Prioritising bridge replacements

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ABSTRACT

Road and Rail managers own a variety of assets which are aging and will need replacement. There is a risk insufficient funding is allocated for these replacements and that funding does not match demand.

When assets meet the required level of service the community benefits. By comparing the benefits of new assets over old asset and the capital replacement cost we can understand the cost / benefit of capital replacements.

Capital replacements projects can be prioritized in order of their benefit cost ratios. Projects with high benefit to cost ratios can be undertaken prior to those with lower ratios. Projects with ratios less than one will be set aside unless consequential benefits can be found.

1 INTRODUCTION

In developing specifications for assets end user requirements are considered and for this reason specifications and drawings can be referred to determine the level of service provided by an asset. Where specifications are missing asset owners can undertake an audits of their assets to understand the level of service those assets are capable of providing.

Assets are replaced when they no longer meet the service levels expected of them. The expected levels of service are obtained from understanding the needs and wants of those groups who wish to use the assets. Those groups include the public, freight industry and others.

The community expects that bridges will be designed and maintained to enable safe travel without restrictions. It is also expected that bridges will minimise travel times.

To provide safe and efficient travel bridges need to provide a sufficient level of service for ;

- Barrier safety
- Load capacity
- Flood immunity
- Bridge geometry
- Bridge location
- Maintenance

When the required level of service is met the benefit to the end user is maximised. Benefits may take the form of efficiencies in travel times, improved safety and less restrictions on the mass of loads.

2 BARRIER SAFETY

Appropriate safety barriers are required to protect road users. The bridge design code, AS5100, provides a chart based and site specific risk based assessment for barrier performance selection based on American studies, adapted for Australian conditions. The intent of the standard is to provide cost effective barriers. By using AS5100 the most appropriate barrier performance level for a bridge is determined. The cost of the chosen barrier can then be determined. Providing barriers of a lesser or greater standard than suggested by the code leads to less than optimal results.

2.1 Example Assessment

Table 1 provides assumed cost rates per metre length for various barrier performance levels. Using Table 1 the benefit of replacing a bridge with respect to its barrier performance level can be determined.

Table 1: Unit Cost Rates for Barrier installation

Performance Level	Cost per metre length
No barrier	$0
Low Performance	$1,000
Medium Performance	$2,000
Special performance	$8,000

A 20 m long bridge without barriers will be replaced with a bridge of the same length consisting of Medium performance level barriers. The benefit of providing the new bridge barriers is 2x20x$2,000 = $80,000. If the existing bridge already had medium performance level barriers there would be no additional benefit.

3 LOAD CAPACITY

The community expects that bridges will allow unrestricted travel for general access vehicles and where bridges become unsafe for such use bridge load limits will be displayed.

Assets, as a minimum, are expected to comply with the standards for which they were built. Asset should also operate up to a level for which they were commissioned eg. If a bridge was designed for 30 tonne vehicles it is expected that it will be managed so that vehicles in excess of that limit will not be permitted to utilise the asset.

Bridge load capacities may vary due to not only to their design but also their condition. Bridges can be broadly grouped by their load carrying abilities. For road and pedestrian bridges some sample groupings are provided in Table 2.

Table 2: Pedestrian/Road bridge capacity groupings

Load Group	Description
Remote pedestrian structures	3 kPa capacity
Pedestrian use	5 kPa capacity
Load restricted	Have a posted load limit
General Access	Satisfy the bridge formula
GML	Suitable for GML vehicles
HML	Suitable for HML vehicles
Over mass suitable	Designed for HLP and or SM1600

For bridges of lesser standard there is a potential cost due to restrictions of use. This cost is born as a lost opportunity cost and or by detour costs.

To understand the cost of detours the detour distance is required along with the current and desired usage patterns. An understanding of current usage patterns is gained from the Annual Average Daily Traffic (AADT) and % heavy vehicle counts from traffic studies. The greater the AADT, detour length and % heavy vehicles utilising a structure the great the benefit a structure provides.

Asset owners may choose to classify their roads along with the level of service to be provided for those roads. Each classification of road may have an associated AADT capacity and cater for a given % of heavy vehicles.   The percentage of heavy vehicles is forecast, since current travel restrictions may be preventing heavy vehicle usage.

3.1 Example Assessment

Table 3 provides the assumed cost per km of detour.

If a bridge has a detour length of 10 km with an AADT of 5,000 with 1% heavy vehicles the benefit of the bridge is (2x0.99+5x0.01)x5,000x365 =$3,704,750 per year. If the bridge is replaced and can cater for 5% heavy vehicles, then benefit would increase to $3,923,750.

Table 3: Detour costs

Usage	Cost per km detour
Passenger vehicle	$2
Heavy Vehicle	$5

4 FLOOD IMMUNITY

The community would like bridges to remain open during flood events. The reality is that many bridges in parts of Australia inundate during flood events. When bridges close due to flood the cost there are costs related to the number of vehicles which are unable to utilise a structure. There can be other secondary effects such as the propensity for some road users to drive through flood waters leading to loss of equipment and in some circumstances life.

The number of lost days per year from flooding is estimated by estimating the flood return interval which will cause inundation. A comparison can then be made between an existing structure and a new structure to determine any flood immunity benefits it provides.

5 BRIDGE GEOMETRY

Bridge geometrical aspects effect the level of service a bridge provides. The number and size of lanes is important to achieving the desired throughput of vehicles on a bridge. An assessment can determine the number of lanes to meet the required level of service. Through use of AS5100 the desirable bridge width is then set.

Increasing the width of the bridge may allow the road class to be improved. For example the bridge may currently be suitable for Regional traffic but upon replacement it will be suitable for District traffic. Indicative benefit amounts for various classes of road are provided in Table 4 to illustrate the process. Further work is required by individual asset owners to classify road classes and the benefits these classes provide to the community, in particular the financial benefit for passenger vehicles and heavy vehicles.

Table 4: Example road classes

Road Class	AADT	% heavy	$ per passenger vehicle	$ per heavy vehicle	Benefit $ /km/day	
Regional	1000	1%	2	5	2030	740950
District	2000	3%	2	5	4180	1525700
State Strategic	4000	5%	2	5	8600	3139000
National Highway	8000	5%	2	5	17200	6278000
Freight Route	10000	8%	2	5	22400	8176000

6 BRIDGE LOCATION

A bridge may be replaced in a more desirable location to meet the level of service expectations of the community. A common example is when a road is reconstructed to fix a poor vertical and or horizontal alignment. The change in road alignment is of benefit to road users due to reduced travel time and may also improve safety.

The benefit of a new bridge location is captured through considering the increased usage of the asset. Any safety improvement related to the road needs to be captured as part of the road upgrade project.

7 MAINTENANCE

Bridge assets are unlikely to be replaced unless they are near the end of their useful life. Assets at the end of their useful life have less intrinsic value and therefore the cost of their replacement is comparatively less since lost opportunity costs are small.

When long life components begin to fail capital replacement of those parts is required and this is expensive. Some asset owners may attempt to delay the works through rehabilitation. The rehabilitation costs do escalate with time.

Hore-Lacy et al (2009), reviewed the asset preservation costs for roads and bridges. They surveyed urban and rural councils and found the cost to maintain a concrete deck bridge was on average \$38/m^2 and ranged from a low of \$1/m^2 to \$89/m^2. Based on assumed bridge construction cost of \$4,000/m^2 the Councils maintenance spend was 0.025% to 2.23% of the assets value per year. The researchers survey found that timber bridges cost approximately 50% more per year to maintain than the concrete deck bridges. Based on the research and applying some engineering judgement Table 5 was developed. Table 5 suggests the likely maintenance costs per year for assets with varying remaining life. Further research is required to understand the appropriateness of the chosen values.

Table 5: Maintenance Costs

Maintenance requirement	Remaining life	Maintenance Cost per year as % of structure cost
Normal - new structure	50% or more	0.01%
Medium - mid age	30% to less than 50%	0.05%
High - near design life	20% to less than 30%	1.0%
Very High - at end of life	9% to less than 20%	1.5%
End of life	0 to less than 9%	5%

The remaining life may be estimated from predictive modelling of the asset using condition data collected from bridge inspection.

8 ASSESSMENT

To undertake a complete benefit cost assessment for the capital replacement of bridges a range of data is required. Data is required for an existing bridge, proposed bridge and general costing data to determine the cost benefit of upgrading a bridge.

8.1 Data required for existing bridge

It is expected that asset owners will obtain bridge valuation data from their annual financial reports. Authorities generally undertake depreciation of assets on an annual basis and inputs and outputs of these assessment provide information such as the value of the asset in its written down value and it value in “as new” condition. Authorities with advanced asset management practices will undertake predictive modelling to determine the remaining life of the assets.

Other factors to consider are the detour lengths if a bridge is closed, the current AADT and percent heavy vehicles, flood immunity and bridge barrier type. The detour length is sometime stored by asset owners but if not an assessment of the network needs to be undertaken. There may be a detour available for certain types of vehicles but not others. The AADT is capture by traffic count surveys but should be derived from the level of service desired for the bridge eg. a bridge may have 300 vehicles per day using it currently but the desired level of service may be 2,000 vehicles per day.

Barrier type requirements can be determined by undertaking barrier risk assessment in accordance with AS5100. AS5100 provides methodologies for determining the current performance level and the desired performance level.

8.2 Data required for proposed bridge

The following data is required for the proposed bridge.

- Cost of new structure
- Life of new structure
- Proposed length of new structure
- AADT and percent heavy vehicles
- Flood immunity
- Barrier type

The above data is usually determined in conjunction with AS5100. AS5100 provides a list of matters for resolution before design commences.

8.3 General data

The following data is required to enable an assessment

- Maintenance costs
- Barrier performance level costs
- Vehicle costs per km of travel

8.4 Example Assessment

Tables 6 to 12 provide an example of the input and outputs to determine the cost benefit of a bridge replacement assessment. For the purpose of the assessment a structure halfway through it design life is assessed.

Table 6: Funding request information

Bridge valuation		
Valuation (as new)	$2,737,350	
Written down value	$1,338,002	
Cost of new structure	$3,476,000	
Design life of existing structure	100	years
Remaining Life of existing structure	48.88	years
Remaining Life of existing structure	48.9	%
Life of new structure	100	years
Proposed length of new structure	55	m
Inconvenience if bridge is close	Low inconvenience	
Detour length if structure closed	1	km

Table 7: Traffic Volumes

Current Road Class	District	
Proposed Road Class	District	
Benefit of existing structure	$1,525,700	per year
Benefit of proposed structure	$1,525,700	per year
Benefit of new structure over old	$ -	per year

Table 8: load capacity

Current bridge	HML limit vehicles	
Proposed bridge	Unrestricted	
Current Truck access benefit	$98,550.00	per year
Proposed Truck access benefit	$109,500.00	per year
Difference in number of heavy vehicles	10%	
Benefit of new structure over old	$10,950.00	per year

Table 9: Flood immunity

Level of service for Flood immunity		
Number of days of lost access per year current structure	2	days
Number of days of lost access per year proposed structure	0	days
Number of days benefit per year	2	days
Benefit of new structure over old	$8,360.00	per year

Table 10: Barrier performance

Current structure	low	
Proposed structure	Regular	
Benefit of new structure over old per year	$275.00	per year

Table 11: Maintenance cost benefits

level of service for structure width		
Maintenance cost per year current structure	$1,368.68	
Maintenance cost per year proposed structure	$347.60	
Benefit of new structure over old	$1,021.08	per year

Table 12: Cost benefit analysis results

level of service benefit	$20,606	per year
Cost of new structure	$48,140	per year
benefit cost (level of service improvement)	0.43	

If we now consider the same bridge as in the prior example but assume it has only has 10 years of remaining life we find the cost benefit of the bridge replacement jumps from 0.43, a bridge not worth replacing, to 1.25 where a bridge replacement would be beneficial.

9 AREAS FOR FURTHER WORK

Although the paper has provided a methodology for prioritizing capital works there is a need for further research to refine input data used in the process.

The suggested maintenance cost are based on limited data which is 10 years old. It is recommended that asset owners assess their costs, with due consideration to asset age to determine an appropriate distribution of maintenance costs.

The procedure for prioritising capital works treats each asset individually. Further work could be undertaken to assess the consequential costs from bridge closures. This further investigation would facilitate the refinement of the assessment results.

It is intended that the cost benefit analysis be coded into asset management software so that the process if fully automated.

10 CONCLUSION

It is possible to determine the cost benefit of capital replacement of an asset by reviewing the level of service requirements the asset provides. The suggested approach uses the annual average daily traffic and other readily available information to make a whole of asset class assessment. By using the approach consistent outcomes can be achieved. Further work could be undertaken to refine the process thereby providing more accurate results.

11 REFERENCES

- Hore-Lacy W, Martin T and Mclean J. Review of asset preservation costs, May 2009, page 7.
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12 AUTHOR BIOGRAPHY

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20 years experience in the design of road and bridge projects in Australia. His work in both the public and private sectors has provided a sound understanding of the complexities of asset management and the skills to successfully project manage multidisciplinary projects through to completion. As national Bridge Engineering Manager at pitt&sherry, Andrew oversees the company's bridge network across Australia, and has a deep understanding of the country's best practices when it comes to bridge design assessment and management. His practical experience is reinforced by a strong theoretical background, which includes a Master of Business Administration and a PhD obtained from the study of the shear strength assessment of reinforced bridge beams.