5.6 Roadway Facility Costs

This chapter examines public expenditures on roadways and pathways, and how these costs are allocated to different types of vehicles. Roadway expenses not borne by user charges (special fuel taxes, vehicle fees and tolls) are considered external costs.

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5.6.2 Definition

Roadway costs are expenditures to build and operate public roadways, including land acquisition, construction, maintenance, and operations. *Cost recovery* refers to the portion of roadway costs that are borne directly by users through special user fees and taxes. To avoid double-counting vehicle costs in Chapter 5.1, only roadway costs not paid by user charges is included in the final values of this chapter. Roadway land opportunity costs are included in chapter 5.7, and traffic services such as policing are included in chapter 5.8.

5.6.3 Discussion

Vehicle travel requires a network of roads. Roadway costs include land acquisition, construction, financing, maintenance and operations. These expenditures are reported in government accounts, although care is needed to identify all expenditures by different levels of government and agencies. Table 5.6.3-1 lists various cost categories and their typical share of total roadway costs.

Table 5.6.3-1 **Roadway Expenditures**[1]

	Portion of Total
Maintenance & Operations	26%
Highway Capacity Expansion	23%
Highway Reconstruction, Rehabilitation & Restoration	19%
Highway Administration	9%
Highway Patrol & Safety	8%
Local Road Capital Improvements	8%
Interest on Debt	4%
Other	3%

Cost Allocation

Cost allocation (also called *cost responsibility*) refers to the share of roadway costs imposed by different vehicle classes or user groups, and how these costs compare with their roadway user payments.[2, 3] Various methods are used to allocate specific costs to specific vehicle types or groups.[4, 5] *User payments* refers to special fees and taxes charged to road users, including tolls, fuel taxes, registration fees and weight-distance fees, but does not include general taxes applied to vehicles and fuel.

Roadway costs can be categorized in various ways for cost allocation analysis:

- *Short Run Marginal Cost* (SRMC) only includes costs imposed using current capital resources, ignoring other costs, such as vehicle and roadway capital costs.
- *Long Run Marginal Cost* (LRMC) includes all costs imposed, including past investment costs and the opportunity cost of land and other resources, but ignores *sunk costs* (unrecoverable costs already incurred).
- *Fully Allocated Costs* (FAC, also called *cost recovery*) includes all infrastructure costs, including sunk costs, allocated among users in some way that is considered equitable.
- *Pay-As-You-Go* (PayGo) means that financial investments made each year are allocated to users as a group during that year, so no funds need be borrowed.

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[1] FHWA (1995), *1995 Status of the Nation's Surface Transportation System: Conditions & Performance*, (www.fhwa.dot.gov).

[2] Joseph Jones and Fred Nix (1995), *Survey of the Use of Highway Cost Allocation in Road Pricing Decisions*, Transportation Association of Canada (www.tac-atc.ca); FHWA (1997), *Federal Highway Cost Allocation Study*, USDOT (www.fhwa.dot.gov); at www.fhwa.dot.gov/policy/hcas/summary/index.htm.

[3] Patrick Balducci and Joseph Stowers (2008), *State Highway Cost Allocation Studies: A Synthesis of Highway Practice*, NCHRP Synthesis 378; at www.nap.edu/catalog/14178/state-highway-cost-allocation-studies.

[4] Cambridge Systematics (2011), Determining Highway Maintenance Costs, NCHRP Report 688, Transportation Research Board (www.trb.org); at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_688.pdf.

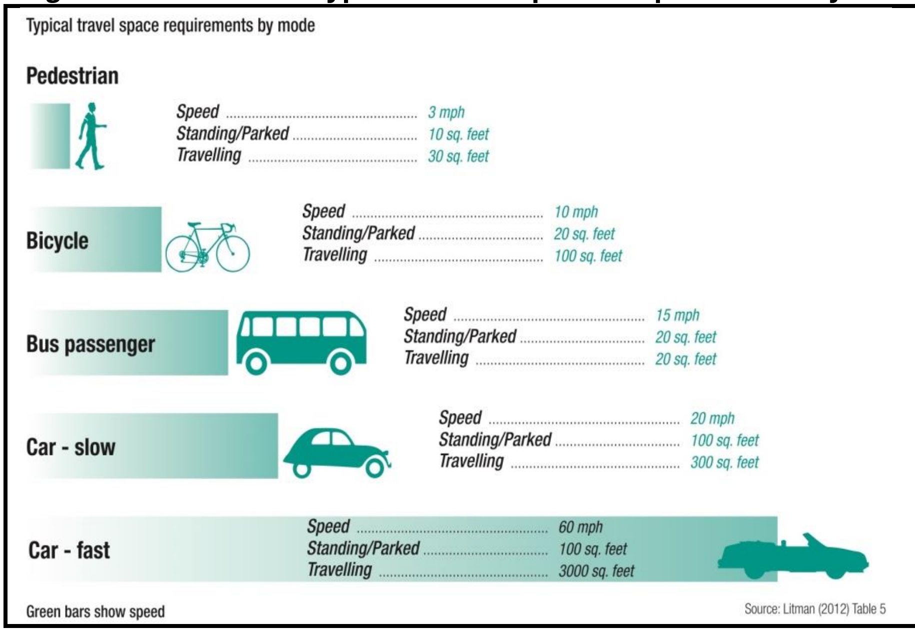
[5] Franziska Borer Blindenbacher (2005), *Study of Methods of Road Capital Cost Estimation and Allocation by Class of User in Austria, Germany and Switzerland*, Transport Canada (www.tc.gc.ca); at www.tc.gc.ca/policy/report/aca/fullcostinvestigation/road/tp14494/tp14494.htm.

Short Run Marginal Costs (SRMCs) only consider immediate costs, such as road wear and congestion delay, accident risk and environmental impacts imposed by vehicle traffic. *Long Run Marginal Cost* also include all ongoing costs to build, maintain and expand infrastructure, but ignores sunk costs, such as past construction costs, and roadway land value (which is considered in Chapter 5.7). Fully Allocated Costs (FACs) include all infrastructure financial expenditures.

Some economists consider SRMC pricing most efficient, but there are reasons to recover all roadway costs from users using Long Run Marginal Cost (LRMC) or FAC pricing: for the sake of horizontal equity (reflecting the principle that consumers should “get what they pay for and pay for what they get” unless subsidies are specifically justified), and economic neutrality (since most products are priced for cost recovery, so failing to charge motorists full costs underprices road transport relative to other goods).

FAC pricing focuses on financial costs and generally excludes costs such as congestion, accident and environmental impacts imposed and borne by road users as a group. This means that costs depend on how groups are defined, for example, whether congestion or risks imposed by one vehicle or motorist type on another, are considered externalities.

Figure 5.6.3-1 **Typical Travel Space Requirements by Mode**[6]



Road space requirements, and therefore roadway costs, increase with vehicle size and speeds. Automobile travel requires far more road space than walking, bicycling, ridesharing and public transit, and faster vehicles require more road space than slower vehicles in order to provide adequate shy distance.

[6] David Banniser (2014), *Typical Travel Space Requirements by Mode*, http://regardssurlaterre.com/en/node/19781.

Table 5.6.3-2 summarizes the costs and appropriate charges based on various roadway cost allocation perspectives.

Table 5.6.3-2 **Comparison of Costs and Charge Concepts**[7]

Category	SRMC	LRMC	FAC	PayGo
Costs				
Return on capital.	Not relevant	Not relevant	Return on capital employed.	Not relevant
Infrastructure costs	Facility wear caused by use.	Facility wear caused by use, and capital costs to increase capacity to accommodate growing demand.	All ongoing infrastructure costs (operations, maintenance and depreciation).	All costs (operating and capital) incurred during a year.
Service provider operating costs	Cost of an additional vehicle km.	Cost of an additional vehicle km.	All costs associated with providing services.	All costs.
Congestion	Costs imposed by one user on other transport system users.	Not included if capacity expansion leaves existing traffic unaffected.	Not relevant since this cost is imposed and borne by infrastructure users as a group.	Not relevant since this cost is imposed and borne by users as a group.
Mohring Effect[8]	Benefits of increased public transport service frequencies due to additional demand.	Benefits of increased public transport service frequencies due to additional demand.	Not relevant, since this impact is imposed and borne by infrastructure users as a group.	Not relevant, since this impact is imposed and borne by infrastructure users as a group.
Accidents	External crash risk costs of an additional unit of travel.	External crash risk costs of an additional unit of travel.	External costs attributed to user groups on the basis of responsibility.	Not relevant
Environmental Costs	Cost of an additional unit of travel.	Cost of an additional unit of travel.	Costs of total vehicle travel.	Not relevant
Charges				
Fuel excise tax and road user charges	Revenue associated with an additional vehicle km.	Revenue associated with an additional vehicle km.	Total revenues from fuel taxes and road user charges.	Total revenues from fuel taxes and road user charges.
Motor vehicle registration and licensing.	If related to additional vehicle travel.	If related to additional vehicle travel	All motor vehicle registration charges	All motor vehicle registration charges
Goods and Services Tax	On all costs.	On all costs.	On all costs.	On all costs.
Fares, fright tariffs and traffic fines.	Associated with an additional unit of travel.	Associated with an additional unit of travel.	All fares, taxes.	All fares, taxes.

This table summarizes differences between various categories of costs and charges.

[7] Booz Allen Hamilton (2005), *Surface Transport Costs and Charges Study*, NZ Ministry of Transport (www.transport.govt.nz).

[8] Herbert Mohring (1972), "Optimization and Scale Economies in Urban Bus Transportation," *American Economic Review*, pp. 591-604.

Cost Factors

Three general factors affect a vehicle's roadway costs:[9]

1. *Strength required and damage inflicted.* Road wear and construction standards increase with vehicle weight. Wear increases exponentially (between the third and fourth power) with axle weight, so heavy vehicles impose much greater (hundreds of times more) repair and maintenance costs than lighter vehicles. Studded tires also increase road repair costs.

2. *Space required.* Road space requirements increase with vehicle size and speed.[10] Larger vehicles require wider lanes, and higher speeds increase the "shy distances" required between vehicles and other objects, so higher speed traffic requires wider lanes, greater road capacity and more clearance. Road space requirements are measured in "passenger car equivalents," or PCEs. A large truck or bus typically imposes 2-5 PCEs, and more when ascending a steep incline.

3. *Design requirements*. Faster traffic requires higher roadway design speeds and imposes greater risk, which increases safety requirements such as barriers and clear space.[11]

The incremental costs of stronger pavements, wider roads and higher design speeds can be assigned to vehicles according to their weight, size and speed. The costs of increasing roadway capacity should generally only be assigned to peak-period trips that contribute to congestion. Some roadway costs, such as planning, law enforcement and lighting costs are not clearly related to a particular vehicle attribute, and any remaining costs are considered *common costs* that can be prorated based on other costs or allocated based on mileage.

Internal and External Costs

In the U.S., user fees (fuel taxes, vehicle registration fees and road tolls) fund most state highway expenditures, but local roads are funded primarily by general taxes that residents pay regardless of how much they drive. Not all user fees collected are spent on highways. Of the 18.4¢ per gallon federal tax on gasoline, 2.86¢ are allocated to public transit and 0.1¢ per gallon for leaking fuel storage tank cleanup, and between 1990 and 1997 a portion of federal fuel taxes were used to reduce budget deficits. However, even if those funds were fully devoted to highways, total user fee revenue only funded about half of roadway costs. For example, in 2018, governments spent $223 billion on roadways, of which road user fees totaled $107 billion or 48%, as indicated in Table 5.6.3-3.

Roadway expenditures not funded through user fees can be considered an external cost or subsidy, since people pay regardless of how much they use roads. The portion of roadway

[9] Kenneth A. Small, Clifford M. Winston, and Carol A. Evans (1989), *Road Work: A New Highway Pricing and Investment Policy*, Brookings Institution Press (www.brookings.edu).

[10] Marie-Eve Will, Yannick Cornet and Talat Munshi (2020), "Measuring Road Space Consumption by Transport Modes: Toward A Standard Spatial Efficiency Assessment Method and an Application to the Development Scenarios of Rajkot City, India," *Journal of Transport and Land Use*, Vo. 13, 1 pp. 651–669 (https://doi.org/10.5198/jtlu.2020.1526).

[11] Todd Litman (2021), *Not So Fast*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/nsf.pdf.

costs paid by users is expected to decline as vehicles become more efficient and alternative fueled vehicles become more common.[12]

Table 5.6.3-3 **U.S. Roadway Expenditures, Payments and Subsidies, 2018**[13]

	Expenditures	User Payments	Subsidies
Total	$223 billion	$107 billion (48%)	$116 billion (52%)
Per Capita (327 million U.S. residents)	$682	$327	$355
Per Vehicle (275 million vehicles)	$811	$389	$422
Per Vehicle-Mile (3,240 billion)	6.9₵	3.3₵	3.6₵

In 2018, governments spent $223 billion on roads of which about half was paid by user fees.

Roadway costs are often greater than indicated by current expenditures due to deferred maintenance and because the opportunity cost of road rights of way. Annual roadway expenditures would need to increase at least 13% to maintain current system performance.[14] Public accounting requirements (GASB Statement 34) require that public facility costs account for deferred investments.[15] Roadway agencies tend to undervalue capital costs compared with what is indicated by standard accounting procedures because capital expenditures are treated as current costs and all past expenditures are considered sunk.[16] Applying business principles, road users would be charged for capital expenditure return on investment. As described by Lee:[17]

Current highway finance practice finances most improvements out of current revenues, eliminating the need for borrowing. If highway users — who are also highway investors — don't have to pay interest on capital improvements, why should they be charged for it? The reason is that money deposited in a highway trust fund earns interest at whatever rate the U.S. Treasury is paying, and that interest is foregone when money is spent. There is no way to pretend that capital investments have no opportunity cost to the funds committed to them. Equally important, the amount spent one year bears little relationship to the value of the capital consumed in that year. If the system is wearing down faster than it is being rebuilt, for example, current users are living off of previous users/taxpayers who built up the capital stock. A capital asset that continues to function as a highway should be earning revenues at least as great as the interest on the invested capital plus depreciation, plus operating costs. To earn less implies that the long run costs are not justified, and the road ought to be phased out of use.

[12] CRS (2020), *Funding and Financing Highways and Public Transportation*, Congressional Research Service; at https://fas.org/sgp/crs/misc/R45350.pdf.

[13] FHWA (2020), *Highway Statistics Report*, Tables HF-1 and HF-2, Federal Highway Administration (www.fhwa.dot.gov); at www.fhwa.dot.gov/policyinformation/statistics.cfm.

[14] USDOT (1997), *1997 Status of the Nation's Surface Transportation System,* USDOT (www.dot.gov).

[15] Anthony J. Kadlec and Sue McNeil (2001), "Applying Governmental Accounting Standards Board Statement 34; Lessons from the Field," *Transportation Research 1747* (www.trb.org), pp. 123-128.

[16] Herbert Mohring and Mitchell Harwitz (1965), *Highway Benefits: An Analytical Framework*, Northwestern University Press (http://nupress.northwestern.edu).

[17] Douglass Lee (1995), *Full Cost Pricing of Highways*, Volpe National Transportation Systems Center (www.volpe.dot.gov), p.13.

Roadway Project Costs

Table 5.6.3-4 summarizes typical project costs. Cost inflation can be tracked using the *Highway Construction Cost Index* (www.fhwa.dot.gov/policy/otps/nhcci) and similar indices.

Table 5.6.3-4 **Roadway Project Costs** (Thousands of 2014 US$ per lane-mile)[18]

Category	Re-construct and Widen Lane	Re-construct Existing Lane	Resurface and Widen Lane	Resurface Existing Lane	Improve Shoulder	Add Lane, Normal Cost	Add Lane, Equivalent High Cost	New Alignment, Normal	New Alignment, High
Rural									
Interstate									
Flat	$1,993	$1,302	$1,128	$462	$86	$2,561	$3,551	$3,551	$3,551
Rolling	$2,234	$1,335	$1,298	$492	$142	$2,777	$4,493	$4,493	$4,493
Mountainous	$4,235	$2,924	$2,151	$728	$297	$8,646	$10,121	$10,121	$10,121
Other Principal Arterial									
Flat	$1,556	$1,042	$941	$371	$57	$2,052	$2,937	$2,937	$2,937
Rolling	$1,757	$1,071	$1,069	$413	$96	$2,197	$3,546	$3,546	$3,546
Mountainous	$3,412	$2,411	$2,072	$583	$126	$7,756	$8,931	$8,931	$8,931
Minor Arterial									
Flat	$1,423	$915	$877	$329	$54	$1,865	$2,618	$2,618	$2,618
Rolling	$1,718	$1,013	$1,091	$354	$99	$2,138	$3,372	$3,372	$3,372
Mountainous	$2,854	$1,871	$2,072	$486	$224	$6,547	$7,857	$7,857	$7,857
Major Collector									
Flat	$1,499	$969	$905	$336	$69	$1,937	$2,617	$2,617	$2,617
Rolling	$1,640	$985	$1,018	$356	$93	$1,979	$3,220	$3,220	$3,220
Mountainous	$2,489	$1,541	$1,482	$486	$143	$4,191	$5,474	$5,474	$5,474
Urban									
Freeway/Expressway/Interstate									
Small Urban	$3,356	$2,324	$2,645	$564	$103	$4,211	$13,784	$5,675	$19,373
Small Urbanized	$3,608	$2,344	$2,736	$667	$137	$4,601	$15,117	$7,649	$26,114
Large Urban	$5,754	$3,837	$4,238	$895	$517	$7,700	$25,826	$11,220	$38,303
Major Urban	$11,509	$7,675	$8,224	$1,483	$1,034	$15,400	$64,219	$22,440	$85,845
Other Principal Arterial									
Small Urban	$2,925	$1,974	$2,420	$473	$105	$3,579	$11,691	$4,474	$15,270
Small Urbanized	$3,130	$1,998	$2,530	$559	$140	$3,878	$12,715	$5,520	$18,841
Large Urban	$4,471	$2,929	$3,702	$703	$451	$5,675	$18,961	$7,577	$25,864
Major Urban	$8,942	$5,857	$7,405	$1,135	$902	$11,350	$43,997	$15,154	$65,597
Minor Arterial/Collector									
Small Urban	$2,155	$1,491	$1,831	$346	$76	$2,643	$8,562	$3,228	$11,019
Small Urbanized	$2,258	$1,508	$1,848	$394	$93	$2,785	$9,050	$3,961	$13,520
Large Urban	$3,040	$2,017	$2,527	$483	$253	$3,861	$12,820	$5,155	$17,594
Major Urban	$6,080	$4,033	$3,822	$804	$507	$7,722	$43,997	$10,310	$54,445

This table indicates typical costs of various types of highway projects.

[18] FHWA (2020), "Appendix A: Highway Investment Analysis Methodology," *Status of the Nation's Highways, Bridges, and Transit*, USDOT (www.fhwa.dot.gov); at www.fhwa.dot.gov/policy/23cpr/appendixa.cfm.

Other Road Uses

It is sometimes argued that not all roadway costs should be charged to motorists. Even non-drivers use roads for walking and bicycling, goods deliveries and utility lines. This can be addressed by establishing a standard of "basic access" that is unrelated to vehicle traffic. In practice this can usually be satisfied by a single lane of light pavement, which is the road quality typically chosen when users purchase a driveway, and which exist in pedestrian cities and campuses. Roadway costs beyond this can be allocated to motor vehicle use. Since most communities have well-developed roadway systems that easily satisfy basic access, the need to increase roadway capacity usually results from motor vehicles' relatively large space requirements. Pedestrian and bicycle facility costs could be charged to motorist if vehicle traffic risk and delay creates the need for separate facilities. This implies that most current road expenditures can be charged to motor vehicle users.

Unit Costs and Cost Recovery

The *Cost Recovery Toll Calculator* (www.vtpi.org/CRTC.xlsx) uses FHWA values from Table 5.6.3-4 to calculate tolls required to repay projects costs. For entirely new roads the costs should be repaid by all users, but for roadway expansions to reduce congestion the costs should be charged to peak-period users. Table 5.6.3-5 shows peak-period cost-recover tolls assuming 4% annual depreciation over 30 years with 6,000 peak-period vehicles per lane 300 days per year. This indicates that cost recovery peak-period tolls are $0.20 to $2.65 for urban highway and $0.15 to $0.78 for major arterials.

Table 5.6.3-5 **Cost-Recovery Tolls for Urban Roadway Expansions**[19]

	2014 Costs		2021 Costs		Toll per Vehicle-mile	
Units	*Thousands*		*Thousands*		*Dollars*	
	Normal	High	Normal	High	Normal	High
Interstate						
Small Urbanized	$4,601	$15,117	$5,291	$17,385	**$0.19**	**$0.62**
Large Urbanized	$7,700	$25,826	$8,855	$29,700	**$0.32**	**$1.07**
Major Urbanized	$15,400	$64,219	$17,710	$73,852	**$0.64**	**$2.65**
Other Principal Arterial						
Small Urbanized	$3,579	$11,691	$4,116	$13,445	**$0.15**	**$0.48**
Large Urbanized	$3,878	$12,715	$4,460	$14,622	**$0.16**	**$0.52**
Major Urbanized	$5,675	$18,961	$6,526	$21,805	**$0.23**	**$0.78**

This table shows the tolls requires per peak-period vehicle-mile to repay typical roadway expansion costs assuming 4% annual discount over 30 years, and 6,000 peak-period vehicles per lane.

Embodied Resources

Roadway construction and operating have significant embodied energy and emissions.[20]

[19] VTPI (2021), *Cost Recovery Toll Calculator*, Victoria Transport Policy Institute; at www.vtpi.org/CRTC.xlsx.

[20] Greg Marsden, Kadambari Lokesh, and Danielle Densley-Tingley (2022), *Everything Counts: Why Transport Infrastructure Emissions Matter*, DeCarbon8 (https://decarbon8.org.uk); at https://bit.ly/33MHsya.

5.6.4 Estimates

Note: all values are in U.S. dollars unless otherwise indicated.

The Federal Highway Administration's, *Status of the Nation's Highways, Bridges, and Transit Conditions & Performance* report includes detailed information on the costs of expanding and maintaining transportation facilities, including appendices that provide detailed information on highways, bridges and public transit investments.[21]

The U.S. Federal Highway Administration's *Highway Statistics Reports*, Tables HF-10, provides information on total roadway expenditures and revenues by all levels of government.[22] The reports also include data on national and state population, vehicle ownership and vehicle travel, which can be used to calculate roadway costs, revenues and subsidies per capita, vehicle and vehicle-mile.

Resources

The following resources can help develop accurate roadway project cost projections:[23]

- *Consolidated Transportation Program Cost Estimate Program*, Maryland DOT (https://roads.maryland.gov/mdotsha/pages/Index.aspx?PageId=687).
- *Project Development Procedures Manual*, California State DOT (www.dot.ca.gov/hq/oppd/pdpm/pdpmn.htm).
- *Construction Cost Estimation Manual*, New Jersey DOT (www.state.nj.us/transportation/eng/CCEPM).
- *Transportation Estimators Association* (http://tea.cloverleaf.net).
- *Transport User Group* (http://tug.cloverleaf.net)—an independent association of State DOT personnel involved in cost estimating
- *Project Cost Estimating: A Synthesis of Highway Practice*, NCHRP Report 20-7 (https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1496) summarizes highway cost-estimating practices.
- The FHWA Office of Planning (www.fhwa.dot.gov/hep) provides information on cost-estimating practices and approaches used by transport planning organizations.
- The American Road and Transportation Builders Association (www.artba.org) provides construction cost forecasts at www.acppubs.com/articles/artba-2021-us-transportation-construction-market-forecast.

[21] FHWA (2020), *Status of the Nation's Highways, Bridges, and Transit Conditions & Performance 23rd Edition*, Federal Highway Administration (www.fhwa.dot.gov); at www.fhwa.dot.gov/policy/23cpr/appendixa.cfm.
[22] FHWA (various years), *Highway Statistics*, Federal Highway Administration (www.fhwa.dot.gov); at www.fhwa.dot.gov/policyinformation/statistics.cfm.
[23] Jim Sinnette (2004), "Accounting for Megaproject Dollars," *Public Roads*, FHWA (www.fhwa.dot.gov), July/August 2004; at www.tfhrc.gov/pubrds/04jul/07.htm.

General Studies

- The U.S. Federal Highway Administration's *Highway Economic Requirements System* evaluates highway improvement needs and benefits, and includes guidance on roadway impact analysis, and construction costs.[24]

- Table 5.6.4-1 summarizes the results of the most recent (1997) federal highway cost allocation study, showing cost responsibility, roadway user payments and external costs (roadway costs not paid by vehicle user payments) averaged over total travel.

Table 5.6.4-1 **Roadway Cost Responsibility Per Mile** (1997 Dollars)[25]

Vehicle Class	VMT (million)	Federal Costs	State Costs	Local Costs	Total Costs	Total User Payments	External Costs
Automobiles	1,818,461	$0.007	$0.020	$0.009	$0.035	$0.026	$0.009
Pickups and Vans	669,198	$0.007	$0.020	$0.009	$0.037	$0.034	$0.003
Single Unit Trucks	83,100	$0.038	$0.067	$0.041	$0.146	$0.112	$0.034
Combination Trucks	115,688	$0.071	$0.095	$0.035	$0.202	$0.157	$0.044
Buses	7,397	$0.030	$0.052	$0.036	$0.118	$0.046	$0.072
All Vehicles	*2,693,844*	*$0.011*	*$0.025*	*$0.011*	*$0.047*	*$ 0.036*	*$0.010*

- The Bureau of Transportation Statistic's *Transportation Economic Trends* report indicates that in 2020, the value of publically-owned U.S. transportation infrastructure totaled $4,918 billion.[26]

- The American Association of Highway and Transportation Officials (AASHTO) *Bottom Line* report, estimates that if U.S. annual vehicle travel grows at 1.4% it must spend $144 billion for roadway expansion, repair and maintenance, but if vehicle travel only grows 1.0% annually the required expenditures decline to $120 billion.[27] This suggests that a 0.4% growth in vehicle travel, which totals about 12 billion annual vehicle-miles, causes $24 billion in annual roadway costs, averaging about $2 per avoided VMT.

- Figure *5.6.4-1* illustrates regional transportation expenditures by mode, indicating that even in highly urbanized regions, highways receive the majority of funding. This suggests that the share of public resources invested in non-auto modes is significantly smaller than their demands.

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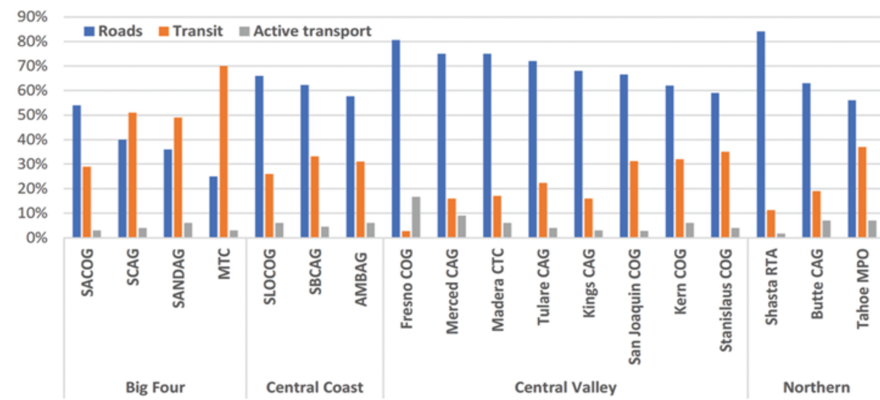
[24] FHWA (2002), *Highway Economic Requirements System: Technical Report*, Federal Highway Administration (www.fhwa.dot.gov); at http://bca.transportationeconomics.org/models/hers-st.
[25] USDOT (1997), *1997 Federal Highway Cost Allocation Study*, USDOT (www.dot.gov), tables II-6, IV-11, V-2.
[26] BTS (2020), *Transportation Economic Trends*, Bureau of Transportation Statistics (www.bts.dot.gov); at https://data.bts.gov/stories/s/ab7y-wzpz.
[27] AASHTO (2014), *The Bottom Line*, American Association of State Highway and Transportation Officials (www.aashto.org); at http://tinyurl.com/o5g23b9.

Figure 5.6.4-1 **Regional Transportation Expenditures by Mode**[28]



Even very urban regions spend the majority of their transportation funds on roads, and little on active modes.

- Transport Canada reports that in 2009–10, all levels of Canadian government spent $28.9 billion on roads, and collected $12.1 billion in fuel taxes and $4.4 billion in other transport user fees, indicating that user fees cover about 64% of roadway costs.[29]

- A Statistic Canada study found that roads and bridges made up the bulk (40%) of local, provincial and federal government infrastructure in Canada.[30] The value of roads per capita peaked at $3,019 in 1979 and declined to $2,511 in 2005 (in 1997 dollars).

- A New Zealand roadway cost allocation study that included roadway facility costs, accident and pollution externalities, concluded that cars pay 64% of their costs, trucks 56% of costs, and buses 68% of costs.[31] Cost recovery was higher (87%) on state highways than on local roads (50%). Rail transport is found to recover 77% of costs.

- CE Delft and ECORYS developed a standardized methodology for calculating total costs for road, rail and inland waterway, air and marine, taking into account infrastructure longevity, discount rates and allocation of shared costs.[32]

- In 2003, Graz, Austria (238,000 inhabitants) municipal government spent €60 million on automobile facilities and services (road, parking facilities and traffic services) compared

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28 Elizabeth Deakin, et al. (2021), *Evaluation of California State and Regional Transportation Plans and Their Prospects for Attaining State Goals*, UC Berkeley ITS (https://doi.org/10.7922/G2MP51KQ).

29 TC (2010), *Transport In Canada: An Overview*, Transport Canada (www.tc.gc.ca).

30 Francine Roy (2008), *From Roads to Rinks: Government Spending on Infrastructure in Canada, 1961 to 2005*, Isights on the Canadian Economy Research Papers, Statistics Canada (http://ssrn.com/abstract=1407694).

31 Booz Allen Hamilton (2005), *Surface Transport Costs and Charges Study*, Ministry of Transportation New Zealand (www.transport.govt.nz).

32 Ecorys Transport and Ce Delft (2005), *Infrastructure Expenditures and Costs: Practical Guidelines to Calculate Total Infrastructure Costs for Five Modes of Transport*, CE Delft (www.ce.nl) for the European Commission (www.ec.europa.eu); at https://bit.ly/3wQTSzh.

with vehicle user fee revenues of €21, a 35% cost recovery rate.[33] These subsidies average €169 annual per capita. Similar results were found in the cities of Genève, Switzerland (local automobile subsidies averaged €142 per capita in 2002) and Ferrara, Italy (local automobile subsidies averaged €44 per capita).

- A study of 258 transportation projects found significant cost underestimates, with greater underestimating for rail compared with highway projects, for tunnels compared with bridges, and for projects in developing countries and Europe compared with U.S. projects.[34]

- The study, "Sustainable Transportation Infrastructure Investments and Mode Share Changes: A 20-Year Background of Boulder, Colorado," analyzed that city's transportation infrastructure investments between 1990 and 2009. Boulder is considered a national leader in non-auto transportation planning so these values represent upper-bound levels. This only reflects municipal spending; the Colorado Department of Transportation makes large investments in state highways in that region, but spends just $2.83 annually per capita on walking and bicycling facilities according to the 2018 *Bicycling and Walking Benchmarking Report*.[35] According to regional travel surveys, during that period non-auto mode shares rose from about 38% to 48%, a 26% increase, compared with a 1.1 percentage point national decline, and Boulder's automobile shares decreased from about 62% to about 52%, a 16% decline, compared with a 2.9 percentage point national increase. This suggests that there is latent demand for non-auto travel, so improving non-auto travel conditions tends can significantly increase use of those modes and reduce driving in some communities.

Table 5.6.4-2 **Boulder Colorado Expenditures by Mode, 1990-2009**[36]

Mode	Operations	Enhancements	Totals	Annual Per Capita	Portion
	Millions of dollars			*Dollars*	*Percent*
Pedestrian	$45.1	$40.4	$85.6	$43	19%
Bicycling	$39.2	$45.5	$84.7	$42	17%
Public transit	$67.1	$12.3	$79.4	$40	16%
Roadways	$154.4	$54.2	$208.6	$104	46%
Totals	$305.8	$152.4	$458.3	$229	

This detailed study indicates that cities with ambitious non-auto transportation programs spend less than $100 annually per capita on walking and bicycling infrastructure.

33 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.

34 Bent Flyvbjerg, Mette Skamris Holm and Søren Buhl (2002), "Underestimating Costs In Public Works Projects: Error or Lie?," *Journal of the American Planning Association*, (www.planning.org/japa) Vol. 68, No. 3 Summer, pp. 279-295; at www.planning.org/japa/pdf/JAPAFlyvbjerg.pdf

35 ABW (2018), *Bicycling and Walking in the U.S.: Benchmarking Report*, Alliance for Biking & Walking, (www.peoplepoweredmovement.org); at https://bit.ly/3BUaEkE.

36 Alejandro Henao, et al. (2014), "Sustainable Transportation Infrastructure Investments and Mode Share Changes: A 20-Year Background of Boulder, Colorado," *Transport Policy* (DOI: 10.1016/j.tranpol.2014.09.012).

- Mansour-Moysey and Semmens calculate that highway user charges would need to increase about 30% to provide a normal 5% return on investment (i.e., for economic neutrality with most goods and industries that recover total costs).[37]

- A 2013 Conference Board of Canada study, *Where the Rubber Meets the Road*, estimates roadway costs and road user payment revenues in Ontario, Canada.[38] It concludes that road users pay 70-90% of road infrastructure costs, with higher rates in urban areas. It used three methods to estimate roadway costs: current expenditures, annualized capital expenditure approach (where depreciation and interest on the net current value of the capital stock is added to operating expenses), and a road inventory approach. It also estimated vehicle ownership and operating costs, accident costs, congestion costs, and environmental costs.

- Oh, Labi and Sinha estimate efficient VMT fees for the State of Indiana, assuming various expenditures and funding scenarios.[39] They found that a 2.9¢ per vehicle-mile fee would cover current state expenditures on state-administered highways. They evaluate how well potential fees self-finance of each facility class. The found that a flat fee results in urban motorists subsidizing rural motorists, rural Interstate users subsidizing rural non-Interstate users, and the urban non-Interstate users subsidizing urban Interstate users. Different VMT fee structures could achieve various equity goals.

- Millard-Ball (2021) developed an economic framework for optimizing street widths. He determined the widths, land areas, and land value of streets in 20 large U.S. counties.[40] The indicates that urban residential street rights-of-way average 55 ft. wide, far greater than the 16 ft. required for basic access, and this land has a total value of $959 billion.

- TeleCommUnity (2002) estimated that U.S. roadway rights-of-way total 22,437 square miles, with a value of $3,565 billion, or up to $10.9 trillion using a *comparable transaction valuation* methodology.[41] Using U.S. federal data they estimate that the entire roadway system has a present value of $4,676 billion, of which $3,565 billion (76%) is land value and $1,110 billion (24%) is for improvements.

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37 Nadia Mansour-Moysey and John Semmens (2001), Value of Arizona's State Highway System," *Transportation Research 1747,* Transportation Research Board (www.trb.org), pp. 3-11.

38 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 www.conferenceboard.ca/e-library/abstract.aspx?did=5697.

39 Jung Eun Oh, Samuel Labi and Kumares C. Sinha (2007), "Implementation and Evaluation of Self-Financing Highway Pricing Schemes," *Transportation Research Record 1996*, TRB (www.trb.org), pp. 25-33.

40 Adam Millard-Ball (2021), "The Width and Value of Residential Streets," *Journal of the American Planning Association* (DOI: 10.1080/01944363.2021.1903973).

41 TeleCommUnity (2002), *Valuation of the Public Rights-Of-Way Asset*, TeleCommUnity (www.telecommunityalliance.org); at www.telecommunityalliance.org/images/valuation2002.pdf.

- van Essen, et al. described infrastructure cost allocation methods, and estimated roadway costs for various vehicles and conditions.[42] Vermeulen, et al. (2004) apply this method to estimate infrastructure cost in The Netherlands, summarized below.

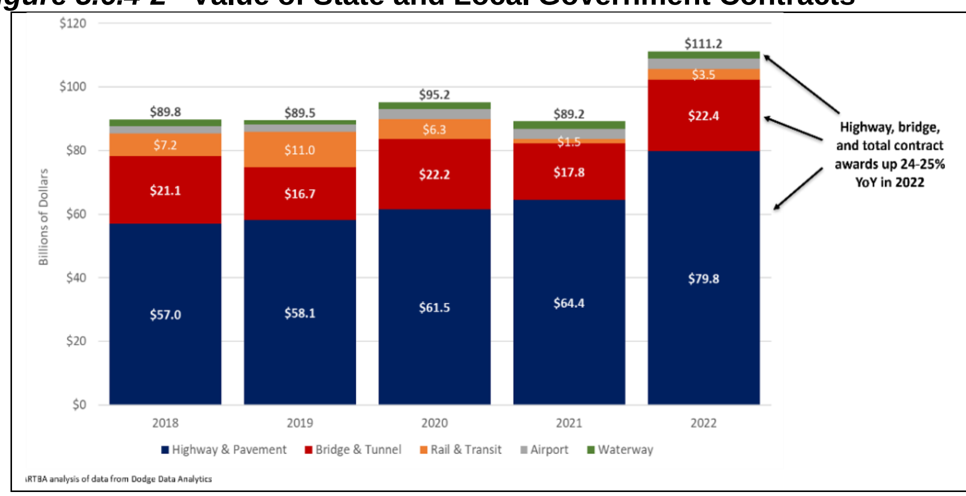
Table 5.6.4-2 **Variable Road Infrastructure Operating Costs** (€ct/vkm)[43]

Vehicle Category	Urban	Rural	Total
Freight Vehicles			
HGV, single unit < 12 t	24.16	0.76	10.12
HGV, single unit > 12 t	5.39	5.17	5.21
HGV, tr/tr comb. > 12 t	7.71	12.87	12.35
Passenger transport			
Car	0.50	0.16	0.24
Bus	7.99	7.78	7.93
Coach	7.43	10.91	10.21
Motorcycle	0.38	0.31	0.34
Moped, scooter	0.32	1.74	0.37
Light Goods Vehicle (truck or van)	1.93	0.18	1.05

This table indicates in Euro Cents per Vehicle-Kilometer the roadway costs of various vehicle types.

- The American Road & Transportation Builders Association (ARTBA) reports on U.S. transportation infrastructure expenditures. The figure below shows 2018-22 spending.

Figure 5.6.4-2 **Value of State and Local Government Contracts**[44]



In 2022, state and local transportation spending totalled $111 billion of which only $3.5 billion (3%) was for rail and transit projects.

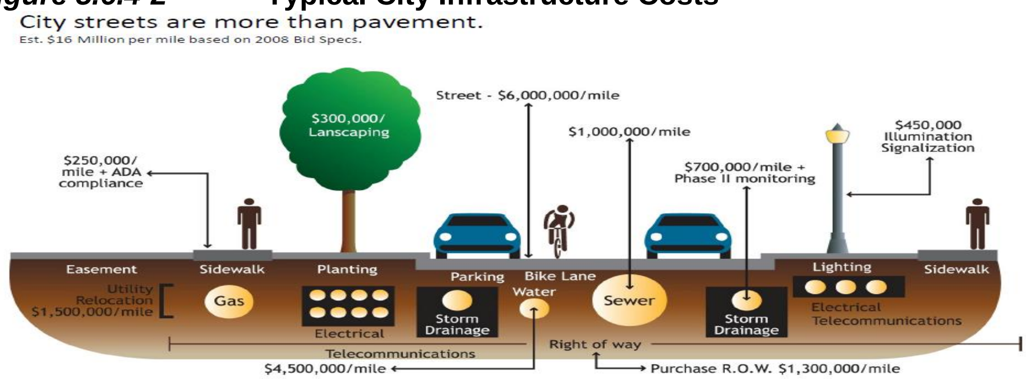
[42] van Essen, et al (2004), *Marginal Costs of Infrastructure Use*, CE Delft; in Vermeulen, et al (2004), *The Price of Transport: Overview of the Social Costs*, CE Delft (www.ce.nl); at www.osti.gov/etdeweb/biblio/20613327.
[43] Vermeulen, et al (2004), *The Price of Transport: Overview of the Social Costs of Transport*, CE Delft (www.ce.nl); at www.ce.nl/eng/pdf/04_4850_40.pdf.
[44] ARTBA (2023), *Economics and Market Analysis,* American Road & Transportation Builders Association (www.artba.org); at www.artba.org/economics.

- A University of Wisconsin-Madison study found that between 2004 and 2008, total (local, state and federal) expenditures on roads in Wisconsin averaged $4.24 billion annually, of which $2.50 billion came road user fees, $1.74 billion from general taxes (primarily property and sales taxes) and $600 million was borrowed, indicating that 41% to 55% of road funding (depending on how borrowing is repaid) is from non-users.[45] An average household pays $779 in general taxes to help finance roads, compared with $50 in road user fees devoted to public transit and $34 devoted to other investments.

- A Washington State Department of Transportation study surveyed total development costs for various highways and bridges.[46] Costs range from $1 million (for rural highway widening) to $188 million per lane-mile (for Boston's Big Dig).

- The Washington State Department of Transportation report, *Complete Streets and Main Street Highways: Case Study Resource* provides typical costs for various roadway design features, including sidewalks, bike lanes and lighting, as illustrated in the figure below.[47]

Figure 5.6.4-2 **Typical City Infrastructure Costs**



- A studded tire removes ½- to ¾-ton of roadway pavement during a typical 30,000-mile operating live, imposing an estimated $8-15 per tire in direct rutting costs and $40-50 per tire if the pavement adjacent to the rutted lane is also replaced.[48]

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[45] SSTI (2011), *Who Pays for Roads in Wisconsin?* State Smart Transportation Initiative, University of Wisconsin-Madison for 1000 Friends of Wisconsin (www.ssti.org).
[46] WSDOT (2005), *Highway Construction Costs: Are WSDOT's Highway Construction Costs in Line with National Experience?*, Washington State DOT (www.wsdot.wa.gov); at www.vtpi.org/WSDOT_HighwayCosts_2004.pdf.
[47] WSDOT (2011), *Washington's Complete Streets and Main Street Highways: Case Study Resource*, WSDOT (www.wsdot.wa.gov/LocalPrograms/Planning) at www.wsdot.wa.gov/research/reports/fullreports/780.1.pdf.
[48] BRCT (2000), *Accords and Options*, Washington State Blue Ribbon Commission on Transportation (www.leg.wa.gov), p 15.

Goods Movement

- Forkenbrock estimates that large intercity trucks cost an average of 0.25¢ per ton-mile of freight shipped in uncompensated roadway costs.[49]

- Lenzi and Casavant estimate the roadway damage costs of trucks to range from 1¢ to 6¢ per ton-mile on state highways, with an average of 5¢, and 2-9¢ per ton-mile on county roads, with an average of 7.5¢.[50] They also estimate the roadway damage costs of overloaded trucks to range from 8¢ to $2.50 per ton-mile, depending on weight.[51]

- Trucks impose marginal infrastructure costs averaging 67¢ Canadian per tonne kilometer (82¢ U.S. per ton-mile).[52] Although heavy trucks make up only about 9% of Canadian vehicle traffic they account for about 25% of roadway costs.

- A study for the New Zealand Transportation Agency found that highway users pay only 40% of total roadway infrastructure costs, representing a $1.5 billion dollar annual subsidy.[53] This results from different ownership models for different transport infrastructure. Ports are largely operated commercially, providing a financial return on economic investments (capital and land). The rail network is state owned and receives an explicit $90 million annual subsidy to cover operating costs. In contrast, the highway network is estimated to be worth $20 billion, but user fees provide no return on capital investments. This makes highway travel in general and truck shipping in particularly relatively cheaper than its competitors.

- The PaveSim computer program developed at the University of Iowa calculates the pavement wear for various types of vehicles under various road conditions.[54]

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[49] David Forkenbrock (2001), "Comparison of External Costs of Rail and Truck Freight Transport," *Transportation Research A*, Vo. 35, No. 4 (www.elsevier.com/locate/tra), pp. 321-337.
[50] Kenneth Casavant and Jerry Lenzi (1989), "Rail Line Abandonment and Public Acquisition Impacts on Economic Development," *Transportation Research Record 1274*, TRB (www.trb.org), pp. 241-251.
[51] Kenneth Casavant and Jerry Lenzi (1993), *Fee and Fine Structure for Overloaded Trucks in Washington*, Transportation Quarterly (www.enotrans.com/Newsmain.htm), Vol. 47, No. 2, April, pp. 281-294.
[52] Transport Concepts (1994), *External Costs of Truck and Train*, Transport Concepts (Ottawa), p.26.
[53] Rockpoint Corporate Finance (2009), Coastal Shipping and Modal Freight Choice, New Zealand Transport Agency (www.nzta.govt.nz); at www.rockpoint.co.nz/publications/Rockpoint%20Coastal%20Shipping.pdf.
[54] M. Asghar Bhatti, Baizhong Lin, Paul Taylor and Leslie Hart (1997), *PAVESIM: Simulation of Pavement Damage Due to Heavy Vehicles*, University of Iowa Public Policy Center (https://trid.trb.org/view/536734).

Pedestrian and Bicycling Facilities

- Sidewalk construction typically costs $5-10 per square foot, totaling $1,250-2,500 for a 5-foot sidewalk on a 50-foot house frontage. This cost averages about $50 per year or $20 per capita assuming 2.5 residents per household. Well-built sidewalks typically last 20-40 years and require minimal maintenance, excepting occasional snow clearing. This suggests that construction and maintenance of a comprehensive sidewalk network probably costs $30-50 annually per capita.

- The table below summarizes costs of various active transportation facilities, although more specific cost data should be used when available.

Table 5.6.4-3 **Active Transportation Facility Costs**[55, 56, 57]

Measure	Typical Costs (2012 U.S. Dollars)
Sidewalks (5-foot width)	$20-50 per linear foot
Marked crosswalk	$100-300 for painted crosswalks, $3,000 for patterned concrete.
Pedestrian refuge island	$6,000-9,000, depending on materials and conditions.
Path (5-foot asphalt)	$30-40 per linear foot
Path (12-foot concrete)	$80-120 per linear foot
Bike lanes	$10,000-50,000 per mile to modify existing roadway (no new construction)
Bicycle parking	$100-500 per bicycle for racks, and $2,000 per locker
Center medians	$150-200 per linear foot
Curb bulbs	$10,000-20,000 per bulb
Curb ramps	$1,500 per ramp.
Chokers	$7,000 for landscaped choker on asphalt street, $13,000 on concrete street.
Curb bulbs	$10,000-20,000 per bulb.
Traffic circles	$4,000 for landscaped circle on asphalt street, $6,000 on concrete street.
Chicanes	$8,000 for landscaped chicanes on asphalt streets, $14,000 on concrete streets.
Traffic signs	$75-100 per sign.
Speed humps	$2,000 per hump
Traffic signals	$15,000-60,000 for a new signal
Traffic signs	$75-100 per sign.
Traffic circles	$4,000 for landscaped circle on asphalt street and $6,000 on concrete street.

This table summarizes examples of active transport facility costs.

- U.S. federal and state departments of transportation typically spend $1 to $3 annually per capita on special walking and bicycling facilities.[58, 59] People walk and bicycle on roads, but because of their small size and light weight, this imposes minimal road wear costs.

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[55] Max A. Bushell, et al. (2013), *Costs for Pedestrian and Bicyclist Infrastructure Improvements*, Pedestrian and Bicycle Information Center (www.walkinginfo.org); at https://bit.ly/30tR53m.

[56] Kevin J. Krizek, et al. (2006), *Guidelines for Analysis of Investments in Bicycle Facilities*, NCHRP Report 552, TRB (www.trb.org); at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_552.pdf.

[57] Charles Zeeger, et al (2002), *Pedestrian Facilities Users Guide*, Pedestrian and Bicycle Information Center (www.pedbikeinfo.org); at www.fhwa.dot.gov/publications/research/safety/01102/01102.pdf.

[58] ABW (2018), *Bicycling and Walking in the U.S.: Benchmarking Report*, Alliance for Biking & Walking, (www.peoplepoweredmovement.org); at https://bikeleague.org/benchmarking-report.

[59] Marisa Jones (2021), *Investing in Health, Safety and Mobility*, Safe Routes Partnership (www.saferoutespartnership.org); at https://bit.ly/3E6uaty.

- The study, *Cost Analysis of Bicycle Facilities* includes the following summary table.

Table 5.6.4-4 **Active Transportation Facility Costs** (60)

Category	Facility Type	Cost
Bike Lanes	Line/stripe removal	$0.62/ft
	Bike Lanes	$0.83-$6.35/ft
	Buffered Bike Lane	$2-$9.33/ft
	Bike Lane Stencil	$250-$270/stencil
Signs and Markings	Remove existing sign	$129/sign
	Remove and Reinstall existing signs	$140/sign
	New stop sign	$150/sign
	Wayfinding sign	$200-$440/sign
	Sharrow	$250-339/sharrow
Flow, Volume, Speed Management	Bike-Thru Median	$721/ft
	Speed Hump	$2,500-$2,800/hump
	Chicanes	$5,000/chicane
	Traffic Circles	$20,000/circle
Intersections and Crossings	Pedestrian and Bicycle crossing signs	$200/sign
	Crosswalk	$1,000/crosswalk
	Raised Crosswalk	$3,500/crosswalk
	Two-stage turn queue box	$1,000/box
	Bike Box	$5,000/box
	Standard Curb Extension	$15,600/extension
	Green Curb Extension	$28,397/extension
	Refuge Island	$1,700-$21,580/island
	Rectangular Rapid Flash Beacon	$7,500-$20,250/RRFB
	Bicycle Signal Head	$5,000/signal
	Bicycle Loop Detection	$6,630-$7,730/lane
	Bicycle Signal Push Button Actuation	$3,000/pole
	Complete Bicycle Signal Retrofit	$52,201/signal
	HAWK Signal	$150,000/intersection
	Full Signal	$140,000-$250,000/intersection
Bicycle Boulevards	Bicycle Boulevard	$9.49-$27.20/ft
Cycle Tracks	At Grade Cycle Track	$24.79/ft
	One Way Raised Cycle Track	$68.16/ft
	Two Way Raised Cycle Track	$188-$698/ft
End of Trip Facilities	Bike Racks	$200/rack
	Bicycle Corral	$3,000/corral

This study developed estimates of various pedestrian and bicycle facilities in 2013 U.S. dollars.

- The *Nonmotorized Transportation Pilot Program* invested about $100 per capita in pedestrian and bicycling improvements in four typical U.S. communities (Columbia, MO; Marin County, CA.; Minneapolis, MN; and Sheboygan County, WI).[61] This increased walking trips 23% and bicycling trips 48%, reduced total vehicle-miles about 3%, and recued active mode crash rates.
- The Washington State Department of Transportation (WSDOT) 2020 *Draft Active Transportation Plan* estimates that upgrading the state transportation system to maximize active travel safety would cost $5.7 billion, which is approximately $750 per capita.[62] If implemented over ten years it would cost about $75 annual per capita and represent about 13% of the WSDOT budget.
- Dutch cities typically spend €10 to €25 annually per capita on cycling facilities, which is considered high and results in high rates of cycling activity.[63]

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[60] Lynn Weigand, Nathan McNeil and Jennifer Dill (2013), *Cost Analysis of Bicycle Facilities: Cases from Cities in the Portland, OR Region*, Portland State University and Robert Woods Johnson; at https://bit.ly/3Oy9DSI.
[61] FHWA (2014), *Nonmotorized Transportation Pilot Program*, John A Volpe National Transportation Systems Center, USDOT (www.fhwa.dot.gov); at https://bit.ly/1KakRWU.
[62] WSDOT (2020), *Draft Active Transportation Plan Part 1*, Washington State Dept. of Transportation (www.wsdot.wa.gov); at https://bit.ly/2OgQk7d.
[63] Fietsberaad (2008), *Cycling in the Netherlands*, Ministry of Transport, Public Works and Water Management (www.verkeerenwaterstaat.nl/english/); at https://bit.ly/3kIlfp9.

- A city engineering study found that approximately 40% of Denver, Colorado's sidewalks are missing or substandard, and filling these gaps would cost between $273 million and $1.1 billion, averaging $14 and $50 annually per capita. The city's new Ordinance 307 will collect special property taxes averaging approximately $50 annually per capita to upgrade and complete the city's sidewalk network over three decades.[64]
- The city of Los Angeles has an estimated 10,750 miles of sidewalks, of which roughly 40% are rated inadequate. A 2016 class-action lawsuit by disability rights advocates requires the City (population 3.8 million) to spend $1.4 billion over 30 years to fix its sidewalks, averaging about $12 annual per capita.[65]
- A British described typical costs of various bicycling facilities as summarized below.

Table 5.6.4-5 Typical Cycling Intervention Costs[66]

Scheme Type	Range of costs	Range of costs
Cycle Superhighway	£1.15-1.45m/km £0.24m/km	two-way physically segregated two-way lightly segregated
Mixed Strategic Cycle Route	£0.46-0.88m/km	
Resurfaced cycle route	£0.14-0.19m/km	canalside routes
Cycle bridge	£0.10-0.50m	bridge upgrades not whole new bridges
20 mph zone	£10,000-15,000/km £2,000-3,000/km	including traffic calming measures without any traffic calming measures
Remodelled major junction	£1.56-1.61m £0.24m	cycling-specific schemes cycling piggybacking on traffic measures
Cycle crossing at major road	£0.14-0.41m	
Area-wide workplace cycle facilities	£0.20-0.75m £6,000-7,000	programme cost cost per workplace grant
Area-wide school and college cycle facilities	£0.22-1.16m £8,000-110,000	programme cost cost per school
Large-scale cycle parking	£2.5m £0.12-0.70m	for a very large bike park for 3,000 bikes for secure bike parks for 10s - 100+ bikes, including changing and showers at the largest
Large-scale provision of bicycles	£1.41m £350	programme cost cost per bike provided
Comprehensive cycle route signage	£12,000/km	
Automatic cycle counters	£28,000 £6,000	programme cost for one cross-city route cost per counter

This study estimated typical costs for various cycling interventions, in 2017 Pounds, based on UK examples.

- Victoria, British Columbia has targets to double active travel from about a quarter to half of local trips. To achieve this goal the city spends about $14 annually per capita on sidewalks and $35 annually per capita on bikeways, and the regional government spends about $12 annual per capita on recreational trails, totalling about $60 annual per Victoria resident.[67] This represents the higher range of local expenditures on active transportation facilities.
- Ithaca, New York charges $70 annually per household (about $30 annual per capita) and $185 per business to build and maintain city sidewalks.[68]

[64] DE (2019), *Denver Moves: Pedestrians & Trails*, City of Denver (www.denvergov.org); at https://bit.ly/3QiOOxm.
[65] Donald Shoup (2022), "A Faster Path to Safer Sidewalks," *Bloomberg* (https://bloom.bg/3ClZjdj).
[66] Ian Taylor and Beth Hiblin (2017), *Typical Costs of Cycling Interventions*, Transport for Quality of Life (www.transportforqualityoflife.com); at https://bit.ly/2wYO74X.
[67] Todd Litman (2021), *Evaluting Bikeway Criticism*, VTPI (www.vtpi.org); at www.vtpi.org/ebc.pdf.
[68] Ithica (2014), *Sidewalk Policy*, City of Ithica (www.cityofithaca.org); at https://bit.ly/2JwOQTC.

- Using detailed field data from Albuquerque, New Mexico, Corning-Padilla and Rowangould estimated that improving all sidewalks to optimum standards would cost approximately $54 million, $60 per capita, or about $6 annual per capita if implemented in ten years.[69]
- Because e-bikes can travel faster and further, carry heavier loads, and climb steeper inclines than pedal bikes they approximately double the portion of trips that can be made by bicycle, increasing the value of bicycle facilities.[70]

Many people assume that walkers and bicyclists pay less than their share of roadway costs because they pay no fuel taxes, but the local roads where most active travel occurs are mainly funded through general taxes that residents pay regardless of their travel activity.[71]

Most road space is currently allocated to automobile facilities: higher-speed traffic lanes and on-street parking.[72, 73] Few roads have bikelanes or low traffic speeds that ensure safe bicycling conditions. Many urban streets have sidewalks that use 5-15% of road rights-of-way (e.g., 4-8 feet of a 40-60 foot ROW), but sidewalk networks tend to be incomplete, particularly on suburban and rural roads, so they probably represent just 2-4% of total roadway rights-of-way (see sidewalk inventory maps such as [Geoinformation and Big Data Research Laboratory maps] and [MORPC Sidewalk Inventory]).

The Transportation Research Board report, *Guide for Roadway Cross Section Reallocation* recommends that urban roadway design emphasize multimodal safety, so busy, high-speed streets provide more space for non-auto modes.[74] The study, *Fair Street Space Allocation: Ethical Principles and Empirical Insights* identified 14 factors to consider when allocating street space. The researchers found that in Berlin, Germany, car users received, on average, 3.5 times more road space than non-car users. They conclude that by virtually any equity-based allocation method, current levels of on-street car parking are unjustified and bicycling deserves more space. The study *Street Space Allocation and Use in Melbourne's Activity Centres*, compared urban street space allocation with traveller volumes.[75] It found that pedestrian receive less than their share of space (pedestrians represent 56% of street users but receive just 33% of street space), while other users receive more, including on-

[69] Alexis Corning-Padilla and Gregory Rowangould (2020), "Sustainable and Equitable Financing for Sidewalk Maintenance," *Cities*, Vo. 107 (doi.org/10.1016/j.cities.2020.102874).
[70] Michael McQueen, John MacArthur and Christopher Cherry (2020), "The E-Bike Potential: Estimating Regional E-bike Impacts on Greenhouse Gas Emissions," *Trans. Res. D* (doi.org/10.1016/j.trd.2020.102482).
[71] Todd Litman (2022), *Fair Share Transportation Planning: Estimating Non-Auto Travel Demands and Optimal Infrastructure Investments*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/fstp.pdf.
[72] Felix Creutzig, et al. (2020), "Fair Street Space Allocation: Ethical Principles and Empirical Insights," *Transport Reviews*, 40:6, 711-733 (DOI: 10.1080/01441647.2020.1762795).
[73] Stefan Gössling, et al. (2016), "Urban Space Distribution and Sustainable Transport," *Transport Reviews* (http://dx.doi.org/10.1080/01441647.2016.1147101).
[74] Conor Semler, et al. (2022), *Guide for Roadway Cross Section Reallocation*, Draft NCHRP Report 1036, Transportation Research Board (www.trb.org); at www.trb.org/Publications/Blurbs/182870.aspx.
[75] C. De Gruyter, S.M. Zahraee and W. Young (2021), *Street Space Allocation and Use in Melbourne's Activity Centres: Working paper*, RMIT University and Monash University, Victoria, Australia; at https://bit.ly/3Xim7n2.

street car parking (13% of users vs. 21% of space), general traffic/bus lanes (29% of users vs. 42% of space), and bicycle lanes (2% of users vs. 12% of total space). By measuring *trips* rather than the time people spent using streets this analysis undercounts non-travel activities (such as window-shopping sidewalk café dining) and undervalues slower modes.

Other studies evaluate the efficiency and fairness of curb space allocation. The study, *Curb Space and Its Discontents: Evaluating and Allocating New York City's Curbs*, found that a disproportionate share of New York City's curb space (more than two thirds) is devoted to free parking.[76] It concludes that this is inefficient and unfair, since it increases congestion, crash risk and pollution, and reduces accessibility by non-auto modes. The Institute of Transportation Engineers' *Curbside Management Practitioners Guide*,[77] and the International Transport Forum's, *Shared-Use City: Managing the Curb*[78] provide guidance for efficient and equitable curb management. Both emphasize the need for better data concerning curb space allocation and use, and better management to support strategic goals such as supporting resource-efficient modes. The figure below illustrates potential uses that should be considered and balanced when allocating curb space.

Table 5.6.4-6 **Potential Curb Space Uses** (79)

Curb management should balance the needs of various potential uses for efficiency and fairness.

The report, *Reclaim the Kerb: The Future of Parking and Kerbside Management in London* surveyed residents concerning their priorities for allocation of street space in their local areas. It found that Londoners prioritize trees and green space, clutter-free pavements and children's play spaces over on-street residential parking, as indicated in the following figure. To support the city's strategic goals the study recommends that that road and kerb space be allocated in accordance with clear user hierarchies, that the city limit the number of

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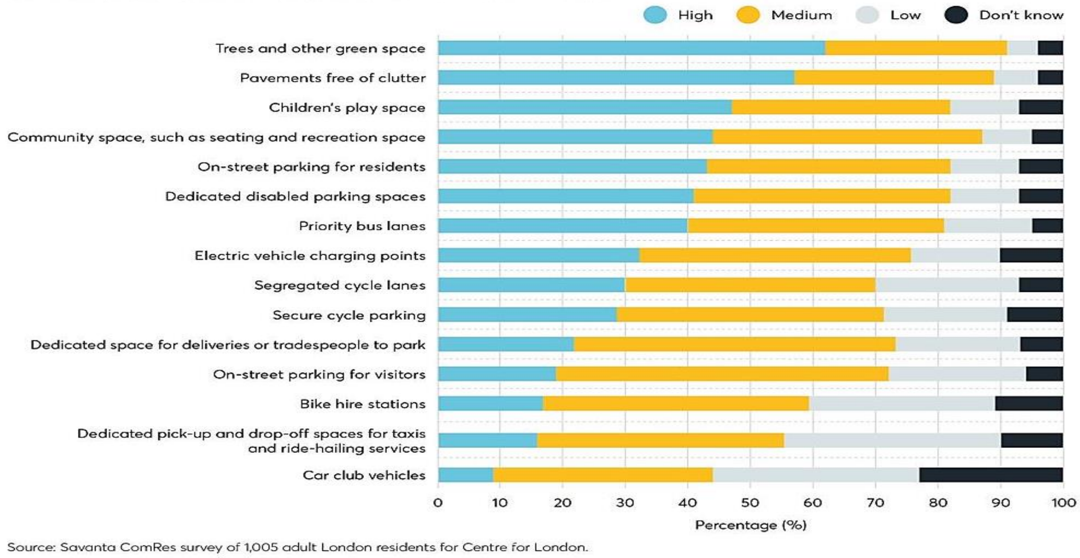
[76] Daniel Comeaux (2020), *Curb Space and Its Discontents: Evaluating and Allocating New York City's Curbs*, New York City Department of Transportation (www.hks.harvard.edu); at https://bit.ly/3zhJ7cc.
[77] ITE (2019), *Curbside Management Practitioners Guide*, ITE (www.ite.org); at https://bit.ly/2Lp2g4S.
[78] ITF (2018), *The Shared-Use City: Managing the Curb*, International Transport Forum (www.itf-oecd.org); at www.itf-oecd.org/sites/default/files/docs/shared-use-city-managing-curb_5.pdf.
[79] ITE (2019); at https://bit.ly/2Lp2g4S.

permits issued, price permits to fully recover costs, and move towards an emission-based charging structure for resident permits, and escalating charges for additional vehicles.

Table 5.6.4-6 **Londoners' Preferences for Street Space Uses**[80]



Most Londoners prioritize green space, walkability and play spaces over on-street parking

Active transport facility unit costs (dollars per foot or mile) tend to increase with population density – for example, city center sidewalks must be wider, and bikelanes compete for valuable road space with traffic and parking lanes – but because their use also increases with density their costs per capita, user and travel-mile tend to decrease.

Overall, these studies suggest that most communities currently spend $30 to $50 annually per capita on walking and bicycling facilities (sidewalks, crosswalks, multi-use paths and bike parking), either through government expenditures or mandates for property owners to build and maintain sidewalks. This spending level results in incomplete and inadequate faciliites. Building and maintaining a comprehensive network of active mode facilities that meets performance standards would require doubling investments to $50-100 annual per capita, and sometimes more for recreational trails. Improving walking and bicycling conditions tends to increase travel by these modes and reduce automobile travel.

[80] CfL (2020), Reclaim The Kerb: The Future of Parking and Kerbside Management in London. London: Centre for London (www.centreforlondon.org); at https://bit.ly/3OkAjrB.

5.6.5 Variability

Road costs vary greatly depending on vehicle type, travel conditions, location, and perspective. Larger and heavier vehicles impose more wear and require larger and stronger facilities, which significantly increases costs. Rural and local roads have lower costs per lane-mile, but due to low traffic volumes tend to have high costs per vehicle-mile of travel.

There are several possible ways to measure roadway costs. Most published estimates reflect average government expenditures on roads, but many analyses, such as optimal pricing or project evaluations, should reflect marginal costs, the incremental costs of accommodating vehicle travel at a particular time and location. For example, although maintaining existing roads only costs a few cents per vehicle-mile, accommodating additional vehicle travel on congested urban roadways typically costs an order of magnitude more than what motorists pay in fuel taxes (e.g., $0.40 to $2.00 per vehicle-mile compared with about 4₵ per mile in taxes).

Table 5.6.5-1 **Costs Included**

	Average Costs	SRMC	LRMC	Cost Recovery
Roadway land value			✓	
Land acquisition costs	✓			✓
Construction costs	✓		✓	✓
Repair/Operating Costs	✓	✓	✓	✓

This table compares the costs typically considered when calculating Average Costs, Short Run Marginal Costs (SRMC), Long Run Marginal Costs (LRMC) and Project Cost Recovery. Average costs and cost recovery divide total costs by total mileage by each vehicle type; marginal costs estimate the incremental costs of travel at a particular time and location.

5.6.6 Equity and Efficiency Issues

Roadway costs are partly internalized through special user fees, but there are often additional external costs. In the U.S. and Canada, most major highway costs can be considered internalized through user fees, but most local roadway costs can be considered external. Non-drivers tend to subsidize drivers through local road budgets. To the degree that road user fees do not accurately reflect the roadway costs imposed by individual vehicles, they can be considered inequitable and inefficient.

5.6.7 Conclusions

In the U.S. in 2018, total roadway costs average 6.9₵ per vehicle-mile of which 3.3₵ is funded by user taxes and 3.6₵ can be considered external. Although a minimal road system is needed for basic access, most current road expenditures can be attributed to vehicle use. This estimate understates total roadway cost because it includes no return-on-investment charge (past capital expenditures are treated as sunk costs), and ignores deferred expenditures needed to maintain current performance.

Urban road costs tend to be higher than rural costs per vehicle-mile, so urban driving costs are increased and rural costs decreased by 25%. Since electric vehicles pay no fuel taxes, their road costs are all external. Rideshare passengers are considered to impose no additional roadway costs. Since public transit buses are often exempt from some fuel taxes their total cost is used, but this would not apply where such exemptions do not exist. A trolley that travels on tracks does not impose road wear costs, but comparable public costs are required to maintain rails and right-of-way.

A minor portion (perhaps 3-5%) of transportation budgets are devoted to sidewalks, bike lanes and other active transportation facilities. The costs of these facilities can be assigned to users of those modes or to motorists, since separated facilities are needed to reduce the risks and discomfort that motor vehicle traffic imposes on nonmotorized travel; areas with little or no motor vehicle traffic often have no sidewalks and bicyclists and pedestrians can safely use the street. Bicycling and walking cause minimal pavement wear and require much less road space than motor vehicles, so their cost is estimated to be 5% of an automobile. Telework imposes no road facility costs.

Estimate **Road Facility External Costs (2007 U.S. Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.026	0.026	0.016	0.021
Compact Car	0.026	0.026	0.016	0.021
Electric Car	0.064	0.064	0.038	0.051
Van/Light Truck	0.035	0.035	0.021	0.028
Rideshare Passenger	0.000	0.000	0.000	0.000
Diesel Bus	0.048	0.048	0.029	0.038
Electric Bus/Trolley	0.048	0.048	0.029	0.038
Motorcycle	0.014	0.014	0.008	0.011
Bicycle	0.002	0.002	0.001	0.002
Walk	0.002	0.002	0.001	0.002
Telework	0.000	0.000	0.000	0.000

Automobile Cost Range

Minimum and Maximum values based on US estimates cited above.

Minimum	Maximum
$0.01	$0.04

5.6.8 Information Resources

Information sources on roadway costing are described below.

AASHTO (2007), *Comparing State DOTs' Construction Project Cost and Schedule Performance*, Quality Information Center (www.transportation.org), AASHTO; at https://bit.ly/3rud3hz.

AASHTO (2014), *The Bottom Line*, American Association of State Highway and Transportation Officials (www.aashto.org); at http://tinyurl.com/o5g23b9.

ABW (2018), *Bicycling and Walking in the U.S.: Benchmarking Report*, Alliance for Biking & Walking, (www.peoplepoweredmovement.org); at https://bikeleague.org/benchmarking-report.

Mohammed Alam, Darren Timothy and Stephen Sissel (2005), "New Capital Cost Table for Highway Investment Economic Analysis," *Transportation Research Record 1932*, TRB (www.trb.org), pp. 33-42; summary at http://trrjournalonline.trb.org/doi/abs/10.3141/1932-05.

APTA (annual reports), *Public Transportation Fact Book*, American Public Transportation Association (www.apta.com); at www.apta.com/research-technical-resources/transit-statistics.

Patrick Balducci and Joseph Stowers (2008), *State Highway Cost Allocation Studies: A Synthesis of Highway Practice*, NCHRP Synthesis 378; at www.nap.edu/download/14178.

Max A. Bushell, et al. (2013), *Costs for Pedestrian and Bicyclist Infrastructure Improvements*, Pedestrian and Bicycle Information Center (www.walkinginfo.org); at https://bit.ly/3o8JG1t.

Cambridge Systematics (2011), *Determining Highway Maintenance Costs*, NCHRP Report 688, Transportation Research Board (www.trb.org); at www.trb.org/Publications/Blurbs/165504.aspx.

Janelle Cammenga (2019), *How Are Your State's Roads Funded?*, Tax Foundation (https://taxfoundation.org); at https://taxfoundation.org/states-road-funding-2019.

CE Delft, (2019), *Overview of Transport Infrastructure Expenditures and Costs*, European Commission (http://europa.eu); at https://bit.ly/3oqsUhZ.

Jeff Davis (2021), *Explainer: What the "80-20 Highway-Transit Split" Really Is, and What it Isn't*, Eno Foundation (www.enotrans.org); at https://bit.ly/3BZD4Xz.

Tony Dutzik, Gideon Weissman and Phineas Baxandall (2015), *Who Pays for Roads? How the "Users Pay" Myth Gets in the Way of Solving America's Transportation Problems*, US PIRG (https://uspirg.org); at https://bit.ly/2G3q1NI.

Ecorys Transport and Ce Delft (2005), *Infrastructure Expenditures and Costs: Practical Guidelines to Calculate Total Infrastructure Costs for Five Modes of Transport*, CE Delft (www.ce.nl) for the European Commission (www.ec.europa.eu); at https://bit.ly/3knCrAC.

FHWA (annual reports), *Highway Statistics*, FHWA (www.fhwa.dot.gov/policyinformation/statistics.cfm).

FHWA (2000), *1997 Federal Highway Cost Allocation Study Final Report*, Federal Highway Administration (www.fhwa.dot.gov); at www.fhwa.dot.gov/policy/otps/costallocation.cfm.

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/30wpfCR.

Stefan Gössling, et al. (2019), "The Social Cost of Automobility, Cycling and Walking in the European Union," *Ecological Economics*, Vol. 158, pp. 65-74 (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).

Todd Litman (2013), *Whose Roads? Evaluating Bicyclists' and Pedestrians' Right to Use Public Roadways*, Victoria Transport Policy Institute (www.vtpi.org); at http://www.vtpi.org/whoserd.pdf.

Greg Marsden, Kadambari Lokesh, and Danielle Densley-Tingley (2022), *Everything Counts: Why Transport Infrastructure Emissions Matter*, DeCarbon8 (decarbon8.org.uk); at https://bit.ly/33MHsya.

NCHRP (2007), *Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction*, NCHRP Report 574, Transportation Research Board (www.trb.org); at www.trb.org/Main/Public/Blurbs/158464.aspx.

NSTIFC (2009), *Paying Our Way: A New Framework Transportation Finance*, Final Report of the National Surface Transportation Infrastructure Financing Commission (http://financecommission.dot.gov); at https://bit.ly/3sHdQuk.

Edward Sullivan, et al. (2008), *Web-Based Guide To Transportation Benefit-Cost Analysis*, *ASCE Journal of Transportation Engineering*, Vo. 134, No. 7, pp. 282-286; at https://bit.ly/3aIgAmz.

Ian Taylor and Beth Hiblin (2017), *Typical Costs of Cycling Interventions: Interim Analysis of Cycle City Ambition Schemes*, Transport for Quality of Life (www.transportforqualityoflife.com).

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

Turner Construction Cost Index (www.turnerconstruction.com/corporate/content.asp?d=20) tracks construction industry cost trends.

van Essen, et al (2004), *Marginal Costs of Infrastructure Use – Towards a Simplified Approach*, CE Delft (www.ce.nl/eng).

Marie-Eve Will, Yannick Cornet and Talat Munshi (2020), "Measuring Road Space Consumption by Transport Modes: Toward a Standard Spatial Efficiency Assessment Method and an Application to the Development Scenarios of Rajkot City, India," *Journal of Transport and Land Use*, Vo. 13, 1 pp. 651–669 (https://doi.org/10.5198/jtlu.2020.1526).

WSDOT (2005), *Highway Construction Costs: Are WSDOT's Highway Construction Costs in Line with National Experience?* (www.wsdot.wa.gov); at www.vtpi.org/WSDOT_HighwayCosts_2004.pdf.