FRAMING MOBILITY INVESTMENT

A review of the inclusion of environmental and social costs in transport appraisal frameworks in four Anglophone countries

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Introduction

Transport appraisal frameworks are widely used across developed countries to guide assessments of major transport projects, and can play a key role in the choice of transport investments and the attainment of funding from government agencies. Transport appraisal frameworks strongly influence the method of analysis, the internal and external costs and benefits included, and the valuation of those costs and benefits (Eliasson & Lundberg, 2012). In many countries, transport appraisal frameworks require a cost benefit analysis to be conducted for major transport investments. Cost benefit analysis in this context refers to social cost benefit analysis, which includes the direct and indirect costs and benefits to society associated with a given project. External costs of transport can be significant; Cravioto, Yamasue, Okumura, & Ishihara (2013) found that the external costs of road transport amounted to between six and nine percent of GDP in five selected countries. External costs, such as environmental and social impacts, have only gradually been acknowledged and have tended to be under-valued or considered impossible to quantify since they are non-market impacts (Peter Bickel & Friedrich, 2013; Jakob, Craig, & Fisher, 2006). The inclusion of externalised environmental and social costs in transport appraisals is desirable as these costs are borne by society at large, and a wider understanding of these costs can lead to transport decisions that maximise benefits while minimising costs, and are thus more efficient.

The current study reviews the inclusion of selected externalised environmental and social costs in transport appraisal frameworks in four Anglophone countries: New Zealand, Australia, the United Kingdom, and Ireland. In the case of Australia, the State of Queensland is used as a case study as states are primarily responsible for transport funding in Australia and develop their own transport appraisal guidance. The four countries have a history of using cost benefit analysis for appraising transport investments and have appraisal frameworks that are strongly informed by one another (Bickel et al., 2006; Mackie & Worsley, 2013). It begins with a brief overview of the academic research on the significance and magnitude of four externalised costs: climate change, air pollution, physical activity levels, and noise. These four costs were chosen for the analysis as they have been identified as significant external costs in previous studies, and unlike other costs, such as congestion and traffic accidents, have only gradually been acknowledged in appraisal guidance (Cravioto et al., 2013; Jakob et al., 2006; Timilsina & Dulal, 2011). It provides a brief overview of the transport appraisal frameworks in the four case study countries and then reviews the inclusion of externalised costs across countries and implications for sustainability.

Externalised Costs of Transport

CLIMATE CHANGE

Climate change is widely accepted as an urgent global environmental challenge, and all of the case study countries have committed to substantially reduce their carbon emissions in the coming decades, most latterly with Nationally Determined Contributions tied to the Paris agreement. Transport is a considerable source of greenhouse gas emissions, and constitutes 15% of global greenhouse gas emissions and 16 to 25% of emissions in the selected case study countries (International Transport Forum, 2015; OECD, 2010). Inclusion of potential climate change implications of government investments during the decision making process is desirable for countries seeking to meet their emission reduction targets, especially as the social cost of carbon, and the costs of reduction commitments are likely to rise over time.

Transport investments can have substantial impacts on carbon emissions, both in the short term and in the longer term due to impacts on the viability of different travel modes and the spatial distribution of urban development. Emissions from transport are a particular concern for countries seeking to meet their emissions reductions goals, as they have increased substantially over the past two decades. For example, in New Zealand road transport emissions increased by 66% over the period 1990-2009 (Ministry for the Environment, 2011). The inclusion of a realistic price on carbon emissions from transport associated with transport investments is desirable, as it allows the carbon emissions impacts to be incorporated into decision making. This can provide a more accurate assessment of the wider relative costs of high and low carbon modes of transport.

Attaching a price per tonne to carbon emissions is a desirable and widely used means of internalising the external costs of climate change, and achieving carbon emissions reductions (Tol, 2005). However, there is considerable debate on the appropriate price per tonne of carbon, as the price necessarily reflects the unresolved uncertainties in the damages caused by climate change. Several different types of costs can be used to assess the price of carbon emissions. The social cost of carbon is the net present value of the impacts over an extended horizon of one tonne of carbon emitted today. Marginal abatement cost refers to the cost of reducing an additional tonne of emissions and may differ from the social cost. Market cost refers to the current cost per tonne in an emissions trading scheme or market for carbon offsets and will reflect the characteristics of the market (Ackerman & Stanton, 2012). The assessment of the social cost of climate change depends on the time horizon used and the discount rate applied to future impacts, as many of the most devastating impacts of climate change may not occur for decades or centuries.

Estimates of the costs of carbon have ranged widely, from $2 to $350 per tonne in one study (Tol, 2005), and even over $500 per tonne in a more recent study (Moore & Diaz, 2015). Van den Bergh and Botzen (2015) reviewed and critically analysed published estimates of the social cost of carbon in order to calculate a lower bound estimate Taking into account uncertainty surrounding future climate change impacts and aggregating results from studies that used low and high discount rates, Van den Bergh and Botzen (2015) estimate a conservative minimum social cost of carbon of US$125 per tonne. Because the costs of climate change and abatement are likely to increase over time, it is desirable that proposed projects with long time horizons take into account likely future increases in carbon prices (van den Bergh & Botzen, 2015).

PHYSICAL ACTIVITY LEVELS

The rise of obesity and physical inactivity seen as a major public health problems across countries, and the decline of active transportation is recognised as an important contributing factor to these trends. Transport related physical activity can be a significant factor in attaining recommended levels of physical activity. It has been well demonstrated that time spent walking and cycling significantly decreases the odds of being obese, while time spent driving increases the likelihood of obesity (Frank et al., 2006; Frank, Andresen, & Schmid, 2004). The built environment and transport network are recognised as key determinants of these transport behaviours (Ewing & Cervero, 2010). Time spent walking and cycling is also associated with decreased risk of dementia, cardiovascular disease, diabetes, breast cancer, colon cancer, and depression (Woodcock et al., 2009). Kelly et al. (2014) conducted a systematic review of the relationship between walking and cycling and reduction in all-cause mortality. Results from 21 studies suggested that walking or cycling 150 minutes per week (an average of 21 minutes per day) reduced all-cause mortality by 11% and 10%, respectively.

There is also increasing empirical evidence that time spent being sedentary, including time spent driving, exerts an independent influence on health in addition to the effects of (not) meeting recommended physical activity levels through active transport (Marshall & Merchant, 2013). Among adults living in Atlanta, Georgia, each additional hour driving per day was found to be associated with a 6% increase in the likelihood of being obese (Frank, Andresen, & Schmid, 2004). A study in Sydney, Australia, found that driving to work increased the odds of obesity and decreased the likelihood of meeting recommended physical activity levels (Wen, Orr, Millet, & Rissel, 2006). A longitudinal study of commuting adults in Adelaide, Australia, found that even among adults meeting recommended levels of physical activity, daily car commuting was associated with significant levels of weight gain over time (Sugiyama, Ding, & Owen, 2013).

Physical activity is also associated with reduced sick days and associated productivity benefits, in addition to substantial health benefits. Hendriksen, Simons, Garre, &

Hildebrandt (2010) conducted a cross-sectional study and found that cycling reduced the number of sick days taken by about 10% per cycling employee, and that longer cycling distances further reduced absenteeism. Amlani & Munir (2014) conducted a meta-analysis of 37 studies examining the relationship between physical activity and absenteeism; 26 studies found that physical activity significantly reduced absenteeism. However, many studies had methodological limitations, including insufficient description of the physical activity and use of self- reported data, highlighting the need for more research in this area.

Quantifying benefits from active transport commonly involves three components: decreased healthcare spending, productivity gains from reduced sick days, and reductions in mortality and morbidity. Due to the difficulty in quantifying the benefits associated with active transport, these benefits are typically underestimated in transportation appraisal (Kahlmeier, Racioppi, Cavill, Rutter, & Oja, 2010; Mulley, Tyson, McCue, Rissel, & Munro, 2013). Kahlmeier et al. (2010) conducted a systematic review of the approaches to the quantification of health benefits from walking and cycling. Methods used to quantify health impacts include quantifying gains in terms of disability adjusted life-years (DALYs), which are the total years of life lost due to premature mortality and years lived with disability and quality-adjusted life years (QALYs), equivalent to one year of perfect health (Kahlmeier et al., 2010). These health related figures can be translated into monetary terms using direct health care costs, stated willingness to pay to avoid negative health outcomes, and value of statistical life figures.

The World Health Organization developed the Health Economic Assessment Tool (HEAT) to create a user friendly tool to measure the economic health benefits of cycling infrastructure and policies (Caulfield, Brick, & McCarthy, 2012; Rutter et al., 2013). HEAT uses user-estimated increases in amount of cycling to project the reduction in mortality and associated economic savings associated with cycling investments but does not quantify benefits from reduced absenteeism, healthcare spending, or morbidity. Using results from various studies, and in particular a longitudinal study with 30,000 participants in Denmark (Andersen, Schnohr, Schroll, & Hein, 2000), the first iteration of HEAT assumed that all else being equal, regular cyclists are 28% less likely to die in any given year as compared to non-cyclists. The economic savings associated with reduced mortality are calculated using national value of statistical life figures. HEAT updated its relative risk reduction figures in 2014 based on data from seven studies, and now assumes that regular cyclists are 10% less likely to die in any given year as compared to non-cyclists (Kahlmeier et al., 2014; Kelly et al., 2014).

The Integrated Transport and Health Impact Modelling Tool (ITHIM) is a tool developed by the UK Centre for Diet and Activity research that estimates a wide range of health impacts from walking and cycling interventions. These impacts include physical activity-related reductions in mortality and morbidity, air pollution exposure, and changes in road injuries (Woodcock, Tainio, Cheshire, O'Brien, & Goodman, 2014). The relationship between physical activity and morbidity is assumed to be non-linear, and risk reduction values are estimated for breast cancer, colon cancer, dementia, depression, diabetes, and heart disease based on systematic reviews identified by Woodcock et al. (2009). The relative risks were taken from studies using broad measures of physical activity rather than studies examining physical activity from walking and cycling for transport (Woodcock et al., 2009, 2014).

AIR POLLUTION

Air pollution from motor vehicles is a significant public health problem, and results in substantial social costs from premature deaths, morbidity, hospital admissions, restricted activity, and reduced productivity (Kuschel et al., 2012). Particulate matter has been shown to have significant negative short term health impacts, including respiratory disease, and cardiovascular disease, and long term health impacts, including increased mortality and increased risk of cancer, diabetes, and cardio-pulmonary diseases (Eze et al., 2015; Hoek et al., 2013). Fine particulate matter is particularly harmful and motor vehicles are a significant source of these emissions. Nitrogen oxides are associated with respiratory disease and asthma (Brugge, Durant, & Rioux, 2007). There is also robust evidence on the short term health impacts of ozone, and less conclusive evidence on the effect of chronic exposure to ozone (Kampa & Castanas, 2008). Transport is a significant source of air pollution; the European Environment Agency estimates that transport is responsible for 60 percent of nitrogen oxide emissions and 24 percent of particulate matter in the European Union (European Environment Agency, 2016).

Assessing the social and economic costs of the air pollution associated with transport projects requires both an understanding of the exposure-response relationship for pollutants and a methodology for monetising health impacts. The exposure-response relationship for pollutants varies across countries, due to variances in covariates (such as smoking) that alter risk, local climate, and other factors (Hoek et al., 2013). The exposure response relationship for air pollutants is generally assessed as linear in the public health literature, but may be non-linear, especially in high pollution environments. Pope et al. (2011) and Xie et al. (2015) found that risk from fine particular matter is non-linear, with an exposure response function that is relatively steep at very low levels of exposure and flattens out at higher levels. This has considerable implications for the monetisation of air pollution costs and air pollution abatement policy. In high pollution areas, considerable improvements in air quality may be required to achieve reductions in disease burden, and conversely, in low pollution areas relatively small increases in air pollution may have substantial impacts (Pope, Cropper, Coggins, & Cohen, 2015). In Europe, the cost of premature deaths from air pollution is estimated to be US$ 1.431 trillion per year, about forty percent of which is due to emissions from road transport (World Health Organization, 2015).

NOISE

Noise pollution is a negative externality associated with both amenity related and health related impacts. Traffic noise that reduces amenity values can substantially reduce property values. For example, in South Korea a one percent increase in highway traffic noise was associated with a 1.3% reduction in land values and in Sweden a one decibel increase in highway traffic noise was associated with a 1.2% reduction in property values (Andersson, Jonsson, & Ögren, 2010; Kim, Park, & Kweon, 2007). Road traffic noise is linked to a range of negative health impacts, including cardiovascular disease, sleep disturbance, stroke, hypertension, and reduced cognitive performance in children. Higher levels of noise are associated with more severe adverse impacts than lower levels of noise pollution, which often have lower, amenity related impacts (Babisch, 2008; Basner et al., 2014; Pirrera, De Valck, & Cluydts, 2010). According to the World Health Organization, the total annual burden of health effects from environmental noise (primarily from road traffic) is greater than one million disability adjusted life-years in Western Europe, even when using the most conservative assumptions (World Health Organization, 2011).

Transport Appraisal Frameworks

THE UNITED KINGDOM

The UK is a country of about 65 million people comprising f England, Scotland, Wales, and Northern Ireland. Transport is considered a 'reserved matter' meaning that each country has the ability to legislate and create policy independently in this area. Motor vehicle ownership rates are the 22nd highest in the OECD, much lower than the OECD average (OECD, 2013). While overall GHG emissions in the UK have been decreasing, transport emissions increased by 21% from 1990 to 2008 (International Transport Forum, 2015).

The UK has been widely regarded as a leader in the valuation of transport investments. It has a long history of using cost benefit analysis and multi criteria analysis for the appraisal of transport projects and producing guidance manuals based on evidence from research studies. While similar, Scotland and England have separate transport appraisal guidance. England's transport analysis guidance ("TAG") is published in a series of online documents and spreadsheets, referred to as WebTAG. England has put emphasis on improving the treatment of social and distributional impacts in guidance documents in recent years. This includes a wide range of impacts, such as severance, heritage impacts, and agglomeration impacts, some of which are assessed quantitatively and some of which are assessed qualitatively (Department for Transport, 2016; Mackie & Worsley, 2013).

In England, major transport investments must develop a business case, which consists of a first stage early assessment and sifting tool to assess a wide range of options and a second stage more detailed appraisal according to webTAG guidance. The full five component business case includes the strategic case, economic case, financial case, commercial case, and delivery case. The economic case is based on both the benefit cost ratio and non-monetary impacts assessed using webTAG. The benefit cost ratio includes some monetised environmental and social impacts, while other environmental impacts are assessed as non-monetary impacts. Projects are assigned a value for money category based on the benefit cost ratio, and very few low value for money projects are approved (Department for Transport, 2016; Mackie & Worsley, 2013)

IRELAND

Ireland is a country of over 6 million people that has repeatedly been classified as one of Europe's most car dependent countries (Commins & Nolan, 2010). Despite this characterisation, motor vehicle ownership rates are the 24th highest in the OECD, substantially lower than the OECD average (OECD, 2013). Transport contributes 20% of overall GHG emissions in the country and has been a key contributor to growth in emissions since 1990 (International Transport Forum, 2015).

In Ireland, the overall direction of transport policy and funding across all modes is determined by the Department of Transport, Tourism, and Sport. Implementation of major road projects is conducted by the National Roading Authority, while rail projects are implemented by Irish Rail. The National Transport Authority, established by national legislation, is responsible for public transport in Dublin, Ireland's largest city.

Ireland has a relatively short history of using cost benefit analysis in transport investment decisions. While previous investment decisions were previously driven by strategic frameworks, cost benefit analyses now provide the primary basis for ranking investment proposals and there is a significant emphasis on economic competitiveness and return on investment in transport investment decisions (Department of Transport, Tourism and Sport, 2015). Ireland's first appraisal guidance *Guidelines on a Common Appraisal Framework for Transport Projects and Programmes* was introduced in 2007, updated in 2009 and replaced in 2016. Ireland's appraisal frameworks have largely been developed by following UK transport appraisal conventions (Ustaoglu et al. 2016).

NEW ZEALAND

New Zealand is a country of under 5 million people that has the highest rate of motor vehicle ownership in the OECD (OECD, 2013). Transport is responsible for 17% of GHG emissions and is also the single largest contributor to the growth in emissions since 1990, contributing 35% of the growth in emissions up to 2014 (Ministry for the Environment, 2015). In New Zealand, cost benefit analysis has been a requirement for major road projects since 1988. Transport appraisal frameworks were originally developed for road projects, with an ingrained principle that road user funds should be spent for road user benefit, rather than for other transport modes (Douglas, Wallis, Lawrence, & Wignall, 2013). The New Zealand Transport Agency (NZTA) is responsible for funding and delivering state highways, as well as the allocation of funding to local and regional councils, which manage local roads, public transport, and walking and cycling infrastructure. NZTA is responsible for both appraising and delivering state highways, and appraises transport proposals produced by local and regional councils. The New Zealand Ministry of Transport is the government's principal transport adviser and is responsible for the *Government Policy Statement on Land Transport Funding*.

Spending is directed by the *Government Policy Statement on Land Transport Funding*, which sets out three year priorities for allocation of funds from the National Land Transport Fund, which is sourced primarily from taxes on vehicles. Transport activities administered by local and regional councils are funded at a national average of 50% from the National Land Transport Fund, while state highways are 100% supported by the Fund.

The first guidance for the analysis of transport projects was published in 1991 and the current version was published in 2016. Prior to 2003 cost benefit analysis was the sole method of assessment and prioritisation of transport spending from the National Land Transport Fund, but there has been a reduced role for cost benefit analysis over the past decade. Since 2009 the NZTA has used a new approach to project selection based on three criteria: 'strategic fit', 'effectiveness' and 'efficiency' (Douglas et al., 2013; Pickford, 2013). Strategic fit refers to how well projects align with government policy statement priorities, effectiveness refers to the level of contribution that projects make to achieving government policy statement priorities, and efficiency refers to the benefit cost ratio as determined using the NZTA published *Economic Evaluation Manual* (New Zealand Transport Agency, 2016). Since the introduction of the new three pronged approach, projects funded from the National Land Transport Fund are increasingly aligned with the government's prioritisation of motorways termed 'roads of national significance' and benefit cost ratios of approved projects have fallen considerably (Pickford, 2013). The Ministry of Transport has identified greater transparency and reporting on the trends in the level of benefit cost ratio and the creation of an investment strategy for transport among its key goals for 2015-2019 (Ministry of Transport, 2015).

AUSTRALIA

Australia is a country of under 25 million comprising six states and two territories. Emissions from transport are 16% of total GHG emissions and accounted for 17% of the growth in emissions from 1990 to 2010 (International Transport Forum, 2015). Motor vehicle ownership rates are the 5th highest in the OECD, higher than the OECD average (OECD, 2013). Australia's transport investments are set within a federal framework, whereby each state takes the lead role in transport planning within its boundaries. States contribute the majority of funding for transport projects and are also responsible for developing their own transport appraisal guidance. Australia has a long history of using cost benefit analysis for transport projects, with the first appraisal guidance and cost benefit analysis introduced in the 1960s. Traditionally, economic appraisal has been a component but not a core component of gaining approval for transport projects, and in recent years the importance of economic appraisal has diminished relative to other factors, such as broader socioeconomic criteria (Mackie & Worsley, 2013).

While each state develops its own evaluation framework, many methods and figures in state frameworks are derived from Austroads research and guidance material. Austroads is a national agency that manages some of the country's motorways and also conducts research and publishes guidance documents for states. Queensland is Australia's second largest and third most populous state, and has some of the most developed transport appraisal guidance in Australia. Queensland was chosen as a case study as it has an appraisal framework that has been updated relatively recently and has appraisal documents that are made publicly available.

Inclusion of External Costs in Transport Appraisal Frameworks

CLIMATE CHANGE

All of the case study countries attach a price per tonne to carbon emissions in their transport appraisal guidance. In two of the countries, England and Ireland, the price per tonne increases with time. When current local prices per tonne are converted to US dollars, England has the highest and Ireland has the lowest price per tonne for carbon emissions (Table 1). By 2050, England's price on carbon emissions is 14 times larger than Australia's price on carbon emissions. However, carbon prices for all of the countries are substantially lower than the conservative estimate of the social cost of carbon of US$125 per tonne of CO_2, or even the more conservative US Interagency Working Group figures.

Ireland's price on carbon emissions was determined by an interdepartmental working group established by the Cabinet Committee on Climate Change and Energy Security. The working group determined that a price should be put on carbon emissions for sectors outside Ireland's emissions trading scheme. The price placed on carbon is set based on the price in the EU emissions trading system, including future prices (Department of Transport, Tourism and Sport, 2016). The EU emissions trading system has been criticised for its politically driven low price (Marcu, Elkerbout, & Stoefs, 2016; The Economist, 2013).

New Zealand's price on carbon emissions in transport appraisal was set based on a 1993 report created for NZTA which determined an average price of NZ$30 per tonne. This figure was updated to NZ$40 per tonne in 2016 to reflect inflation rather than changes in knowledge of the impacts of carbon emissions (New Zealand Transport Agency, 2016). It is not stated whether this is intended to represent the social cost of carbon, the abatement cost of carbon, or the market price for carbon.

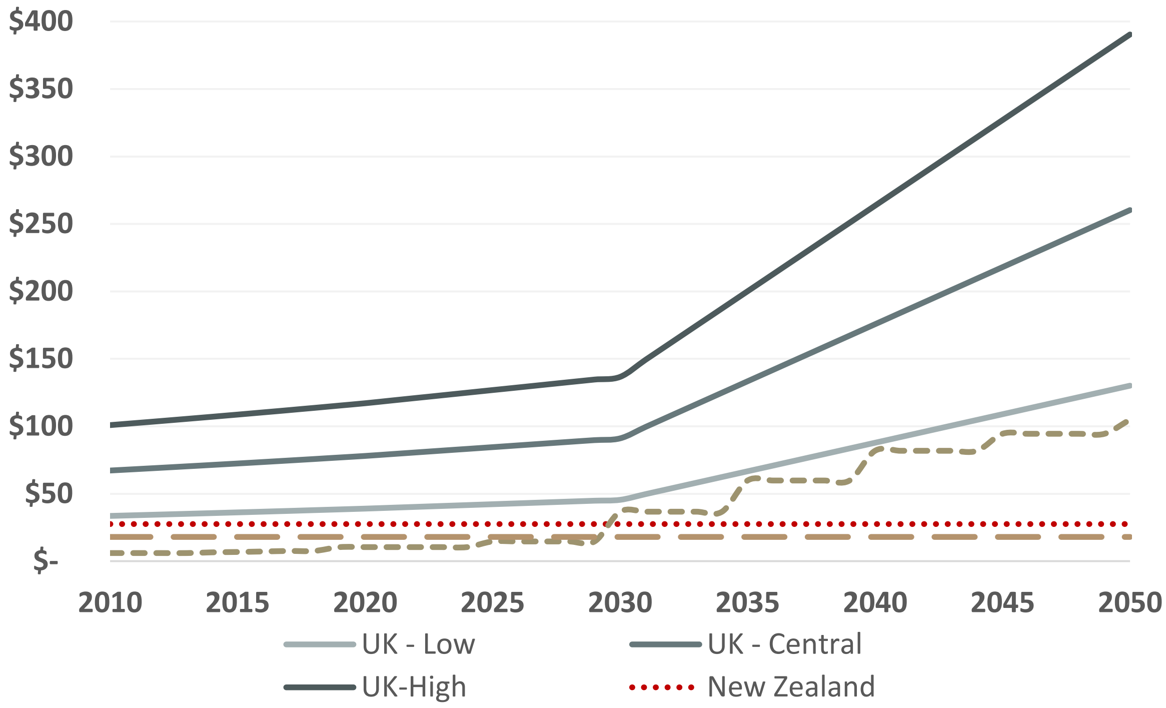
In Queensland, Australia, the values for carbon emissions are expressed in cents per kilometres driven with values based on a price of A$25 per tonne. Values are based on a 2003 Austroads study which cited a 1999 report on environmental externalities conducted for the European Commission (Eyre, Downing, Hoekstra, & Rennings, 1999). Austroads published updated guidance in 2014 which suggested a social cost of carbon of US$46-269 per tonne, based on a 2011 study based on research in 27 European countries but this has yet to be incorporated into Queensland's transport appraisal guidance (Department for Transport and Main Roads, 2011; van Essen et al., 2011).

A monetary valuation for carbon emissions was introduced into English appraisal guidance in 2006. While monetary values were originally based on the social cost of carbon, in 2008 this was changed to a shadow price of carbon, based on guidance from the Department for the Environmental and Rural Affairs (DEFRA) and the Stern Review (Mackie & Worsley, 2013; Stern, 2007). The current carbon price is determined based on the marginal abatement costs to achieve national greenhouse gas reduction targets. In order to take uncertainties into account, a sensitivity analysis with lower, central, and upper price estimates is suggested for projects with large carbon emissions impacts. The lower price estimate used in the UK is higher than the central carbon price in the three other countries.

Table 1: Carbon Prices in Selected Countries

Country	Price per tonne - 2016 (local currency)		Price per tonne -2016 (USD)		Price per tonne -2050 (USD)	
New Zealand	$	40.00	$	27.60	$	27.60
Australia (QLD)	$	25.00	$	18.04	$	18.04
Ireland	€	13.22	$	13.80	$	105.00
UK (England)	£	58.85	$	73.47	$	260.28

Figure 1: Carbon Prices Used in Transport Appraisal (US$/tonne)



AIR POLLUTION

While all the case study countries attempt to monetise the cost of air pollution, the pollutants monetised and the methods used vary greatly across countries. New Zealand, Australia, and Ireland monetise air emissions based on the quantity emitted by vehicles. In Australia and Ireland this is expressed in dollars per tonne emitted while in New Zealand it is expressed in dollars per vehicle kilometre travelled. In England, the costs of air emissions are assessed based on exposure to pollutants.

England has monetised the costs of air pollution since 2012, and monetises the direct mortality and morbidity costs associated with particulate matter and nitrogen dioxide emissions, as well as the willingness to pay for avoiding the adverse health risks associated with air pollution. The economic valuation of air pollution is conducted based on based on exposure to pollutants, which is determined using location specific modelling that estimates changes in pollution concentrations. The cost of air pollution was determined by a research report conducted by the Interdepartmental Group on Costs and Benefits, which was an 11 member group from across the British government. Monetary values for willingness to pay for reductions in mortality were taken from a 2004 DEFRA study that surveyed 665 respondents. The study used a random probability sampling method to gain a representative sample of adults across England, Scotland, and Wales (Chilton, Covey, Jones-Lee, Loomes, & Metcalf, 2004).

Ireland monetises the cost of air pollution based on willingness to pay to avoid air pollution, but its basis is not transparent. It is not stated whether these are mortality or morbidity benefits, a specific study is not cited, and it is not stated which costs are monetised. Particulate matter (PM10 and PM2.5), nitrogen oxides, and volatile organic compounds are assigned a price in euros per tonne.

New Zealand's Economic Evaluation Manual states that cost values for particulate matter are based on UK mortality costs from a 1995 report, adjusted for New Zealand life expectancy and costs of life and increased by 30% to account for morbidity as well as mortality costs (Tinch, 1995). At best, estimates based on such studies could be outdated, perhaps by 25 years or so. In that time, knowledge of particulate matter and its impacts have improved dramatically. While the approaches in New Zealand and the UK to monetising the impact of particulate matter are similar, the methodologies for assessing pollution impacts are divergent (New Zealand Transport Agency, 2016).

In Queensland, Australia, the values for air emissions are based on a 2008 Austroads report, which cites a 2003 Austroads report, which in turn cites a European study from 2000 which was produced for the International Union of Railways. Again, such an approach is outdated. Air pollution is assessed based on dollars of cost per kilometre driven, which is given separate values for passenger cars and busses and urban and rural travel.

Table 2: Air Pollution Values in Selected Countries

Country	PM10	NOx	PM2.5	VOC
New Zealand	NZ$40 /person/µg/m³			
Australia (QLD)	A$304,298/tonne	A$1,912/tonne		
Ireland	€19,143/tonne	€5,851/tonne	€16,985-48,779/tonne	€1,438-200,239/tonne
UK (England)	£92.7 /household/µg/m³	£955/tonne (damage) £29,000/tonne (marginal abatement)[1]		

Health Benefits from Active Transport

Three of the four case study countries monetise the health benefits associated with active transport. England and Ireland monetise the benefits of reduced mortality associated with active transport, with values taken from a longitudinal study in the Copenhagen area that was also originally used to construct the HEAT tool (Andersen, Schnohr, Schroll, & Hein, 2000). Cycling is assumed to reduce the relative risk of mortality by 22% (given 42 minutes cycled per work day) and walking is assumed to reduce the relative risk of mortality by 11% (given 38 minutes walked per work day). This is a slightly larger impact than that estimated by Kelly et al. (2014) and currently used by the HEAT tool. These figures are multiplied by the average risk of death for working age adults to determine the number of avoided deaths, the value of which is quantified using the value of a statistical life.

In both Ireland and England, cycling or walking 30 minutes per day is assumed to reduce absenteeism by 6%, as this is reported to be the lower bound estimate reported in a World Health Organization report (World Health Organization, 2003). The source cited in the report is a 1996 report by the US Department of Health and Human Services,

[1] The marginal abatement cost value is used in areas where projects are expected to result in changes to air quality in areas exceeding EU air pollution limit values.

which cites earlier research. However, the research investigated the reduction in absenteeism associated with organised workplace health programmes rather than walking and cycling for transport. Many of the organised workplace health programmes included elements besides physical activity promotion, and furthermore the report did not estimate the relationship between time spent in physical activity and reductions absenteeism. As such, this source is not applicable to reductions in absenteeism from walking and cycling (US Department of Health and Human Services, 1996).

Queensland, Australia does not does include active transport benefits in its transport analysis guidance, while New Zealand includes active transport benefits from road traffic reduction as well as health benefits. In New Zealand, walking is assumed to have a health benefit of $NZD 2.60 per kilometre and cycling is assumed to have a health benefit of $NZD 1.30 per kilometre, but it is not stated whether these are mortality or morbidity benefits. A report was commissioned by the NZTA in 2008 to estimate the value of the health benefits from walking and cycling. The report conducted a literature review and suggested a benefit of $NZD 1.77 to $NZD 2.51 per kilometre for cycling and $NZD 3.53 to $NZD 5.01 per kilometre for walking (Genter, Donovan, Petrenas, & Badland, 2008). The study assessed the benefits from reduced mortality, morbidity, and direct health care spending using estimates from six sources published between 2004 and 2008. These included a UK Department for Transport study, a World Health Organization report, a report by a New Zealand consultancy, and three peer reviewed journal articles.

Table 3: Cycling Benefit Values in Selected Countries

Country	Mortality Reduction	Morbidity Reduction	Health Care Cost Saving	Absenteeism Benefit
New Zealand	$1.30 per km	n/a	n/a	n/a
Australia (QLD)	n/a	n/a	n/a	n/a
Ireland	Reduce by 22%	n/a	n/a	Reduce by 6%
UK (England)	Reduce by 22%	n/a	n/a	Reduce by 6%

NOISE

There is wide variation across countries in the methods for quantifying the costs of noise emissions, the costs that are quantified, and the magnitude of those costs. In the UK, Ireland, and New Zealand, transport noise is assessed based on a price per decibel per person exposed, while in Australia it is given a price per kilometre driven.

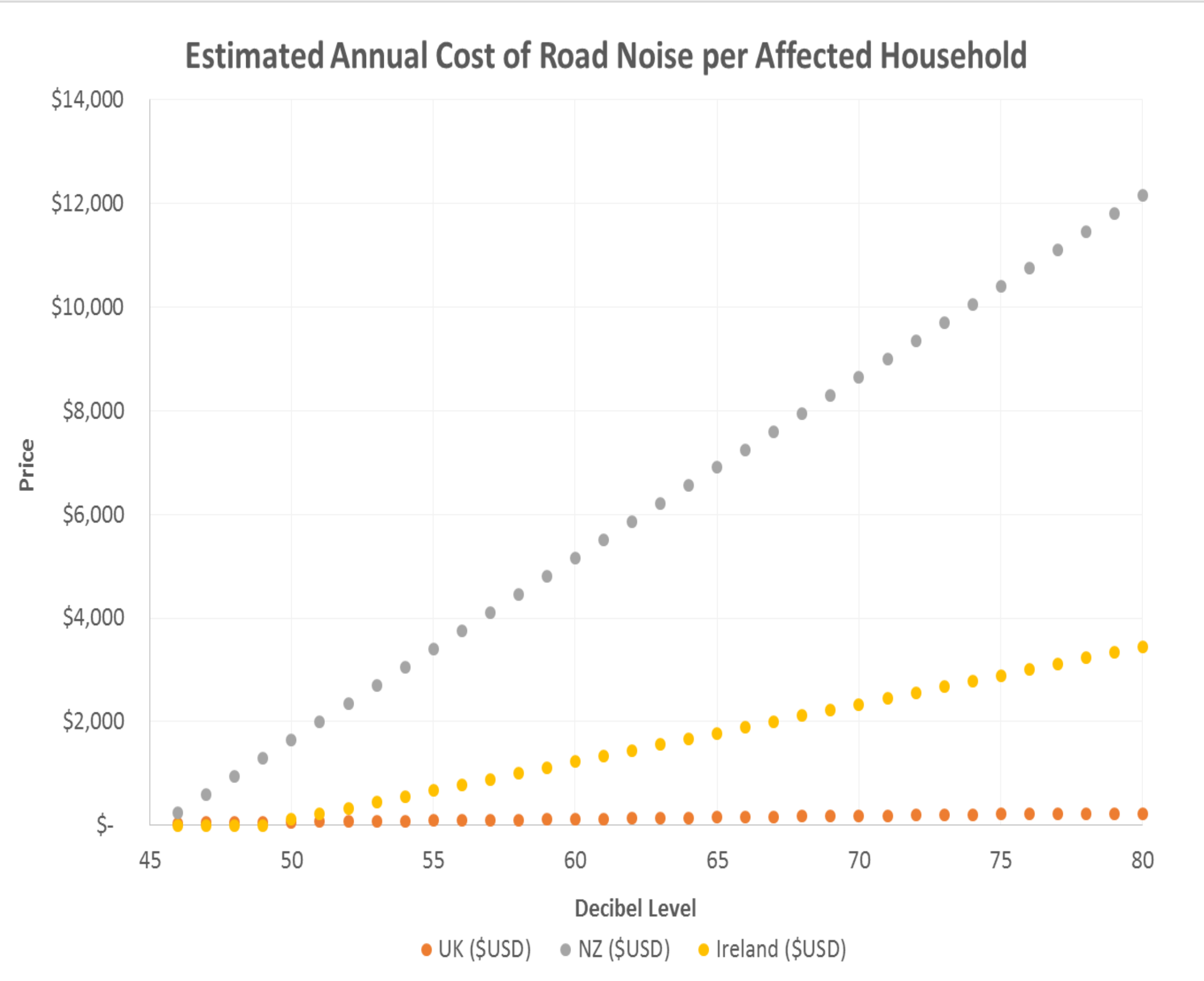
Monetary valuation of noise impacts was introduced into English appraisal guidance in 2006 (Mackie & Worsley, 2013). Monetary valuation for noise are based on changes in health outcomes, which are estimated based on the change in Disability-Adjusted Life Years, assuming a value of £60,000 per DALY. The valuation of noise in England is based on extensive internal and external research, including a 2005 study of the valuation of transport noise commissioned by the Department for Transport, a report commissioned in 2008 by DEFRA examining the health impacts of noise pollution, and a 2010 report by the World Health Organization (Department for Transport, 2016).

In Ireland, monetisation of noise impacts is not required for preliminary proposals, and is recommend but not required for larger scale projects with detailed designs. A value of €30 per decibels per person per year is recommended based on results from two uncited surveys. The manual states that only incremental noise impacts above 50 decibels should be assessed (Department of Transport, Tourism and Sport, 2016).

In New Zealand, monetisation of noise impacts is based on impacts on property values, with values based on two government produced studies from the 1990s conducted in the UK and Canada (Bein, Johnson, & Litman, 1995; Tinch, 1995). The British study suggested that the value of noise is 0.7% of affected property values per decibel, while the Canadian study suggested that the overall cost of noise is about twice as high due to effects on non-residents, increased impacts as noise rises, and lack of consideration of full effects at the time of house purchase. Assuming a value of noise of 1.2% of property values, an average house price of $450,000, a time period of 40 years, and a 6% discount rate, the annual cost of noise per decibel is estimated to be $350 per decibel per household (New Zealand Transport Agency, 2016).

In Australia, the values for noise impacts are based on a 2008 Austroads report, which cites a 2003 Austroads report, which in turn cites a 2000 research report that attempted to quantify the external costs of transport in Europe based on previous studies. The research report quantified the external cost of noise from three sources: medical costs due to transport noise, mortality from cardiac events, and inhabitants' willingness to pay for reductions in noise exposure (Maibach et al., 2000). Willingness to pay to avoid a one decibel increase in noise level was found to be 0.11% of per capita

Figure 2



income. Individuals exposed to road traffic noise over 65 decibels are assumed to have €180 in medical costs. These figures are adjusted for inflation and currency, resulting in a value of 82 cents per kilometre for urban passenger vehicles (New Zealand Transport Agency, 2016).

Implications for Sustainable Outcomes

Over the past two decades, countries have increasingly attempted to account for externalised costs when evaluating potential transport investments and have incorporated methods for quantifying external costs into evaluation frameworks. Although external costs can be extensive for transport systems, the vast majority of costs identified in cost benefit analyses of transport projects are direct construction costs, while the vast majority of benefits are related to travel time savings. This may partly be due to a widespread omission of induced demand in traffic models, which can substantially reduce estimates of external costs, as well as assessments of individual projects rather than wider transport systems (Næss, 2012). Another potential cause for the underestimation of external costs of transport is the values established in transport appraisal guidance documents published by government agencies.

The present study examined the valuation of four externalised costs (carbon emissions, local air emissions, noise, and physical activity) in four selected countries (England, Ireland, Australia, and New Zealand). Although the four case study countries are culturally similar and have economic evaluation frameworks that have been informed by each other, the valuation of externalised costs varies widely. There appears to be the most similarity across countries in the valuation of carbon emissions, with all countries studied putting a relatively low price on carbon emissions: in effect, the carbon costs of transport developments are substantially downplayed. Despite it being apparent from the early 1990s that carbon emissions were damaging, the cost of carbon emissions were not included in any of the case study countries until 2006. In some countries, carbon prices are not taken as rising over time, whereas there is strong evidence that the social cost of carbon will do so. There is variation in the type of price being put on carbon, with different countries using a market price, social cost, or abatement cost of carbon. With regard to noise emissions, local air pollution, and physical activity impacts, there is a wide variation across countries in the impacts quantified, the monetisation method, and the price chosen.

For noise pollution, each of the four countries has a different approach to monetisation. In Ireland it is not required, in England it is based on health impacts only, in New Zealand it is based on impacts on property prices, and in Australia it is based on health impacts and willingness to pay. For all countries but England values appear to be based on either very outdated research or no research at all. This results in widely disparate values (Figure 2).

England and Ireland include mortality and reduced absenteeism benefits from increased walking and cycling. In the two countries, the evidence used to quantify absenteeism benefits appears to be very outdated and not directly applicable. New Zealand only monetises health benefits from active transport, and uses a very conservative estimate of benefits. Australia does not include any benefits from active travel. While three of the four countries include health benefits for walking and cycling projects, *none* of the countries requires the monetisation of negative health impacts associated with increased driving. Projects that increase driving likely have adverse health impacts associated with decreased active travel and increased sedentary time. Although their approaches differ, all of the countries appear to under-value the benefits of active travel and could improve their guidance by including morbidity benefits, up to date absenteeism benefits, and dis-benefits associated with projects that are likely to reduce active travel and increase time spent travelling by car.

With regard to air pollution impacts, there is wide variety in the types of pollution that are included and the price attached to local air pollution. Only England's approach to monetising the costs of air pollution takes into account the fact that the amount of pollutants emitted will have disparate health impacts depending on the local environment.

There appears to be a trend across countries to underestimate externalised costs of transport investments. All of the four case study countries could improve their transport appraisal guidance by using reliable and up to date sources for the values of external costs being quantified. In many cases, the sources used are more than 20 years old, are not peer reviewed, and are applied incorrectly even though the transport appraisal guidance for all countries has been updated within the past two years. Clearly communicating the costs that are being monetised, the rationale being used, and the sources cited, would contribute to greater transparency. Accurately accounting for external costs can lead to transport investment decisions that maximise benefits to society.

References

Ackerman, F., & Stanton, E. (2012). Climate risks and carbon prices: Revising the social cost of carbon. *Economics: The Open-Access, Open-Assessment E-Journal*, *6*, 10.

Amlani, N. M., & Munir, F. (2014). Does Physical Activity Have an Impact on Sickness Absence? A Review. *Sports Medicine*, *44*(7), 887–907. https://doi.org/10.1007/s40279-014-0171-0

Andersen, L. B., Schnohr, P., Schroll, M., & Hein, H. O. (2000). All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. *Archives of Internal Medicine*, *160*(11), 1621–1628.

Andersson, H., Jonsson, L., & Ögren, M. (2010). Property Prices and Exposure to Multiple Noise Sources: Hedonic Regression with Road and Railway Noise. *Environmental and Resource Economics*, *45*(1), 73–89. https://doi.org/10.1007/s10640-009-9306-4

Babisch, W. (2008). Road traffic noise and cardiovascular risk. *Noise and Health*, *10*(38), 27. https://doi.org/10.4103/1463-1741.39005

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. *The Lancet*, *383*(9925), 1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X

Bein, P., Johnson, C. J., & Litman, T. (1995). *Monetization of Environmental Impacts of Road*. Victoria, B.C.: Ministry of Transportation and Highways.

Bickel, P, Friedrich, R., Burgess, A., Fagiani, P., Hunt, A., De Jong, G., … Mackie, P. (2006). HEATCO Developing Harmonised European Approaches for Transport Costing and Project Assessment, Deliverable 5: Proposal for Harmonised Guidelines. *Stuttgart: Institut Für Energiewissenschaft Und Rationelle Energieanwendung*.

Bickel, Peter, & Friedrich, R. (2013). *Environmental external costs of transport*. Springer Science & Business Media.

Brugge, D., Durant, J. L., & Rioux, C. (2007). Near-highway pollutants in motor vehicle exhaust: A review of epidemiologic evidence of cardiac and pulmonary health risks. *Environmental Health*, *6*, 23. https://doi.org/10.1186/1476-069X-6-23

Caulfield, B., Brick, E., & McCarthy, O. T. (2012). Determining bicycle infrastructure preferences – A case study of Dublin. *Transportation Research Part D: Transport and Environment*, *17*(5), 413–417. https://doi.org/10.1016/j.trd.2012.04.001

Chilton, S., Covey, J., Jones-Lee, M., Loomes, G., & Metcalf, H. (2004). *Valuation of health benefits associated with reductions in air pollution*. London, UK: Department for Environment, Food, and Rural Affairs.

Commins, N., & Nolan, A. (2010). Car ownership and mode of transport to work in Ireland. *The Economic and Social Review*, *41*(1), 43–75.

Cravioto, J., Yamasue, E., Okumura, H., & Ishihara, K. N. (2013). Road transport externalities in Mexico: Estimates and international comparisons. *Transport Policy*, *30*, 63–76. https://doi.org/10.1016/j.tranpol.2013.08.004

Department for Transport. (2016, July 28). Transport analysis guidance: WebTAG - GOV.UK. Retrieved January 9, 2017, from https://www.gov.uk/guidance/transport-analysis-guidance-webtag

Department for Transport and Main Roads. (2011). *Cost-benefit Analysis Manual: Road projects*. Queensland, Australia: Queensland Government.

Department of Transport, Tourism and Sport. (2015). *Investing in our transport future: A strategic framework for investment in land transport*. Dublin, Ireland. Retrieved from http://www.dttas.ie/sites/default/files/publications/corporate/english/public-consultation-investing-our-transport-future/consultation-sfilt-investing-our-transport-future-steering-group-report.pdf

Department of Transport, Tourism and Sport. (2016). Common Appraisal Framework for Transport Projects and Programmes. Retrieved from http://www.dttas.ie/corporate/english/appraisal

Douglas, N. J., Wallis, I., Lawrence, A., & Wignall, D. (2013). Annex 7: New Zealand Country Report. In *International Comparison of Transport Appraisal Practice*. Leeds, United Kingdom: University of Leeds Institute for Transport Studies. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209537/annex-7-new-zealand.pdf

Eliasson, J., & Lundberg, M. (2012). Do Cost–Benefit Analyses Influence Transport Investment Decisions? Experiences from the Swedish Transport Investment Plan 2010–21. *Transport Reviews*, *32*(1), 29–48. https://doi.org/10.1080/01441647.2011.582541

European Environment Agency. (2016, December). Emissions of air pollutants from transport — European Environment Agency [Indicator Assessment]. Retrieved December 19, 2016, from http://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-4

Ewing, R., & Cervero, R. (2010). Travel and the Built Environment. *Journal of the American Planning Association*, *76*(3), 265–294. https://doi.org/10.1080/01944361003766766

Eyre, N., Downing, T., Hoekstra, R., & Rennings, K. (1999). Global Warming Damages. In *ExternE: Externalities of Energy*. Luxembourg: Office for Official Publications of the European Communities.

Eze, I. C., Hemkens, L. G., Bucher, H. C., Hoffmann, B., Schindler, C., Künzli, N., … Probst-Hensch, N. M. (2015). Association between Ambient Air Pollution and Diabetes Mellitus in Europe and North America: Systematic Review and Meta-Analysis. *Environmental Health Perspectives (Online)*, *123*(5), 381. https://doi.org/http://dx.doi.org/10.1289/ehp.1307823

Frank, L., Andresen, M. A., & Schmid, T. L. (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine*, *27*(2), 87–96.

Genter, J., Donovan, S., Petrenas, B., & Badland, H. (2008). Valuing the health benefits of active transport modes. *New Zealand Transport Agency Research Report*, *359*, 72.

Hendriksen, I. J. M., Simons, M., Garre, F. G., & Hildebrandt, V. H. (2010). The association between commuter cycling and sickness absence. *Preventive Medicine*, *51*(2), 132–135. https://doi.org/10.1016/j.ypmed.2010.05.007

Hoek, G., Krishnan, R. M., Beelen, R., Peters, A., Ostro, B., Brunekreef, B., & Kaufman, J. D. (2013). Long-term air pollution exposure and cardio- respiratory mortality: a review. *Environmental Health*, *12*, 43. https://doi.org/10.1186/1476-069X-12-43

International Transport Forum. (2015). *Transport Greenhouse Gas Emissions: Country Data 2010* (Text). 2011. Retrieved from http://www.itf-oecd.org/transport-greenhouse-gas-emissions-country-data-2010

Jakob, A., Craig, J. L., & Fisher, G. (2006). Transport cost analysis: a case study of the total costs of private and public transport in Auckland. *Environmental Science & Policy*, *9*(1), 55–66. https://doi.org/10.1016/j.envsci.2005.09.001

Kahlmeier, S., Cavill, N., Dinsdale, H., Rutter, H., Götschi, T., Foster, C., … Fordham, R. (2014). *Health economic assessment tools (HEAT) for walking and for cycling. Methods and user guide, 2014 Update*. Copenhagen: World Health Organization.

Kahlmeier, S., Racioppi, F., Cavill, N., Rutter, H., & Oja, P. (2010). " Health in all policies" in practice: guidance and tools to quantifying the health effects of cycling and walking. *Journal of Physical Activity & Health*, *7*(1), S120.

Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. *Environmental Pollution*, *151*(2), 362–367. https://doi.org/10.1016/j.envpol.2007.06.012

Kelly, P., Kahlmeier, S., Götschi, T., Orsini, N., Richards, J., Roberts, N., … Foster, C. (2014). Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *International Journal of Behavioral Nutrition and Physical Activity*, *11*, 132. https://doi.org/10.1186/s12966-014-0132-x

Kim, K. S., Park, S. J., & Kweon, Y.-J. (2007). Highway traffic noise effects on land price in an urban area. *Transportation Research Part D: Transport and Environment*, *12*(4), 275–280. https://doi.org/10.1016/j.trd.2007.03.002

Mackie, P., & Worsley, T. (2013). *International Comparison of Transport Appraisal Practice: Overview Report*. Leeds, United Kingdom: Institute for Transport Studies, University of Leeds. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209530/final-overview-report.pdf

Maibach, M., Banfi, S., Doll, C., Rothengatter, W., Schenkel, P., Sieber, N., & Zuber, J. (2000). External costs of transport: Accident, Environmental and Congestion Costs in Western Europe (INFRAS/IWW study). *Zürich/Karlsruhe, INFRAS, Consulting Group for Policy Analysis, and IWW, University of Karlsruhe. Printed by International Union of Railways (UIC)*.

Marcu, A., Elkerbout, M., & Stoefs, W. (2016). *2016 State of the EU ETS Report*. Brussels, Belgium: Carbon Market Form and Energy Climate House. Retrieved from http://www.ceps-ech.eu/publication/2016-state-eu-ets-report

Marshall, S. J., & Merchant, G. (2013). Advancing the Science of Sedentary Behavior Measurement. *American Journal of Preventive Medicine*, *44*(2), 190–191. https://doi.org/10.1016/j.amepre.2012.11.001

Ministry for the Environment. (2015). *New Zealand's Greenhouse Gas Inventory 1990–2014*. Wellington, New Zealand: Ministry for the Environment.

Ministry of Transport. (2015). *Statement of Intent 2015 -2019*. Wellington, New Zealand: Ministry of Transport. Retrieved from http://www.transport.govt.nz/assets/Uploads/About/Documents/statement-of-intent-2015-2019.pdf

Moore, F. C., & Diaz, D. B. (2015). Temperature impacts on economic growth warrant stringent mitigation policy. *Nature Climate Change*, *5*(2), 127–131. https://doi.org/10.1038/nclimate2481

Mulley, C., Tyson, R., McCue, P., Rissel, C., & Munro, C. (2013). Valuing active travel: Including the health benefits of sustainable transport in transportation appraisal frameworks. *Research in Transportation Business & Management*, *7*, 27–34. https://doi.org/10.1016/j.rtbm.2013.01.001

Næss, P. (2012). Traffic forecasts ignoring induced demand. *European Journal of Transport and Infrastructure Research*, *12*(3), 291–309.

New Zealand Transport Agency. (2016). *Economic Evaluation Manual*. Wellington, New Zealand: New Zealand Transport Agency.

OECD. (2010). *Reducing Transport Greenhouse Gas Emissions: Trends and Data*. Leipzig, Germany: OECD International Transport Forum. Retrieved from http://www.internationaltransportforum.org/Pub/pdf/10GHGTrends.pdf

OECD. (2013). *Environment at a Glance 2013*. Paris: Organisation for Economic Co-operation and Development. Retrieved from http://www.oecd-ilibrary.org/content/book/9789264185715-en

Pickford, M. (2013). State Highway Investment in New Zealand: The decline and fall of economic efficiency. *Policy Quarterly*, *9*(2). Retrieved from http://igps.victoria.ac.nz/publications/files/30aaf9a4518.pdf

Pirrera, S., De Valck, E., & Cluydts, R. (2010). Nocturnal road traffic noise: A review on its assessment and consequences on sleep and health. *Environment International*, *36*(5), 492–498. https://doi.org/10.1016/j.envint.2010.03.007

Pope, C. A., Burnett, R. T., Turner, M. C., Cohen, A., Krewski, D., Jerrett, M., … Thun, M. J. (2011). Lung Cancer and Cardiovascular Disease Mortality Associated with Ambient Air Pollution and Cigarette Smoke: Shape of the Exposure-Response Relationships. *Environmental Health Perspectives*, *119*(11), 1616–21.

Pope, C. A., Cropper, M., Coggins, J., & Cohen, A. (2015). Health benefits of air pollution abatement policy: Role of the shape of the concentration–response function. *Journal of the Air & Waste Management Association*, *65*(5), 516–522. https://doi.org/10.1080/10962247.2014.993004

Rutter, H., Cavill, N., Racioppi, F., Dinsdale, H., Oja, P., & Kahlmeier, S. (2013). Economic Impact of Reduced Mortality Due to Increased Cycling. *American Journal of Preventive Medicine*, *44*(1), 89–92. https://doi.org/10.1016/j.amepre.2012.09.053

Stern, N. (2007). *The economics of climate change: the Stern review*. Cambridge University Press.

Sugiyama, T., Ding, D., & Owen, N. (2013). Commuting by Car: Weight Gain Among Physically Active Adults. *American Journal of Preventive Medicine*, *44*(2), 169–173. https://doi.org/10.1016/j.amepre.2012.09.063

The Economist. (2013, April 20). ETS, RIP? *The Economist*. Retrieved from http://www.economist.com/news/finance-and-economics/21576388-failure-reform-europes-carbon-market-will-reverberate-round-world-ets

Timilsina, G. R., & Dulal, H. B. (2011). Urban Road Transportation Externalities: Costs and Choice of Policy Instruments. *The World Bank Research Observer*, *26*(1), 162–191. https://doi.org/10.1093/wbro/lkq005

Tinch, R. (1995). *The valuation of environmental externalities: full report* (Report to the Department of Transport). London, UK: HMSO. Retrieved from /view.aspx?id=1166000

Tol, R. S. J. (2005). The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. *Energy Policy*, *33*(16), 2064–2074. https://doi.org/10.1016/j.enpol.2004.04.002

US Department of Health and Human Services. (1996). *Physical activity and health: a report of the Surgeon General*. Atlanta, Georgia: US Department of Health and Human Services.

van den Bergh, J. C. J. M., & Botzen, W. J. W. (2015). Monetary valuation of the social cost of CO2 emissions: A critical survey. *Ecological Economics*, *114*, 33–46. https://doi.org/10.1016/j.ecolecon.2015.03.015

van Essen, H., Schroten, A., Otten, M., Sutter, D., Schreyer, C., Zandonella, R., … Doll, C. (2011). *External Costs of Transport in Europe*. Delft, the Netherlands: CE Delft, INFRAS, Fraunhofer ISI. Retrieved from http://www.cedelft.eu/publicatie/external_costs_of_transport_in_europe/1258

Wen, L., Orr, N., Millet, C., & Rissel, C. (2006). Driving to work and overweight and obesity: findings from the 2003 New South Wales Health Survey, Australia. *International Journal of Obesity (2005)*, *30*(5), 782–786. https://doi.org/10.1038/sj.ijo.0803199

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B. G., Ashiru, O., Banister, D., … Roberts, I. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *Lancet*, *374*(9705), 1930–1943. https://doi.org/10.1016/S0140-6736(09)61714-1

Woodcock, J., Tainio, M., Cheshire, J., O'Brien, O., & Goodman, A. (2014). Health effects of the London bicycle sharing system: health impact modelling study. *BMJ*, *348*, g425. https://doi.org/10.1136/bmj.g425

World Health Organization. (2003). *Health and development through physical activity and sport*. Geneva, Switzerland: World Health Organization.

World Health Organization. (2011). *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe*. Bonn, Germany: World Health Organization. Retrieved from http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf

World Health Organization. (2015). *Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth*. Copenhagen: WHO Regional Office for Europe. Retrieved from http://www.euro.who.int/en/media-centre/events/events/2015/04/ehp-mid-term-review/publications/economic-cost-of-the-health-impact-of-air-pollution-in-europe

Xie, W., Li, G., Zhao, D., Xie, X., Wei, Z., Wang, W., … Liu, J. (2015). Relationship between fine particulate air pollution and ischaemic heart disease morbidity and mortality. *Heart*, *101*(4), 257. https://doi.org/http://dx.doi.org/10.1136/heartjnl-2014-306165