ZZCA6510 2: Quantitative Decision Analysis

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1 Decision Tree

In the case of Samuel Jackson vs CXC Construction Company, Mr Jackson, after initially claiming $1.5 million in damages, has offered to settle for $750,000. The legal representative of CXC Construction, Howard Insurance, has two options; the first is to accept the offer and settle for $750,000, and the second is to make a counter-offer of $400,000.

This is considerably lower than the $750,000 claimed, but if Mr Jackson accepts it, then CXC Construction will have saved a substantial amount of money. However, precisely because this counter-offer is so low, there is only a small chance of him accepting it.

Part (a)

Surprisingly, the best decision is for Howard Insurance to make the $400,000 counter-offer. Mr Jackson's possible responses are as follows:

- There is a 40% chance of Mr Jackson rejecting the offer and going immediately to trial. If this happens, the expected damages bill (when the three possible jury decisions are weighted against their probabilities) will be $825,000.
- The more likely outcome, with a 50% chance of occurring, is that Mr Jackson will make a new counter-offer of $600,000. At this point, a second decision must be made, on whether to accept this counter-offer or to go to trial, where the expected outcome is again $825,000. Here, the best choice would be to accept the $600,000 counter-offer and avoid the trial.
- The least likely scenario, at 10%, is that Mr Jackson accepts the $400,000 counter-offer.

The expected damages bill, when these three responses are weighted against their probabilities, is $670,000. This means that ultimately, making the $400,000 counter-offer is likely turn out cheaper than accepting the $750,000.

This recommendation is validated by the decision tree shown in Figure 1. This tree depicts all the decisions that Howard Insurance is required to make on behalf of CXC Construction, as well as all the possible outcomes of those decisions. Starting at the final outcomes, the expected damages at each branch are calculated by weighting the outcomes against their probabilities. These are back-propagated until the start of the tree is reached, where the recommended decision path, and its expected cost, become apparent.

Part (b)

Once a $400,000 counter-offer is made, Mr Jackson will respond in one of three ways; these are listed above. Two of these responses will lead to a final outcome with no further input required by Howard Insurance:

- Mr Jackson unexpectedly accepts the $400,000 settlement, thereby limiting the final cost to this relatively small amount.

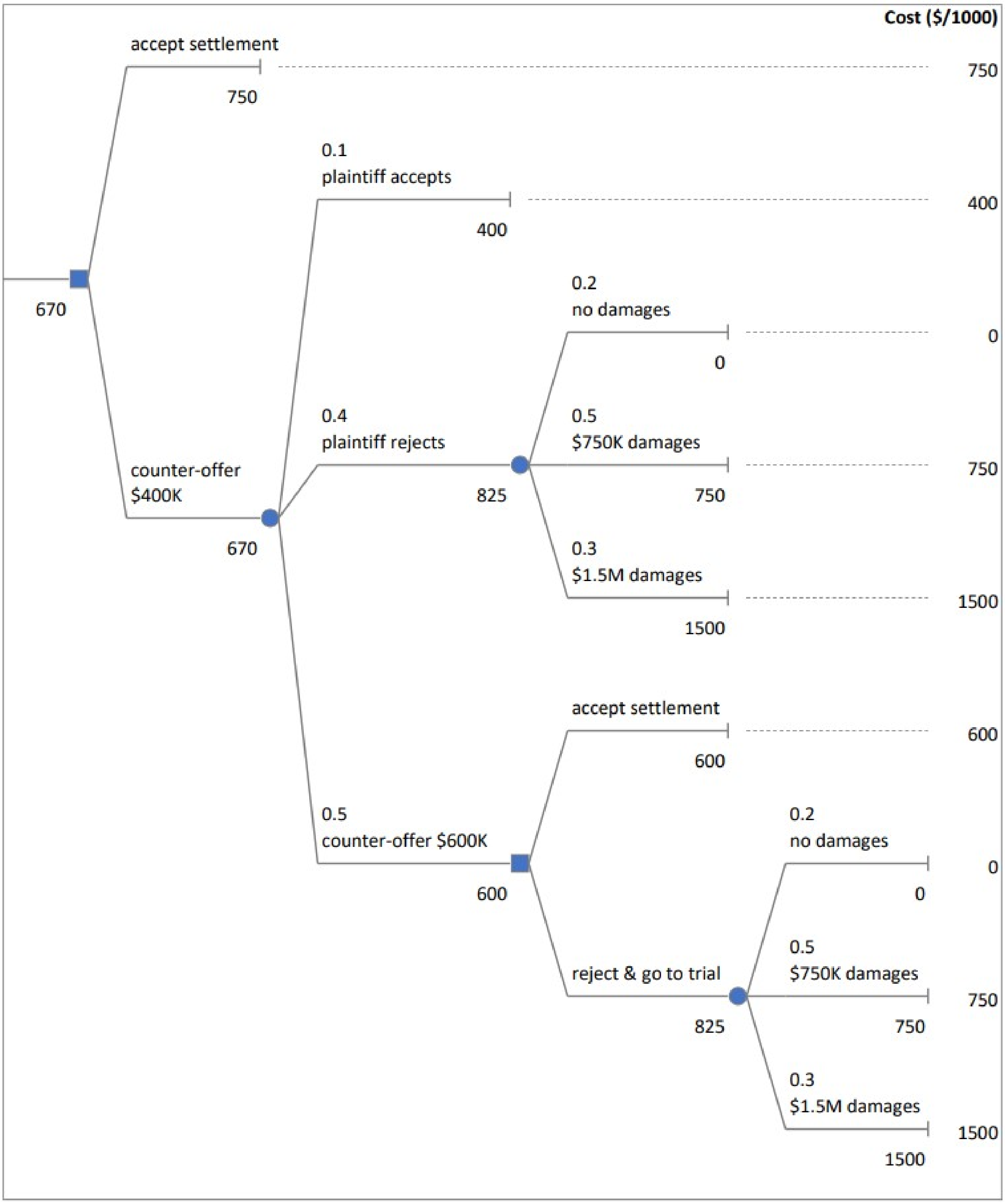

Figure 1: Decision Tree

- Mr Jackson is sufficiently aggrieved to terminate negotiations and go immediately to trial. As discussed earlier, the expected outcome of this scenario is a $825,000 damages bill.

However, the third possible response, which is a $600,000 counter-offer, will require a second decision to be made; whether to accept the offer or go to trial. As discussed earlier, the expected damages bill after a trial is $825,000, which is substantially higher than the $600,000 payout.

Therefore, once a $400,000 counter-offer has been made, the recommendation is to accept any future counter-offer and avoid a trial.

2 SMART Analysis

Danaos Corporation has secured office space at Karabar; however, the QueanBeyan and Palerang Regional Council (QPRC) would like to acquire this site and has offered Danaos Corporation a choice of four alternative sites.

Part (a)

To decide between these four sites, as well as the original site at Karabar, the CEO of Danaos Corporation has identified a number of attributes (criteria), and assigned them weights to convey their relative importance. These weights have been normalised as shown in Table 1.

	Raw	Normalised
Closeness to Customers	70	23
Size of Site	100	32
Car Parking Facilities	90	29
Visibility	10	3
Working Environment	40	13

Table 1: Normalised Weights

In addition, the CEO has scored each of the five sites for their performance on the specified attributes. These have been used, in conjunction with the aforementioned weights, to calculate a weighted sum of all the scores for each alternative. These weighted sums represent the aggregate benefit of leasing the sites, and are shown in Table 2.

	Queanbeyan	Bungendore Dr	Isabella St	Jerabomberra	Karabar
Closeness to Customers	0	70	30	100	90
Size of Site	70	0	100	80	100
Car Parking Facilities	80	100	30	20	80
Visibility	100	30	50	70	20
Working Environment	50	90	70	0	100
Aggregate Benefit	55.5	57.4	58.4	56.5	89.4

Table 2: Weighted Sums

	Rates ($)	Power ($)	Maint ($)	Total ($)
Queanbeyan	105000	50000	25000	180000
Bungendore Drive	60000	40000	40000	140000
Isabella Street	35000	45000	45000	125000
Jerabomberra	75000	20000	35000	130000
Karabar	90000	25000	50000	165000

Table 3: Costs

Following this, itemised costs that were provided by the CEO have been aggregated to give the overall cost for each site (refer to Table 3). When the aggregate benefits for the alternative sites are plotted against their costs, an efficient frontier becomes apparent, as seen in Figure 2.

This efficient frontier connects the sites that dominate the others. There are two sites in contention for selection: Isabella St and Karabar. Although Isabella St is much cheaper than Karabar, it also represents a heavy drop in benefit value. Given that the CEO was already content with paying for Karabar, the recommendation is to remain at Karabar.

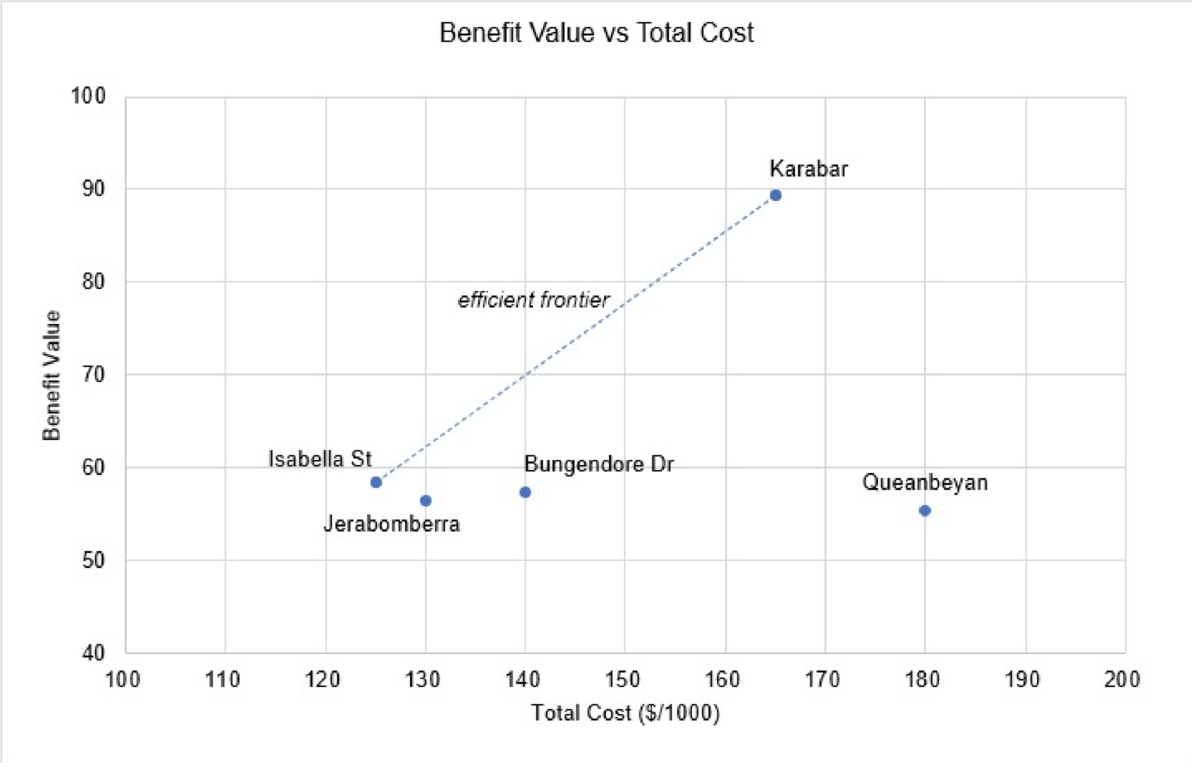

Figure 2: Efficient Frontier

If the efficient frontier is discarded and all the data points are placed back into contention, then it is clear that moving to any of the four alternative sites would represent a significant drop in benefit value. This validates the recommendation to remain at Karabar.

Part (b)

If the CEO decides to move to a different site, then it should be noted that all four sites have a benefit value somewhere between 55 and 60, making them all similar in this regard. However, they are markedly diverse in terms of cost.

QueanBeyan would be more expensive than Karabar, for a smaller benefit, and should be disregarded immediately. Of the remaining choices, Isabella St is both the cheapest and the most beneficial. Therefore, the recommendation is to choose Isabella St.

Part (c)

Sensitivity analyses have been undertaken on the three attributes that were deemed by the CEO to be most important: closeness to customers, size of site and car parking facilities. Graphs for these analyses are shown in Appendix A.

The outcomes of the analyses are as follows:

- If the weight of any attribute of interest is changed, Karabar continues to be the best choice, regardless of how high or low the new attribute weight is.
- During all the sensitivity analyses, none of the alternate sites are able to compete at all with the benefit value of Karabar, with the exception of Bungendore Place, when the weight of the size attribute drops to 0.

Overall, it can be concluded that the SMART process for deciding between office sites is robust against changes to the most important attributes.

3 Independent Analysis

3.1 Abstract

The Victorian government is engaged in an extensive program of public infrastructure works, with a specific focus on road and rail (State Government of Victoria, 2022). However, the process by which the government identifies, prioritises and commits to these projects is not publicly documented, and this has led to some doubt as to whether roadworks funding is being targeted in the most beneficial way.

This analysis makes the case for wider adoption of MCDM (multi-criteria decision making) methods in planning processes, and demonstrates the use of one such method, SMART, in the identification of a road location that is most in need of safety improvements. This procedure is shown to be effective and robust for such purposes, and an entreaty is made to the Victorian government to employ MCDM in a program of transparent and defensible decision making.

3.2 Introduction

The purpose of this analysis is to assess and shortlist the most dangerous road locations in Victoria, and then to use a multi-criteria decision analytics approach to select the location that is most in need of major redevelopment.

The impetus for this undertaking came from an observation that was recently made in the author's locality in Victoria. This observation was of a local road and intersection that have undergone a costly, time-consuming and disruptive reconstruction process (Major Road Projects Victoria, 2021b), only to appear, at the conclusion of these works, to have changed very little in terms of both function and appearance.

The road and intersection in question have never been marked by severe traffic congestion or frequent collisions. Publicly available data show that the intersection, denoted in records by the identifier 332806, was involved in only 4 collisions in the five-year period to June 2020 (VicRoads, 2021a). Furthermore, the government has not published - or validated - the process by which this location was prioritised.

By contrast, the method proposed in the present analysis, multi-criteria decision-making (MCDM), has been validated as an approach to road infrastructure planning by researchers. The analytical heirarchy process (AHP) has been used to assess and prioritise road surface repairs (Miyamoto and Ximenes, 2021), and a hybrid approach combining multi-criteria and cost-benefit analyses has also been done (Gühnemann, Laird, and Pearman, 2012). In addition, Patel et al. (2017) validates the applicability of SMART (simple multi-attribute rating technique) across a broad range of technical and planning activities.

The present analysis is, however, limited in that an exhaustive investigation and primary data collection cannot be done due to time and budget constraints. Because of this, care has been taken to only select attributes about which information is already available, while ensuring that the main causes of road risk are adequately covered. To this end, the author has made use of data published online by government bodies, either as downloadable data files or as interactive web applications.

Despite these limitations, a considerable amount of relevant data have been found, leading to the shortlisting and subsequent selection of a road location that is most in need of redevelopment. Furthermore, the process has been found to be robust against changes. It is hoped that this analysis can provide a blueprint from which the Victorian government may make sound, evidence-based, planning decisions.

3.3 Problem Identification

The identification of road improvement as a suitable subject for a decision analytics problem came about as a result of the author's failure to locate information justifying the major reconstruction works being undertaken at the intersection mentioned earlier.

Attempts were made to establish the rationale for the Victorian government's decision to redevelop this road and intersection. These attempts have been fruitless; the only available information pertains to the purported benefits of the project, and a discussion of some community consultation that occurred after a commitment was already made to proceed (Major Road Projects Victoria, 2021a).

This was followed by an examination of Victorian government websites, in order to find the following:

- a list of "black spot" intersections; these are intersections that are marked as particularly dangerous, which are sometimes allocated funding for improvement works by the federal government (Australian Government Department of Infrastructure, Regional Development, Communication and the Arts, 2022)
- any form of analysis or documentation, such as a cost-benefit analysis or a business case, that explains how and why any road project has been approved in recent years

While they may be publicly available, none of these documents could be found within a reasonable amount of time. There is documentation on the processes that VicRoads, the body responsible for smaller projects like the installation of safety barriers, uses when identifying and prioritising potential targets for improvement (VicRoads, 2016). However, it is not apparent that this has been used in major construction projects, which are outside VicRoads' scope of work.

From the above, it is apparent that the government does provide information about the benefits of major improvement works, but only after it has committed the resources. Additionally, while there is some information - through VicRoads - about the processes the government might use, there is no publicly available evidence of their use in specific projects.

It is this absence of evidence of a methodical approach to roadwork prioritisation that motivates the present analysis. MCDM has already been endorsed for its utility in transport planning projects. Of particular note is the encouragement of MCDM methods by Infrastructure Australia and the Queensland Department of Transport and Main Roads (Queensland Department of Transport and Main Roads, 2016), both of which have published detailed technical guidelines on assessing projects. In addition, research such as that by Akpan and Morimoto (2021), wherein multi-criteria methods are used to prioritise repairs to a large number of rural roads, as well as the studies mentioned earlier, comprehensively build the case for Victorian adoption of MCDM in road infrastructure planning.

However, the aforementioned studies involve extensive data collection and the use of specialised equipment to quantify the specified attributes; by contrast, the author of the present study seeks to show that a desktop analysis, relying only on data that are already available, can be a capable and efficient stand-in when resources are constrained.

3.4 Solution Approach

SMART (simple multi-attribute rating technique) has been deemed the most appropriate method for evaluating different road locations for redevelopment. This procedure provides a methodical approach that gives proportionate consideration to competing objectives, preventing a decision that overemphasises one objective to the detriment of others (Goodwin and Wright, 2014). In addition, the attention paid to the selection and measurement of attributes enables a decision-making process that is transparent and defensible (ibid.), qualities that are particularly important for government accountability.

The SMART approach is, as its name suggests, simple. As outlined by Patel et al. (2017), the procedure involves the following actions:

1. Identify the person(s) who will make the decision.
2. Identify the problem.
3. Identify the decision alternatives that should be considered.
4. Select attributes (criteria) upon which to compare the alternatives.
5. Order the attributes from most important to least.
6. Assign each attribute a weight that represents its importance, relative to the other attributes.
7. Normalise the attribute weights.
8. For each attribute, rank the alternatives such that a rank represents the degree to which the
9. decision maker prefers this alternative to the others.
10. For each alternative, compute a weighted sum using its own scores and the attribute weights.
11. Make a decision - this is likely to be the alternative with the highest weighted sum.

At the end of this procedure, the alternative with the highest weighted sum is considered to be the strongest candidate when the competing criteria are considered together, with proportionate consideration given to each one.

AHP (analytical heirarchy process) was also considered, but this is more appropriate when many of the selected attributes are non-quantifiable. In the present case, all of the selected attributes are quantifiable, either directly or indirectly, making them good candidates for evaluation through value functions such as those used in SMART.

In addition, risk-based models like decision trees are also not appropriate, because the problem at hand is not one of probabilities and risks (the outcome of improving a dangerous road or intersection is almost certainly an increase in safety and a decrease in collisions); what is being contested is which location represents the most beneficial use of resources.

3.5 Results and Discussion

3.5.1 Shortlisting of Alternatives

As aforementioned, once the decision maker (in this case, the author of the present analysis) and the problem (choosing a road location to upgrade) has been identified, the decision alternatives must be determined. There are 150,000 km of road available to general traffic in Victoria (VicRoads, 2021b); therefore, in order to identify the locations most in need of redevelopment, road accident statistics were obtained from VicRoads (VicRoads, 2021a). The six locations with the most accidents over the reporting period were chosen as decision alternatives (refer to Table 4).

3.5.2 Selection of Attributes

The following attributes were chosen because they are easily measurable or quantifiable; and, when taken together, they form a sufficiently broad and complete picture of the importance and urgency of a potential road development project.

Danger:

	Node ID	Latitude	Longitude	Address	Suburb
A	36335	-37.7923	144.9684	cnr Lygon St, Princes St	Carlton Nth
B	10592	-37.9332	145.1568	cnr Springvale Rd, Police Rd, Princes Hwy	Springvale
C	42680	-37.9612	145.3612	cnr Wellington Rd, Berwick Rd	Belgrave Sth
D	45524	-37.8050	144.6959	cnr Boundary Rd, Derrimut Rd	Derrimut
E	29361	-37.7849	144.9751	cnr Canning St, Richardson St	Carlton Nth
F	35605	-37.9822	145.0714	cnr Nepean Hwy, Warrigal Rd	Mentone

Table 4: Shortlisted Locations

- This is decomposed into two quantifiable sub-attributes, Severe Accidents and Other Accidents.
- The figures for these sub-attributes are obtained from the VicRoads statistics aforementioned (VicRoads, 2021a), and are considered a suitable indicator of danger level.
- A third sub-attribute, Fatal Accidents, has been removed, because there were too few fatal accidents at the shortlisted locations to impact the analysis.

Congestion:

- This encapsulates the high traffic volumes that often characterise hazardous driving conditions. According to one insurance company, 27% of its collision claims are for accidents that occurred between 8-9am and 3-6pm on weekdays (Youi Insurance, 2021).
- VicRoads has published traffic volume data (DataVic, 2021), but this is available only as a very large file that is unable to be processed by the author's data analysis equipment. Therefore, the extent of congestion at a location has been estimated with a ”congestion ratio”; this is a ratio of the time it takes to travel through a 1km section, at peak and off-peak times. These travel times are obtained from a web application (Google, 2023).

Benefaction:

- This attribute seeks to capture the extent to which the local community would benefit from a road location being redeveloped, and has been decomposed into two more easily quantifiable sub-attributes, Proximity to Vulnerable Populations and Size of Local Population.
- The closer a road location is to schools, hospitals and aged care facilities, the more there is to be gained from making that location safer. Therefore, in this analysis, locations that are very close to these facilities are preferred. Each location is given a weighted sum of its distance from the three categories of facility. The distances have been acquired from a web application (ibid.).
- When a road is improved, all of the residents local to that area are potentially beneficiaries of this improvement, as they are likely to use that road. While it is difficult to estimate the number of people living directly in the vicinity of a location, it is easy to obtain data on the population of a local government area (Australian Government Centre for Population, 2021). Therefore, in this analysis, a location within a high-population municipality is preferred.

Together, these attributes are considered to contribute to the relative ”exigency” of a road development project; that is, a blend of the importance and urgency of making a location safer.

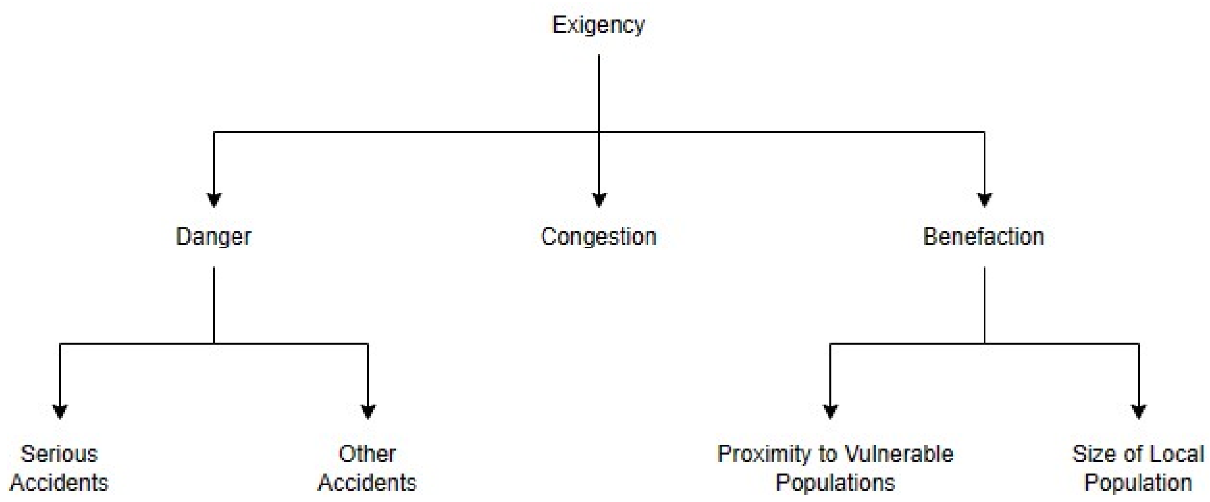

Figure 3: Value Tree

As shown in Figure 3, ”costs” and ”benefits” are not being measured in this analysis; rather, it is exigency that is being measured, which this is an entity that has no cost.

Tables 5-8 contain the raw data that have been collected for the six alternatives.

	Total	Fatal	Serious	Other
A	25	0	10	15
B	23	0	14	9
C	23	1	9	13
D	22	0	8	14
E	21	0	7	14
F	21	0	9	12

Table 5: Road Accidents

	School	Hospital	Aged Care
A	0.6	1.9	0.5
B	0.24	3.9	0.21
C	2.8	12.9	10
D	3.2	6.6	3.9
E	1	1.5	0.6
F	0.16	2.8	0.45

Table 6: Proximity to Vulnerable Populations

	2:00 AM	5:00 PM	Congestion Factor
A	2	9	4.5
B	2	3	1.5
C	1	1	1.0
D	2	3	1.5
E	3	4	1.3
F	2	3	1.5

Table 7: Congestion

	LGA	Population (1000s)
A	borders Yarra and Melbourne	287
B	borders Monash and Greater Dandenong	373
C	Yarra Ranges	160
D	borders Wyndham and Melton	456
E	Yarra	103
F	Kingston	167

Table 8: Local Population

3.5.3 Weighting of Attributes and Alternatives

All of the attributes are quantifiable; therefore, a different value function has been used to scale each one (refer to Appendix B). These functions are subjective in that they are based on the author's own judgements. They are created with the "bisection" method that has been described in Goodwin (2014); in this analysis, they mostly appear to be nearly linear, not following the idealised curved examples shown in the text mentioned. However, linear value functions are considered acceptable (Patel, Vashi, and Bhatt, 2017).

The relative weight of each attribute has also been assessed and normalised (refer to Table 9); again, subjective judgements by the author have been used.

	Raw Weight	Norm. Weight
Serious Accidents	100	27
Other Accidents	80	22
Congestion	80	22
Proximity to Vulnerable Populations	60	16
Local Population	50	14
Sum of Weights	370	100

Table 9: Normalised Weights

3.5.4 Evaluation of Alternatives

Each location alternative has been scored on all attributes, using the value functions. Then a weighted sum of these scores has been calculated using the attribute weights. These final evaluations can be found in Table 10. Based on this analysis, it is clear that location A has the most pressing need for improvement works.

	Serious Accidents	Other Accidents	Congestion	Proximity	Population	Weighted Sum
A	50	100	100	100	72	82.7
B	100	0	25	95	87	59.6
C	33	67	0	0	29	27.3
D	17	83	25	35	100	47.1
E	0	83	22	98	0	38.6
F	33	50	25	100	33	45.8

Table 10: Weighted Sum

Unlike other SMART analyses, there is no cost attribute to model, and therefore no efficient frontier; the prevailing alternative is simply the one with the most exigency.

3.5.5 Sensitivity Analysis

In order to assess the robustness of this model, three sensitivity analyses were carried out, with the following considerations in mind:

1. Serious Accidents has the highest weight of all the attributes. Changes to this weight may have significant impacts on the final decision; this possibility needs to be either confirmed or ruled out.

2. Although this is counter to the principles of public service, important government decisions - even those involving health and safety - are sometimes made for political advantage (The Guardian, 2023). A government might determine that focusing on locations with high congestion and high local populations will deliver improvements that are more noticeable to more people, thereby increasing the government's chances of re-election. Therefore, it would be useful to ascertain whether this model is sensitive to changes in the weights of those two attributes.

Graphs for these sensitivity analyses can be found in Appendix C. It is clear that if the weights of any of the three attributes of interest (Serious Accidents, Congestion and Local Population) are altered in any way, then location A will remain the preferred alternative, regardless of how low or high the altered attribute is weighted. This seems remarkable, but is not surprising when one considers that location A scored 100 on three out of five attributes, making it very difficult to dislodge as the preferred redevelopment location.

The sensitivity analyses also show that location C will always be the least-preferred alternative, regardless of how the three attributes of interest are weighted. Again, this is not entirely surprising, because this area is located on the outskirts of Melbourne, so it scored 0 on Congestion and Proximity to Vulnerable Populations, and relatively low on Local Population.

3.5.6 Appraisal of the approach

The stability of the analysis outcome confirms that for this problem, the decisions to use SMART over other methods, as well as to define the problem in terms of exigency rather than traditional costs and benefits, has resulted in a robust tool that can successfully be applied to road infrastructure planning activities.

3.6 Conclusion

This analysis used SMART, a multi-criteria decision making method, to select a road location that is most in need of improvement in terms of traffic safety. The successful application of this approach, and its robustness against changes, validates its use in the Victorian context.

There are, however, limitations to consider. The available data on traffic volumes was unusable, and the "congestion ratio", which is based upon online estimates of travel time, is a crude replacement. Ideally, if this analysis were to be repeated, real traffic data would be acquired.

Nevertheless, it is hoped that this analysis provides a blueprint for how the Victorian government can adopt a more methodical, transparent and defensible approach to project planning.

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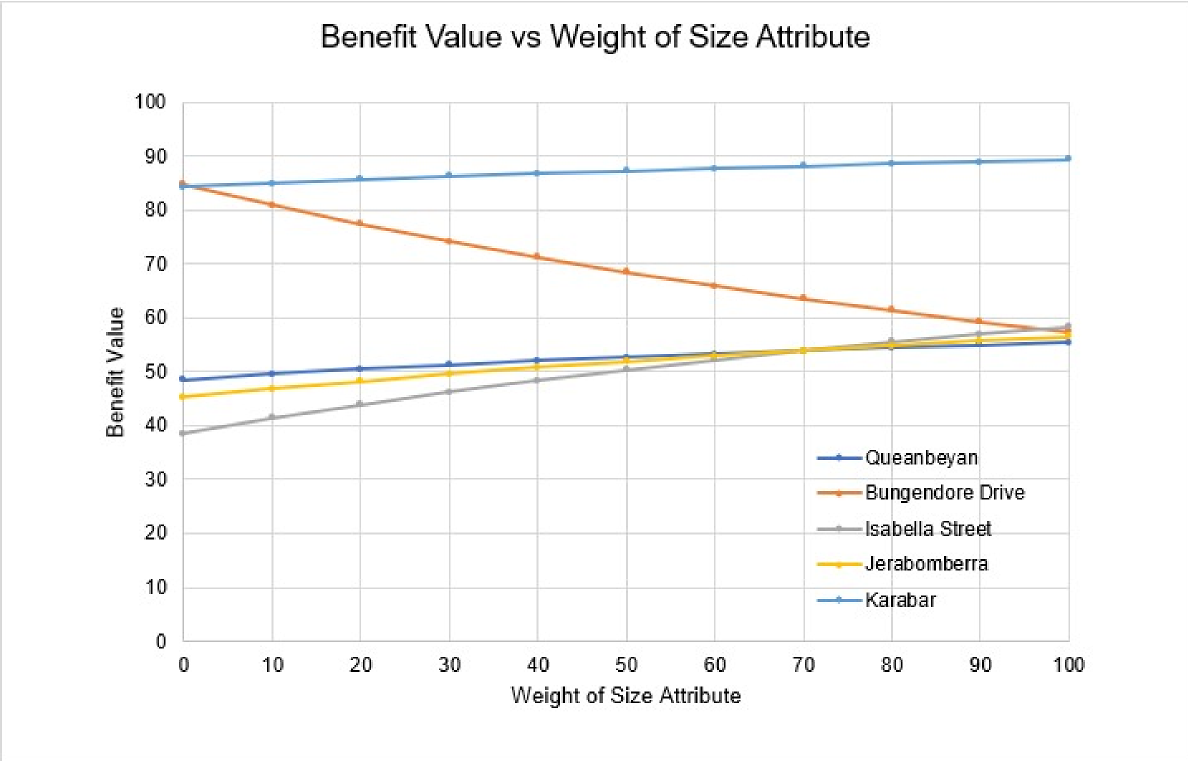
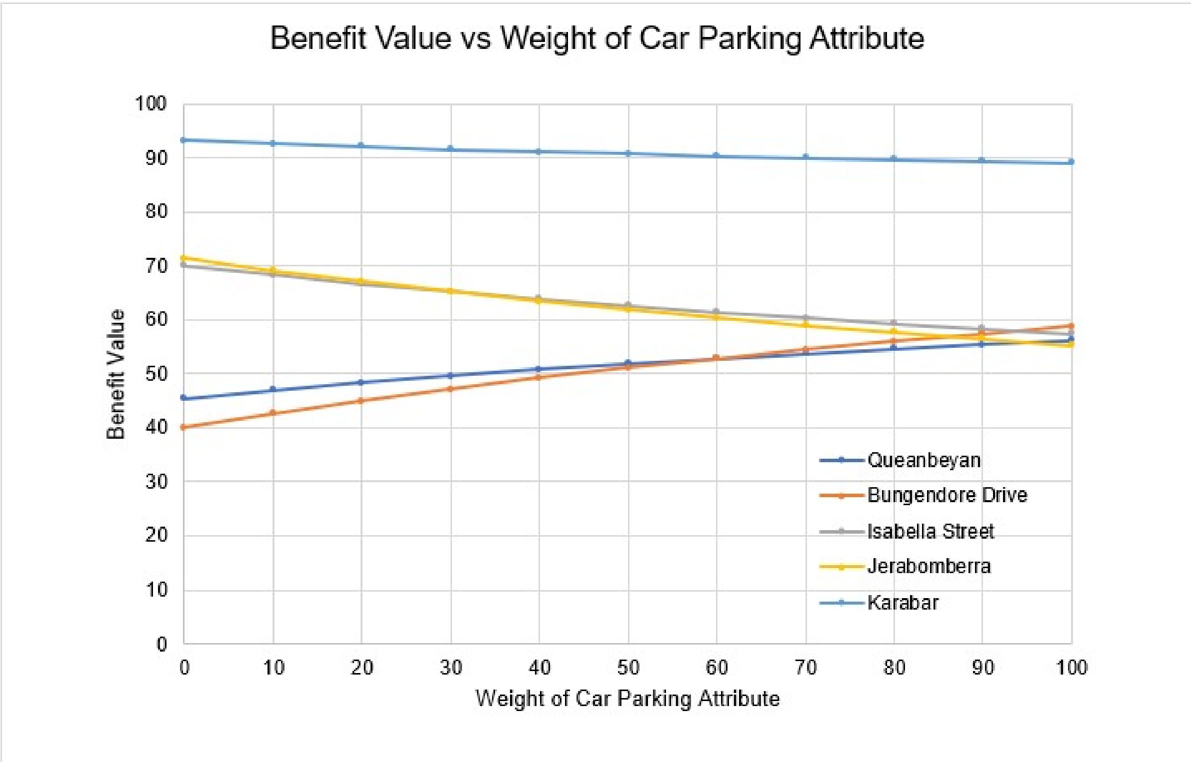
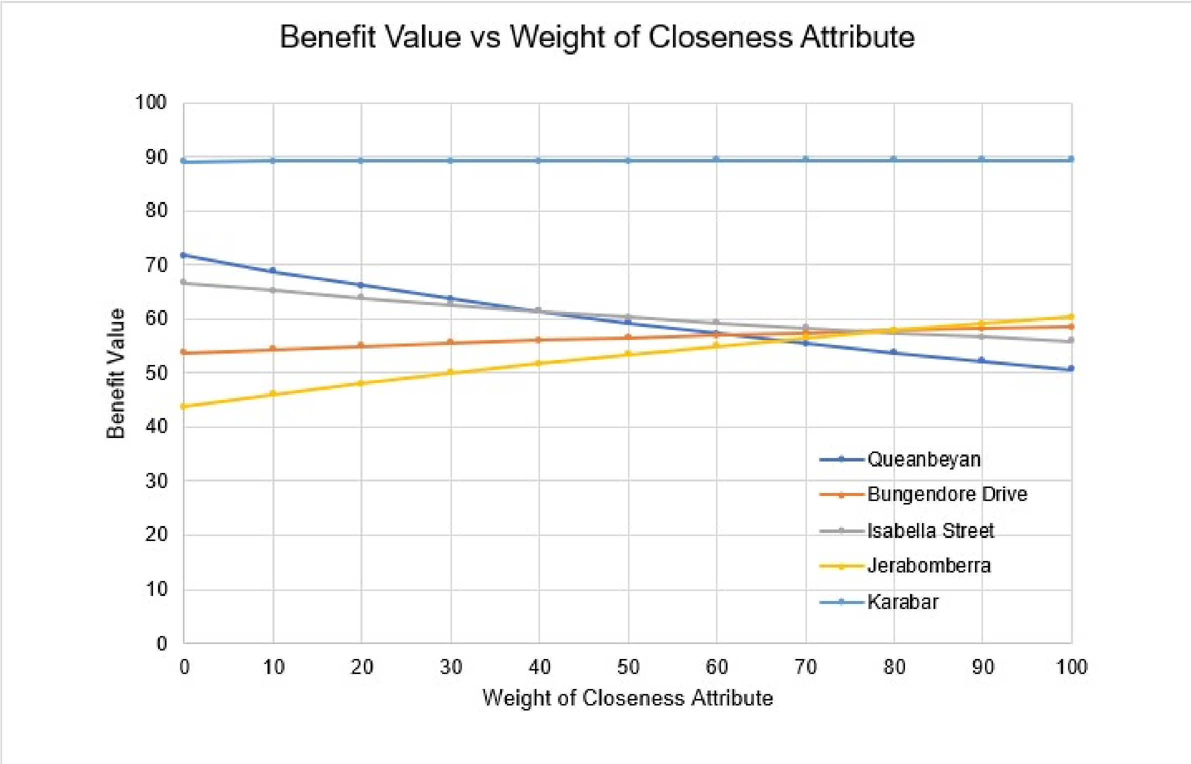
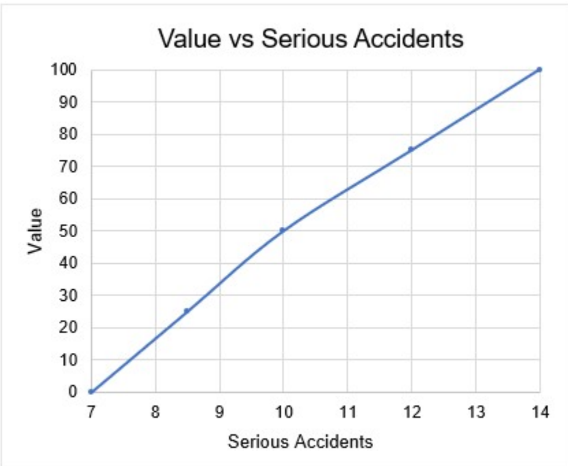
Appendix A: Sensitivity Analysis for Task 2

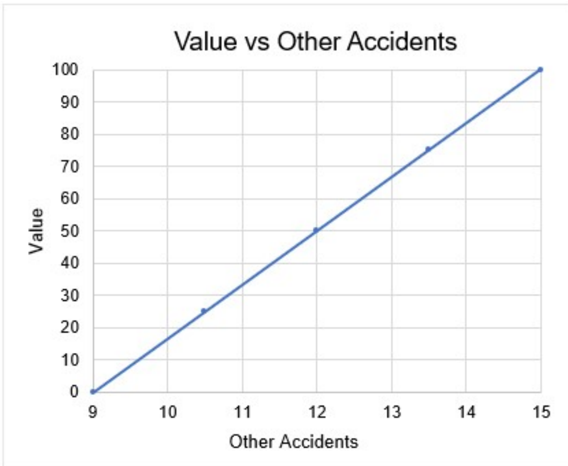


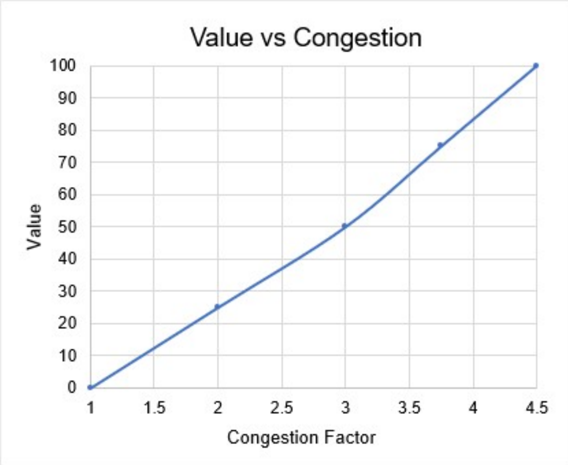


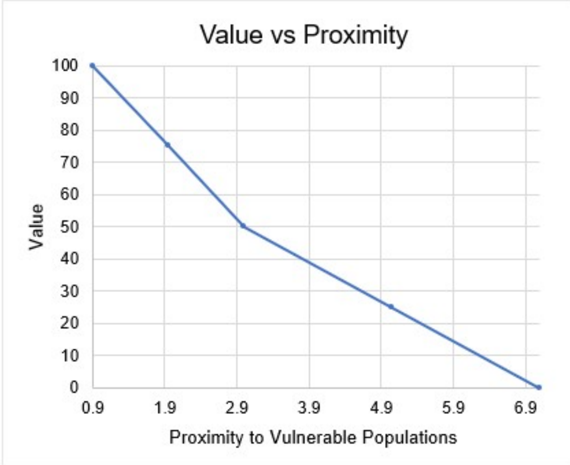


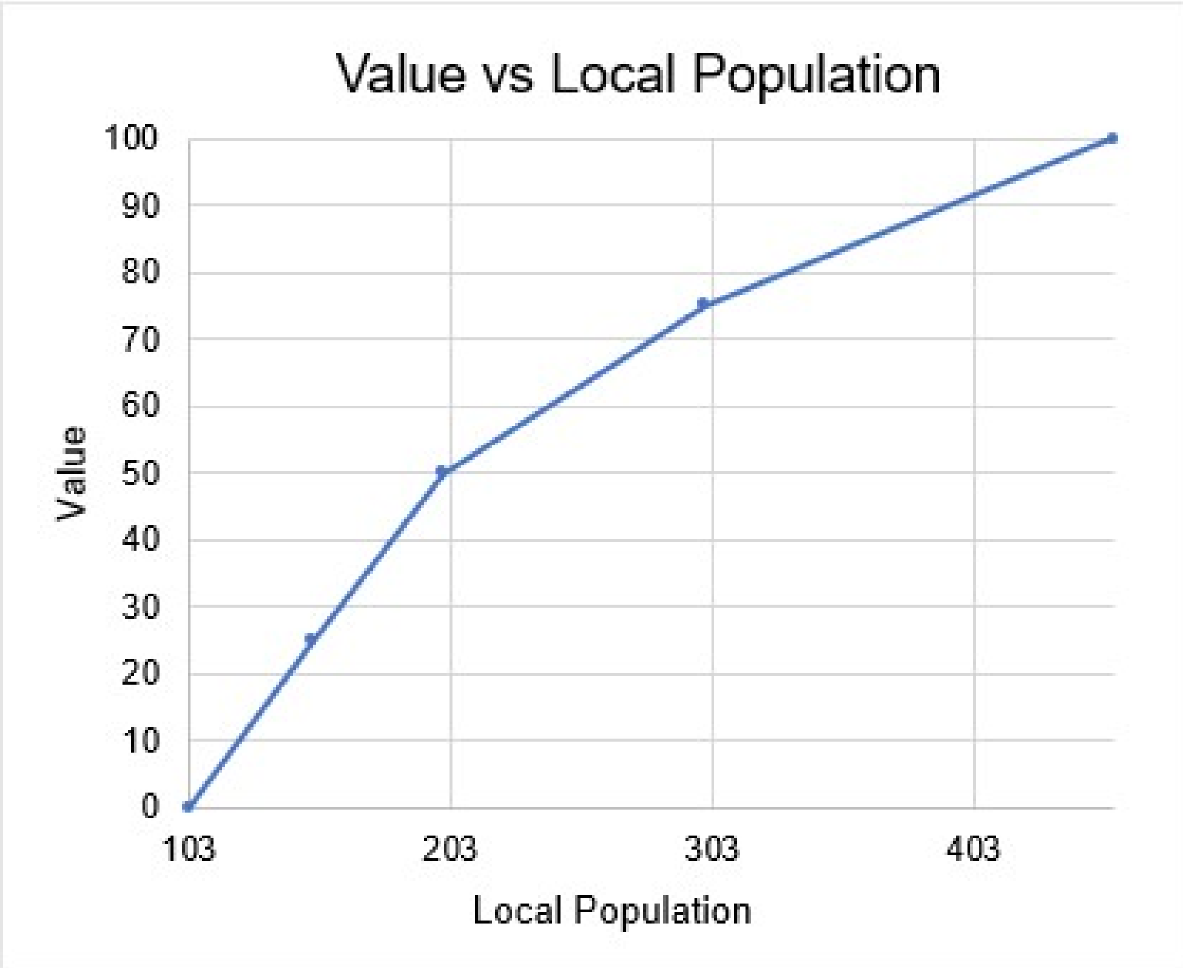
Appendix B: Value Functions For Task 3



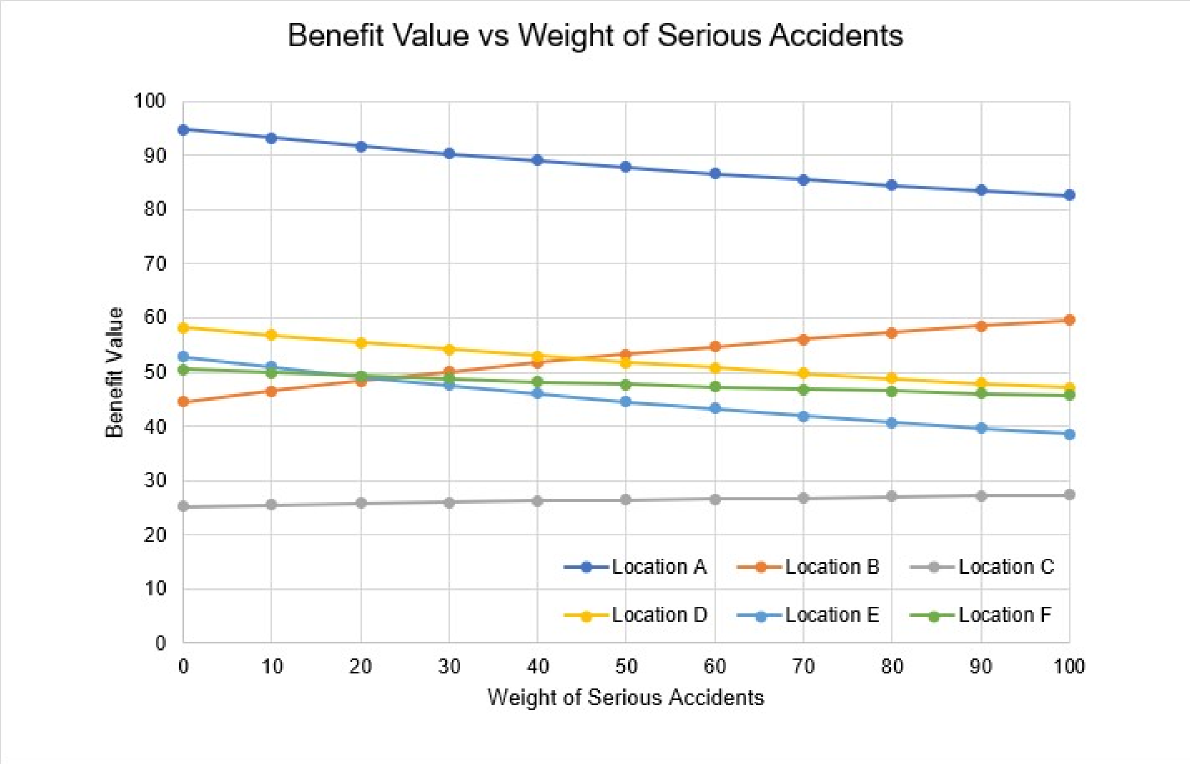


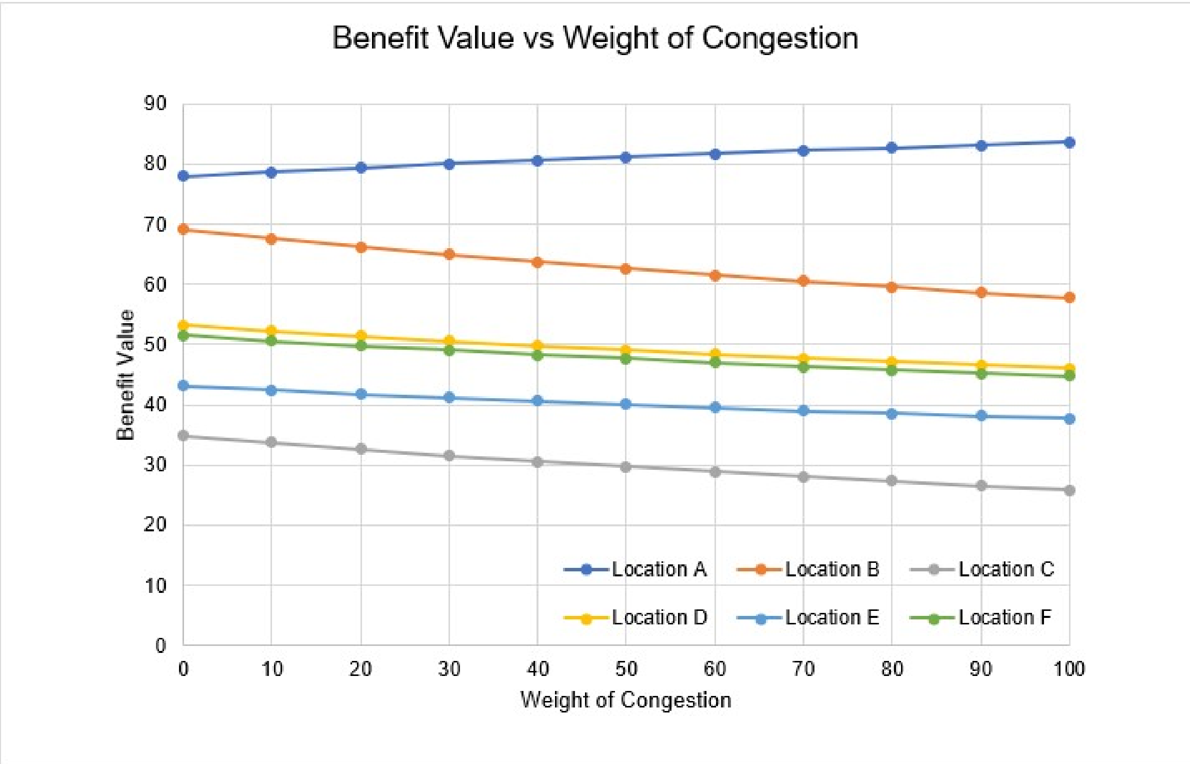


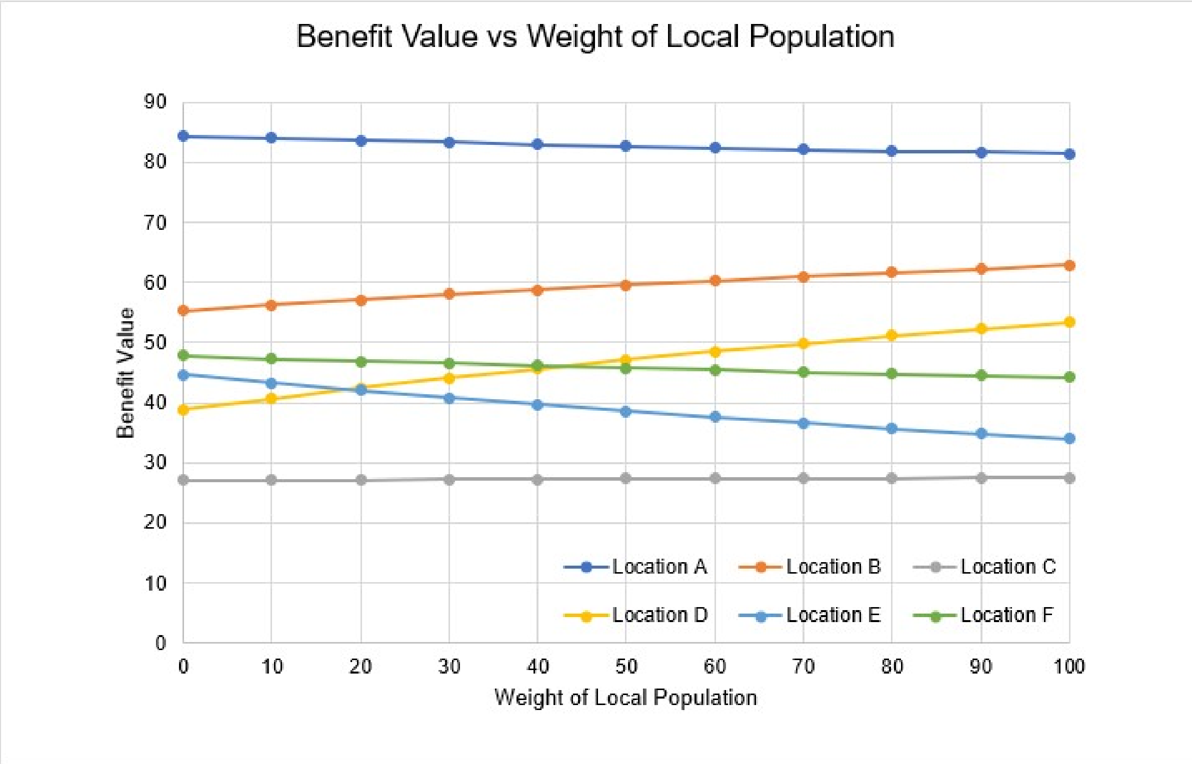




Appendix C: Sensitivity Analysis For Task 3


Benefit Value vs Weight of Serious Accidents
Benefit Value
Weight of Serious Accidents
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Location A
Location B
Location C
Location D
Location E
Location F


Benefit Value vs Weight of Congestion
Benefit Value
Weight of Congestion
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Location A
Location B
Location C
Location D
Location E
Location F


Benefit Value vs Weight of Local Population
Benefit Value
Weight of Local Population
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Location A
Location B
Location C
Location D
Location E
Location F