Feasibility Assessment of High Street Level Crossing Removal Project

1. Introduction

The feasibility study is an important part of the project before it start. A good feasibility study can ensure the smooth completion of the project and ensure that the project is beneficial to stakeholders in economic, environmental and social aspects. This report provides a feasibility analysis of the different options(Bridge and Tunnel) at the High Street level crossing removal, showing the rewards and impacts of each option, and find that the bridge is better than the tunnel.

2. Background

2.1 Project Context

In April 2018, the State Government announced the grade separation of the High Street and The three track Maley line as part of its Level Crossing Removal Program.

High street, Ginley, a six lane divided road located about 7.5 km from Melbourne Central, provides a strategic link between Northern Highway and industrial and commercial centers in the east. It carries on average about 42000 vehicles in a day. High street is also a public transport bus route for the 110 and 231 bus services serving around 21 buses in a day.

The three track Maley line, carrying both suburban and freight services, intersects High Street near the Ginley shopping mall. The Maley line carries 225 electrified passenger trains and an average of 5 freight services in a day.

2.2 Identified Problem

There are two problems this project is intended to resolve; travel time reliability and pedestrian safety.

Travel Time Reliability

High Street and the Maley Line are both busy routes. When a train passes through the level crossing, all traffic on High Street is stopped by means of boom gates. The varying frequency of trains has made travelling time for users of High Street very unreliable. As the boom gates close to allow the passage of a train, long queues of traffic develop on the road. With an increasing population, the road usage and the frequency of trains is expected to rise causing the problem to worsen in the future. Available statistical data shows a high variability in travel times. Traffic modelling based on maintaining the status quo predicts boom gate closure of over 50% of the peak hour causing unacceptable traffic delays.

Pedestrian Safety

The Ginley neighborhood is a pedestrian priority area. Currently, pedestrians cross the rail line using actuated pedestrian gates or by the underpass on the northeast side of High Street. The underpass has ramps that are very steep and are not Disability Discrimination Act (DDA) compliant. Furthermore, the underpass does not allow passive surveillance making its users susceptible to assault/thieving.

There also exists a primary and senior school in the vicinity and therefore the level crossing is used by a number of students. Young children are prone to high risk behavior and it is of primary concern to ensure that the risk of a serious incident in the future is to be eliminated. Over the last five years, VicRoads CrashStats data has recorded 42 crashes or near misses due to the level crossing.

2.3 Goals and Benefits

The project is expected to deliver two key benefits to the community:

Improving of transport network efficiency remains the most important benefit. The projects intends to reduce the variability in travel time by 50%, reduce the average travel time by 6% and ensure less than 50m distance between different transport modes.

Increased safety for pedestrians is the second key benefit. The project intends to reduce conflict points by 50% and ensure zero accidents at the level crossing.

2.4 Project Stakeholders

This project will directly benefit a lot of people, such as commuters, the government and involved companies, also will have a wide impact on the surroundings. So we should think broadly and analyze it from different aspects like economic, environmental and social to make sure all potential stakeholders are considered. The following is a list of stakeholders of the intended project.

- Commuters
- Pedestrians
- Victorian State Government
- Construction companies/contractors/designers
- Tax Payers
- Real Estate Developers
- Environmentalists
- Surrounding businesses
- Maintenance and hygiene firms
- Emergency Services

2.5 Project Options

The following are a series of options for this project. Different options have different feasibility and impact. We need to analyze and select the most feasible and beneficial options.

<table>
<tr><th>Strategic option</th><th>Project option</th></tr>
<tr><td colspan="2">Strategic Option 0: Do Nothing</td></tr>
<tr><td>No investment</td><td>Project Option 0: No investment</td></tr>
<tr><td colspan="2">Strategic Option 1: Grade Separation</td></tr>
<tr><td rowspan="4">Separates road and rail networks at the intersection.</td><td>Project Option 1A: Road Over Rail</td></tr>
<tr><td>Project Option 1B: Road Under Rail</td></tr>
<tr><td>Project Option 1C: Rail Over Road</td></tr>
<tr><td>Project Option 1C: Rail Under Road</td></tr>
<tr><td colspan="2">Strategic Option 2: Close High Street at Level Crossing</td></tr>
<tr><td>Removes level crossing by closing the road, requiring possible alternative routes.</td><td>Project Option 2: High Street Closure</td></tr>
</table>

Table 1. Project option

Option 0: Maintain Status Quo

The existing road and rail network is maintained as is. Models made considering population growth show that the problems mentioned earlier are expected to exacerbate. With an increased unreliability of travel time and risk to pedestrians, the continuing deterioration of the existing rail apparatus are likely to lead to further problems. This report will not further investigate this option.

Option 1A: Road over Rail

In this option, the rail will be maintained as is and the road will be elevated above the rail by approximately 7m. The high street was originally two intersections. If the road is raised, it will build a secondary bridge leading to other winding roads. This will be a huge circular overpass, and the existing intersection obviously does not have enough space to accommodate this. This option is unfeasible.

Option 1B: Road under Rail

The rail will remain intact while the roadway would pass underneath it through a trench at approximately 5.5m depth. The same problem exists with 1A, because high street contains two intersections, which will lead to the construction of complex tunnels or the addition of large-scale above-ground auxiliary roads to ensure that cars can turn into intersecting roads. This lead the option unfeasible.

Option 1C: Rail over Road (Rail Bridge)

The rail is elevated by means of a bridge and the roadway remains intact. The bridge will need to be long as the slope needs to be lesser than 2%. But this solution can avoid complicated structures and does not require branch bridges. This report will further investigate this option.

Option 1D: Rail under Road (Tunnel)

The rail is depressed with respect to the roadway approximately by 7m. Once again, the slope must not exceed 2%. However, it may still disrupt underground utilities and damage adjacent structures. This report will further investigate this option.

Option 2: High Street Closure

This option will truncate High Street at the level crossing causing uninterrupted rail services and pedestrian movement. However, this would put massive pressure on adjoining roads to accommodate the extra traffic will require extensive upgradations. This will also drastically reduce access to local businesses and will effectively decrease property value. This report considers this option is unfeasible.

In the later sections of this report, only option 1C(Bridge) and 1D(Tunnel) are considered as an attempt to decide between the two is made.

3.Technical description

We plan to introduce 3D scanning technology into our project to increase the feasibility of both options (Bridge and Tunnel)

3.1 Hardware

For the Hardware, the most important part is this camera, which can sent laser to the object, and recording the specific colors and shapes of the object.

Using this technology to do the survey has a lot of benefits.

- It can reduce the measurement error to half millimeter.
- And it can save 50% time than traditional survey methods. (Chillachi D, 2017)
- Finally, it is safer, because people don’ t need to touch the object, they can do the survey outside the Rail or Road.

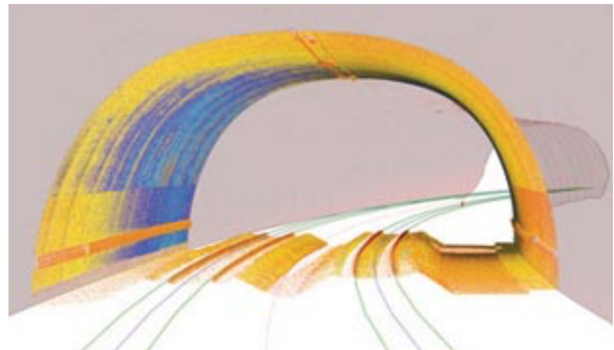
Support case: Highway construction, Colombia, 2018

The construction company needs to renovate the bridge. The traditional method of survey requires the surveyor to walk in the traffic and must measure on every sides, which is very dangerous, also some locations below the bridge are unreachable by the surveyor. So they used 3D scanning technology to safely complete the bridge measurement and get more data than ever before(Gröninger T, 2018).

3.2 Software

For the software, it can build a 3D model based on the scanning data.

- The designer can easily measure any length from a 3D model.
- The most important thing is that the 3D model can save lots of money for the construction, For example, we can scan the structure every week to make sure it is same with the design. In this way it can reduce the rework cost from 15% to 1%(Hayes C & Richie E, 2015)



Support case: Apartment Concrete Pour, Houston, 2015

Before the concrete was poured, the construction company needed to ensure that all the structures were in the right position. In order not to delay the construction, they used 3D scanning technology to deliver the scan results within 24 hours and corrected the position of a sleeve before pouring the concrete. This saved the company thousands of dollars and If the problem was not be found, the loss may be times(TruePoint, 2015).

3.3 Effect

Using 3D technology can save time and cost for the project, avoid possible errors, injuries and waste, have good economic, environmental and social impacts, thence improve the feasibility of the project as much as possible.

4. Economics-Based assessment

4.1 Cash Flow (Option 1: railway bridge)

Initial cost

In this option, building a railway bridge above the road at High-stress level crossing. Consider construction, infrastructure, earthwork, and post-management costs. Detailed cash flow will be shown below:

Construction:

In High-street level crossing removal project. Cause of soil, harder rock material, and low groundwater table, using the monopile approach is the best way to building the railway bridge. (level crossing removal, 2019). Also, the railway bridge needs to span the road, so steel beams with larger spans are used instead of U-beams. In this design, 30 bridge columns are expected, with a single steel beam spanning approximately 25 meters and a total length of 750 meters. The total cost of construction is $20.45 million, and the detail shown in Table 1.

Name	Detail	Ideal cost	Cost in this case
Bridges	Short steel beam (span 5-80m)	$25m/km	$18.75m
Track	Dual track (design speed 250km/h)	$2.25m/km	$1.7m
Total			**$20.45m**

Table 2. Cost of construction in railway bridge option (Hot rail, 2013).

Infrastructure:

In this part, power infrastructure, signaling equipment, control equipment, and some genera civil works be considered. The detail is shown in Table 2. The total cost of infrastructure is $14.6 million

Name	Detail	Ideal cost	Cost in this case
Power Infrastructure	250-350km/h (dual track)	$3m	$3m
Communications Cable	Each route	$125k	$125k
Wi-fi Tower	Each	$800k	$800k
Control Center Equipment	Each	$7m	$7m
Security Fence	Linear-km	$100k	$75k
Noise Attenuation Wall	Linear-km	$4.8m	$3.6m
Total			**$14.6m**

Table 3. Cost of infrastructure in railway bridge option (Hot tail, 2013)

Earthwork:

One of the components of cost is the cost of earthwork. Earthwork costs are less in this option because only the earthwork produced by piling needs to be considered. A total of 30 piles are required for the bridge construction, each pile has a diameter of 2.1 meters

and a depth of 28 meters (level crossing removal, 2019). The amount of earthwork produced is 2910 cubic meters. Considering the cost of landfill and transportation per cubic meter is $22, so the total cost of earthwork is **$64k**.
To sum up, the initial cost of building railway bridge is **$35.114 million.**

4.1.2. Maintenance cost

The life of railway bridge is about 50 years (Nielsenl, Chattopadhyay and Ramanl, 2013). Rail maintenance, vegetation control and sediment control are required annually. The annual cost is approximately $240,913 (ARTC, 2017). This cost also includes the salary of the maintenance staff. In this case, hire a maintenance team that includes a team leader and two workers.

4.1.3. Benefits

Economic benefits mainly include four parts: travel time reliable saving, PT benefits (public transport benefit), total accident reduction benefits, and other wider economic benefits. The primary benefit is created by travel time reliable saving because this project changed the journey time of private, commercial, and freight vehicles. This way can increase people's productivity and create extra rest or working time. According to LXRP (2017), the benefit of travel time reliable saving is $2.6 million per year. Second, the project has increased people's confidence in public transportation and encouraged more people to choose public transportation modes. The PT benefit created is $0.59 million per year. Third, the level crossing removal project can avoid the accident. It can save $0.15 million per year. Moreover, the level crossing removal project has some wider economic benefits such as agglomeration benefits or create work opportunities. It will create $0.32 million per year. Finally, when the railway bridge ends its life, the residual value is 10% of the total construction cost, it is $3.5 million

Benefits	$2016 m, NPV (7% discount rate)
Non-business vehicle trips	$1,440
Business vehicle trips	$313
Freight vehicle trips	$145
Total travel time savings	**$1,898**
PT network benefits(time savings and reduced crowding)	$141
Interchange improvement benefits	$292
Total PT user benefits	**$433**
Direct LX-related collision reduction	$145
VKT related collisions	-11
Total accident reduction benefits	**$134**
Wider economic benefits	**$240**
Total benefits	**$2,705**

Table 4. Benefit of level crossing removal project

$$Total\ benefits\ per\ year = \frac{Total\ benefits \times (1-q)}{1-q^n}$$

$$Benfits\ per\ year = \frac{Total\ benefits\ per\ year}{\text{Project number}}$$

Where :

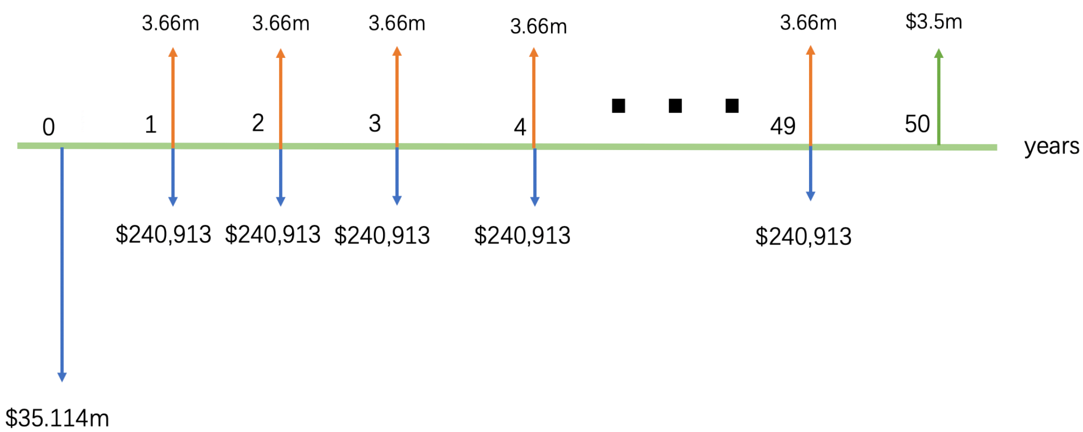
common rate $q = \frac{1}{1+i}$

discount rate I = 7%

Number of years n = 50 years

Project number = 50

Solve equation and find benefits is **3.66 million per year**



4.2 Cash Flow (Option 2: Tunnel)

Initial cost

In this option, building the tunnel under the road. Same as railway bridge option, consider construction, infrastructure, earthmoving, and post-management costs. The detail will be shown below

Construction:

In this project. Because the groundwater location of the high street is low, it is feasible to build a train tunnel under the road. However, the underground rock at High street is Tholeiitic basalt (Melbourne Geological Map, 1997). This rock texture is hard and difficult to excavate, so building the train tunnel will spend more.

Moreover, the life of this project is about 50 years. Among them, the technology of the train is expected to improve, so this project uses the high-speed dual track to prevent rail replacement after train upgrade. The design speed is 300km/h, the length of the tunnel is 450m, the OD of the tunnel is 14.6 meters, construction cost is about $32.9 million (Hot rail, 2013).

Infrastructure:

The infrastructure required for the tunnel is only power infrastructure, communications cable, and control center equipment. The cost is 10.125 million.

Earthwork:

Building a tunnel will produce a lot of sand and rock. In this case, the radius of the tunnel is 7.3 meters, and the length is 500 meters. The amount of earthwork produced is 336812 cubic meters. Considering the cost of landfill and transportation per cubic meter is $22, so the total cost of earthwork is $0.81 million.

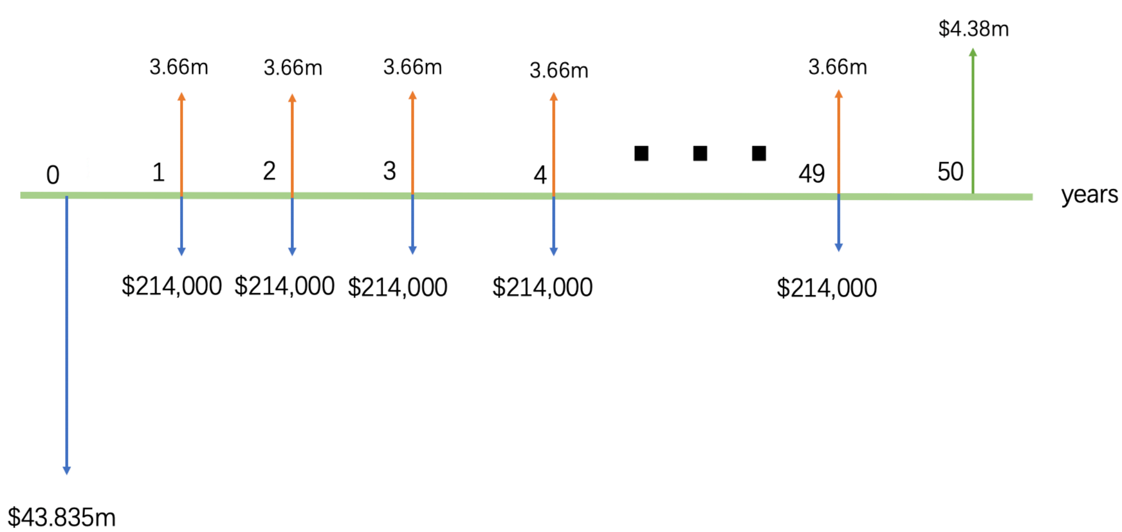
To sum up, the initial cost of building a tunnel is **43.835 million**.

Maintenance cost

Compare with the railway bridge option, the maintenance cost of the tunnel is less. According to Montara (2016), The maintenance cost is $214,000 per year.

Benefits

The significant benefit is the same as option 1. The residual value is 4.38 million (10% of initial cost).



4.3 BCR

According to Hou (2019), BCR analysis dealing with annual value, so it needs to spread initial costs to each year. In this report, the BRC of two different options were calculated separately, and the calculation process and results are shown follows.

Option 1: Railway bridge

The first step is to calculate annual cost. The formula is $\boldsymbol{A}=\boldsymbol{P}*\boldsymbol{i}(\mathbf{1}+\boldsymbol{i})\hat{}\boldsymbol{n}/[(\mathbf{1}+\boldsymbol{i})\hat{}\boldsymbol{n}-\mathbf{1}]$
P: initial cost = \$35.114 million
i: interest rate = 7%
n: evaluation year = 50 years
$\therefore C_A =$ 2.54 million /year
C_A = initial cost =2.54 million/year
C_2 = maintenance cost = \$240,913/year
B = annual benefit = \$3.66 million/ year

$$\therefore \ BCR = \frac{3.66}{2.54+0.24} = 1.32$$

The BCR of the railway bridge is 1.32

Option 2: Tunnel

The first step is to calculate annual cost. The formula is $\boldsymbol{A}=\boldsymbol{P}*\boldsymbol{i}(\mathbf{1}+\boldsymbol{i})\hat{}\boldsymbol{n}/[(\mathbf{1}+\boldsymbol{i})\hat{}\boldsymbol{n}-\mathbf{1}]$
P: initial cost = \$43.835 million
i: interest rate = 7%
n: evaluation year = 50 years
$\therefore C_A =$ 3.17 million /year
C_A = initial cost =3.17 million/year
C_2= maintenance cost = \$214,000/year
B = annual benefit = \$3.66 million/ year

$$\therefore \ BCR = \frac{3.66}{3.17+0.21} = 1.08$$

The BCR of the tunnel is 1.08

4.4 Payback Period

The payback (PB) period is the time it takes for an investment to recover its initial outlay from benefits. The PB period does not take into consideration inflations or discount rates. The PB can be calculated through the formula below:

$$Pay\ Back\ Period = \frac{Initial\ Investment}{Annual\ Benefits - Annual\ Operating\ Costs}$$

The payback period for the bridge and tunnel can be seen in the table below:

	Bridge	Tunnel
Initial Investment	35.11m	43.83m
Annual Benefits	3.66m	3.66m
Annual Operating Costs	0.24m	0.21m
Payback Period	**10.27Years**	**12.7 Years**

Table 5. Payback Period for Bridge and Tunnel

According to the table above the bridge solution will be recoup the investment in 2.42 years less than a tunnel solution.

4.5 Internal Rate of Return

The internal rate of return (IRR) is a metric used to estimate the profitability of potential investments. The IRR essential is the discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. The IRR can be calculated through the formula below:

$$NPV = -I_0 + (B - C)PVF_{i,n} + L_n/(1+i)^n$$

The internal rate of return for the bridge and tunnel can be seen in the table below:

	Bridge	Tunnel
Initial Investment	35.11m	43.83m
Annual Benefits	3.66m	3.66m
Annuals Operating Costs	0.24m	0.21m
Residual Value (10%)	3.51m	4.38m
Number of Years	50 Years	50 Years
Internal Rate of Return	**10.14%**	**7.98%**

Table 6. Internal Rate of Return for Bridge and Tunnel

It was assumed that if the IRR fell below 8% the project would not be feasible. Therefore, according to the results depicted in the table above both solutions are feasible. Although considering that both projects have a significantly different capital investment requirement. The IRR could be misleading; therefore the net present value was taken as the best indicator of feasibility.

4.6 NPV

Through NPV we can judge whether this option makes money. We should choose the option with the biggest NPV

$$NPV = -I_0 + (B - C)PVF_{i,n} + L_n/(1 + i)^n$$

Where:
I_0 – Initial capital investment
B – annual net benefits
C – annual net costs
$PVF_{i,n}$ – present value factor $= [(1 + i)^n - 1]/i(1 + i)^n$
L_n – liquidation yield (residual value)
i – discount rate
n – number of years

Bridge	
I_0	35.11
B	3.66
C	0.24
i	0.07
n	50
L_n	3.51
NPV	**12.21**

Tunnel	
I_0	43.83
B	3.66
C	0.21
i	0.07
n	50
L_n	4.38
NPV	**3.93**

For the two options , Bridge and Tunnel, the different things are Initial capital investment, annual net costs and residual value. After calculation we find the NPV of the bridge is bigger than the tunnel. Also, because every factors can be a little bit different each year, so we do the Sensitivity analysis for NPV.

We assume that each factor will have a 5% change, use uniform and normal model, and do the simulation.

For the Bridge

Distribution Type	Task	Parameters		Input Parameters
Uniform	**Initial Capital Investment**	**Min**	**Max**	
		41.64	46.02	43.83
Normal	**Annual net Benefits**	**µ**	**σ**	
		3.66	0.183	3.66
Normal	**Annual net Costs**	**µ**	**σ**	
		0.21	0.0105	0.21
Normal	**Discount Rate**	**µ**	**σ**	
		0.07	0.0035	0.07
Normal	**Number of Years**	**µ**	**σ**	
		50	2.5	50
Uniform	**Residual Value**	**Min**	**Max**	
		4.16	4.6	4.38

Table 7

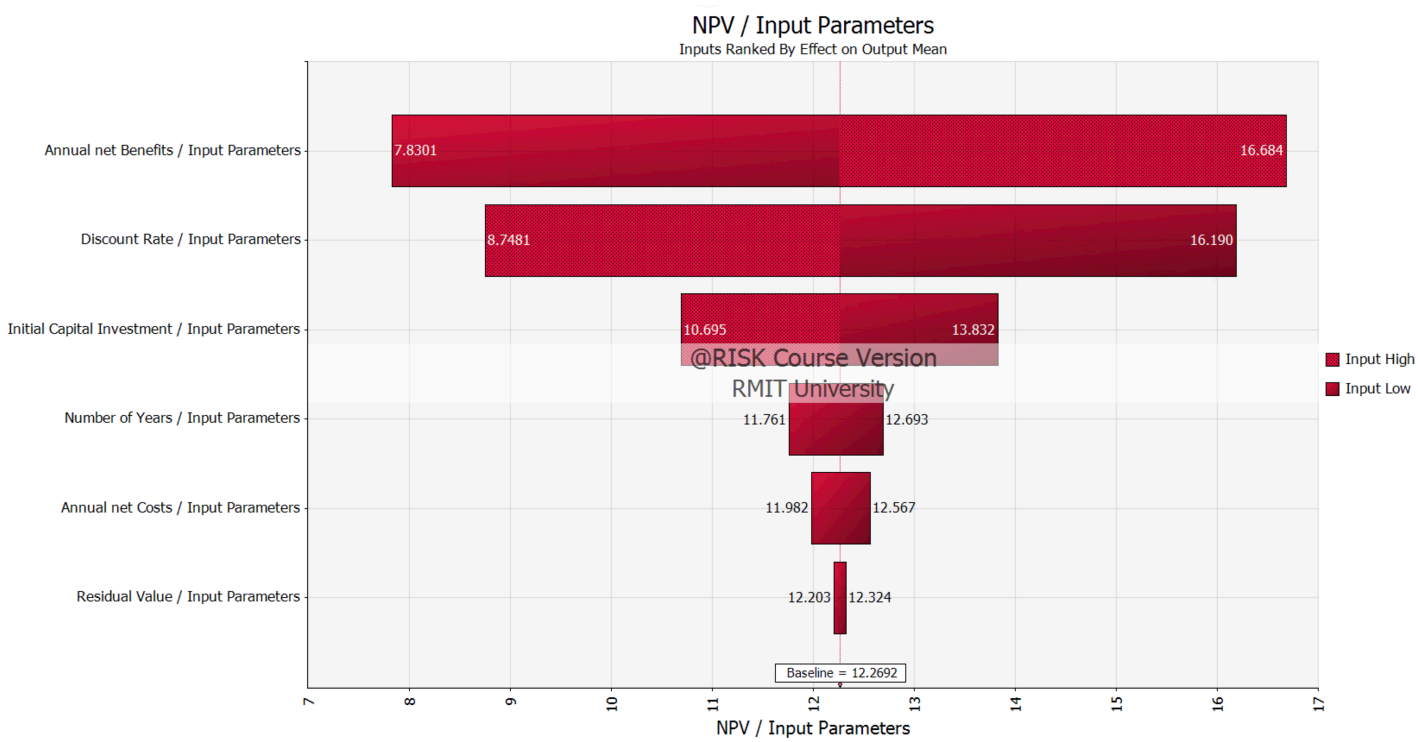


Figure 1

For the Tunnel

Distribution Type	Task	Parameters		Input Parameters
Uniform	Initial Capital Investment	Min	Max	
		33.35	36.87	35.11
Normal	Annual net Benefits	μ	σ	
		3.66	0.183	3.66
Normal	Annual net Costs	μ	σ	
		0.24	0.012	0.24
Normal	Discount Rate	μ	σ	
		0.07	0.0035	0.07
Normal	Number of Years	μ	σ	
		50	2.5	50
Uniform	Residual Value	Min	Max	
		3.34	3.69	3.51

Table 8

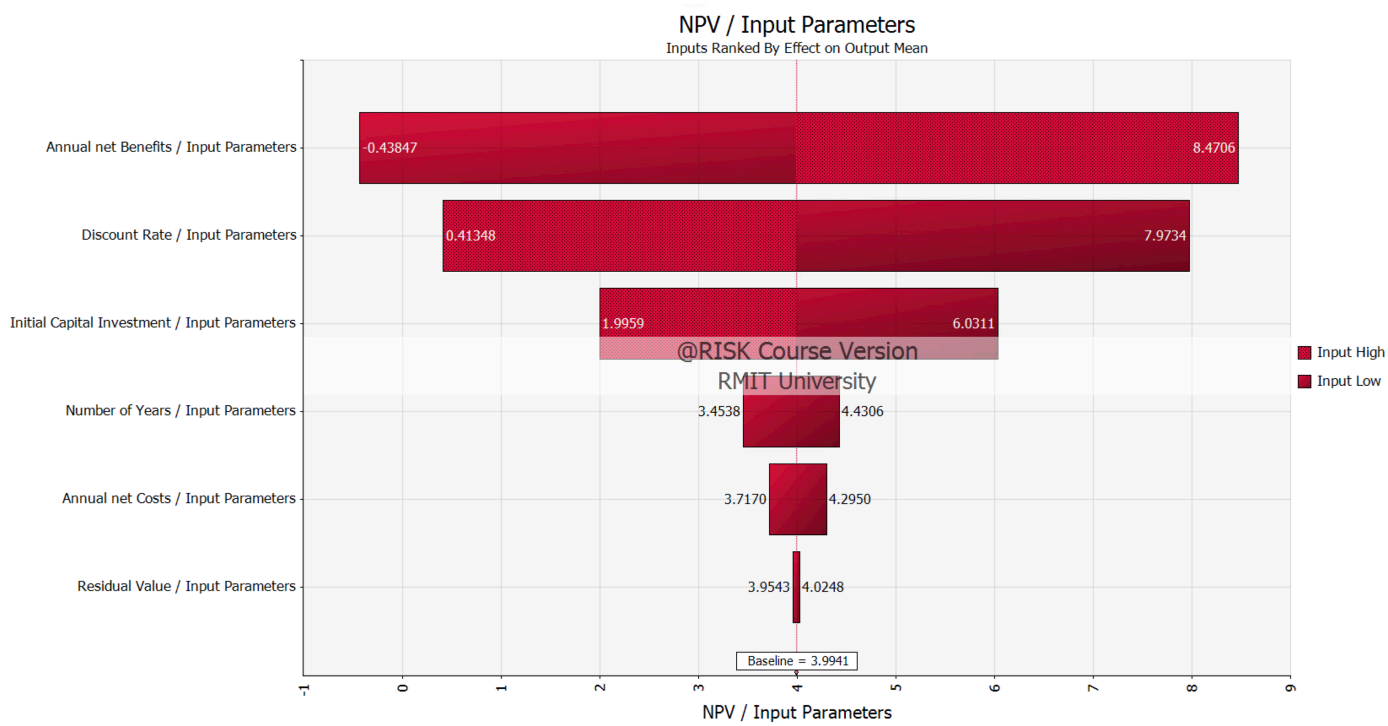


Figure 2

We find the first two important factors are Benefit and discount rate. So we need do more research on these two factors to predict them more accurate.

5. Non economics-based assessment

Alongside economic considerations, there are other factors that make a big difference in the final decision of a project.

5.1 Engineering concerns

Sometimes a project might be economically viable, but it is overly complex and poses serious potential safety risks, and in such a case, that project's options should be reconsidered.

Ground property:

Because one of the options is constructing an underpass, the quality of the ground at the project site plays a significant role in the feasibility of the construction of a tunnel. If the ground is too hard, it makes the project a lot more costly to finish, as well as taking a lot more time. If the ground is too soft/unstable, it might affect the surrounding buildings.
For the location of the high street, we can see from the map taken from the official website of the project.

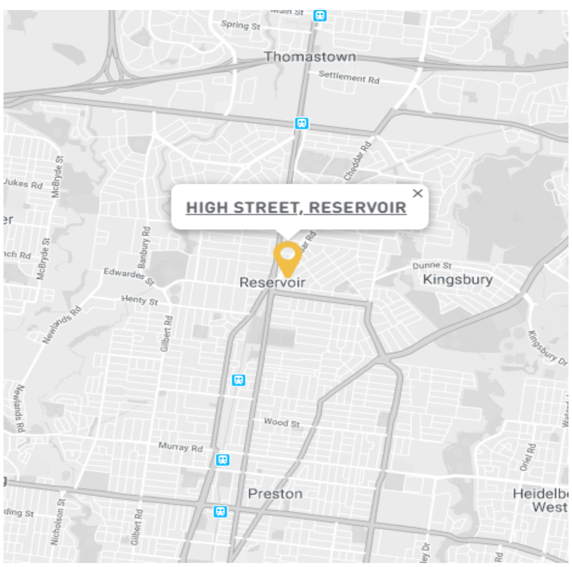
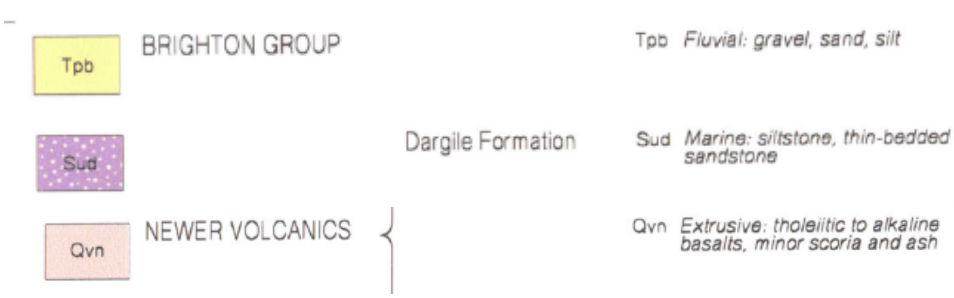


Figure 3. Location of the project

Figure4. Geological map of the area

Combined with these two maps. We can see that the location of the High street project is either denoted as Tbp, Sud or Qvn, definitions of which are provided in the legends as follow:



The former two are soft rocks, and the latter is a very hard rock. Considering that the length of the rail track is heavily restricted by the grade limit, if a tunnel were to be built, it would encounter a combination of two or more of those geological features. And because of this, the monetary and time cost would be **significantly higher than that of building an overpass.**

Annual/seasonal precipitation

Another primary concern in building and maintaining a tunnel/underpass is flooding. Depends on the annual/seasonal rainfall of the local area, the cost for construction, as well as potential delays, varies drastically. According to the Australian Bureau of Meteorology, the annual rainfall average of the area is approx. 600mm/year (Bureau of Meteorology, 2010), which is fortunately not a lot, and therefore **the feasibility of neither the underpass nor the overpass is affected.**

5.2 Environmental Impact

While it is positive environmental impacts of the project is well researched and documented, the focus of this report is to explore the different impacts that the two options in discussion will affect the environment.

Building a rail tunnel/underpass

Building a rail underpass will involve using a tunnel boring machine (TBM), which would be assembled on-site, then used to excavate the length of the tunnel. An Average TBM in steady, stable ground moves around 15 meters a day. For a tunnel length of 1km, it would take 66 workdays in the right conditions.
Although many TBMs are electric-powered, there are still many diesel-powered, the emission of which is not only greenhouse gases but also very harmful to humans. However, even with electric TBM, the supporting equipment will also contribute to emission. Most notably dump trucks that move the debris away from the site, as well as moving concrete (raw or prefabs) to the site. Additionally, some pumps move water that acts as a lubricant and to remove the debris, generators for networks, etc.
Aside from air pollution, there is a risk of ground/underground water pollution from the tedious process. However, proper surveying and caution during excavation will mitigate this risk considerably.
For this assessment, we assume that the TBM that would be used is electric-powered, which reduces the emission by a significant amount.
The first calculation would be the CO2 emission from freighting the debris away from the excavation site, using 32tons capacity trucks.

Tunnel length (m)	TBM cutterhead Diameter (m)	Number of tunnels	Total Volume (m^3)	Debris density (ton/m^3)
450	7	3	51954.08851	2
Total Weight (ton)	Truck Capacity (ton)	Number of trips	Distance per trip (km)	Total distance (km)
103908.177	32	3247.130532	20	129885.2213

Table 9: Volume of debris and transport distance calculations

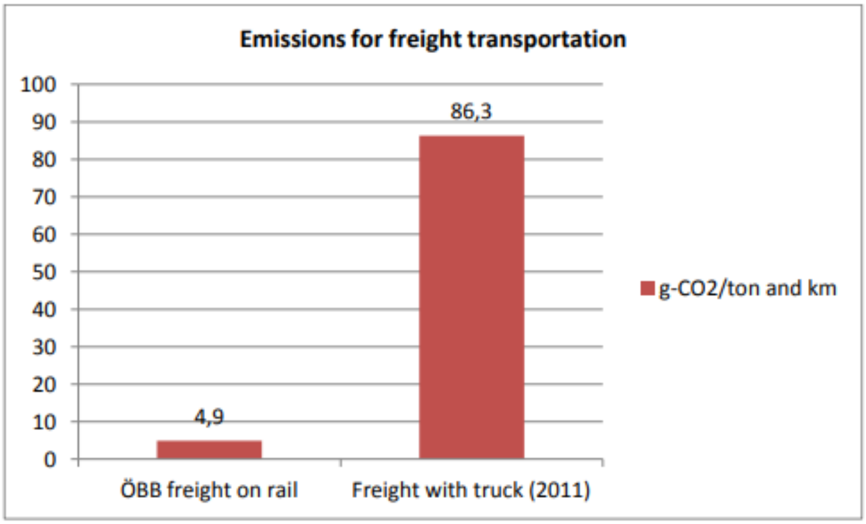


Figure 6- Emissions for freight transportation

Figure 5. Emissions for freight transport (Fahnehjelm, 2014)

	Average Diesel engine exhaust composition (Reif 2014)[17]	Average Diesel engine exhaust composition (Merker, Teichmann, 2014)[18]
Species	**Mass percentage**	**Volume percentage**
Nitrogen (N_2)	75.2 %	72.1 %
Oxygen (O_2)	15 %	0.7 %
Carbon dioxide (CO_2)	7.1 %	12.3 %
Water (H_2O)	2.6 %	13.8 %
Carbon monoxide (CO)	0.043 %	0.09 %
Nitrogen oxide (NO_x)	0.034 %	0.13 %
Hydrocarbons (HC)	0.005 %	0.09 %
Aldehyde	0.001 %	n/a
Particulate matter (Sulfate + solid substances)	0.008 %	0.0008 %

Figure 6: Diesel emission composition by mass

From these two figures above, using Merker's estimations, we can calculate the NOx and Sulfate emission of the trucks based on the amount of CO2:

	% by mass	Weight (g/km.ton)	Total Emission (kg)
CO2	12.3	86.3	269018270.3
NOx	0.13	0.912113821	2843282.532
Sulfates	0.0008	0.005613008	17497.12327

Table 10: Emission mass calculations

Using these numbers, combined with factors of environmental impacts, we can calculate the effective impact of these emissions to the environment:

		Factors			Impact		
	Total Emission (kg)	GWP	AP	HTP	GWP	AP	HTP
CO2	269018270.3	1	NA		269018270.3		
Nox	2843282.532	206	0.5	1.2	585716201.5	1421641.266	3411939
Sulfates	17497.12327	NA	1.2	0.1		20996.54793	1749.712
				Total	854734471.8	1442637.814	3413689

Table 11: Equivalenced environmental impact of emissions from freight trucks

Building a bridge/overpass

Building an overpass will not involve as much on-site heavy equipment as a tunnel would, because once the foundations are built, the bridge itself can be assembled using prefabs produced off-site, and crane towers do not produce emission. Nevertheless, unlike a tunnel, where an electric TBM would excavate the ground, as well as seal the tunnel and install concrete slabs in place, heavy construction vehicles would need to prepare the foundation of the bridge, which would result in closing the railway during the preparation period. This will create more emissions from diverted traffics and train replacement buses. This number, however, is negligible compared to that of the diesel-powered trucks that would be involved in tunnel construction.

Emission from material and construction

Because of the grade limit, if a tunnel were to be constructed, the length would be 450m, but if a bridge was the choice, it would be 750m. This would result in different level of emission from the production of the materials used during construction.
Taking into consideration the CO2 emission in the production of steel and concrete, as well as on-site equipment, the figure below provides the emission of building bridges.

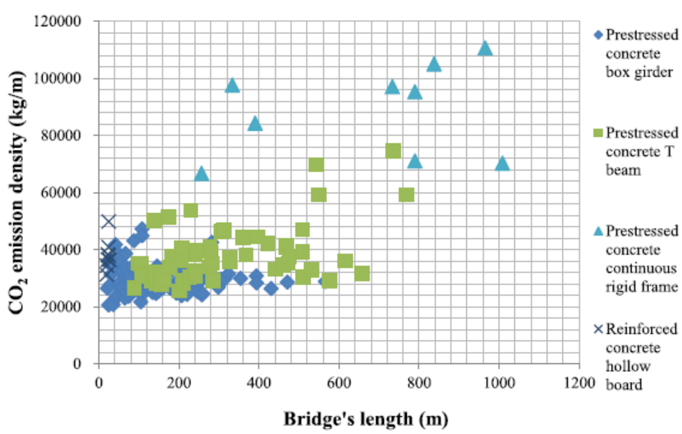


Figure 7. Emission density from material and construction activities for bridges (Wang et al. 2014)

For this assessment, the type of bridge used will be Prestressed concrete box girder, 750m long, and the value of CO2 emission density used will be 27500kg/m.
And in the figure below, the emission density of building different types of bridges:

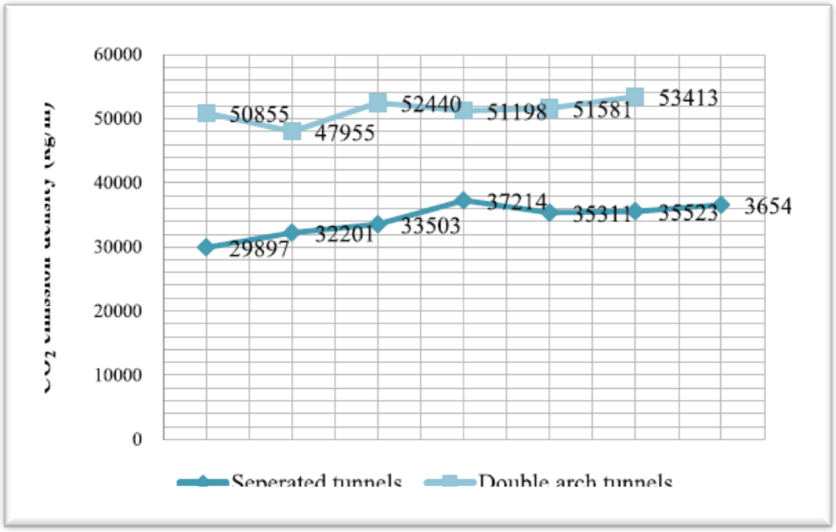


Figure 8. Emission density from material for tunnels (wang et al. 2014)

For this assessment, the type of tunnel used will be double arch tunnel, 450m long, and the value of CO2 emission density used will be the average of the values in the figure at 51240kg/m.
Using these values, the total emission for each project option is calculated as below:

Structure	Length	CO2 emission (kg/m)	**Total CO2 Emission (ton)**
Bridge	750	25700	**19275**
Tunnel	450	51240	**23327.0182**

Table 12: Total estimated CO2 emission comparison

5.3 Social Impact Assessment (SIA)

This section will identify the factors that most significantly affect the community due to each grade separation option respectively. Subsequently, their importance to the inhabitants of the community is established. For this study, information is collected through the distribution of questionnaires in the local community along with considerations from existing statistical data, prevalent legislation, and past project documentation.
Each of the factors is first explained, and the method which was used to estimate their weight is laid out. This is followed by a quantitative analysis of the available data to decide between option one and option two.

Factors Affecting the Community

In light of comprehensive studies done on previous similar projects, there are *seven* key social factors or *criteria* that need to be considered (Taylor and Crawford, 2009).

Risk of death or injury:

There are more than 21000 level crossings in Australia, and therefore safe for the commuters, and the pedestrians using the level crossing are a primary concern. An essential objective of the grade separation is to bring to zero the number of fatalities or near misses at intermodal transport junctures. (ARTC, 2016). The determination of the weight of this factor was derived from the results of the questionnaires and the data collected from VicRoads (Crash Stats 2018) and the Australian Level Crossing Assessment Model (ALCAM 2007) study.

Bridged rail is expected to score higher than tunneled rail as surveillance is trying for and robberies and assaults are more common in underground stations. Bridged rail is expected to score higher than tunneled rail as surveillance is difficult for and robberies and assaults are more common in underground stations.

Community Severance:

Community severance is defined as the *barrier effect* that is caused by physical elements in the landscape, such as roads and rails. This has an adverse effect on the movement of pedestrians and social interaction between the sides separated by the physical element (Paulo Rul Anclaes, 2015.) An increased community severance is undesirable as it divides the community and also negatively affects business and development opportunities in the area. For example, if there is a common marketplace for the area, a poorly designed grade separation could make it difficult for one side of the community to access it.

Since underground stations allow ample space for above ground movement, tunneled rail is expected to score higher. Scores are determined through public and project stakeholder feedback.

Visual Amenity:

Visual amenity is defined as the degree of how much a project affects factors such as landscape, lighting and aesthetics of an area. To carry out an effective analysis on the visual impacts of the projects, it is necessary that a thorough study of the landscape is done and *sensitive visual receptors* are identified. These are locations in the area for which the view will change the most. Subsequently, two techniques are used to present stakeholders how the area will look after the completion of the project; *photographic montage representation,* which is a conceptual graphic representation of the area post project completion, and *3D Visualization,* in which a 3D model of the area with the project incorporated is constructed. Points of concern are identified and a mitigation action is proposed. (New Hope Group, 2015).

The determination of the weight for this factor was made by stakeholder reviews of the models presented. Tunneled rail is expected to score higher as bridged rail will expose all the structures and will require detailed aesthetics (Taylor and Crawford, 2009).

Noise Amenity :

Noise amenity is defined as the degree of exposure to traffic noise to the residents of a community. As a general guide, a traffic noise level of over 16 L_{10}(18h) dB(A) requires further investigation resulting in mitigation action. A noise assessment is carried out by first determining the existing acoustic environment and predicting the noise impact over a 10 year period. Noise reduction strategies are introduced and recommendations are incorporated into the current project design. (Department of Transport and Main Roads, 2013).

The statistical data for noise related to each option was collected from previous experiences and the results communicated to stakeholders. In light of available data and stakeholder response, a weightage for noise amenity was established. Tunneled rail is expected to score higher as bridged rail will allow the noise to spread over a larger area (Taylor and Crawford, 2009).

Potential for Development:

Past experience with similar projects has shown that grade separations often create opportunities for significant development in the adjoining areas resulting in increased livability and business opportunity. It is an objective of this project to ensure new public space can be created easily and be activated for passive and active community recreational uses (Woodcock and Stone, 2016).

Determination of factor weight here is very subjective however data from previous similar projects and the views of long term residents of the area were considered. Bridged rail is expected to score better because in several previous instances, it has provided potential for active frontages to develop where they previously could not (Woodcock and Stone, 2016).

Improvisation of Connectivity and Accessibility:

A primary objective of the project is to *increase* the transport connectivity in the area and make it more accessible. This means that *intermodal transfers* (changing the medium of transfer, for example, from a train to a tram) become easier, safer and accessible (that is, in compliance with Disability Discrimination Act). Furthermore, the project must enhance transport efficiency (Mayor of London, 2002). This factor essentially defines the need for the project and, therefore, in consultation with urban planning and transport experts, enjoys a high weightage. Scores are determined through advice of experts.

Preserving Sites of Social Significance:

The stakeholders of the project recognize the significance of the historical sites and the project aims to maintain either the status quo for these sites or afford permissible upgradation. (Level Crossing Removal Project, 2019). The sites are appraised based on local knowledge and inspection of mapping and aerial photography (Taylor and Crawford, 2009). The weightage and respective scores have been assigned with respect to the local sentiment about the sites.

Scaled Checklist

This segment considers the above-mentioned criteria in context of the two plans proposed for the High Street Level Crossing Removal project. The method used is called *Scaled Checklist.* Each criterion is awarded a *weight*, which highlights the importance of that factor and a *score*, which is marker of how well a proposed plan addresses the particular criterion. (UNU, 1995).
The *weight* is assigned a number between 1 and 5, 5 being 'indispensable' and 1 being 'not important.' The *score* is assigned a number between -5 and +5, -5 being 'Plan addresses this criterion poorly' and +5 being 'Plan addresses this criterion efficiently.'
Option 1 is 'Elevated Rail (Railway Bridge)' and Option 2 is 'Depressed Rail (Tunnel)'. The *aggregated weighted score* for each plan is calculated and the one with the highest points is selected.

We take a questionnaire and collected 16 views on stakeholders for the weights of these seven factors.

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	AVG
Safety	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	**4.88**
Convenience	2	4	5	5	5	3	3	3	2	5	4	4	4	4	4	4	**3.81**
Visual	3	2	3	4	3	1	1	2	2	3	3	2	2	4	1	3	**2.44**
Noise	2	3	3	4	4	3	4	3	2	3	4	4	4	4	5	5	**3.56**
Development	2	3	3	3	2	2	3	3	2	3	2	3	3	3	3	1	**2.56**
Disabled	5	5	4	4	5	4	4	4	3	4	3	3	1	3	2	2	**3.5**
Historical Sites	2	3	3	3	2	2	3	3	1	3	2	2	1	3	1	2	**2.25**

Table 13. Result of weight

We take the average of the above weights and use this average weight to calculate the final score.

Criterion	Weight	Scores		Weighted Scores	
		Plan 1 (Bridge)	Plan 2 (Tunnel)	Plan 1 (Bridge)	Plan 2 (Tunnel)
1	4.88	1	-1	4.88	-4.88
2	3.81	-1	3	-3.81	3.81
3	2.44	-1	1	-2.44	2.44
4	3.56	-1	1	-3.56	3.56
5	2.56	2	1	5.12	2.56
6	3.50	3	1	10.5	3.5
7	2.25	1	1	4.5	2.25
Total				**15.19**	**13.24**

Table 14. Aggregated weighted score for each plan against given criteria

The analysis shows that Plan 1 (Bridge) has a narrow edge over Plan 2 (Tunnel). This section therefore recommends grade separation to be carried out through elevated rail (bridge) option.

6. Decision making and recommendation

For this level crossing removal project, based on calculative Economical analysis measured close to precision, and non-economic based assessment relying on Social and Environmental influences each option possess, ultimately, the construction of Bridge is more feasible and reliable for the better option. Although, there is a slight disadvantage in the annual operating cost compared to that of tunnel by about $ 0.03 million dollars for an equal annual benefit, however, this doesn't halt the Bridge's dominance having Benefit Cost ratio 1.32 over 1.08 that of Tunnel and Payback period being 2.42 years earlier than Tunnel. With initial investment $8.72 million dollars cheaper, the Internal Rate of return for the Bridge project proved feasibility scoring 10.14% of the 8% benchmark, even though we relied mostly on the Net present value as the best indicator of feasibility as IRR could be misleading. The net present value of the Bridge project showed 12.21 million while the Tunnel had 3.93 million. Thus the financial and economic based appraisal certainly proved construction of bridge to be the better choice for removing level crossing at High Street, Ginley.

Evaluations made on the environmental and social impact of these two projects, were focused on the pre, post and during, long-term and short-term influences. The ground property assessment proved that constructing bridge is monetary and time-cost efficient as the geological map of High Street demonstrated a mixture of hard rock, causing hindrance in building a tunnel. Comparing on the emission pollution produced from materials and during construction, considering Prestressed concrete box girder for a 750m long bridge, and double arch type tunnel, 450m long, the average CO_2 emission density predicted a difference of 3962.97tons less for Bridge. Then the Social Impact Assessment, based on Risk of death or injury, Community Severance, Visual Amenity, Noise Amenity, Potential for Development, Improvisation of Connectivity and Accessibility and Preserving Sites of Social Significance, each weighted and assigned a score for Scaled Checklist evaluation, shows that Plan 1 (Bridge) has a narrow edge over Plan 2 (Tunnel), therefore recommends grade separation to be carried out through elevated rail (bridge) option.

In conclusion, the calculative Economic, and Non-economic appraisal evaluated to the best of our knowledge backed with reliable resources and literature analyzed from previous implementation, and taking into consideration the most practical measure in prediction, Grade Separation by bridge proves to be the most feasible and optimal method to encounter the level crossing removal concern.

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Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	4
Convenience	2
Visual Amenity	3
Noise Amenity	2
Potential for Development	2
Accessibility for the disabled	5
Preserving historical sites	2

Signature: WEi Yan

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	4
Visual Amenity	2
Noise Amenity	3
Potential for Development	3
Accessibility for the disabled	5
Preserving historical sites	3

Signature: Tina

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	5
Visual Amenity	3
Noise Amenity	3
Potential for Development	3
Accessibility for the disabled	4
Preserving historical sites	3

Signature: Doay

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	5
Visual Amenity	4
Noise Amenity	4
Potential for Development	3
Accessibility for the disabled	4
Preserving historical sites	3

Signature: Joy

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	5
Visual Amenity	3
Noise Amenity	4
Potential for Development	2
Accessibility for the disabled	5
Preserving historical sites	2

Signature:

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	3
Visual Amenity	1
Noise Amenity	3
Potential for Development	2
Accessibility for the disabled	4
Preserving historical sites	2

Signature: Robert

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	3
Visual Amenity	1
Noise Amenity	4
Potential for Development	3
Accessibility for the disabled	4
Preserving historical sites	3

Signature: ZHAO

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	3
Visual Amenity	2
Noise Amenity	3
Potential for Development	3
Accessibility for the disabled	4
Preserving historical sites	3

Signature: Mandy

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	4
Convenience	2
Visual Amenity	2
Noise Amenity	2
Potential for Development	2
Accessibility for the disabled	3
Preserving historical sites	1

Signature: ____________

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	5
Visual Amenity	3
Noise Amenity	3
Potential for Development	3
Accessibility for the disabled	4
Preserving historical sites	3

Signature: Keri

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	4
Visual Amenity	3
Noise Amenity	4
Potential for Development	2
Accessibility for the disabled	3
Preserving historical sites	2

Signature: Mr Liu

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation: 'Safety**' means the impact on travel and personal safety caused by bridges or tunnels; **'Convenience'** means the potential obstacles when you cross them; **'Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	4
Visual Amenity	2
Noise Amenity	4
Potential for Development	3
Accessibility for the disabled	3
Preserving historical sites	2

Signature: Monica.

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation**: '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	4
Visual Amenity	2
Noise Amenity	4
Potential for Development	3
Accessibility for the disabled	1
Preserving historical sites	1

Signature: Kaidnd;

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation:** '**Safety**' means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	4
Visual Amenity	4
Noise Amenity	4
Potential for Development	3
Accessibility for the disabled	3
Preserving historical sites	3

Signature: Owen

Questionnaire

We are doing a risk report of comparing the two options of remove level crossing which are building railway bridge and building railway tunnel.

We divide the following criteria of social impact into to 5 levels (**1 never care /2 don't care too much/ 3 better to have/ 4 important / 5 indispensable**).

Please tell us(choose number) that if you are one of the nearby residents, what you care most about the new structure that should be built to remove the level crossing.

(**Explanation: 'Safety'** means the impact on travel and personal safety caused by bridges or tunnels; '**Convenience**' means the potential obstacles when you cross them; '**Potential for Development**' means the positive impact on community development and ease or complexity of future expansion)

Criteria	Level
Safety	5
Convenience	4
Visual Amenity	1
Noise Amenity	5
Potential for Development	3
Accessibility for the disabled	2
Preserving historical sites	1

Signature: [illegible]

Questionnaire

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Criteria	Level
Safety	5
Convenience	4
Visual Amenity	3
Noise Amenity	5
Potential for Development	1
Accessibility for the disabled	2
Preserving historical sites	2

Signature: ____________