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Program Evaluation: An Applied Case Study[1]

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Abstract

Transport and Main Roads (TMR) Cost Benefit Analysis (CBA) Team conducted the economic evaluation of most of the projects proposed in a TMR strategic plan. The evaluation included almost 200 overtaking lanes, over 400kms of road widening and shoulder sealing in various locations, over 50 capacity focused projects and over 15 flood immunity projects (TMR 2013). The total projected capital costs of all projects proposed as part of this strategic plan amounted to several billion dollars. The program evaluation conducted, due to the short timeframes, lack of available data and strategic nature of the plan, has been 'coined' a strategic evaluation.

This paper focuses on the economic evaluation methodology applied to the projects proposed in the strategic plan. A TMR designed project/program evaluation model (CARP V1.0[2]) was used to evaluate the majority of the proposed projects. The model produces streams of discounted benefits and costs of the projects in the plan using limited and incomplete data. The large scale of work and the close proximity of projects allowed for an integrated approach to the analysis, which considered the impact projects have on each other.

The result of the program if all evaluated projects are included is a benefit cost ratio (BCR) of approximately 0.71 at a discount rate of 7%. If the less viable projects are removed from the program, the program can obtain a BCR of greater than one with a sufficiently large number of projects remaining.

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[1] As the economics report has not been published, the names of the program, projects, highway and funding body have not been disclosed in this paper. Instead, projects are referred to by indeterminate project identification numbers (flood immunity project identification numbers will begin with 'FL' and capacity project identification numbers will begin with 'CA') the program is referred to as Program Z, the highway is referred to as Highway Z, and funding body is referred to as Z Program.
[2] Concise Analysis of Road Programs (CARP) Version 1.0

1. Introduction

A Transport and Main Roads (TMR) strategic plan, to be referred to as Program Z in this paper, is an engineering based needs assessment that aims over a ten-year period to address capacity, flooding and safety problems along the entire length of a highway (TMR 2013), to be referred to as Highway Z in this paper. Program Z proposes over sixteen billion dollars worth of improvements to Highway Z over the next ten years (TMR 2013). The projects proposed as part of Program Z include road widening and shoulder seals, overtaking lanes, bypasses and ring roads, lane duplications, raised bridges and approaches, road realignments, intersection upgrades and minor safety treatments (TMR 2013). The poor safety record, frequent flooding and high traffic growth rates are the major impetuses for Program Z (TMR 2013).

The TMR cost benefit analysis (CBA) team was given the task to evaluate and provide economic advice regarding the initial viability and prioritisation of the initial projects to be proposed as part of Program Z. The Program Z program evaluation consists of projects to be funded under the Nation Building Program 1 (NBP1), Nation Building 2 Program (NB2) and Z Program. As part of Program Z, all proposed projects require CBAs. Projects to be funded under NBP1 had already undergone CBAs; these projects due to the application of different methodologies have not been combined with the NB2 and Z Program projects. The focus of this paper is the evaluation of projects to be funded as part of NB2 and Z Program.

The Program Z program evaluation was intended as a strategic quantitative evaluation of all projects proposed to be constructed along Highway Z in both the short run and long run. There was an intended timeframe of approximately 3 months from July 2012 to early October 2012 to complete the evaluation of the projects. Given many of the projects were in the early planning stages, complete information about the scope or data was not available. Considering the short timeframe and limited data and scope of projects, a rapid approach to evaluation had to be devised to complete the task.

2. The Application of Concise Analysis of Road Programs (CARP) Model

CBA6.1 is the prescribed model used to evaluate road projects in TMR. CBA6.1 enables a detailed evaluation of a wide range of projects and provides a wide range of flexibility in regards to traffic growth, traffic composition and road treatments that influence road conditions over the life of the project. Unfortunately, many of the data fields used in CBA6.1 to calculate results could not be populated rendering evaluations incomplete or forcing many possibly unfounded assumptions to be made. CBA6.1 is designed for project evaluation rather than program evaluation and lacks the flexibility to combine large numbers of projects without the help of specially designed spreadsheets. Given the above-mentioned limitations and the tight timeframes, CBA6.1 was deemed not the most suitable model for the job. Instead, another model, CARP (V1.0), developed in early 2012 was used as the primary model to evaluate the NB2 and Z Program funded projects, CARP (V1.0) was designed to rapidly evaluate programs or packages of projects with minimal comprise to the accuracy of the evaluation.

Literature suggests that there are a number of advantages of evaluating projects as a program of works. Such advantages include the recognition and evaluation of benefits of interdependent projects (Nemhauser and Ullmann, 1969, Gear and Cowie, 1980, Fox et al, 1984 and Tao and Schonfeld, 2006), improved transparency of project ranking and options analysis, clear identification of the net gains of a program and improved rigour of analysis

(Davies 2012). CARP is designed to capture all of the above-mentioned benefits of program evaluation as well as provide the flexibility to evaluate projects individually.

CARP reduces time spent on collecting data by reducing the data requirements of each project. The project data that often require more time to acquire or are not normally available are generally not required in CARP. Project parameters requiring data for CARP are parameters with the highest sensitivity to road user cost (RUC) calculations. Parameters that RUC are most sensitive to are section length, average annual daily traffic (AADT), model road states (MRS)[3], traffic growth rates, road alignments and traffic breakdown (TMR 2011a). Of the above-mentioned parameters, only traffic breakdown has been slightly compromised as the eight vehicle types used in CBA6.1 are reduced to just two vehicle types (cars and heavy vehicles). This compromise is small as traffic data for all eight vehicle types is rarely available, thus requiring assumptions to be made of that breakdown. Other data requirement omissions include surface and pavement types (all pavements are assumed to be sprayed seal), detailed maintenance schedules, flexible annual traffic growth rates and annual adjustments to roughness. The impact of excluding these parameters in most cases is minimal and in the case of most of the NB2 and Z Program funded projects, exact data was often not available. For models capable of providing detailed evaluation, such as CBA6.1, the above-mentioned parameters would be based on the best estimates of the analyst, which may not necessarily be consistent across all projects evaluated.

3. Project Evaluation Methodology

The project evaluation methodology applied to CARP to calculate RUC is consistent with Austroads and TMR CBA tool (CBA6.1). Austroads AP-R264/05 harmonisation paper is the source for the vehicle operating cost and travel cost algorithms applied to CARP. Accident cost algorithms are sourced from Austroads AP-R184, Road Transport Authority (RTA), TMR and Austroads Part 4: Guide to Project Evaluation (2012). Emission cost unit values per tonne of fuel consumed and the externality costs per vehicle travelled are sourced from Austroads Part 4: Guide to Project Evaluation (2012).

The economic measures/indicators produced by CARP are the benefit cost ratio (BCR), net benefit investment ratio (NBIR), net present value (NPV) and internal rate of return (IRR). The BCR is calculated according to the formula stated in Austroads (1996) and the NBIR is calculated according to the Australian Transport Council (2006) BCR formula, quoted as 'NBIR' as stated by Campbell and Brown (2007). The application of discount rates to projects is flexible and users of CARP have an option to sensitivity test options with a range of discount rates. CARP also incorporates sensitivity testing around calculated benefits and costs to provide a maximum and minimum BCR or NBIR. Table 1 provides a summary of the methodologies applied to calculate each RUC savings.

[3] MRS defines the number of carriageways, seal width and accident rate for a specific road type (TMR 2011a)

Table 1: Summary of Methodology Applied in CARP

Methodology Applied (Benefits)	Applied to Base and Project Case
Travel Time Cost Savings	(Distance × Unit Value/Operating Speed) × AADT × 365.25 (Operating speed is calculated using freespeed arrays adjusted for horizontal, vertical alignment, sign posted speed and congestion).
Vehicle Operating Cost Savings	Fuel + Oil + Tyre Wear + Maintenance & Repair + Interest& Depreciation (incorporates horizontal & vertical alignment factors and operating speed, refer to CBA6 manual, excludes lookup values for congestion impacts on vehicle operating costs (VOC)).
Accident Cost Savings	Accident costs calculated based on MRS accident rates adjusted for horizontal alignment and Austroads unit values for accidents adjusted for operating speed.
DCA Code Accident Cost Savings	Accidents identified according to DCA codes for projects with minor safety treatments and intersection upgrades. Treatment reduction based on RTA Accident Reduction Guide and Austroads unit values for road user movements (RUM).
Road Closure Cost Savings	Road closure savings consist of reduced waiting (same methodology as travel time costs (TTC) but based on average duration of closure (ADC) and average annual time of closure (AATOC) instead of 365.25 days, costs of diverting (reduced VOC + TTC + Accident) and not travelling costs (Reduced costs of not reaching destination calculated as loss of consumer surplus).
Emission Cost Savings	Emissions derived based on fuel consumed derived according to AP-R264/05 methodology multiplied by Austroads costs of emissions (includes CO2, CO, NOX and SO2).
Other Externalities	Externalities calculated per change in vehicle kilometres travelled (VKT) multiplied by Austroads unit costs for externalities.
Generated Traffic Benefits	Calculated as the gain in consumer surplus of generated traffic also known as rule of half (perceived road user cost savings per existing road user × generated road users / 2 (TMR 2011a)).
Other Benefits	Benefits not calculated in CARP but manually entered by user.
Unit Values and Algorithms generally applied to benefits calculated	
Unit Values	Unit values are provided by Austroads publication - Part 4: Project Evaluation Data (Updated Road User Effects Unit Values), 2012 Version, all unit values are updated using the latest CPI.
Algorithms	Algorithms are provided by Austroads publication - AP-R264/05.
Methodology Applied (Costs)	
Net Construction/Capital Costs	Project Case Capital Cost - Base Case Alternative Cost (P50 without escalation).
Net Increase in Operating Costs	Annual Project Case Operating Costs - Annual Base Case Operating Costs multiplied by evaluation period.

Source: Table 2, TMR 2013,

4. Program Z Evaluation Methodology

The program evaluation methodology would ideally be applied in two stages. The first stage involves the analysis of options to determine the optimal project option to be included in the program. The incremental benefit cost ratio (IBCR) or the incremental net benefit investment ratio (INBIR) are compared with the program cut-off BCR/NBIR to determine the optimal option to be included in the program. The second stage involves the ranking of projects according to BCR or NBIR, until the allocated budget is reached or the cut-off BCR/NBIR has been reached.

The sequential and simultaneous approaches outlined in Davies (2012) can be applied to the program evaluation using CARP. The sequential approach is based on the assumption that projects have been ranked prior to the evaluation; projects are evaluated in order of ranking. If the sequential approach is applied, the user of CARP can choose to select a predetermined ranking rather than the BCR or NBIR[4]. The simultaneous approach is based on the assumption that all projects in the program will proceed in the project case and none of the projects will proceed in the base case. Timing of projects is not considered in the simultaneous approach. For Program Z, the simultaneous approach was deemed most appropriate as the ranking of projects was yet to be finalised and project timings were unavailable. Using the simultaneous approach, the results of the program evaluation could be used as an input to project ranking within the program.

All projects evaluated as part of Program Z using the CARP model were subject to a number of general assumptions; these assumptions are as follows.

- Evaluation period is 31 years (1 year of construction and 30 years of benefits).
- All projects are assumed for simplicity to be constructed simultaneously[5].
- June 2012 prices have been applied to all benefits and costs.
- Discount rate of 7% and sensitivity tested at discount rates of 4% and 10%.
- Results are sensitivity tested for 50% increase or decrease in benefits.
- Results are sensitivity tested for 20% increase or decrease in costs.

4.1. Methodology Applied to Flood Immunity Projects

The data provided for most of the flood immunity projects were limited to project costs, annual average time of closure (AATOC), maximum time of closure (Q50 flood events), road ID and chainage of the location of the project. The chainage and road ID was used to acquire road and traffic data from Chartview[6]. Even with the acquisition of data from Chartview, a number of parameters such as the length and road characteristics of the diversion routes and nature of road closures remained unknown.

For each project, two types of road closures were assumed, Q50[7] for serious flood events and Q2 for local flood events. For Q50 floods, maximum time of closure is assumed to equal the average duration of closure (ADC) and the AATOC is assumed to equal ADC/50. For local flood events, AATOC equals the AATOC provided minus the AATOC of the Q50 flood

[4] The BCR has been presented in the Program Z report rather than the NBIR as the BCR was stated as the requirement from the TMR Program Z committee.
[5] Although this assumption is unrealistic, in order to compare project results, all projects need to be evaluated over the same period.
[6] Chartview is an ARMIS database containing road characteristics and traffic data.
[7] Q50 Bridge is built to a standard where it will only flood during a 50-year or worse flood event.

and the ADC equals AATOC multiplied by two. Project FL13 was evaluated over three flood periods due to the availability of additional data.

Google maps was used to identify diversion routes during local flood events and no diversion routes were assumed available during Q50 flood events. The road characteristics of the diversion routes were held constant at a lower standard than that of Highway Z.

Road user behaviour has not been specified for any of the flood immunity projects, therefore, the assumption that road users opt for the least cost approach to reach a destination has been applied which is consistent with flooding methodology described in Davies (2011).

The flood immunity program of works has been evaluated based on the assumption that all projects will be constructed in the project case and no projects will be constructed in the base case. This method is appropriate for the initial evaluation of projects to determine a ranking based on BCR. To assess the impact of potential interrelatedness between projects, projects within close proximity of each other have been re-evaluated based on the assumption that not all interrelated projects are constructed in the project case. This approach has been adopted for Projects FL4, FL5, FL8a, FL8b. Stage 1 of Project FL8 is a possible alternative to Projects FL8a, and FL8c. Stage 2 of Project FL8 is a possible alternative to Project FL8b and Project FL8c[8] to improve flood immunity while also allowing through traffic to bypass a town. The methodology applied to the Project FL8 projects/options is explained in more detail Section 4.4.1. See Davies (2012) for more information on program evaluation approaches for interrelated projects.

4.2. Assumptions Applied to the Flood Immunity Projects

Given the limited availability of data, a number of assumptions have been made and applied consistently across all flood immunity projects.

- Assets of a life of 100 years (mostly bridges) are apportioned 20% of capital costs.
- The residual value of the bridges is calculated as follows: Capital cost × 20% × (100yrs – 30yrs) / 100yrs.
- Two types of flood events Q2 and Q50 with the exception of Project FL13.
- Average maintenance cost decrease of $100,000 per km[9].
- Diversion routes have constant generic road characteristics.
- Lengths of diversion and improved routes have been taken from Google maps.
- Existing traffic on diversion routes are assumed to be unaffected by diverting traffic.
- All road upgrades such are assumed to be of engineering standards (MRS of 15).
- For projects involving deviations, all vehicles are assumed to use the deviation.
- For Project FL16, 75% of traffic is assumed to be through traffic and 24% of the through traffic is heavy vehicles.
- For proposed projects in close proximity of each other, 50% of the road closure time at the project site with the lowest closure times is assumed to be resolved by the upgrade of both projects.
- Some interrelated projects are combined into one evaluation when benefits for each project are not clearly divisible (Projects FL4 & FL5 and FL8).

[8] Project FL8c is a proposed upgrade of a bridge to allow oversized vehicles to cross a river.
[9] Maintenance costs are based on information provided by the Regions.

4.3. Results of the Flood Immunity Projects

Project FL16 is the only flood immunity project with a NPV greater than zero and a BCR greater than one. To maximise the NPV of the program, Project FL16 should be the only project to be included in the program. A number of other projects with BCRs below one could be included in the program without pulling the overall NPV of the program below zero. Table 2 contains the projects proposed to be included in the program based on the strategic economic analysis described in this report. The preferred option for Project FL8 described in the Project FL8 options analysis section is also included in the results in Table 2. See Appendix A for the NPV and BCR for all projects proposed in the Program Z flood immunity program.

For the sensitivity analysis, benefits of all projects are subject to a sensitivity of plus or minus 50% due to lack of data. Costs are subject to a sensitivity of plus or minus 20%, which is a standard sensitivity test for most evaluations conducted by TMR.

Table 2: Results of Program by Project (Recommended Projects)[10]

Rank	Project Name	NPV ($)	BCR	Benefits Sensitivity	Costs Sensitivity	Min BCR	Max BCR
1	Project FL16	240,839,436	6.20	50%	20%	2.46	12.54
2	Project FL8	-377,662,248	0.74	50%	20%	0.31	1.38
3	Project FL3	-27,037,566	0.65	50%	20%	0.27	1.23
4	Project FL13	-149,309,621	0.49	50%	20%	0.20	0.92
Total	Without Project FL8	64,492,249	1.16	50%	19%	0.48	2.17
Total	With Project FL8	-286,169,999	0.84	50%	20%	0.35	1.58
Total	FL3, FL8 & FL16	-163,467,305	0.89	50%	20%	0.37	1.67

Source: TMR 2013

4.4. Methodology Applied to Capacity Projects

For the flood immunity projects, a standard methodology could easily be applied across all projects but for the capacity projects, such a methodology was not possible as the projects varied considerably in nature. Therefore, the methodologies of only a few select projects have been included in this paper. The selected projects demonstrate the interrelated nature of projects that are within close proximity to each other. The BCR and NPV of the capacity projects are included in Appendix A.

[10] Projects are recommended based on obtaining a BCR above one for the Flood Immunity Program of Works rather than each project achieving a BCR above one.

4.4.1. Project FL8 Methodology

A number of options are available to improve the flood immunity, capacity and enable large vehicles to cross the River Z along Highway Z near two small towns. In this report, nine options are presented, these options are as follows:

1) Construct only Stage 1 of Project FL8
2) Construct both Stages 1 & 2 of Project FL8
3) Construct Stage 1 of Project FL8 and Project FL8a
4) Construct only Project FL8a and Project FL8b
5) Construct Stage 1 & 2 of the Project FL8, Project FL8c and Project FL8b
6) Project FL8c
7) Project FL8c, Project FL8a and Project FL8b
8) Project FL8c and Stage 2 of Project FL8
9) Project FL8c, Stage 2 of Project FL8, Project FL8a and Project FL8b

The existing Bridge has height and width restrictions that prevent some of the heavy vehicles from crossing the River Z, thus, forcing these vehicles to permanently divert to cross the River Z at an alternative location. Heavy vehicles that cannot cross the Bridge travelling between Mackay and Townsville are assumed to travel an extra 252km to avoid the Bridge. Two alternatives have been proposed to resolve this problem; construct a new bridge and approaches (Stage 1 of FL8) or upgrade the existing bridge.

Flooding occurs at several creeks in the vicinity of the two small towns. Projects FL8a and FL8b or Stage 1 of Project FL8 will improve the flood immunity of Highway Z for all road users. Alternatively, Stage 2 of Project FL8 will improve the flood immunity of Highway Z, benefiting through traffic more than local traffic. Stage 2 of Project FL8 provides additional benefits by allowing through traffic to bypass the second small town.

Stage 1 of Project FL8 will resolve the partial road closure to 10% of the heavy vehicles passing through the second small town (vehicles that do not meet the existing bridge specifications). In the base case, cars and 90% of the heavy vehicles cross the existing bridge, while 10% of the heavy vehicles travel an extra 252km to cross River Z. Stage 2 of Project FL8 has been treated as a bypass that improves flood immunity and capacity. All other assumptions applied to other flood immunity projects holds true for the bypass. The bypass also includes railway crossings, the benefits of these crossing have been excluded from the analysis due to lack of crash related data.

4.4.2. Project CA49

Project CA49, located approximately 20km-30km south of Gympie (TMR 2012a), has been evaluated as a simple duplication from a two-lane highway to a four-lane highway section of road. Increased capacity results in benefits to travel time and reductions in vehicle operating costs. The additional capacity and cost reductions in travel is assumed to generate traffic. A capacity constraint has been applied to the base case; this capacity constraint will prevent the traffic volume from exceeding the capacity of the road. The project case has a larger capacity than the base case; therefore, traffic volume in the project case will exceed that of the base case. The additional traffic is treated as generated traffic.

4.4.3. Project CA47

Project CA47, located approximately 10km-20km south of Gympie (TMR 2012a), has been treated as a duplication and realignment of Highway Z that also improves flood immunity. This project is subject to the same assumptions as the flood immunity projects; see Section

4.1 for flood immunity methodology. If Projects CA45 and CA46 are not constructed, the flood immunity benefits for Project CA47 are removed from the evaluation; see Appendix A for both sets of results. The methodology applied to the duplication of Project CA47 is similar to the methodology proposed for Project CA49, but also includes a reduction in section length and a change in horizontal alignment from curvy to straight. The improved alignment will enable higher operating speeds, reduced tyre wear and fuel consumption, and improved safety. The reduction in section length will reduce road user costs proportionate to the percentage reduction in section length.

4.4.4. Projects CA45 and CA46

Projects CA45 and CA46, located through Gympie and up to 20km north of Gympie (TMR 2012a), has been evaluated as a realignment and duplication of Highway Z. The project also includes flood immunity benefits similar in nature to Project CA47. These flood immunity benefits were excluded to avoid double counting, as Projects CA47, CA45 and CA46 are required to be upgraded to improve the flood immunity of the link through Gympie.

4.4.5. Project CA43

Project CA43, located 12km north of Gympie (TMR 2012b), has been evaluated as the replacement of the current at-grade intersection with an overpass to enable traffic turning onto Highway Z from Highway K to move freely. Project CA43 has been evaluated twice, one evaluation is subject to the assumption that Project CA47 proceeds while the other evaluation is subject to the assumption that Projects CA45 and CA46 do not proceed. The construction of Project CA45 and CA46 will improve the base case, as the traffic along Highway Z will be substantially reduced thus reducing delays to vehicles turning right onto Highway Z.

Safety benefits for the entire intersection have been evaluated using definition of classification of accidents (DCA) codes. Treatments and the travel time cost and vehicle operating cost savings have been evaluated for vehicles turning onto Highway Z (AADT against gazettal). Distance travelled through the intersection has been halved in the project case to simulate delays and vehicle operating costs accrued by vehicles waiting at the intersection. Delays have also been reduced by 25% in the base case if Projects CA45 and CA46 proceed to simulate the impact of reduced traffic volumes along Highway Z (Old).

4.4.6. Project CA53 (Upgrade of Interchange)

Project CA53, located at the interchange of Road M and Highway Z south of Burpengary (TMR 2011b), has been evaluated based on SIDRA[11] data and accident data collected at the project site. The SIDRA data was used to determine peak traffic volume, average travel time for peak periods, average operating speed and average distance travelled through the intersection[12]. Average distance travelled was adjusted in the project case based on travel time and used as a proxy to determine travel time costs and vehicle operating costs (VOC). Average distance was chosen over average speed as a proxy as distance has a simple multiplicative relationship to cost calculation, whereas speed influences both VOC and accident cost calculations in CARP. Average speed reductions in the base are due to start-stop rather than a constant speed, therefore would artificially distort accident cost

[11] SIDRA Intersection is a well-known software package used worldwide for intersection capacity, level of service and performance analysis by traffic design, operations and planning professionals (VIASTRADA 2008).

[12] VOC have been calculated within CARP due to the absence of fuel consumption data from SIDRA data provided.

calculations. The treatment of engineering standard grade separation was applied to evaluate accident cost savings using DCA code accident reduction factors.

4.4.7. Project CA54 (Managed Motorways)

'Managed Motorways' is the term used to describe urban motorways that have intelligent information (TMR 2010). The proposed Intelligent Transport System (ITS)[13] is expected to increase capacity of Highway Z by up to 25% during peak periods (TMR 2010). First section of Highway Z from chainage 0km to 23km has a MRS of 22 (3 lanes in either direction). To simulate an increase in capacity of 25%, the MRS of the project case has been assumed to be increased to 23 (4 lanes in either direction). All other road characteristics are assumed unchanged. In order for the ITS to be implemented, Project CA53 requires implementation to the specifics stated in Section 4.4.6. A proposed project at Avenue B, though not evaluated as part of Program Z due to undefined scope, also requires upgrading for the full benefits of ITS to be realised. The costs and benefits of Project CA53 have been included in this analysis, whereas costs and benefits from the Avenue B project have been excluded.

4.4.8. Results of the Capacity Projects

The results of the capacity projects was mixed with some projects obtaining high BCRs ─ such as Project CA54 and Project CA24b ─ while other projects obtained low BCRs ─ such as Project CA16 and Project CA1. AADT, volume capacity ratio (VCR), traffic growth rate and capital cost were the key factors in determining the NPV and BCR of most capacity projects. Section 6 highlights some other factors that may have distorted results. The capacity projects have been subject to the same sensitivity tests as the flood immunity projects described in the Section 4.2. The complete results of the capacity projects are included in Table 9 in Appendix A.

4.5. Methodology Applied to Safety Projects

The safety projects were separated into overtaking lane projects, and road widening and shoulder seal projects. The methodologies applied to the overtaking lane projects vary considerably from road widening and shoulder seal projects. Overtaking lane projects are more complicated to evaluate as they not only improve safety but also travel time. Overtaking lanes also include upstream[14] and downstream areas[15], which improve safety and travel time. The road widening and shoulder seal projects are almost entirely focused on improving safety with limited impact on other benefit categories. The road widening and shoulder seal projects as part of Program Z were not clearly defined as projects but rather the upgrade of any sections of Highway Z not currently at the vision width (10m seal).

4.5.1. Overtaking Lane Projects

One hundred and eighty-nine overtaking lane projects have been proposed as part of Program Z. The short timeframes and the insufficient information to the exact location of each overtaking lane prompted the use of a link evaluation approach rather than the evaluation of each individual overtaking lane. Ten links were identified along Highway Z. The

[13] 'Intelligent Transport Systems (ITS) cover any technology applied to transport and infrastructure to transfer information between systems for improved safety, productivity and environmental performance' (Department of Infrastructure and Transport 2013)
[14] The upstream area is the section of road immediately preceding the overtaking lane (TMR 2011a).
[15] The downstream area of the overtaking lane is the section of road immediately following the overtaking lane (TMR 2011a).

total proposed lengths of the overtaking lanes, downstream and upstream areas per link were combined into one evaluation. The vision distance between overtaking lanes was determined based on the average AADT per link.

The overtaking lanes are spaced according to the AADT on the highway. If the AADT is between 2000 and 4000, the overtaking lanes are spaced 20km apart, if the AADT is between 4000 and 6000, the overtaking lanes are spaced 10km apart and if AADT is greater than 6000 the overtaking lanes are spaced 5km apart. The overtaking lanes have an assumed section length of 1.2km and have upstream areas of 3km and downstream areas of 5km. For sections with AADT of greater than 6000 vehicles, we assume there are no upstream benefits and downstream benefits are reduced to 3.8km. The parameters of the road and traffic data applied to each link are weighted averages for the whole link. The results for each link are given Table 3.

Table 3: Results of the overtaking Lane Link Evaluations

Link	Cost ($)	NPV ($)	BCR
Link 1	131,520,000	- 61,571,472	0.53
Link 2	102,750,000	- 82,618,785	0.20
Link 3	32,880,000	110,251,473	4.35
Link 4	94,530,000	- 74,859,079	0.21
Link 5	82,200,000	- 67,084,031	0.18
Link 6	45,210,000	- 33,639,177	0.26
Link 7	106,860,000	- 87,481,252	0.18
Link 8	115,080,000	312,937,848	3.72
Link 9	53,430,000	- 37,284,973	0.30
Link 10	12,330,000	- 2,122,820	0.83

Source: Table 5, TMR 2013

The results indicate that the viability of the links is almost solely dependent on the weighted average AADT for the link. Other parameters such as vertical and horizontal alignment of the links did not vary due to averaging. The capital costs for each overtaking lane are also assumed constant for the entire length of Highway Z.

4.5.2. Widening/Shoulder Seals

Widening of shoulder seals was proposed for the length of Highway Z for sections of road that did not meet the vision seal width of 10m (MRS of 14). Of the 1667km length of Highway Z, 404km did not meet the vision seal width. The distance of 404km was calculated by summating all the scattered sections of Highway Z with narrow seals. The safety benefits for the widened road sections were calculated using accident rates per million vehicle kilometres travelled (mVKT) according to the MRS of the section. In the base case, the MRS of the narrow sections of road ranged between 10 and 12. Table 4 has the distance in kilometres for the sections of road with MRS 10, 11 and 12 with their corresponding accident rates per mVKT. Table 4 also contains the accident rate for MRS 14 to be applied to the project case.

Table 4: Road Widening/Shoulder Data Inputs

MRS	Section Length (km)	Accident Rate (mVKT)
10	5	0.3785
11	9	0.3257
12	390	0.2817
14	404 (Project Case)	0.2289

Source: Table 1, TMR 2012c

The combined NPV and BCR for the road widening and shoulder seal projects at a discount rate of 7% were $41,549,300 and 1.12 respectively. The benefits of the road widening and shoulder sealing projects are likely to be understated, as accident cost savings were the only benefits considered, benefits from improved capacity and smoother road surface have not been included due to lack of specific project information.

5. Results of the Program[16]

If all projects are assumed to be included in Program Z, the program will not be economically viable as the NPV falls below zero. Table 5 contains the results of the program CBA when all projects (Z Program & NB2 funded projects) are included.

Table 5: Results of Program Z according to Programs

Program	NPV ($)	BCR
Flooding	-1,983,825,834	0.49
Capacity	-1,765,183,215	0.78
Overtaking lanes	-23,472,268	0.97
Road Widening	41,549,300	1.12
Total	-3,730,932,017	0.71

Source: Table 11, TMR 2013

If projects are ranked according to BCR and a cut-off BCR of one is established to eliminate the projects deemed economically unviable based on the analysis, the program will have greatly improved results as shown in Table 6.

Table 6: Results of Program Z according to Programs (Cut-off BCR = 1)

Program	NPV ($)	BCR
Flooding (FL16)	240,839,436	6.20
Capacity	1,433,500,000	2.00
Overtaking lanes (Links 3 & 8)	423,189,321	3.86
Road Widening	41,549,300	1.12
Total	2,139,078,057	2.13

If a cut-off BCR of one is applied, the program will consist of only one flood immunity project, eight capacity projects, two of the ten links for the overtaking lanes and the road widening program. Considering the rapid nature of the project evaluations, applying a cut-off BCR of one may eliminate some of the projects that would have obtained BCRs above one if analyses had been conducted in more detail. Another approach would be to lower the cut-off BCR to less than one. Nominating such a cut-off BCR creates a dilemma given that a cut-off BCR that is too low will reduce the overall program NPV to below zero[17] and a cut-off BCR, which is too high could result in the exclusion of some projects with underestimated benefits. A cut-off BCR of 0.6 allows for the inclusion of potentially viable projects given a more detailed analysis but does not reduce the NPV of the program to below zero. Table 7 contains the results of the program if a cut-off BCR of 0.6 is selected.

[16] The results covered in this section are just a broad overview of the program. A detailed discussion of the benefit and cost streams of each project or even the program as a whole would require another paper. The TMR Program Z report contains more information regarding the results.

[17] Maintaining a program NPV of greater than one is important to demonstrate the overall viability of the program form a strategic approach even though the benefits of some of the projects are understated.

Table 7: Results of Program Z according to Programs (Cut-off BCR = 0.6)

Program	NPV ($)	BCR
Flooding (FL3, FL8, FL16)	-163,467,305	0.89
Capacity	747,410,000	1.16
Overtaking lanes (Links 3, 8 & 10)	64,008,984	1.10
Road Widening	41,549,300	1.12
Total	689,500,979	1.10

If a cut-off BCR of 0.6 is used instead of one, an additional two flood immunity projects, five capacity projects and overtaking lane link can be included in the program without reducing the NPV of the program to below zero. A cut-off BCR of below one had not been proposed in Program Z report but has been raised in this paper as another possible method of selecting projects for Program Z and/or for future more detailed evaluation. Eventually, when a fixed budget is decided for Program Z, a cut-off BCR can be determined based on the last project ranked according to BCR to exhaust the budget. The prescribed cut-off BCR should be above one, once more detailed analysis has been conducted.

6. Limitations and Questionable Assumptions

The purpose of the Program Z program evaluation was to provide strategic guidance to the viability of a large number of proposed projects rather than an accurate CBA of all projects. The time and resources were not available at the time of the analysis to produce comprehensive CBAs of the standard to be included in a detailed funding submission. Projects that performed favourably or have been identified as having insufficient data for an adequate evaluation at this time will be revisited. Projects that have performed poorly in the strategic analysis and the limitations in data are not deemed to significantly change the results are not expected to undergo a more detailed CBA.

The requirements of the evaluations depended on what data was available. This approach limits the ability of decision makers to compare projects in the program. Projects CA30 and CA31 are examples of projects with limited available information regarding scope and no available intersection modelling. Whereas, projects such as Project CA13 had detailed intersection modelling and well documented scope. The projects with more complete information had higher BCRs than those with less complete information but it is difficult to ascertain how responsible the lack of information is for the differences in BCRs. Therefore, some of the comparisons between projects cannot be relied upon for prioritizing projects within the program. Another clear limitation in respect to the overtaking lanes and road widening projects is that projects were not individually evaluated but instead the links where these projects were intended to be located. A link may have a very low NPV but there may be a number projects at locations where the NPV could be significantly higher due to high traffic volumes, more heavy vehicles or steeper terrain. For links with high NPVs, there could be projects at locations where the NPV could be substantially lower due to the close proximity of existing overtaking lanes or the proximity of key turn offs for some heavy vehicles.

Another key limitation is the model; Program Z was the first time CARP had been applied to an evaluation. The model had been tested using sample evaluations and projects that had been evaluated using TMR's standard CBA model, CBA6.1, but not all aspects of the model had been carefully tested; there is the potential for errors in calculations that may not be identified when results are reviewed. The complexity of some of the bypass and diversion projects would not have been adequately captured in CARP. CARP is limited to averages of sections of road and if longer sections of road had varying characteristics, the impacts of

these variances will not be recognised in the evaluation. The intersection component of CARP is very basic and relies on changes in speed for travel time cost savings and start stop effects on fuel consumption is not considered. The intersection component of the model was designed mostly to cater for safety upgrades rather than capacity upgrades.

Possibly the greatest area of concern relates to the scopes of projects. Many of the Program Z projects did not have clearly defined scopes, thus requiring the team, with advice from the Regions, to make a number of simplifying assumptions. Data collection was an ongoing task during the evaluation process, consequently in order for the team to progress through the evaluations in a timely fashion, proxies (and in some cases dummy values) were inserted into evaluations. The proxies that were used were rules of thumb around inputs such as maintenance per kilometre or the years in which future maintenance is likely to be implemented in both the base and the project cases. The dummy values were nothing more than deductions using the best information available. For example, some of the lengths and even locations of some project sites were approximated based on early drafts of projects. The dummy values were not intended to remain in the final results but just merely hold the evaluation together until better defined scopes were available.

A major area of note and inconsistency was that a number of projects to be included in the Program Z report had been previously evaluated. As mentioned earlier in the paper, the NBP1 funded projects had already been evaluated but were still required to be included as part of Program Z for completeness. The NBP1 project evaluations had been evaluated using numerous and often inconsistent methodologies. Unfortunately, the documentation of the NBP1 projects was not sufficient to harmonise the methodology applied to those projects with each other or the Program Z projects evaluated using CARP. In the final report submitted, all projects were included but this paper does not cover the scope of the methodology applied to the NBP1 projects.

The detail applied to the estimation of capital costs for each project varied for a number of projects. Some projects only had very raw strategic estimates, while others had P50[18] estimates and some had P90 estimates[19]. Often only one estimate was available for each project, giving the team no choice but to apply that estimate. P50 estimates minus escalation are typically applied to CBAs as the closest expected value of capital costs. Projects with strategically estimated capital costs are likely to have more favourable results as capital costs are likely to have been underestimated due to lack of inclusion of contingencies. Projects with P90 estimates are likely to have less favourable results as capital costs include contingencies beyond their expected value. The Program Z report informed decision makers that results were biased in favour of projects with strategic estimates and were biased against those with P90 estimates by including the type of estimate applied to each evaluation. The sensitivity tests of increasing and decreasing costs by 20% was applied to all projects for consistency. For projects with P90 estimates, the 20% increase is likely to produce unreasonably high costs. For projects with raw strategic estimates, the 20% reduction is likely to produce unreasonably low costs. Appendix B contains notes describing the type of estimate applied to each project.

The limitations of the Program Z program evaluation are numerous and cannot be fully covered in this paper but the most important point to consider is the purpose of the evaluations. If the Program Z program evaluation can be used as a useful strategic input into the future planning of the upgrade to Highway Z, the many limitations stated in this paper are

[18] P50 estimate is an estimate with a 50% confidence of not being exceeded at project completion, while not being conservative TMR (2012d).
[19] P90 estimate is an estimate with a 90% confidence of not being exceeded at project completion, while not being conservative TMR (2012d).

not a major concern as long as the results produced are not completely inaccurate. The use of CARP for the Z Program and NB2 funded projects provides some consistency to allow some comparison between projects. The accuracy of the Program Z evaluations will be revealed once the selected projects are evaluated in greater detail. If the CBA Team is involved in this process, the applied methodologies to Program Z can be reviewed and improved upon for future such program evaluations.

7. Application of the Advice provided by the Program Z Report

In early 2013, there was a media release by the Department of Infrastructure and Transport outlining the Australian Government's new commitments to Highway Z. Of the 18 projects announced as new commitments, 17 were evaluated using the methodology discussed in this paper. The 17 projects to be funded and their respective NPVs and BCRs calculated using CARP are given in Table 8.

Table 8: Projects Evaluated as part of Program Z announced as New Federal Government Commitments

Project Name	NPV ($)	BCR
FL5	-109,714,804	0.21
FL6	-397,283,384	0.11
FL9	-43,725,950	0.09
FL10	-70,035,637	0.07
FL13	-149,309,621	0.49
CA3	-57,478,893	0.01
CA21	12,370,545	1.12
CA24	606,633,413	2.35
CA30	-80,876,381	0.15
CA31	-76,000,000	0.04
CA45	-505,185,103	0.75
CA47	376,668,653	1.63
CA51	-1,408,359,418	0.25
CA54	370,704,869	2.72
NA	-23,472,268	0.97
NA	NA	1.12
NA	NA	1.12

Source: TMR 2013

The NPVs and BCRs presented in Table 8 are current as of October 2012. Most of the projects in Table 8 are currently or will be undergoing CBAs that are more detailed; therefore, the results presented in this paper will not necessarily correspond to those included in the final funding submissions. The selection of projects to be funded is in partial agreement to the advice provided by the Program Z report and spreadsheets. Projects such as Project CA54, Project CA47, Project CA24b and Project CA21 have been included. Projects such as Project FL16 and Project CA42 would have been economically viable inclusions. Some of the projects with low BCRs such as the Projects CA30 and CA31 did not have peak traffic data, therefore benefits from improved traffic flow at peak times were not incorporated in the CBA.

8. Conclusions

The Program Z program evaluation is unique in many ways. The sheer number of projects to evaluate in the space of such a short time was very challenging. The limited scope and data required team members to devise innovative methods of evaluating some projects. These methods would mostly need to be validated by further analysis but for the purpose of the exercise obtained results that should prove to be a rough indicator of the viability of projects and how they could be prioritised within the program.

One of the important advantages of evaluating projects as part of a program is that the interrelatedness between projects can be identified. This was the case for some of the flood immunity and capacity projects located within close proximity of each other. If these projects had been evaluated in isolation, the impacts these projects have on each other would not have been identified.

Excluding the NBP1 projects, the methodology applied to the evaluations is consistent enough for rough comparisons, as projects were evaluated using the same model (CARP V1.0), to be made between projects and allow projects to be ranked according to BCR. If an assumed cut-off BCR is applied, a proposed list of economically viable or close to economically viable projects can be short-listed for further analysis. Normally a cut-off BCR of one or greater than one (Miller 2005) is suggested, given the rapid nature of the evaluations, the recommendation of this paper is that the cut-off BCR should be lowered to account for the benefits excluded from the projects. When projects are re-evaluated with sufficient data and the budget is more clearly defined, the cut-off BCR should be raised to reflect the most efficient use of that budget.

Most projects evaluated did not obtain NPVs greater than zero. This is partly related to the rapid nature of the analysis and the unavailability of data that might have produced larger benefit streams. Some projects did not produce NPVs greater than zero simply because the traffic volumes were not high enough, the proposed project did not fully address the problem or the capital costs were too high. The positive response from both State and Federal Governments is a good indication that the work on the Program Z program evaluation is being applied and contributing to investment decisions. The ongoing more detailed CBAs of projects will provide an indication of how close the strategic analysis discussed in this paper has come to providing accurate results.

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Appendix A

Table 9: Results of Program Z Capacity Projects Evaluated with CARP

Project	Funding	NPV ($)	BCR
CA1	Z Program	-77,213,044	0.03
CA3	NB2	45,820,000	2.00
CA4	Z Program	-156,797,288	0.48
CA11	Z Program	-25,251,631	0.34
CA13	NB2	24,411,154	2.00
CA16	Z Program	-25,713,888	0.04
CA19	Z Program	6,000,000	2.20
CA20	Z Program	-30,352,887	0.24
CA21	NB2	12,370,545	1.12
CA23	NB2	13,610,000	2.40
CA24b	Z Program	606,633,413	2.35
CA26	Z Program	-218,508,625	0.44
CA27	Z Program	-15,145,614	0.43
CA28	Z Program	-191,770,422	0.34
CA29	NB2	-4,515,257	0.69
CA30	Z Program	-80,876,381	0.15
CA31	Z Program	-72,730,761	0.04
CA32	Z Program	-19,097,193	0.59
CA42	Z Program	23,851,426	1.48
CA43	Z Program	-44,268,686	0.11
CA43	Z Program	-39,240,964	0.22
CA44	Z Program	-112,261,525	0.12
CA45/CA46	Z Program	-505,185,103	0.75
CA47	Z Program	376,668,653	1.63
CA47	Z Program	346,013,096	1.58
CA49	NB2	-124,540,496	0.84
CA50	Z Program	-43,642,984	0.79
CA51	Z Program	-1,408,359,418	0.25
CA53	Z Program	-2,788,076	0.97
CA54	NB2	370,704,869	2.72
		-1,765,183,215	**0.78**

Source: TMR 2013

Table 10: Results of Program Z Flood Immunity Projects Evaluated with CARP

Project	Funding	NPV ($)	BCR
FL3	Z Program	-26,644,493	0.65
FL4	Z Program	-702,502,989	0.11
FL4/FL5	Z Program	-763,858,109	0.18
FL5	NB2	-109,714,804	0.21
FL6	Z Program	-397,283,384	0.11
FL8	Z Program	-377,662,248	0.74
FL9	NB2	-43,725,950	0.09
FL10	NB2	-70,035,637	0.07
FL11	Z Program	-304,170,956	0.07
FL12	Z Program	-9,116,930	0.37
FL13	NB2	-149,309,621	0.49
FL14	Z Program	-44,566,698	0.16
FL15	Z Program	-38,291,244	0.25
FL16	Z Program	240,839,436	6.20
		- 1,983,825,834	**0.49**

Source: TMR 2013

Appendix B

Table 11: Capital Costs and Estimate Stage (Capacity Projects)

Project	Type	Capital Cost ($)	Estimate Stage
CA1	Z Program	80,000,000	P90
CA3	NB2	58,000,000	P90
CA4	Z Program	300,000,000	P90
CA11	Z Program	30,000,000	Other
CA13	NB2	26,000,000	P50
CA16	Z Program	20,000,000	Other
CA19	Z Program	5,000,000	Planning
CA20	Z Program	40,000,000	Other
CA21	NB2	80,000,000	Other
CA23	NB2	9,000,000	Other
CA24b	Z Program	450,000,000	Planning
CA26	Z Program	390,000,000	Strategic
CA27	Z Program	20,000,000	Strategic
CA28	Z Program	290,000,000	Other
CA29	NB2	11,000,000	Other
CA30	Z Program	95,000,000	Unit Rates
CA31	Z Program	75,000,000	Unit Rates
CA32	Z Program	30,000,000	Strategic
CA42	Z Program	50,000,000	Other
CA43	Z Program	50,000,000	Other
CA43	Z Program	110,000,000	Other
CA44	Z Program	2,050,000,000	Concept
CA45/CA46	Z Program	600,000,000	Concept
CA47	NB2	790,000,000	Concept
CA47	Z Program	209,000,000	Unit Rates
CA49	Z Program	1,875,000,000	Prelim
CA50	Z Program	110,000,000	Prelim
CA51	NB2	215,000,000	Strategic

Source: TMR 2012e

Table 12: Capital Costs and Estimate Stage (Flood Immunity Projects)

Project	Funding	Capital Cost ($)	Estimate Stage
FL3	Z Program	80,000,000	Concept
FL4	Z Program	810,000,000	PPR
FL4/FL5	Z Program	145,000,000	PPR/Concept
FL5	NB2	955,000,000	Concept
FL6	Z Program	460,000,000	Tender
FL8	Z Program	1,430,000,000	Prelim
FL9	NB2	49,000,000	Prelim
FL10	NB2	80,000,000	P90
FL11	Z Program	340,000,000	PPR
FL12	Z Program	15,000,000	Prelim
FL13	NB2	296,000,000	Prelim
FL14	Z Program	55,000,000	P90
FL15	Z Program	52,000,000	Strategic
FL16	Z Program	60,000,000	Strategic

Source: TMR 2012f