2. Transportation Cost Literature Review

This chapter summarizes previous transport cost studies, including several that focus on freight costs.

2.1 Index

2.2 Introduction

Several previous studies have investigated various types of transportation costs. This chapter summarizes some of them.

Different types of studies have different purposes, which affects their perspective, methodologies and scope. For example, most highway cost allocation and investment evaluation studies are primarily concerned with direct market costs, such as road construction and maintenance, travel time, vehicle operating costs, and crash damages, and how these vary depending on vehicle type and roadway conditions. They assumed that the total amount of vehicle travel does not change and so were unconcerned with vehicle ownership and parking costs. Other types of studies incorporate environmental impacts, primarily air pollution, but sometimes also noise and water pollution, and various categories of land use impacts. Some studies only consider tax subsidies or external costs (Delucchi and Murhpy 2008). Their results differ significantly due to differences in methodology and scope (for discussion see Quinet 2004).

The following factors should be considered when comparing cost studies:

- The purpose of the analysis, and therefore its perspective, such as whether it considers only short-run marginal costs, long-run costs, and or total social costs.
- Categories of impacts considered, including vehicle costs, travel time costs, roadway costs, traffic services, parking costs, congestion impacts on other road users, delays to nonmotorized travelers, accident costs, pollution emissions and other environmental impacts.
- Data sources and methodologies used to calculate costs, particularly non-market costs such as the costs of accident injuries and deaths, and environmental damages.
- How possible double-counting is addressed, such as whether taxes are counted as costs or economic transfers, and whether congestion costs are summed with travel time costs.
- Geographic scope and time period evalauted, and the inflation indecies and exchange rates used to convert values to a common monetaory unit.[1]

[1] Unless otherwise noted, in this document other currencies are converted in the base year to US dollars and then adjustments for inflation are done by consumer price index (CPI). The source for both currency conversion factors and CPI adjustment factors is Samuel H. Williamson (2008) MeasuringWorth www.measuringworth.com. For a discussion of the significant variation possible using different methods see Lawrence H. Officer and Samuel H. Williamson (2007), *Measures of Worth. 2007*; at www.measuringworth.com/worthmeasures.html.

- Driving conditions, such as whether the costs represent urban-peak, total urban, rural or overall average driving conditions.
- Differences in measurement units, such as between miles and kilometers, and between vehicle miles and passenger miles.
- The types of vehicles considered, such as whether cost estimates are for cars, automobiles, the fleet of personal vehicles, total roadway vehicles (including freight vehicles) or total motor vehicles (including train, air and marine vehicles).
- Whether cost estimates are point values or ranges.

2.2 General Cost Studies

Cost Estimates Summary Table

The table below identifies which costs are described or estimated in each report.

Table 2.2-1 **Transport Costs in Current Literature** (D = Described; Q = Quantified/Monetized)

Study No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	35	36	37	38	39	40	41	42	43	44
Cost Categories	Keeler 1975	Hanson 1992	Mac Kenzie 1992	Kågeson 1993	KPMG 1993	Works N.Z. 1993	Miller & Moffet 1993	Apogee, CLF 1994	US DOT, FRA 1993	CEC 1994	EPA, Aust. 1994	OTA 1994	Poorman CDTC 1995	Lee 1995	IBI 1995	Black et al. 1996	Maddison et al. 1996	IIEC 1997	Delucchi 1996	FHWA 1997 & 2000	DS & JF (TRB) 1997	Elwanger 2000	INFRAS 2000 / 2004	Sansom, et al 2001	Quinet 2004	NZMOT 2005	Tran. Canada 2003 / 05	CE 2004	Auckland 2006	CE Delft 2019	Land Trans. NZ 2006	Clark and Prentice 2009	Smith, Veryard & Kilvington	COWI, 2009	Becker, Becker & Gerlach 2012	Ricardo-AEA, 2014	Sen, Tiwari and Vrajaindra	Santos, et al. 2010	ATAP, 2018	Gössling, et al. 2018	Wijngaarden, e ta. 2019	ICF 2021
Vehicle Costs	Q			D	Q		Q	Q				Q	Q		Q	Q		Q	Q		Q			Q	Q	Q	Q		Q		Q		Q	Q					Q	Q		Q
Travel Time	Q			D	Q			Q				Q	Q			Q		Q	Q							Q	Q					Q	Q						Q			
Accidents	Q	D	Q	Q	Q		Q	Q	D	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	D	Q	Q	Q	Q	Q	D	Q	Q	Q	Q
Parking	Q	D	Q		Q		Q	Q				Q	Q	Q	Q	Q		Q	Q		Q					Q		Q	Q		D	Q							Q		Q
Congestion	Q	D	Q	D	Q		Q	Q	D	Q	Q	Q	Q		Q	D	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	D	Q	Q		Q	Q	D	Q	Q	Q	Q
Facilities	Q	D	Q	Q	Q		Q	Q		Q		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q			Q	Q	Q	Q	Q	Q		D	Q					D		Q	Q	Q
Roadway Land	Q	D	D		Q		D	Q				Q	Q	Q		D		Q	Q						Q	Q	Q	Q													Q
Mun. Services	Q	D	Q	D	Q		Q	Q		Q		Q	Q	Q	Q	D		Q	Q		Q			Q		Q		Q			D	D				Q				Q		Q
Local Air Pollution	Q	D	Q	Q	Q	D	Q	Q	D	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	D	Q	Q	Q	Q		D	Q	Q	Q	Q
Global Air Pollution		D	Q	Q		D	Q	Q	D	Q		Q	Q		Q	D	Q	Q	Q			Q	Q	Q	Q	Q	Q	Q	Q	Q	D	Q	Q	Q	Q		D	Q	Q	Q	Q
Noise &Vibration	Q	D	Q	Q	Q	D	Q	Q	D		Q	Q	Q	Q		D	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	D	Q	Q		Q	Q			Q	Q	
Resources/Energy		D	Q		Q	D	Q	Q	D	Q		Q	Q	Q		D		D	Q		Q		Q		Q					Q	D	Q			Q		D		Q	Q	
Barrier Effect		D		D		D							Q			D	D														D	D									
Land Use/Sprawl				D	Q	D	D	D					Q			D		D	D			Q	Q	Q					D	Q		D			Q				Q	Q	Q	
Inequity							D						Q			D		D	D																						
Water		D		D	Q	D	Q	Q	D	Q		Q	Q	Q		D		D	Q		Q	Q								D											
Waste Disposal						D						Q	Q	Q		D		D	Q		Q																				
Activity Benefits																														Q	D	Q	Q							Q		

This table indicates which costs are described (D) or quantified (Q) in the various studies summarized below.

Studies

This section describes specific transportation cost studies.

1. Keeler, et al (1975), *The Full Costs of Urban Transport; Intermodal Comparisons*, Institute of Urban and Regional Development (Berkeley).
This report compares commuting costs of automobile, bus and rail in the San Francisco Bay area. It includes marginal congestion costs, public services, noise, air pollution, facilities, accidents, parking, and user costs. This is the oldest study of its type. The analysis is still highly regarded.

2. Mark Hanson (1992), Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use, U.S. Federal Highway Administration.
This report identifies external costs of urban roadway transport and describes costing methods. It also includes recommendations for better calculating external costs, incorporating costs into user prices, and applying least-cost planning to transportation.

3. James MacKenzie, Roger Dower, and Donald Chen (1992), *The Going Rate,* World Resources Institute (Washington DC; www.wri.org); at http://pdf.wri.org/goingrate_bw.pdf
This is a comprehensive study of U.S. motor vehicle costs. Cost categories include roadway facilities and services, parking, air pollution, oil import costs, congestion, traffic accidents, noise, and land loss. Concludes that driving incurs $300 billion annually in external costs.

4. Per Kågeson (1993), *Getting the Prices Right; A European Scheme for Making Transport Pay its True Costs*, European Federation for Transport and Environment (www.transportenvironment.org)
This study estimates pollution, crash and infrastructure costs in European countries. Cost summaries for the UK are shown in Table 2-1. Similar estimates are made for other countries.

Table 2.2-2 **External Transport Costs** (ECU/1000 passenger km)

Mode	Air Pollution	CO_2	Noise	Accidents	Total	Total ($/mile)
Car	14.6	4.5	0.9	8.9	28.9	$0.060
Electric train	0.9	2.2	0.2	3.8	7.1	$0.015
Aircraft	7.3	9.2	1.2	0.2	17.9	$0.037

5. KPMG (1993), *The Cost of Transporting People in the British Columbia Lower Mainland*, Transport 2021/Greater Vancouver Regional District (www.gvrd.bc.ca). This study develops cost estimates for 12 modes using local research and generic estimates. Costs are listed in Table 2.2-3.

Table 2.2-3 **Costs of Transporting People in B.C. Costs**

Direct User	Indirect Parking	Transport Infrastructure	Time	Urban Sprawl	Environmental and Social
Fixed vehicle costs		Road construction		Infrastructure	Unaccounted accident costs
Variable vehicle costs	Residential	Road maintenance	Personal	Loss of open space	Air pollution
Parking fees	Commercial	Road land value	Commercial	Future transport	Noise pollution
	Government	Transit land value	delays		Water pollution
		Protection services			

6. Works Consultancy (1993), *Land Transport Externalities*, Transit New Zealand (Wellington).
This comprehensive study is part of New Zealand's efforts to rationalize transport planning. It attempts to describe all external costs of road transport, and identify costing methodologies. Cost categories are shown in Table 2.2-4.

Table 2.2-4 **Works Consultancy Cost Categories**

Pollution Effects	Intrusion Effects	Interference Effects	Land Use
Air Pollution & Dust	Visual Effects	Community Disruption	
Impacts on the Global Atmosphere	Habitat impacts	Urban and Rural Blight and Stress of Change	
Effects on Water Systems	Effects on Landscape	Lighting Effects	
Noise & Vibration	Archaeological Sites	Community Severance and Accessibility	
Disposal of Waste	Cultural & Spiritual Effects	Hazard Effects	
	Recreational Effects		
	Strategic Effects		

7. Peter Miller and John Moffet (1993), *The Price of Mobility*, Natural Resources Defense Council (www.nrdc.org).
This study attempted to quantify total costs for automobiles, buses, and rail transport in the U.S. It is one of the most comprehensive efforts in terms of costs described and quantified. Costs included are listed in the table below.

Table 2.2-5 **The Full Cost of Transportation in the U.S.A.**

Personal	Gov. Subsidies	Societal	Unquantified
		Energy	
		Congestion	
		Parking	Wetland lost
		Accidents	Farmland lost
		Noise	Historic property
		Vibration	Property value impacts
Automobile ownership	Capital and operating	Air pollution	Inequity
Transit fares	Local government	Water pollution	Sprawl

8. Apogee Research (1994), *The Costs of Transportation*, Conservation Law Foundation (www.clf.org).
This study estimates user, accident, congestion, parking, road facilities and services, air pollution, water pollution, energy, and noise costs. Urban sprawl and aesthetic degradation are mentioned but not estimated. A costing model is developed which calculates the total cost of trips by nine modes, in three levels of urban density, during peak and off-peak periods. This model is applied to case studies of Boston and Portland, Maine urban travel costs.

9. FRA (1993), *Environmental Externalities and Social Costs of Transportation Systems - Measurement, Mitigation and Costing*, Federal Railroad Administration, Office of Policy (Washington DC).
This study describes various motor vehicle social costs. It includes two charts that describe a taxonomy of costs and mitigation strategies, summarized in Table 2.2-6.

Table 2.2-6 **Federal Railroad Administration Costs**

Social Costs				
Land Use	Community Disruption	Energy	Safety	Congestion
Direct land use for facilities Alters land use patterns (sprawl)	Divides community Impacts local government Visual pollution Relocation impacts	Oil spills Air pollution Political instability from foreign oil Oil price fluctuations affecting world economy	Accidents cause death, injuries, insurance and legal costs, lost productivity, medical costs, emotional losses, congestion.	Wasted time Wasted fuel Added pollution Lost productivity Vehicle repair and insurance costs Stress Land use impacts
Environmental Costs				
Air	Noise	Water	Electromagnetic Fields	Hazardous Materials
Carbon Monoxide VOCs SO^2 NOx CO^2 Air Toxics Particulates CFCs Odor	Construction/ repair Night operations Engines Wheels/tires Congestion Braking/acceleration Idling Whistles	Air pollution fallout Fuel releases and spills Construction/ maintenance De-icing Runoff from roads and parking lots	(Cost of electric vehicles) Possible biological hazard Possible hazard to migrating birds Problems to electronic equipment	Accidental releases Intentional releases

10. CEC (1994), *California Transportation Energy Analysis Report*, California Energy Commission (www.energy.ca.gov).
This report attempted to "*fully evaluate the economic and environmental costs of petroleum use, and the economic and environmental costs of other transportation fuels, including the costs and values of environmental externalities, and to establish a state transportation energy policy that results in the least environmental and economic cost to the state."* Includes congestion, accidents, infrastructure maintenance, services, air pollution (including global warming), petroleum spills, and energy security costs. These are monetized (per vehicle mile or gasoline equivalent gallon), and presented as a point value or range.

11. EPA (1994), "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, Environment Protection Authority (Melbourne, Australia).
This report discusses external cost implications, costing methods, and estimates some costs.

12. OTA (1994), *Saving Energy In US Transportation*, Office of Technology Assessment (Washington DC); at www.fas.org/ota/reports/9432.pdf.
This report provides a comprehensive analysis of transportation costs and their economic and environmental impacts. Discusses various policy options for improving energy efficiency.

13. John Poorman (1995), *Estimating Marginal Monetary Costs of Travel in the Capital District*, Capital District Transportation Committee (Albany).
This report describes a Least Cost framework and model, with performance measures and monetized costs for evaluating transport investments and policies, and comparing various modes.

14. Douglas Lee (1995), *Full Cost Pricing of Highways*, USDOT Volpe National Transportation Systems Center (www.volpe.dot.gov).
This study analyzes efficient road pricing. Table 2.2-7 summarizes its external costs.

Table 2.2-7 **Estimates of Highway Costs Not Recovered From Users** ($1,000/yr)

Cost Group	Cost Items	Estimate
Highway Capital	Land (interest)	$74,705
	Construction:	
	Capital Expenditures	42,461
	Interest	26,255
	Land acquisition and clearance	
	Relocation of prior uses and residents	
	Neighborhood Disruption	
	Removal of wetlands, acquirer recharge	
	Uncontrolled construction noise, dust and runoff	
	Heat island effect	
Highway Maintenance	Pavement, ROW, and structure maintenance	20,420
Administration	Administration and research	6,876
	Traffic police	7,756
Parking	Commuting	52,877
	Shopping, recreation, services	14,890
	Environmental degradation	
Vehicle Ownership	Disposal of scrapped or abandoned vehicles	706
Vehicle Operation	Pollution from tires	3,000
	Pollution from used oil and lubricants	408
	Pollution from toxic materials	1
Fuel and Oil	Strategic Petroleum Reserve	4,365
	Tax subsidies to production	9,000
Accidental Loss	Government compensation for natural disaster	
	Public medical costs	8,535
	Uncompensated losses	5,850
Pollution	Air	43,444
	Water	10,861
	Noise and vibration	6,443
	Noise barriers	5,117
Social Overhead	Local fuel sales tax exemptions	4,302
	Federal gasohol exemption	1,129
	Federal corporate income tax	3,389
	State government sales taxes	13,218
	Local government property taxes	15,962
	Total	$382,134
	Current User Revenues	52,096
	Loss	330,037
	cents/VMT	$0.152

15. IBI Group (1995), *Full Cost Transportation Pricing Study*, Transportation and Climate Change Collaborative (Toronto).
This study estimates costs for truck, rail, automobile, public transit and air travel in Ontario, Canada. Reviews cost estimates from previous studies. Costs are divided into user charges, external costs, and "basic subsidies" (government costs minus revenues). This is used to evaluate potential measures to encourage sustainable transport.

16. William Black, Dean Munn, Richard Black and Jirong Xie (1996), *Modal Choices: An Approach to Comparing the Costs of Transportation Alternatives*, Transportation Research Center, Indiana University (Bloomington).
The report and ALTERNAT software provide a framework for comparing highway, bus and rail projects. Costs are listed in Table 2.2-8. Estimates are based on previous published research.

Table 2.2-8 Costs Recognized In *Modal Choices* Model

- Accident costs not covered by insurance.
- Capital costs not covered through transport taxes.
- Operating costs of vehicles.
- Parking costs (fines and fees only)
- Air pollution costs
- Rehabilitation costs
- Value of time (personal and commercial)

17. David Maddison, David Pearce, Olof Johansson, Edward Calthrop, Todd Litman, and Eric Verhoef (1996), *The True Costs of Road Transport*, Blueprint #5, Earthscan (London).
This book discusses the economic efficiency and equity implications of roadway transport externalities. Develops estimates of external costs in the U.K., including air pollution, noise, congestion, roadway facility costs, and accident costs. Also includes individual chapters on roadway externalities in Sweden, North America, The Netherlands, and international estimates.

18. Christopher Zegras with Todd Litman (1997), *An Analysis of the Full Costs and Impacts of Transportation in Santiago de Chile*, International Institute for Energy Conservation (www.iiec.org); at http://web.mit.edu/czegras/www/Santiago%20Full%20Cost%20Study.pdf.
This is one of the first comprehensive transport cost studies in the developing world. Includes vehicle, roadway, parking, congestion, crash, and environmental costs. Although automobile ownership is relatively low compared with developed countries, rapid (10% annual) growth in vehicle ownership imposes considerable medium-term costs in terms of increased congestion, facility needs, pollution, etc. Because Chile imports most vehicles and fuel, increased automobility also imposes macroeconomic costs by capturing a major portion of foreign exchange and potential investment funds.

19. Mark Delucchi (1996), *Annualized Social Cost of Motor Vehicle Use in the United States, Based on 1990-1991 Data*, University of California at Davis (www.its.ucdavis.edu), 1996-97; summarized in "Total Cost of Motor-Vehicle Use," *Access* (www.uctc.net), No. 8, Spring 1996, pp. 7-13, and updated in *The Social-Cost Calculator (SCC): Documentation of Methods and Data, and Case Study of Sacramento*, UCD-ITS-RR-05-37 at www.its.ucdavis.edu/publications/2005/UCD-ITS-RR-05-18.pdf.
This series of 20 comprehensive reports attempts to identify, categorize and estimate total U.S. motor vehicle costs. Table 2.2-9 summarizes ranges of major cost categories.

Table 2.2-9 **Delucchi's Estimates of Motor Vehicle Costs**

Cost Item	Examples	Per Veh. Year	Per Veh. Mile
Personal nonmonetary costs of using motor vehicles	Motorist personal travel time and accident pain and suffering.	$2,180-3,189	17.4-25.5¢
Private-sector motor-vehicle goods and services	Vehicle expenses, paid travel time.	$5,020-5,659	40.2-45.3¢
Bundled private sector costs	Parking subsidized by businesses.	$337-1,181	2.7-9.4¢
Public infrastructure and services	Public roads, parking subsidized by local governments.	$662-1,099	5.3-8.8¢
Monetary externalities	External accident damages, congestion.	$423-780	3.4-6.2¢
Nonmonetary externalities	Environmental damages, crash pain.	$1,305-3,145	10.4-25.2¢
Total		*$9,927-15,053*	*$0.79-1.20*

20. FHWA (1997 and 2000), *1997 Federal Highway Cost Allocation Study Final Report* (and *Addendum*), Federal Highway Administration (www.fhwa.dot.gov); at www.fhwa.dot.gov/policy/otps/costallocation.cfm. This report is concerned with whether various motor vehicle categories (automobiles, light trucks, and various types of heavy vehicles) are charged according to the costs they impose on the highway system. Focuses on Federal user fees and federal highway payments, but also includes costs for total roadway expenditures, plus costs of congestion, crashes, air pollution and noise (based mainly on Delucchi's estimates). Table 2.2-10 summarizes these costs.

Table 2.2-10 **Vehicle Costs Under Various Conditions** (1997 cents per mile)

Vehicle/Highway	Pavement	Congestion	Crashes	Air Pol.	Noise	Total
Autos/Rural Interstate	0	0.78	0.98	1.14	0.01	2.91
Autos/Urban Interstate	0.1	7.70	1.19	1.33	0.09	10.41
40 kip 4-axle SU Truck/Rural Int.	1.0	2.45	0.47	3.85	0.09	7.86
40 kip 4-axle SU Truck/Urban Int.	3.1	24.48	0.86	4.49	1.50	34.43
60 kip 4-axle SU Truck/Rural Int.	5.6	3.27	0.47	3.85	0.11	13.30
60 kip 4-axle SU Truck/Urban Int.	18.1	32.64	0.86	4.49	1.68	57.77
60 kip 5-axle Comb/Rural Int.	3.3	1.88	0.88	3.85	0.17	10.08
60 kip 5-axle Comb/Urban Int.	10.5	18.39	1.15	4.49	2.75	37.28
80 kip 5-axle Comb/Rural Int.	12.7	2.23	0.88	3.85	0.19	19.85
80 kip 5-axle Comb/Urban Int.	40.9	20.06	1.15	4.49	3.04	69.64

SU = Single Unit; Comb. = Combination

21. Patrick Decorla-Souza and Ronald Jensen-Fisher (1997), "Comparing Multimodal Alternatives in Major Travel Corridors," *Transportation Research Record 1429*, TRB (www.trb.org), pp. 15-23.
Table 2.2-11 summarizes the various costs for comparing investment alternatives.

Table 2.2-11 **Examples of Unit Costs**

Cost Item	Automobile	Bus	Rail
Vehicle Operation	7.4 cents/VMT	$1.50-3.00/Trip	$4.25/Trip
Vehicle Ownership	$3.12/Trip		
Parking, Downtown	$3.00		
Parking, Other	$1.00		
Highway Operations	1.8 cents/VMT	2.9 cents/VMT	
Added Highway Capacity	62¢/Peak-VMT	99¢/Peak-VMT	
Public Services	1.1 cent/VMT	1.1 cent/VMT	0.22 cents/VMT
Accident (Market)	4.2 cents/VMT	8.4 cents/VMT	1.68 cents/VMT
Accidents (Nonmarket)	7.8 cents/VMT	15.6 cents/VMT	3.12 cents/VMT
Air Pollution	2.4 cents/VMT		
Water Pollution	0.2 cents/VMT		
Noise	0.16 cents/VMT		
Solid/Chemical Waste	0.2 cents/VMT		
Oil Extraction	1.5 cents/VMT		

22. Gunther Ellwanger (2000), "External Environmental Costs of Transport - Comparison of Recent Studies," *Social Costs and Sustainable Mobility*, ZEW, Physica-Verlag, pp. 15-20.
These paper provides estimates of external costs for Car, Bus, Rail, Air and Water-way transport (passenger and freight) based on four previous European studies, as summarized in Table 2.2-12.

Table 2-11 **External Costs of Transport in Western Europe**

	Passenger (ECU/1,000 Pkm)		Freight (ECU/1,000 Tkm)	
	Road	*Rail*	*Road*	*Rail*
IWW/INFRAS	50.1	10.0	58.4	7.3
ECMT, 1996	50-65	10-19	18-30	4-7.5
ECMT, 1998	49	12	62	9
EU-Greenbook	35.5	8.0	33.2	5.3
ZEW-QUITS	44.3	4.9	30.6	2.8

23 Silvia Banfi, et al (2000), *External Costs of Transport: Accident, Environmental and Congestion Costs in Western Europe*, INFRAS (www.infras.ch) and IWW (www.infras.ch).
This study develops accident, noise, air pollution, climate change, other environmental effects, and congestion costs for four modes (road, rail, air and water transport) in 17 European countries for 1995 and 2010. It calculates total and marginal costs for each country. Marginal costs are intended for pricing. An updated version was published in 2004 by the Community of European Railway and Infrastructure Companies and the International Union of Railways. It concluded that in 2000, external costs for all modes combined totaled 650 billion euro, or 7.3 % of European GDP, up 12% since 1995, indicating am increase in the economic and social burden. The direct causes of this increase are traffic volume growth, especially in road and air transport, and incresed pollution costs. Road transport accounts for 84% of external costs, followed by air transport with 14%. Rail is responsible for 1.9 % of these costs, and waterways, 0.4 %.

24. Tom Sansom, C. A. Nash, Peter J Mackie, J. D. Shires and S. M. Grant-Muller (2001), *Surface Transport Costs and Charges*, Institute for Transport Studies, University of Leeds (www.its.leeds.ac.uk/projects/STCC/surface_transport.html), for the UK DETR.
This study compares the social costs of road and rail transport with current user charges. UK roadway costs are estimated for 1998 on two different bases - marginal costs associated with an additional vehicle km, and fully allocated costs. The resultant analysis framework and empirical results are intended to inform policy making in the areas of charging, taxation and subsidies. The analysis includes infrastructure, vehicle, congestion, crash, and pollution costs. Estimates that automobile use generally covers costs, but underprices with respect to marginal costs.

Table 2.2-13 **UK Road Costs and Revenues** (1998 UK Pence Per Veh-Km)

	Fully Allocated Costs		Marginal Costs	
	High	Low	High	Low
Costs				
Infrastructure capital costs	0.78	1.34	n/a	n/a
Infrastructure operating costs and depreciation	0.75	0.97	0.42	0.54
Vehicle operating costs	0.87	0.87	0.87	0.87
Congestion	n/a	n/a	9.71	11.16
Mohring effect (public transit vehicle only)	n/a	n/a	-0.16	-0.16
External accident costs	0.06	0.78	0.82	1.40
Air pollution	0.34	1.70	0.34	1.70
Noise	0.24	0.78	0.02	0.78
Climate change	0.15	0.62	0.15	0.62
VAT not paid	0.15	0.15	0.15	0.15
Cost subtotal	*3.34*	*7.20*	*12.32*	*17.05*
Revenues				
Fares (public transit vehicles only)	0.84	0.84	0.84	0.84
Vehicle excise duty	1.10	1.10	0.14	0.14
Fuel duty	4.42	4.42	4.42	4.42
VAT on fuel duty	0.77	0.77	0.77	0.77
Subtotal of revenues	*7.14*	*7.14*	*6.17*	*6.17*
Difference (costs-revenues)	*-3.79*	*0.07*	*6.15*	*10.88*
Ratio (revenues/costs)	*2.13*	*0.99*	*0.50*	*0.36*

This table summarizes estimated costs and revenue of UK road transport using two perspectives, full allocation (i.e., total costs allocated to users) and marginal (incremental costs).

25. Emile Quinet (2004), "Meta-Analysis Of Western European External Cost Estimates," *Transportation Research D*, Vol. 9 (www.elsevier.com/locate/trd), Nov. 2004, pp. 465-476.
This study compares results of 14 transportation cost studies performed in Western Europe from 1998-2003 (one from 1991). It analyzes their methodologies and compares their results using regression analysis. It finds that external cost estimates vary significantly, but these differences can be explained by differences in they types of costs and conditions evaluated, and that issues of scientific uncertainty are a smaller contribution of variation. It concludes that, when properly applied, cost studies can provide justifiable values that are useful for economic analysis.

26. NZMOT (2005), *Surface Transport Costs and Charges: Summary of Main Findings and Issues*, New Zealand Ministry of Transport (www.transport.govt.nz).
This study analyzes the full costs of road and rail travel in New Zealand, both passenger and freight, including internal costs (vehicle, travel time and internal accident risk), and external costs (road and rail infrastructure, accident externalities, environmental externalities and resource opportunity costs such as land value). The table below summarizes estimates of external costs. It estimates that cars directly pay 64% of their costs, trucks directly pay 56% of their costs and buses directly pay 68% of their costs. Long-distance truck transport imposes external costs of 2.9¢ to 3.4¢ per tonne-kilometer, compared with 0.1¢ to 0.8¢ for rail.

Table 2.2-14 Total Road System External Costs (Million NZ$, 2001-02)

Cost	Best Estimate	Minimum	Maximum
Road system operation	$770	$750	$850
Road system maintenance	$380	$380	$380
Road system assets (roadway land value)	$750	$300	$980
Accident externalities	$670	$330	$1,340
Environmental impacts	$1,170	$600	$2,400
Totals	*$3,740*	*$2,360*	*$5,950*

27. Transport Canada (2003-2007), *Investigation of the Full Costs of Transportation: A Discussion Paper* & documents covering transmodal, road, rail and other subjects. Economic Analysis Policy Group, Transport Canada (www.tc.gc.ca/eng/policy/aca-fci-menu.htm). Technical analysis discussed in Anming Zhang, Anthony E. Boardman, David Gillen and W.G. Waters II (2005), *Towards Estimating the Social and Environmental Costs of Transportation in Canada*, Centre for Transportation Studies, University of Britsh Columbia (www.sauder.ubc.ca/cts); at www.bv.transports.gouv.qc.ca/mono/0965490.pdf.
This three-year project investigates the full costs of transportation, including comprehensive financial and social costs (accidents, noise, congestion delays and environmental damages) associated with infrastructures, services, vehicles, and with the movement of people and goods.

28. CE (Vermeulen, et al) (2004), *The Price of Transport: Overview of the Social Costs of Transport*, CE Delft; van Essen, et al (2004), *Marginal Costs of Infrastructure Use – Towards a Simplified Approach*, CE Delft (www.ce.nl); at www.ce.nl/?go=home.downloadPub&id=456&file=04_4597_15.pdf.
These related studies analyze the social costs of various transport modes, including road and rail transport (both passenger and freight) and inland shipping (freight only), in The Netherlands. It discusses cost categories, the magnitude of these costs, the share of the costs borne directly by user groups, and the extent to which existing pricing is efficient.

29. Astrid Jakob, John L. Craig and Gavin Fisher (2006), "Transport Cost Analysis: A Case Study of the Total Costs of Private and Public Transport in Auckland," *Environmental Science & Policy*, Vol. 9 (www.sciencedirect.com), pp. 55-66.
This study assesses the external (unpaid) and internal (user paid) cost of transport. It focuses on estimating the total cost of both private and public transport, using a case study for Auckland, New Zealand's largest city. The external costs (primarily external accident costs, air pollution, and climate change) are significant, 2.23% of regional GDP. Of this private transport generated 28 times more external cost than public transport. The internal cost assessment showed that total revenues collected did not even cover 50% of total transport cost. The study concludes that current pricing results in economically excessive motor vehicle travel.

30. CE Delft (2019), *Handbook on Estimation of External Cost in the Transport Sector,* European Comission; at https://cedelft.eu/publications/handbook-on-the-external-costs-of-transport-version-2019.
This study provides a comprehensive overview of approaches for estimating external transport costs for policy and pricing analysis. It provides best available input values for such calculation (e.g. value of one life year lost), and default unit values of external cost for different traffic situations (e.g. air pollution cost of a vehicle in Euro per kilometre).

31. NZTA (2020), *Monetized Benefits and Costs Manual*, Waka Kotahi NZ Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual.
Land Transport NZ's *Land Transport Benefits Framework and Management Approach: Guidelines* defines standard practices for the economic evaluation of transport infrastructure projects and transportation demand management strategies. It includes impacts on health and safety, noise and air pollution emissions, congestion productivity and reliability, user experience, and regional economic development.

32. Harry Clarke and David Prentice (2009), *A Conceptual Framework For The Reform Of Taxes Related To Roads And Transport*, School of Economics and Finance, La Trobe University, for the Australia Treasury *Australia's Future Tax System* review; at http://apo.org.au/research/conceptual-framework-reform-taxes-related-roads-and-transport.
This report evalutes transportation pricing efficiency in Australia. It discusses various economic principles related to efficient prices and taxes, estimates various transportation-related external costs (road and parking facilities, congestion, accidents, energy consumption and pollution), evaluates the efficiency of current pricing and taxes, and recommends various reforms to help achieve transportation planning objectives.

33. Sangjune Park (2009), "KRW 53 Trillion (5.4% of GDP), "Estimates of the External Costs of Transport in 2007," *KOTI World-Brief*, Vol. 1, No. 3, Korea Transport Institute (www.koti.re.kr), July 2009, pp. 8-10; at http://english.koti.re.kr/upload/eng_publication_regular/World-Brief03.pdf.
This study estimates that in South Korea during 2007, household expenditures on transportation totaled 11.4% of GDP, and external transportation costs (congestion delays, accident damages and pollution emissions) totaled 5.4% of GDP. The study compares Korea's transport costs with other countries, and indicates changes over time. Recommends using this information for policy analysis and pricing.

34. Swiss ARE (2005 and 2010), *External Cost of Transport In Switzerland*, Swiss Federal Office of Spatial Development (www.are.admin.ch); at www.are.admin.ch/are/en/home/transport-and-infrastructure/data/costs-and-benefits-of-transport.html.
This Swiss government sponsored research program estimates various transportation costs, including accidents, noise, building damages, environmental damages (air pollution, climate, natural and landscape damages) and traffic congestion. Table 2.2-16 summarizes the estimated costs for 2005. These estimates are based on accident statistics, pollutant or noise emissions and aerial photo analysis. The transport-related proportions were determined and converted into costs. Those costs not amenable to direct quantification were estimated using the so-called willingness-to-pay approach. The values and assumptions underlying the calculations are deliberately cautious. The adopted methods result in an understatement of the effective external transport costs. As a result, the figures presented reflect conservative estimates.

Table 2.2-15 **Swiss External Transportation Costs** (million CHF)

Cost	Road	Rail	Total

Accidents	2,017	30	2,047
Noise	1,101	74	1,174
Health	1,834	121	1,954
Building damage	274	15	289
Climate	1,256	7	1,264
Other environmental costs	906	98	1,004
Nature and landscape	687	110	797
Subtotal	*8,074*	*455*	*8,529*
Congestion	1,240	---	1,240
Total	***9,314***	***455***	***9,769***

35. TC (2008), *Estimates of the Full Cost of Transportation in Canada*, Economic Analysis Directorate of Transport Canada (www.tc.gc.ca); at https://publications.gc.ca/site/eng/9.691980/publication.html.
This report summarizes the results of Transport Canada's Full Cost Investigation (FCI) project, which included a number of studies concerning various transportation costs, including costs of vehicle ownership and operations, infrastructure ownership and operations (including land opportunity costs), congestion, accidents and environmental costs. Tables 2.2-16 and 2.2-17 summarize these estimates.

Table 2.2-16 **Financial Cost Estimates by Major Mode** (Billion 2000$CA)

Mode	Vehicle & Carrier	Infrastructure				Minus User Charges	Sector Total
		Capital	Operating	Land	Total		
Road	$128.57	$28.68	$4.91	$6.81	*$40.4*	$12.61	$156.35
Rail	$4.30	$2.92	$1.77	$0.26	*$4.95*	$0.17	$9.08
Marine	$1.91	$0.50	$0.53	$0.19	*$1.22*	$0.09	$3.04
Air	$15.16	$0.95	$1.37	$0.17	*$2.49*	$1.76	$15.89
Total	*$149.93*	*$33.06*	*$8.57*	*$7.43*	*$49.06*	*$14.63*	*$184.36*

This table summarizes estimated infrastructure and vehicle costs of various modes in Canada.

In addition, roadway transportation also imposes $29.59 billion in social costs. Other modes also impose uncompensated costs, which are smaller in total magnitude compared with roadway costs, but not necessarily smaller per passenger-mile or as a portion of user charges. The study analyzes these costs in various ways, including by activity (local passenger, intercity passenger and freight transport), by province and city, and per passenger-trip and passenger-km for various modes. The study also compared transportation costs as a portion of GDP between Canada and various other countries.

Table 2.2-16 **Social Cost Estimates by Major Mode** (Billion of 2000CA$)

Mode	Accidents	Congestion Delay	Air pollution	GHG	Noise	Total
Road	$15.78	$5.17	$4.73	$3.68	$0.22	$29.59
Rail	$0.30	Not covered	$0.44	$0.19	$0.00	$0.93
Marine	$0.06	Not covered	$0.54	$0.24	Not covered	$0.84
Air	$0.10	Not covered	$0.03	$0.47	$0.03	$0.64
Total	$16.24	$5.17	$5.74	$4.58	$0.26	$32.00

This table summarizes estimated non-market costs of various modes in Canada.

36. Nariida C. Smith, Daniel W. Veryard and Russell P. Kilvington (2009), *Relative Costs And Benefits Of Modal Transport Solutions*, Research Report 393, NZ Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/research/reports/393/docs/393.pdf.
This report describes the outcomes of a study commissioned by the NZ Transport Agency to inform local authorities about the costs and benefits of transport modes. The aim of the study has been to provide general advice on the relative cost and benefits of alternatives with a focus on passenger transport in urban areas. It explores the issues decision makers face in estimating costs, and sets out an approach to providing estimates. It provides estimates of various cost, including vehicle costs, infrastructure, operating, travel time, accident risk, health impacts, and pollution costs, which can then be applied to the number of vehicles and the distance they travel, so readers may tailor comparisons to their own situation. This quantitative exercise is supplemented by contextual discussion of some important issues in urban transport including drivers of the transport mix, the relationship between land use and transport planning, and road space and traffic management. A selection of case studies drawn from mainly New Zealand urban areas provides some specific illustrations of the issues raised.

36. COWI (2009), *Economic Evaluation of Cycle Projects - Methodology and Unit Prices*, *Samfundsøkonomiske Analyser Af Cykeltiltag - Metode Og Cases* and the accompanying note *Enhedsværdier for Cykeltrafik*, prepared by COWI for the City of Copenhagen (www.kk.dk/cyklernesby).
The City of Copenhagen has developed a standard cost-benefit analysis (CBA) methodology for evaluating cycle policies and projects, and applied that model in two case studies. Table 2.2-19 summarizes unit cost values used in the economic analysis. The unit costs for cars are from the Ministry of Transportation's official unit cost catalogue (Transportøkonomiske Enhedspriser). The external values for cars are reported for gasoline cars under urban off-peak conditions. In total, cycling is estimated to have net costs (costs minus health benefits) of 0.60 Danish Kroner per kilometer. Health benefits include reduced medical and disability costs valued at 1.11 Danish Kronor (DKK) to users and 2.91 DKK to society, plus 2.59 DKK worth of increased longevity. Car travel is estimated to have net costs (costs minus duties, which are large because Denmark has very high fuel taxes) of 3.74 Danish Kroner per kilometer. This would be even higher under urban-peak conditions due to higher congestion costs.

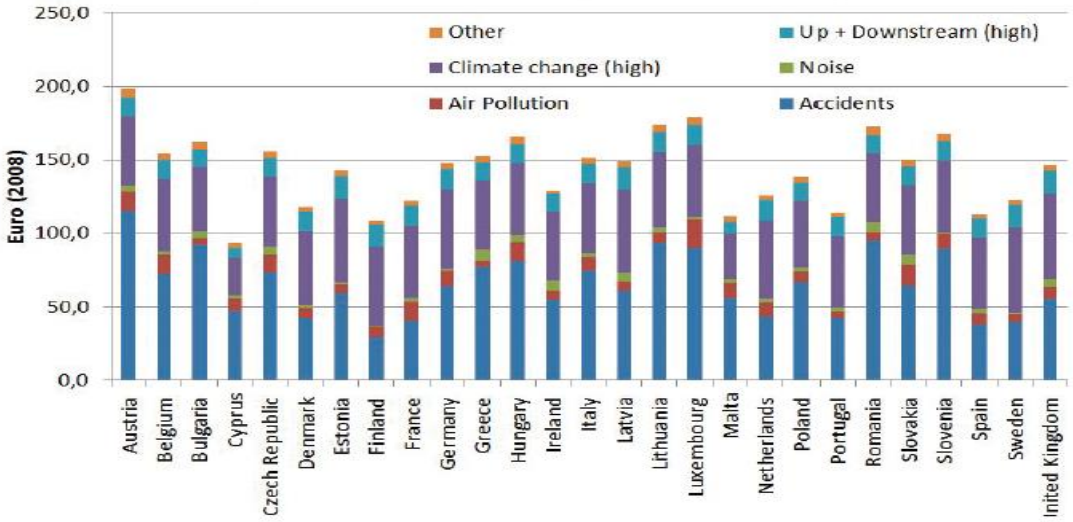
Table 2.2-18 **Average Costs Per Kilometre For Cycling (2008 Danish Kroner)**

	Cycling (16 km/h)			For Reference: Car (50 km/h) in city			
	Internal	External	Total	Internal	External	Duties	Total
Time costs (non-work)	5.00	0	5.00	1.60	0	0	1.60
Vehicle operating costs	0.33	0	0	2.20	0	-1.18	2.20
Prolonged life	-2.66	0.06	-2.59	0	0	0	0
Health	-1.11	-1.80	-2.91	0	0	0	0
Accidents	0.25	0.54	0.78	0	0.22		0.22
Perceived safety	+ (?)		+ (?)	?	?	?	?
Discomfort	?	0	?	?	?	0	?
Branding/tourism	0	-0.02	-0.02	?	?	0	?
Air pollution	0	0	0	0	0.03	0	0.03
Climate changes	0	0	0	0	0.04	0	0.04
Noise	0	0	0	0	0.36	0	0.36
Road deterioration	0	0	0	0	0.01	0	0.01
Traffic congestion	0	0	0	0	0.46	0	0.46
Total	*1.81*	*-1.22*	*0.60*	*3.80*	*1.13*	*-1.18*	*3.74*

This table summarizes unit cost values used for economic evaluation of cycling projects.

37. Ing. Udo J. Becker, Thilo Becker and Julia Gerlach (2012), *The True Costs of Automobility: External Costs of Cars Overview on Existing Estimates in EU-27*, TU Dresden (http://tu-dresden.de/en); at www.greens-efa.eu/fileadmin/dam/Documents/Studies/Costs_of_cars/The_true_costs_of_cars_EN.pdf.
This report estimates the external costs of automobile travel, including accidents, noise, air pollution and climate change emissions. It concludes that motor vehicle travel imposes significant net external costs, beyond user charges and taxes.

Figure 2.2-1 **Average External Costs From Cars Per 1,000 Vkm By Country**



38. **Ricardo-AEA (2014)**, *Update of the Handbook on External Costs of Transport Final Report*, European Commission (http://ec.europa.eu); at http://ec.europa.eu/transport/themes/sustainable/studies/doc/2014-handbook-external-costs-transport.pdf.
This European Commission study provides a comprehensive overview of approaches for estimating transport external costs and recommends a set of methods and default values for use when conceiving and implementing transport pricing policy and schemes. It coveres external environmental, accident and congestion costs for various motorized transport modes. The focus was on the marginal external costs of transport activity as a basis for the definition of internalisation policies such as efficient pricing schemes. It updates research by Maibach et al., (2008) as an output of the IMPACT study.

39. **Akshaya Kumar Sen, Geetam Tiwari and Vrajaindra Upadhyay (2010)**, "Estimating Marginal External Costs of Transport in Delhi," *Transport Policy*, Vol. 17, pp. 27–37; at www.vref.se/download/18.6a462c7912efb9dc85f80004555/2010+Sen.pdf.
This article developed a model and methodology for estimating the marginal external cost of congestion, air pollution, road accidents and noise for automobiles and buses operating in Delhi, India. This is one of the few studies of transport external costs in developing countries.

Table 2.2-19 **Marginal External Costs in Delhi, India** (Sen, Tiwari and Upadhyay 2010)

Vehicle Type	Congestion	Air Pollution	Accidents	Noise	Total	Total
	(Rs./km)					(US$/km)
Petrol Car						
Peak small	4.91	0.28	0.067	0.05	5.307	0.118
Peak large	4.91	0.31	0.067	0.05	5.337	0.119
Off-peak small	0.32	0.27	0.067	0.13	0.787	0.017
Off-peak big	0.32	0.30	0.067	0.13	0.817	0.018
Diesel Car						
Peak small	4.913	1.674	0.067	0.05	6.704	0.149
Peak large	4.913	2.736	0.067	0.05	7.766	0.173
Off-peak small	0.316	1.030	0.067	0.13	1.543	0.034
Off-peak big	0.316	1.665	0.067	0.13	2.178	0.048
Bus						
Peak	9.826	14.140	1.771	0.49	26.227	0.583
Off-peak	0.632	9.106	1.771	1.28	12.788	0.284

This table summarizes various estimated external costs for motor vehicles operating in Delhi, India.

40. ATAP (2017), *Australian Transport Assessment and Planning Guidelines*, ATAP Steering Committee Secretariat (https://atap.gov.au) Australia Department of Infrastructure and Regional Development.
The Australian Transport Assessment and Planning (ATAP) Guidelines provide a comprehensive framework for planning, assessing and developing transport systems for varius modes and strategies including Travel Demand Modelling, Cost Benefit Analysis, Wider Economic Benefits, Productivity Metrics, Distributional (Equity) Effects, and Benefit Management. Economic impacts include vehicle operation, travel time values, crash costs, health impacts, and environmental impacts.

41. Georgina Santos, et al. (2010), "Externalities and Economic Policies in Road Transport," *Research in Transportation Economics*, Vo. 28, pp. 2–45 (doi.org/10.1016/j.retrec.2009.11.002); at https://bit.ly/2yUimuN.
This study reviews various transport external costs (accidents, road damage, environmental damage, congestion and oil dependence) and compares the effectiveness of various policies (regulations and pricing reforms) to reduce the resulting inefficiencies.

42. Stefan Gössling, et al. (2018), "The Social Cost of Automobility, Cycling and Walking in the European Union," *Ecological Economics*, Vol. 158, pp. 65-74 (https://doi.org/10.1016/j.ecolecon.2018.12.016); at https://bit.ly/2SD9IPw.
Calculates external and private costs of automobility, cycling and walking in the European Union. Results indicate car travel external costs average €0.11 per kilometer, while cycling and walking provide €0.18 and €0.37 per kilometer benefits. Extrapolated to the total number of passenger kilometers driven, cycled or walked in the European Union, the cost of automobility is about €500 billion per year. Due to positive health effects, cycling is an external benefit worth €24 billion/year and walking €66 billion/year. Recommends expanding CBA frameworks to better include the full range of externalities.

43. Lisanne van Wijngaarden, et al. (2019), *Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities*, European Commission, Directorate-General for Mobility and Transport (https://data.europa.eu/doi/10.2832/246834). Conference papers at https://fsr.eui.eu/event/5th-florence-intermodal-forum-internalising-the-external-costs-of-transport.
This report presents the main findings of the project 'Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities'. The aim of this project was to assess to what extent EU Member States and selected other countries (i.e. Norway, Switzerland, United States, Canada and

Japan) have implemented the 'user-pays' and the 'polluter-pays' principles. As input for this analysis, the infrastructure and external costs of all main transport modes (i.e. road, rail, inland navigation, maritime transport and aviation) were estimated and a comprehensive overview of transport taxes and charges applied in the various countries was made. The results show that external and infrastructure costs of transport in the EU28 are only partly internalised. For most transport modes, only 15 to 25% of these costs are covered by revenues from current transport taxes and charges. There is also little evidence that marginal social cost pricing principles are applied on a large scale. Finally, for most transport modes (except maritime transport and aviation) the infrastructure costs are not covered by infrastructure charges, reflecting that the 'users-pays' principle is often not met.

44. Stefan Gössling, Jessica Kees and Todd Litman (2022), The Lifetime Cost of Driving a Car," *Ecological Economics*, Vo. 194 (https://doi.org/10.1016/j.ecolecon.2021.107335).
Estimates 23 private (inernal) and ten social (external) costs of transportatio, and estimates them for three popular German car models. The results indicate that motorists underestimate the full private costs of car ownership, while policy makers and planners underestimate social costs. For the typical car driven 15,000 annual kilometers, the total lifetime cost of car ownership (50 years) ranges between €599,082 for an Opel Corsa to €956,798 for a Mercedes GLC. The share of this cost born by society is 41% (€4674 per year) for the Opel Corsa, and 29% (€5273 per year) for the Mercedes GLC. Findings suggest that for low-income groups, private car ownership can represent a cost equal to housing, consuming a large share of disposable income. This creates complexities in perceptions of transport costs, the economic viability of alternative transport modes, or the justification of taxes.

45. ICF (2021), *The Costs of the Vehicle Economy in Hawaii*, Ulupono Initiative (https://ulupono.com); at https://ulupono.com/media/ingpfb23/final-report-costs-of-vehicle-economy-in-hawaii-03-9-21.pdf.
Estimates the public and private costs of transportation in Hawai'i, including vehicles, and infrastructure (roads, bridges, and parking facilities), plus pollution and congestion costs. It concludes that these costs total approximately $21.8 billion. More than half of the total is borne by the public in government expenditures, road-related injuries and fatalities, congestion, and pollution costs), plus the value of land used for roadways and parking spaces.

46. Daniel Schröder, et al. (2022), "Ending the Myth of Mobility at Zero Costs: An External Cost Analysis," *Research in Transportation Economics* (https://doi.org/10.1016/j.retrec.2022.101246).
Estimates the external costs of various modes of transportation, including public transport, motorized individual transport, sharing services, and active mobility in the city of Munich, Germany. External cost categories include air pollution, climate, noise, land use (including road and parking facility costs), congestion, accidents, barrier costs, as well as health benefits of active mobility. The results show that diesel and gasoline cars impose 80% of external costs, and vehicle fleet electrification only provides a limited reduction in overall external costs. Recommends mode shifts to more sustainable transport modes (active and public transport) to reduce total external costs.

2.3 Freight Cost Studies

The studies below focus on freight transport costs.

F-1. Transport Concepts (1994), *External Costs of Truck and Train*, Brotherhood of Maintenance of Way Employees (Ottawa).
This study compares external costs of train and truck freight transport to justify increased truck taxes or increased subsidies for rail. Table 2.3.1 summarizes their results.

Table 2.3-1 **External Costs of Train Vs. Truck** (1994 Canadian Cents per Tonne Kilometer)

Cost	Intercity Truck Average	Truck Semi Trailer	Truck B-Train	Rail System Average	Rail Piggy Back	Rail Con-tainer	Rail Box Car	Rail Hopper Car
Accidents	0.40	0.40	0.40	0.06	0.06	0.06	0.06	0.06
Pollution	0.71	0.72	0.58	0.23	0.36	0.29	0.25	0.15
Interference (congestion)	0.64	0.65	0.52	-	-	-	-	-
Infrastructure	0.67	0.69	0.52	-	-	-	-	-
Cash Subsidy	0.09	-	-	0.28	0	0	0	0
Cost Subtotal	2.51	2.46	2.02	0.57	0.42	0.35	0.31	0.21
Fuel Taxes	-0.29	-0.29	-0.22	-0.06	-0.09	-0.07	-0.04	-0.04
License Fees	-0.07	-0.07	-0.07	-	-	-	-	-
Revenue Subtotal	-0.36	-0.36	-0.29	-0.06	-0.09	-0.07	-0.04	-0.04
Net External Costs	*2.15*	*2.10*	*1.73*	*0.51*	*0.33*	*0.28*	*0.27*	*0.17*

F-2. Transmode Consultants Inc. (1995), *Ontario Freight Movement Study*, National Round Table on the Environment and the Economy (Toronto).
This study focuses primarily on air pollution, particularly greenhouse gas emissions. Component 2 uses case studies to evaluate the feasibility of more efficient practices.

F-3. Committee for Study of Public Policy for Surface Freight Transport (1996), *Paying Our Way; Estimating Marginal Social Costs of Freight Transport*, TRB (www.trb.org).
This study uses previous cost research and case studies to estimate and compare marginal costs of freight transport, including internal costs to carriers, congestion, accidents, air pollution, energy consumption externalities, noise, and public facility costs. The study concludes that external costs represent an additional 7-20% cost over existing internal costs, and tend to be higher for truck and barge than for rail. The greatest external costs are associated with urban freight distribution where congestion and high population densities increase these costs. Policy applications and further research needs are discussed.

F-4. Thomas Bue Bjørner (1999), "Environmental Benefits from Better Freight Transport Management: Freight Traffic in a VAR Model," *Transportation Research D*, Vol. 4, No. 1, January 1999, pp. 45-64.
This article summarizes various estimates of the external costs of freight. Concludes that these costs (air pollution, noise, accidents and congestion) are about four times higher for one truck-kilometer than for a private car.

F-5. David Gargett, David Mitchell and Lyn Martin (1999), *Competitive Neutrality Between Road and Rail*, Bureau of Transport Economics, Australia (www.bitre.gov.au)..

This study uses estimates of the full costs of road and rail freight to estimate the price changes that would result from full-cost pricing. The study indicates that current pricing tends to favor trucks over rail by failing to internalize many costs.

Table 2.3-2 **External Costs of Rail Vs. Truck** (Australian Cents Per Net Tonne-Km)

	Rail			Truck		
	Cost	Payment	Balance	Cost	Payment	Balance
Infrastructure Use	0.87	0.87	0.0	0.97	0.64	0.33
Accident Costs	0.03	0.01	0.02	0.32	0.16	0.16
Enforcement Costs	NA	0.0	0.0	0.05	0.0	0.05
Congestion	NA	0.0	0.0	0.03	0.0	0.03
Air Pollution	0.004	0.0	0.004	0.01	0.0	0.01
Noise	0.02	0.0	0.02	0.034	0.0	0.034
Totals	*0.924*	*0.88*	*0.044*	*1.454*	*0.84*	*0.614*

This table indicates the estimated external costs of each mode, how much they pay under the current price structure, and the balance of external costs that result.

F-6. David Forkenbrock (1999 & 2001), "External Costs of Intercity Truck Freight Transportation," *Transportation Research A*, Vol. 33, No. 7/8 (www.elsevier.com/locate/tra), Sept./Nov. 1999, pp. 505-526; David Forkenbrock, "Comparison of External Costs of Rail and Truck Freight Transport," *Transportation Research A*, Vol. 35, No. 4, May 2001, pp. 321-337.
These articles summarize existing intercity truck internal costs. Internal costs are estimated at $1.25 per vehicle-mile, or 8.42¢ per ton-mile in 1994 (these values are disaggregated by cost category and trip length). Rail external costs are much smaller in magnitude but larger as a portion of internal (private) costs. Estimates of external costs are as indicated in Table 2.3-3. Concludes that heavy truck road user charges would need to approximately triple to internalize these costs.

Table 2.3-3 **Estimated External Costs of Intercity Truck**

Cost Category	1994 Cents Per Ton-Mile
Accidents	0.59
Air pollution	0.08
Greenhouse gases	0.15
Noise	0.04
Roadway external costs	0.25
Total	*1.11*

F-7. H. Link, J.S. Dodgson, M. Maibach and M. Herry (1999), *The Costs of Road Infrastructure and Congestion in Europe*, Physcia-Verlag (www.springer.de).
This book is based on the final report of a project funded by the European Commission (DGVII) entitled "Infrastructure Capital, Maintenance and Road Damage Costs for Different Heavy Goods Vehicles in the EU" (Project No.: B1-B97-B2 7040-SIN 5317-ETU). It examines the ways in which the costs of transport infrastructure and congestion can be calculated and allocated to different types of traffic, focusing mainly on road freight transport.

F-8. Oxford Economic Research Associates (1999), *The Environmental and Social Costs of Heavy Goods Vehicles and Options for Reforming the Fiscal Regime*, English, Welsh, and Scottish Railway, (www.ews-railway.co.uk).
This report investigates the full social and environmental costs of road freight, including factors such as pollution and uncovered costs of structural damage, and concludes that road freight currently pays only 70% of its full costs. Including interest payments on the capital costs of road infrastructure lowers the ratio of paid costs to full costs to 59%. The report discusses alternatives for incorporating full costs into road freight charges, including a time-based payment along the lines of the Eurovignette scheme currently in use in several European countries, or a distance-based scheme in operation in Sweden and New Zealand.

F-9. TRB (2002), "Comparison of Inland Waterways and Surface Freight Modes," *TR NEWS 221*, Transportation Research Board (www.trb.org), July-August 2002, p. 10-17.
Includes information comparing various freight modes, as summarized in the table below.

Table 2.3-4 **Freight Modes Compared** (per ton-mile)

	Costs	Fuel	Hydrocarbons	CO	NOx
Units	*Cents*	*Gallons*	*Lbs.*	*Lbs.*	*Lbs.*
Barge	0.97	0.002	0.09	0.20	0.53
Rail	2.53	0.005	0.46	0.64	1.83
Truck	5.35	0.017	0.63	1.90	10.17

F-10. ICF Consulting (2001), *Freight Benefit/Cost Study: Compilation of the Literature*, Office of Freight Management and Operations, Federal Highway Administration (http://ops.fhwa.dot.gov/freight/freight_analysis/econ_methods/comp_lit/index.htm#toc), 2001.
This study includes a review of freight transport costing and describes a comprehensive analysis tool that can capture the full benefits and costs of freight transportation improvements.

F-11. Vermeulen, et al. (2004), *The Price of Transport: Overview of the Social Costs of Transport*, CE Delft; van Essen, et al. (2004), *Marginal Costs of Infrastructure Use – Towards a Simplified Approach*, CE Delft (www.ce.nl); at www.ce.nl/index.php?go=home.showPublicatie&id=181.
These studies analyze the social costs of various transport modes, including road and rail transport (both passenger and freight) and inland shipping (freight only), in The Netherlands. They discusses cost categories, the magnitude of these costs, the share of the costs borne directly by user groups, and the extent to which existing pricing is efficient.

F-12. Michael F. Gorman (2008), "Evaluating The Public Investment Mix In US Freight Transportation Infrastructure," *Transportation Research A*, Vol. 42, 1 (www.elsevier.com/locate/tra), Jan. 2008, pp. 1-14.
This study evaluates truck and rail freight social costs (congestion, safety and pollution) and investments. Estimates that governments currently spend $18.7 billion annually on roadways to accommodate trucks, 24% of which is subsidized (not paid by users), and that public investments in rail would be more cost effective overall.

F-13. **TC (2008)**, *Estimates of the Full Cost of Transportation in Canada*, Economic Analysis Directorate of Transport Canada (www.tc.gc.ca); at www.tc.gc.ca/media/documents/policy/report-final.pdf.
This report, which summarizes the results of Transport Canada's Full Cost Investigation (FCI) project, includes costs of vehicle ownership and operations, infrastructure ownership and operations (including land opportunity costs), congestion, accidents and environmental damages for freight transport activity.

Table 2.3-5 **Freight Cost Estimates and Activity Level**

	Financial Costs	Social Costs	Full Costs	Tonne-Kms	Financial Costs	Social Costs	Full Costs	Social/ Full Costs
	Billion 2000$CA			*Billion*	*2000$CA per tonne-km*			
Truck	$49.83	$4.01	$53.84	244.97	$0.203	$0.016	$0.220	7%
Rail	$6.73	$0.90	$7.63	322.44	$0.021	$0.003	$0.024	12%
Air	$1.24	$0.03	$1.27	2.04	$0.607	$0.016	$0.623	3%
Total	*$60.21*	*$5.72*	*$65.94*	*569.46*	*$0.106*	*$0.010*	*$0.116*	*9%*

This table summarizes the estimated costs of freight transport modes in Canada.

F-15. M. Piecyk and A. McKinnon (2007), *Internalising The External Costs Of Road Freight Transport In The UK*, Logistics Research Center, Heriot-Watt University (www.sml.hw.ac.uk/logistics); at www.greenlogistics.org/SiteResources/1fbb59ff-3e5a-4011-a41e-18deb8c07fcd_Internalisation%20report%20(final).pdf.
Mid-range estimate is that the total infrastructural, environmental and congestion costs attributable to UK-registered heavy goods vehicles (HGVs) in 2006 were £7.1 to £7.6 billion, of which special taxes on these vehicles paid about two-thirds of these costs. The proportion of the total cost internalised varied by vehicle class, with the lightest category of rigid vehicles covering only 55% of their allocated costs, but the heaviest rigid vehicles covering 79%. Overall, the analysis suggested that taxes on lorries would have to rise by around 50% to fully internalise infrastructural, environmental and congestion costs. About 40% of the total external costs is attributable to congestion, 23% to infrastructure, 19% to traffic accidents, 8% to greenhouse gases, 7% to other air pollution emissions, and 2% to noise.

F-16 GAO (2011), *Comparison of the Costs of Road, Rail, and Waterways Freight Shipments That Are Not Passed on to Consumers*, Government Accountability Office (www.gao.gov); at www.gao.gov/new.items/d11134.pdf.
Analysis in this report indicates that truck freight transport tends to generate significantly more costs (infrastructure, air pollution, accidents and traffic congestion) that are not passed on to consumers than rail or water freight transport. It estimates that costs not passed on to consumers were at least 6 times greater for truck than rail and at least 9 times greater than waterways costs per ton-miles of freight transport. Most of these costs were external costs imposed on society. These are considered lower-bound estimates.

f-17 David Austin (2015), *Pricing Freight Transport to Account for External Costs*, Congressional Budget Office (www.cbo.gov); at http://1.usa.gov/1H1xODF.
This study describes and estimates external costs of freight transport including wear and tear on roads and bridges, traffic congestion delays, accident, and pollution damages; how to efficiently price these impacts, and the effects that would result.

2.4 Information Resources

Information on transportation cost analysis studies are described below.

Steve Abley, Paul Durdin and Malcolm Douglass (2010), *Integrated Transport Assessment Guidelines*, Report 422, Land Transport New Zealand (www.nzta.govt.nz); at www.nzta.govt.nz/resources/research/reports/422.

ATAP (2017), *Australian Transport Assessment and Planning Guidelines*, ATAP Steering Committee Secretariat (https://atap.gov.au) Australia Department of Infrastructure and Regional Development; at www.atap.gov.au/user-guide/2-the-atap-guidelines-website.

David Austin (2015), *Pricing Freight Transport to Account for External Costs*, Congressional Budget Office (www.cbo.gov); at http://1.usa.gov/1H1xODF.

Udo J. Becker, Thilo Becker and Julia Gerlach (2012), *The True Costs of Automobility: Overview on Existing Estimates in EU-27*, TU Dresden (http://tu-dresden.de/en); at https://bit.ly/3PwRpBZ.

CE, INFRAS, ISI (2011), *External Costs of Transport in Europe – Update Study for 2008*, Studie im Auftrag des Internationalen Eisenbahnverbandes (UIC), CE Delft (www.cedelft.eu), INFRAS AG, Zürich, Fraunhofer-ISI, Karlsruhe, External Transport Cost Study (http://ecocalc-test.ecotransit.org); at http://ecocalc-test.ecotransit.org/CE_Delft_4215_External_Costs_of_Transport_in_Europe_def.pdf.

CE Delf (2019), *Handbook on Estimation of External Cost in the Transport Sector,* CE Delft (www.ce.nl); at https://bit.ly/2Z9P5sE.

Harry Clarke and David Prentice (2009), *Conceptual Framework for the Reform of Taxes Related to Roads and Transport*, La Trobe University, for the Australia Treasury *Australia's Future Tax System* review; at http://apo.org.au/research/conceptual-framework-reform-taxes-related-roads-and-transport.

Commuter Solutions (2010), *How Much Does It Really Cost You To Drive?*, Commuter Solutions (www.commutesolutions.org); at http://commutesolutions.org/external/tcod.html.

COWI (2009), *Economic Evaluation of Cycle Projects - Methodology And Unit Prices*, *Samfundsøkonomiske Analyser Af Cykeltiltag - Metode Og Cases* and the accompanying note *Enhedsværdier for Cykeltrafik*, prepared by COWI for the City of Copenhagen (www.kk.dk/cyklernesby).

Felix Creutzig and Dongquan He (2009), "Climate Change Mitigation and Co-Benefits of Feasible Transport Demand Policies In Beijing," *Transportation Research D*, Vol. 14, pp. 120-131; at www.user.tu-berlin.de/creutzig/trd.pdf.

Mengying Cui and David Levinson (2018), *Full Cost of Travel on the Twin Cities Road Network ($/veh-km)*, University of Sydney; at https://ses.library.usyd.edu.au//bitstream/2123/18776/2/FullCostAnalysis.pdf.

Mark Delucchi (1996), *Annualized Social Cost of Motor Vehicle Use in the United States, Based on 1990-1991 Data*, Institute of Transportation Studies (www.its.ucdavis.edu); at https://bit.ly/3enJhBS.

Mark Delucchi (2007), Do Motor-Vehicle Users In The US Pay Their Way?, *Transportation Research A*, Vol. 41/10, Dec., pp. 982-1003 (www.sciencedirect.com/science/article/pii/S0965856407000444)

DfT (2006-2020), *Transport Analysis Guidance*, UK Department for Transport (www.dft.gov.uk); at www.gov.uk/guidance/transport-analysis-guidance-webtag.

Jos M.W. Dings, Marc D. Davidson and Maartje N. Sevenster (2003), *External and Infrastructure Costs of Road and Rail Transport - Analysing European Studies*, CE Delft (www.ce.nl); at http://bit.ly/1LHc297.

EDRG (2007), *Monetary Valuation of Hard-to-Quantify Transportation Impacts: Valuing Environmental, Health/Safety & Economic Development Impacts*, NCHRP 8-36-61, National Cooperative Highway Research Program (www.trb.org/nchrp); at www.statewideplanning.org/_resources/63_NCHRP8-36-61.pdf.

EEA (2007), *Size, Structure and Distribution of Transport Subsidies in Europe*, European Environmental Agency (http://reports.eea.europa.eu); at http://reports.eea.europa.eu/technical_report_2007_3/en.

EU (2014), *Guide to Cost-Benefit Analysis of Investment Projects: Economic Appraisal Tool for Cohesion Policy 2014-2020*, European Commission (http://ec.europa.eu); at https://bit.ly/2YpE1Is.

Caroline Evans, et al. (2015), *Updating Environmental Externalities Unit Values*, Austroads (www.austroads.com.au); at www.onlinepublications.austroads.com.au/items/AP-T285-14.

ExternE (2015), *Externalities of Energy*, European Commission (www.externe.info); at https://bit.ly/3dNhZ9k.

FHWA (1997 and 2000), *1997 Federal Highway Cost Allocation Study* (including appendices) USDOT (www.fhwa.dot.gov/policy/hcas/summary/index.htm).

FHWA (annual reports), *Highway Statistics*, FHWA, USDOT (www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm) include roadway expenditure and user fee revenue data.

Vijay Gill and John Lawson (2013), *Where the Rubber Meets the Road: How Much Motorists Pay for Road Infrastructure*, Conference Board of Canada (www.conferenceboard.ca); at https://bit.ly/2Rv0T3l.

David Greene, Donald Jones and Mark Delucchi (1997), *Full Costs and Benefits of Transportation*, Springer (www.springer.de).

Michael F. Gorman (2008), "Evaluating the Public Investment Mix in US Freight Transportation Infrastructure," *Transportation Research A*, Vol. 42, Is. 1 (www.elsevier.com/locate/tra), January, pp. 1-14.

Stefan Gössling and Andy S. Choi (2015), "Transport Transitions in Copenhagen: Comparing the Cost of Cars and Bicycles," *Ecological Economics*, Vol. 113, pp. 106-113 (DOI:10.1016/j.ecolecon.2015.03.006).

Stefan Gössling, et al. (2018), "The Social Cost of Automobility, Cycling and Walking in the European Union," *Ecological Economics*, Vol. 158, pp. 65-74 (https://doi.org/10.1016/j.ecolecon.2018.12.016).

Stefan Gössling, Jessica Kees and Todd Litman (2022), "The Lifetime Cost of Driving a Car," *Ecological Economics*, Vo. 194 (https://doi.org/10.1016/j.ecolecon.2021.107335).

HEATCO (2006), *Final Technical Report*, Harmonised European Approaches for Transport Costing and Project Assessment (http://heatco.ier.uni-stuttgart.de). The HEATCO project involved development of tools, indicators and operational parameters for assessing sustainable transport and energy systems performance (economic, environmental and social).

Matthew Holian and Ralph McLaughlin (2016), *Benefit-Cost Analysis for Transportation Planning and Public Policy: Towards Multimodal Demand Modeling*, Mineta Transportation Institute (http://transweb.sjsu.edu) for the California Department of Transportation; at http://bit.ly/2bYJ0Zj.

Hyder Consulting (2008), *Understanding Transport Costs and Charges (UTCC) Phase 1*, New Zealand Ministry of Transport (www.transport.govt.nz); at https://bit.ly/3o7aQFR.

ICF Consulting (2001), *Freight Benefit/Cost Study: Compilation of the Literature*, Office of Freight Management and Operations, Federal Highway Administration (http://ops.fhwa.dot.gov/freight/); at http://ops.fhwa.dot.gov/freight/freight_analysis/econ_methods/comp_lit/index.htm.

ICF (2021), *The Costs of the Vehicle Economy in Hawaii*, Ulupono Initiative (https://ulupono.com); at https://ulupono.com/media/ingpfb23/final-report-costs-of-vehicle-economy-in-hawaii-03-9-21.pdf.

ICLEI (2005), *Hidden Subsidies for Urban Car Transportation: Public Funds for Private Transport*, European Commission Directorate General for Environment, International Council for Local Environmental Initiatives (www.iclei.org).

INFRAS and IWW (2004), *The True Costs of Transport: Time to Act – Update Study*, Community of European Railway Companies (www.cer.be) and International Union of Railways (www.uic.asso.fr).

Astrid Jakob, John L. Craig and Gavin Fisher (2006), "Transport Cost Analysis: A Case Study of the Total Costs of Private and Public Transport in Auckland," *Environmental Science & Policy*, Vol. 9 (www.sciencedirect.com), pp. 55-66.

Kara Kockelman, et al. (2013), *The Economics of Transportation Systems: A Reference for Practitioners*, TxDOT Project 0-6628, University of Texas at Austin (www.utexas.edu); at https://bit.ly/2OdfPok.

Jason D. Lemp and Kara M. Kockelman (2008), *Quantifying the External Costs of Vehicle Use: Evidence From America's Top Selling Light-Duty Models*, *Transportation Research Part D: Transport and Environment*, Vol. 13, Issue 8, December, pp. 491-504; at http://bit.ly/1Q0pN5E.

Todd Litman (2001), *What's It Worth? Life Cycle and Benefit/Cost Analysis for Evaluating Economic Value*, Presented at Internet Symposium on Benefit-Cost Analysis, Transportation Association of Canada (www.tac-atc.ca); available at www.vtpi.org/worth.pdf.

Todd Litman (2009), *Transportation Cost and Benefit Analysis*, Victoria Transport Policy Institute (www.vtpi.org/tca).

Todd Litman (2014), *Economically Optimal Transport Prices and Markets: What Would Happen If Rational Policies Prevailed?* Int. Transportation Economic Development Conf.; at www.vtpi.org/ITED_optimal.pdf.

Todd Litman (2021), *Socially Optimal Transport Prices and Markets*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/sotpm.pdf.

MIRA (2010 and 2016) *Internalisation of External Costs of Transport in Flanders*, Transport and Mobilty Leuven (www.tmleuven.be); at www.tmleuven.be/project/miraexternekostenupdate/home.htm.

Christopher Nash and Bryan Matthews (2005), *Measuring the Marginal Social Cost of Transport*, Research in Transportation Economics Vol. 14, Elsevier (www.elsevier.com).

NJDOT (2007), *Cost of Transporting People in New Jersey*, New Jersey Department of Transportation and the Region 2 University Transportation Research Center, U.S. Department of Transportation; at www.nj.gov/transportation/refdata/research/reports/FHWA-NJ-2007-003.pdf.

NZTA (2020), *Monetized Benefits and Costs Manual*, Waka Kotahi NZ Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual.

Kaan Ozbay, Bekir Bartin, Ozlem Yanmaz-Tuzel and Joseph Berechman (2007), "Alternative Methods for Estimating Full Marginal Costs of Highway Transportation," *Transportation Research Part A*, Vol. 41, No. 8 (www.sciencedirect.com), pp. 768-786.

Sangjune Park (2009), "KRW 53 Trillion (5.4% of GDP), "Estimates of the External Costs of Transport in 2007," *KOTI World-Brief*, Vol. 1, No. 3, Korea Transport Institute (www.koti.re.kr), July 2009, pp. 8-10; at http://english.koti.re.kr/upload/eng_publication_regular/World-Brief03.pdf.

Emile Quinet (2004), "A Meta-Analysis of Western European External Cost Estimates," *Transportation Research D*, Vol. 9 (www.elsevier.com/locate/trd), Nov. 2004, pp. 465-476.

Ricardo-AEA (2014), *Update of the Handbook on External Costs of Transport Final Report*, European Commission (http://ec.europa.eu); at https://bit.ly/34Ci8ZU.

Andrea Ricci, et al (2006), *Pricing For (Sustainable) Transport Policies – A State of the Art*, Deliverable 1, Project contract no. 006293, IMPRINT-NET: Implementing pricing reforms in Transport – Networking (http://vplno1.vkw.tu-dresden.de/psycho/download/imprint-net_d1.pdf).

T. Sansom, et al. (2001), *Surface Transport Costs and Charges*, Institute for Transport Studies, University of Leeds (www.its.leeds.ac.uk/projects/STCC/surface_transport.html), for the UK DETR.

Georgina Santos, et al. (2010), "Externalities and Economic Policies in Road Transport," *Research in Transportation Economics*, Vol. 28, pp. 2–45 (https://doi.org/10.1016/j.retrec.2009.11.002); at https://bit.ly/2yUimuN.

Daniel Schröder, et al. (2022), "Ending the Myth of Mobility at Zero Costs: An External Cost Analysis," *Research in Transportation Economics* (https://doi.org/10.1016/j.retrec.2022.101246).

Akshaya Kumar Sen, Geetam Tiwari and Vrajaindra Upadhyay (2010), "Estimating Marginal External Costs of Transport in Delhi," *Transport Policy*, Vol. 17, pp. 27–37; at www.vref.se/download/18.6a462c7912efb9dc85f80004555/2010+Sen.pdf.

Niklas Sieber and Peter Bicker (2008), *Assessing Transportation Policy Impacts on the Internalization of Externalities of Transport*, Transport & Mobility Leuven for the European Commission; at www.tmleuven.be/project/refit/d3-3.pdf.

Nariida C. Smith, Daniel W. Veryard and Russell P. Kilvington (2009), *Relative Costs and Benefits of Modal Transport Solutions*, Research Report 393, NZ Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/research/reports/393/docs/393.pdf.

Surface Transportation Environment and Planning Cooperative Research Program (www.fhwa.dot.gov/hep/step/index.htm) provides information on Planning, Environment and Land Use.

Swiss ARE (2005, 2010 and 2021), *External Cost and Benefits of Transport In Switzerland*, Swiss Federal Office of Spatial Development (www.are.admin.ch); at https://bit.ly/2G7lIRd and https://bit.ly/3WjF1t6.

TC (2005-08), *The Full Cost Investigation of Transportation in Canada*, Transport Canada (www.tc.gc.ca); at http://publications.gc.ca/site/eng/9.691980/publication.html.

Harald Thune-Larsen, et al. (2016), *Marginal External Costs of Road Transport*, TØI Report 1307/2014, Norwegian Centre for Transport Research (www.toi.no); at https://bit.ly/3FJjfHS.

Govinda R. Timilsina and Hari B. Dulal (2011), "Urban Road Transportation Externalities: Costs and Choice of Policy Instruments," *World Bank Research Observer*, Vol. 26/1, pp. 162-191; at http://bit.ly/1PV5rf3.

van Essen, et al (2004), *Marginal Costs of Infrastructure Use – Towards a Simplified Approach*, CE Delft (www.ce.nl); at www.ce.nl/?go=home.downloadPub&id=456&file=04_4597_15.pdf.

H.P. van Essen, B.H. Boon, M. Maibach and C. Schreyer (2007), *Methodologies for External Cost Estimates and Internalization Scenarios: Discussion Paper for the Workshop on Internalisation*, CE Delft (www.ce.nl); at www.ce.nl/4288_Inputpaper.pdf.

Vermeulen, et al. (2004), *The Price of Transport: Overview of the Social Costs of Transport*, CE Delft (www.ce.nl); at www.ce.nl/index.php?go=home.showPublicatie&id=181.

Waka Kotahi (2021), *Monetized Benefits and Costs Manual*, New Zealand Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual.

Rui Wang (2011), "Autos, Transit And Bicycles: Comparing the Costs in Large Chinese Cities," *Transport Policy*, Vol. 18, Issue 1, January, Pages 139-146; summary at https://bit.ly/3Vy4RZQ.

Glen Weisbrod, Teresa Lynch and Michael Meyer (2007), *Monetary Valuation Per Dollar of Investment in Different Performance Measures*, NCHRP Project 08-36, Task 61, National Cooperative Highway Research Program, Transportation Research Board (www.trb.org); at https://bit.ly/3UBasNM.

Lisanne van Wijngaarden, et al. (2019), *Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities*, European Commission, Directorate-General for Mobility and Transport (https://data.europa.eu/doi/10.2832/246834). Conference papers at https://fsr.eui.eu/event/5th-florence-intermodal-forum-internalising-the-external-costs-of-transport.

Christopher Zegras with Todd Litman (1997), *An Analysis of the Full Costs and Impacts of Transportation in Santiago de Chile,* International Institute for Energy Conservation (www.iiec.org); at http://web.mit.edu/czegras/www/Santiago%20Full%20Cost%20Study.pdf.

Anming Zhang, Anthony E. Boardman, David Gillen and W.G. Waters II (2005), *Towards Estimating the Social and Environmental Costs of Transportation in Canada*, Centre for Transportation Studies, University of British Columbia (www.sauder.ubc.ca/cts), for Transport Canada; at www.bv.transports.gouv.qc.ca/mono/0965490.pdf.