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Evaluating transport greenhouse gas emissions: Aligning transport appraisals to help shape a net zero future

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Abstract

In Australia, the transport sector is responsible for 19% of net greenhouse gas emissions[1]. This makes the transport policies we enact and the projects we build a vital component of our efforts to mitigate climate change.

Transport policies and projects are typically evaluated using strategic transport models, which provide data for economic cost benefit analysis (CBA) models. A CBA model evaluates whether project benefits outweigh the costs, with benefits including reductions in carbon emissions.

The current methods for estimating vehicle emissions outlined in Australian transport evaluation guidance are based on the total distance travelled by vehicles. More refined methods should better reflect the fuel and energy usage characteristics of vehicle types, and the social cost of carbon emissions. This paper focuses on the fuel usage components. Improvements can be achieved by:

- Enhancing the method of estimating vehicle emissions to consider:
    - Increased fuel efficiency of vehicle fleet, and how this changes over time
    - Levels of traffic congestion, types of roads and travelling conditions.

  These factors can be incorporated within strategic transport models by aligning how vehicle emissions are estimated with existing methods to calculate fuel consumption.
- Escalating the social cost of carbon emissions over time, to account for the increasing cost of climate change, and the respective benefit of policies or projects that cut emissions. This is recommended by the Intergovernmental Panel on Climate Change (IPCC), and will lead to valuing carbon emissions at up to five times current values.[2]

Addressing these two areas will significantly alter the contribution of vehicle emissions impacts within the economic evaluation of transport projects, and potentially change the types of investments we make in our transport infrastructure.

1. Introduction

Transport is one of the largest contributors to our carbon footprint – in 2020, the transport sector was responsible for 19% of Australia's total emissions, including 25% of Victoria's emissions and 17% of Western Australia's emissions[3]. All Australian State and Territory Governments

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[1] DCCEEW (2020)
[2] IPCC (2018)
[3] DCCEEW (2020)

have set long-term emissions reduction targets for net zero greenhouse gas emissions by the year 2050 and significantly reduced greenhouse gas emissions by 2030[4]. Reducing emissions from the transport sector will be vital to meeting emissions targets and our progress towards a sustainable transport future.

However, the analysis tools available to appraise transport policies and projects generally do not consider greenhouse gas emissions with the level of detail required. This prevents meaningful assessment of the emissions generated by vehicles moving around our transport network.

Measuring and forecasting transport emissions is critical in shaping our actions and accountability towards reaching our net zero targets, and our approach needs to adapt to include new fuels and transport technologies. There is currently a disconnect between our policies and the appraisal framework that requires a change to an adaptable approach. This will better enable us to understand and quantify the emissions impacts of our transport investment funding.

2. Challenges with our current approach to estimating and valuing greenhouse gas emissions costs

The Australian Transport Assessment and Planning Guidelines (ATAP) provide the framework for planning, assessing and developing transport systems and initiatives. The ATAP guidelines form the basis for transport assessments in Victoria as well as for other states and jurisdictions in Australia, and contain economic and demand forecasting methodologies and parameters to support and standardise transport assessments, underpinned by detailed research.

The application of the ATAP guidelines for the purposes of calculating vehicle emissions assumes a simple relationship between emissions and vehicle kilometers travelled (VKT). This methodology has not evolved to draw upon the latest available evidence and information. The current ATAP guidelines released between 2018 and 2021 do not reflect the current changes in vehicle types and the fuel efficiency improvements we are likely to see in the future. There has been rapid growth in sales of electric vehicles – 7 per cent of total vehicle sales in Australia in the first quarter of 2023 were electric vehicles, up from less than 1 per cent prior to 2021[5,6]. The current guidelines were based upon extrapolated data sets and modelling derived from the 1990s, when a 1995 Holden Commodore or a 1998 Toyota Camry were amongst some of the most popular new vehicles on our roads, with no guidance on likely changes to vehicle types in the future. The assessment of carbon emission costs for transport infrastructure that will be serving us for the next 50 to 100 years needs to advance to reflect our changing future.

The current ATAP VKT approach to estimate carbon emissions includes some key limitations:

- The assumption that emission rates per VKT remain constant over time. Different VKT rates are provided for different vehicle types, however, there is no provision for how the vehicle fleet mix changes, such as fuel type or vehicle efficiency changes.
- Emission rates per VKT vary by urban and rural roads, however, they do not vary with levels of congestion. Vehicles in stop-start traffic use more fuel per kilometre to accelerate and brake compared to cars moving in free-flow conditions.
- The carbon price (the social and economic cost of releasing an additional metric tonne of carbon emissions, used to assess whether the costs and benefits of an initiative to abate emissions is justified) is assumed to remain constant over time. The ATAP

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[4] DEECA (2023), Energy NSW (2023), DELW (2023), DWER (2023), DEW (2023), DSG (2023), DEPWS (2023), ACT Government (2023).

[5] AAA (2023)

[6] Electric Vehicle Council (2022)

guidelines do not allow for escalation in the cost of carbon emissions as the impacts of climate change accumulate. This therefore does not align with the recommendations from the IPCC[7] or with the objectives and targets set by the Australian government, and all State and Territory governments, to achieve net zero emissions by 2050.

The guidelines in relation to the estimation of carbon emission costs and their application to vehicle travel are ambiguous – and consequently are applied differently in each jurisdiction. This contrasts with the far more detailed analysis in ATAP underpinning methods to calculate individual vehicle operating costs (used to estimate driver decision making), which do factor in travel speeds and conditions. However, this analysis is not currently harnessed for the purposes of calculating vehicle emissions.

These limitations jeopardise our ability to understand the impact of our transport system on the environment and hinder our ability to make appropriate decisions towards change.

3. An improved approach is needed

3.1. Using fuel and energy consumption as the basis for calculating emissions

The ATAP guidelines provide useful advice on methodologies to quantify a range of economic benefits due to transport investment, which comprise components of CBA models. These include user and non-user benefits (such as reduced vehicle operating costs and travel time savings from lower congestion or switching from car to public transport) and societal benefits (such as reduced carbon emissions or health system cost savings from fewer crashes).

To calculate vehicle operating costs, ATAP provides methodologies to estimate fuel consumption for different vehicle types and a range of driving conditions. The guidelines provide advice for converting fuel consumption into various types of vehicle emissions, including greenhouse gas emissions. However, in practice, these two pieces of information are rarely combined to produce estimates of emissions based on fuel consumption.

There are two approaches to estimating emissions outlined in ATAP. Section PV2 (containing parameter values to calculate road transport outcomes) of ATAP provides conversion parameters from litres of fuel to grams of emissions to support vehicle operating cost calculations, while section PV5 (which deals with environmental impacts) of ATAP provides parameters based on total VKT for estimating greenhouse gas emissions.

It is unclear why the ATAP guidelines do not directly recommend using fuel consumption, and it is also unclear how many practitioners opt to use the VKT approach rather than a fuel consumption approach for estimating emissions. A KPMG review of publicly released business case reports for Victorian State government major road project CBAs indicates that the VKT approach has been used, which is consistent with ATAP guidelines[8].

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[7] The Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the science related to climate change, recommends policies reflecting a high price on emissions, escalating over time, are necessary in models to achieve cost-effective pathways to limit global warming to 1.5°C or below. IPCC indicates that climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C. IPCC (2018)

[8] ATAP (2021)

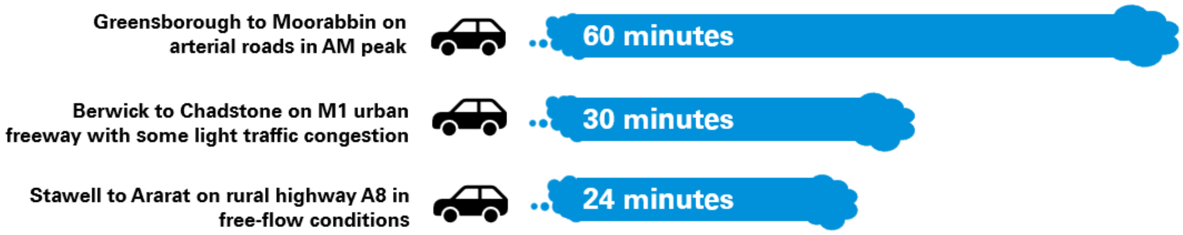
This contrasts with guidance across other jurisdictions, such as New Zealand and the UK, where transport emissions are quantified using parameters for different vehicle classes, based on a function of average speed in kilometres per hour (km/h)[9,10].

3.2. Incorporate impacts of congestion on fuel use

The current VKT approach for estimating emissions takes no account of differences in travelling efficiency impacted by travel time, speed, congestion or network stop-start conditions. Data from the UK indicates fuel consumption values in urban conditions can be 20 to 50 per cent higher than the combined value of both urban and rural travel conditions.[11]

Using the current VKT approach, the calculated carbon emissions would be equal for any journeys of the same distance, irrespective of variations in travel time or conditions. For example, despite having significant travel time variations, the three journeys shown in Figure 1 would be assumed to have the same carbon emissions across any time of the day or week, as the journey distance is approximately equal at 30 kilometres.

Figure 1: 30 kilometre journey comparisons of different travel time and conditions



Source: Travel time and distance from GoogleMaps 2021

The reality of fuel consumption for each of these journeys would be quite varied. Over time, as road congestion within our cities worsen, the increasing impacts of vehicle accelerating and braking due to road congestion may significantly worsen our rate of emissions.

Proposed approach – estimate fuel consumption by the characteristics of each road link, rather than distance

A more accurate approach to estimate fuel consumption would reflect the type of road, and be determined based on the average vehicle speed on each link (road section) of the network.[12]

Different fuel consumption speed curves can be applied for different road types, for example urban, rural and urban freeways. This would reflect the varied rates of fuel consumption in stop-start versus free-flow conditions. In addition, this approach factors in the higher consumption and emissions costs of travel in peak periods versus travel during off-peak periods. Fuel consumption will also increase as congestion worsens over time, causing emission costs to increase.

Specific fuel consumption curves should reflect the characteristics of each vehicle fleet, and vary for cars, light commercial vehicles (LCVs) and heavy commercial vehicles (HCVs). These fuel consumption curves should be adjusted as needed over time based upon changes to fleet mix assumptions and fuel efficiencies.

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[9] UK Department of Transport (2023)

[10] NZTA (2020)

[11] Department of Infrastructure, Transport, Regional Development, Communications and the Arts (2023)

[12] Average speed of road link defined as the distance divided by the time to traverse the link, including intersection delays.

ATAP guidelines provide advice for calculating fuel consumption rates based on average speed for the purpose of calculating the perceived Vehicle Operating Costs (VOC), as well as conversion rates to convert fuel consumption into estimates of emissions. However, these parameters are not provided as environmental parameters. Instead, the environment parameter section of ATAP provides VKT based parameters for estimating emissions.

Modifications to ATAP fuel consumption guidance

The ATAP guidelines provide advice on how to estimate fuel consumption for different vehicle types where fuel consumption is a function of vehicle speed. These estimates are used as a component to calculate VOC, but not for estimating carbon emissions.

Separate equations for fuel consumption are provided for stop-start conditions and for free-flow conditions as shown in Equation 1 and 2 below, and as shown in Figure 2:

Equation 1: Fuel consumption for stop-start model

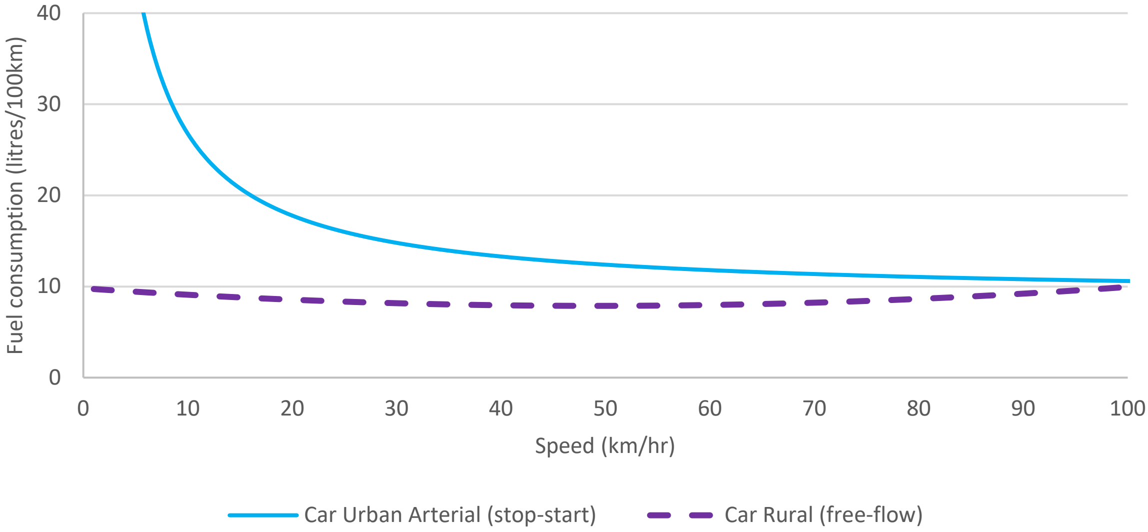
Stop-start model: $c = A + B/V$

Equation 2: Fuel consumption for free-flow model

Free-flow model: $c = C_0 + C_1V + C_2V^2$

Where c = fuel consumption, V = average vehicle speed, and A, B, C_0, C_1, C_2 = coefficient constants from ATAP

Figure 2: ATAP medium car fuel consumption rate by average link speed



Source: ATAP (2021)

This methodology could be applied to use fuel consumption estimates as a basis for calculating emissions. However, there are currently some impediments to this process:

- The equations produce very high fuel consumption rates (approaching infinity) at very low speeds. This makes the current equations impractical at an individual link level, particularly if the transport model incorporates detailed junction delays.
- There are challenges in determining how and when to apply the stop-start equation or the free-flow equation. For example, urban freeways can operate in both free-flow and stop-start conditions, and transitioning from one equation to the other can create step-change issues.

These impediments can be overcome by implementing a few minor modifications to the ATAP fuel consumption guidance:

- Setting a minimum speed to limit extreme fuel consumption rates at low speeds – this will allow the practical application for individual link level calculations. This may also involve averaging junction delays over the approach links.
- For urban freeways, where both start-stop and free-flow curves may apply, the two equations can be converted into a single equation, and the coefficients developed varying by vehicle type and stop-start / free-flow conditions, as follows:

Equation 3: Fuel consumption for start-stop and free-flow conditions

$$c = a1 + b1/V + c1V + d1V^2$$

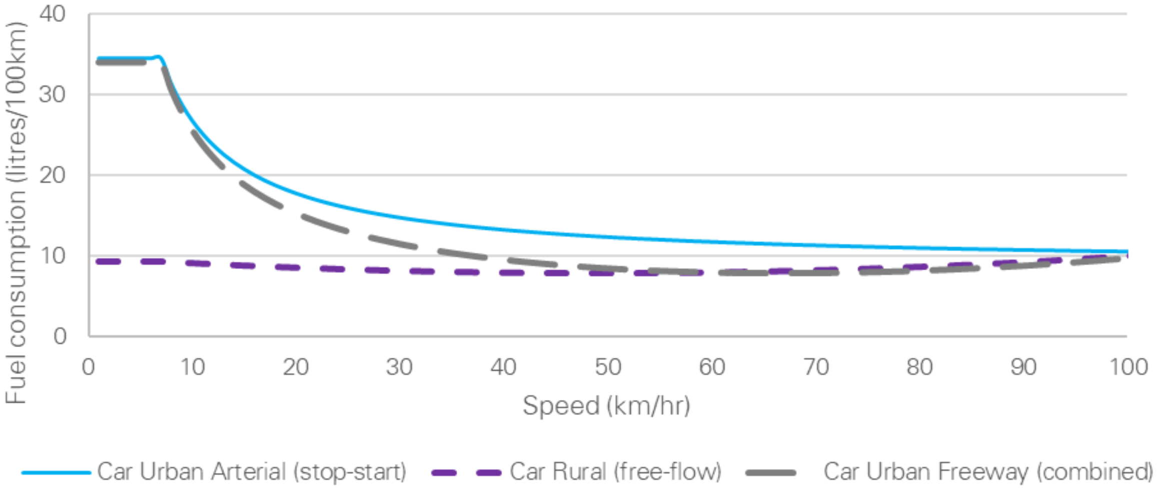
Where c = fuel consumption (per link), V = average vehicle speed, and a1, b1, c1, d1 = coefficient constants

- This single functional form can be used to represent equations for stop-start conditions (urban arterial roads), free-flow conditions (rural roads), and urban freeways, with the coefficient constants varying between the three road types.

The ATAP coefficient constants can be re-arranged into this single equation (see Equation 3), simplifying the process and allowing the calculations to be undertaken at the link level, where the coefficient constants vary by link type (refer to Appendix for coefficients). To prevent the equations producing extreme fuel consumption rates at the link level, a minimum speed can be applied.

Examples of the modified fuel consumption curves for cars are provided in Figure 3 showing the new derived curve for urban freeways, alongside the existing stop-start and free-flow curves with new minimum speed cut-off points to limit extreme fuel consumption at low speeds (set at 7 km/h in this example). The urban freeway fuel-consumption curve matches the free-flow fuel consumption for speeds greater than 60 km/h, and transitions from the free-flow curve to the stop-start curves for speeds less than 60 km/h.

Figure 3: Amended car fuel consumption rate by average link speed



***Source: Derived by KPMG from ATAP** (2021)*

The impact of using a fuel consumption approach compared to a distance-based VKT approach can dramatically vary the scale of the estimated impacts of emissions. In some instances, calculating carbon emissions using a fuel consumption approach instead of VKT may actually alter whether the project appraisal yields a positive or negative impact on emissions compared to the base case scenario. The following two case studies illustrate the difference in impact between the two approaches.

Case study A – Proposed town bypass

A new town bypass is proposed to reduce traffic and its impacts in a country town, and travel time between major towns. The bypass will cater for through traffic that would have previously travelled via the town's local roads, reducing congestion and stop-start traffic conditions in the town. The through traffic will take the slightly longer but much faster route on the bypass, with free-flow conditions and no need to stop, saving on average around 5 minutes in travel time.

In this example, the bypass reduces VKT on local roads by 33,000 km/day while increasing VKT on freeways by 59,000 km/day. This produces a net increase in VKT of 26,000 km/day. The calculation of emissions using the VKT approach and fuel consumption approach for this scenario is shown in Table 1.

Table 1: VKT and Fuel consumption, base versus project, case study A (Discounted to $2016)

	VKT (km/day)	Fuel consumption (litres/day)
Base Case Scenario		
Local roads	650,000	87,700
Freeways	404,000	41,600
Total	1,054,000	129,300
Project Case Scenario (Town Bypass)		
Local roads	617,000	81,800
Freeways	463,000	46,500
Total	1,080,000	128,300
Change (Project – Base)		
Local roads	-33,000	-5,900
Freeways	+59,000	+4,900
Total	**+26,000**	**-1,000**
Emissions approaches	**VKT Approach**	**Fuel Consumption Approach**
7.11 dollars/1,000 km	Cost 185 $/day	
2,282 GHG tonnes/ million litres		Saving 2.28 tonnes/day
Value 60 $/tonne		Saving 137 $/day
Annualisation factor 330	Cost 60,000 $/year	Saving 45,000 $/year
Tonne/year	Additional 1,000	Reduction 750

Source: KPMG analysis, using ATAP PV5 and PV2 approaches

Despite the increase in VKT, fuel consumption is improved by the project. Travel in stop-start traffic conditions (on local roads) decreases, while travel in free-flow traffic conditions (on freeways) increases. Fuel consumption (per kilometre) on highly congested local roads can be up to double the rate on freeways operating at free-flow conditions. Total fuel consumption and associated greenhouse gas emissions will subsequently decrease as vehicles transfer to more efficient travel conditions on the bypass. Local roads will become less congested resulting in slightly improved travel speeds, reducing the fuel consumption for remaining local traffic as well.

Using the VKT approach as currently suggested in the ATAP guidelines, emissions are estimated to increase by approximately 1,000 tonnes per year due to the net increase of 26,000 VKT per day generated by the project. Under the fuel consumption approach, the estimated greenhouse gas emissions will reduce by 750 tonnes per year due to the improvement in travel conditions.

Case study B – Proposed orbital rail line

A new orbital rail line and associated infrastructure is being delivered to transform a city and deliver urban renewal outcomes. The new rail line will connect, via public transport, suburbs of a large city that were previously difficult to access other than by car. The new connectivity and access opportunities will promote modal shift towards public transport, producing more sustainable transport outcomes and reducing the burden of congestion across the city. This will remove 310,000 vehicle kilometres per day from the road network and reducing fuel consumption by 38,600 litres per day, as shown in Table 2.

Table 2: VKT and Fuel consumption, base versus project, case study B (Discounted to $2016)

	VKT (km/day)	Fuel consumption (litres/day)
Base Case Scenario		
Local roads	7,920,000	1,132,800
Freeways	7,370,000	352,000
Total	15,290,000	1,484,900
Project Case Scenario (Orbital Rail Line)		
Local roads	7,760,000	1,102,300
Freeways	7,220,000	343,900
Total	14,980,000	1,446,200
Change (Project – Base)		
Local roads	-160,000	-30,600
Freeways	-150,000	-8,000
Total	**-310,000**	**-38,600**
Emissions approaches	**VKT Approach**	**Fuel Consumption Approach**
7.11 dollars/1,000 km	Saving 2,204 $/day	
2,282 GHG tonnes/M litres		Saving 88 tonnes/day
Value 60 $/tonne		Saving 5,285 $/day
Annualisation factor 330	Saving 727,000 $/year	Saving 1,744,000 $/year
Tonne/year	Reduction 13,000	Reduction 29,000

Source: KPMG analysis, using ATAP PV5 and PV2 approaches

Under the VKT approach, the reduction in total VKT abates approximately 13,000 tonnes of greenhouse gas emissions per year. Using the fuel consumption approach, the assessment results in an even bigger decrease in greenhouse gas emissions as the reduction in road congestion also creates improved vehicle efficiency with respect to fuel consumption. The estimated greenhouse gas emissions will reduce by 29,000 tonnes per year due to the improvement in travel conditions.

Decision makers require access to a more accurate reflection of the emissions impact of transport projects – and importantly, an accurate reflection of whether infrastructure is creating a positive or negative environmental outcome.

3.3. Incorporating fuel efficiency of vehicles

Our vehicles are changing, but the vehicle fuel efficiency assumptions proposed in ATAP guidelines for the purpose of project appraisal remain the same. Fuel consumption rates are decreasing as hybrid and electric vehicles, and vehicles with smaller engine capacity and higher fuel efficiency, are increasing in popularity. Average fuel consumption has declined from 11.4 litres per 100 km for pre-2000 vehicle models to around 10.3 litres per 100 km for post 2011 vehicles. CO_2 emissions from new light vehicles have decreased by 22% in the last ten years.[13]

The Australian Government requires all new light vehicles to display a label demonstrating fuel consumption (litres per 100 km travelled) under both urban and combined traffic conditions. While Australian consumers are encouraged to consider fuel efficiency in their vehicle choice decisions, ATAP does not stipulate that transport scheme appraisals accurately reflect these differing rates of fuel consumption.

Similarly, ATAP offers limited guidance on the expected future take-up rates of low and zero emission vehicles for inclusion in economic appraisal. This contrasts with UK Transport Analysis Guidance (TAG) which provides the projected proportion of kilometres travelled by vehicle types (including electric vehicles) to 2050.[14]

As we look to the future, using pre-2000 vehicles such as a 1998 Holden Commodore as part of the future vehicle fleet indicates we are not attempting to accurately forecast our carbon emissions. We need to incorporate vehicle fleet fuel efficiency and its changes over time into our assessments to better understand its impact on carbon emissions. This needs to be further investigated and researched for more accurate representation in our appraisals. As part of this process, a proposed approach for updating the fuel consumption method for internal combustion engines is outlined. A similar and expanded method could also be determined to consider the energy usage for electric vehicles, however this is beyond the scope covered within this paper.

Proposed approach – estimate base fuel consumption rates by vehicle type

To calculate the cost of carbon emissions from a transport project, it is recommended that fuel consumption for internal combustion engine vehicles be estimated in litres using the existing approach contained within ATAP for calculating vehicle operating costs – but with some further adjustments and improvements. As an initial basis, the existing data and assumptions contained within ATAP will provide indicative fuel consumption rate values, until updated data is available.

This new methodology should separate fuel costs, fuel usage and fleet mix assumptions, to allow opportunities to separately adjust fuel price and fleet mix over time, reflecting the changing mix and capabilities of vehicle technology. This will also allow sensitivity tests around fuel efficiency of the vehicle fleet to be conducted to aid and guide policy development.

Fuel efficiency can be incorporated into the existing ATAP fuel consumption curve equations by bringing out a ‘base fuel’ parameter, which represents the optimum fuel consumption for each vehicle type, as shown in Equation 4:

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[13] BITRE (2017)

[14] UK Department of Transport (2023)

Equation 4: Fuel consumption including base fuel parameter

c = base fuel x (a2 + b2/V + c2V + d2V^2)

Where: c = fuel consumption (per link), base fuel = the base fuel consumption rate for the vehicle and road type, V = average vehicle speed (per link), and a2, b2, c2, d2 = coefficient constants.

Potential coefficients for car fuel consumption rates are shown in Table 3. These are consistent with the medium size car fuel consumption rates from ATAP. Notable attributes of these fuel consumption curves include:

- The base fuel rate for rural roads is set by the minimum of the stop-start curve for cars
- The base fuel rate for urban freeways is set to the same as for rural roads
- The base fuel rate for urban arterial roads is set as the fuel consumption rate at 50km/hr, however, this value can be refined based on observed data
- Base fuel x a2 = a1, base fuel x b2 = b1, base fuel x c2 = c1, base fuel x d2 = d1

Table 3: Re-arranging ATAP coefficients into a single equation

Vehicle	Base Fuel	a_2	b_2	c_2	d_2
Car urban arterial	12.39548	0.71007	14.49633		
Car rural road	7.87570	1.24451		-0.00997	0.00010
Car urban freeway	7.87570	0.94938	9.17011	-0.00401	0.00004

Additional guidance on upstream emissions of electric vehicles is required. The updated guidance should reflect the latest Australian research that shows that electric vehicles generate 40% fewer lifecycle emissions compared with similar sized internal combustion engines.[15]

3.4. Value of emission costs

Once the fuel consumption methodology has been updated, emissions costs can be adjusted to reflect their cumulative impacts over time. Transport projects often have long lifespans extending beyond 30 years. The increasing burden of emissions and the 2050 net zero target means changes to emissions pricing over time is essential to reflect the national and international agreements that will place an increasing social and economic cost on the failure to achieve emissions targets. Once an update to fuel consumption methodology has been included, emission costs can be adjusted to more accurately reflect impacts.

The proposed methodology should allow for the rising cost of carbon emissions over time, as recommended by the IPCC[16], the UK Government[17] and the NSW Government[18]. The projected carbon cost within Australia is illustrated in Figure 4, with carbon costs escalating from $79 per tonne in 2020 to $318 per tonne by 2050. Infrastructure Australia acknowledges the high degree of uncertainty and complexity surrounding the cost of carbon, and currently refers practitioners back to their existing state and territory valuation approaches.[19]

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[15] Smit, Whitehead, Washington (2018)

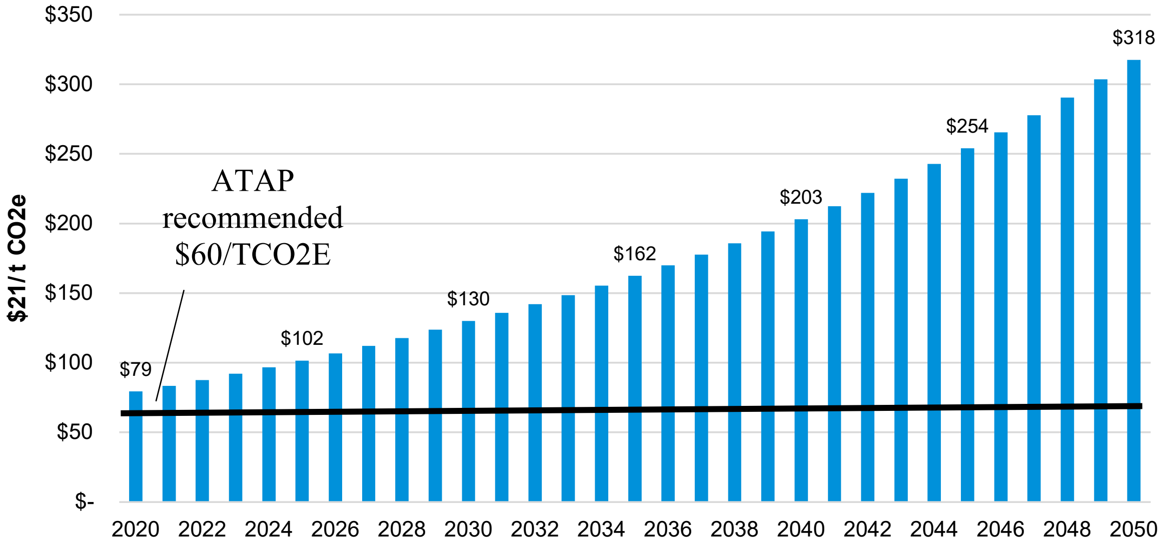
[16] IPCC (2018)

[17] UK Government (2021

[18] NSW Treasury (2023)

[19] Infrastructure Australia (2023)

Figure 4: Projected carbon costs ($FY21/TCO2E)



Source: KPMG analysis based on Jacobs (2017) and Australian Bureau of Statistics (2021)

The impact of increasing the cost of emissions over time in line with IPCC recommendations will significantly alter the contribution that vehicle emissions impacts have within the overall economic evaluation of transport projects. Within a cost-benefit analysis, putting a higher price on future carbon emissions will penalise projects that do not produce enough benefits over their economic life to justify these costs. The impact of using the escalating approach is demonstrated in the following case study.

Case study A & B – Escalating carbon price over time

The town bypass and orbital rail line case studies outlined previously in this paper show that using the fuel consumption approach for estimating vehicle emissions can produce materially different results to the VKT approach. In addition, using the escalated price of carbon as recommended by IPCC, rather than the flat $60 per tonne carbon price, as nominated in ATAP, will also materially impact outcomes.

This analysis is presented in Table 4, and includes a discount rate of 7%, which is commonly used for standard transport appraisals, alongside a discount rate of 4%, which is sometimes adopted for intergenerational transport appraisals. As shown in the analysis, in isolation, escalating the price of carbon emissions to over $300 per tonne by 2050 yields approximately triple the NPV impacts (either positive or negative) making the impact of carbon reduction (or gains) more significant in relation to total project benefits.

For example, for Case study A, using the VKT approach, the NPV of GHG benefits will change from -$1.1 Million to -$3.0 Million (with a 7% discount rate). When applying this change in combination with the fuel consumption approach, the NPV change in the case studies shown is even greater, with the result being +$2.3 Million for Case study A (a relative change in NPV of +$3.4 Million between the two approaches).

For Case study B, using a 4% discount rate that might apply for an intergenerational investment, the net NPV for GHG benefits alters from $23.1 Million to $171.4 Million when applying both the fuel consumption and escalating carbon cost approach.

Table 4: Combined impacts of new emissions estimations and valuation

	VKT approach	Fuel consumption approach
Case study A: Town bypass road project		
Change in vehicle kilometres travelled (km/day)	26,000	26,000
Change in fuel consumption (litres/day)	n/a	-1,000
Change in GHG (tonnes/day)	+1,000	-136
Economic impact ($/year)	-$60,000	+$45,000
NPV of GHG benefits over 50 years – using current non-escalating carbon price		
$60 per tonne (@7% discount rate)	**-$1.1M**	**+$0.8M**
$60 per tonne (@4% discount rate)	**-$1.8M**	**+$1.3M**
NPV of GHG benefits over 50 years – using escalated carbon price (new recommended approach)		
Escalating cost (@7% discount rate)	**-$3.0M**	**+$2.3M**
Escalating cost (@4% discount rate)	**-$5.9M**	**+$4.4M**
Case study B: Orbital rail project		
Change in vehicle kilometres travelled (km/day)	-310,000	-310,000
Change in fuel consumption (litres/day)	n/a	-12,760,000
Change in GHG (tonnes/day)	n/a	-29,000
Economic impact ($/year)	+$727,000	+$1,744,000
NPV of GHG benefits over 50 years – using current non-escalating carbon price		
$60 per tonne (@7% discount rate)	**+$14.2M**	**+$31.6M**
$60 per tonne (@4% discount rate)	**+$23.1M**	**+$51.6M**
NPV of GHG benefits over 50 years – using escalated carbon price (new recommended approach)		
Escalating cost (@7% discount rate)	**+$39.5M**	**+$88.3M**
Escalating cost (@4% discount rate)	**+$76.7M**	**+$171.4M**

A more appropriate approach to carbon pricing in our assessments will better reflect the costs of inaction for policy and decision makers. This will help to elevate the importance of reducing vehicle emissions as a key objective for transport projects. A shift in our appraisal methodology could help to drive investment that furthers our progress towards a more sustainable transport future.

4. Review criteria

If we intend to realistically advance our net zero policy objectives, the data and analysis that informs our decision making needs to adequately reflect the real emissions impacts of our transport schemes. The analysis should have the capability to change with the advancement of new technologies, modern vehicle and fuel types, and account for the increasing costs to society of carbon emissions.

As outlined in this paper, an advancement is needed in the approach to estimating vehicle emissions and their value on society. This paper puts forward an updated approach as follows:

- Calculate emissions using a disaggregated approach where vehicle fuel consumption is moderated according to driving conditions, rather than solely using distance travelled.
- The impacts of traffic congestion, and different road conditions, plays an important role in fuel efficiency and should be reflected in the fuel consumption rates.
- Vehicle fuel efficiencies and the fleet mix are changing significantly over time. Our appraisals should be capable of incorporating these shifts and considering the impacts of policy settings which shape them.
- The increasing burden of emissions and the cost of failing to achieve committed emissions targets needs to be reflected in our appraisals by escalating carbon costs over time, to align with IPCC recommendations and the net-zero greenhouse gas emissions targets of governments in Australia.

Using the disaggregate fuel consumption-based approach to estimating emissions and calculating the economic cost of their impact with escalated carbon costs will increase the importance of emissions reduction within transport planning and appraisals. This will raise the importance of properly planning transport projects to help us achieve our emissions reduction goals.

Further research and assessment will be required to appropriately determine the fuel consumption coefficients given the improvements in fuel efficiency of the vehicle fleet.

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Appendix

ATAP equations: Stop-start model: $c = A + B/V$ Free-flow model: $c = C0 + C1V + C2V^2$

Proposed equation: Single equation: $c = \text{base fuel} \times (a + b/V + cV + dV^2)$

Table 5: Proposed car fuel consumption parameters

Vehicle	Base Fuel	a_2	b_2	c_2	d_2
Car urban arterial	12.39548	0.71007	14.49633		
Car rural road	7.87570	1.24451		-0.00997	0.00010
Car urban freeway	7.87570	0.94938	9.17011	-0.00401	0.00004
LCV urban arterial	56.21207	0.80959	9.52035		
LCV rural road	26.60242	1.20432		-0.01109	0.00015
LCV urban freeway	26.60242	0.272	29	-0.004	0.00014
HCV urban arterial	86.36051	0.87312	6.34417		
HCV rural road	40.72518	1.12573		-0.00778	0.00012
HCV urban freeway	40.72518	0.286000	23	0.0001	0.0001