# Riverbend Version 2 Narrative (for use with the EDGeS Tool)

## Background

Riverbend is a small city with a population of 50 000. It is situated in a valley along the Central River and was settled by farmers and loggers over 160 years ago, because of its surrounding fertile land for agriculture and abundant timber resources. The Riverbend economy consists of agriculture, manufacturing, finance, and real estate. It is a typical middle-class city with a median household income close to the national average. Over the past few years, the logging and mining industries have experienced a downturn; however, Riverbend has been successful in transforming its economy by attracting employers to its other growing economic sectors.

The four-lane interstate bridge over the Central River, between Riverbend and neighboring Fallsborough, was a major concern for the community because it was the only crossing that carried traffic and clean water into Riverbend, and the traffic volume was higher than capacity. It operated below driver expectation during peak hours. This structure was sensitive earthquake events, and it served as a main link for emergency vehicles during fire and rescue.

## Candidate Strategies

The Riverbend planning team considered two alternatives to increase community resilience against both seismic event hazards. Consideration of seismic events was driven by the known hazards of the region and the potential loss of life, infrastructure damage, and economic impacts in the event of a disaster. In developing their alternatives, the planning team assumed a 5 % discount rate and a 50-year planning horizon. The design event was an earthquake with a 25-year return period. All discounting is done using continuous compounding.

### Plan 1. Upgrade the Central River Bridge (Retrofit)

The existing bridge is scheduled and budgeted for a deck replacement in 10 years, creating an opportunity to upgrade the bridge to be more resilient to seismic events. To upgrade the bridge, it must be closed to emergency services and regular traffic. The additional vehicle-hours from rerouting, as well as the effect on emergency vehicles, are real costs that must be considered. Heavier traffic on alternative routes will also decrease the life of those roads, as they may not be designed for the additional equivalent single axle loads they would be carrying.

**Costs**

Estimates place the direct cost (including engineering) of retrofitting the bridge at $3 000 000[[1]](#footnote-1), with an additional $500 000[[2]](#footnote-2) in indirect costs (including costs of diverted traffic). Concerned about the realities of financing a project of this size, uncertainty estimates were also obtained. Based on typical values from literature, the planners estimate the upper end of the costs due to cost overrun to be 128 % the point estimates[[3]](#footnote-3). Although the planning team assumes the project being underbudget is highly unlikely, there is a chance a bid may come in under their estimate should they choose to retrofit and be on budget. The lower end is assumed to be 95 % of the point estimates[[4]](#footnote-4). Triangular distributions were assigned accordingly. Additional operations, maintenance, and repair (OMR) costs are negligible.

**On-Disaster Benefits**

A study[[5]](#footnote-5) examining the benefits of retrofitting the bridge indicated that the retrofit would reduce direct losses by $260 000, indirect losses by $2 000 000, and response and recovery losses by $600 000. A conservative estimate put the coefficient of variation (COV) for each category at roughly 0.3. Gaussian distributions[[6]](#footnote-6) were assumed for all variables.

**Fatalities Averted**

By retrofitting the bridge, the possibility of a failure of a component, or the inability of an emergency vehicle to respond in a prompt time is reduced. This leads to fewer fatalities per disaster. Rough estimates put the number of fatalities averted at 0.1 per event[[7]](#footnote-7). The value of statistical life for both alternatives is $7 500 000.

**Non-Disaster Related Benefits (Resilience Dividend)**

There are no assumed non-disaster related benefits to the retrofit. The bridge will continue to operate at original capacity after completion.

**Externalities**

No externalities are considered for the retrofit[[8]](#footnote-8).

### Plan 2. Construct a Second Bridge Over the Central River

The new bridge would be built with an offset alignment from the original bridge and according to current seismic codes and a design life of 125 years. The original bridge would continue to service traffic, but should a seismic event occur, all traffic will be maintained by the new bridge. Sharing traffic between the bridges will reduce traffic during peak hours and provide an additional water supply that would benefit long-term economic development. Apart from the immediate benefits, the new bridge would be used to carry traffic when the old bridge eventually needs to be replaced and would also support a non-motorized path.

**Costs**

The planning team divided the costs related to constructing a new bridge into two categories. The cost associated with constructing the bridge, and those associated with constructing new road and upgrading the existing road on either side of the river to accommodate the new bridge. The direct costs of constructing the new bridge are estimated at $4 250 000[[9]](#footnote-9). This includes purchasing right of way, land acquisition, and environmental impact study, and engineering. Indirect costs are $175 000[[10]](#footnote-10), and include the indirect rate for the construction firm, as well as the costs of an environmental study. The new bridge would also add $25 000 a year in OMR costs. Triangular distributions are assumed for direct and indirect costs under the 95 % to 128 % range used for the retrofit costs. OMR uses a rectangular distribution bounded by $21 375 and $30 000.

The additional road work is estimated to cost $2 500 000[[11]](#footnote-11) in direct costs, $150 000[[12]](#footnote-12) in indirect costs, and add a year OMR cost of $3 710[[13]](#footnote-13). Triangular distributions are assumed for direct and indirect costs under the 95 % to 128 % range used for the retrofit costs. OMR uses a rectangular distribution bounded by $3500 and $4250.

**On-Disaster Benefits**

On-disaster loss reductions were commissioned for the new bridge alternative. There are no direct loss reductions, as the old bridge will behave identically to a scenario where no resilience action is taken and any damage it sustains will not affect the new bridge. For estimation purposes, it is assumed that the new bridge will perform as designed under seismic loading, and will therefore not increase the amount of direct losses. Indirect loss reductions are estimated to be $3 500 000, due to no interruption to traffic flow across the river while the old bridge is repaired. Response and recovery losses are reduced by $1 000 000 due to the ability of emergency vehicles to travel easily across the river. As before these values are assumed to be normally distributed with a COV of 0.3.

**Fatalities Averted**

Unlike the retrofit alternative, the new bridge avoids fatalities by maintaining traffic flow, even if there is a failure on the old bridge. This allows emergency vehicles to continue to travel as needed across the river. In total, 0.2 fatalities[[14]](#footnote-14) are expected to be averted under the new bridge.

**Non-Disaster Related Benefits (Resilience Dividend)**

The new bridge helps reduce travel time during peak flow by providing alternative lanes and better roads on either side of the bridge. A study found this would save $100 000 per year in vehicle-hours lost in traffic[[15]](#footnote-15). A triangular distribution is assumed for these savings, with a low value of $70 000 and a high value of $115 000.

**Externalities**

Transportation projects are traditionally associated with negative externalities. New roads bring traffic, which brings noise and pollution to the local area. That is not the case here. It is assumed that traffic stays constant after construction, so no new noise would be associated with the new bridge and by reducing vehicle-hours in traffic, the amount of pollution decreases. Using data from Queensland Australia’s government[[16]](#footnote-16), and assuming the new bridge saves the following in travel distance:

The equivalent of 1 car 1000 km in travel distance a year,

The equivalent of 1 light freight vehicle carrying 6.8 tonnes 200 km in travel distance a year[[17]](#footnote-17)

The equivalent of 1 heavy freight vehicle carrying 22.8 tonnes 75 km in travel distance a year,

the reduction in externalities due to water pollution can be estimated as $39 081, and externalities due to greenhouse gasses are $77 329. Additionally, the walking path increases community connectivity, producing another $39 799 in positive externalities.

Under uncertainty, these externalities are assumed to follow a discrete distribution with three values; low, with a 0.25 probability, most likely, with a 0.5 probability, and high, with a 0.25 probability. Specifically:

Greenhouse gases: Low - $64 043, Most Likely - $77 329, High - $81 387

Water pollution: Low - $24 587, Most Likely - $39 081, High - $56 566

Linking communities: Low - $21 750, Most Likely - $39 799, High - $53 006

## Analysis

Using the values from the candidate strategies two separate analyses can be done. The first uses only the point estimates to calculate the results, the second utilizes the uncertainty information.

### Point Estimates

All the analysis was performed using the Economic Decision Guide Software (EDGeS) tool. The EDGeS tool was developed to implement the methodology of the Community Resilience Economic Decision for Buildings and Infrastructure Systems[[18]](#footnote-18) (The Guide). At its core, The Guide outlines how to perform a lifecycle cost (LCC) analysis in the context of resilience actions.

**Inputs**

The following EDGeS tool input is shared across both alternatives

Planning horizon – 50 years

Recurrence rate of Seismic Event – 25 years

Discount rate – 5 %

Hazard magnitude[[19]](#footnote-19) – 1/16 of replacement cost (6.25 %)

Risk preference[[20]](#footnote-20) – Neutral

Value of a statistical life - $7 500 000

Table 1 summarizes the input into the EDGeS tool for the *Retrofit* alternative[[21]](#footnote-21) ignoring uncertainty.

Table . EDGeS Tool input for Retrofit option using point estimates

|  |  |  |
| --- | --- | --- |
| Class | Item | Retrofit |
| Costs | Direct Costs | $3 000 000 |
| Indirect Costs | $500 000 |
| On-Disaster Benefits | Direct Loss Reduction | $260 000 |
| Indirect Loss Reduction | $2 000 000 |
| Repair and Replacement Loss Reduction | $600 000 |
| Estimated Fatalities Averted[[22]](#footnote-22) | | 0.1 |

The input for the *New Bridge* alternative is provided in Table 2[[23]](#footnote-23).

Table . EDGeS Tool input for New Bridge option using point estimates

|  |  |  |
| --- | --- | --- |
| Class | Item | Retrofit |
| Costs | Bridge Construction Direct Costs | $4 250 000 |
| Bridge Construction Indirect Costs | $175 000 |
| Bridge Construction OMR Costs | $25 000 |
| Additional Roadwork Direct Costs | $2 500 000 |
| Additional Roadwork Indirect Costs | $150 000 |
| Additional Roadwork OMR Costs | $3710 |
| On-Disaster Benefits | Indirect Loss Reduction | $3 500 000 |
| Repair and Replacement Loss Reduction | $1 000 000 |
| Estimated Fatalities Averted[[24]](#footnote-24) | | 0.2 |
| Resilience Dividend | Reduced Commute Time | $100 000 |
| Externalities | Reduced Greenhouse Gas Emissions | $77 329 |
| Reduced Water Pollution | $39 081 |
| Better Linking of Communities | $39 799 |

**Output**

Running the EDGeS tool provides the results in Table 3.

Table . Results from the EDGeS Tool using point estimates

|  |  |  |
| --- | --- | --- |
|  | Retrofit | New Bridge |
| **Disaster Economic Benefits** |  |  |
| Response and Recovery Costs | $451,706 | $752,843 |
| Direct Loss Reduction | $195,739 | $0 |
| Indirect Losses | $1,505,687 | $2,634,951 |
| **Disaster Non-Market Benefits** |  |  |
| Value of Statistical Lives Saved | $564,632 | $1,129,265 |
| Number of Statistical Lives Saved | 0.2 | 0.4 |
| **Non-disaster Related Benefits** |  |  |
| One-Time | $0 | $0 |
| Recurring | $0 | $1,790,317 |
| **Costs** |  |  |
| Direct Costs | $3,000,000 | $6,750,000 |
| Indirect Costs | $500,000 | $295,000 |
| **OMR** |  |  |
| One-Time | $0 | $0 |
| Recurring | $0 | $514,000 |
| **Externalities** |  |  |
| **Positive** |  |  |
| One-Time | $0 | $0 |
| Recurring | $0 | $2,796,636 |
| **Negative** |  |  |
| One-Time | $0 | $0 |
| Recurring | $0 | $0 |
| **Total: Present Expected Value** |  |  |
| Benefits | $2,717,764 | $6,307,376 |
| Costs | $3,500,000 | $7,559,000 |
| Net | ($782,236) | ($1,251,624) |
| Net with Externalities | ($782,236) | $1,545,012 |
| **Economic Indicators[[25]](#footnote-25)** |  |  |
| Savings-to-Investment Ratio | -0.22 | -0.18 |
| Internal Rate of Return (%) | 3.45 | 3.79 |
| Return on Investment (%) | 1.55 | 1.67 |
| Non-Disaster ROI (%) | 0.00 | 0.47 |

**Notes on the Output Values**

The output from the EDGeS Tool contains intermediate results, and the final economic indicators used in decision making. The non-disaster related output is calculated using discounted cash flows for the planning horizon. Using the *Non-Disaster Related Benefits (NDRBs)* for the *New Bridge* alternative as an example, the annual *NDRBs* for the *New Bridge* is $100 000. This is discounted at 5 % for the entire 50-year planning horizon. Therefore, the total discounted NDRBs are:

Values that occur in year zero are not discounted, which is why the direct costs and indirect costs equal the sum of all inputs for those line items.

On-disaster benefits represent the annualized expected value of the benefits assuming a Poisson distribution for the return rate of the disaster in question. Thus the $260 000 direct loss reduction from Table 1 is used to find the expected annual value of benefits based on the Poisson distribution assumption, and then discounted to the present value as shown:

After bringing all values to net present value, the final economic indicators are *Present Expected Value (PEV)*, *Savings to Investment Ratio* *(SIR)*, *Internal Rate of Return (IRR)*, *Return on Investment (ROI)*, and *ROI* excluding the on-disaster benefits.

The *PEV* represents the total cost of a project or cash flow brought back to present day dollars. The premise is essentially that a future dollar is worth less than a dollar at the present time. The classic example is whether a person would like to have 100 dollars now, or 200 dollars in two years. While the 200 dollars in two years is greater, the 100 dollars now tends to be more attractive, as having money immediately allows it to be used or invested in some way that may produce more value than having twice the amount in two years. The future money’s value is discounted at some rate, in the case of the planning team for Riverbend, that rate is taken as 5 %. The *PEV* values for the Net value (*NPV*) are then compared, and the highest value is considered the best alternative. In general, the *NPV* should be the preferred ranking method for alternatives.

The *SIR* is the ratio of savings (in this case benefits) to increases in investment-related costs. A positive value indicates that the savings are greater than the investments required to obtain them. The *IRR* represents the discount rate required for the *PEV* of benefits to equal the *PEV* of costs. In practice the *IRR* is compared against an entity’s required rate of return, and if the *IRR* exceeds it, then the project is desirable. The *ROI* is a ratio of the difference between the benefits and the costs of the investment, divided by the cost. It measures the net benefit compared to the cost.

**Interpreting the Riverbend case**

There are two *NPV* s given in the output, with externalities and without. Based on the *NPV* without externalities the *Retrofit* is preferable over the *New Bridge* as it has a higher *NPV*. However, both have a negative *NPV* value. If the project is optional, it may be that the best option economically is the implicit alternative of doing nothing. Whether doing nothing has any political ramifications that may compel action is also a consideration, though not necessarily an economic one.

If externalities are included in the *NPV*, the *New Bridge* alternative is not only the better option, but has a positive *NPV*. One difficulty for Riverbend is the question “Should externalities be included?”. Although these externalities represent benefits, they are not accrued by parties outside of the decision makers.

Another difficulty is where to cut off external parties[[26]](#footnote-26). The reduction in pollution could also decrease costs at a water treatment plant downstream for instance. Where the boundaries should be set for externalities needs to be seriously considered if external parties are to be included. The final decision will therefore come down to how important the externalities are to the primary stakeholders, and if the public is willing to incur potential economic losses for benefits that may not present any economic return. Assuming the planning team is considering the externalities, the preferred alternative is constructing the new bridge.

All other economic indicators suggest that the *New Bridge* is the best option as well.

### Estimates Under Uncertainty

Decisions are often made under uncertainty. The EDGeS Tool allows users to incorporate uncertainty in their analysis as a result. Distributions of variables can be defined for four common distribution types, for costs, on-disaster benefits, the resilience dividend, and externalities. A Monte Carlo simulation is then run using these distributions until the simulation means converge on four key variables, the total costs, the total benefits, the net present value, and the net present value with externalities.

**Inputs**

The *Retrofit* inputs under uncertainty are located in Table 4.

Table . EDGeS Tool input for Retrofit option under uncertainty

|  |  |  |  |
| --- | --- | --- | --- |
| Class | Item | Distribution Type | Parameters |
| Costs | Direct Costs | Triangular | Low – $2 850 000  Most Likely – $3 000 000  High – $3 840 000 |
| Indirect Costs | Triangular | Low – $475 000  Most Likely – $500 000  High – $712 500 |
| On-Disaster Benefits | Direct Loss Reduction | Gaussian | Mean – $260 000  Std. Dev – $78 000 |
| Indirect Loss Reduction | Gaussian | Mean – $2 000 000  Std. Dev – $600 000 |
| Repair and Replacement Loss Reduction | Gaussian | Mean – $600 000  Std. Dev – $180 000 |
| Estimated Fatalities Averted[[27]](#footnote-27) | | Deterministic | Value – 0.1 |

The inputs with uncertainty for the *New Bridge* are presented in Table 5.

Table . EDGeS Tool input for New Bridge option under uncertainty

|  |  |  |  |
| --- | --- | --- | --- |
| Class | Item | Retrofit |  |
| Costs | Bridge Construction Direct Costs | Triangular | Low – $4 037 500  Most Likely – $4 250 000  High – $5 440 000 |
| Bridge Construction Indirect Costs | Triangular | Low – $166 250  Most Likely – $175 000  High – $224 000 |
| Bridge Construction OMR Costs | Triangular | Low – $21 375  High – $30 000 |
| Additional Roadwork Direct Costs | Triangular | Low – $2 375 000  Most Likely – $2 500 000  High – $3 000 000 |
| Additional Roadwork Indirect Costs | Rectangular | Low – $142 500  Most Likely – $150 000  High – $180 000 |
| Additional Roadwork OMR Costs | Rectangular | Low – $3500  High – $4250 |
| On-Disaster Benefits | Indirect Loss Reduction | Gaussian | Mean – $3 500 000  Std. Dev – $1 050 000 |
| Repair and Replacement Loss Reduction | Gaussian | Mean – $1 000 000  Std. Dev – $300 000 |
| Estimated Fatalities Averted[[28]](#footnote-28) | | Deterministic | Value – 0.2 |
| Resilience Dividend | Reduced Commute Time | Triangular | Low – $70 000  Most Likely – $100 000  High – $115 000 |
| Externalities | Reduced Greenhouse Gas Emissions | Discretea | Low – $64 043  Most Likely – $77 329  High – $81 387 |
| Reduced Water Pollution | Discretea | Low – $24 587  Most Likely – $39 081  High – $56 566 |
| Better Linking of Communities | Discretea | Low – $21 750  Most Likely – $39 799  High – $53 006 |
| a Low has a 0.25 probability of occurrence, Most Likely has a 0.5 probability of occurrence, High has a 0.25 probability of occurrence | | | |

**Output**

The results from the EDGeS Tool for the results under uncertainty are found in Table 6. All confidence intervals are at the 95 % level.

Table . Results from the EDGeS Tool under uncertainty

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Retrofit | | | | New Bridge | | | |
|  | Point Estimatea | Lower Bound | Upper Bound | Point Estimatea | | Lower Bound | Upper Bound |
| **Disaster Economic Benefits** |  |  |  |  | |  |  |
| Response and Recovery Costs | $451,706 | $182,601 | $706,807 | $752,843 | | $305,141 | $1,199,353 |
| Direct Loss Reduction | $195,739 | $76,224 | $315,020 | $0 | | $0 | $0 |
| Indirect Losses | $1,505,687 | $601,450 | $2,407,985 | $2,634,951 | | $1,094,259 | $4,215,606 |
| **Disaster Non-Market Benefits** |  |  |  |  | |  |  |
| Value of Statistical Lives Saved | $564,632 | $564,632 | $564,632 | $1,129,265 | | $1,129,265 | $1,129,265 |
| Number of Statistical Lives Saved | 0.2 | 0.2 | 0.2 | 0.4 | | 0.4 | 0.4 |
| **Non-disaster Related Benefits** |  |  |  |  | |  |  |
| One-Time | $0 | $0 | $0 | $0 | | $0 | $0 |
| Recurring | $0 | $0 | $0 | $1,790,317 | | $1,361,010 | $1,982,572 |
| **Costs** |  |  |  |  | |  |  |
| Direct Costs | $3,000,000 | $2,914,971 | $3,702,992 | $6,750,000 | | $6,661,267 | $7,906,390 |
| Indirect Costs | $500,000 | $487,844 | $708,976 | $295,000 | | $291,392 | $344,483 |
| **OMR** |  |  |  |  | |  |  |
| One-Time | $0 | $0 | $0 | $0 | | $0 | $0 |
| Recurring | $0 | $0 | $0 | $514,000 | | $455,560 | $602,941 |
| **Externalities** |  |  |  |  | |  |  |
| **Positive** |  |  |  |  | |  |  |
| One-Time | $0 | $0 | $0 | $0 | | $0 | $0 |
| Recurring | $0 | $0 | $0 | $2,796,636 | | $2,214,013 | $3,346,120 |
| **Negative** |  |  |  |  | |  |  |
| One-Time | $0 | $0 | $0 | $0 | | $0 | $0 |
| Recurring | $0 | $0 | $0 | $0 | | $0 | $0 |
| **Total: Present Expected Value** |  |  |  |  | |  |  |
| Benefits | $2,717,764 | $1,763,266 | $3,649,709 | $6,307,376 | | $4,557,952 | $7,929,330 |
| Costs | $3,500,000 | $3,455,304 | $4,297,839 | $7,559,000 | | $7,495,841 | $8,749,153 |
| Net | $782,236 | $2,149,233 | $63,902 | $1,251,624 | | $3,562,479 | $31,779 |
| Net with Externalities | $782,236 | $2,149,233 | $63,902 | $1,545,012 | | $960,569 | $2,825,505 |
| **Other Economic Indicators** |  |  |  |  | |  |  |
| Savings-to-Investment Ratio | -0.22 | -0.54 | -0.02 | -0.18 | | -0.46 | 0.00 |
| Internal Rate of Return (%) | 3.45 | 0.84 | 4.87 | 3.79 | | 1.61 | 4.97 |
| Return on Investment (%) | 1.55 | 0.92 | 1.96 | 1.67 | | 1.14 | 1.99 |
| Non-Disaster ROI (%) | 0.00 | 0.00 | 0.00 | 0.47 | | 0.33 | 0.51 |

**Notes on the Output Values**

The output in Table 6 displays the point estimate output, but now includes intervals. These intervals define the limits where 95 % of the simulation values lie, they are not confidence interval on the mean. One thing that is immediately noticeable is that the intervals of many of the output values are skewed in relation to the point estimates. This is easiest seen in the cost categories. Since the underlying triangular distributions were heavily skewed towards the high end, the point estimate is below the mean, meaning the expected costs are likely to be higher than the point estimate.

**Interpreting the Riverbend case**

Adding uncertainty complicates interpretation. While the additional information more accurately reflects the potential range of outcomes, it also means that choices must be made balancing risk and desired outcome. For instance, an alternative with a higher mean *NPV* but a large amount of uncertainty may not be as attractive as an alternative with a lower *NPV* but a smaller amount of uncertainty.

Looking at the Riverbend analysis, while the point estimate for the *New Bridge* is higher, there is also the potential that the result would be worse than the point estimate of the *Retrofit*. At the same time, there is also the possibility that the *New* Bridge could be vastly superior *NPV-*wise. In such cases the final decision is determined by the risk preference of the decision maker(s)[[29]](#footnote-29) and how confident they are in the estimate. In this case, assuming externalities are included, the fact that the 95 % confidence interval indicates that a significant portion of the distribution of the *New Bridge* simulations is better than the *Retrofit*, and that the *New Bridge* also has a large portion of its distribution in the positive *NPV* range, it would appear[[30]](#footnote-30) be the preferable option.

1. Based on estimate for bridge replacement for I-94 from Masonic Blvd. to M-29 [↑](#footnote-ref-1)
2. Based on values from Bhatt and Martinez (2013). “Bridge Collapse Could Have Major Economic Implications for Region”. The Seattle Times. May 28 [↑](#footnote-ref-2)
3. Flyvbjerg, Bent, Mette K. Skamris Holm, and Søren L. Buhl. "What causes cost overrun in transport infrastructure projects?." Transport reviews 24.1 (2004): 3-18. [↑](#footnote-ref-3)
4. More than likely there is dependence between the distributions of direct costs and indirect costs. If the direct cost increases, so too does the indirect cost. This is also true for the on-disaster benefit related categories and possibly the externalities. At present, such dependencies are not addressed in the EDGeS tool. [↑](#footnote-ref-4)
5. The cost of completing this study is assumed already incurred, making it a sunk cost. Therefore, it is not included in the lifecycle cost analysis performed later. [↑](#footnote-ref-5)
6. Sometimes referred to as the normal distribution. [↑](#footnote-ref-6)
7. Uncertainty around fatalities averted is being considered for a future iteration of the EDGeS Tool. Uncertainty output for fatalities averted in the current version of the tool is related to uncertainty in the recurrence rate. [↑](#footnote-ref-7)
8. Realistically there would be externalities; noise due to construction activity, or increased confidence in the bridge’s safety, for instance. Construction externalities are omitted due to their relatively short duration compared to the overall planning horizon for both alternatives. Whether this is reasonable may be project or jurisdiction dependent. [↑](#footnote-ref-8)
9. Based on estimate for bridge replacement for I-94 from Masonic Blvd. to M-29 [↑](#footnote-ref-9)
10. Based on values from Bhatt and Martinez (2013). “Bridge Collapse Could Have Major Economic Implications for Region”. The Seattle Times. May 28 [↑](#footnote-ref-10)
11. Based on values provided in “Generic Cost Per Mile Models” from the Florida Dept. of Transportation, < http://www.fdot.gov/programmanagement/Estimates/LRE/CostPerMileModels/CPMSummary.shtm> [↑](#footnote-ref-11)
12. 6 % rate based on values provided on a Florida Office of Inspector General document from 2013. < http://www.fdot.gov/ig/Reports/14I-6002.pdf> [↑](#footnote-ref-12)
13. Based on a Forest Service estimate for 2011. < https://www.fs.usda.gov/Internet/FSE\_DOCUMENTS/fseprd528063.pdf> [↑](#footnote-ref-13)
14. Indicating injuries and no deaths. [↑](#footnote-ref-14)
15. This analysis assumes that traffic volume remains constant in both alternatives. In practice, a more efficient road network would attract more users and more regional or local growth. [↑](#footnote-ref-15)
16. State of Queensland (Department of Transport and Main Roads) (2011). Cost-benefit Analysis Manual: Road projects. [↑](#footnote-ref-16)
17. The definition of light and heavy freight comes from “Freight Facts and Figures” released by the U.S. Dept. of Transportation (2013). Capacity uses the mid-range from Table 3-8 in the document converted to metric tons. [↑](#footnote-ref-17)
18. Gilbert, S. W., Butry, D. T., Helgeson, J. F., & Chapman, R. E. (2015). Community resilience economic decision guide for buildings and infrastructure systems. NIST Special Publication, 1197. [↑](#footnote-ref-18)
19. Not currently implemented in the EDGeS tool [↑](#footnote-ref-19)
20. Not currently implemented in the EDGeS tool [↑](#footnote-ref-20)
21. For brevity, any potential EDGeS tool inputs for which there were no values in the alternative are omitted [↑](#footnote-ref-21)
22. Although this benefit occurs on-disaster, it is separated from the input for other on-disaster benefits to account for additional inputs. [↑](#footnote-ref-22)
23. For brevity, any potential EDGeS tool inputs for which there were no values in the alternative are omitted [↑](#footnote-ref-23)
24. Although this benefit occurs on-disaster, it is separated from the input for other on-disaster benefits to account for additional inputs. [↑](#footnote-ref-24)
25. These economic indicator calculations do not include externalities in this version of the EDGeS Tool. [↑](#footnote-ref-25)
26. In this context “external” means outside of the parties whose costs are internalized in the analysis. [↑](#footnote-ref-26)
27. Although this benefit occurs on-disaster, it is separated from the input for other on-disaster benefits to account for additional inputs. [↑](#footnote-ref-27)
28. Although this benefit occurs on-disaster, it is separated from the input for other on-disaster benefits to account for additional inputs. [↑](#footnote-ref-28)
29. Calculations based on risk preference are being considered for inclusion in a future version of the EDGeS Tool. [↑](#footnote-ref-29)
30. The use of “appear” is intentional. When making decisions under uncertainty, there is no way to know what the *correct* decision is, the goal is to make the *best* defensible decision given the information currently at hand. [↑](#footnote-ref-30)