the proportional profit margin boundaries.

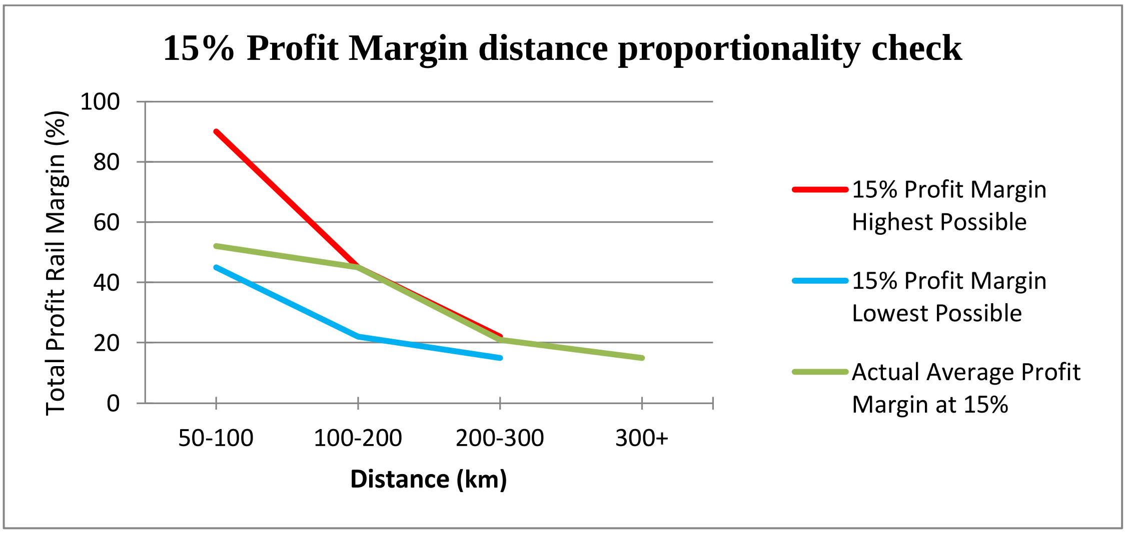


Figure 45: Total profit margin border is proportional through distance when 300km has a 15% profit margin

Coal Wagon Cost

The cost of purchasing coal wagons is difficult to estimate accurate values as it depends on the number of wagons which are purchased and the location required. The Queensland Government in 2007 invested $133 million for 510 coal wagons. The cost of a single coal wagon is worth approximately $0.22 million dollars which was used within the financial model (Australian Mining, 2007).

Number of Locomotives per Wagon

Pacific national is one of Australia's largest Rail companies and in their stocks they have 6000 wagons and 170 locomotives. While this is only estimation they have 1 locomotive for every 35 wagons. This is appropriate for the actual trains per locomotives used for transporting coal in Queensland. It is this factor which will be used to determine the number of locomotives required. (Pacific National, 2010) This factor has a very low impact on the overall financial model.

Wagon Capacity

The capacities of coal transported by a number of wagons are varied between projects and have many variables which can highly impact the capacity.

For this investigation only one case study has been identified to determine the amount of coal one wagon is capable of transporting in one year. The reason for this is that this scenario is similar to the Surat Basin alignments. In South Africa an extra 200 wagons are able increase the capacity of conventional coal Rail by 28.6 MTPA for a distance of 600 kilometres (Batwell, 2013). From this real case scenario it is assumed that a single wagon (both Rail and Maglev) is needed to transport 0.143 Mtpa.

3.4 Maglev Economic Data

The financial model is used to look at the financial feasibility of two different scenarios. Table 8 gives a description of the two financial scenarios which are analysed within this report. It shows how the different Maglev systems financial data is being incorporated into each scenario in the model.

Table 8: Overall Maglev guide to the financial scenarios

Scenario	Time Frame	Capital Costs	Operational Cost	Comments
1 - Present	Present	Transrapid	Transrapid	Commercially in operation - Financial data available
2 - Future	Possibly the MLX when Commercially ready by 2025	Transrapid	Projected MLX	Theoretical - Financial data is for test track only

This chapter discusses and identifies following financial information relevant to the two Maglev scenarios:

- Total Life Cycle Costs
  - Research and Development
  - Production and Construction Costs
  - Operation, Maintenance and Support Costs
  - Retirement and Disposal Costs
- Capital Costs
- Operational Costs
- Speed
- Weight Capacity

3.4.1 Total lifecycle Costs

There are four main categories in the total lifecycle cost for any Maglev Train and are identified below: (US Department of Electrical Engineers, 2005)

1. Research and Development
2. Production and Construction Costs
3. Operation, Maintenance and Support Costs
4. Retirement and Disposal Costs

Research and development

The primary source of financial data has been from information reports discussing a number of aspects regarding Maglev's and tenders which have been bid by Maglev transportation construction companies. It is these companies who are currently developing the Maglev technology and paying for the research and development. It is through this research that they will be able to develop state of the art feasible Maglev technology.

The aspects which are currently being looked into are:

- Conceptual research
- Prototype and test guideway production
- Control systems research
- Advanced Safety features

These areas of research are discussed further within the Literature Review.

Construction Costs

The construction costs are split into

- Fixed Facility Costs
- Vehicle Costs
- Land Costs

The fixed facility costs include

- Industrial Engineering
- Guideway construction
- Maintenance and control centre facilities

The following are a list of factors which will impact the guideway construction cost of Maglev:

- The type of Maglev technology (Transrapid, MTX)
- Land use (Populated areas, unpopulated areas, mountainous areas)
- Length of overall track
- Flood protection
- Earthquake protection

Table 9 shows the number of average overall cost of the different Maglev systems per km. These costs include stations, tunnels and other infrastructure related with the Maglev system.

Table 9: Total capital costs for different Maglev systems

Item	Cost	Source
Transrapid Double Track Maglev system	Estimated $31 to $62 million per km	(US Department of Transportation Federal Railroad Administration, 2005, p. 9)
Transrapid Single Track Maglev system	Estimated $15 to $30.34 million per km	(US Department of Transportation Federal Railroad Administration, 2005, p. 9)
Transrapid Double Track in Shanghai	Approximately $64 million per km	(US Department of Transportation Federal Railroad Administration, 2005, p. 8)
Second Generation Maglev 2000 system	Estimated $7.4 million per km of guideway	(Danby, 2003)
MTX-01	Estimated $120 million per km as of 2000 at start of development	(ATIP Japan, 2000)

The costs of carriages/wagons will be dependent on the type of Maglev used and the purpose. The following costs would have to be taken into consideration:

- Engineering costs
- Material Costs
- Cost of superconducting magnets and possible refrigeration facilities
- construction costs
- Location and design constraints
- Purposed of the vehicle (economy or business class passenger travel or transporting freight)

Operational, Maintenance and Support Costs

There are a number of different costs which have to be taken into account when determining the overall operational cost as it comprises of running costs, maintenance costs and support costs. The impact Maglev has it that it will have a lower operational cost compared to Rail. The operational cost would also have to take into account.

- Power supply/fuel
- Training of staff
- Staff Salaries
- Spares and repairs
- Diagnostic equipment
- Customer facilities (ticketing, parking etc.)

How much does each contribute to operational costs Rail transport (US Department of Electrical Engineers, 2005).

- Staff wages are 30%
- Fuel costs 15%

Claims of improvements of future Maglev compared to Rail are from a wide variety of sources and vary. Some of the results and predictions are: (US Department of Electrical Engineers, 2005)

- Reduce fuel/energy costs by 30 - 50%
- Reduced staff requirement by 30%
- Maintenance costs is reduced by about 50%

Retirement and Disposal costs

There is no known value for the retirement and disposal costs of a Maglev system due to the fact there has not been any values publically released.

3.4.2 Tender Data for Proposed US Transrapid in 2005 - Las Vegas to Primm

The US Department of Transportation Report to Congress of the Cost and Benefits of Magnetic Levitation provides a large amount of information regarding the costs of installing a Transrapid Maglev passenger line. This is the primary source of financial data for the Maglev used within the financial model.

Of all the Maglev routes within the US report which have financial data there was only one which had relevance to our proposal. The Las Vegas to Primm had only 2 stations and travelled a majority in non-urbanised areas which matches close with the proposal specifications. This is a majority single guideway Transrapid which was analysed in the early 2000's. The purpose of the Maglev was to act as an airport connector and attract tourist. This proposal was only the first section to be considered from Las Vegas to Anaheim.

The US Report to Congress document provided financial feasibility for 6 different proposals. Of these the Las Vegas to Primm was the cheapest as it was in a rural alignment compared to urban alignments. Of all 6 proposals there was an average cost of $30.6 million per kilometre for all capital costs related to the guideway.

The Las Vegas to Primm had a distance of 56 km and had two stations planned. The Maglev would have operated 3 eight section trains with 20 minutes headway. This was able to occur as 33% of the distance was dual track allowing for passing. This Maglev system was a combination of at grade and elevated grade. It utilised 33% elevated and 66% at grade. The average speed was 500 km/hr which had a maximum grade of 3%.

Data for the Financial Model

Table 10 shows the calculated values from the data collected from the US Report to Congress which are used as the primary Maglev data in the financial model. In Appendix C the financial tables are provided from the US Report to Congress on the Feasibility of Maglev which was used to calculate the values. The calculations are shown in Appendix D.

Table 10: Primary Maglev Financial Data (collected from Appendix C and D)

Item	Cost	Comments
Single Guideway Cost - Rural Region	$15.8 Million/km	Las Vegas to Primm Proposal Cost. Appendix C Table A-1and D
Single Guideway Cost - Urban Region	$ 20.1 Million/km	Maximum Price Range of Single Guideway (conservative) - (US Department of Transportation Federal Railroad Administration, 2005, pp. A-11)
Single Guideway Cost - Mountainous Region	$24.1 Million/km	Pittsburgh Proposal (60% Double guideway making it conservative) in hilly topology with rivers
Total O and M	$17.9/ Train/ km	Appendix C - Table A-1
Coal Operational Cost	$0.031964/tonnes/km	Appendix D
Cost of Carriages	$8.9 million	Appendix C - Table A-1

The guideway costs incorporate the guideway, propulsion, control, communications and power distribution and infrastructure. While stated single guideway, the costs are for a 2/3 single and 1/3 double guideway to allow for passing of trains. Assumptions regarding these values are presented in the financial model results in Chapter 6.1.2 and 6.1.3.

3.4.5 Speed Capacity

Table 11 shows the current maximum speeds which have been reached by a number of different Maglev trains. The impact of Maglev high speeds are discussed in the advantages analysis in Chapter 4.1.1.

Table 11: Maximum speeds of each different form of Maglev trains

Maglev Type	Speed (km/hr)
Japanese HSST	100
German Transrapid	501
Japanese MLX-01	581
Theoretical Vacuum Maglev	+1000
Korea UTM-01	110
Swissmetro	500
Inductrack	500

3.4.6 Maglev weight capabilities

The present design limit of operational Transrapid is 70 tonnes of freight per carriage. (Elizabeth, 2003, p. 3) (Blow, 2010, p. 2) The design of this Maglev system has been passenger focused and not freight and weight focused. In Chapter 4.1.1 there is a discussion on the design of Superconductors to allow Maglev to be capable of transporting heavier loads.

Within the Model it is assumed that both the Maglev and conventional Rail will transport the same weight. As there are so many unknown variables which would play an impact in the weight capability of Maglev similar values are used, even though they both have the potential to increase.

The impact of weight will change the cost in the number of areas

- Capital cost of extra carriages
- Operational cost of these extra carriages
- Extra time required in loading and unloading

The following is what could be input into the model to present future alternatives, but overall this variable only has a small measureable impact on the capital cost and does not impact the operational cost. It is for this reason that the financial model is not using this information.

Chapter 4: Qualitative Data

4.1 Detailed Advantages and Disadvantages Analysis of Maglev Transporting Coal

This chapter analyses Maglev's characteristics to Rail and how it is affected by transporting coal. Some of these topics are discussed within the Literature Review, but mainly identified within Chapter 2.4.3.

4.1.1 Advantages of Maglev Technology

The following are the advantages for the overall Maglev technology:

<u>High Speed</u>

Because the carriages move without physical contact the speed has no major speed restriction due to friction like conventional and high speed trains. The maximum speed which a Maglev train has achieved is 581km/h. Only forces which hinder the speed of the Maglev is magnetic drag (which is small) and aerodynamic drag. To overcome the aerodynamic drag requires a high amount of energy. The limiting top speed for commercial uses will be a trade-off between speed and cost. (US Department of Electrical Engineers, 2005)

A table 2 in Chapter 2.2 and table11 in Chapter 3.4.5 show the current achievable speeds of Maglev. These are speeds which would be accomplished for passenger transport. The following things have to be taken into account when determining the speed of Maglev moving coal.

- Weight capacity of the wagon
- Maximum speed and its cost
- Maximum acceleration and deceleration capacity
- Air resistance
- Speed reductions due to curves
- Safe speed for coal transportation

<u>Turning Curve</u>

All trains have a maximum turning radius to prevent the train from derailing when turning. The turning radius is dependent on a number of factors such as weight, speed and type of gauge railway. The impact of the turning curve is large design criteria as it has to be meeting when designing the alignment. The advantages of having a higher turning radius is that it is able to better navigate the environment to prevent costly infrastructure such as building large bridges, removing large amounts of soil and avoid protected vegetation areas. It has been speculated by a number of sources that while the cost of Maglev will higher than high-speed Rail per mile to install, the added cost of all the infrastructure needed will equal or be over the cost of Maglev trains where it can avoid these expensive alignments. It is also for this reason that Maglev is better economically favourable for urban landscapes and mountainous areas. An example of this is the planning of the UK ultrasound project where there was huge savings for the use of Maglev compared to HSR.

As no studies have been carried out on the effect of a minimum radius with heavy freight such as coal, this is an area of future study once the technology has been developed. (Review of Maglev train technologies doc, Lee)

Grade

The current grade of slope which iron wheels train has a maximum grade of 30-10/1000m. Current Maglev has the ability to operate at a higher slope of around 80-100/1000m (Lee, 2006). This means that a Maglev is capable of travelling a steeper grades allowing for a more fixable alignment which would have savings due to decreased infrastructure and more favourable alignment options. As no studies have been carried out on the effect of grade with heavy freight such as coal, this is an area of future study once the technology has been developed.

Shared Transport Corridors

Maglev designs have been used to utilise shared corridors with other forms of transport. By having cooperation between the owners of the corridor the various forms of transport are able to pass each other without being interrupted as they use separate tracks. This has the primary advantage of having less land to be acquisitioned.

Reduced Maintenance Costs

Because there is no physical contact between the wagon and the guideway there is no physical abrasion and large focus points on the track. The lift and guidance forces are distributed over a large area which means there is less frequency of maintenance required. It is estimated that the costs of maintenance will be less then High Speed Rail by 75% but exact figures are unknown due to lack of long life operating experience. (US Department of Electrical Engineers, 2005) (US Department of Transportation

Federal Railroad Administration, 2005, p. 36). The effect on costing are discussed in the economic analysis in Chapter 3.3 and 4.5

Small land requirements

As shown below in table 12, the land requirements for Maglev are smaller than other modes of transport due to the narrower guideway and overall corridors. Also the Maglev guideway can be elevated above the ground to avoid collision with animals and humans. The turning radius is smaller than Rail which means more design controllability. (US Department of Electrical Engineers, 2005). As can be seen below there is a major decrease in the land required for the Transrapid compared normal railroad infrastructure which would make it more appealing to land owners and would cause less environmental damage.

Table 12: Land Requirements for different modes of transport (US Department of Electrical Engineers, 2005)

Guideway Road	Width (m)
4 Lane Highway (Corridor)	30
Normal 2 way Railroad	14
Transrapid (2 way guideway)	12
Surat Basin Rail Corridor	60

There has been no publically released data for the required land needed for the Japanese MLX Maglev system.

Number of Prototypes and interest

As can be seen in the Literature Review there are a large number of different Maglev prototypes. The interest was quite high in the early 2000s but has lowered drastically due to the financial crisis and future prospects of feasible Maglev designs such as the Japanese MLX which would utilise superconductor technology. Investors are now aware that Maglev is not the most feasible option presently, but the technology has potential in the near future. It is for this reason that there has been a lot of financial investment in superconductor advancement to allow a number of technologies such as Maglev utilise its special properties. Future discussions can be found regarding Maglev prototypes and superconductors in Appendix B.

Potential of Superconductors in the future

There is a large potential of superconductor technology in the future as discussed in depth in Chapter 2.2.7. The following is a list of superconductor applications which will make Maglev technology more feasible. These are other advantages of superconductors apart from the primary use for levitation as discussed in Chapter 4.2.1.

- *Cost of Superconductors*: With the increased demand of superconductors the cost is likely to drop through scale of economics.
- *Electricity Supply and control*: Superconducting power cables allow higher currents, smaller diameters and lower transmission losses. Superconductors allows for an increase in efficiency of power related applications such as current limiters, transformers and more as discussed in depth in Chapter 2.2.7. This will lower costs in the long term and allow a more reliable and controlled energy supply.
- *Energy Supply*: Magnetic energy storage will allow the collection of energy from renewable sources to be stored and distributed as needed. This will lower the cost of electricity.

The impacts of superconductors directly for Maglev are discussed in Chapter 4.2.1.

Rate of Superconductor Advancement

Over the last two decades there has been a rapid technological rate of advancement of superconductor technology and Maglev trains. In Appendix B.4 there are detailed discussions on the rate of superconductor advances. It shows how the rates of advancements have increased exponentially. This is in the best interest of Maglev for it is critical to allow the future models of Maglev to be operational and financial feasible

Society Push to become more sustainable and greener

Prior to 2013 there has been a big push within the public to be more sustainable and greener. This can be shown by the increase in popularity of the greens party and the introduction of the carbon tax.

The impact of this new push in the future is unpredictable. It is undeniable that sustainability and environmentalism will increase and cause an impact on future design and planning. There have been many advancements in the standards regarding to sustainability and environmentally friendly over the last 100 years and it is only going to continue now that humanity are beginning to come to terms with humans impact to the environmental.

The impact of this push has the capacity to make a big impact on society and the feasibility of projects. For example the Carbon Tax introduced by the Labour

Government in July 2012 has had a large influence on the community and businesses. The effect on this policy for coal mines is that an independent study has found that 17% of black coal mines may not be profitable and forced to close. While Australian Greens deputy leader Christine Milne says “With more evidence about what will happen in Australia if we fail to act on the warnings of climate scientists, it is time to get started with that action, and that is what the Clean Energy Future bills will do”. (Latimer, 2011). While the impact has been less than expected due to the poor state of the economy it still highlights the impacts that politics has on the feasibility of projects. Currently this topic is of high turbulence in the political agenda and when planning for the future anything can occur.

The impact of this scenario feasibility of this project has both good and bad features. It is bad in the short term as it may make coal mines which were proposed in the Surat Basin unviable. An advantage is that the energy efficiency of Maglev will save money in the long term. The impacts will be dependent on the policy and who it is impacted.

Positive Socioeconomic effects

There are a number of positive effects Maglev will have in the socioeconomic environment. Examples are:

- Job creation for full time employees.
- Job creation for the construction of the guideway and related infrastructure.
- Purchasing of local and national products.
- Increased usage if designed incorporated with passenger transport.
- New jobs caused by the opening the Surat Basin to the export coal market.
- If designed for passenger transport it will have the same socioeconomic effects as conventional trains such as accessibility to new job markets, Allows access for the elderly and disabled.

Environmental Effects

Maglev has significantly less environmental impacts then other modes of transport. The following is a list of environmental facts that relate to Maglev technology (US Department of Electrical Engineers, 2005) (US Department of Transportation Federal Railroad Administration, 2005, p. 36) (Blow, 2010)

- Maglev (Transrapid) produces no onsite gas or liquid pollution

- While it uses a large amount of energy which could have been burned from coal power plants, but in the future sources of energy should be significantly greener and renewable. The effectiveness of renewable energies is advanced if superconductor advancements continue.
- A comparison of emissions in milligrams/seat per km for various transportation systems are shown in the table below

Table 13: Emission in mg/seat/km (US Department of Electrical Engineers, 2005, p. 2)

	CO	**NO2**	**SO2**	**CH**	**CO2**
Transrapid 200km 300km 400km	2.0 2.8 3.9	8.5 11.7 16.4	7.1 9.7 13.5	0.20 0.27 0.37	11,000 15,000 21,000
Airbus A 320 <600km	225	449	44	17	139,000
Automobile with catalytic converter	510	132	12	42	71,000

Other studies have shown that expected increase in air emissions from local power plants to power the Maglev will be less than the option of using other forms of transport. The environmental impact will be dependent on the fuel source such as coal, natural gas, nuclear, wind or hydroelectric energy production. (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-15)

Passenger Service Quality

The services Maglev can provide to the passenger would influence the model choices of travellers. The following reasons are why:

- A high standard ride by passengers.
- Be able to penetrate into the heart of cities and service airports and outer suburbs.
- Maglev is currently door to door time competitive with transporting some distances with air travel (Example New York to Boston). (US Department of Transportation Federal Railroad Administration, 2005, p. 37)

Safety

The current derailment protection systems are very safe and reliable compared to other high speed Rail systems. One great advantage is that the Maglev can safely travel under extreme weather conditions. The types of Maglev which have the higher gap tolerance would have the higher protection against derailment. The vehicles are constructed out of non-combustible material provides extra safety. (Blow, 2010, p. 3)

The Transrapid has a safe hovering concept where the vehicle will only stop where safe evacuation can occur. What this means is that the train will not pass a safe location when it cannot act independently of guideway power. The on board batteries has a minimum travelling time of 7.5 minutes without external charge. If the ability to collect electricity was to be lost then the on-board braking system would slow the train to slow speeds where it slide along the skids and come to a halt. (US Department of Electrical Engineers, 2005) (US Department of Transportation Federal Railroad Administration, 2005, p. 36)

It also depends on which type of guideway the Maglev train utilises. Most Maglev designs such as the German Transrapid utilises an elevated guideway preventing the likelihood risks involved with grade crossings and inappropriate pedestrian access. In Appendix 4 of the US report to Congress on the feasibility of Maglev technology has a in depth discussion of Safety (US Department of Transportation Federal Railroad Administration, 2005, pp. App 4 - 83)

<u>Health effects (Magnetic Fields)</u>

The current Transrapid Maglev doubles the Magnetic field which you would normally experience for the Earth's magnetic field. The Transrapid is about 1/9th less the than magnetic field which you would experience going on the subway.

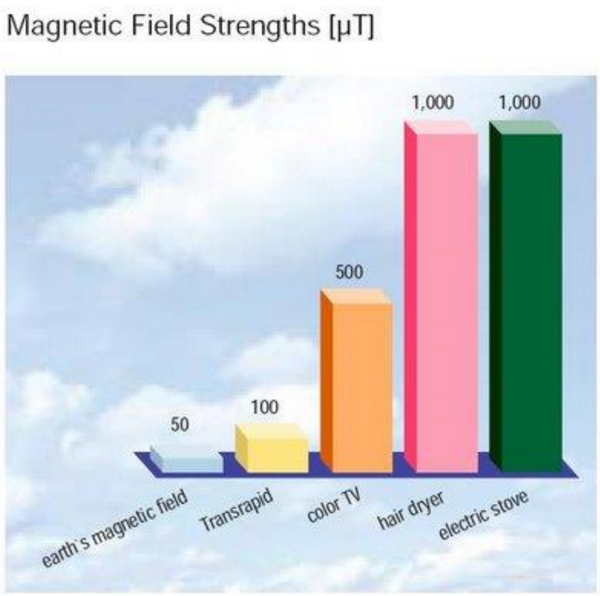


Figure 46: Magnetic Field Strength (US Department of Electrical Engineers, 2005)

Lower amounts vibration and noise

The noise level is much lower than conventional trains since there is no noise from physical contact. At slow speeds in an urban environment different types of Maglev (Transrapid) can travel 25% faster before breaking the peak noise restriction of 80 to 90 dBa. At high speeds the high speed Maglev is 60 to 65 dBa. (Lee, 2006)

Current vibrations impacts on building damage are not known due to the mostly preliminary state of design of Maglev systems. The analysis of site specific data will have to occur during detailed designs is being undertaken. (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-21) For transporting coal at higher speeds in non-developed locations increases the feasibility of more rural alignments.

Doesn't use petroleum based products

The Maglev train can operate independent of petroleum based fuels since it is electricity operated. This means this technology has a number of advantages compared to other technologies. Unlike cars and planes an interruption of the non-renewable source of power due to depletion and disruption will cause these transport options to be unavailable. With the use of more efficient and renewable sources of energy Maglev will meet the requirement for being both environmentally friendly and sustainable.

High Capacity for Passenger Transport

While these figures are not relevant for coal transportation, one Transrapid guideway can achieve a high capacity of 12 thousand passengers per hour. This is equal to 60 Boeing 767's per hour and about a 10 line highway. (US Department of Electrical Engineers, 2005)

Maglev competitive to Air Travel and HSR Alternative

While this is not relevant to for coal transportation it is important knowing what the primary advantages of this technology is being targeted for. By knowing the strengths of this technology will help engineers make technology more competitive and utilise it in different markets.

When looking into costs of passengers there are the financial costs and a time costs. From the analyse of this relationship engineers are now seeing while Maglev will have the approximate cost, the large margin of time savings will make Maglev a more feasible alternative for passengers. Maglev aims to not have the problems of such time consuming security checks, airport waiting time and congested highways. There are airports which are meeting capacity, and there have been only one new major airport built in America in the last 30 years. Due to the massive construction costs airports are expanding which also cost millions of dollars. They also have problems such as environmental concerns, noise pollution and highway infrastructure.

Although the construction cost of Maglev is higher than recently constructed high speed Rail, the high speed Rail actual cost due to the route may approach or exceed Maglev. In situations where the line would follow an existing route the high speed Rail will not be able to follow it due to geometric design requirements. This might require building new elevated structures and occasionally tunnels. Currently in Japan they estimate the MLX will cost 20 to 30% more than current high speed Rail. (US Department of Transportation Federal Railroad Administration, 2005, p. 36) Another advantage of Maglev is that it can increasingly improve, but high speed Rail has a limiting plateau with its achievable speed due to power output efficiency due to friction loss. (US Department of Transportation Federal Railroad Administration, 2005, p. 36)

4.1.2 Advantages of Maglev for transporting Coal

Requirement to move coal

There will always be a requirement for the transportation of coal if it's still being used as a major source of cheap energy. While there are different methods of transporting coal, it is a choice at the time of planning at to which method is the most feasible and meets all the design requirements. While there may be a time in the future that society may not need coal, this is not in the foreseeable near future.

Right of Way

The advantage of Maglev trains is that it has its own track which no other forms of transport can use. This means that the Maglev trains have the right of way causing less congestion. For example it is hard for to transport coal to the ports in Brisbane because coal trains have the lowest priority when scheduling with Freight transport and passenger transport. This is discussed within Chapter 3.2.3.

Impact on National Security

Every new infrastructure has been analysed to determine its impact on National security. What this aims to do is make sure that the public and the national economy is not at threat of being made incapable of providing services to the population in times of war, national disaster or similar situations.

The aim of the Maglev proposal is for it to transport coal from the Surat Basin to be exported. It has been identified that transportation coal is a critical requirement to provide electricity to the population. This is a very important infrastructure requirement as it provides water, refrigeration and allows everyday life and commerce. Maglev system doesn't provide this service as conventional Rail transports coal to the local power plants. This means that if there was a major event to stop the operation of Maglev system it will not stop the supply of electricity to the public.

The only negative impact it could have is financial loss if the Maglev was not able to operate for a short period of time. Planners will have to have contingency plans in place for scenarios such as a breakdown.

Average Speed Energy Saving

Under a near constant cruise conditions Maglev is very efficient compared to other modes of transport such as auto, Rail and air. But if the route required a constant change in speeds due to stations or speed limits due to alignment within a city the energy required would be increase making the operational cost advantage disappear. (US Department of Transportation Federal Railroad Administration, 2005, p. 38)

4.1.3 Disadvantages of Maglev Technology

Peak speed versus average speed

If the Maglev train is located in a congested corridors will not be able to maintain the high average speed. Because of the strict alignments the operations have maximum speeds at which the train can travel at. This lowers the feasibility of shorter sections of track in congested corridors. (US Department of Transportation Federal Railroad Administration, 2005, p. 36)

Availability of Lower-cost alternative

While the cost of high speed Rail is comparable with Maglev, there are a large number of other forms of transport such as conventional Rail, cars, trucks and aeroplanes. The case of Maglev is stronger when there is no existing infrastructure as it needs to have separate infrastructure. The costs are discussed in Chapter 3.1.

Complicated and Expensive Switching Lanes

Switching is complex in both forms of Maglev which require a large section of movement of the track to allow diversion at high speeds. This has higher costs and complexity compared to conventional Rail.

Energy consumption

While the energy overall used is more efficient, a large amount of energy is required for the changing of speeds. This means that if there are a lot of stops or changes in acceleration the previous energy efficiency to other modes of transport may be lost. (US Department of Transportation Federal Railroad Administration, 2005, p. 36)

Guideway construction

The guideway construction costs are a large segment of the overall price.

Currently not competitive

The quality of transportation is currently primarily measured in terms of speed, frequency of service, accessibility, reliability, safety and cost competitive. For Maglev to succeed in the future then it must be superior to the competition in meeting most of these factors. Currently many believe that this is not case.

Mostly Experimental Phase

Many people believe that it is still in its experimental phase. While this partly true as the experimental phase is where most of the work has been completed in the last 30 years. But below are two recent examples of practical moves to make this commercially viable. (E.Blow, 2010)

In 2003, the city of Shanghai, China installed the world's first commercial high speed commercial high speed Maglev route. They used the German Transrapid Maglev technology to connect its airport with its urban financial district with a distance of 30 km's and reaching speeds of 430km/hr. More utilisation of this technology is underway.

By 2025 the Central Japanese Railway Company aims to commercialise its own high speed superconducting Maglev system. It is at this stage that the technology of the MLX-01 would be planned to become economically feasible. They have designed a track to connect Tokyo, Nagoya and Osaka which would have an approximate length of 800km with a travel time of less than 2 hours.

Political parties and Politicians

People or groups of political parties may be for or against a project due to many reasons. These people or groups have the capabilities to hinder or prevent projects from coming into tuition. An example of a view negative to Maglev is of the Shanghai Maglev where some politicians view it be a white elephant. They say that the extra cost is not worth the current benefits of the technology. After operating for a number of years the passenger traffic is lower the expected. (Ren, 2012)

Another negative view towards Maglev is that people don't want it near them. While it is quieter than current high speed Rail, there are still many against proposals. For example the middle class near Shanghai where a Maglev Train Extension is proposed. A news report describes protects against the government and the retaliation of the Chinese Government back against the people. (AlJazeeraEnglish, 2008)

Negative Socioeconomic effects

There are a number of negative effects Maglev will have in the socioeconomic environment. Many of these negative social economic effects cannot be determined until a detailed design of the Maglev and the alignment occur. The following are two identified negative socioeconomic effects:

- Displacement of people and families due to new jobs
- Property acquisitions

4.1.4 Disadvantages for Maglev transporting Coal

Currently no large freight cargo in operation

There have been no operational or experimental operations of conventional Maglev trains being used to transport bulk material such as coal, metals, cereal grains etc. (E.Blow, 2010)

The German Transrapid is the only Maglev service which has practiced freight transport but this is only for standardised air freight. The extent of this operation is unknown but they are able to have 20 sections of 19 tonnes per section. This means it can carry 389 US tonnes of air cargo in one vehicle. This uses the conventional carriage but the interior is modified. But from the outset the Transrapid has be developed to be able to transport express shipping containers as well.

There have been reports that Chinese has been experimenting with Maglev to Transport coal via Maglev, but the extent of this operation is not known due to confidentiality. It could be Maglev trains or the use of Maglev technology such as Magpipes or other inventions. Until more information is released we cannot make any acknowledgements of this existence.

Incompatible with Rail Infrastructure

Both the Japanese MLX-01 and the German Transrapid cannot be combined with existing Rail infrastructure. No Maglev technology will be able to be combatable with existing Rail technology. This is only a problem if Maglev and the existing Rail system are meant to be a part of the same system. Because of this Maglev is currently economically feasible if it is installing to provide a service that has no existing infrastructure. Also new infrastructure at the ports will have to be developed to allow for Maglev. If the proposed port already has the infrastructure to unload conventional coal trains, it will increase the capital cost for the Maglev System.

No known investigations are underway for transporting coal with Maglev

There currently have been no investigation findings and report findings relating to transporting Coal within Maglev which are publically available. While it has been mentioned within a couple of documents it is considered that this has not been analysed by any professional body in any detail. It is for this reason that there are a lot of uncertainties regarding this topic by professionals. Currently there are bigger projects utilising Maglev technology which transporting coal would be a modification of the standard Maglev design.

One reason which could explain the lack of information in English is that most Maglev development is carried out in non-English speaking countries. For example the Japanese, Germans, Swiss and Chinese are known to be working on experimental Maglev technology and if they did publically release a report relating to the transportation of coal it would not be able to be found due to the language barrier.

4.2 Event Probability and Impact upon overall feasibility

The primary aim of this chapter is to identify and discuss future events and what impact they will have to the overall feasibility of Maglev and its ability to transport coal. This will allow future designers when starting research on the feasibility to know where to start investigating for possible events in the future.

The second aim is of this chapter is to gain an understanding of what events could and apply estimations to be applied to a society push which is calculated within the financial model. It was determined that accurate impacts on the Maglev financial data was no released so no data analyse has been completed. While the model has been completed to account for these events, there is no academic value in discussing estimations without evidence. The impact of these events will only be known by someone within the Maglev industry who is familiar with the costing. Assumptions related to these events are identified in Chapter 6.1.

Probability

The Probability of these event occurring is termed under the category of High, Medium and Low.

- High - The likelihood of this event occurring is high and this event has to be expected to occur in the future
- Medium - The likelihood of this event occurring is medium and this event has to be expected to as a possibility to occur in the future
- Low - The likelihood of this event occurring is low and this event is unlikely to occur in the future but has be considered.

Requirement/Impact

The impact of these event occurring is termed under the category of high, medium and low.

- High - Difference between being feasible or not.
- Medium - Likely to cause large saving or losses but will not cause the technology to be not feasible.
- Low - Small impact on economic feasibility. Are small advantages or small complications.

There are hundreds of different events which could impact on the feasibility of the proposal using Maglev to transport coal. The following just analyses of the events which would cause the largest impact.

4.4.1 Variable Impact Events

Variable impact events have the possibility to have a positive or a negative influence on the feasibility of Maglev technology.

Global Requirement for Coal

The requirement for coal as a source of power is likely to experience change in the future. While in the near future the demand for coal is expected to increase we have to know that coal is not a long term solution for energy production. This is due to coal being a non-renewable resource and also having high emissions. There will be a time in the future where coal will not be required due to new sources of energy production.

There are a number of issues relating to trade, environmental issues and research discussed in depth within the following Chapters.

- 3.1.1 Queensland Coal Industry
- 3.2.5 Analyse on the future of Coal

Probability = Medium

Impact = High

Position of the global economy

The feasibility of Maglev will be highly dependent on the economy of Australia and the World. The economy of Australia is always changing and major events both positive and negative impacts and are likely to occur within the proposals project life cycle. The following discuss the impacts of the global economy.

If the Australian and the World economy were strong there are a number of reasons to seriously consider this investment.

- Investments are of less risk when there is a strong and stable economy.
- People are willing to try new solutions to solve problems.
- Societies are willing to invest in technology which will advance it technological status.
- Societies are willing to invest extra for the service to be more sustainable.

No country going through a financial hardship is going to

- Invest in something that they may feel has high risk
- Something that doesn't provide improved living standards of it citizens

- Provide export material when the market is very flat with no demand is not worth investing in large infrastructure projects.
- Decrease in demand of materials makes high volume transportation of coal unfeasible.

The proposal will not take into account economic variations. The impact of the economy is very variable which makes it impossible to predict it in the future and its possible impact on the feasibility of Maglev technology. Planners have to access the situation at the time of proposal.

Probability = Medium

Impact = High

<u>Politicians and public policies and agenda's</u>

Society is constantly changing and it will always impact upon the feasibility of projects. The effect society have on projects is likely to be large but not enough make any project unfeasible as long as good communication is accomplished.

This is discussed in detail in Chapter 4.2 in

- 4.2.1 Society Push to become more sustainable and greener
- 4.2.1 Positive Socioeconomic events
- 4.2.3 Negative Socioeconomic events
- 4.2.4 Political parties and Politicians

Probability = High

Impact = Medium

<u>The long term effects of terrorism and the resultant changes in travel demand</u>

The effect on society regarding the security environment can effect total travel times and the competitive position of other modes of transport. With these changes consumer choice can impact of the cost effectiveness of the mode of transport.

While this doesn't directly impact this Maglev proposal as discussed in depth in Chapter 2.2.4, it will affect the market of transportation if Maglev is seen as a safe option. Maglev could be widely implemented for this reason causing a decrease the cost of Maglev due to scale of economics. This can also work against the feasibility of Maglev if target by terrorists.

Probability = High

Impact = Low/Medium

Society changes travel demands and modes

Travel demands of humans have constantly changed over the last hundreds of years. The method to travel depends on distance, cost, time, safety and comfort. These will constantly improve to meet the requirements of modern society.

While the proposal does not directly relate to the transportation of people, transport coal is likely to be designed by the same companies who economically commercialize passenger Maglev trains. The changes in society can be both positive and negative for the feasibility of Maglev trains transporting coal.

Probability = Medium

Impact = High

4.4.2 Possible Positive events

Positive events are which have the possibility to have a positive influence on the feasibility of Maglev Technology are discussed below:

Scale of economics increased due to widespread implementation

In the future if there is a large scale mobilisation of Maglev technology then this would cause the cost to be decrease compared to present day costs. The following reasons are why the costs will decrease:

- Cheaper manufacturing of products required due to increased quantity required and increased invest to find improvements.
- Cheaper construction methods to build the Maglev infrastructure due to increased knowledge and experience.
- The more products sold the less the profit margin for each Maglev route.
- Society would be accepting of this technology and promote its use.

The extent of the impact will depend on the scale of the implementation of Maglev technology in the world.

Probability = Medium

Impact = Medium

Effect on unexpected breakthrough in the field.

There is a possibility that in the future an unexpected technical breakthrough will increase the feasibility of Maglev trains in the future. In history there have been technical advancements that were not expected and they advanced the technology to increase its feasibility.

In no scenario is a breakthrough expected to occur. The impact would also be variable which could have to possibility to impact on any aspect of Maglev design and operation. Designers cannot expect event to occur but have to be aware of the potential to best react if this event occurred.

Probability = Low

Impact = Medium

Continued advancement of Superconductors properties

As discussed in much detail within the Literature Review and Appendix B there is a lot of work currently being carried out in many countries to develop and apply superconductors to solve present day problems. The aims of this research it to make superconductors cheaper as well as to have increased properties. There are a large number of different applications from a large number of different industries.

These analyses on the continued development to advance the feasibility of superconductors are in the chapter below:

- 2.2.4 Rate of development of room temperature superconductors
- 2.2.6 Current Limitations
- 2.2.7 Current and future uses of Superconductors

Probability = High

Impact = Medium

Clean and cost effective conversion of coal to energy

The problem with the proposal in this feasibility study is that we are transporting a material which is used to provide cheap energy while having very negative environmental impacts. There is no doubt in the future that society will have the technology that will allow for a more environmentally friendly and renewable source of energy.

As discussed in Chapter 3.1.5 there have recently been advances in extracting power from coal without any emissions. While this is only been completed in a laboratory it is know that this is possible and may in the future be economically feasible to do so. While coal is only a finite source of power, societies are likely to keep using coal as long as it is economically and environmentally viable

Probability = Low
Impact = High

4.2.3 Possible Negative events

Negative events which have the possibility have a negative influence on the feasibility of Maglev Technology are identified and discussed below.

The installation of the Surat Basin Railway or other Infrastructure

For the feasibility of Maglev transporting coal there cannot be existing infrastructure available to the majority of the Surat Basin. If the Surat Basin Rail project as discussed in Chapter 3.2.4 was to be completed then it is extremely likely that Maglev will not be feasible.

Probability = Medium
Impact = High

Higher than predicted total costs of preliminary estimations

It is not uncommon for initial estimation and early commercial operation to underestimate the total cost of the project. This can be due to many problems such as the lack of information and experience, unseen difficulties and change in circumstances. An increase in knowledge and experience of estimating Maglev technology will provide a more accurate prediction on the financial feasibility.

The scenario will not take into account errors which may have occurred with previous estimations. The data has to be accessed and what seems as the most accurate data chosen. For pre- feasibility estimations it is expected that the estimations are not correct and may have a variation of 30% plus or minus.

Probability = Medium
Impact = Low

High reduction in conventional Rail and High-speed Rail costs

If there was to be a major decrease in the cost for construction and operation of convention Rail or High-speed Rail then it could become more competitive than a Maglev alternative. Currently track on wheel trains are at their capacity when it comes to efficiency of energy usage and maintenance as identified previously in the report in chapter 4.1.1.

Probability = Low

Impact = Medium

Transportation and Coal industry against change

There will be some which believe that Maglev is not required to transport coal as it is a total change to the transportation type previously used. But once the savings and system is described then they will hopefully be more cooperative. The coal industry outside of Australia have been keen to look at different forms of transporting coal such as using Magpipes and various types of slurries. It is dependant of the final design which is being considered at the time but one which utilises existing work methods will provide the easies transition phase.

Probability = High

Impact = Low

Chapter 5: Maglev Design for Coal in the Surat Basin

5.1 Future Maglev Coal Train Design Considerations

The following ideas in Chapter 5.1 and 5.2 have been theoretical developed from information provided within this report. These ideas may have flaws that cannot be identified until critically analysed by professionals in this field. To date there has been no released research into the transportation of Coal using Maglev to verify my assumptions.

Below is a description of design requirements that are required for Maglev coal transportation system. The following is a list of common requirements that do not need an explanation.

- Train must levitate
- Train must be able to accelerate and decelerate
- Train must be able to safely stop on the guideway in case of an emergency
- Train must be able to retrieve, store and unload coal.
- Guideway must be sturdy enough to hold train if not levitated.
- Must be economically feasible compared to other transportation types.
- Must reach speeds that makes the operation feasible
- Must be able to have a high number of carriages
- Must be able to hold a large amount of Coal
- Must operate in all weather conditions
- Must have emergency procedures for possible problems with the train, track or the overall system.
- Guideway must be positioned along desired locations
- Be environmentally friendly

This chapter looks at the design requirements required for Maglev to transport coal. It is assumed that the Maglev system proposals are able to meet design criteria. Chapter 5.1.1 discusses design requirements for any Maglev system but Chapter 5.1.2 and 5.1.3 analyse how the Transrapid and MLX will transport coal.

5.1.1 Primary design requirements for Maglev to transport Coal

There are a number of important design requirements that need to be addressed for Maglev to be able to transport coal. Some of these design requirements are:

- Utilising Superconductors
- Transporting coal to Maglev loading stations
- Loading and unloading coal
- Speed
- Cost

These are discussed below as well as expanded within Chapter 4.1.2 where these design requirements are considered for the individual maglev systems.

<u>Importance of the costing in Superconductor technology advancements</u>

The cost of making Superconductors and the cost of cooling them are a big factor as to why the more advanced Maglev designs are not presently financially feasible. As discussed in depth in Appendix B superconductors have a large amount of potential but have limitations which prevent their wide spread utilization. The large factors which impact of the cost of superconductors are the need to be manufactured and constructed to meet required property strength. The methods developed need to be cost effective and to be able to be mass produced. Examples and further discussions are available with Appendix B.

The critical temperature (Tc) and the operating temperature will determine if there needs to be cooling. If it needs to be cooled then this will increase the cost dramatically. For example the MLX-01 has on board nitrogen coolers to keep the superconductors at the required temperature which is why presently it has a high operating cost.

<u>Importance of Superconductor technology advancements for increasing weight capacity</u>

The higher the critical temperature the higher the weight capabilities of a Maglev train. Superconductors do have limited strength and they are dependent on critical current, critical magnetic field and critical temperature. These constraints are discussed in detail in Appendix B.3. Below is a discussion of the important factors regarding design of the superconductors and weight capacities.

Maglev trains can use superconductors to make electromagnets used to create the propulsion or attraction forces. The increase in the weight of the carriage will increase the downward force causing a higher current required to maintain the opposing magnetic field. Superconductors have a critical magnetic field which it can repel before it loses its superconducting state. If the material was to lose its superconducting material the material would burn as the resistance would drastically increase and elevation of the train would suddenly stop.

While superconductors developed over the last two years now have a critical temperature above room temperature, at these temperatures the critical current and magnetic field resistance is very low. The operating temperature has be well below the critical temperature to create a high critical magnetic and high current properties required for Maglev to operate efficiently. This means the operating temperature may need to be cooled to allow a Maglev train to be able to carry a certain weight with recent superconductor developments. As stated the properties of the superconductor increase as it is cooled, but there is a limiting factor where any further decease in the temperature will not cause a further increase in properties.

The perfect superconductor would be one which has strong critical current and magnetic capacity while having the operating temperature high requiring limited or no cooling. This would mean that the critical temperature would have to be much higher than room temperature. The possible advancement of superconductor technology is stated and discussed further in Chapter 3.4.8 and Appendix B.

It is out of the scope to determine what exact superconductor properties are required but presently Maglev are able to transport 70 tonnes (Transrapid which uses technology at least a decade old and its electromagnets are not even superconducting). With recent Superconductor technology advances as identified in Appendix A1.4 the capabilities for Maglev to transport higher weight capacities for Maglev will be able to be achieved if the same rate of development occurs.

<u>Transportation of Coal from mine to Maglev Station</u>

A design requirement which has to be considered if utilising a Maglev system is that how will coal be transported from the mines to the Maglev loading station. It is to be expected that the Maglev train loading station will not be able to be located near every mine as the alignment of the Maglev track will be designed to service the largest area with a least distance as possible. It will depend on the design but there will be a number of loading stations proposed dependant on the location of all mines.

There are a number of different methods how this can be achieved but most require double handling and would have a varied amount of loading time. They are discussed below:

- Use Trucks to transport coal to the closed loading station. This would utilise existing equipment but has the same disadvantages other coal transportation such as cost and impact on roads. A discussion of trucks transporting coal is discussed in Chapter 3.2.3
- Use trains to transport coal to the loading station, and then unload the coal into the Maglev carriages. This could use existing infrastructure or if nothing exists would be cheaper than getting a Maglev track to the location of the mine. The Railroad track would be able to service a number of mines in the area. A discussion using conventional Rail for transporting coal is discussed in Chapter 3.2.3
- Surry pipes and Magpipes are another option which each would have to be designed and installed to service only a mine. A discussion using Magpipes for transporting coal is discussed in Chapter 3.2.3
- In Chapter 5.1.2 it discusses combining the conventional Rail system to the Maglev train system for the Japanese MLX technology which would greatly increase the feasibility as it can access cheaper and previous built Railway lines.

<u>Loading and Unloading Coal</u>

A design requirement of a Maglev system transporting coal is that it can load and unload the coal. There is also a discussion on how the present individual systems may handle this design requirement discussed in Chapter 5.1.2 and 5.1.3. It is assumed that the design requirement of loading and unloading coal will be meet and to the same standard of conventional coal trains unloading and loading times and cost.

The following is a list of aims for the procedure of loading and unloading

- Time efficient
- Cheap to install and operate
- Safe to operate for staff
- Not damaging the Maglev wagons or infrastructure.

The various ways that this can be achieved is discussed in Chapter 5.1.2 as it depends on the type of Maglev system.

Speed

The speed at which Maglev will be able to transport coal will have a large impact on the feasibility of the Maglev technology. This speed will have high impacts on the tonnage capacity which there service will be able to provide. The speed could mean the difference between one or two tracks.

While this variable is of high importance, it is one of many factors which determine the overall travel time. Some other times which have to be considered is loading and unloading times, gaps between trains, availability of carriages. These other variables cannot be estimated at this technology has not yet been developed and impossible to predict. Chapter 3.4.7 states the speeds which can be currently accomplished.

The speed of Maglev is not being analysed in the model as the capacity is the variables for which are being tested. The capable speed which a Maglev system will be able the gain will have a large impact of the capacity and this can only be determined as a part of a detailed capacity study completed by specialists.

Cost

The cost of the overall system is going to greatly impact on the feasibility of the project. Due to this reason smart engineering has to occur to find cheap ways to produce the required products without reducing efficiency or safety. The effect of the price on the model is discussed in Chapter 5.

5.1.2 Attractive Levitation Maglev coal transportation design analysis

The German Transrapid is the most prominent and successful model of attractive levitation model and this Chapter identifies and discusses design considerations which will have to be considered for this system to transport coal. The following identifies the advantages of this system and discusses how it may handle the major requirement of loading and unloading coal.

Important Design Characteristics

- Able to levitate at low speeds
- Lower magnetic field
- Actual working model

These advantages are very important to the overall feasibility of the project as discussed within the important design considerations in Chapter 4.1.1 and advantages of a Maglev system in Chapter 4.2.1.

Loading and Unloading

The German Transrapid has multiple methods to use wagons to unload coal at the port. Figure 47 shows two methods which the Transrapid is able to unload coal. It is able to apply the bottom opening and side tipper unloading methods used by normal coal wagons. The different methods are shown and discussed in Chapter 3.2.3. The unloading method of rotary wagon tipper is not suited towards Transrapid as the wagon is levitated even at low speeds, so the tipper will have to take the full weight support and make sure that it doesn't damage the levitating and propulsion coils. While it could be done, the Transrapid is more suited towards the other methods.

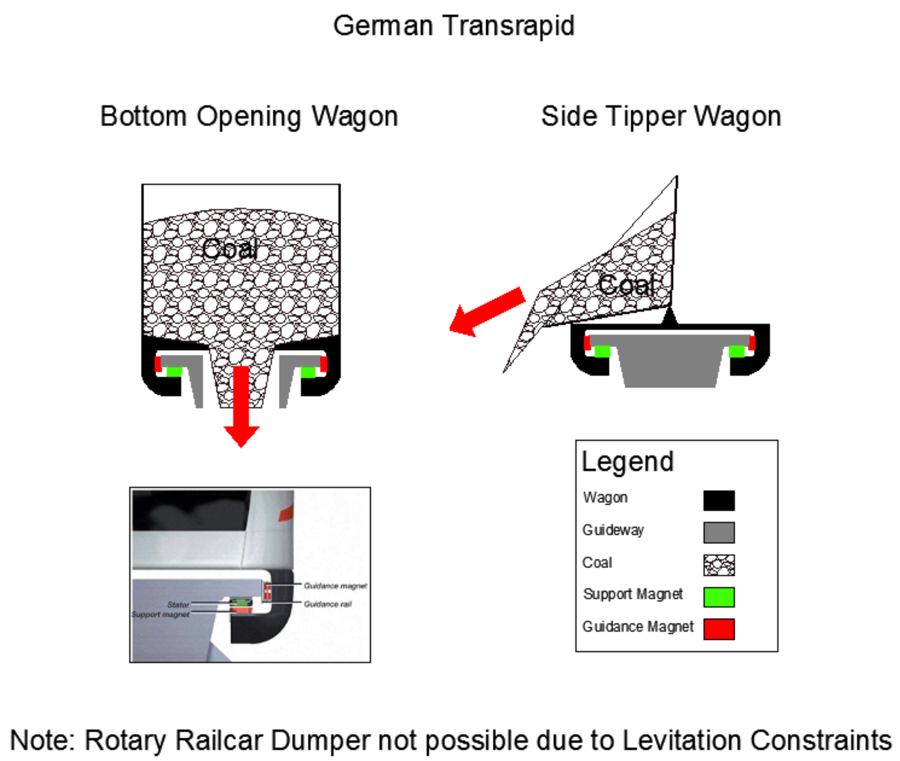


Figure 47: German Transrapid Unloading Coal Methods (Appendix F)

5.1.3 Propulsive Levitation Maglev coal transportation design analysis

The Japanese MLX-01 is the most advanced model of propulsive levitation model and this Chapter identifies and discusses design considerations which will have to be considered for this system. The following is a list of positive and negative design implications for transporting coal and compared to the Transrapid Maglev System.

Important Design Characteristics

- Higher Speed (581 km/hr)
- More advanced technology utilisation
- Larger Gap (10cm)
- Higher weight capacity.
- Currently unable to levitate at low speeds hence wheels for low speeds (<150km/hr)

Design capacity for conventional Rail tracks

A design requirement of the Japanese MLX is that it has wheels since at low speeds it is unable to levitate. The reason for this as discussed in the Literature Review is that there is only a small levitating force provided by the coils in the guideway for a short period of time due to the resistance. At high speed this doesn't matter since the carriage has passed before the field drops. Superconductors could be added to the track at points of slow speed due to them not having resistance when under the critical temperature but not recommended due to the high cost.

For transporting coal this can be used in advantage as the wheels can be conventional Rail tracks. This has the possibility of connecting the conventional Rail tracks to the Maglev tracks which would remove the need for double handling. The Maglev wagons on the Rail tracks can be loaded at the mine and transported at design speeds with a locomotive to the Maglev station. The locomotive can be disconnected and the Maglev wagon can then travel on the Maglev guideway.

This would drastically increase efficiency but would require a large number of expensive carriages and the life span of the wagons will decrease. This is an idea which can be investigated when this technology is more feasible. Below in figure 48 the diagram of the MLX is shown with Rail wheels, but normally they are designed with rubber.

Loading and Unloading

The Japanese MLX has two possible methods of unloading coal from its wagon. In figure 48 below shows the method of unloading through a bottom opening. The second method is the Rotary Wagon Tipper shown in figure 33 in Chapter 3.2.3. The MLX is capable of this method as when travelling at low speeds the wagon runs on wheels which will allow it to operate on the mechanism. The only concern for this method is the impact of the rotating connections required for the wagons and how they impact Maglev stability.

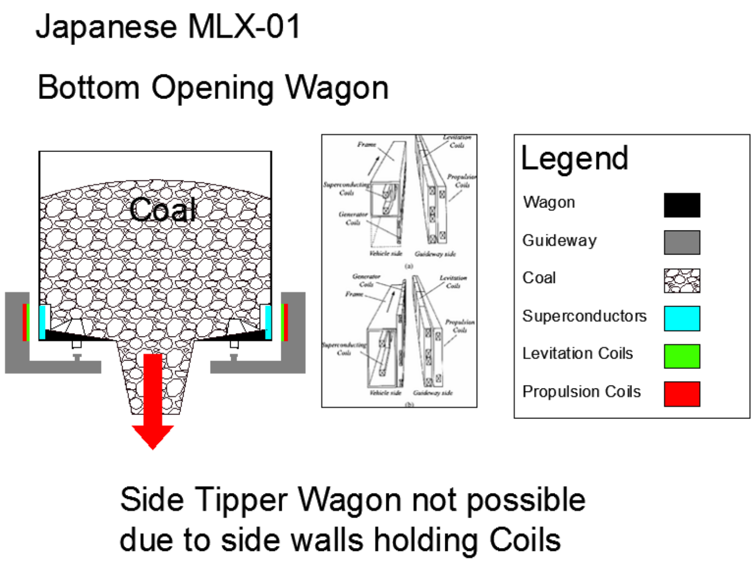


Figure 48: Japanese MLX-01 bottom unloading wagon (Plans in Appendix F)

5.1.3 Locality design impacts and considerations

There are external design considerations that have to be designed for to account for the local environment of the guideway of the Maglev and the Railway. These issues are considered dependant on the location of the proposed track. These topics where identified for Maglev systems for passenger transport in the America in the Environmental Impact Statement of the Maglev deployment program in the appendix of the US Report to Congress of Costs and Benefits of Magnetic Levitation. (US Department of Transportation Federal Railroad Administration, 2005)

<u>Topography, Geology and Soils</u>

The construction and operation of a properly constructed and well-designed Maglev system would result in insignificant adverse impacts to the physical setting by preliminary identifying possible impacts on topology, geography and soils. Constructing Maglev guideway will result in a small impact on these considerations compared to rail, but will still occur due to required excavations, grading and possibly blasting. The impact will be reduced compared to other transportation methods due to the high flexibility of the tracks location requirement. There would be potential risk of erosion during construction of any transportation method.

With the increase in transport requirements, the topography has adverse impacts such as erosion, sedimentation, loss or damage to mineral deposits would be higher for other forms of transport such as Rail and road. (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-8)

<u>Environmental and Climate considerations</u>

There are a large number of different natural disaster and events which could cause a major impact on the operation of Maglev Trains. It should be noted that these events would cause impacts on most forms of transport which is presently used or alternatives proposals. The climate has the opportunity to have a large impact on the operations, service schedule and maintenance requirements. The following is a list of all the possible climate impacts on Maglev in South East Queensland.

The high temperature variations and possible sandstorms could interrupt services due to track and guideway distortion causing higher maintenance costs and reducing Maglev and train visibility.

The possibility of floods and landslides are a high risk event which has to be designed for especially in the areas which are threatened by flood waters in Queensland. This can cause a large amount of trouble such as track destruction and damage, weak supports and making roads unable to access areas for maintenance. The effect of flooding will depend on the particular location and the design of the Maglev system. The design of the guideway, supports and other facilities will determine to what extend flooding will cause damage. This has to be considered when making a decision on which Maglev system will be used in the Surat Basin as this is a likely high risk environmental occurrence.

Natural Ecosystems, Wetlands and Endangered Species

There are a few concerns regarding Maglev and its impaction on the Natural Environment.

The effect of the radio waves and electromagnetic fields are not known to what extent the impact it will have on the wildlife and the natural environment. There have been studies which have concluded that there was no noticeable effect on the environment due to the radio and electric fields. (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-13)

The design of the alignment will be dependent on the location of any protected sites and local legislation. The federal government and the local government legislation may prevent the location of the Maglev Train on the location of wetlands, protected vegetation, endangered species and historic sites. The effect on threatened and endangered species will have to be identified and appropriate action taken to prevent or reduce its impact.

Water Quality

The effect on water quality is dependent on the Maglev system utilizing elevated guideway or having the guideway at ground level. There is also the added impact of the impervious services caused by other related infrastructure such as buildings and car parks. These other infrastructure provides services which have the potential to increase runoff and associated sediment and contaminant loads to local waterways.

For an elevated Maglev design the guideway will occupy small amount of land surface area causing no major changes to drainage patterns. A large impact on the water quality will occur if the guideway are on the ground. This will cause a major disturbance on the natural flow of water and every location has to be examined to prevent or reduce its effect on the environment and the quality of water.

Solid and Hazardous Waste

While the operation of Maglev is not considered a substantial producer of solid and hazardous waste the choice of the system constructed and the location will impact on the amounts and types of waste. The construction and operation would generate waste requiring collection, transport and removal. Most of these will be commercial wastes that any business will create. A plan has to be in place to allow for this as they will have to follow local government and federal government waste polices and laws. (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-16)

Land Use

Maglev has different land requirements depending on which system is utilised. Even with the guideway on the ground it still requires less land then conventional Rail. The land use will be for the supports of the guideway and the supporting infrastructure such as buildings. It will be expected that some residential and commercial relocations will be required but this can be minimised through careful and effective planning.

It is likely that change in land use will have to occur due to the effects on adjacent land holders such as noise and restricted movement. The specific site use impacts are not known as most designs are of the conceptual stage of planning and design.

Visual and Aesthetic Resources

Any form of transportation is going to cause visual impacts, but an aim of the engineer is to provide a visually pleasing design. There will be visual impacts from the elevated guideway, stations, parking lots and associated infrastructure. Each site will have its own impacts but it can be assumed that some locations will have the high potential for significant adverse visual impacts.

Historic, Archaeological and Cultural Resources

The current stage on Maglev has not been able to accurately assess the site specific impacts to historic, architectural and archaeological and cultural resources (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-18). Most of the disturbance will occur during the construction and the operation of the Maglev system. But when comparing to alternative systems such as trains or roads the Maglev system would cause less disturbance due to small land requirements, more fixable alignment and reduced noise pollution.

Within any possible alignment within the Surat Basin there are a number of cultural significant sites. These sites could be Aboriginal heritage sites or historic heritage settler. It is up to the engineers to prevent or reduce the Maglev's impaction on the sites.

Effect on Local Transportation

There are a number of different impacts on local transport that the proposed Maglev system will create. It will have an impact on the traffic in the areas of the terminals and road crossings.

There will be an increase in traffic within specific locations close to the station. This will impaction intersection congestion and vehicle delay caused from the additional traffic going to and from the site. This will have to be analysed during the detailed design of the Maglev system to try and prevent or reduce its impacts.

Other major impact will be regarding crossing the track for the local community. This will be high dependant on the fact if the Maglev System is elevated or not. If the Maglev system was elevated then cars, people and animals are able to pass beneath the guideway without any inconvenience or safety risk. The other option is for at grade crossing will present risks which are present for conventional trains. There is more risk for Maglev as it will be travelling at higher speeds meaning the sight distance will have to be higher to stop encase of something on the track. This will be dependent on the breaking capacity of the Maglev System. The major advantage of the elevated track as it will be a lot safer to travel at higher speeds as it will be unable for human, animal or object to be on the elevated guideway.

Energy

One consideration is whether the increased electrical demand on local utility companies is able to cope with the increased load. This is a separate analysis which has to be taken in the future when Maglev is being seriously considered along a specific route. Other studies carried out in America have shown Maglev would have a lower impact than other alternative forms of transport. These studies found no extra strain on the distribution of power and will not cause an increase in cost of power in the area. (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-19)

Maglev is considered an efficient technology and approximately used 30% less power than High speed Rail travelling at the same speeds. Compared to other forms of transport such as roads and air travel Maglev per person is 3 to 5 times more efficient. (US Department of Transportation Federal Railroad Administration, 2005, pp. E-19)This causes a decrease in the use of fossil fuels and emissions caused through power generation.

Public Safety and Health

Discussions about the safety of Maglev cannot be carried out currently due to the large number of conceptual designs and lack of actual data apart from the Transrapid. But when Maglev will be feasible to transport coal it will be with the Maglev system which will have to be analysed by independently and government bodies to determine that it is safe for utilisation. A discussion on safety is within Chapter 4.2.1.

Noise and Vibrations

Any form of transport there are negative external impacts such as Noise and Vibration pollution. Any form of coal transportation will have impactions similar to Maglev. When comparing Maglev to Rail it is considerably less but still has to be continued designed for to reduce its impact. A detailed discussion of noise and vibration is within the advantages discussion in Chapter 4.2.1.

The noise and vibrations have limits set by local, state and federal governments which can restrict the speeds which Maglev can travel. Governments aim to protect residences, schools, hotels, motels, caravan parks, churches and recreational and community centres. These locations will have to be avoided for the final alignment design.

Construction impacts

There are a large number of external impacts that will occur for the construction of a Maglev system. They may result in localised short term air, noise, vibration, water quality, traffic, visual, utility and public safety impacts. The above factors have to be planned for and plans enacted so the impacts are removed or reduced. This can occur through best management practices, dust control measures, construction staging and sequencing, maintenance plans and traffic management plans. (US Department of Transportation Federal Railroad Administration, 2005, pp. ES-22)

5.2 Maglev Surat Basin Alignment Proposals

There could be the possibility of a large number of different routes which Maglev could follow to service the two major ports of Gladstone and Brisbane. Due to these infinite possible options this report is just estimating the alignment of two possible routes to be analysed within the financial model.

There are two aims for the design of the location of the two Maglev guideway alignments proposals within this report. The first is that these alignments will be input into a model and applied with a number of scenarios to estimate effect of variables on the feasibility. The second is to start looking at what considerations need be identified when designing a Maglev guideway alignment so that in the future this report may be used as a starting point for future designers and engineers. The second aim has been completed in Chapter 5.1

The design criteria for the alignment of Maglev has been identified and discussed in detail throughout the report. The following chapters listed below have identified and discussed what would need to be considered for a detailed design of a Maglev guideway alignment:

- Chapter 2.2 - Prominent Maglev Systems
    - The Prominent Maglev Systems and their guideway design.
- Chapter 3.2.2 - Surat Basin Coal
    - Number and location of present and planned Coal Mines
    - Location and details about other coal Rail tracks in the area.
    - Location and Future Plans of the ports of Brisbane and Gladstone
    - Competition and other possible methods to transport coal to connect mines to the Maglev stations.
- Chapter 3.3 and 3.4 - Coal Train and Maglev economic data
    - The cost of installing track/guideway is dependent on length and the terrain which it covers.
- Chapter 4.1.3 - Important Design impacts and considerations
    - Topography, Geology and soils
    - Environment and Climate Considerations
    - Natural Ecosystems, Wetlands and endangered Species
    - Water Quality and Land Use
    - Solid and Hazardous Waste

- Visual and Aesthetic Resources
- Historic, Archaeological and cultural resources
- Effect of local transportation and access
- Energy
- Public Safety and health
- Noise and Vibrations
- Construction Impacts

- Chapter 4.2 - Advantages and Disadvantages of Maglev transporting coal.
  - Speed
  - Turning curve capabilities
  - Grade Capabilities
  - Shared Transport Corridors
  - Smaller land requirements

Many of these factors identified cannot be used directly in the design of the alignment since there is no standards available since this type of project has not been completed before and the required depth of the design does not require it. But for a detailed design in the future these design requirements will have to be identified and applied. The only factors that can be taken into account are the location of the Surat Basin and its mines, the local railways and ports.

A factor of 1.2 has been increased to the overall lengths calculated due to a number of reasons (1.1 for the Surat Basin Railway). This is due to possible requirement to have minor detours as calculated for straight alignments, passing sections of track or other unexpected causes for increased costs.

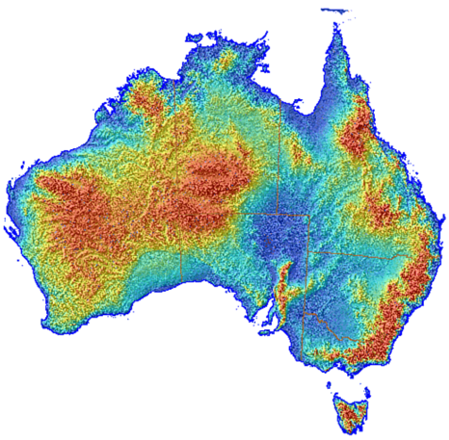


Figure 49: Australia's Topographic Map (Virtual Australia, 2013)

The mountainous areas in the Surat Basin are assumed to be the areas of higher elevation as shown in figure 49 as the colour red. The areas which were considered urban were completed through looking at local maps.

5.2.1 Maglev Alignment Proposal 1 - Gladstone Port

The following is a diagram which shows the location of the Maglev alignment for the first proposal to the Gladstone port.

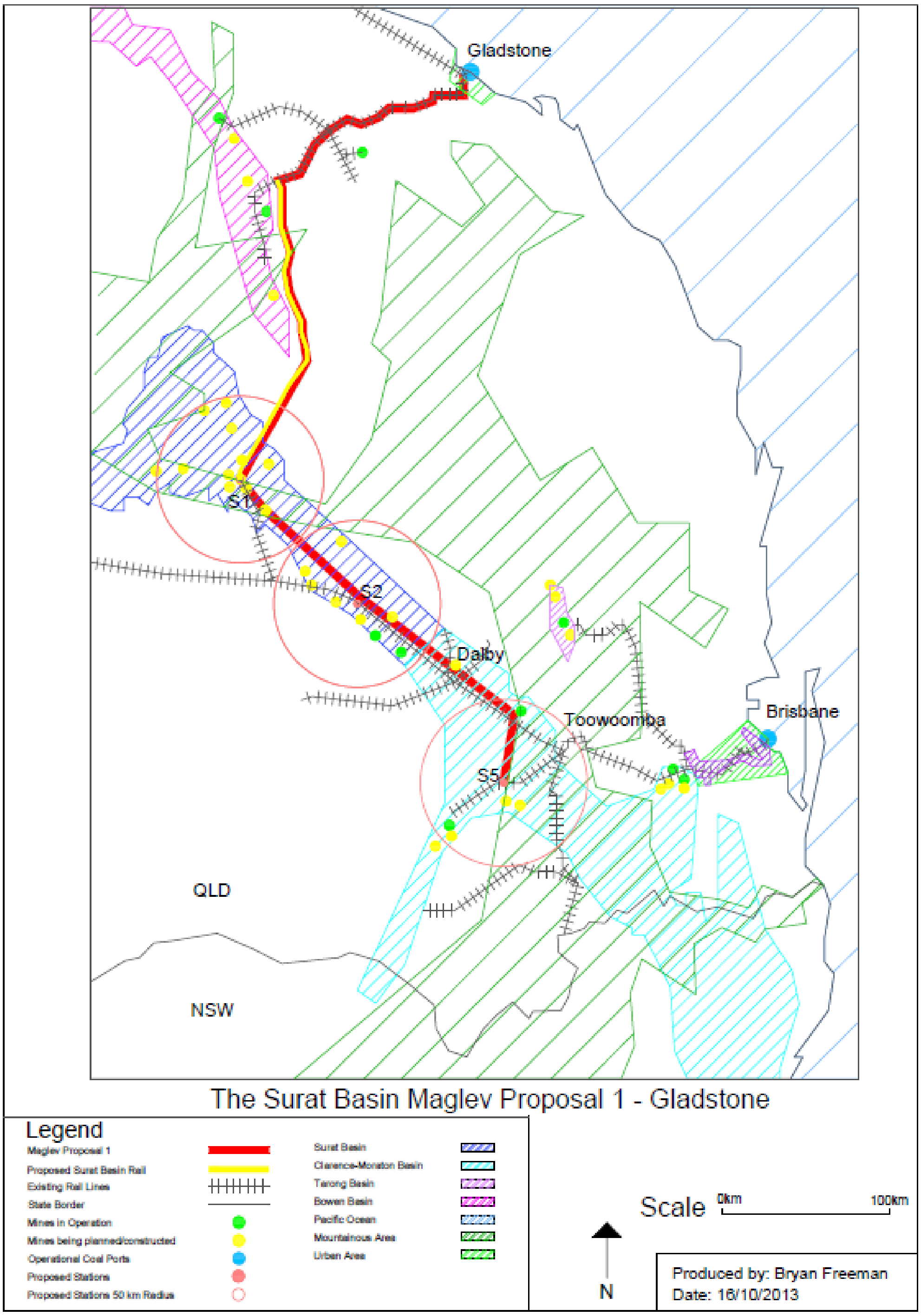


Figure 50: The Surat Basin Maglev Proposal 1 to Gladstone (Appendix F for Plan).

Table 14: Proposal 1 Design Characteristics and Assumptions

Proposal 1 Characteristics	Values	Source
Length	Total Length: 711.8 km Rural: 645 km Urban: 13.9 km Mountainous: 47.9 km	Appendix F
Port	Gladstone Present Capacity: 140 Mtpa Possible Future Capacity: 310 Mtpa (P.G Tonna, Wiggins and Balaclava Island) Ability to expand further: High	Ch 3.2.3
Proposed Rail System	Length: 204 km Type: Diesel with capability to be electrified Capacity: 42 Mtpa	Ch 3.2.4
Existing Rail: Moura System	Length: Approximately 175 km Type: Non-electrified Capacity: 17 Mtpa Comment: Would have to be upgraded if Surat Rail was installed	Ch 3.2.3
Service ability	Total Coal Basin west of Toowoomba:19228km^2 Coal Area within 50km of Station: 12966	Appendix F

This route starts at Station 5 servicing the area of the northern Clarence Morton Basin and heads in a north direction to meet up with the existing Rail corridor near Toowoomba. It follows the Rail corridor from Toowoomba to Chinchilla where it breaks off the Rail corridor and continues North West to Station 2 which services the South East Surat Basin. Here are a number of proposed coal mines from a number of different mining companies as identified in chapter 3.2.4. It then continues North West to the Xstrata's Wandoan coal project serviced by Station 1. It then follows the path of the Surat Basin Rail to the Moura Railway System then follows the Rail corridor to Gladstone. Along this Rail corridor it passes the Southern end of the Bowen Basin which could also present an opportunity to transport coal from this location.

The following are the advantages and disadvantages of this alignment proposal.

Advantages

The advantages of the Gladstone alignment are:

- Gladstone Port has a higher capacity to export coal through its port in the future and with ability to expand to meet demand.
- Travel through less urban areas
- Utilises existing Rail corridors.
- May be able to also service Bowen Basin if required
- Able to transport other bulk material such as wheat.
- Possible Alignment corridor utilises Surat Basin Rail alignment design.
- Able to navigate cross the Great Dividing Range as has a much higher grade than conventional Rail.
- Able to be further South in the Clarence Morton Basin to service those mines.

Disadvantages

The disadvantages of the Gladstone alignment are:

- Longer length means higher capital cost
- Unable to service Eastern Clarence Basin and Ipswich Basin
- Head office and workshops will have to be based in Gladstone or Toowoomba rather than Brisbane. Could find it hard to find specialist workforce.
- The existing rail link corridor will have to expand to allow for the Maglev corridor.

5.2.2 Maglev Alignment Proposal 2 - Brisbane Port

The following is a diagram which shows the location of the Maglev alignment for the second proposal to Brisbane Port.

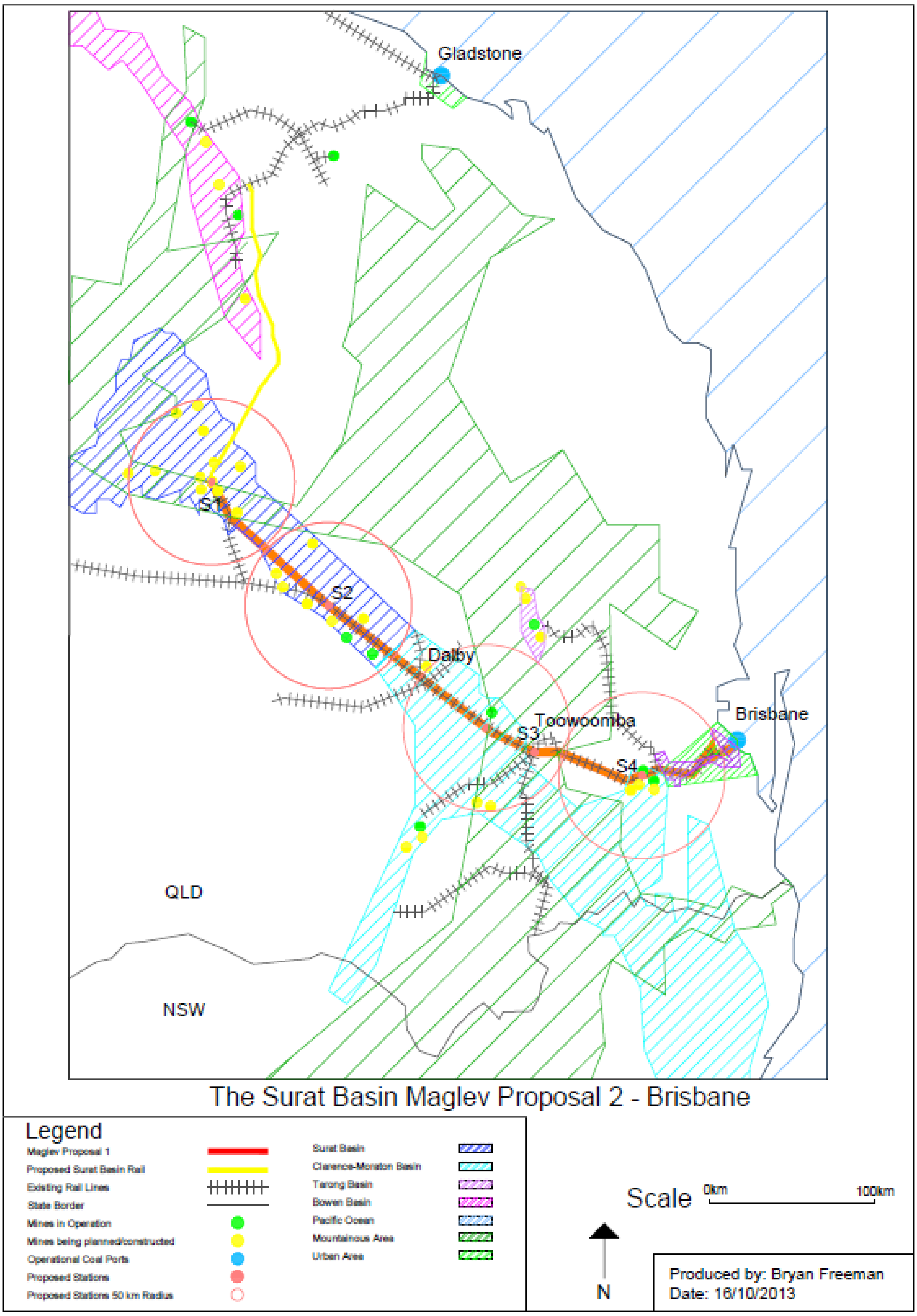


Figure 51: The Surat Basin Maglev Proposal 2 to Brisbane (Appendix F for Plan).

Table 15: Proposal 2 Design Characteristics and Assumptions

Proposal 2 Characteristics	**Values**	**Source**
Length	Total Length: 477.7 km Rural: 320 km Urban: 72.2 km Mountainous: 85.8 km	Appendix F
Port	Brisbane Present Capacity: 10 Mtpa Present Planned Capacity: Unsure as needs Rail improvement Ability to expand further: Low	Ch 3.2.3
Existing Rail: West Moreton Railway	Length: Approximate 175 km Type: Non-electrified Capacity: 7 Mtpa and a low 15.7 tonnes axial load Comment: Would have to be upgraded if high capacity and major dissatisfaction by residents in Brisbane and Ipswich.	Ch 3.2.3
Service ability	Total Coal Basin west of Toowoomba:19228km^2 Coal Area within 50km of Station: 12621	Appendix F

The alignment proposal starts at Station 1 which services the Wandoan Xstrata Coal Mines and travels south east to Chinchilla and follows the Rail corridor to Toowoomba. At Chinchilla is Station 2 which services the coal mines proposed in the area and then another station outside of Toowoomba to service the South East Surat Basin and North Wester Clarence Morton Basin. There are a number of alternatives for the alignment going down the range due to increased design capabilities (for Maglev) or utilise existing rail corridors, or connect with the Toowoomba by Pass. Depending on possible alignment opportunities the track will go down the range due to increased grade capabilities or become a part of the Toowoomba Range Crossing. This then follows the original rail corridor past station 4 which would service the Eastern Clarence Morton

Basin and the Ipswich Basin. It continues east into urban Brisbane to the Brisbane Port or any other likely location which would be able to support the capacity of export coal.

The following are the advantages and disadvantages of this design.

<u>Advantages</u>

- Shorter length meaning decreased capital costs
- Head office and workshops able to be based in Brisbane or Toowoomba. Easier to employ specialist in Brisbane.
- Able to service Eastern Clarence Basin and Ipswich Basin
- Utilises existing Rail corridors
- Able to navigate cross the Great Dividing Range as has a much higher grade than conventional Rail. Could utilise the range crossing in Toowoomba if feasible.

<u>Disadvantages</u>

- Large amount of alignment in urban locations through Ipswich and Brisbane.
- Large amount of negativity towards Coal trains by the population in Brisbane and Ipswich due to noise and vibration pollution and coal dust.
- Brisbane Port has a limited capacity to increase the export capacity even if the rail line was improved. Unable to service a high capacity rail line.
- The existing rail link corridor will have to expand to allow for the Maglev corridor.

Chapter 6: Preliminary Financial Model Results

This chapter provides results which would help determine the overall financial feasibility and the methods and calculations used to determine these results. The discussion of these results and its impact on the financial feasibility is in Chapter 7.

6.1 Values and Assumptions

This report has identified a number of important financial considerations which have to be considered when completing a financial comparison of Maglev technology to Rail.

6.1.1 Accuracy

As discussed in depth in Chapter 3.3 there are a number of reasons why this model would only be used for approximate estimating. These reasons are:

- The Maglev costs are only from limited publically released data which is based on decade old technology which only serves as passenger transport.
- There is no design or costing for Maglev transporting coal publically released.
- The Coal Industry does not publically release accurate financial data due to confidentiality.

6.1.2 Major Assumptions and Important Notes

- The model is only looking at the Surat Basin export capacity of 50 Mtpa or higher as this would require total reconstruction of all Rail lines in the Moura rail system and Brisbane systems. The Surat Basin Rail line proposed having an export capacity of 42 Mtpa which is well below what the area is capable of which is at least 80 Mtpa with planned and operational mines). There is no reason to analyse Maglev feasibility of the Surat Basin if it was only to export 42 Mtpa for two reasons. One it would halve the distance of new track to be installed in the Gladstone alignment. Secondly it will not be feasible as the small coal export capacity will not allow the increased operational saving which is the primary reason which makes the Maglev alternative financially feasible.
- There is still a requirement for coal in the near to medium future and the Surat Basin will still have operational feasibility to service this demand of coal.
- The German Transrapid is the Maglev system which the costing are based upon. The Transrapid is currently the most commercially viable Maglev and because of this it is only form of Maglev which has basic cost data publically accessible. As discussed in Chapter 3.4 this financial data is mostly from the US Department of Transportation report to Congress on the costs and benefits of

Magnetic Levitation. (US Department of Transportation Federal Railroad Administration, 2005)

- As identified within the technical feasibility discussions in Chapter 7.2 the technical capabilities and overall costs of Maglev are likely to become more competitive in the future. This has been taken into account by decreasing the cost by varying amounts shown on the graph as discussed further in this chapter.
- It is assumed that the ports are able to process and export the amount of coal modelled to transport. This will be true for Gladstone Port as it can export a high capacity of coal. But for the port of Brisbane it would unlikely meet a high coal export capacity hence why no analyse of the results are completed. This has been considered within the technical feasibility of the alignment proposals as discussed in Chapter 7.2.
- The costs identified are assuming that the Australian Dollar is at parity with the American Dollar. Due to the large changes in the currencies as they have been above and below parity over the last decade when this data was published, it has been assumed that it is equal in value. For a detailed preliminary financial costing this would have to be accounted for. Also inflation has not been account for.
- There has not been any consideration for transportation of coal from the mine to the Maglev station or coal station taken into account in the model. The options have been discussed in Chapter 5.1.5.
- It is assumed there is no difference for loading and unloading coal impacting the cost or time factors. This factor is discussed in Chapter 5.1.5.
- It is assumed there is no difference in cost between Maglev and Rail when comparing turning circles, grade capacity, transport corridors and land requirements. While this would decrease the cost of Maglev, it cannot be accurately calculated as no designs have been completed. This has been discussed in Chapter 5.1.5.
- There are a large number of locality Maglev and Rail design considerations identified and discussed in Chapter 5.1.3. While these would have an impact on the cost, these can only be determined by a detailed design and financial study.
- Things which are assumed to remain similar between the two systems are:
    - Staff and skilled operators
    - Training

- Land usage
- Cost of Tendering, gaining approvals and other administration activities
- Loading and unloading facilities

6.1.3 Costs and their assumptions

This chapter identifies the source of the values used within the model and any assumptions that relate to these costs. The aim of the model makes a preliminary estimation of the feasibility of Maglev compared to Rail by finding the number of years it would take for Maglev to become more financially viable. The Maglev system has to have a lower operation and maintenance cost than Rail to be financially feasible. Tables 16 and 17 show the financial figures determined in Chapter 3.3 and 3.4.

Table 16: Primary Rail Financial Data used within the model from Chapter 3.3

Item	Cost	Comments
Single Guideway Cost - Rural Region	$4 Million/km	Determined in Chapter 6.1.3
Single Guideway Cost - Urban Region	$ 5 Million/km	Determined in Chapter 6.1.3
Single Guideway Cost - Mountainous Region	$6 Million/km	Determined in Chapter 6.1.3
Freight Rates	$4 cents/tonne/km	Determined in Chapter 3.3.2
Total Coal Operational Cost	3.4 cents/tonnes/km	Determined in Chapter 6.1.3
Cost of Carriages	$0.2 million	Determined in Chapter 3.3.2

Table 17: Primary Maglev Financial Data used within the model from Chapter 3.4

Item	Cost	Comments
Single Guideway Cost - Rural Region	$15.8 Million/km	Las Vegas to Primm Proposal Cost. Appendix C Table A-1and D
Single Guideway Cost - Urban Region	$ 20.1 Million/km	Maximum Price Range -Appendix D
Single Guideway Cost - Mountainous Region	$24.1 Million/km	Pittsburgh Proposal (Double Track) which is hilly topology with numerous rivers
Transrapid Total O and M Cost	$17.9/ Train/ km	Appendix C - Table A-1
Transrapid Operational Cost for Coal	$0.031964/tonnes/km	Appendix D
Cost of Carriages for Transrapid	$8.9 million	Appendix C - Table A-1

Alignment of track length and terrain

The AutoCAD alignment proposal was used to determine an estimated length of track for each proposal. With the AutoCAD drawing the length and terrain of the track were able to be estimated.

Table 18: Maglev Proposal 1 Length Calculations

Path	Rural (km)	Urban (km)	Mountainous (km)	Total (km)	Alignment factor	Total Distance (km)
S5 - S3	36.3	0	0	36.3	1.2	43.56
S3- S1	198.8	0	23.9	222.7	1.2	267.24
S1 - Surat Basin Rail	186.5	0	17.5	204	1.1	224.4
Gladstone - End of Moura System	135.6	11.6	0	147.2	1.2	176.64
Total	649.99	13.92	47.93			711.84

Table 19: Maglev Proposal 2 Length Calculations

Path	Rural (km)	Urban (km)	Mountainous (km)	Total (km)	Alignment factor	Total Distance (km)
S1- S3	198.8	0	23.9	222.7	1.2	267.24
S3-Brisbane Port	67.6	60.2	47.6	175.4	1.2	210.48
Total	319.68	72.24	85.8			477.72

The following are a list of assumptions relating to the proposed guideway length:

- As can be seen in table 18 and 19 there is an alignment factor of 1.2 to allow for unexpected detours as the alignment calculated is straight. This is discussed further is Chapter 5.2.
- The location of urban areas and Mountainous areas was determined using elevation mapping and Google Earth. This is explained further in Chapter 5.2.
- There are no reduced cost factors from following the alignment within existing Rail reserves which most of the proposed alignment is.

Guideway Cost

The following two tables show the calculations to determine the overall guideway costs for the Brisbane and Gladstone proposals for both Maglev and Rail.

Table 20: Guideway and Related Capital Costs for Maglev

			Gladstone Route		Brisbane Route	
Cost Factor	**Terrain Type**	**Cost ($Million)**	**Distance (km)**	**Gladstone Cost ($Million)**	**Distance (km)**	**Brisbane Cost ($Million)**
%	Rural	15.8	649.99	10269.842	319.68	5050.944
	Urban	20.1	13.92	279.792	72.24	1452.024
	Mountainous	24.1	47.93	1155.113	85.8	2067.78
Total			711.84	$11,705	477.72	$8,571

Table 21: Guideway and Related Capital Costs for Rail

			Gladstone Route		Brisbane Route	
Cost Factor	**Terrain Type**	**Cost ($Million)**	**Distance (km)**	**Gladstone Cost ($Million)**	**Distance (km)**	**Brisbane Cost ($Million)**
%	Rural	4	649.99	2599.96	319.68	1278.72
	Urban	5	13.92	69.6	72.24	361.2
	Mountainous	6	47.93	287.58	85.8	514.8
Total			711.84	$2,957	477.72	$2,155

Wagons Cost

The costs of wagons are a complex quantity as there are normally a large number of factors which impact the requirement of wagons. This would require detailed scheduling completed by specialists. Some of the variables identified are length of track, number of clients, size of trains, size of cargo and size of wagons. The largest factor for the number of wagons is the capacity which this model takes into consideration. The calculations use data identified in Chapter 3.3 and 3.4.

Table 22: Wagon capital cost dependant on capacity

Type	**MTPA**	**Number of Carriages**	**Number of Locomotives**	**Cost ($Million)**
Maglev	50	111	0	1000
	75	167	0	1500
	100	222	0	2000
	125	333	0	2500
Conventional Rail	50	333	17	100
	75	500	25	150
	100	667	33	200
	125	1000	50	214

Operating and Maintenance Costs

The operation and maintenance costs are a complex quantity as there are a large number of factors which impact the costs. Many of these variables are discussed within Chapter 3.3, Chapter 3.4 and Chapter 4. Table 23 shows the Maglev and Rail cost per tonne. This data has the highest impact on the results of the feasibility.

Table 23: Operational Costs of Maglev and Rail

	Rail	**Maglev Scenario 1 - Present**	**Maglev Scenario 2 - Future**
Maglev operational cost saving	NA	0.002	0.01
Operational and Maintenance Cost (dollar/tonne/km)	0.034	0.0319	0.0239
% Saving	NA	5.8%	29.8%

6.2 Society's Push and Impact Study

The primary aim is through modelling shows what variation on feasibility is caused by small changes in capital and operational costs caused by the external market. The list below shows the different scenarios which are being modelled:

1. Present day
2. 25 years
    a. Industrial Push
    b. Continued Push
    c. Sustainability Push
3. 50 years
    a. Industrial Push
    b. Continued Push
    c. Sustainability Push

Table 24 shows the different variables which are being incorporated into the model. These are totally hypothetical numbers as the research completed for this thesis was unable to find any values which corresponded to industrial, mixed and sustainable scenarios discussed in chapters below. This reason is why no analyse has been completed for the results.

Table 24: The scenario variables incorporated into the model

Push	**System**	**Costs**	**20 years**	**40 years**
Industrial	Maglev System	Capital Costs	0.925	0.85
		Operational Costs	1	1
	Conventional Rail	Capital Costs	1	1
		Operational Costs	1	1
Mixed	Maglev System	Capital Costs	0.9	0.8
		Operational Costs	0.975	0.95
	Conventional Rail	Capital Costs	0.975	0.95
		Operational Costs	1	1
Sustainable	Maglev System	Capital Costs	0.875	0.75
		Operational Costs	0.95	0.9
	Conventional Rail	Capital Costs	0.95	0.9
		Operational Costs	1	1

The following chapters are a description of the impact of hypothetical years and the 3 different economic pushes that are being analysed.

6.2.1 Impact of Hypothetical Years

The effects of years in the future are generated through the hypothetical 20 and 40 years where the Maglev costs have decreased by a certain percentage. For every 20 years it's estimated that the decrease in capital costs of Maglev is 10% and the decrease in operational and maintenance costs decrease by 2.5%. With hindsight these values may change but provide a realistic view on what is trying to be achieved within the Maglev industry.

The following is a list of variables identified which will cause a decrease in the overall cost of Maglev.

- Decrease in capital guideway and carriages costs (Chapter 4.1.1)
- Decrease in operational and maintenance costs (Chapter 4.1.1)
- Decrease in construction method costs (Chapter 4.1.1)
- More Maglev commercial operations causing a scale of economics (Chapter 4.1.1)
- Increase of Superconductor technology advancements (Chapter 5.1.1 and Appendix B)
- Increase in Maglev efficiency (Chapter 5.1.1)

The list above provides a large amount evidence of opportunities in the future that would cause a decrease in the overall cost of Maglev. As previously discussed a lot of work is underway in many countries around the world to meet these targets.

While Maglev has the potential to decrease cost, conventional Rail does not have the same opportunities. Rail still has opportunities to reduce the capital costs such as reduced construction costs or others identified previously for Maglev. The operations and maintenance are not likely to be decreased for Rail hence this is a major advantage for Maglev. This is assumed as previously discussed since Rail has reached the highest capacity possible for cost saving.

6.2.2 Industrial Push

An Industrial push would decrease the feasibility of Maglev through factors identified for the hypothetical year cost variables. Maglev can only become a reality when there is a joint effort by scientists, industry and government to make this technology feasible.

The following is a list of what events are likely to decrease the advancement of Maglev technology. These factors are identified and discussed in Chapter 4.1.3 and 4.1.5.

- Bad economy causing decreased investment
- Maglev seen as a risky investment
- People and companies don't want change
- Negative view by political parties or politicians.
- Poor regards for the environment
- continued push for oil based services
- Business's only looking in the short term
- There will be a high demand for coal so it will increase the feasibility of a higher capacity proposal.
- Continued slow rate of Maglev ventures
- Slow rate to technical advances in Maglev technology

6.2.3 Mixed Push

The mixed society trend push is aiming on modelling current society trends into the future by identifying and making estimations of these future costs variables. The mixed push means that there is a possibility of both industrial events and sustainable events which cause an overall continuation of expected values and variables. The possibility of events is listed in the industrial push and sustainability push section within this chapter. For this reason the mixed push has no impact on the year cost reductions.

6.2.4 Sustainability Push

A Sustainability push would increase the feasibility of Maglev through factors in the hypothetical year cost variables. Maglev can only become a reality when there is a joint effort by scientists, industry and government to make this technology feasible. The following is a list of what events are likely to increase the advancement of Maglev technology. These factors are identified and discussed in Chapter 4.1.1 and 4.1.2.

- Society has a push to become greener and more sustainable making a much more positive view towards project like this.
- Society is looking for productivity in the long term regards to investments.
- Businesses are willing to invest in more risky projects with a higher return over a longer time.
- Doesn't use petroleum products.

- An increase in renewable energy sources will decrease the environmental effect of Maglev.
- There are other Maglev commercial ventures which have decreased costs through scale of economics.
- High rate of technical advances of Maglev technology
- The carry on financial impacts from superconductors being used for other purposes in the business (Literature Review A 1.7)
- Government incentives.
- Government, political parties and politicians welcoming of new ideas.
- There may be fewer requirements for coal due to its pollution properties, making for lower capacities more feasible.
- Research could make energy extraction from coal emission free. This would create high demand for coal (Chapter 3.2.5).

6.3 Preliminary Financial Feasibility Model Results

The Preliminary Financial Model has been developed to highlight the present financial feasibility based on preliminary investigations. As identified within the methodology of the report only two scenarios will be analysed to determine a preliminary verdict on the present and future financial feasibility of the alignment proposals. While there are the results of a number of scenarios provided, the only scenarios analysed within this report is only for a mixed societal push for the alignment proposal from the Surat Basin to Gladstone Port. This allows accurate results but more importantly allow for clear verdicts on Maglev's feasibility. Table 25 shows the findings that have been calculated for the present feasibility based on calculations for scenario 1 for the present feasibility.

Table 25: Model results for Scenario 1 - Present Day

Scenario	**Future Scenario**	**Scenario Type**	**50 Mtpa Breakeven Year**	**75 Mtpa Breakeven Year**	**100 Mtpa Breakeven Year**	**150 Mtpa Breakeven Year**
Present	Gladstone	None	136	95	74	62
	Brisbane	None	153	109	86	73
Cost Decrease of 10% Capital and 2.5% Operating	Gladstone	Industrial	122	85	67	56
		Mixed	85	59	47	39
		Sustainable	64	45	35	29
	Brisbane	Industrial	138	98	78	66
		Mixed	96	68	54	46
		Sustainable	73	52	41	35
Cost Decrease of 20% Capital and 5% Operating	Gladstone	Industrial	109	76	60	50
		Mixed	57	40	31	26
		Sustainable	37	26	20	17
	Brisbane	Industrial	123	88	70	59
		Mixed	64	46	36	31
		Sustainable	42	30	24	20

As identified in Chapter 5.2 the Gladstone Proposal is operationally feasible. It is for this reason the report the only analyses and discusses Gladstone alignment results. The calculations where still carried out for the Brisbane Alignment Proposal as seen in table 25 above, and within tables in Appendix D. The reason for the Brisbane alignment proposal still calculated is that in the near future the Brisbane Port may be unexpectedly release plans to drastically increase the export capacity of coal, allowing for future decision making regarding recommending feasibility studies. The reason that the industrial and sustainable society pushes not being analysed are the values have been assumed and cannot be confirmed meaning there would be not academic value analysing the data. This is further discussed in Chapter 6.2.1.

6.3.1 Scenario 1 - Present

The findings of the model for Scenario 1 have been developed to show an indication of the present and future financial feasibility of Maglev with present operating costs. It has been determined that the present operational cost of Transrapid Maglev is approximately 0.2 cents cheaper than coal per tonne/km. This value has been determined from Chapter 6.3.1. Table 26 shows the preliminary Financial Scenario Model results and the graph in figure 52 show the results for the Gladstone Proposal.

Table 26: Preliminary Financial Scenario Model for Scenario 1

Scenario	Proposal	50 Mtpa Breakeven Year	75 Mtpa Breakeven Year	100 Mtpa Breakeven Year	125 Mtpa Breakeven Year
Present Day Costs	Gladstone	133	93	73	61
	Brisbane	151	107	85	72
Cost Decrease of 10% Capital and 2.5% Operating	Gladstone	84	59	46	38
	Brisbane	95	67	54	45
Cost Decrease of 20% Capital and 5% Operating	Gladstone	56	39	31	26
	Brisbane	64	45	36	30

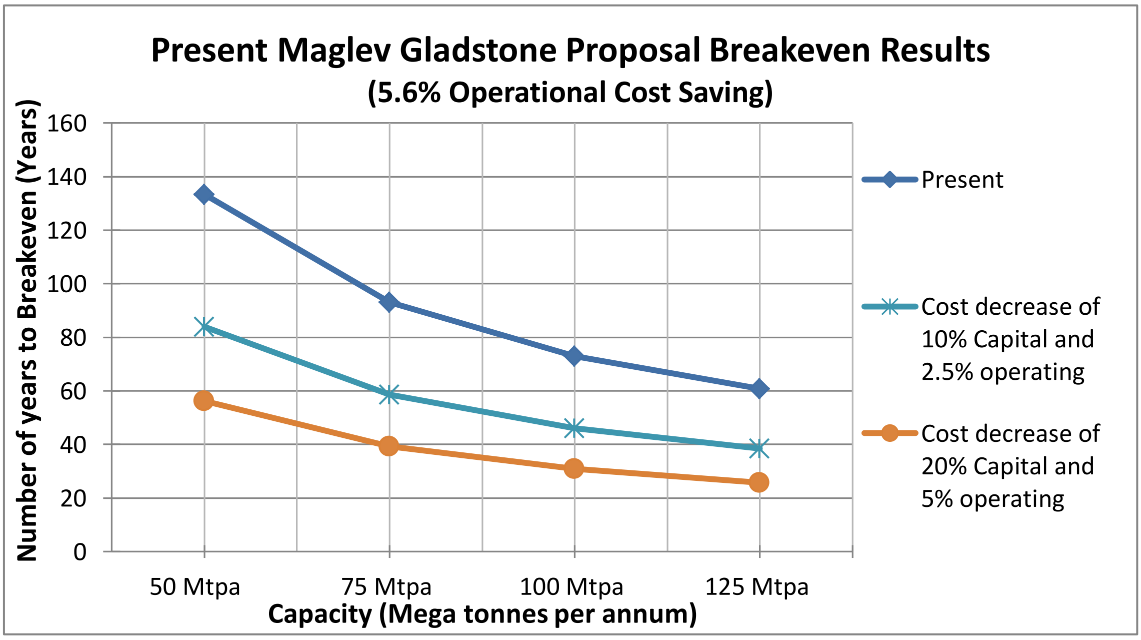


Figure 52: Graph showing the present Gladstone proposal breakeven results

6.3.1 Scenario 2 - Possible Future

The findings of the model for Scenario 2 have been developed to show an indication of the present and future financial feasibility of the projected future Japanese MLX Maglev with operating costs utilising future superconductor technology. For this scenario it is assumed that future operational cost of Maglev is 1 cent cheaper than coal per tonne/km. This operational cost decrease of Maglev is 29.4% less than Rail. This value has been discussed within Chapter 6.3.3. Table 27 shows the preliminary Financial Scenario Model results and graph in figure 53 show the results for the Gladstone Proposal. The discussion regarding the financial feasibility is in Chapter 7.3.2.

Table 27: Preliminary Financial Scenario Model for Scenario 2

Years in the Future	Proposal	50 Mtpa Breakeven Year	75 Mtpa Breakeven Year	100 Mtpa Breakeven Year	125 Mtpa Breakeven Year
Present Day Costs	Gladstone	27	19	15	12
	Brisbane	31	22	17	15
Cost Decrease of 10% Capital and 2.5% Operating	Gladstone	22	16	12	10
	Brisbane	25	18	14	12
Cost Decrease of 20% Capital and 5% Operating	Gladstone	18	13	10	8
	Brisbane	21	15	12	10

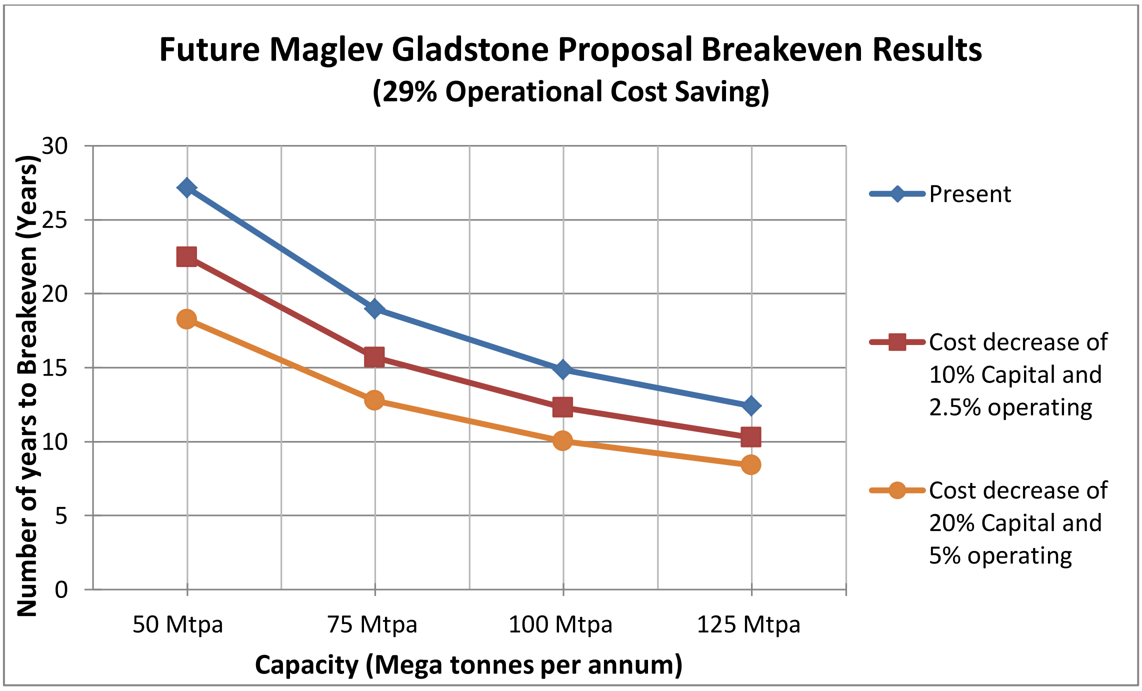


Figure 53: Graph showing the projected future Gladstone proposal breakeven results

Chapter 7: Viability Discussion and Recommendations

The following chapters are discussions of the feasibility of various factors for the proposal of Maglev coal transportation system servicing the Surat Basin.

7.1 Operational Feasibility

Operational feasibility is a measure of the problem and how well the proposed system will be able to solve it. This is achieved by looking at the feasibility of the desired outcomes of the proposal and making sure that the proposed system is solving the required problem of the scenario. By doing this it makes sure that the aim of the proposed Maglev Train are solving the required problem.

7.1.1 Discussion

The feasibility is analysed through a number of questions relating to the operational feasibility discussed within this report.

Is there a requirement for coal to be exported?

There is a high demand for Australian export coal. Currently the rate of coal demand is increasing by approximately 5%. As of 2012 Australia has exported 164 Mt of Coal and because of this projected increase in demand it is estimated to export 271 Mtpa by 2017. This would still be below Indonesia's current export capacity of over 300 Mtpa. With an increase of 5 to 10% per year in coal production in Australia it provides a perfect opportunity to create more coal mining opportunities for the next decade. Further information and discussions regarding this topic are provided within Chapter 3.2.1.

Is there a requirement for a coal transportation system for the Surat Basin?

Currently there are only 8 mines in the Surat Basin and the surrounding area. All of these mines currently only have limited access to exporting capabilities so one of their main aims is to also provide coal to local power plants. Mines in the Surat Basin are using trucks to transport the coal when Rail is not able to meet the requirements which are very costly.

Due to limited infrastructure for transporting coal, it is not presently feasible to invest in opening a new mine in the area until there is an ability to cheaply export coal. Currently there have been plans from big mining companies including Xstrata Coal and Cockatoo Coal to open coal mines if the opportunity to export coal through rail occurred.

Together the present plans have at least a capacity of 60 Mtpa and with another dozen proposed mine locations. For these reasons it clearly identifies that there is a high demand for a Rail link from the Surat Basin to a local port. Further information and discussions regarding this question are provided within Chapter 3.2.2.

<u>What transport infrastructure will a proposed coal transportation system have to utilise?</u>

The method for exporting coal from the Surat Basin is present in the form of Rail and Trucks to the ports of Brisbane. As discussed in Chapter 3.2.3 the Rail which connects the Surat Basin to Brisbane has a very low capacity and the cost of transporting coal by truck is very high. The current scenario regarding exporting coal through Brisbane port is that the port itself and the Rail line connecting it has a low capacity of 10 Mtpa. Even if the rail was able to handle the higher capacity the port also has land restrictions not allowing expansions. The current low Rail capacity problem is caused from the Brisbane Rail lines being congested. Also there is a large amount of community dissatisfaction due to coal dust, noise and vibrations from the people in Brisbane. The Brisbane West Moreton coal Railway also only has a low capacity and any increase will require upgrading the Railway. The costing of trucks transporting coal is not considered, as the price of this is so high compared to Rail. There is no possible way which it would be a feasible option for a long term plan. Further information on topics discussed is expanded further within Chapter 3.2.2.

Currently there is a proposal to have a rail link from the Surat Basin to the Gladstone port. The Surat Basin Rail Link proposes joining the Surat Basin to the Moura System. This is proposed from Wandoan Mining Project to the port of Gladstone by installing another 207 kilometres of track. This Railway is a much more feasible option compared to Brisbane. This Surat Basin Rail proposal is also follows the alignment of the first Maglev proposed alignment. Presently Gladstone Port only exports 60 of the maximum possible of 80 Mtpa. There are plans of upgrading to 135 Mtpa in the near future. Gladstone port also has more capabilities to expand in the future than the Brisbane Port. Further information on the topics discussed is expanded in Chapter 3.2.2.

<u>What infrastructure projects currently planned will affect the operational feasibility?</u>

The projects which have been identified have a high and positive impact on the operational feasibility. These projects are either for proposed coal mines, rail infrastructure and other related infrastructure.

The project which will have the biggest impact on feasibility is the Surat Basin Rail Project. This will remove the requirement for infrastructure in the Surat Basin to transport Coal. This proposal connects the Surat Basin to Gladstone port with an export capacity of 42 Mtpa. The planning started in 2008 for the Surat Rail Link project and since has only made small advances in the last 5 years in the overall planning process required to make this proposal given the approval. This is due to longer than expected approvals and negotiations. Currently they have preliminary approvals and are communicating with land owners. The alternative proposal which this report has focused on is the feasibility of Maglev to complete the same task. Maglev as discussed in this report is not presently technically viable but may be so in the near future. If the Surat Basin Rail Link was to be constructed than the Maglev proposal will not be feasible as it solves the problem. But there may be a time in the future where if the Rail link is not constructed, than Maglev will become a more feasible option. This is discussed more in depth in the financial feasibility discussions. Chapter 3.2.4 provides further information on the Surat Basin Rail.

There are a number of big mining projects which are planned which would have to be approved for the feasibility of any Rail system to be constructed. Two coal mining projects which plans have been publically released are the Xstrata Wandoan Coal Project and Cockatoo Coal mine proposals. The Xstrata project is in the north Surat Basin and has an expected output of 30 Mtpa for 30 years. The Cockatoo Coal projects are situated in the middle of the Surat Basin North of Myles and Chinchilla. They have land presently accessible with 300 MT of marketable coal and another 1700 Mt in coal reserves. All the mining companies are waiting for final approvals and the okay for construction of the Surat Basin Rail Link before they make any executive decisions regarding investment. There are also other mining companies with investments in the area such as New Hope Cooperation, Stanwell, Northern Energy and Stanmore Coal. This highlights the great potential for coal mines within the Surat Basin area with the possibility of requiring a high capacity Railway. More information on these proposed projects is available in Chapter 3.2.4.

There are always opportunities when planning for new projects to utilise different technologies. Within Chapter 3.2.4 there has be analyses of different forms of transporting coal. These alternative methods are Slurry pipelines and Magpipes. These methods are not being analysed within this report but have to be considered as they may have feasibility, for example using Magpipes to transport coal from the mines to the Maglev stations.

What are the possible external events that would impact the feasibility of coal?

There are many external factors which could have an impact on the feasibility of extracting energy from coal in the future. Currently planners are only expecting coal to be a primary source of power in the short to medium term future. There are a large number of articles which portray a negative outlook of the future of the Australian coal industry while other planners say the demand for coal will only increase in the near future. While most of these impacts cannot be estimated it is important to know the impact of these possible events on the future feasibility of coal. While this feasibility doesn't aim at predict the future feasibility of coal it's important to be made aware of these possible events.

There are a number of positive events which will increase the future feasibility of coal. Within Chapter 3.2.5 there are a number of discussions on future coal trade which expects Australian export coal industry to drastically increase and the global require for coal to increase. This Chapter also discusses an attempt to improve the environmental impacts of coal power stations but they are presently not feasible for large scale implementation. This shows that society recognise that this is a problem and are finding ways to decrease the environmental impacts. One primary example within the Chapter shows how researchers around the world are completing research and getting successful results transferring coal to energy through environmentally friendly means.

There are also a number of negative events which will decrease the future feasibility of coal. As discussed in Chapter 3.2.5 there is a large amount of uncertainty and risk caused from varying demand and coal prices. There is also problems regarding the environmental impact and concerns on the life span of the coal industry as the public would prefer to replace with different sustainable energy sources. It is for these reasons that any long term coal mining project will have to take these possible events into consideration to best reduce the risk.

What are we looking for when determining the best long term method for transporting coal from the Surat Basin?

When determining the best long term method for transporting coal, there are a number of different considerations which will have heavy weight upon determining the best method. The following factors would have to have the highest impact on feasibility

- Solves the problem
- Cost (Capital and Operational)
- Technical capable of transporting coal
- Efficient use of resources and power
- Sustainable design considerations
- No safety risk and low environmental impact.
- Reliable

This is why the operational feasibility is so important at it identifies and discusses the problem which the proposal is aiming to solve. While some factors may have more weight than others, each of these has to be taken into account. Only after a detailed feasibility study can each be fully understood and an accurate verdict of a proposal is determined.

7.1.2 Operational Feasibility Verdict

The operational feasibility study provides compelling evidence to suggest probable cause to investigate different proposals to transport coal from the Surat Basin. This verdict has been determined from analysing the most important factors which relate to exporting Surat Basin Coal. The report has shown how there is a requirement for coal to be exported and that the Surat Basin is capable of exporting coal if a transportation method was constructed. From current preliminary plans there are at least 80 Mtpa coals which could be able to be exported and more likely when a Rail connection is installed. The verdict has also concluded to recommend future detailed feasibility studies to gain a clear understanding of the present and future economic climate and determine how it would impact the future feasibility of coal. For this reason discussions have been provided in this report should be read to identify these event when completing future detailed operational feasibility studies.

Identifying future infrastructure and mining projects has shown how large mining businesses have come to the same conclusion regarding the requirement for a transportation method for coal from the Surat Basin to a local port. When determining the viability of a method to solve the problem, there must be a number of alternatives which are analysed so that the most feasible proposal is implemented.

From this analyse it has highlighted the opportunity for a larger export capacity rail system than the alternative proposed Surat Bain Rail which is restricted to 42 Mtpa. This restriction is aimed at reducing costs by utilising the Moura link which would require large upgrades to meet any increased capacity. But why only have a small capacity when there are so much potential mining opportunities within the Surat Basin. The Xstrata Wandoan mining project has a possible planned capacity of 30-90 Mtpa itself, disregarding all the mother mining companies and proposals. As shown in the financial results and feasibility discussion Maglev is not highly feasible with exporting low amounts of coal, but its primary selling point is that if the Mining companies want to export more than 42 Mtpa, Maglev is a better alternative than completely reconstructing the entire line again to meet the higher capacity.

7.2 Technical Feasibility

Technical feasibility is a measure on how well the technical aspects of the proposed system meet the design requirements. This chapter contains discussions for questions which would be relevant to identify the technical aspects of Maglev transporting coal. While presently there are no designs for Maglev transporting bulk commodities such as coal, it has to be researched and identified if the possibility exists. Because of this reason only a number of potential technical issues have been identified and provided with proposals to solve the problem as many future issues are not known. While there are a number of unknown variables this chapter makes comments on available information to make a verdict on the technical feasibility of Maglev and its ability to transport coal.

7.2.1 Discussion

The feasibility is analysed through a number of questions relating to the technical feasibility discussed within this report.

What impact do Maglev's advantages have in its technical feasibility?

Maglev has a large number of advantages which have a positive influence on its technical feasibility. The major technical advantages over conventional Rail are increase capacity, higher design capabilities, less infrastructure required, lower operational cost and increasing business interest. All of these technical advantages improve the technical feasibility and are a result from a large number of individual technical advantages from the Maglev system. All of the technical advantages identified are discussed in depth in Chapter 4.1.1 and 4.1.2.

Maglev has a higher capacity to transport coal due to increased speed, possible increased weight capacity in the future and having right of way. It is because of these reasons that Maglev will be able to transport more coal than a conventional Railway if the same scheduling methods were applied. Being able to transport more coal increases the efficiency of the service and improves the technical feasibility.

Maglev has higher design capacity over Rail as it has higher turning circles and operational grades. Maglev also has lower external vibration on the surrounding ground as well as less noise pollution. This is only made possible by having reliable safety systems in operation. These identified advantages improve the technical feasibility as there is more flexibility with the design alignment which would drastically decrease costs from removing needs for tunnels, bridges and can avoid locations of cultural and environmental significance. The identified advantages also improve the technical feasibility as it has less impact on the surrounding area being a safe and reliable form of transport.

Maglev also requires fewer infrastructures due to many of the identified advantages discussed. This is from having higher speeds, higher weight capacities with higher turning circles and grade capacity. Another advantage of Maglev's smaller land requirements is its ability to use shared transport corridors and lessening the environmental impact. There have also been designs completed for the report showing how Maglev could possibility is integrated with existing rail infrastructure in chapter 5.3.1. If this was able to occur then there would be major technical advantages as it would highly impact the overall feasibility. Maglev has many advantages regarding the infrastructure and it plays a large part in the overall technical feasibility as well as reducing a large amount of costs increasing the financial feasibility.

Maglev's lower operational cost is a direct result from the technical advantages related to the operation of the Maglev system. The advantages which have been identified is that Maglev will be running at a constant speed, moving without friction or physical contact, possible future higher weight capacities and drastically reduced maintenance costs. By having lower operating costs due to the technical specifications of the Maglev proposal, it will have high overall savings in the long term.

There are a number of reasons why international businesses have been taking interest and making investment in Maglev technology. The primary reason is that they see a high amount of technical potential in the future over current forms of transportation. This has been identified through the large number of prototypes, the rate of superconductor advancements, superconductor cost savings and its low impact on national security. From these points discussed the technical advantages have a large impact on making Maglev technically feasibility in the future.

What impact do Maglev’s disadvantages have in its technical feasibility?

There are a number of technical disadvantages for Maglev which is the primary reason why it is not presently feasible. The reason why presently Maglev transporting coal is not technically feasible is because it has not be considered or designed. If these designs where completed than the next major technical disadvantage of Maglev to Rail is that it has high capital costs as well as technical complications and problems which arise from the technical uncertainty. The identified complications relate to switching lanes, energy consumption decrease in efficiency with acceleration and deceleration and future design uncertainties. All of the identified disadvantages decrease the technical feasibility and are a result from a large number of individual disadvantages from the Maglev system. All of the reasons identified are discussed in depth in Chapter 4.1.3 and 4.1.4.

The primary reason why Maglev is not presently feasible is that there has been no professional research or design carried out by anyone. This presently has a high impact of the feasibility as it will take a number of years for the required design to occur allowing present or future models of Maglev to be capable of transporting coal. There is also the problem there are no certainties of what problems may rise in the future due to no detailed designs been completed by professionals within the field. Within the report there has been proposals designed to show how the Transrapid and the MLX wagons can be modified to transport coal. Another technical problem identified is how Maglev will interact with existing infrastructure. Again designs have been proposed in the report to give an example on how this problem may be fixed. What these designs have been able to achieve is to show how the present models of Maglev may be modified to transport coal indicating that Maglev may be technically feasible once detailed designs have been completed.

If there were designs of the wagons to transport the coal developed and technically feasible the next largest disadvantage is that Maglev has high capital costs completed to the cheaper alternatives. . Maglev has an overall very high capital costs due to high guideway and carriage costs as these technologies are new and expensive to produce and construct. A disadvantage for the operational cost is that while the overall operational costs are lower than conventional Rail, it still has comparative high costs due for accelerating and decelerating and also Maglev has the requirement to have higher skilled operators. With the initial high cost for this technology, it makes it unfeasible for business and investors. The financial data and feasibility is further discussed in Chapter 3 and Chapter 6.

<u>What impact do possible events have on the overall technical feasibility?</u>

There are a number of events identified within the probability and impact study which would impact the future technical feasibility. These events are large scale implementation of Maglev, unexpected breakthroughs in Maglev technology, the continued advancement of superconductor technology, conversion of coal through clean and efficient processes to energy and a possible reduction is operating cost of Rail. These events could have a possible positive and negative impact on the overall technical feasibility, and could be the difference in becoming overall feasible. These events are discussed in depth in Chapter 4.2 and are individually identified as having a high to medium impact the future feasibility of Maglev.

What impact on the technical feasibility does the identified primary design considerations have?

The technical feasibility relies heavily on a number of important design considerations identified and discussed in Chapter 5.1.1. Each of the design characteristics can be the difference between Maglev being technical feasibility and Maglev being incapable of providing the required service efficiently. The areas which were identified as the primary design considerations are superconductor properties, loading and unloading, coal transporting methods from the mines to the Maglev station, the capable speed and most important the overall cost. Within Chapter 5.1.1 are detailed descriptions of these design issues and it highlights their importance for the technical feasibility.

How do the identified locality design considerations impact the technical feasibility?

The locality design considerations have a wide variety of impact identified from within Chapter 5.1.4. These issues are considered dependant on the location of the proposed track and have to be considered when designing the location of the Maglev Train. Each of the identified locality design considerations are considered of high importance, but each has a varying impact on the technical feasibility. Many of these are only discussed briefly as there was not a detailed alignment design carried out within this report for the proposals. By having these resources and initial discussions allow future researchers to continue the work.

The following locality design considerations which would have a high impact on Maglev's technical feasibility are the environment and climate considerations, energy, effect on local transport, public safety and health, noise and vibrations. The following locality design considerations which would have a medium impact on Maglev's technical feasibility are Topography, Geology, Soils, Natural ecosystems, Wetlands, endangered species, land use, visual and aesthetic resources, historic and cultural resources and construction impacts. The following locality design considerations which would have a low impact on Maglev's technical feasibility are water quality, solid and hazardous waste removal.

What is the future feasibility of the German Transrapid and the Japanese MLX?

Presently the German Transrapid is the most feasible option of the current available Maglev systems due to its identified advantages of speed, technology, financial and operational feasibility. In the near future the Japanese MLX has been identified to have the potential to surpass the technical achievements of the German Transrapid. As identified the Japanese MLX is in the testing and development phase and has current surpassed the specifications of the two prominent Maglev systems as discussed in Chapter 2.2 the German Transrapid was commercially operational in 1991, highlighting how much time has passed from the presently feasible Maglev system. Due to the current testing and development the MLX being applied with the latest technology to allow the increased efficiency and design principals giving it apply the last technological advances over the last 20 years giving it the projected technical supremacy. The areas which highlight the improved design of the MLX are Chapters 2.6, 2.7 and in Appendix F.

While the technical achievements of the Transrapid are known, it is not expected that any technical specifications will be accurate until after 2025 when the MLX will be in commercial operation. Until those details are released the MLX impact on the Coal transporting capabilities are unknown. The present financial feasibility study has been modelled with the present model of the German Transrapid. While the MLX specifications are more efficient than the Transrapid, the overall findings of the model will increase according to amount the technical specifications increase.

<u>What is the most feasible alignment proposal for transporting coal with Maglev technology from the Surat Basin?</u>

The most technically feasible alignment proposal was determined to be from the Surat Basin to Gladstone Port. While the financial feasibility may be higher for the Brisbane proposal due to its decreased length, the Brisbane alignment proposal is not technically feasible.

The reason for the Gladstone alignment proposal being more technically viable is from a number of advantages which have a high impact of the overall technical feasibility. The most important advantage is that Gladstone Port has the capability to export the coal required to make Maglev feasible while Brisbane does not. Gladstone Port has plans which will be able to meet the high growth of the Surat Basin if a rail line was installed, but also be able to export the capacity to make Maglev feasible. Another primary reason was that Gladstone port has less community issues from less congestion, less visual disturbance, less noise complaints and less vibration impact as there is only a small urban area which the proposal would impact compared to the large area of urban land for the Brisbane Proposal. These discussed advantages and many other advantage are discussed in depth in Chapter 5.2.1.

7.2.2 Technical Feasibility Verdict

The technical feasibility study finds that presently Maglev is not technically feasible as there has been no research or designs to modify Maglev technology to transport Coal or other bulk commodities. Research and designs completed within this report provides compelling evidence to suggest that Maglev has the potential to meet the design requirements to transport Coal in the future. This verdict has been determined from analysing the most important factors which relate to the technical design aspects. While many of the specific details of a Maglev system capable of transporting coal are unknown as it has not yet been designed, there are clear examples within the report suggesting how these can be technically achieved. The verdict that Maglev can be technically feasible in the future has been shown through identifying and discussing its advantages, disadvantages, design considerations and what alignments proposals are best suited towards this technology.

It has be identified that there are many technical attributes of Maglev that improves its feasibility over Rail such as higher capacity potential per line of track, less infrastructure required, lower operational cost and increased business interest. While there are many advantages there are larger disadvantages with the present state of Maglev that cause the present overall feasibility to be not possible. The primary reason is that there has not been a design completed and that current Maglev is very high costs with only small operational cost savings. It is for these two reasons that Maglev will not be technically feasible in the near future unless there are significant technical progress which would impact upon Maglev's technical feasibility. The identified events which would have a large impact on the technical feasibility in the future are the continued advancements in Maglev and superconductor technology, wide spread implementation of Maglev for other purposes, and conversion of coal to energy through clean and efficient methods.

As identified a large disadvantage on the present unfeasibility of Maglev is that there has been no design completed for Maglev transporting coal. For the reason of making preliminary verdicts on the technical feasibility in the future there have been designs completed in the report to show how possible major problems can be solved. The report has shown solutions for major Maglev design requirements such as loading and unloading coal, importance of superconductors to increase efficiency, transporting coal from mines to the station, high speeds and low operating cost. These designs and discussions provide evidence that Maglev will be technically feasible in the future once detailed designs have been completed. This entire report provides a preliminary template for future engineers to base their work when designing a Maglev system that will be able to transport coal within the future.

While all the important design considerations identified above for Maglev transporting Coal are very important, it still has to be able to be transported through Queensland. It has been identified and discussed that the locality of the track will also have a high impact on the technical feasibility of Maglev. While the specific location of the track will have an impact on the technical feasibility, the overall alignment will have far greater impact on the technical feasibility and overall feasibility. The alignment proposal was compared with the other option of Brisbane Port, but Gladstone Port was found to be far more feasible as it has a higher port export capacity and less community concerns. While the Brisbane Port is more feasible due to shorter length, the port does not have the capacity to upgrade the required amount to make Maglev feasible.

7.3 Financial and Economic Feasibility

7.3.1 Overall financial and Economic Feasibility Questions

What are the impacts and probabilities of different events on the future financial feasibility?

There are a large number of events which would have a large impact on the financial feasibility of the proposal for Maglev transporting coal from the Surat Basin. All of the events identified could have a positive or negative effect dependant on how the event unfolded. While these events have been incorporated into the model through the use of social pushes, it is not being analysed in the financial discussion. The reason for this is that there was no data to indicate how much of an impact these events would have on the financial feasibility. This has moved the aim of this section of the report from data analyse to identifying possible impacts for future designers.

As stated the events have not been directly been incorporated into the model, but some have been classified as being a part of different social pushes such as industrial related events and sustainable events. The aim of the discussions in chapter 4.2 is to allow for future designers gain a starting point for their own research. It is up to the operational feasibility to determine the scenario of the time of investigation to determine these impacts as has been done within this report.

The events which have been identified to have a positive impact on the financial feasibility are increased global requirement for coal, a strong economy, politician and public keen for innervations and risky but sustainable investments, high Maglev implementation rates and breakthroughs reducing costs and efficiencies. There are also a large number of events which would have a negative impact on the financial feasibility. These are a decrease in coal demand, poor economy, politicians and public who are uncertain about the future and want low risk, higher than predicted preliminary costs and a decrease in Rail costs. All of these events identified have a varying impact on the future financial feasibility and have been discussed in detail in Chapter 4.2.

What is the impact of industrial, mixed or sustainable society pushes on the financial feasibility?

The impact of societies overall push will have a large impact on the financial and economic feasibility of the proposals, but to what extent is undeterminable. Discussions regarding industrial, mixed and sustainable pushes give an approximation on how these would impact the feasibility. Chapter 6.2.2 has identified a number of characteristics of an industrial future and these are mostly all negative events for Maglev which would only slow or stop advancement of the technology. The opposite is for a sustainable future as identified in Chapter 6.2.3. All of these events have a positive impact on Maglev technology which would cause increased research rates and relative decrease in costs compared to Rail.

It has been identified in Chapter 6.2 that for each of the society pushes there are a large number of events that could occur, giving endless possibilities on its impact. While the model has accounted for these events, only approximations have been entered but cannot be proven. This is due to the inability to find any data identifying how these factors will impact the financial feasibility of the proposal. This is why no analyse has been completed regarding the financial data for this section as it will not add any academic value to the report.

7.3.2 Financial Model Questions

<u>What difference do the Gladstone alignment and the Brisbane alignment have on the Financial Feasibility?</u>

There are a number of discussions regarding the Gladstone and Brisbane alignments effect on the operational feasibility identified in chapter 7.1. The following discussions are on the findings relating to the financial feasibility of these two proposals.

1. The alignment to Brisbane would be the more financially feasible option if it was operationally feasible.

Even though the number of breakeven years is less for the Gladstone proposal, it is still not a preferable option as the overall cost would be much higher. The costs for both the Gladstone and Brisbane Rail and Maglev are shown in Appendix E. All avenues should be investigated to transport coal to Brisbane, but as determined by the operational feasibility in Chapter 7.1 this is not an option. The proposal for Gladstone should only then be used if Brisbane is not suitable, so the increased costs have to occur regardless. The advantage for Maglev is that the Gladstone proposal characteristics such as length and capacity play to its advantages.

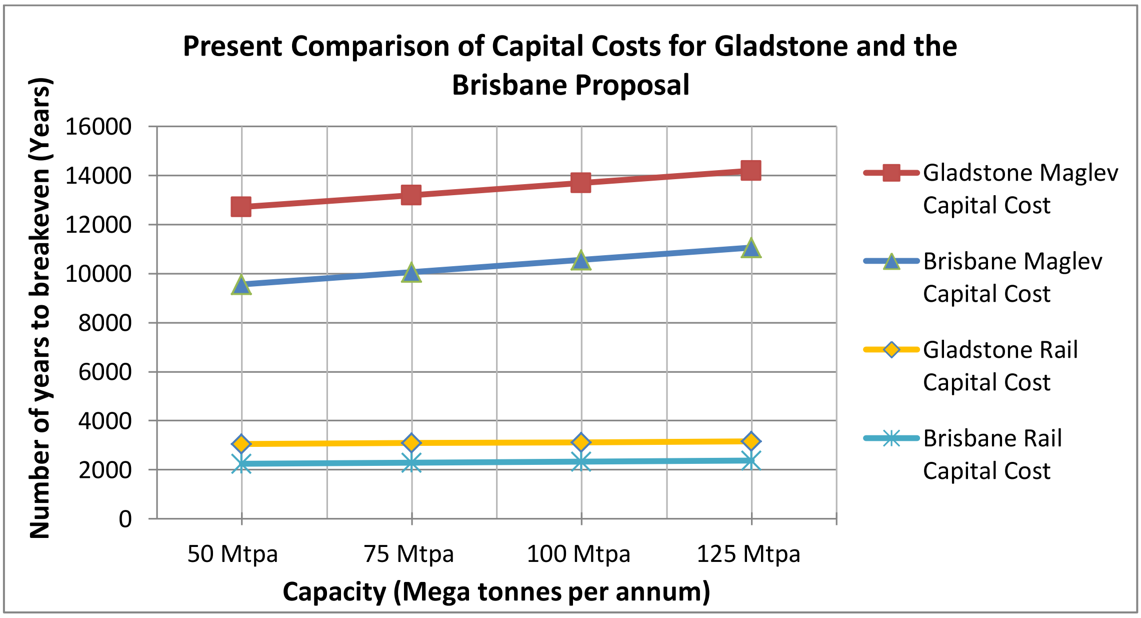


Figure 54: Graph of capital cost of two proposals

2. The Gladstone proposal has a smaller number of years for Maglev to breakeven with Rail than Brisbane due its longer length even though it has a much higher capital cost.

There is approximately a 17% to 11% improvement on the number of years before breakeven will occur between the Gladstone Proposal and the Brisbane proposal as can be seen in figure 55. The reason for this is that the distance of Gladstone proposal is 230 km longer which provides increased opportunity for the operational cost savings of Maglev to add up/. This is proven in figure 55 as it shows the large difference in capital cost between the Gladstone and Brisbane Capital costs and still the Gladstone has a higher pay back time.

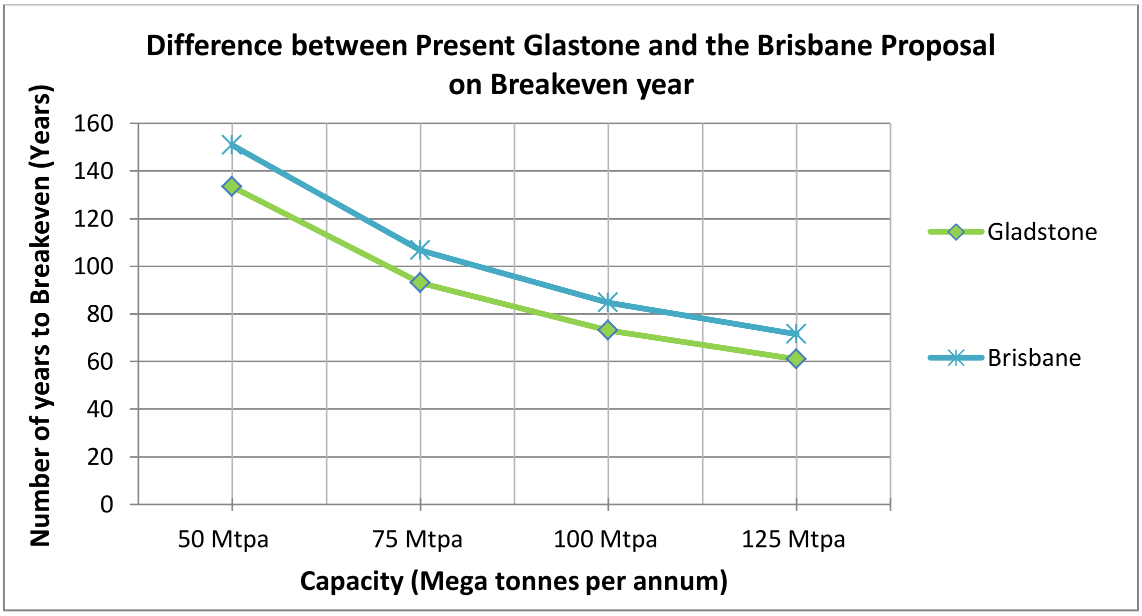


Figure 55: Difference between proposals on breakeven years

What is the verdict of Financial Feasibility for Scenario 1?

The financial verdict from results found in Chapter 6.3.1 is that Maglev is not presently financially feasible using Transrapid technology. From figure 52 the Gladstone proposal would take 93 years for Maglev to be feasible based on present day financial values and planned mine capacity within the Surat Basin. As identified in Chapter 3 at least 75 Mtpa export capacity is planned, plus more from other mining *companies interested* in opening mines in the area. While the export capacity of the Surat Basin may increase presently, it would take 60 years to become feasible if 125 Mtpa was exported. For a mining business which is in an industry with high risks due to periods of high and low growth it would not be acceptable. This financial unfeasibility verdict is also is true when looking at the time frame of the operational life. This impact on financial feasibility has to be considered due to society's push to become sustainable in its form of energy production. In the time it takes to make breakeven, the requirement for coal may stop due to no more coal being feasible to extract. This means that there has to be a higher saving of more than just 6% in all operational costs for Maglev to be a financially feasible alternative.

The second verdict is that even with a low operational saving of just 6% of all operational costs a 10% or 20% decrease in capital costs will make Maglev becomes a viable option worth further investigation. As can be seen in figure 52 a 20% decrease in capital costs when transporting 75 Mtpa will cause the years to breakeven with coal to be approximately 40 years. Pre-feasibility prediction of this nature will cause business to consider completing more detailed financial feasibility studies. This increase in feasibility is assuming there are developments with the Transrapid technology and reduction in capital costs. The areas which would cause this decrease in the capital cost are identified in Chapter 6.2.1. Regardless, this scenario is unlikely to occur in the near future so it has had no impact on the present day verdict of the financial feasibility. This analyse purpose was to show that if cost savings where to occur in the near future then detailed financial and technical feasibility studies should be completed to determine a more accurate verdict on the financial feasibility.

What is the verdict of Financial Feasibility for Scenario 2?

The financial feasibility verdict concluded from the results in Chapter 6.3.1 is that projected future Maglev transporting would be financially feasible. Scenario 2 analyses the projected future of Maglev financial feasibility when the Japanese MLX is operational (assuming same capital cost as the Transrapid). From figure 53 it can be seen that if the Surat Basin was able to export 75 Mtpa than the number of years for Maglev overall costs to breakeven with Rail overall costs would be 19 years. As identified in Chapter 3 at least 75 Mtpa export capacity are planned with other mining companies interested. While the export capacity of the Surat Basin may increase presently it would take 13 years to become feasible if 125 Mtpa was exported.

The breakeven table for Rail verses projected future maglev when exporting 75 Mtpa is shown seen in figure 53. As stated previously the number of years to breakeven is 19 years. It can be seen that there is a large difference in the initial capital cost, but regardless the operational cost has a major impact on the overall financial cost. Each year there has been a saving of $536 million. If Maglev was operational for 40 years the saving will be $11.2 billion dollars. From a business view point this would be within the time frame which would be considered feasible. If in the near future the projected efficiencies would require mining and rail companies to complete a detailed operational, technical and financial feasibility study to confirm these results and allow for future decision making.

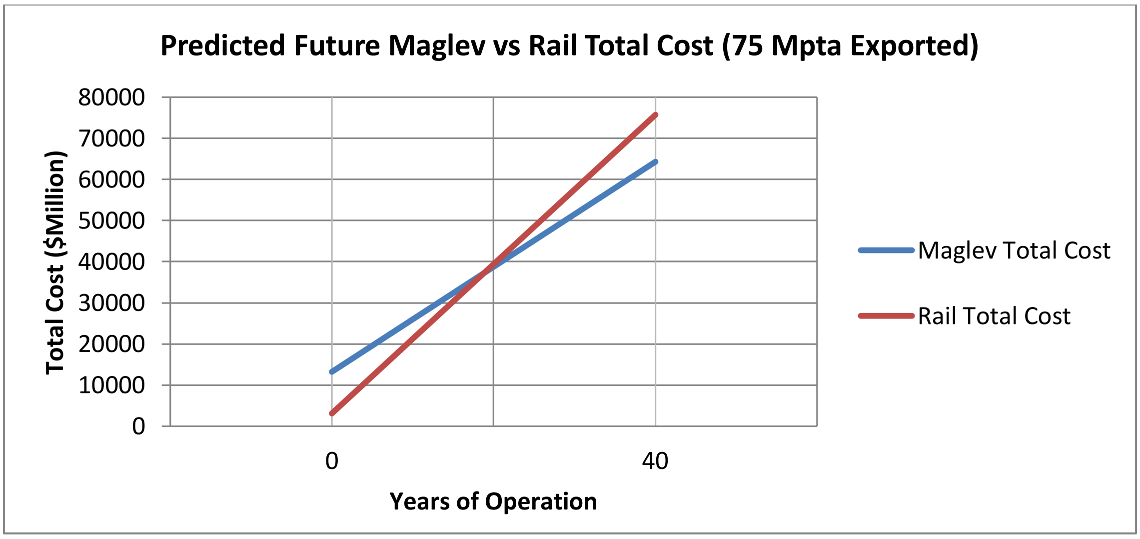


Figure 56: The Breakeven for Rail verses the projected future Maglev when exporting 75 Mtpa.

The future cost of Maglev used in this scenario has an operational cost saving of 29.4% less than Rail. This is considered conservative as Maglev companies project future operational costs savings of 30% to 50% compared to Rail depending on the information source. The primary reason for this extra decrease in operational cost is the Japanese MLX utilisation of technology advancements over the last 20 years such as superconductors to increase the operating efficiency and many more as discussed in the Literature review and Appendix B.

The second verdict is that a saving of 29% of operational costs with a further 10% or 20% decrease in capital costs will make Maglev a very feasible alternative to Rail. As can be seen in figure 53 a 20% decrease in capital costs when transporting 75 Mtpa will cause the years to breakeven with coal to be approximately 15 years. This is what a business would consider to be very financially feasible alternative, but this is assuming there are massive developments with the Transrapid technology and reduction in costs. This analyse purpose was to show that if cost savings in operational cost and capital cost than mining companies and rail companies should complete a detailed operational, technical and financial feasibility studies to determine a more accurate verdict on the financial feasibility and allows future decision making to occur regarding implementing this technology.

How does the Capital Cost and Operational Cost impact upon the financial feasibility?

The capital cost and operational cost have a variable impact on the results of the model and are discussed below:

1. The operational cost saving made my by Maglev has a large impact on the number of years it takes for Maglev to breakeven in total cost with Rail.

As discussed the present day Maglev capable of 6% operational saving requires 93 years to breakeven with Rail (for 75 Mtpa). While an increase of operational savings to 29% requires only 19 years of operation to breakeven with Rail (for 75 Mtpa). The impact of decreasing the operational cost by 23% causes the breakeven years required to operate to drop by 53 years which is an 80% decrease in time. Figure 57 shows the difference in dropping operational cost compared to dropping the capital cost for 75 Mtpa.

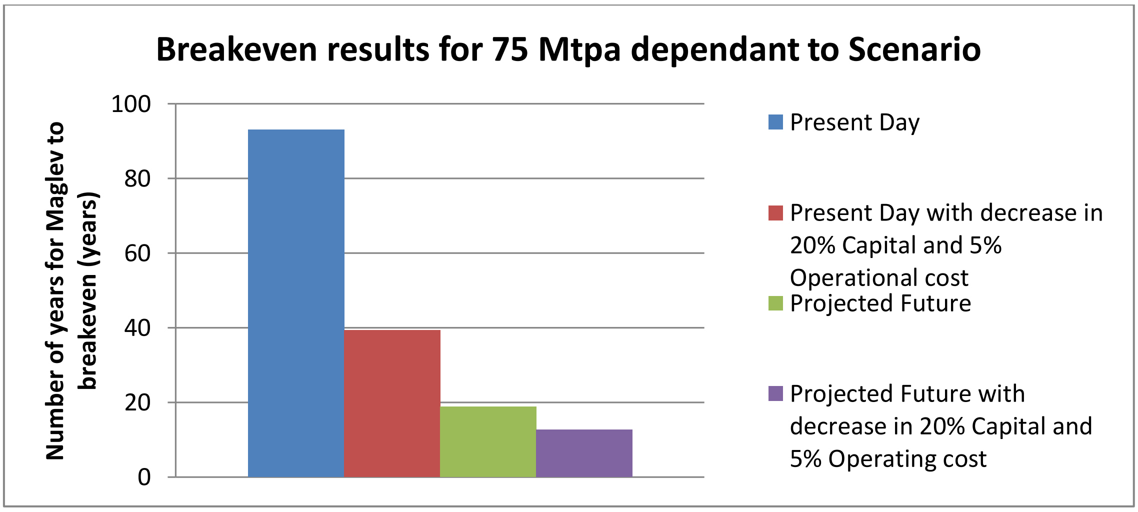


Figure 57: Graph of the breakeven results for 75 Mtpa dependant on the scenario

The Operational cost saving is also observed when looking at the model exporting 125 Mtpa. The present day Maglev capable of 6% operational saving needs 60 years to breakeven with Rail (for 125 Mtpa). While an increase of operational savings to 29% requires only 13 years of operation to breakeven with Rail (for 75 Mtpa). The impact of decreasing the operational cost by 23% causes the breakeven years required to operate to drop by 47 years which is an 80% decrease in time. Figure 58 shows the difference in dropping operational cost compared to dropping the capital cost for 125 Mtpa.

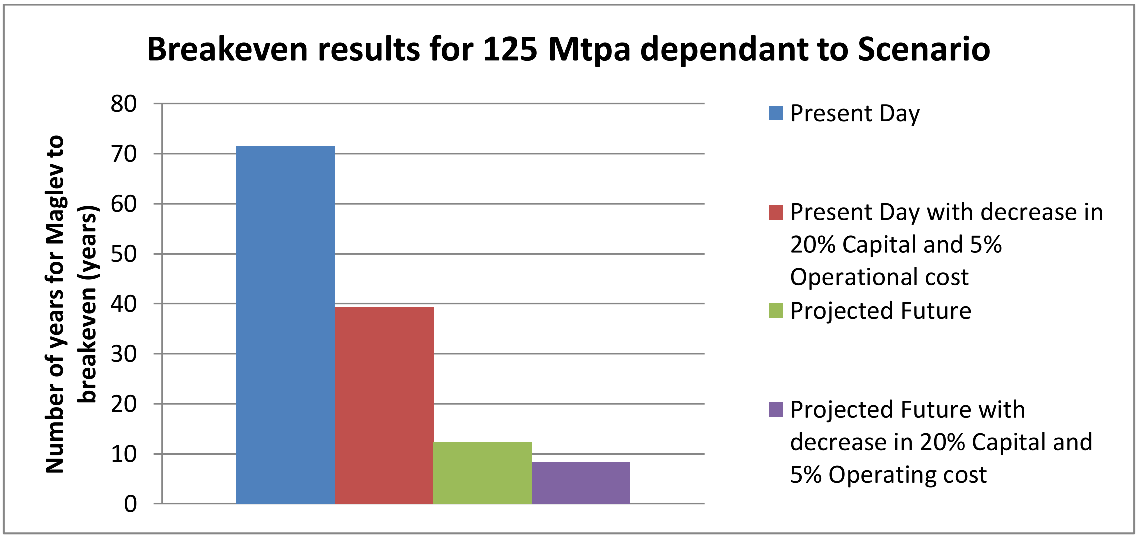


Figure 58: Graph of the breakeven results for 75 Mtpa dependant on the scenario

Both of these results confirm the drastic increase in financial feasibility by increasing the operational efficiency and cost. By decreasing the operational cost by 1% reduces the number of years for Maglev to break even by approximately 3.5%.

2. A decrease in capital cost has an overall medium impact on the number of years it takes for Maglev to breakeven in total cost with Rail.

From figures 57 and 58 it shows how a decrease in the present day and projected future number of years required to breakeven caused from large decrease in capital cost (-20%) and a small decease in operational cost (-5%).

The results show that for exporting 75 Mtpa with present Maglev technology (operational saving of 6% compared with rail) with the added decrease in operational and capital cost creates a saving reduction of 54 years or an overall 58% decrease in time. But when investigating the higher operational saving of 29% with these extra savings the impact is less. By having a decrease of 20% of capital cost and 5% decrease in operational cost the saving is only 7 years (or 33%).

What this determines is that decreasing the capital cost only has a high impact on the feasibility when there is a small factor of saving from the operational cost of Maglev. As Maglev has a high operational cost saving the higher capital cost has a small overall impact on the financial feasibility.

8.3.2 Financial Feasibility Verdict

The financial feasibility is one of the largest factors which have been analysed when considering any proposals feasibility. This report has identified a number of important financial results and considerations to provide an overview of the number of aspects which affect the overall financial feasibility of Maglev transporting Coal from the Surat Basin compared to rail.

There have been a large number of possible events which would affect the financial feasibility. The primary aim of this chapter is to identify these events for future designers and researchers. These have not be analysed within the report as there was no academic value in analysing assumptions as there is no present data showing how Maglev will be financially effect by these events.

The choice determined in the operational feasibility that the Gladstone Proposal is the only feasible method has a number of impacts on the financial feasibility. While the overall cost is much higher for both Maglev and Rail to transport coal to Gladstone rather than Brisbane, the characteristics of this alignment are in Maglev's favour as it has is longer length allowing extra opportunity for the operation cost saving characteristics of Maglev to save large amounts of money over the long term.

The alignment for the Surat Basin to the Gladstone port has been analysed under two conditions representing different time frames, impacting the cost savings for the operational cost per tonne per kilometre. Scenario 1 represents Transrapid Maglev technology and the data provided from this system to determine the financial feasibility compared to Rail. It was calculated the current saving of Maglev to Rail's operating cost was 6%. The model predicts the number of years for Maglev to be more financially feasible to Maglev is 93 years if 75 Mtpa was exported and 60 years if 125 Mtpa was exported. From these results the concluded present day verdict was that Maglev is not a feasible alternative to Rail. What differs is that scenario two is that the model calculates the operational cost for the projected future characteristics of the Japanese MLX predicted to be commercially operational in 2025. With an operational saving of 30% Maglev becomes financially feasible in 19 years if exported 75 Mtpa or 13 years if exported 125 Mtpa. These results provided compelling evidence that Maglev will be a feasible alternative in the future, giving reason for Mining and Rail Companies compelling evidence to completed detailed operational, technical and financial feasibility studies once the MLX becomes commercially operational.

From analysing the results from the financial model it was determined that the operational cost has a large impact on the financial feasibility as 1% saving in capital cost decreases the number of years to breakeven by 3.5% when transporting 75 Mtpa. While the capital cost have a large impact on the financial feasibility for low operational savings, they are almost made irrelevant through the continued overall savings made from the operational costs.

It has also been determined that Maglev is not a feasible alternative to a low capacity Rail proposal such as the Surat Basin Rail because only 42 Mtpa can be exported. Preliminary calculations predict approximately 160 years of operation is required for the present Transrapid Maglev to be more financially feasible to the Surat Basin Rail line as it utilise the existing Moura Line giving a low capital cost. Even with the operational saving of 30% it only makes the Maglev alternative more finically feasible in 33 years when transporting 50 Mtpa. This proves that Maglev is not suited for low capacity coal transportation. But if the Mines want to export anything over the 42 Mtpa which has been identified as highly possible and likely, than Maglev is definitely a feasible option worth investigating in the future.

Chapter 8: Conclusion

8.1 Feasibility Verdict

In both the technical and financial feasibility aspects, it is evident that Maglev is not currently feasible compared to conventional rail. The primary reason is that there have been no designs of Maglev to transport coal or other bulk commodities. Preliminary designs completed within this report show how this is possible, by revealing that once detailed designs and are prototypes developed, than Maglev transporting coal can be technically feasible. While the German Transrapid Maglev is currently the most feasible model it is not financially viable. The expected release of the Japanese MLX in 2025 will have increased characteristics and properties, and lower operational costs. For these projected Maglev characteristics to occur there is still much advancement in technology required, most importantly improving superconductor technology. It is only after these technological advances will Maglev be feasible for being an alternative solution to Rail for transporting coal from the Surat Basin to the Port of Gladstone. Maglev would only be a feasible alternative if the mining companies wanted to have a higher export capacity than what is currently restricted throughout the Surat Basin Rail Link proposal. While Maglev technology is not currently available, in the near future Maglev may become a feasible alternative if the current delays continue to prevent the Surat Basin Rail Link from being approved. It is in the discussion below where each point of the feasibility conclusions has been identified.

Technical feasibility currently has the highest impact on the overall feasibility as the proposed Maglev system must be a capable and viable method of coal transportation. From completing a preliminary technical feasibility analyses, the primary conclusions are:

1. Presently Maglev transporting coal is not technically feasible primarily because there have been no publically released research or designs for Maglev transporting coal.
2. Maglev is capable of being technically feasible of transporting coal in the future as identified within this report. Discussion and preliminary designs have investigated the most apparent design considerations and proposed solutions.

3. The most feasible alignment proposal for transporting coal is from the Surat Basin to Gladstone following existing rail corridors. The primary reasoning behind this decision was that the Port of Gladstone has future operational feasibility.
4. The advancement of Superconductors is a critical requirement for the technical and financial feasibility of proposed future models of Maglev. The Literature Review and Appendix B has revealed the rapid increase in superconductor technology over the last 10 years and publicized its future potential in making Maglev feasible.

Operational feasibility is the second most important aspect when looking at the overall feasibility. The problem and all related variables must be clearly identified as to determine if the alternative of Maglev is feasible. From completing a preliminary operational feasibility analyses, the primary conclusions are:

5. The Surat Basin has a higher coal export capacity than the 42 Mtpa currently restricted from the Surat Basin Rail Line proposal.
6. If the mining companies desire to export more than the present proposal capacity of 42 Mtpa, detailed feasibility studies may show Maglev being a feasible alternative in the future.
7. The Surat Basin would be the most feasible location in Queensland for Maglev transporting coal as the alignment properties of high length and high capacity greatly increase Maglev Financial Feasibility.
8. The operational feasibility is hard to predict as there are so many variables. These have to be considered when planning for the future to reduce risky investment decisions.

Financial feasibility is what investors see as the most important aspect of feasibility as long as the proposal solves the problem. From completing a preliminary financial feasibility analyses, the primary conclusions are:

9. The only way for Maglev to be financially feasible it Maglev has to have a lower operational cost compared to rail as Maglev have very high capital costs.
10. With the available Transrapid Maglev technology (with a calculated saving of 6% operational cost per tonne per kilometre) the number of years it would take Maglev to breakeven, with the cost of Rail is 93 years and 60 years for the Gladstone alignment when exporting 75 Mtpa and 125 Mtpa respectively. This would not be financially feasible.

11. With the predicted MLX Maglev technology (with a predicted saving of 30% operational cost per tonne per kilometre) the number of years it would take Maglev to breakeven with the cost of Rail is 19 years and 13 years for the Gladstone alignment when exporting 75 Mtpa and 125 Mtpa respectively. When exporting 75 Mtpa of coal the capital cost of Maglev is 4.28 times higher than Rail, but the savings per year from the lower operational cost is calculated to be $536 million. This saving every year will pay back the high capital cost in 19 years. If Maglev was operational for 40 years the saving will be 11.2 billion dollars. This shows that Maglev is financially feasible based on preliminary data and if this efficiency predictions are met than the completion of a detailed feasibility is recommended.
12. The projected decrease in MLX operational cost savings is a realistic goal as determined from understanding the capabilities and potential of superconductors in the future.
13. The effect of the operational cost saving has a high impact on the financial feasibility. Approximately 1% saving in operational cost decreases the number of years for Maglev to breakeven with Rail by 3.5%.
14. Only when there is a low operational cost saving for Maglev does the capital cost play a large factor in the financial feasibility.
15. If the mining companies do not require an increased export volume of coal over 42 Mtpa than Maglev will not be financial feasible alternative.
16. There are a large number of national and local events which would drastically impact the financial feasibility of Maglev transporting coal which has to be considered when planning for the future as to reduced risk.
17. Maglev also has the potential to be more financially feasible to transport reliable bulk commodities due to lower operational costs than transporting passengers at high speeds.

Each of the Operational, Technical and Financially Feasibility discussions identified have a large impact on the overall feasibility. For further detailed discussions on each of these three feasibility types, see Chapter 7. From the conclusions found in this report a number of recommendations in Chapter 8.3 have been provided to best utilise the information and findings collected within this report.

8.2 Project Objectives

The aims that have been set out within this pre-feasibility study have been achieved to a high standard where possible, with the restrictions on confidential data from the Queensland mines and rail companies. This report has been a comprehensive but broad study of the viability of the proposal to determine whether Maglev that has potential to become feasible to transport coal in the future. It looks at the operational, technical, and financial feasibility compared to conventional Rail, to determine an overall verdict of feasibility as provided within this chapter. From these conclusions recommendations have been determined.

The primary objectives of this report were to determine the feasibility of maglev transporting coal and this has been achieved. The second aim was also achieved as this report can serve as a document with the overall feasibility information regarding the Maglev transporting coal. The reason for this is that future engineers may be considering this feasibility and there is no documentation publically released. Along with explaining how the feasibility was determined, the report also investigated a number of themes which are not analysed have a direct impact of the feasibility for this report, but would have to be considered and analysed for future detailed feasibility designs. They have been to identify and complete a detailed analysis of the advantages and disadvantages of Maglev technology and its ability to transporting coal, complete a preliminary probability and impact feasibility analysis for the transportation of export coal using Maglev technology and identify the design requirements needed for the alignment and make preliminary design proposals on possible track alignments from the Surat Basin to a local port.

8.3 Recommendations for Future Research

The recommendations provided from the report have been concluded from the findings. As this report is a preliminary feasibility study most of the recommendations are related to future research or future detailed feasibility studies.

There are areas of future research that would identify current uncertainties regarding the overall feasibility of Maglev transporting coal from the Surat Basin. These proposals of future research could not have been completed in this report due to lack of data access, confidentiality and time limitations. The following are recommendations for engineers prior to the commercial release of the Japanese MLX:

1. If access to mining financial and technical data is available, compare and update the financial model to provide a verdict on the financial feasibility as identified in Chapter 3.3 and 6.1.
2. If access to detailed Maglev costing data is available, then accurate values can be applied to the social push on financial feasibility discussed in Chapter 4.2 and 6.2.
3. Determine the design capacity of the four coal export volumes and determine if it can be serviced by only a single guideway or will a double guideway be required.
4. What other services could be provided by the Maglev line such as passenger transport or transportation of other bulk commodities such as wheat?

The following are recommendations to the Mining, Rail and Maglev Companies:

1. Mining, Transportation and Maglev companies should complete research and design Maglev wagons capable of transporting bulk commodities such as coal. This would investigate if Maglev is technically feasible of transporting coal. This would also decrease the timelines for any future project as the designs have already been developed.

2. If the proposed Surat Basin Rail Link is constructed prior to the commercial release of the MLX or another advanced Maglev then do not consider Maglev as a feasible alternative to rail.

3. Strongly recommend a detailed technical feasibility study when the Japanese MLX or any other advanced Maglev design becomes commercially available for its ability to transport coal.

4. If any future technical feasibility studies determine that transporting coal with Maglev is feasible then complete a detailed operational and financial feasibility study.

Therefore, this project has extensive further research possibilities which will ultimately determine if Maglev is a suitable and favourable technology for transporting bulk commodities for exportation.

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Appendix A - Project Scope

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project

Project Specification

FOR:	Bryan Freeman
TOPIC:	A Preliminary Feasibility Study For Transporting Surat Basin Export Coal Using Maglev Technology.
SUPERVISORS:	Trevor Drysdale
ENROLLMENT:	ENG4111 - S1,OC, 2013 ENG4112 - S2,OC, 2013
PROJECT AIM:	The objective of my proposal is to undertake a preliminarily feasibility study for applying realistic present and future Maglev technology for the transportation of export coal from the Surat Basin.
SPONSORSHIP:	None
PROGRAMME:	Issue C, 23th of July 2013

1. Research and identify the background information related to the current state of Maglev technology and superconductors.
2. Complete a preliminary investigation to identify prominent current and future Maglev Transportation Systems.
3. Complete a preliminary investigation to identify the present status of the coal industry within the Surat Basin to determine the operational feasibility.
4. Collect available financial data on the costs of Maglev technology and conventional coal trains.
5. Identify and complete a detailed analysis of the advantages and disadvantages of Maglev technology and its ability to transporting coal.
6. Compete a preliminary probability and impact feasibility analysis for the transportation of export coal using Maglev technology.
7. Identify and discuss the required primarily future design requirements for Maglev technology to transport coal and provide preliminary designs.
8. Identify the design requirements needed for the alignment and make preliminary design proposals on possible track alignments from the Surat Basin to a local port.
9. Determine the feasibility of technical, environmental and social aspects of the proposal.
10. Complete a preliminary financial feasibility model with the identified possible alignments to determine the financial feasibility of the project.
11. Present the overall feasibility verdict and provide future recommendations for this proposal.

Mentors Signature:

Appendix B - Superconductors

This chapter is not in the Literature Review as it is not required to understand Maglev or the proposal for Maglev to transport coal. There are numerous times within the report where superconductors are mentioned to be capable of making the future MLX feasible. This appendix is for any engineers who are interested on how these conclusions are founded or superconductor's capabilities.

B.1 Introduction

1n 1991 a Dutch scientist Heike Kamerlingh Onnes of Leiden University observed the remarkable disappearance of all electrical resistance from a thin capillary of mercury metal cover in liquid helium. Again 76 years later in America this property occurred again for a ceramic pellet sitting in warmer liquid nitrogen. These two events are known as the discovery of superconductivity and high temperature superconductors. (Smith, 1988, p. vii)

Superconductors have seen great progression in the last decade allowing advances in areas of medicine, electronics, astronomy, transportation and experimental science. There have been 8 Nobel Prizes awarded towards the development of Superconductor theories. People working within this industry aim to deliver a future were superconductors have a major and beneficial influence on society.

This Appendix's aim is to go into the details to allow an appreciation of discussions within this project and show what the technology is capable of. I will also discuss the possible advances in superconductor technology and how it will help Maglev feasibility through improving Maglev capabilities and through related areas of design such as energy storage and no loss with transmission lines.

B.2 Superconductors

Superconductivity is explained by the BSC theory. It states when a material is in its superconducting state the conduction electrons propagate without causing any electrical resistance since they move in pairs (Cooper's pairs). These Cooper pairs are formed as a result from the interaction of the mechanical vibrations of the crystal lattice and electrons. What occurs is the atomic vibrations in the lattice diminish the repulsive forces between elections. The characteristics which cause this property are dependent on the vibrations which are caused by the temperature of the martial. The temperature which Superconductors transfer to this state is called a critical or transition temperature (Tc). (American Insitute of Aeronautics and Astronauitics, 2008, p. 291)

There are two types of superconductors. They are differentiable by the distance apart from the copper pairs (coherence length) and the field decay length (London penetration depth). The two types are discussed below:

- Type 1 Superconductors
  These occur when the coherence length is greater than the penetration depth. These become superconducting at very low transition temperatures (5-10K) and low intensity fields. If either of these two properties is interrupted then the superconducting state disappears. These are generally naturally occurring minerals and are currently used within a number of industries.

- Type 2 Superconductors
  These occur when the penetration depth is greater than the coherence length. This difference allows them to become superconducting at higher temperatures (>120K) and can handle high magnetic field intensity. This allows more current to be able to flow through the material. Type 2 superconducting materials are ceramics, along with other materials with a high transition temperature are called high temperature superconductors. Well known Type 2 superconductors are YBCO, yttrium, barium and copper oxide ceramic. (American Insitute of Aeronautics and Astronauitics, 2008, p. 292)

B.3 Special Properties

There are number of impressive properties which are exclusive to superconducting materials and are discussed below.

No Resistance

During the initial experiments of Onnes in 1911, he found some amazing properties of materials when cooled with liquid helium. When Onnes cooled mercury, the resistance didn't smoothly decrease, but was a sudden drop. This was the same with other metals such as tin and lead but this property occurred at different temperatures.

The transition temperature (Tc) is the temperature which a material changes from its common metal property to a superconductor. It is much like the transition from ice to water as there is a clear Tc. If you were to measure the drop in resistance, there is a continual drop in resistance with decrease in temperature. When it reaches its Tc, there is a sudden increase in the rate of loss of resistance, as can be seen in figure 59. (Smith, 1988, p. 21)

Figure 59 shows a type 2 superconductors critical temperature:

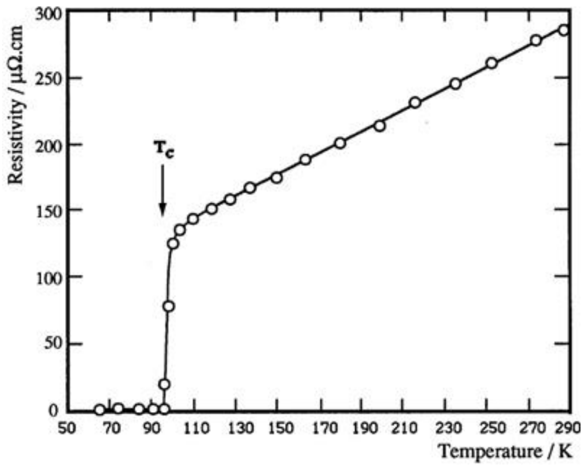

Figure 59: Resistivity of YBa2Cu3O7 with temperature. (University of Cambridge, 2008)

The amount of resistance has been calculated to be basically zero ohms. This was measured using electromagnets by making a closed ring of a superconductor and then inducing a current. We can use the principal of a flowing electrical current creating a magnetic field. If the current in the superconducting coil lowers due to resistance, the magnetic field will decrease. This experiment found the resistance to be less than a billionth of a billionth the resistance of the best ordinary conductor. (Smith, 1988, pp. 21,22)

Zero resistance flow is only for direct electrical current. Within electrical supplies there are two forms of current, Direct current (DC) and Alternating current (AC). The standard household is alternating current and is reversing its direction 120 times per second. While there is resistance for AC currents, it is measurable but still only a fraction of copper conductors.

This feature can revolutionise many technologies. One example is that it can store electricity without loss. This makes time or weather operated power sources viable such as solar power and wind power. There is a lot of potential in other industries such as Maglev to apply this technology.

Magnetism

James Clark Maxwell in the 19th century developed the classical theory of electromagnetism. Unknown to him his theory had made remarkable predictions about what was learnt about superconductor's decades before they had been discovered.

A special property of superconductors is that it will actively exclude any magnetic field present. This allows the property of levitation through magnetic fields. What can be seen below in figure 60 is the induced current within the superconductor creating a magnetic field which repels the external magnetic field.

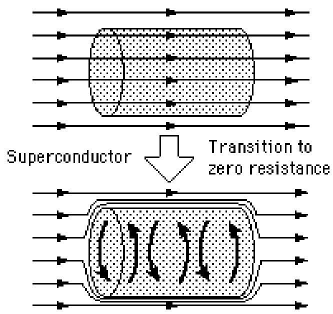

Figure 60: Magnetic forces effect on a superconductor (Hyperphysics, 2012)

Below are two images which help describing the practical implication of the Messier effect.

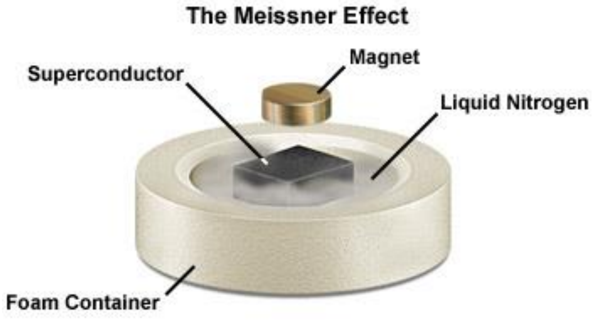

Figure 61: The Messier Effect (National High Magnetic Field Laboratory , 2013)

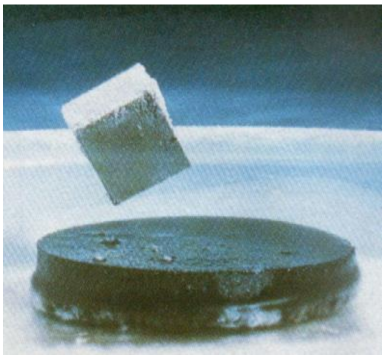

Figure 62: The Messier Effect (SCLinks, 2013)

<u>Limited strength of superconductivity</u>

One special property of superconductors is that the property of superconductivity is very fragile. The strength of superconductivity in a material refers to its resistance to external forces which would destroy the superconducting properties. Changes in the environment can easily make the material lose its superconductive properties. The three factors which can destroy this property are; critical temperature, critical current and critical magnetic fields.

Critical Current

When you increase the current in a normal conductor it heats up until there is too much current for the conductor so it will melt. A way to avoid this problem with superconductors is to increase the diameter of the conductor. The term used to define the current capacity of a wire is the current density. This is the case with superconductors. While there is no resistance, there is a current limit which a superconductor can tolerate. When a superconductor passes its critical current, it suddenly losses its superconducting property and will change back into its original properties. This can be disastrous for the original material due to its original properties, and will be destroyed due to the high currents. (Smith, 1988, p. 27)

Critical Magnetic Field

Previously I have discussed how magnetic fields are displaced by superconductors with a property called the messier effect. There is a limit the amount of magnetic fields which a superconductor can repel and it is called critical magnetic field. The reason for critical current is the fact that there is a critical magnetic field since when current following creates a magnetic field. Enough current flowing through a superconductor and it will produce a strong magnetic field which will surpass over the critical magnetic field. (Smith, 1988, p. 27)

Critical Temperature

Critical current and critical magnetic field condition values are dependent on the temperature of the superconductor. The higher critical values are best the cooler the superconductor is. What is observed is its maximum strength at approximately half the critical temperature. At critical temperature it is easy to destroy the superconducting properties. Explanations of these properties are discussed with the Chapter discussing the physics behind superconductors. (Smith, 1988, p. 28)

B.4 Rate of development of Room Temperature Superconductors

Figure 63 and 64 shows the advancement of Superconductors to the date of the latest discovery in September 2013 pushing it to 42 degrees Celsius. There has been a rapid increase in the highest superconductor critical temperature over the last decade and can only be expected to further increase in the future. Many companies around the world are working on improving this technology as shown in this Chapter it has great potential. Currently there are seven superconducting materials which have their critical temperature over room temperature (21C). (Superconductors.org A, 2013)

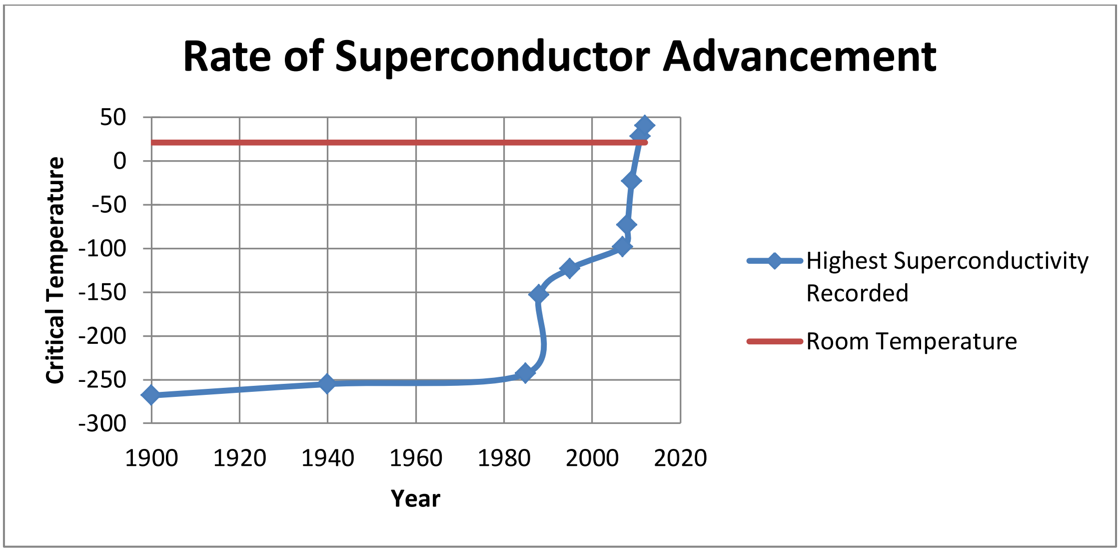

Figure 63: Rate of Superconductor Advancement (Superconductors.org A, 2013)

The following table shows the earlier date and the type of the critical temperature found prior to 2010.

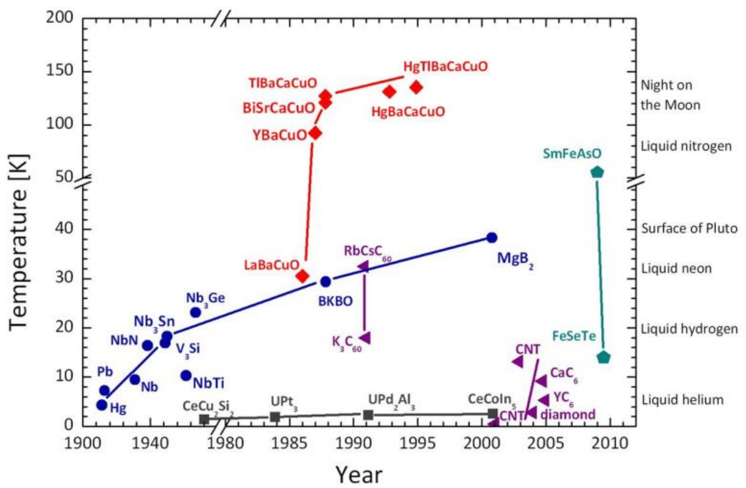

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Figure 64: Date and type of Superconductor Advancements (DPMC, 2010)

B.5 Current High Temperature Superconductor Material Technology

Below is a brief description of three well known and recognised High Temperature Superconductor (HTSC) materials. There are many other types available.

BSCCO phases

Currently this material is being commercial produced to act as a High Temperature Superconductor. It presents a practical critical current density, but there are still minor improvements which need to occur during the fabrication and processing techniques. The critical current density decays rapidly when exposed to high magnetic fields. Its effective use is restricted to below 110K which is well below liquid nitrogen. (American Insitute of Aeronautics and Astronauitics, 2008, p. 293)

YBCO and YBCO-Coated Phases

The YBCO - Coated conductor is a thick superconductor layer deposited on a multilayer buffer thin film grown to a textured metallic substrate. Its critical temperature is around 90K. The surface must be well textured to overcome the weak link nature of the grain boundaries. This is overcome by doping. (American Insitute of Aeronautics and Astronauitics, 2008, p. 294)

MgB_2

This is a recently discovered HTSC. While it requires a much lower temperature there are a number of properties which are an advantage over other HTSC. The following properties are

- Grain boundaries do not act as an obstacle to high currents
- The phase is less anisotropic then most other HTSC.
- Tolerant of processing conditions
- It's cheaper

While it has these properties, its critical temperature is around 39K and has a low magnetic field tolerance. Understanding is quickly growing allowing the commercial production of a 1km long tape showing the signs it is currently a strong contender for future to HTSC.

B.6 Current Limitations

The list of application of superconductivity is long and constantly changing due to scientists and engineers over the last 75 years developing devices to exploit the special properties. While some have come into existence, the primary factors for them to remain as research only are due to the present requirement to be able to cool the superconductors. Industries currently use LTSC since the can be made into electromagnets but have to be cooled.

When ceramic HTSC are immersed in high magnetic fields the resistivity can rise to 100 times a normal conductor such as copper. This can be avoided if the ceramic high temperature superconductor is lowered to a temperature of 20-30% of its critical temperature. When a high current is flowing, it interacts with a different lattice structure then the LTSC. This disorganised and aggregated lattice structure (liquid of vortices) creates a force (Magnus force) and it acts perpendicular to both the current and the fluxiod. Energy is dissipated by the difference of potential induced creating the resistance in the metal. (American Insitute of Aeronautics and Astronauitics, 2008, p. 292)

There are some issues with the development of the creation of HTSC wire. Currently only HTSC is only being produced in a thin tape geometric design. They have had issues with fluxiod motion and developers have found that the introduction on nanometre scale defects into the material nearly eliminate the problem. The tape geometry makes it more difficult to make the superconducting cable, and can lead to problems with electrical and magnetic properties. All current manufactures are now using this technology in their second generation HTSC production. (American Insitute of Aeronautics and Astronauitics, 2008, pp. 292, 293)

While the thin tape geometric design has appealing properties, there is another problem which could prevent manufacturing lengths of wire practical for devices. Where the structure consists of multiple grains, the boundaries impede the super current passage. This is when the process of doping occurs. Doping is normally a technique used by semiconductors to vary the number of electrons and holes. This increases the conductivity of a semiconductor by increasing the number of electrons and holes present (PV Education, 2013). This is the same principal with HTSC. For example for TBCO, some Yttrium ions (Y+3) are replaced by calcium ions almost identical in size. Studies have shown doping enhances current density at temperature less the 77K. An over doping of calcium ions can lead to a net decay of the superconducting properties and all enhancements are lost. A solution to this problem requires of over doping the grain boundaries by growing a calcium doped YBCO film over the undoped one. This is a problem which scientists are presently trying to solve. (American Insitute of Aeronautics and Astronauitics, 2008, pp. 292, 293)

B.7 Current and Future Uses Of Superconductors

Throughout the world there is growing interest by major companies in the research, development and manufacturing of superconductors. They see the broad potential of the applications and a future for global demand.

A group of companies called Conectus (Consortium of European Companies determined to Use Superconductivity) are working together to strengthen the basis for commercial applications of Superconductivity in the future. They work together and exchange findings and resources. They expect during the next decade the market will start to develop due to cost reductions and product improvement and to be viable to new industries. Below are two images which show projected market sizes in the future. (Conectus, 2012)

Global Market for Superconductivity (in M€)
Conectus, March 2012

Business Field	Year 2011	Year 2012	Year 2014	Year 2016
Research & Technological Development (RTD)	920	945	1030	1115
Magnetic Resonance Imaging (MRI)	4050	4125	4230	4330
TOTAL of RTD & MRI	**4970**	**5070**	**5260**	**5445**
New Large Scale Applications	50	55	80	125
New Electronics Applications	60	60	80	95
TOTAL of Emerging New Businesses	**110**	**115**	**160**	**220**
TOTAL MARKET	**5080**	**5185**	**5420**	**5665**
Market Shares for Low-Tc Superconductors	5050	5155	5350	5535
Market Shares for High-Tc Superconductors	30	30	70	130

Figure 65: Global Market for Superconductivity (Conectus, 2012)

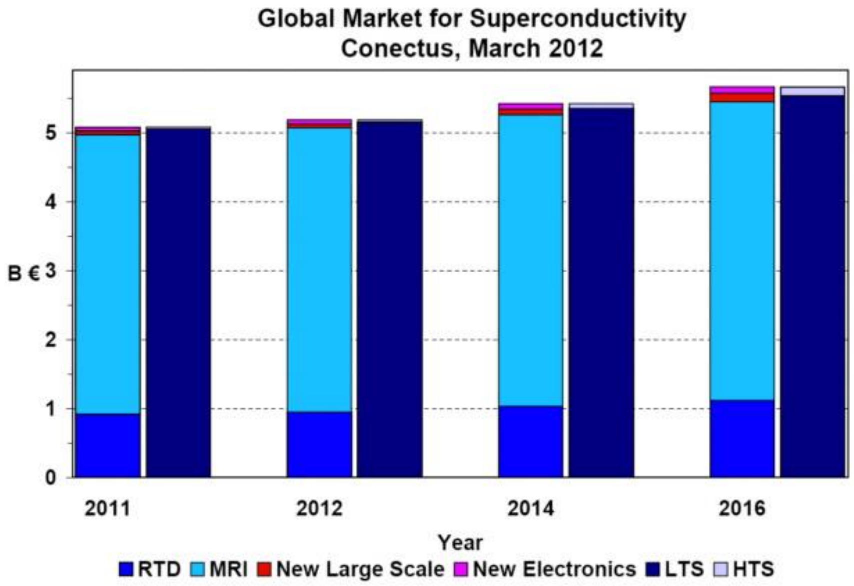
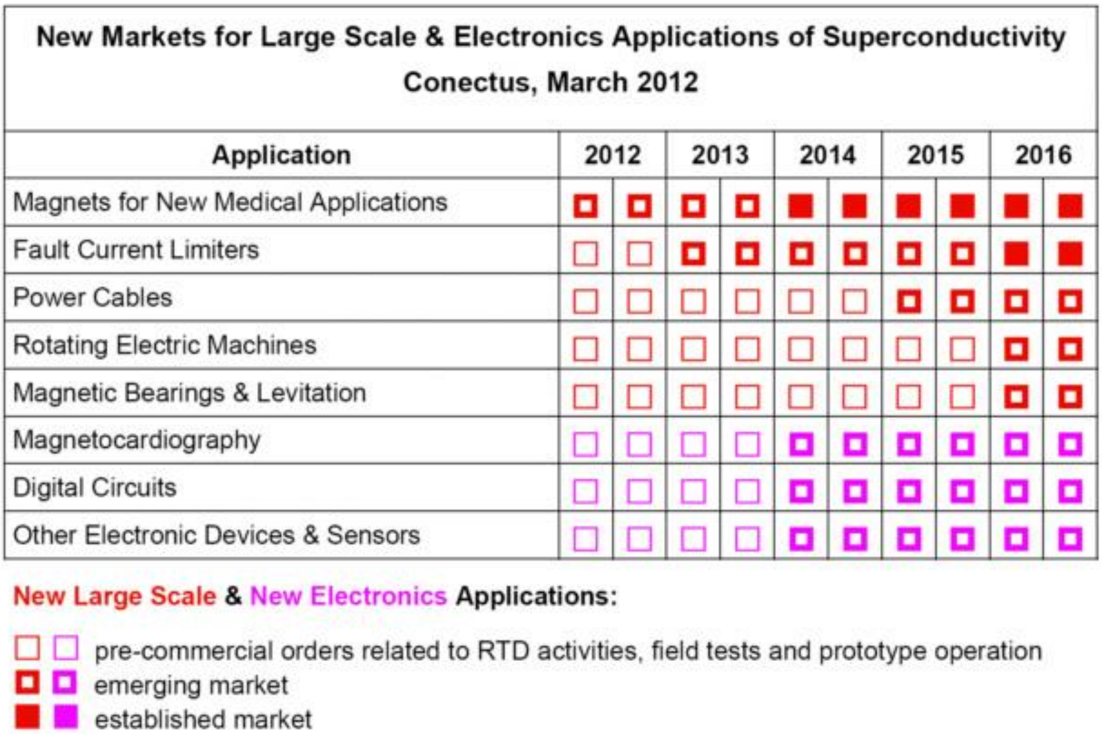


Figure 66: Global Market for Superconductivity (Conectus, 2012)

As we know the prime concern for the application of superconductors it cost. Low Temperature superconductors currently have most of the applications within the market due to low temperature cooling technology already available. Figure 67 shows the current projected usage of Superconductors over the next 5 years.



New Markets for Large Scale & Electronics Applications of Superconductivity
Conectus, March 2012

Application	2012		2013		2014		2015		2016	
Magnets for New Medical Applications	▣	▣	▣	▣	■	■	■	■	■	■
Fault Current Limiters	□	□	▣	▣	▣	▣	▣	▣	■	■
Power Cables	□	□	□	□	□	□	▣	▣	▣	▣
Rotating Electric Machines	□	□	□	□	□	□	□	□	▣	▣
Magnetic Bearings & Levitation	□	□	□	□	□	□	□	□	▣	▣
Magnetocardiography	□	□	□	□	▣	▣	▣	▣	▣	▣
Digital Circuits	□	□	□	□	▣	▣	▣	▣	▣	▣
Other Electronic Devices & Sensors	□	□	□	□	▣	▣	▣	▣	▣	▣

New Large Scale & New Electronics Applications:

□ □ pre-commercial orders related to RTD activities, field tests and prototype operation
▣ ▣ emerging market
■ ■ established market

Figure 67: Market Applications of Superconductivity (Conectus, 2012)

Future Applications Overview

When looking ahead into the future there is a lot of demand for HTSC technology. The following is a list of major technical changes to different products. Figure 68 and 69 are tables compiled by Conectus which show the present and future applications of superconductivity.

Large Scale Applications of Super-Conductivity	
Application	**Major Technical Features**
Power Cables	higher current densities, smaller conductor diameters, lower transmission losses, (side effect: oil-free)
Current Limiters	highly non-linear super-normal-conductor transition, self-controlled current limitation
Transformers	higher current densities, smaller size, lower weight, lower losses, (side effect: oil-free)
Motors / Generators	higher current densities, higher magnetic fields, smaller size, lower weight, lower losses
Magnets for RTD, Magnetic Energy Storage, Magnetic Separation, .. NMR Spectroscopy, MRI, ... Magnetic Levitation Systems	higher current densities, higher & ultra-high magnetic fields, higher magnetic field gradients, smaller size, lower weight, lower losses persistent currents, ultra-high temporal field stabilities stronger levitation forces, larger air gaps
Cavities for Accelerators (based on LTS sheets or coatings)	lower surface resistances, higher quality factors, higher microwave-power handling capability
Magnetic Bearings (based on HTS bulk material)	higher current densities, lower losses, stronger levitation forces, self-controlled autostable levitation

Figure 68: Large Scale Application of Superconductivity (Conectus, 2012)

Electronics Applications of Super-Conductivity	
Application	**Major Technical Features**
High-Frequency Sensor Coils for NMR	lower resistive losses, higher quality factors, smaller size
Microwave Filters for Wireless Communication	lower surface resistances, smaller size, lower transmission losses, higher quality factors
Resonators for Oscillators & Other Passive Microwave Devices	lower surface resistances, higher quality factors, lower transmission losses, smaller size
Far-Infrared Bolometers	highly non-linear super-normal-conductor transition, higher irradiation-mediated temperature sensitivities
Microwave Detectors	highly non-linear junction characteristics, higher conversion efficiencies for frequency-mixing
X-Ray Detectors	lower particle excitation energies, higher photon energy resolutions
SQUID Sensors for RTD, Medical Diagnosis & Non-Destructive Testing SQUID-based Amplifiers	persistent currents, quantum interference effects, ultra-high magnetic field sensitivities low-noise low-signal amplification
Voltage Standards for Metrology & Industry	voltage steps in microwave-irradiated junction arrays, quantum-precision output voltages
Digital Circuits & Microprocessors	persistent currents, single flux quantum signal levels, ultra-fast ultra-low power data transfer & processing

Figure 69: Electronic Applications of Superconductivity (Conectus, 2012)

Other uses of Superconductors are described below.

Magnetic Resonance Imaging (MRI)

Doctors need a non-invasive means of determining what is occurring within the body. By using superconducting magnets doctors are able to expose patents to magnetic fields which force hydrogen atoms within the body to face a direction. When this magnetic field is operational, osculate the atoms at a different frequency which can be detected and displayed graphically on a computer.

Recently a Korean Superconductivity group developed a double-relaxation oscillation SQUID (Superconducting Quantum Interference device) for the use of Magneto encephalography. This is capable of sensing a small change in a magnetic field. This will allow the body to be examined without the need for strong magnetic fields associated with MRI's. (Superconductors.org, 2012)

They use low temperature superconductors (NbTi) wires with helium coolant to make an electromagnet to create a magnetic field. This technology is very reliable and accurate for imagery purposes. Currently they are trying to improve the liquid helium cooling technology. However the high temperature superconductors would be replaced if they are developed within the future with the required properties. (American Insitute of Aeronautics and Astronauitics, 2008, p. 297)

Electric Motors

An electric motor using superconducting wire has a much higher efficiency compared to the conventional generators with copper wire. They have efficiency above 99% and are half the size of conventional motors, which makes this very lucrative venture for power companies. (Superconductors.org, 2012)

Power Stability

Using the technology used for energy storage power companies has installed a Distributed Superconducting Magnetic Energy Storage System (D-SMES). This stabilizes the lines voltage during disturbances in the power grid. (Superconductors.org, 2012)

Commercial Superconducting Wire

Currently there are plans in USA, Denmark and Japan to replace underground copper cables with Superconducting BSCCO cables with in-conduit cooling with liquid nitrogen. They have calculated in one section 250 pounds of superconducting wire would replace 18000 pounds of vintage copper wire making it more space efficient by over 7000%. While they have done short tests, it remains expensive and impractical to cool kilometres of superconducting wire at cryogenic temperatures. (Superconductors.org, 2012)

Current Military Research

- SQUIDS
- Flying EMP drives
- Hypervelocity accelerators
- Direct MHD ship propulsion
- Electric thrusters
- MHD lift and airflow control in aircraft

Most of these are classified and cannot be document due to its military nature (American Insitute of Aeronautics and Astronauitics, 2008, p. 298)

Future space applications

- Electric propulsion for spacecraft
- Electric Micro propulsion
- Solar radiation magnetic fields for interplanetary missions
- Solar Electric Propulsion
- Nuclear Electric Propulsion
- Hybrid Nuclear Thermal-Electric Propulsion (American Insitute of Aeronautics and Astronauitics, 2008, p. 295)

Appendix C - Financial Data Tables for Transrapid

The following tables where used to as a basis to determine the Maglev financial data identified in Chapter 3.4. The calculations are shown in Appendix D.

Table 28: Financial Data for Las Vegas to Primm and Pittsburgh (Part 1) (US Department of Transportation Federal Railroad Administration, 2005, p. A13)

Table A - 1: Summary Statistics for Planned Maglev Projects in U.S.& Germany

Project	Baltimore-Washington	Pittsburgh	Pittsburgh IOS	Anaheim-ONT	Las Vegas-Primm	Munich
Date most recent data supplied by project	2/4/2004	8/31/2004	8/31/2004	3/22/2004	2/5/2004	2/4/2004
PROPOSED OPERATING CHARACTERISTICS						
Train Sets (initial operation)						
Number (including spares)	7	8	4	6	3	5
Sections per Train Set	3	3	3	4	8	3
Seated Capacity per Train	190	148	148	338	720	156
Passenger Capacity per Train	396	344	344	568	940	307
Peak Hour Seated Capacity (one direction)	1,140	1,036	888	2,028	2,160	936
Peak Hour Total Capacity (one direction)	2,376	2,408	2,064	3,408	2,820	1,842
Operational Speed						
Average in mph	126	92	88	130	174	137
Maximum in mph	258	250	250	199	311	217
Travel Time End-to-end in minutes	18.5	35	11	14.5	11	10
Frequency of Service (headways)						
Peak Period Headway in minutes	10	8.5	10	10	20	10
Off-peak Headways in minutes	20-30	10	10	10	30	20
Peak Period Headway in minutes	10	8.5	10	10	20	10
Million Train-mi per year	1.82	3.47	1.09	2.61	1.24	1.93
Hours of Operation						
Daily Operation in Total Hours	20	18	18	19	19	20
Number of Stations	3	5	3	2	2	2
Passengers, Fares & Revenues						
Year	2010	2012	2010	2010	2010	2015
Annual Passengers, millions	9.17	14.2	3.3	10.3	13.5	7.9
Pass.-mi , millions	244.4	323.1	58.0	324.5	469.8	180.8
Annual Revenues ($M)						
Farebox	$184.00	$96.60	$18.80	$93.10	$78.60	$71.80
Other	$12.40	$43.40		$6.30	$4.40	
Total Annual	$196.40	$140.00	$18.80	$99.40	$83.00	$71.80
Average Fares in ($)						
Average Fare/passenger	$20.07	$6.80	$5.70	$9.00	$5.82	$9.09

Table 29: Financial Data for Las Vegas to Primm and Pittsburgh (Part 2) (US Department of Transportation Federal Railroad Administration, 2005, p. A14)

Project	Baltimore-Washington	Pittsburgh	Pittsburgh IOS	Anaheim-ONT	Las Vegas-Primm	Munich
Average Fare/passenger-mi	$0.76	$0.31	$0.32	$0.45	$0.16	$0.40
Capital & Operating Costs In Constant Monetary Units						
Monetary unit base year	2002	2003	2003	2000	2000	2002
Contingency Factor Applied	10-30%	10-30%	10-30%	10% - 20%	10% - 20%	
Capital Costs, ($M)						
Right-of way	$92.00	$151.00	$66.20	$67.00	$10.10	$37.10
Guideway	$1,694.00	$1,802.30	$725.40	$1,717.70	$599.50	$951.70
Propulsion, Control & Communication Systems	$589.00	$246.80	$88.80	$310.20	$244.90	$358.40
Maintenance Facilities	$68.00	$44.40	$44.40	$59.90	$33.60	
Power Distribution	$47.00	$64.00	$32.00	$26.00	$36.50	$34.60
Stations & Parking	$396.00	$386.10	$141.40	$79.40	$20.80	
Vehicle Acquisition	$245.00	$208.80	$104.40	$234.40	$213.50	$201.50
Financial & Other	$610.00	$821.90	$347.40	$276.00	$127.70	$394.30
Total Capital Cost	$3,741.00	$3,725.30	$1,550.00	$2,770.60	$1,286.70	$1,977.50
Unit Capital Costs, Initial Yr.						
Guideway Cost, ($M/mi)	$43.29	$33.15	$41.20	$54.23	$17.22	$41.68
Propulsion, Control and Communications, ($M/mi)	$15.13	$4.51	$4.99	$9.82	$7.08	$15.61
Guideway Cost, passenger-mi / $	2.67	2.17	4.85	2.05	0.50	2.05
Maintenance Facilities Cost, $M/vehicle	$3.20	$1.90	$3.70	$2.50	$1.40	
Power Distrib. Cost, ($M/mi)	$1.13	$1.13	$1.77	$0.80	$1.13	$1.45
Average Station Cost, ($M/station)	$132.00	$77.20	$47.10	$39.70	$10.40	
Vehicle Cost, ($M/vehicle)	$11.70	$8.70	$8.70	$9.80	$8.90	$13.40
Total Capital Cost, ($M/mi)	$95.76	$68.56	$88.19	$87.39	$37.01	$86.42
Annual Operation & Maintenance Costs, (M$/yr.)						
Year	2020	2012	2010	2020	2020	2015
Energy Consumption Cost	$11.30	$10.20	$5.00	$13.30	$11.10	$11.25
Total Operating & Maintenance Costs	$53.00	$37.30	$16.70	$44.90	$35.70	$40.17
Annual O & M Unit Costs, ($)/Unit						
Energy cost, ($/MWhr)	$98.80	$56.00	$56.30	$89.90	$72.70	
Energy Cost/Train-mi	$6.21	$2.95	$4.60	$5.10	$8.93	$5.84
Total O & M Costs/Train-mi	$29.13	$10.78	$15.29	$17.22	$28.81	$20.92
Total O & M Costs/ passenger-mi	$0.21	$0.11	$0.29	$0.14	$0.08	$0.23

Table 30: Las Vegas to Primm and Pittsburgh Scope (US Department of Transportation Federal Railroad Administration, 2005, pp. A-15)

Table A - 2: Indicators of Project Diversity

Project	Baltimore to Washington	Full Pittsburgh	Pittsburgh IOS	Anaheim to Ontario	Las Vegas to Primm	Munich
Guideway Length						
Route Length (mi)	39.1	54.4	17.6	31.7	34.8	22.9
Track Length (mi)	78.2	88.0	33.7	63.4	46.3	45.7
%Track Length, Dual	100.0%	61.9%	91.5%	100.0%	33.0%	100.0%
%Track Length Single	0.0%	38.1%	8.5%	0.0%	67.0%	0.0%
% Route Elevated	32.6%	100.0%	100.0%	81.6%	33.9%	34.5%
% Route At-Grade	51.7%	0.0%	0.0%	19.4%	66.1%	46.2%
% Route Tunnel	15.7%	0.0%	0.0%	0.0%	0.0%	21.7%
Annual Ridership						
Passengers	9.2	14.2	3.3	10.3	13.5	7.9
Passenger-mi	244.4	323.1	58.0	324.5	469.8	180.8
Number Vehicles	21	24	12	24	24	15
Stations						
Number	3	5	3	2	2	2
Average Spacing (mi)	19.5	13.6	8.8	31.7	34.8	22.9
Speed (mi/hr)						
Maximum	257.9	249.8	249.8	198.8	310.7	217.5
Average	126.3	92.0	88.2	130.5	174.0	136.7
Maximum Grade (%)	3.2	8.1	6.5	2.0	3.1	NA
Service Provided						
Vehicle Travel (MVehicle-mi)	5.5	10.4	3.3	10.4	9.9	5.8
Energy Use (KWh/Vehicle-mi)	21.0	17.5	27.2	14.2	15.3	NA

Table 31: Las Vegas to Primm Total Operating Costs ($/Train/Mile) (US Department of Transportation Federal Railroad Administration, 2005, pp. A-17)

Table A - 4: Comparison of Estimated Annual O&M Costs, & Unit Costs for Currently Planned Maglev Projects

Project	Baltimore to Washington		Full Pittsburgh		Pittsburgh Initial Op. Seg		Anaheim to Ontario		Las Vegas to Primm		Munich	
Year of Operation	2020		2012		2010		2020		2020		2015	
Annual O&M Costs		% of Total		% of Total		% of Total		% of Total		% of Total		% of Total
Energy Consumption Cost (M$/yr.)	$11.3	21.3%	$10.2	27.3%	$5.0	29.9%	$13.3	29.6%	$11.10	31.1%	$11.1	28.0%
Total Annual O&M Cost (M$/yr.)	$53.0	100.0%	$37.3	100.0%	$16.7	100.0%	$44.9	100.0%	$35.70	100.0%	$39.5	100.0%
Unit Costs of Annual O&M,												
Energy Costs ($/MWh)	$98.8		$56.0		$56.3		$89.9		$72.5		NA	
($/Train-mi)	$6.2		$2.9		$4.6		$5.1		$8.9		$5.7	
($/Vehicle-mi)	$2.1		$1.0		$1.5		$1.3		$1.1		$1.9	
Total O&M Costs ($/Train-mi)	$29.1		$10.8		$15.4		$17.2		$28.7		$20.5	
($/Vehicle-mi)	$9.7		$3.6		$5.1		$4.3		$3.6		$6.8	

Appendix D - Financial Calculations

D.1 Calculating Maglev Guideway costs

From data collected in Appendix C

D.1.1 Total Rural Guideway Capital Cost

Las Vegas to Primm (Rural Setting) = Guideway, propulsion, control, communications and power distribution and infrastructure

Las Vegas to Primm (Rural Setting) = (17.2+7.1+1.1)/1.609 = $15.8 million/km

D.1.2 Total Urban Guideway Capital Cost

Maximum guideway for mixed single/dual = Guideway, propulsion, control, communications and power distribution and infrastructure

Maximum guideway for mixed single/dual = (24.1 (US Department of Transportation Federal Railroad Administration, 2005, pp. A-11) + 7.1 + 1.1)/1.609 = $20.1 million/km

This value is for maximum guideway, but can be larger if has infrastructure like bridges or extensive earth works required for Mountainous regions as shown below.

D.1.3 Total Mountainous Guideway Capital Cost

Pittsburgh (Moderate mountainous setting) = Guideway, propulsion, control, communications and power distribution and infrastructure

Pittsburgh (Moderate mountainous setting) = (33.15 + 4.51 + 1.1)/1.609

D.2 Cost $/tonne/km

Total Operational Cost = 28.82 $/Train/mile (Appendix C) /1.609 = $17.91/Train/km

Number of carriages per train = 8 (Appendix C)

Weight Capacity of Maglev train = 70 tonnes (Chapter 3.4.7)

Total Tonnes per Train = 8 (carriage) * 70 (tonnes per carriage) = 560 tonnes per train

Cost = $17.91/Train/km / 560 tonnes per train = $0.0319/tonne/km

D.3 Financial Model

D.3.1 Preliminary Calculations

There are a number of preliminary calculations which were undertaken to be used as input for the financial model. They were the Maglev and Rail Guideway Capital Cost, the Carriages Cost which are summarised in tables 16 and 17.

D.3.2 Financial Model Equations

Maglev and Rail Capital Cost

Capital Cost ($Million) = (Total Guideway Cost (dependant on if Gladstone/Brisbane and Maglev/Rail from table 20/21) + Wagon Cost (Dependant on if it is for Maglev/Rail and Export Capacity found in table 22) * Social Push Factor (dependant of if Industrial, mixed or Sustainable push and the hypothetical years found in table 24)

Maglev and Rail Operating Costs

Operating Costs ($Million/year) = Export Capacity (50, 75, 100 or 125 Mtpa) * Coal Transporting Cost (dependant on if Rail or Maglev scenario 1 or 2 as shown in table 23) * Social Push Factor (dependant of if Industrial, mixed or Sustainable push and the hypothetical years found in table 24)

Calculating Breakeven Year

Number of years for Maglev and Rail to Breakeven = Total cost Maglev is more expensive (Maglev Capital Cost - Rail Capital Cost) / Yearly Saving by Maglev (Rail Operating Cost - Maglev Operating Cost)

Appendix E - Economic Model Data

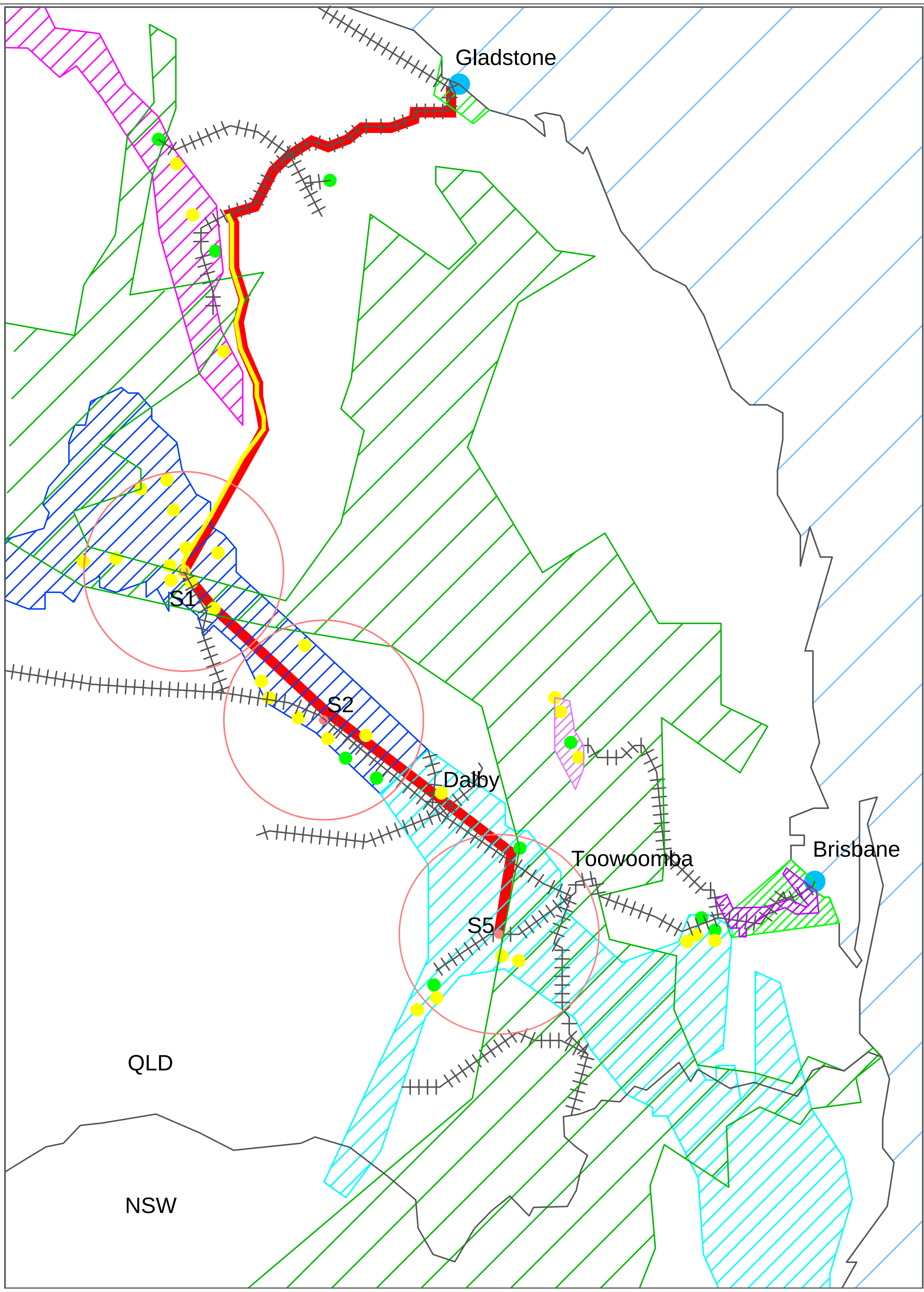
Table 32: Present Preliminary Financial Scenario Model

				50	Mtpa				75	Mtpa				100	Mtpa				125	Mtpa			
Years in the Future	Future Scenario	Scenario Type	Transportation Type	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year
Present	Gladstone	None	Maglev System	12705	1138	9662	72	133	13205	1707	10119	109	93	13705	2275	10576	145	73	14205	2844	11033	181	61
			Rail	3043	1210				3086	1815				3129	2420				3171	3025			
	Brisbane	None	Maglev System	9571	763	7330	49	151	10071	1145	7787	73	107	10571	1527	8245	97	85	11071	1909	8702	122	72
			Rail	2240	812				2283	1218				2326	1624				2369	2030			
20	Gladstone	Industrial	Maglev System	11752	1138	8709	72	120	12214	1707	9129	109	84	12677	2275	9548	145	66	13139	2844	9968	181	55
			Rail	3043	1210				3086	1815				3129	2420				3171	3025			
		Mixed	Maglev System	11434	1109	8467	101	84	11884	1664	8876	151	59	12334	2218	9284	202	46	12784	2773	9692	252	38
			Rail	2967	1210				3009	1815				3050	2420				3092	3025			
		Sustainable	Maglev System	11117	1081	8226	129	64	11554	1621	8623	194	44	11992	2162	9020	259	35	12429	2702	9416	323	29
			Rail	2891	1210				2931	1815				2972	2420				3013	3025			
	Brisbane	Industrial	Maglev System	8853	763	6613	49	136	9315	1145	7032	73	96	9778	1527	7452	97	77	10240	1909	7871	122	65
			Rail	2240	812				2283	1218				2326	1624				2369	2030			
		Mixed	Maglev System	8614	744	6429	68	95	9064	1117	6837	102	67	9514	1489	7246	135	54	9964	1861	7654	169	45
			Rail	2184	812				2226	1218				2268	1624				2310	2030			
		Sustainable	Maglev System	8374	725	6246	87	72	8812	1088	6643	130	51	9249	1451	7040	174	41	9687	1813	7436	217	34
			Rail	2128	812				2169	1218				2210	1624				2251	2030			
40	Gladstone	Industrial	Maglev System	10799	1138	7756	72	107	11224	1707	8138	109	75	11649	2275	8520	145	59	12074	2844	8903	181	49
			Rail	3043	1210				3086	1815				3129	2420				3171	3025			
		Mixed	Maglev System	10164	1081	7273	129	56	10564	1621	7632	194	39	10964	2162	7992	259	31	11364	2702	8351	323	26
			Rail	2891	1210				2931	1815				2972	2420				3013	3025			
		Sustainable	Maglev System	9529	1024	6790	186	36	9904	1536	7126	279	26	10279	2048	7463	372	20	10654	2560	7799	466	17
			Rail	2739	1210				2777	1815				2816	2420				2854	3025			
	Brisbane	Industrial	Maglev System	8135	763	5895	49	121	8560	1145	6277	73	86	8985	1527	6659	97	68	9410	1909	7041	122	58
			Rail	2240	812				2283	1218				2326	1624				2369	2030			
		Mixed	Maglev System	7657	725	5528	87	64	8057	1088	5887	130	45	8457	1451	6247	174	36	8857	1813	6606	217	30
			Rail	2128	812				2169	1218				2210	1624				2251	2030			
		Sustainable	Maglev System	7178	687	5162	125	41	7553	1031	5498	187	29	7928	1374	5835	250	23	8303	1718	6171	312	20
			Rail	2016	812				2055	1218				2094	1624				2132	2030			

Table 33: Projected Future Preliminary Financial Scenario Model

				50	Mtpa				75	Mtpa				100	Mtpa				125	Mtpa			
Years in the Future	Future Scenario	Scenario Type	Transportation Type	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year	Capital Cost ($Mil)	Operating Cost ($ Million/year)	Capital Difference ($Mil)	Operating Difference ($Mil)	Breakeven Year
Present	Gladstone	None	Maglev System	12705	853	9662	357	27	13205	1279	10119	536	19	13705	1706	10576	714	15	14205	2132	11033	893	12
			Rail	3043	1210				3086	1815				3129	2420				3171	3025			
	Brisbane	None	Maglev System	9571	572	7330	240	31	10071	859	7787	360	22	10571	1145	8245	479	17	11071	1431	8702	599	15
			Rail	2240	812				2283	1218				2326	1624				2369	2030			
20	Gladstone	Industrial	Maglev System	11752	853	8709	357	24	12214	1279	9129	536	17	12677	1706	9548	714	13	13139	2132	9968	893	11
			Rail	3043	1210				3086	1815				3129	2420				3171	3025			
		Mixed	Maglev System	11434	832	8467	379	22	11884	1247	8876	568	16	12334	1663	9284	757	12	12784	2079	9692	946	10
			Rail	2967	1210				3009	1815				3050	2420				3092	3025			
		Sustainable	Maglev System	11117	810	8226	400	21	11554	1215	8623	600	14	11992	1621	9020	800	11	12429	2026	9416	1000	9
			Rail	2891	1210				2931	1815				2972	2420				3013	3025			
	Brisbane	Industrial	Maglev System	8853	572	6613	240	28	9315	859	7032	360	20	9778	1145	7452	479	16	10240	1431	7871	599	13
			Rail	2240	812				2283	1218				2326	1624				2369	2030			
		Mixed	Maglev System	8614	558	6429	254	25	9064	837	6837	381	18	9514	1116	7246	508	14	9964	1395	7654	635	12
			Rail	2184	812				2226	1218				2268	1624				2310	2030			
		Sustainable	Maglev System	8374	544	6246	268	23	8812	816	6643	403	17	9249	1088	7040	537	13	9687	1359	7436	671	11
			Rail	2128	812				2169	1218				2210	1624				2251	2030			
40	Gladstone	Industrial	Maglev System	10799	853	7756	357	22	11224	1279	8138	536	15	11649	1706	8520	714	12	12074	2132	8903	893	10
			Rail	3043	1210				3086	1815				3129	2420				3171	3025			
		Mixed	Maglev System	10164	810	7273	400	18	10564	1215	7632	600	13	10964	1621	7992	800	10	11364	2026	8351	1000	8
			Rail	2891	1210				2931	1815				2972	2420				3013	3025			
		Sustainable	Maglev System	9529	768	6790	442	15	9904	1151	7126	664	11	10279	1535	7463	885	8	10654	1919	7799	1106	7
			Rail	2739	1210				2777	1815				2816	2420				2854	3025			
	Brisbane	Industrial	Maglev System	8135	572	5895	240	25	8560	859	6277	360	17	8985	1145	6659	479	14	9410	1431	7041	599	12
			Rail	2240	812				2283	1218				2326	1624				2369	2030			
		Mixed	Maglev System	7657	544	5528	268	21	8057	816	5887	403	15	8457	1088	6247	537	12	8857	1359	6606	671	10
			Rail	2128	812				2169	1218				2210	1624				2251	2030			
		Sustainable	Maglev System	7178	515	5162	297	17	7553	773	5498	445	12	7928	1030	5835	594	10	8303	1288	6171	742	8
			Rail	2016	812				2055	1218				2094	1624				2132	2030			

Appendix F - Plans



The Surat Basin Maglev Proposal 1 - Gladstone

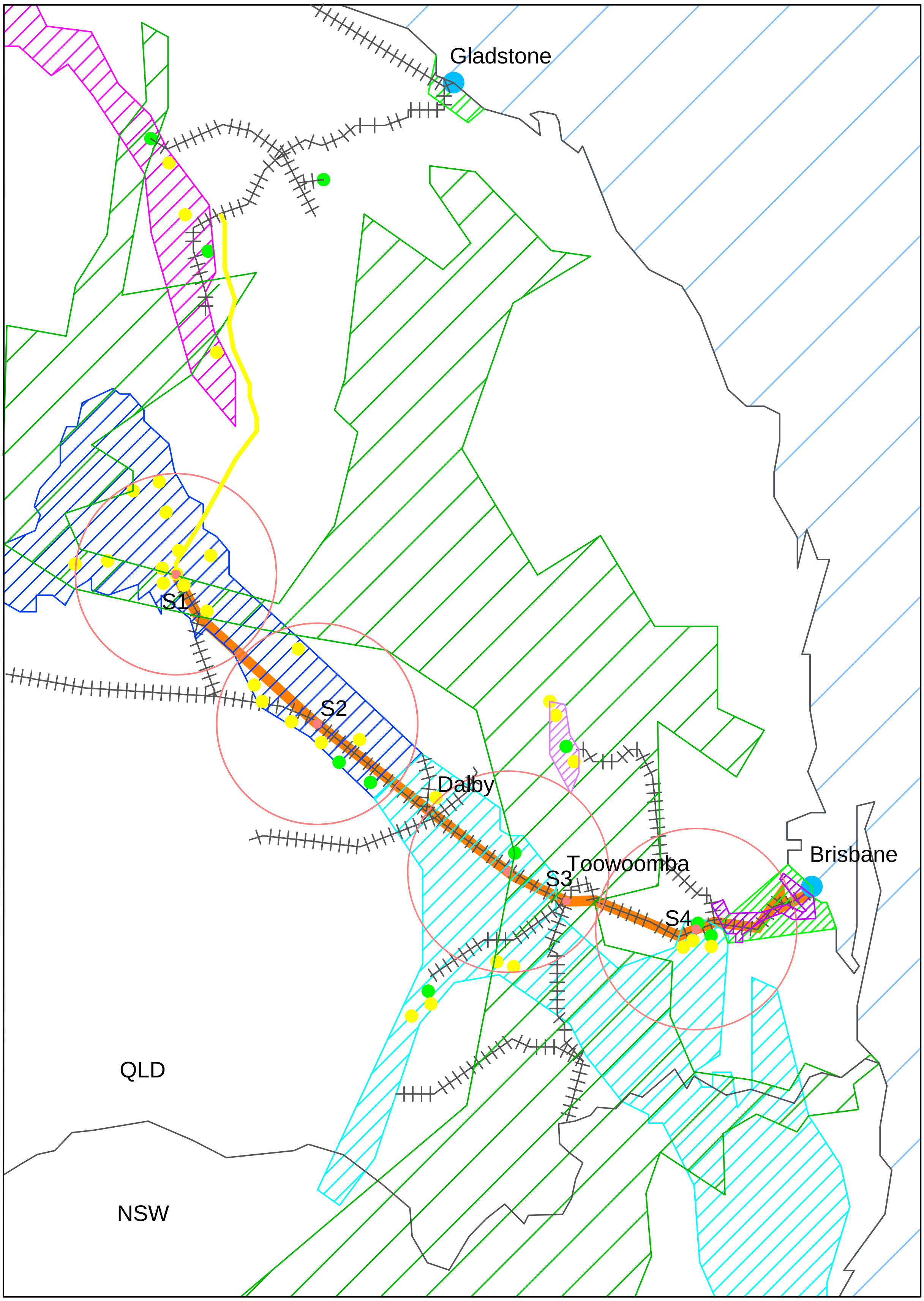
Legend

- Maglev Proposal 1
- Proposed Surat Basin Rail
- Existing Rail Lines
- State Border
- Mines in Operation
- Mines being planned/constructed
- Operational Coal Ports
- Proposed Stations
- Proposed Stations 50 km Radius
- Surat Basin
- Clarence-Moraton Basin
- Tarong Basin
- Bowen Basin
- Pacific Ocean
- Mountainous Area
- Urban Area

Scale 0km 100km

N

Produced by: Bryan Freeman
Date: 16/10/2013



The Surat Basin Maglev Proposal 2 - Brisbane

Legend

- Maglev Proposal 1
- Proposed Surat Basin Rail
- Existing Rail Lines
- State Border
- Mines in Operation
- Mines being planned/constructed
- Operational Coal Ports
- Proposed Stations
- Proposed Stations 50 km Radius
- Surat Basin
- Clarence-Moraton Basin
- Tarong Basin
- Bowen Basin
- Pacific Ocean
- Mountainous Area
- Urban Area

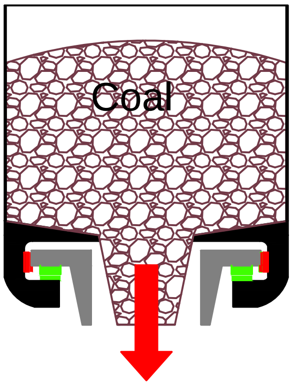
Scale 0km 100km

N

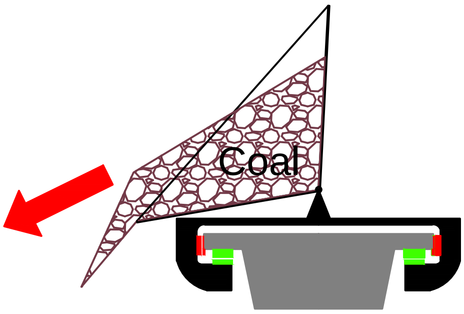
Produced by: Bryan Freeman
Date: 16/10/2013

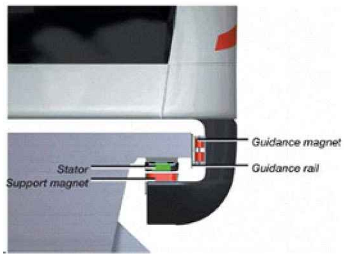
German Transrapid Design Proposals

Bottom Opening Wagon



Side Tipper Wagon





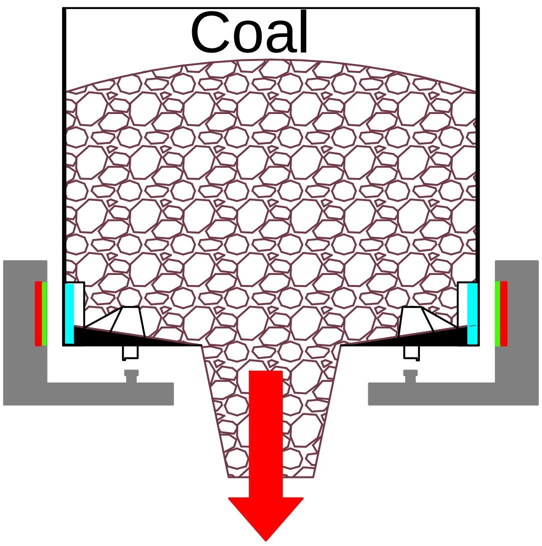
Legend

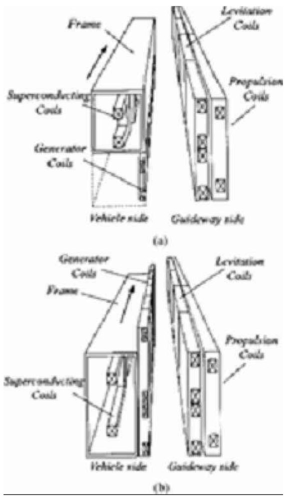
- Wagon
- Guideway
- Coal
- Support Magnet
- Guidance Magnet

Note: Rotary Railcar Dumper not possible due to Levitation Constraints

Japanese MLX-01 Design Proposal

Bottom Opening Wagon





Legend

- Wagon
- Guideway
- Coal
- Superconductors
- Levitation Coils
- Propulsion Coils

Side Tipper Wagon not possible due to side walls holding Coils

Produced by: Bryan Freeman
Date: 16/10/2013