

# Application of above average crash costs in road infrastructure cost benefit analysis: a case study example<sup>1</sup>

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## ABSTRACT

Application of robust, technically appropriate evaluative methodologies are critical in supporting informed decision making and prioritising portfolio investment management decisions.

This paper outlines the approach taken within the Queensland Department of Transport and Main Roads in conducting cost benefit analysis of a proposed road project. The project features a reduction in section length, road improvement and realignment of the Bruce Highway at Gin Gin, Queensland.

Importantly, the road section features above average crash rate incidence and accident severity, and a non-standard approach using historical crash record data is adopted in assigning project case economic valuation of crash costs.

Project benefits are reported in terms of travel time cost savings, vehicle operating costs, accident cost savings and externality savings. Indicators of financial viability including net present value and cost benefit ratio are calculated. The role of economic evaluation in informing the business case for proposed public works is explored within the context of governmental agency program specification, project prioritisation and funding allocation.

Results of analysis indicate project viability when assessed at the Federally-mandated discount rates of four and seven per cent. At a discount rate of four per cent, net present value is \$18.4M, with a benefit cost ratio of 2.14:1.

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<sup>1</sup> This paper expands on Best (2012), *A cost benefit analysis the southern approach to Gin Gin, Queensland: an operational case study perspective*, submitted to the 2012 Australasian Road Research Board (ARRB) Conference, May 2012.

## Abbreviations

AADT	Annual average daily travel
ARMIS	Automated road management information system
BCR	Benefit cost ratio
CBA	Cost benefit analysis
CBA6	Cost benefit analysis, version 6
CBR	Cost benefit ratio
CPI	Consumer price index
DVR	Digital Video Road (viewer)
GHD	Gutteridge, Haskins and Davey
km	kilometre
Km/h	Kilometres per hour
MRS	Model road state
NAASRA	National Association of Australian State Road Authorities
NIMPAC	National Association of Australian State Road Authorities improved model for project assessment and costing
NPV	Net present value
NRM	National Association of Australian State Road Authorities roughness measure
TARS	Traffic analysis and reporting system
TMR	Queensland Department of Transport and Main Roads
TTC	Travel time costs
VKT	Vehicle kilometres travelled
VOC	Vehicle operating costs

## Executive Summary

The Wide Bay/Burnett Region of the Queensland Department of Transport and Main Roads (TMR) proposes a realignment and improvement of the southern approaches of the Bruce Highway (TMR Road ID 10C) into the township of Gin Gin, Queensland. The site of the project is located between chainage 110km and 111.7km of the Bruce Highway between Maryborough and Gin Gin (TMR, 2011a). This road section has recorded above average crash rates and accident severity. The proposed project provides for the improved alignment of the road section including elimination of the low speed, curved and hilly road section immediately leading into the township. Additionally, the proposal includes improvements to vertical alignment and model road state (TMR, 2011a).

Cost benefit analysis of this project reveals that the proposed project is economically viable when assessed at Federally-mandated discount rates of four and seven per cent. At a discount rate of four per cent, the net present value generated is \$18.4 M, with a benefit cost ratio of 2.14:1. Applying a discount rate of seven per cent, net present value is \$6.8 M, with a benefit cost ratio of 1.44:1 (TMR, 2011b). Table 1 contains a summary of project results.

**Table 1: CBA Results<sup>2</sup>**

<b>Discount Rate</b>	<b>4%</b>	<b>7%</b>
Discounted Costs	\$ 16,133,863	\$ 15,334,419
Discounted Benefits	\$ 34,527,518	\$ 22,099,242
<b>Net Present Value (NPV)</b>	<b>\$ 18,393,656</b>	<b>\$ 6,764,823</b>
<b>Benefit Cost Ratio (BCR)</b>	<b>2.14:1</b>	<b>1.44:1</b>

**These results provide a basis for an economic justification of the proposed project and support the recommendation to proceed with the project.**

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<sup>2</sup> Subject to rounding

## Introduction

This paper contains cost benefit analysis (CBA) for a project to realign and improve the Bruce Highway leading into Gin Gin in the TMR Wide Bay/Burnett region of Queensland under project 74/10C/900<sup>3</sup>. The project includes road realignment and improved southern approaches into the township of Gin Gin and is expected to reduce crash incidence and severity and improve vehicle speeds<sup>4</sup>.

The paper develops and outlines base case and project case scenarios for detailed cost benefit economic evaluation, based on regionally sourced data. The data is used in calculating valuations of net project benefits.

Adopted methodologies applied are outlined, including relevant sourced input data and assumptions used. Project benefits are assessed, including calculation of above average crash incidence. Detailed project investment schedule and operating costs for the life of asset are cited. Finally, results are reported, along with sensitivity testing of results. These results form the basis for the drawing of the conclusion to proceed with the project.

## Cost benefit analysis

Cost benefit analysis (CBA), alternately known under numerous name variations including benefit-cost analysis (BCA), is an analytical microeconomic technique for comparing investment and generated returns. It is a widely accepted analysis for use in project evaluation. Zerbe and Bellas (2006), note it as a technique of analysing proposed or previously enacted projects to determine whether doing them is in the public interest, or to choose between two mutually exclusive projects. The technique assigns a monetary value to each input and each output resulting from the project. The values are then compared.

It is a technique for assessing the economic efficiency of resource allocation. It allows us to compare alternative approaches to individual projects and to set priorities amongst competing projects. It uses as its framework the values of all costs and benefits to the community which can be quantified in money terms (Austroads, 1996). Ultimately, the essence of cost benefit analysis is that initial costs and the costs of continuing operation throughout the 'life' of the project are compared with the estimates of the benefits (and losses) due to the operation of the project over the same life span (Andreassen, 1993).

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<sup>3</sup> This paper is an extension of the work conducted by Best in conducting the initial cost benefit analysis of this project. Within that document, the same methodology was applied, but full explanatory notations of the approach not provided (TMR, 2011b).

<sup>4</sup> Currently, vehicles traverse a curved, steeply undulating approach to town, with posted speed limits progressively slowing vehicle approach to 40 kilometres per hour. The project includes road widening, an increase in vehicle speed limits and elimination of the dangerous curved road section.

Evaluation is an essential tool in managing government programs (Department of Finance, 1994). Building up a number of projects leads to detailed evaluation at the program level.

## **Project scope definition**

In describing the project initiative, the Australian Transport Council (2006), specifies numerous designators including description of specific location, physical characteristics, function, estimated costs, timing and main benefits.

The Gin Gin case study consists of an approximately 1.7 kilometre long section of road between chainage 110km and 111.7km of the Bruce Highway between Maryborough and Gin Gin (TMR Road ID 10C). This section of road consists of an undulating approach within a highway environment leading into a series of sharp, hilly, slow speed (40 Km/h) curves. The slower speed environment is necessitated due to the road climbing a high feature leading directly into the town. Above average crash rates have been recorded along this more curvy section due to road surface and poor road alignment.

Visually, a notable difference in accident history along the road section was seen by viewing the recorded accident history of the project site. The project case consists of realignment and improvement in the road section, removal of this extremely curved section and a reduction in overall length of some 100 metres.

## **Base Case**

The base case consists of whatever would be done in the absence of any new initiative being implemented or by following a business as usual scenario (Austroads, 2006). In terms of the studied project case study, the defined base case consists of two distinct sections of road<sup>5</sup>, with section A running from chainage 110.04km to 111.2km for a length of 1.16 kilometres. The balance of the base case (Section B) proceeds from the northern end of section A to the end of project at chainage 111.72km. In calculating base case length, an additional 100 metres has been included to account for the overall reduction in road length under the proposed project. In terms of maintenance and rehabilitation ongoing costs, cost structures have been drawn from regionally supplied capital investment and cost structure estimates. Proposed ongoing costs for the base case (without the project) have been apportioned in line with respective road portion lengths.

## **Project Case**

In accordance with the specified base case, the project case is divided into separate sections of roadway. Section A corresponds to the base case, sharing the same section length of 1.16 kilometres. Section B is defined as running

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<sup>5</sup> Although the project length has been split into two distinct portions, this has been done in order to complete appropriate analysis. Ultimately, the two portions are combined within the overall analysis.

between chainage 111.2km to 111.72km, a length of 0.52 kilometres. Note here that there is an overall road length reduction of 100 metres under project implementation. In terms of projected maintenance and rehabilitation costs, estimates are applied from regionally supplied data and apportioned in line with project portion lengths (i.e. split proportionally across the length of the project, subject to the initial disaggregation applied in dealing with road sections with differing characteristics as outlined below).

### **Additional specification**

Due to the fact that the specified chainages consists of two distinctly different road sections (a high speed, gently curved approach to a hilly, treacherous road section featuring numerous accidents), the case study has been divided into two sections. This sectionalisation also assists ease and accuracy of analysis. Northbound, the first section (specified as section A) consists of road improvement and the second section (specified as section B) consists of the curvy, hilly approach immediately proceeding into the township of Gin Gin. Importantly, this section currently features poor horizontal and vertical alignment.

Under the project proposal (TMR, 2011a), the proposed alignment works:

- Provide sufficient capacity for project traffic volumes
- Improve highway alignment to reduce the number of “roll over” type accidents occurring in this section of the highway
- Improve other safety issues in particular those associated with the Bundaberg- Gin Gin Road and Bruce Highway intersections (including intersection legibility)
- Address community concerns with regard to minimising impacts on local cultural localities and events
- Provide works that minimise maintenance and operational costs.

## **Assumptions and Methodology**

### **Methodology**

In terms of the methodology used, the Transport and Main Roads (TMR) cost benefit assessment tool CBA6.1 was used in combination with Microsoft Excel spreadsheet software in generating project evaluation results.

In assessing the project, the designated road section was broken down into two defined sub-sections to allow ease of analysis. Detailed plans, as well as the TMR Digital Video Road Viewer (DVR) were used in specifying the two relevant

road section lengths<sup>6</sup>. Regionally supplied planning documentation- including maps, plans and investment schedules- proved useful in project orientation, definition and assessment.

Due to higher than average crash rates in the base case road sections, accident costs were calculated within a Microsoft Excel spreadsheet for input into CBA6.1. Crash incidence and severity was taken from TMR ChartView ARMIS database for the applicable chainage markers. The difference between the base case (above average) crash rates and modelled road state crash rates were combined and the difference netted to extract net crash cost benefits. The expected crash rates for the newly constructed road way was taken from model road state expected crash rates and calculated in CBA6.1. Further details are provided in the following section.

The Transport and Main Roads (TMR) cost benefit estimation tool CBA6.1 has been used in calculating the net cost savings associated with the proposed project. This software tool is used in calculating net present value (NPV) and benefit cost ratio (CBR) after all known and expected data is inputted. The tool draws on accepted Austroads logarithms and relationships between known road conditions and modelled vehicle wear rates in deriving expected costs<sup>7</sup>. Basic parameters were inputted in accordance with specified base case road condition and project investment scheduling.

Costs data was apportioned according to project road lengths for input. Externalities were calculated by applying the vehicle composition breakdown to appropriate accepted vehicle kilometres travelled summations.

Vehicle composition was drawn from the historic data, based on vehicle compositions from 2009<sup>8</sup>. These figures were inflated in accordance with a specified vehicle growth rate estimate to derive current and expected growth rate<sup>9</sup> and vehicle composition<sup>10</sup>.

Following the production of output data from CBA6.1, both the defined road section result scenarios were inputted into a Microsoft Excel spreadsheet to allow for further analysis and refinement.

Accounting for the fact the CBA6.1 benefits drew on 2007 road user equivalent values<sup>11</sup>, an inflation figure was applied to initial results. Applying a consumer

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<sup>6</sup> In defining the two distinct sub-sections, it was much a case of aligning accident history to road chainages, and defining these sub-sections (A and B) in terms of what were apparently very distinctly different sections of roadway.

<sup>7</sup> To be clear, user of CBA6.1 have the option of either specifying input data in regards to expected crash occurrence OR relying upon default values drawn from an SQL database, which relies upon Austroads derived modelled road state (MRS), based upon road width. In this analysis, the value of (above) average crash rates were calculated outside of CBA 6.1 and manually inputted.

<sup>8</sup> In this case, drawn from a traffic analysis and reporting system (TARS) report.

<sup>9</sup> Nominated at three per cent compound growth.

<sup>10</sup> In this particular case with the assumption that vehicle fleet *composition* remains unchanged across the project life.

<sup>11</sup> Current at time of analysis, now updated to 2010 values following publication of Austroads (2011), AP-373-11.

price index (CPI) inflation figure allowed for time value of money effects to be accounted for and permitted comparison of dollar amounts in current<sup>12</sup> -2011-values. After accounting for the inflationary effects upon vehicle operating costs (VOC), travel time costs (TTC) accident savings and externality savings, the two road sections were combined and final results generated. These initial results are reliant upon best guess estimation of project costs and derived benefits.

Finally, sensitivity testing was undertaken on key input assumptions, based upon likely changes to these project inputs in order to test the robustness of calculated results.

## Above average accident costs

The method of operation for the CBA6.1 cost benefit calculation software tool is typically to draw information from defined, databases featuring known and accepted relationships between input data. Much of the sourcing of such data is from Austroads sources; included as references to this paper. For example, within CBA6.1, accident costs are calculated using a default accident rate based on road type model road state and the average cost of a crash. CBA6.1 calculates accident cost from estimations of average crash costs based on the crash severity and historical crash rates determined by the model road state (MRS). Accident costs are a Queensland average, based on Austroads unit crash data (TMR, 2011c).

Total crash cost calculation is determined by the number of vehicles on the road, the (Austroads-specified) accident rate and the average crash cost, and can be found through the application of the following formula:

$$CrashCost_{RT} = MVKT \times A_{TR} \times AACC_{RT}$$

Where:

- $CrashCost_{RT}$  is the crash cost in dollars per road type
- $MVKT$  is millions of vehicle kilometres travelled
- $A_{TR}$  is total crash rate (accident/MVKT)
- $AACC_{RT}$  is average crash cost for road type (\$).

And therefore,

$$CrashCost = \frac{AADT \times 365.25 \times SecLength}{1,000,000} \times A_{TR} \times AACC_{RT}$$

Where:

- $AADT$  is annual average daily traffic (vehicles)

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<sup>12</sup> Current at time of analysis.

- *SecLength* is road section length (km)

**Source: TMR (2011c)**

Such relationship specification is one of the advantages of using a dedicated tool, is in line with Australian Transport Council guidelines covering such matters and is time efficient because of automation within the CBA 6.1 calculation tool.

However, additional flexibility is available from CBA6.1 through the use of *manual overrides* of inputted data<sup>13</sup>. In dealing with the above average accident costs evident in the case study, it was necessary to modify the routine practice of designating the project road width in the form of modelled road state within CBA6.1. The reasoning logic behind such an approach is that not undertaking such additional analysis would necessarily undervalue expected crash costs in both the base and project case for the analysis, leading to an overall distorted and under representative valuation of net project benefits and ultimately inaccurate analysis.

Following Andreassen (1993), accidents were disaggregated into accident type thereby overcoming two problems. The first is that the average casualty class distribution for each accident-type group is stable over time and thus only frequencies of particular accident types are of concern. Secondly, the effects can be given in terms of the changes in particular accident-types, not just the change in total number of accidents. The effect of such application is resultant increases in analytical accuracy.

Turning now to the calculations conducted within the case study analysis, specifically the derivation of base case (above average crash incidence) accident rate and cost calculations...

In selecting any data set for further applicative usage, considerations included accuracy (including precise definitional description and completeness) and appropriateness. Eleven years of data, including the most recently available complete year of data from 2010, were included for two reasons. The first was the obvious aim of compiling a data set that was thought to be of sufficient length to be a "typical" representation. As well the absence of any major works conducted on the case study road section within this timeframe; positively affecting road safety and reducing accident occurrence. Put another way, the lack of implementation of any major accident reduction safety initiative would mean that recorded accidents were solely due to the (base) case road status characteristics including surface and section alignment.

It was concluded that the data from the year 2000 to the year 2010 would prove a sufficient set from which to extract accident cost data. A secondary reason for the choice of eleven years was that, due to fact of there being an odd number of

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<sup>13</sup> Let there be no doubt that the modification of calculated net benefit away from automated calculation, through manual modification is the remit of a specialised user with extensive appreciation of the implications and consequences of such usage!

data collection years, there would be a “middle” year of data (2005 in this case), perfectly between the start and end period data collection years. From this, data could be calculated back to be the nominated year of typical crashes along the road section; all other calculations would then ultimately come from this median year<sup>14</sup>.

The first part of the data manipulation and calculation exercise was the simple application of a compounding of average annual daily traffic to inflate it to the base period of analysis. This was required as 2009 was the most recently available average annual daily traffic count and vehicle fleet composition that could be furnished for the cost benefit analysis. This step was completed according to the formula:

$$AADT_{11} = AADT_{09} \times (1 + 0.03)^2$$

Where:

- $AADT_{11}$  was the average annual daily traffic for the year 2011
- $AADT_{09}$  was the average annual daily traffic for the year 2009.

That is, the average annual daily traffic was grown by three per cent compound growth. The resultant calculation of 4,973 vehicles was used road traffic data (base and project case) within CBA6.1.

In calculating average accident cost, the following formula is applied:

$$AC_{AV} = \frac{(nAC_f \times C_f) + (nAC_s \times C_s) + (nAC_m \times C_m) + (nAC_{pdo} \times C_{pdo})}{nAC_{TOT}}$$

Where:

- $AC_{AV}$  is average accident cost
- $nAC_f$  is the number of fatal accidents recorded
- $C_f$  is the cost of fatal accident
- $nAC_s$  is the number of serious accidents recorded
- $C_s$  is the cost of a serious accident
- $nAC_m$  is the number of minor accidents recorded
- $C_m$  is the cost of a minor accident
- $nAC_{pdo}$  is the number of property damage only accidents recorded

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<sup>14</sup> Otherwise, crash costs would have been skewed upwards, with the growth applied over the time series driving up accident costs from the inflationary effect of average annual daily traffic growth rate.

- $C_{pdo}$  is the cost of a property damage only accident
- $nAC_{TOT}$  is the number of total accidents recorded along the road section within the reference of the data time frame.

Next to consider is the calculation of the data mid-point, given by the formula:

$$AADT_{05} = AADT_{09} \times \frac{1}{(1+r)^n}$$

Where:

- $AADT_{05}$  is the average annual daily traffic for the year 2005
- $r$  is the rate of growth in average annual daily traffic
- $n$  is the number of years.

Application of this formula sees average annual daily traffic of 4,165 vehicles for the year 2005. This figure is further applied within the analysis in calculating total traffic volume for the time period by the formula:

$$TV_{TOT} = n \times 365.25 \times AADT_{05}$$

Where:

- $TV_{TOT}$  is the total traffic volume.

This gave a total traffic volume for the 2000-2010 time period of 16,734,842 vehicles for all vehicle types.

Base case accident rate is given by the formula:

$$AR_{BC} = \frac{nAC_{TOT} \times 1,000,00}{TV_{TOT} \times d}$$

Where:

- $AR_{BC}$  is (base case) accident rate
- $d$  is the road section length.

Application of the above formula saw a crash rate calculation of 1.3493 accidents per million vehicles.

Finally, the average crash cost given the newly calculated vehicle crash rate is calculated using the formula:

$$CC_{BC} = \frac{AC_{AV} \times AR_{BC} \times 365.25 \times AADT_{11} \times d}{1,000,000}$$

Where:

- $CC_{BC}$  is (base case) crash cost.

Ultimately, the crash cost for the road section under review is some \$508,525 for the base year of analysis.

In calculating project case accident costs, Austroads predicted crash rate per million vehicle kilometres travelled of 0.206866197 was used.

### Data inputs

The following data inputs were used in BCA6.1 in calculating the cost benefit analysis:

- Total included project capital costs of \$19,200,000<sup>15</sup>
- Calendar year capital cost outlays of \$200,000 (2011), \$18.8 M (2012) and \$200,000 (2013)
- The evaluation period of the project is 32 years, including the remaining year of planning and preparation, one year of construction and 30 years for the continued operation of the asset
- The base case road section has an initial roughness of 112 NRM
- The newly constructed road works have an estimated roughness of 60 NRM
- Accidents costs of the base case are calculated using historical data; while accident costs of the project case are calculated using a predefined rate and cost calculated within CBA6
- 2011 average annual vehicle travel (AADT) is calculated at 4,973
- The assumed traffic breakdown is private cars 75.02%, commercial cars: 4.75%, buses: 1%, rigid (non-articulated) trucks: 6.06%, articulated trucks: 7.41%, B-doubles: 5.53%, road train (type 1): 0.21% and road train (type 2): 0.02%

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<sup>15</sup> In conducting this CBA, foregone costs for project scoping and planning incurred prior to 2011 have been treated as (irrecoverable) sunk costs. Sunk costs are those that are already incurred or irreversibly committed to before the moment of the decision which the CBA is trying to guide, so that they cannot be affected by that decision (Snell, 2011).

- Externalities have been calculated using the sum of externality unit rates per vehicle kilometres travelled (VKT) in accordance with Austroads paper IR-156/08
- Base case costs include maintenance costs of \$24,000 (year 1), \$26,800 (year 2), \$28,800 (year 3), \$31,200 (year 4) and rehabilitation costs of \$2,000,000 (year 5)
- Base case rehabilitation costs of \$250,000 would be incurred in year 15 and year 25.

### **Assumptions**

A number of basic assumptions have been applied to this CBA as data for input into CBA6.1 and Microsoft Excel worksheets. The assumptions include:

- Rehabilitation works reduce road roughness to 60 NRM
- Section B of the project case is 100m shorter than Section B of the base case
- Vehicle composition is held constant over the course of the analysis
- A 3% compound traffic growth rate has been assumed based on ARMIS predictions
- Project case rehabilitation costs include rehabilitation of \$250,000 in years 10 and 20 post construction.
- All costs and benefits are calculated in (March) 2011 prices
- Discount rates of four and seven per cent have been applied.

### **Input Data**

In sourcing data, a number of TMR Departmental data harvesting and visual representation tools as well as additional data sources have been used. These include:

- TMR ChartView
- TMR DVR
- TMR traffic analysis and reporting system (TARS)
- ARMIS database
- Regionally supplied data from James Stephens, Bundaberg-based GHD engineering support officer.

### **Costs and Benefits**

Costs are defined within this analysis as those borne by Transport and Main Roads in terms of the initial project planning, design and engineering works, as well as capital and ongoing maintenance costs across the life of the project. Defined benefits encompass road user benefits including reduced crash

incidence cost, vehicle operating costs, travel time savings and savings in externalities.

**Costs**

Project costs include incurred road agency costs. These include initial planning, detailed design and engineering works, ongoing routine maintenance, periodic maintenance, rehabilitation and initial and ongoing capital costs. A summary of undiscounted costs for both the base and project cases are given in table 2.

**Table 2: Road agency costs**

Year	2011	2012	2013	Total
Amount	\$200,000	\$18,800,000	\$200,000	\$19,200,000

Costs are in 2011 nominal dollar values and exclude project cost escalation.

**Benefits**

The benefits of highway projects occur primarily because of highway use; road users are the initial beneficiaries of both reductions in cost and improvements in road quality. Savings to automobile and truck operators in terms of shorter or faster trips, reduced operating costs, and safer travel are included in traditional analysis (Hibbard and Miller, 1974). Road user benefits relevant to this analysis include reduced crash rates, improvements in vehicle operating costs (VOC), travel time savings (TTC) and externalities in the form of reduced vehicle emissions. Where a project has demonstrable potential reductions in vehicle usage (by travelling reduced distances) there can reasonably be expected concurrent reductions in vehicle wear and tear and rates of depreciation. Similarly, where project road works result in a safer driving environment, benefits in the accident cost reductions may also be expected<sup>16</sup>.

The indexing method applied to unit values is the application of an inflationary figure<sup>17</sup>. The effect of this calculation is to convert 2007 prices to 2011 monetary values using the inflationary figure. This avoids distortion through using difference basis years and ensures that accrued project costs and benefits allow for the time value effects of discounting applied throughout the analysis<sup>18</sup>.

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<sup>16</sup> It must be noted that in deriving benefits, a human cost approach has been adopted. For a brief early discussion around potential shortfalls of such an approach, as well as merits around adopting (internationally-recognised) “willingness to pay” methodology, see Kearns, 1987.

<sup>17</sup> An inflationary calculation figure of 12.19%, drawn from contemporary consumer price indices, has been applied and allows for the appropriate inflating of the mid-2007 benefits calculation data used within CBA6.1.

<sup>18</sup> Or put another way, the application of a numeraire.

## Accident Cost Savings

Accident savings are the largest road user cost saving in this project, accounting for 39% of total projected project benefits. Historical data reveals above average accident incidence and severity. Outside of the road section, where above average crash costs have been applied as discussed, the road project realignment and improvement of the road section of road is expected to reduce the rate and severity of accidents in line with the Austroads prescribed (modelled) rate. Accident cost savings in this project are estimated to be \$13,841,532 at a discount rate of four per cent.

## Vehicle Operating Cost (VOC) Savings

Vehicle operating costs (VOC) include fuel and oil usage, tyre wear, repair and maintenance, interest repayments and depreciation. VOC is calculated using National Association of Australian State Road Authorities improved model for project assessment and costing (NIMPAC) algorithms.

Under the project, there are improvements in road surface roughness and vehicle fleet operating speeds, as well as the removal of a hilly, curvy and historically dangerous route.

Table 3 shows the breakdown between private and commercial VOC.

**Table 3: Vehicle operating costs project benefits breakdown (Discount rate 4%)**

Vehicle operating cost	Project Case
Private	\$ 6,745,790
Commercial	\$ 7,262,795
Total	\$ 14,008,585

## Travel Time Cost (TTC) Savings

Due to the reduction in road length under the project case, net TTC savings can reasonably be expected in the project case. As shown in Table 4, net discounted TTC savings are \$5,454,858.

**Table 4: Travel time savings project benefits breakdown (Discount rate 4%)**

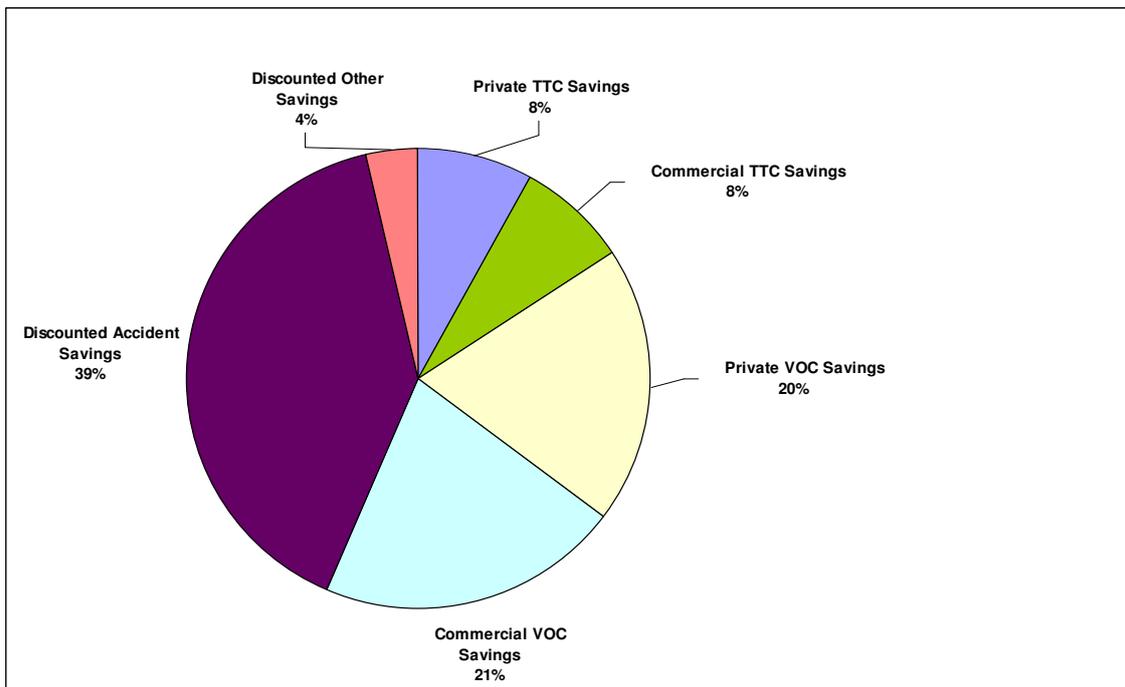
Travel Time Savings	Project Case
Private	\$ 2,798,071
Commercial	\$ 2,656,787
Total	\$ 5,454,858

## Externality Savings

Externality savings includes reductions in greenhouse gases, air pollution, noise pollution, water pollution, nature and landscape, urban separation, and upstream and downstream costs. All values for externality costs have been sourced from Austroads paper IR-156/05. Externality cost savings are calculated using vehicle kilometres travelled (VKT) per vehicle type. Externality savings are sensitive to changes to annual average daily travel (AADT), composition of AADT and section length. Within the project, road section length has been reduced therefore producing externality cost savings through reduced distance travelled. The calculated project externality benefits are relatively small due to the relatively small reduction in road section length and are calculated to be \$1,222,544 at a discount rate of four per cent.

## Summary of Benefits

As can be seen by reference to Figure 1, accident cost savings are the largest source of benefits of this project, accounting for 39% of the project benefits. There are significant VOC savings, with commercial and private VOC saving accounting for 21% and 20% of project savings, respectively. TTC savings are relatively small, as are externality savings due mostly to the relatively small reduction in road length proposed under the project. It can be seen that externality and TTC savings make up the remaining portions of project benefits.



**Figure 1: Breakdown of project benefits**

Given the elimination of a dangerous, circuitous route, improvement in road surface and model road state, the resultant project benefits are in line with

expectations. In terms of comparison between calculated private and commercial benefits, both TTC and VOC breakdown is highly variable to defined vehicle composition.

## Results and Sensitivity Analysis

In undertaking applied economic analysis, benefit cost ratio (BCR) and the net present value (NPV) are used in determining project viability. For a proposed project to be considered economically viable, the NPV should be greater than zero, with a BCR in excess of a ratio of one at the prescribed discount rates. The discount rates applied to this CBA are four and seven per cent and are derived from Federally-mandated requirement standards.

At a discount rate of four per cent the project BCR is 2.14:1 and the NPV is \$18,393,656. At a discount rate of seven per cent, the BCR is 1.44:1, with an NPV of \$6,764,823. Therefore, given current input data, the project is economically viable at both discount rates. Current project estimation relies upon best guess estimates of numerous input data. The results of the CBA (best estimate) are presented in Table 5.

### Results

Cost benefit analysis of the proposed project results in the following results breakdown shown in Table 5.

**Table 5: Project evaluation cost benefit analysis, breakdown of results**

Discount Rate	4%	7%
<b>Discounted Costs</b>	<b>\$16,133,863</b>	<b>\$15,334,419</b>
Discounted Capital Costs	\$17,751,764	\$16,770,824
Discounted Other Costs	-\$1,617,901	-\$1,436,405
<b>Discounted Benefits</b>	<b>\$34,527,518</b>	<b>\$22,099,242</b>
Private TTC Savings	\$2,798,071	\$1,780,008
Commercial TTC Savings	\$2,656,787	\$1,709,809
Private VOC Savings	\$6,745,790	\$4,321,727
Commercial VOC Savings	\$7,262,795	\$4,657,071
Discounted Accident Cost Savings	\$13,841,532	\$8,849,042
Discounted Externality Cost Savings	\$1,222,544	\$781,585
<b>Net Present Value (NPV)</b>	<b>\$18,393,656</b>	<b>\$6,764,823</b>
<b>Benefit Cost Ratio (BCR)</b>	<b>2.14:1</b>	<b>1.44:1</b>

As can be seen from the results, at a discount rate of four per cent, project NPV is equivalent to \$18.4 M, with a benefit cost ratio (BCR) of 2.14:1. At a discount rate of seven per cent, project NPV is \$6.8 M, with a BCR of 1.44:1. These results imply that the project is economically viable at these discount rates. These results are further tested using sensitivity testing.

### **Sensitivity<sup>19</sup> Analysis**

In order to test the robustness of modelled results, sensitivity testing was undertaken<sup>20</sup>. These sensitivity tests further analysed the project in terms of scenarios where:

- Project costs increased by 20% (S1)
- Project costs decreased by 20% (S2)
- Project benefits increased by 20% (S3)
- Project benefits decreased by 20% (S4)
- Project costs increased by 20%, coupled with a 20% reduction in project benefits (S5)
- A discount rate of 10% is applied to the project (S6).

The results of this sensitivity testing can be seen in Table 6.

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<sup>19</sup> In accounting for a range of possible alternate project outcomes, variables recommended by Austroads (1996) were adopted. An alternative is the application of risk analysis software such as the highly regarded Palisade @Risk suite, which allows for individual specification of (deterministic) input cells within Microsoft Excel spreadsheets; thereby permitting generation of probabilistic results and derivation of cumulative probabilities around specific project outcomes. It should further be acknowledged that such an approach is reliant upon quite extensive statistical data sourcing and analysis. Another handy source for discussion around a stochastic approach to project evaluation is contained in Austroads (2005), Annex to Part 2: Risk Analysis.

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**Table 6: Sensitivity Analysis (Discount Rate 4%)**

Sensitivity Test	BCR	NPV (\$)
Best Estimate	2.14:1	\$ 18,393,656
S1	1.78:1	\$ 15,166,883
S2	2.68:1	\$ 21,620,428
S3	2.57:1	\$ 25,299,159
S4	1.71:1	\$ 11,488,152
S5	1.43:1	\$ 8,261,380
S6	1.04:1	\$ 524,409

The results of the sensitivity analysis indicate that the project remains economically viable in alternate scenarios where costs and benefits are adjusted by 20% in either direction or when the discount rate is 10%. This is indicative of project result robustness, however, it should be noted the project becomes increasingly marginal at higher discount rates.

#### **A note on portfolio management context**

The abstract of this paper promised some discussion around the subject of the role of economic evaluation in informing business cases within the context of governmental agency program specification, project prioritisation and funding allocation.

As noted by Turner (undated), all road and traffic authorities need to direct their funding wisely to road safety treatments that ensure the most cost-effective returns in crash and injury reductions.

The very case study that has formed the basis of this paper was conducted for the purpose of a Federal Government funding submission, a common practice within State-level Government. Since the initial, detailed economic analysis (April-May 2011), the duly submitted funding application has indeed proven successful (Ian Grotherr, pers. comm.).

Within a context of portfolio management, it could well be hoped that such funding submissions were the subject of a refined, co-ordinated and well considered approach to investment funding and allocation throughout the Department. Indeed, as noted by Andreassen (1993), the application of cost benefit analysis is a procedure that one would hope to see used more frequently to justify the expenditure of public monies in all transport projects. Essentially, the basic objective of cost benefit analysis is to evaluate investment projects systematically, so that they can be more readily compared (Kolsen and Stokes, 1968).

However, recent internal reporting research is indicative of a distinct lack of the application of economic evaluation to Departmental-level project funding

selection and prioritisation. Citing information of funded projects, Davies suggested a concerning lack of such economic evaluation to the extent that something like a full **80%** of approved and funded projects *did not have* adequate benefit cost analysis conducted (TMR, 2011).

Fortunately, a recent change in business rule now appears to have been adopted within the applicable guidelines whereby a newly developed business rule now states explicitly, albeit somewhat belatedly, that for addition to the Departmental investment plan known as QTRIP (Queensland Transport and Roads Investment Plan), whereby “project business case submissions must be accompanied by a rigorous cost benefit analysis to be included on the QTRIP” (TMR, 2012, page 54). It appears unfortunate from a purely economic assessment and project viability point-of-view that such an approach has not been applied with an appropriate level of rigour previously. Of course, it can only be hoped that the addition of this explicitly stated business rule is applied vigorously into the future and leads to an improvement of value for money assessments. Still apparently unexplained though, is exactly how projects came to be placed on the investment plan- fully funded- without conduct of economic evaluation having occurred.

Within such a context, and noting criticisms of a cost benefit analysis approach, Zerbe and Bellas (2006), talk of a shifting in the burden of proof after conduct of a cost benefit analysis to those who may make a decision contrary to economic evidence and indeed further; the very constraint of more arbitrary, politically-driven choice through the very application of a technically robust, evidence-based approach like cost benefit!

Such issues are indicative of profound underutilisation of applied economic analysis at higher strategic decision-making levels- either through choice or ignorance- in the continual development of a transparent and coherent approach to portfolio investment co-ordination and its ongoing management. This will likely be familiar ground for the practitioner of applied economics, as will likely be issues around a lack of appropriate organisational enforcement. Thus providing much content for any discussion around (inter) Governmental decision-making processes, investment allocation and the application of rigorous technical analysis including cost benefit approaches...

## **Conclusion**

This paper reported on an economic case study evaluating the proposed realignment and improvement of the Bruce Highway approach to Gin Gin under TMR project number 74/10C/900. Derivation of above average costs was demonstrated and applied within the cost benefit analysis. Additional discussion around the more strategic use of cost benefit analysis within a portfolio management context was also provided.

The results of the case study indicate project viability across a range of possible scenario changes using sensitivity testing. Sensitivity testing indicates project viability at discount rates ranging up to 10%, project cost increases of 20%, a

decrease of 20% in project benefits, as well as a scenario combining benefit decreases of 20%, coupled with cost increases of 20%.

The ability of the project to withstand such sensitivity testing is indicative of the overall economic robustness of the project and its ability to absorb a range of potential project shocks. Overall, findings from the cost benefit analysis support a recommendation to proceed with this project on economic grounds.

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## **AUTHOR BIOGRAPHY**

Mark holds a Bachelor of Agricultural Economics from Sydney University and worked for over eight years as an Agricultural Economist with the Queensland Department of Primary Industries. His work included rural marketing development, strategic policy formulation, and financial investment analysis, with emphasis on broad acre agriculture and intensified horticultural industries. He has been based in Brisbane, Rockhampton and Toowoomba, and has travelled extensively throughout key production regions.

More recently, Mark has joined the cost benefit analysis team within the Queensland Department of Transport and Main Roads, providing a range of economic services including the conduct of economic evaluation of infrastructure proposals.