Australasian Transport Research Forum 2022 Proceedings
28-30 September, Adelaide, Australia
Publication website: http://www.atrf.info

Measuring road travel time reliability benefits in Victoria

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Abstract

Improved reliability is often cited as a benefit of road projects but there is no national standard approach to estimating this benefit. ATAP recently released a consultation paper which proposes a procedure for estimating the parameters required for calculating reliability benefits, which it then applies using data collected from Perth. In this paper we apply a slightly modified version of ATAP's approach and estimate the same set of parameters using data from Victoria. We find material differences in the parameters for the two states and across arterial road classes within Victoria. We then apply these parameters to a hypothetical road project. The resulting estimated reliability benefits are substantial, being equivalent to up to 50 to 150 per cent of time savings benefits if a reliability ratio of 1 is used. The estimated reliability benefits using this approach are substantially lower in Victoria than in Perth for arterial road projects, while the opposite is true for freeway projects.

1. Introduction

Road travel time reliability can be described as people's perception on their degree of confidence that a road journey can be undertaken in a consistent travel time or pattern. It is an important part of people's road travel journey decision making. Poor travel time reliability causes people to factor in additional travel time into their journeys to reduce the probability of being late or being late more often. It can also influence people's decisions on travel route decisions and their willingness to pay for tolls and faster journeys. Ideally reliability would be a key part of how road network managers and planners measure road network performance and user experience.

Whilst the significance of road travel time is widely recognised, how to measure road travel time reliability continues to be an active area of research in Australia and internationally. Currently, in Australia, there is no official standard guidance on how to value the benefits from improved reliability on roads.

In 2021, the Transport Infrastructure Council Australian Transport Assessment and Planning (ATAP) Steering Committee released a consultation research paper on a potential approach to valuing road reliability (ATAP, 2021). The paper used the standard deviation of travel time over a given period as a unit of measure for road reliability. Standard deviation is commonly used to measure variability or uncertainty. It summarises the average variation in observed travel times from an average travel time.

To measure the improvement in road reliability this standard deviation needs to be estimated for scenarios with and without the reliability improvement interventions. The difference is taken as the improvement as expressed in units of time. Hence, the benefit from improved reliability resulting from a transport project can be calculated by multiplying the improvement in reliability by the per unit value of improved reliability as given in equation (1):

Road Travel Time Reliability Benefits = (Change in standard deviation of travel times (minutes)) * (Per minute $ value placed on improved reliability). (1)

The per minute dollar value is often referred to as the reliability ratio.

However, predicting the standard deviation, the unit of road reliability, from a strategic transport model is challenging. The source of uncertainty must be specified and multiple travel demand simulations conducted to estimate the standard deviation. In addition, parameter values on each potential source of uncertainty, such as congestion levels, must be provided.

The ATAP (2021) research paper provides procedures for estimating changes in travel time reliability in a road network at a road link, route and network level. It provides models for estimating reliability with parameter values based on econometric analysis undertaken on data from Perth. Separate estimates are provided for arterial roads and freeways. Although the estimated models are generally successfully applied to cases from Brisbane, the Gold Coast and Sydney as well as Perth, it is worthwhile to explore the robustness of the parameters to being estimated using data from a different city. Road design, weather, transport demands can all vary by city resulting in different parameter values for these relationships. Indeed, in ATAP (2021) researchers are encouraged to estimate these parameters with local data.

This research paper applies similar procedures to estimate parameters using Victorian data. In addition, we estimate separate sets of parameters for each of several types of arterial roads and freeways. Finally, we apply our model to estimate the benefits from a set of hypothetical road projects.

We find material differences between the parameters estimated for Perth and Victoria. For Victoria, travel time variability appears less responsive to congestion levels on arterial roads, but more responsive on freeways. There are also systematic differences in the correlation between travel times for links along a road. We also find material differences across different types of arterial roads in Victoria. There are two main results from applying our models to hypothetical road projects. First, that the reliability benefits are substantial. If we use a reliability ratio of 1, the reliability benefits are between 50 and 150 per cent of time savings benefits. They scale with the assumed reliability ratio but even at the suggested lower bound in ATAP (2022) could be as high as 50 per cent of time travel savings. There are also substantial differences across Perth and Victoria. For our example, the benefits to arterial road projects are greater in Perth and to freeways in Victoria.

In the next section we provide more background on how the benefits from improved reliability of travel on roads are calculated, including an overview of the equations proposed in ATAP (2021). Section 3 covers the data that we use. Section 4 presents the results of estimating the equations proposed in section 2 with the data introduced in section 3. Section 5 applies the results of the work to an illustrative example of a business case. Section 6 suggests some future work and section 7 concludes.

2. Approach to estimating Victorian specific route reliability parameter values[1]

For business cases and other analysis, we are interested in what happens along an arterial road or freeway or even sets of these roads. However, the output of model simulations, as well as actual data, is often reported for sections of roads e.g. between two intersections or two sets of exits. These sections are often referred to as links. In this section we present the set of models presented in ATAP (2021) emphasising how we incorporate outputs and data at the link level so to produce estimates of reliability at the route level – the level we are really interested in.

The three models or equations presented in ATAP (2021) are:

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[1] The discussion of the theoretical background for focussing on the standard deviation as a measure of reliability is based on Nicholson (2015) as is the specification of the correlation route model (CRM). The discussion of the correlation route model then follows ATAP (2021) unless stated otherwise.

- Correlation Route Model (CRM)
- Link Model (LM)
- Correlation Coefficient Model (CCM)

The CRM is used to estimate the reliability of a road at a route level. This requires two sets of values: (1) the standard deviation of travel times at the link level (2) the correlation in travel times between different links of a route. The LM provides estimates of the standard deviation of travel times at the link level. The CCM provides estimates of the correlation in travel times between different links of a route.

In the next three subsections we present each of these models and how we econometrically estimate the parameters of the LM and CCM

2.1 The correlation route model (CRM)

ATAP's proposed CRM is used to estimate road reliability impacts at a route level. They note that the CRM is based on the Nicholson (2015) model, as presented in equation (2). The variance of travel times for a route is the sum of travel time variances of all links along the route plus an adjustment for correlation between travel times between links reflecting inter-dependencies between them.

$$\sigma_r^2 = \sum_{i=1}^{n} \sigma_i^2 + 2 \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \rho_{ij} \sigma_i \sigma_j \, , i < j \quad (2)$$

Where:

- σ_r^2 is the variance of travel times on road r,
- σ_i^2 is the variance of travel times on link i,
- σ_i is the standard deviation of travel times on link i and,
- ρ_{ij} is the correlation coefficient between travel times on links i and j.

The standard deviations should all be positive. In theory, the correlation coefficients could be positive, negative or zero. This approach allows for any pattern of relationships between each link that makes up a route.

2.2 The link model (LM)

The ATAP (2021) link model is used to estimate reliability of travel times at a road link level as shown in equation (3) below.

The dependent variable for the econometric model is the coefficient of variation (CoV) of travel times as ATAP (2021) notes that this measure enables comparisons between links of varying lengths without further adjustments or controls.

For the link model the coefficient of variation is modelled as positively related to congestion. The functional form chosen for this relationship is given by equation (3): It expresses travel time coefficient of variation (CoV) as a function of the congestion index (CI; defined as the ratio of average travel time and free-flow travel time) on a link.

$$\text{Ln}(CoV) = a_L + b_L * \ln\left(\frac{CI - 1}{CI}\right) \quad (3)$$

Where:

- The parameters a$_L$ and b_L are the key parameters to be estimated with jurisdiction specific data. b_L is the elasticity of the coefficient of variation of travel times with respect to $\left(\frac{CI-1}{CI}\right)$, where CI is the congestion index defined below. Hereafter this ratio is referred to as the congestion index ratio. It is expected that b_L would be positive. a$_L$ reflects the level of variability independent of congestion, subject to the limitation that it is determined by the functional form as we do not observe roads with a CI of 1.

- The CI is specified in equation (4) and has a minimum value of 1, when the mean travel time (T) equals the free flow travel time (T_f).[2] As travel time along a piece of road increases relative to the free flow travel time, the congestion index also increases.

$$CI = max\left(1, \frac{T}{T_f}\right) \quad (4)$$

Rearranging equation (3) yields equation (5) that calculates the standard deviation of travel times, by link and time period, as a function of the applicable congestion index and mean travel time:

$$\sigma = e^{a_L}\left(\frac{CI-1}{CI}\right)^{b_L} T \quad (5)$$

Where:

- σ is the standard deviation of travel times
- T is the mean travel time
- T_f is the free flow travel time
- CI is the congestion index
- CI, T and T_f can be obtained from a transport model or data.

Equation (5) can be applied to model simulations for the base and project cases.

2.3 The correlation coefficient model (CCM)

The correlation coefficient model is used to construct estimates of the correlation coefficients for travel times between links. ATAP (2021) suggest that the closer the mid-points of two different links the greater the correlation is likely to be. Specifically, denote L_{ij} as the distance between the midpoints of links i and j. They suggest the following relationship between distance and the correlation coefficient:

$$\rho_{ij} = \max\left[0, b + a * \ln L_{ij}\right] \quad (6)$$

where b and a are parameters. This functional form is chosen in ATAP (2021) as it provides a better fit to their data. It does not allow for negative correlation between travel times on different links. Plausibly, they state that the simple linear-log model does not accommodate negative correlations and suggest extra explanatory variables might be needed.

Equation (6) can be used in two ways. First, using estimates of the correlation coefficients and distances, equation (6) can be estimated using non-linear least squares to yield estimates of a and b. This is done in ATAP (2021).

Secondly, equation (6) can be used to estimate correlation coefficients for use in a business case. All that is needed is estimates of the distances, L_{ij}, so this equation can be applied even to roads that do not yet exist.

3. Data

The data used for estimation in this is research is from the Victorian Department of Transport Transport Analytics Platform (TAP). This combines data from freeway data stations, bluetooth and SUNA traffic data. It contains a mixture of observed and modelled data. While it is similar in several respects to the Perth NetPres data we make slightly different exclusions and also cut the data in different ways. The reason we cut the data in different ways is to yield results that can be more easily applied with the Victorian Integrated Transport Model (VITM), the Department of Transport's strategic transport model.

The data characteristics are:

- Data is analysed at a road link level. Links are between 13 metres and 9.13 kilometres long, with a median value of 679 metres. If a road goes in two directions, each direction of the road is reported as a separate link e.g. Springvale Road heading north from the

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[2] The CI is preferred to the volume-to-capacity ratio to mitigate challenges with measuring link capacities and inconsistencies between volume and demand.

Burwood Highway is a separate link from Springvale Road heading south towards the Burwood Highway.

- Two variables were collected:
  - Average speed by 15 minute intervals for all intervals between 5 am and 9 pm on working days i.e. public holidays and weekends were excluded.
  - Link lengths
- Data was collected for each of the five months from August to December 2019. This is the last regular period before COVID-19 significantly impacted travel demand.
- Data was collected for about 52 sets of arterial roads and freeways. We discuss this in more detail below.

Unlike in ATAP (2021) we did not exclude observations on links during periods when the average speed was less than 10 km/h. This is because for certain links at certain times, departmental data experts advise it is normal for there to be significant stationary time resulting in an average speed of less than 10 km/h.

The first stop in choosing a set of links was to choose sets of roads belonging to different link classes defined in the VITM – link classes are types of roads that are assumed in the VITM to have common characteristics, such as speed-flow relationships. We then selected all of the links in TAP associated with these roads. The nine VITM link classes we collected data for are listed in Table 1.

Table 1 VITM link classes considered for analysis

Link class	Title
6	Secondary arterial – inner – high impedance
7	Secondary arterial – inner – low impedance
10	Primary undivided arterial – inner – high impedance
11	Primary undivided arterial – inner – low impedance
14	Primary divided arterial – inner – high impedance
15	Primary divided arterial – inner – low impedance
17	Primary divided arterial – outer – low impedance
18	Freeway – inner
19	Freeway – outer

Other classes were omitted either because data on the roads were not included in the TAP dataset (like the main rural roads) or the roads were not long enough to produce a meaningful sample for the purpose of this analysis e.g. link class 16 - Primary divided arterial road – outer – high impedance.

3.1 Data for route level reliability

We selected roads that were reasonably long so as to enable estimation of reliability for routes. We began with class 19 for which we selected links for all of the longer freeways. For the remaining classes we selected about five sets of roads, except for class 14 for which we could only find two reasonably long sets of roads. In a few cases a single road is assigned to more than one class. For example, the Eastern Freeway west of Bulleen Road is classified as link class 18 whereas east of Bulleen Road is classified as link class 19. The Western Ring Road also has sections classified as link class 18 and other sections classified as link class 19. Sections of roads in different link classes are treated as separate roads when constructing the dataset. To generate some longer roads we combined sets of roads that ran into each other. For example, Wellington Avenue, Bridge Road, Church Street, High Street (Kew) and Doncaster Rd up to Balwyn Road are all link class 10 and treated as a single road. A complete set of roads and maps of the roads are included in an appendix available from the author.

This approach yielded 1,400 links in the TAP database. For each link we would expect there would be 6720 observations for our sample period (64 observations per day (between 5am and 9pm) and 105 working days in August to December 2019).

However, the TAP data was not complete for all of these links. Average speed was missing for 215,209 observations, which were dropped. There were also 3,731 observations for which average speed was equal to 0. These were also dropped. After reviewing the number of observations for each link we found out of 1,400 links, 1,116 had a complete set of observations. Twenty-seven had no observations at all and another four had very few observations. Hence, we drop 31 links from our dataset. This left us with 1,369 links and 9,181,709 observations. Table 2 reports the descriptive statistics of the raw data.

Table 2 Descriptive statistics of 15-minute link data

Variable	Mean	Standard deviation	Skewness	First percentile	Median	99th percentile
Average speed (km/h)	60	29	0.08	11	54	104
Link length (km)	0.97	0.99	2.89	0.023	0.68	5.60
Travel time (minutes)	1.1	1.1	13.52	0.04	0.82	4.43
Free flow speed (km/h)	78	22	-0.09	35	76	114
Free flow time (minutes)	0.74	0.64	2.11	0.02	0.57	3.25

Source: Calculations on raw data of 9,181,709 observations

The average speed of all observations in the dataset is 60 km/h, which is lower than the average free flow speed of 78 km/h. Most speed observations fall within 11 and 104 km/h. The median length of a link is 680 metres, with most observations falling between 23 metres and 5.6 kilometres. The typical travel time for a link is about 1 minute. There is a very small number (94) of observations which feature travel times of more than 30 minutes. These observations are associated with extremely slow average speeds. They are left in as they are an extremely small number but likely to be genuine observations.

The next step was to compile the free flow speeds – these are calculated at the 99th percentile average speed by link and month. The free flow speeds and free flow travel times are all above and below the average speeds and travel times as expected.

The next step was to calculate the monthly means and standard deviations for each link. This left us with 438,080 observations.[3] So the unit of observation, which we use for the regressions and for when we apply equation (5) to estimate reliability, is by link by time of day by month.

We now use this data to compile the variables used for the link model and report their descriptive statistics. This is followed by a more extended discussion of how we constructed the data for the correlation coefficient model.

3.2 Data for the link model

For the link model, the descriptive statistics of the dependent variable, the coefficient of variation of travel times for the monthly data, by link class, are reported in Table 3.

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[3] A further 163 observations which had either 0 standard deviation or had a congestion index set equal to 1 were dropped for the regressions.

Table 3 Descriptive statistics of monthly coefficient of variation of travel time link data by VITM link class

Link class	Observations	Mean	Standard deviation	First percentile	Median	99th percentile
6	28160	0.22	0.14	0.04	0.19	0.73
7	27520	0.20	0.13	0.06	0.16	0.66
10	32508	0.20	0.12	0.07	0.18	0.69
11	27520	0.23	0.15	0.05	0.19	0.78
14	10240	0.20	0.10	0.07	0.17	0.55
15	36480	0.20	0.14	0.04	0.16	0.68
17	87360	0.18	0.14	0.03	0.14	0.69
18	25592	0.21	0.28	0.006	0.10	1.25
19	162537	0.10	0.16	0.005	0.05	0.78

In general, there is not much variation across the different link classes, with the exception of the much larger link class 19 (outer freeways) for which the mean and standard deviation are much lower.

Table 4 reports a similar set of descriptive statistics for the explanatory variable in the link model, the congestion index ratio.

Similar to the coefficient of variation there is not a great deal of variation in the congestion index ratio for the arterial roads (link classes 6 to 17). However, there are lower levels of average congestion for freeways and less variability in congestion for outer freeways.

Table 4 Descriptive statistics of monthly congestion index ratio by link by VITM link class

Link class	Observations	Mean	Standard deviation	First percentile	Median	99th percentile
6	28160	0.46	0.16	0.09	0.47	0.83
7	27520	0.41	0.15	0.09	0.40	0.79
10	32508	0.47	0.16	0.10	0.48	0.79
11	27520	0.44	0.16	0.10	0.44	0.81
14	10240	0.47	0.15	0.11	0.49	0.81
15	36480	0.36	0.14	0.08	0.35	0.73
17	87360	0.35	0.15	0.07	0.34	0.73
18	25592	0.20	0.18	0.01	0.13	0.70
19	162537	0.12	0.10	0.01	0.10	0.55

To get a preliminary sense of the relationship between the two variables that will be used in the link model we calculated correlation coefficients between the coefficient of variation and the congestion index ratio. There is a positive correlation of 0.61 between the coefficient of variation and the congestion index ratio. We repeated the calculations separating the sample into arterial roads and freeways. We find a value of 0.57 for arterial roads and 0.71 for freeways. This suggests a positive relationship between congestion and reliability. And that there is a stronger connection between congestion and variability for freeways than for arterial roads.

3.3 Data for the correlation coefficient model

Before discussing how we compile the data for estimating the correlation coefficient model we briefly discuss what we know about the approach taken in ATAP (2021). This part is less well documented than the construction of the data for estimating the link class model but we assume that they estimated, from the data, the correlation coefficients specified in equation (2). As an example, for a road with four links, they calculated six correlation coefficients: $r_{1,2}$, $r_{1,3}$, $r_{1,4}$, $r_{2,3}$, $r_{2,4}$ and $r_{3,4}$.

However, this is not the only way to generate a valid dataset. As equation (5) models each correlation coefficient as solely a function of the distance between each link, a dataset of any set of correlation coefficients and distances is acceptable. The main potential risk is that if we miss longer distances generated by the strict method described above, we will not be using the data to estimate the relationship between distance and correlation but solely relying on functional form to generate the relationship. However, if the separation between the links is great enough it is likely that the true value is zero anyway.

The approach we took to generate correlation coefficients was to generate correlation coefficients for 10 spatial lags for each link. There are two reasons for taking this approach. The first reason is that we believe it covers the distances for which there is likely to be any positive correlation between travel times. The second reason is that it is much easier to calculate the correlation coefficients in the econometric package we use, Stata, than the correlation coefficients we believe were calculated for ATAP (2021).

In theory this could have meant estimating 4,380,800 correlation coefficients. However, in practice we estimated a lot less than this. The main reason is that roads have beginnings and limited lengths. For example, a road has to have at least 10 links to be able to generate a correlation coefficient $r_{1,10}$. A second, though numerically less important, is that multiple links have missing values and so we are unable to construct correlation coefficients that use observations that are missing.

The distances were calculated as straight-line distances between the mid-points of each link. This could lead to some underestimation of distances if the roads are particularly winding.

Table 5 reports the descriptive statistics for our sample for estimating the correlation coefficient model.

Table 5 Descriptive statistics of the correlation coefficients for estimation of the correlation coefficient model

Link class	Observations	Mean	Standard deviation	First percentile	Median	99th percentile
6	78080	0.15	0.31	-0.44	0.11	0.95
7	117760	0.10	0.29	-0.46	0.07	0.95
10	158416	0.11	0.27	-0.45	0.09	0.94
11	119040	0.15	0.32	-0.45	0.11	0.95
14	41600	0.13	0.29	-0.45	0.11	0.95
15	194560	0.10	0.29	-0.47	0.08	0.95
17	695360	0.08	0.30	-0.57	0.06	0.95
18	128960	0.30	0.36	-0.38	0.27	0.95
19	1106880	0.28	0.36	-0.41	0.23	0.95

The main difference between the different link class samples is between arterial roads (classes 6 to 17) and freeways (18 and 19). The average correlation between links is much higher for freeways than arterial roads. Within the two groups the results are fairly similar. While the correlation coefficients may seem low, the average includes correlation coefficients for links that are up to 10 links apart. In addition, note about one third of correlation coefficients are less than 0.

Table 6 reports the descriptive statistics of the distance variable for estimating the correlation coefficient model.

The average distance between links may seem high but recall this includes up to 10 links. Unlike for the correlation coefficients link class 17, Divided Arterial Roads in Outer Melbourne, is more similar to freeways than other arterial roads. While the shortest distance between links is less than 50 metres, the longer distances can be around 30 kilometres.

Table 6 Descriptive statistics of the distance variable for estimation of the correlation coefficient model

Link class	Observations	Mean	Standard deviation	First percentile	Median	99th percentile
6	78080	1.26	0.83	0.08	1.07	3.36
7	117760	2.53	1.79	0.20	2.16	6.81
10	158416	2.91	1.96	0.34	2.60	8.63
11	119040	1.70	1.12	0.05	1.51	4.74
14	41600	1.71	1.06	0.25	1.50	4.17
15	194560	2.35	1.56	0.22	2.01	6.14
17	695360	5.75	5.72	0.09	4.31	29.9
18	128960	3.94	3.29	0.30	3.07	14.65
19	1106880	6.23	4.52	0.47	5.20	19.26

One difference between ATAP (2021) and this paper is that as well as estimating different versions of the correlation coefficient model for inbound and outbound directions we also estimate separate models for roads that are not obviously going inbound or outbound. For example, Bell St runs in an east-west direction across the north of Melbourne and so is not obviously inbound or outbound. Rather than guessing the direction the traffic flows we classify these roads according to whether traffic flows north, south, east or west and estimate separate models for them.

4. Results

In this section we report the results of running the two sets of regressions. In the first subsection we report the results of estimating the link model. In the second subsection we report the results for estimating the correlation coefficient model.

We find substantial differences between the model parameters estimated using data from Perth and those estimated with Victorian data. For the link model, the results suggest that variability is less responsive in Victoria than in Perth for arterial roads whereas for freeways variability is more responsive to congestion in Victoria. We also find material differences in the coefficients for different link classes of arterial roads. The correlation coefficient models for Victoria suggest greater correlation of travel times for close links than in Perth, but less correlation between travel times for more distant links.

4.1 Link model

In this section we report the results of estimating the link model. We report results for three sets of models. The first two sets are results of our estimation: (1) by link class (2) by arterial roads and freeways. The third set of results are those from ATAP (2021) which are included for easy comparison. All three sets of results are reported in Table 7.

The results for freeways and arterial roads for Victoria differ from those reported in ATAP (2021). For arterial roads, the slope term on the congestion index is smaller and the intercept term is more negative. For freeways, the slope term on the congestion index and the intercept a bit more positive. There is some variation in the responsiveness of variability to the congestion index across the different arterial road link classes. The inner primary arterial roads (whether divided or undivided) feature smaller responsiveness to congestion than the other five classes (including inner secondary arterials). Whether this variation is meaningful is best explored by, for a business case, comparing the results of using the link class specific parameters with those from using those in ATAP (2021) or for freeways and arterials.

Table 7 Estimates of link model by freeways and arterial roads and the result for ATAP (2021)

	b_L (Congestion index ratio)	Standard error	a_L (Constant)	Standard error	N	R^2	RMSE
Victoria: By link class							
6	0.86***	(0.009)	-0.93***	(0.007)	28160	0.43	0.446
7	0.80***	(0.008)	-0.99***	(0.008)	27520	0.37	0.442
10	0.55***	(0.009)	-1.26***	(0.008)	32508	0.29	0.407
11	0.84***	(0.009)	-0.87***	(0.008)	27520	0.39	0.446
14	0.54***	(0.012)	-1.31***	(0.010)	10240	0.22	0.402
15	0.79***	(0.007)	-0.94***	(0.008)	36480	0.35	0.491
17	0.83***	(0.005)	-0.98***	(0.006)	87360	0.41	0.498
18	1.20***	(0.005)	0.08***	(0.010)	25592	0.76	0.678
19	1.18***	(0.003)	-0.20***	(0.006)	162537	0.71	0.652
Victoria: By arterials and freeways							
Freeways	1.20***	(0.002)	-0.13***	(0.005)	188129	0.72	0.661
Arterials	0.78***	(0.003)	-1.01***	(0.003)	249788	0.39	0.470
Results from ATAP (2021)							
Freeways	1.08***	(0.003)	-0.23***	(0.007)	79,655	0.67	0.652
Arterials	0.97***	(0.002)	-0.52***	(0.003)	162,301	0.56	0.472

***: Statistically significantly different from zero at 1 per cent.

4.2 Correlation coefficient model

This section begins by comparing the results from ATAP (2021) with estimating the correlation coefficient model using Victorian data for the same aggregations and categories. In the Victorian data, for these results, all observations that are not inbound or outbound are omitted. The results are reported in Table 8.

The results for the correlation coefficient model all have the correct signs. Furthermore, the size of both coefficients are broadly similar across Perth and Victoria. However, the coefficients for Victoria tend to be a bit larger than those for Perth. This means that for links that are close together that the correlation between travel times tends to be greater but that the correlation drops to a greater extent with distance such that, potentially, there may be less correlation between links over greater distances in Victoria than in Perth.

For arterial roads, in Victoria, the distances at which correlation in travel times goes to zero ranges between 5 and 16 kilometres for arterial roads and between 18 and 25 kilometres for freeways. In other words, the model suggests that there is zero correlation between travel times on links further than these distances apart. The correlation between travel times on arterial roads varies between 0.34 and 0.45 for arterial roads and between 0.6 and 0.9 for freeways. In general, the degree of correlation between travel times is higher in Victoria than in Perth but also the distance over which correlation goes to zero is much shorter for arterial roads and substantially shorter for freeways.

We also estimate the correlation coefficient model for each link class. We report the results for link class 10 as an example, as we will be using these results in our application. Results for all link classes are available in an appendix from the author.

Table 8 Estimates of correlation coefficient model – ATAP (2021) and Victorian – for highways and arterial roads

Road Type	Direction	Time period	N	a	b	RMSE
Results from ATAP (2021)						
Arterial	Inbound	AM peak		-0.0482***	0.1658***	0.1012
		Inter peak		-0.0236***	0.0638***	0.0665
		PM peak		-0.0308***	0.0848***	0.0961
		Off peak		-0.0445***	0.1590***	0.1091
	Outbound	AM peak		-0.0302***	0.1076***	0.0912
		Inter peak		-0.0234***	0.0631***	0.0623
		PM peak		-0.0393***	0.1121***	0.0838
		Off peak		-0.0391***	0.1362***	0.0871
Freeways	Inbound	AM peak		-0.1098***	0.3477***	0.1483
		Inter peak		-0.0870***	0.2653***	0.1287
		PM peak		-0.0991***	0.3045***	0.1473
		Off peak		-0.0992***	0.3128***	0.1362
	Outbound	AM peak		-0.0620***	0.2078***	0.1161
		Inter peak		-0.0745***	0.2293***	0.1184
		PM peak		-0.1207***	0.4181***	0.1710
		Off peak		-0.0979***	0.3539***	0.1464
Victorian results						
Arterial	Inbound	AM peak	99084	-0.077***	0.214***	0.297
		Inter peak	198216	-0.086***	0.152***	0.283
		PM peak	99076	-0.088***	0.183***	0.285
		Off peak	132112	-0.078***	0.153***	0.295
	Outbound	AM peak	98064	-0.065***	0.146***	0.283
		Inter peak	196176	-0.076***	0.153***	0.278
		PM peak	98064	-0.077***	0.190***	0.282
		Off peak	130744	-0.081***	0.141***	0.282
Freeways	Inbound	AM peak	81540	-0.217***	0.631***	0.311
		Inter peak	163080	-0.169***	0.503***	0.327
		PM peak	81540	-0.172***	0.506***	0.325
		Off peak	108720	-0.163***	0.497***	0.320
	Outbound	AM peak	81900	-0.137***	0.424***	0.324
		Inter peak	163800	-0.157***	0.456***	0.313
		PM peak	81900	-0.203***	0.612***	0.303
		Off peak	109200	-0.134***	0.436***	0.322

***: Statistically significantly different from zero at 1 per cent.

The results for estimating the correlation coefficient model for link class 10 are in Table 9. There are a small number of observations for roads running East-West (well under a thousand). When we estimate the model using this data the results are unintuitive and tend to be sensitive to starting values so they are omitted.

Table 9 Estimates of correlation coefficient model – Victoria – for VITM link class 10

Direction	Time period	N	A	b	RMSE
Inbound	AM peak	14844	-0.060***	0.211***	0.270
	Inter peak	29736	-0.071***	0.155***	0.257
	PM peak	14836	-0.079***	0.195***	0.260
	Off peak	19792	-0.060***	0.149***	0.272
Outbound	AM peak	14844	-0.049***	0.145***	0.264
	Inter peak	29736	-0.070***	0.147***	0.252
	PM peak	14844	-0.063***	0.176***	0.263
	Off peak	19784	-0.073***	0.139***	0.257

***: Statistically significantly different from zero at 1 per cent.

5. Application of the results

In order to determine whether the differences between the parameters estimated with Perth and Victorian data are material, we apply both sets of parameters to two illustrative examples of projects: one on a set of arterial roads and the other on a freeway. There are two main findings from this example. The first main finding is that the differences in parameters across Perth and Melbourne and across different types of arterial roads in Melbourne result in substantial differences in the estimated benefits. The second main finding is that the choice of the reliability ratio is important as it can substantially raise or reduce benefits.

5.1 The hypothetical project

The arterial road project is an improvement at an inner Melbourne intersection of R1 (which runs North-South) and R2 (which runs East-West). Both roads include trams. The improvement affects two links in each direction.

The freeway project is an improvement that affects two links. The features of the two examples required to calculate the benefits are listed in the table below:

Table 10 Assumptions for the hypothetical projects

Variable	Value	
	Arterial Road	Freeway
Average speed before	20 km/h	40 km/h
Average speed after	30 km/h	55 km/h
Free flow speed	40 km/h	100 km/h
Length of roads and AM and PM peak throughputs:		
R1 North	1.7km (AM: 2600) (PM:3000)	1.7km (AM: 2600) (PM:3000)
R1 South	1.7km (AM: 1400) (PM: 1800)	1.7km (AM: 1400) (PM: 1800)
R2 East	0.8km (AM: 6000) (PM: 6000)	
R2 West	0.7km (AM: 3600) (PM: 3700)	
Value of time per hour*	$18.79	
Value of time saved by reliability improvements relative to time savings	1	

*Value of time calculated by taking 40 per cent of seasonally adjusted full time average weekly earnings converted to an hourly rate (5 days, 7.6 hours per day). This is for non-work travel time.

Because of the location and trams, these roads are classified as VITM Link class 10 (Undivided arterial road – inner – high impedance).

A key assumption is the value of time saved by reliability improvements relative to regular time savings. This a focus of ongoing work by ATAP. For now, we assume a 1 to 1 relationship. This is also assumed in TfNSW (2020). However, TfNSW report from the literature that there is a range of values out there from 0.1 to 3.23. ATAP (2022) suggests that, for any below the line calculations, a value between 0.3 and 1 can be used.

We explore the robustness of our results in two ways. First, we redo the results for arterial roads using the parameters for VITM Link Class 6 (Secondary arterial roads – inner – high impedance). Second, we re-estimate the benefits using a reliability ratio of 0.3.

5.2 The results

With this information we do the following, using the parameters for Victoria:

1. Use the road lengths and speeds to calculate three sets of travel times for each of the four links: Before, after and free flow
2. We use this information to calculate the congestion index for each link.
3. These values are substituted into equation (5) to estimate the standard deviation of travel times for each link for before and after the project.
4. We calculate the distances between the mid-points using the road lengths and substitute this into the correlation coefficient model (equation (6)) to estimate the correlation coefficients between each set of links.
5. We substitute the results from steps three and four into the correlation route model (equation (2)) to estimate the standard deviation of travel times for each route before and after the project.
6. The changes for each route are calculated and multiplied by the matching volume of traffic and the value of time to calculate the benefits from improved reliability from the project.

We then repeat the six steps above using the parameters for arterial roads for Perth. The results are summarised in Table 11:

Table 11 Benefits from the hypothetical projects

	Present Value (million dollars)	
	Arterial Road	Freeway
Time savings	41.0	8.5
Reliability benefits		
Melbourne parameters (base)	19.8	12.2
Perth parameters	35.6	10.5
Melbourne parameters – Link class 6	23.9	
Melbourne parameters – Link class 10 – Reliability ratio of 0.3	5.9	3.7

Present value calculated from daily value, assuming 320 days per year, 30 years of benefits and a discount rate of 7%.

There are three findings to note from these examples. First, the value of reliability benefits are considerable – between about 50 per cent and 150 per cent of the time savings benefits. Second, the differences across link classes are also substantial. The benefits for link class 6 are more than 20 per cent larger than for link class 10. Third, there are substantial differences between the values for Melbourne and for Perth. The benefits from improving reliability in Melbourne are less than for Perth for arterial roads and vice versa for freeways. These results demonstrate how the choice of reliability ratio is important as it materially affects the values of the benefits.

6. Future work

There are two possible directions for future work in this area.

The first direction is to improve the correlation coefficient model by incorporating the negative correlation coefficients. To do this requires a closer analysis of the circumstances under which negative correlation coefficients occur e.g. is it due to a sequence of particular road characteristics. If this can be determined, and the determinants can be measured, then it could be possible to estimate a switching model i.e. where the correlation coefficient switches sign. Such a model could then be applied under other conditions, as long as the variables that determine whether a negative correlation coefficient occurs or not are observable.

The second direction is to explore the implications of the choice of the econometric models for the calculated benefits. For example, benefits could be calculated at different levels and for different changes in congestion. The estimated benefits for the illustrative example presented here are quite large and we could determine whether their size is due to the specific levels and changes in congestion or are common across a wide range of congestion levels etc.

7. Conclusions

In this paper we successfully estimate the set of models proposed in ATAP (2021) to generate parameters for estimating the reliability benefits of road projects. Specifically, we estimate the models using data for Victoria rather than Perth. In addition, we estimate the models for a more disaggregated set of road types than in ATAP (2021).

There are material differences between the parameter estimates for Perth and Victoria. Variability is less responsive to congestion in Victoria for arterial roads but more responsive for freeways. In addition, over short distances, travel times are more correlated in Victoria, but less so over long distances. We also find material differences across different types of arterial roads in Victoria.

As a first step to determine whether the differences are material we estimate the benefits from reliability for two hypothetical road projects. We find that the estimated benefits are substantial – between 50 and 150 per cent of those from time savings, using a reliability ratio of 1. Even if we use the lower bound of reliability ratios in ATAP (2022), the benefits can still be 50 per cent.[4] We also find substantial differences across Perth and Victoria in line with the differences in parameters. For the example we consider, reliability improvements on freeways have greater benefits in Victoria than in Perth. The opposite holds for arterial roads.

Finally, we conclude with two suggestions for future work to develop this approach to estimating the benefits from reliability improvements on roads.

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[4] It is worth noting that ATAP is expecting to be recommending unit values of time and reliability ratios, based on the results of a national willingness-to-pay service. Adopting the recommended values would enable a more precise estimate.