POLLUTION AND ENERGY CONSUMPTION OF RAILROAD TRANSPORTATION

A
TECHNICAL REPORT
TEXAS RAIL SYSTEM EVALUATION

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY
MARCH 1977

POLLUTION AND ENERGY CONSUMPTION OF RAILROAD TRANSPORTATION

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Texas Rail System Evaluation
Technical Report

Texas Transportation Institute
Texas A&M University

January, 1977

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INTRODUCTION

In order to make rational decisions with regard to the public assistance that might be necessary to maintain a viable transportation system for Texas, the decisionmakers should have knowledge of the energy consumption and pollution emission characteristics of competing modes of transportation. This is especially true with respect to energy consumption at the time when the nation is being made acutely aware of its dwindling supply of petroleum fuels used by motor vehicles, airplanes, and locomotives.

The emphasis is on fuel efficiency and conservation in all modes of transportation. As prices of petroleum fuels continue to increase, the mode of transportation that is the most fuel efficient in transporting people and goods will become more and more attractive to commuters and shippers. Also, other fuels, such as coal (converted to gas or electricity), will be used more and more to furnish the energy needs of competing modes of transportation.

As our cities in Texas and the Nation continue to grow, it will become increasingly difficult to maintain clean air to breathe. Therefore, the mode of transportation which pollutes the air the least will become more and more desirable, especially in the major urban areas of the State. All forms of pollution (air, noise, water, etc.) are receiving more and more attention in the quest to maintain a healthy and pleasing environment for everyone.

ENERGY CONSUMPTION CHARACTERISTICS OF TRANSPORTATION

Criteria for Intermodal Comparisons

The energy consumed to transport people and goods depends on many factors such as: mode of travel, location of travel, route taken, type of fuel used, speed of travel, size and weight of load, weight of vehicle, number of stops and speed changes, vehicle idling time, length of trip, condition of travel facilities, and weather conditions. The number and importance of these factors vary among modes of transportation and cause some difficulty in making intermodal fuel consumption comparisons. It would be ideal to make fuel consumption comparisons of, say, land modes where varying quantities and types of goods or people are transported equal distances along parallel routes. But it is difficult to find the same types and quantities of goods and people transported over existing routes of competing modes which are parallel and equal in length. Usually, the route of one mode is more direct and level than the routes of competing modes or the load carried by one mode is bulky and light whereas the load of another mode is compact and heavy. Also, one mode may have a return haul, but the other does not.

Most of the standardized fuel consumption studies conducted in the past have involved only one mode, particularly motor carriers. Very few of these studies have been comprehensive enough to take into account many of the above factors which affect the quantity of fuel consumed by one mode. Even fewer studies have been conducted to estimate the fuel consumption of competing modes of transportation under standardized conditions. The results of these studies are limited in their application to determine differences in energy consumption and intensiveness between or among modes. It is very important to know the assumptions and conditions under which the results of these studies can be applied.

Energy Consumption by Freight Modes

A study sponsored by the U.S. Department of Transportation (1),(2) derived estimates of fuel consumption of motor and rail carriers making one-way trips of 5 to 75 miles (including return trip) for movements up to 220 tons (approximately five carloads) of cargo. These estimates are shown in Table 1 and are based on standardized conditions for short hauls of light density traffic which characterize many of the light density railroad lines presently operating in Texas. The data indicates that as the tonnage moved over light density lines drops, trucks can be competitive with railroads at greater and greater distances. Therefore, the abandonment of many short haul light density rail lines and substituting heavy trucks should reduce the direct energy consumption required to transport the same cargo.

Peat, Marwick, and Mitchell brought together the results of several studies of energy consumed by various transportation modes as shown in Table 2 (3). Each mode is ranked according to intensity of energy use, as expressed in Btu's per net ton mile, net ton miles per gallon of diesel fuel, and gallons of diesel fuel per 1000 net ton miles. If the nature of freight, length of haul, intermodal transfer, and circuity of travel are ignored, modal comparisons can be made on general and intercity freight movements. For instance, the truck/rail energy intensiveness ratios are 3.98 and 3.80 for general and intercity freight movements. These ratios are almost the same as those based on other studies which have compared the energy consumption of trucks and trains that carried cross-country (intercity) freight over level terrain (4,5,6,7,8).

TABLE 1. Estimated Total Fuel Consumed by Rail and Motor Carriers

Net shipments (tons)	Mode	Number of vehicle loads	1-way trip distance (miles includes return trip; gallons)						
			5	10	15	20	25	50	75
44	Rail	1	13.3	21.7	30.1	38.5	46.9	93.8	140.7
	Truck	2	4.9	9.1	3.4	17.7	22.0	44.0	65.9
88	Rail	2	18.9	27.9	37.0	45.9	54.9	109.8	164.7
	Truck	4	9.7	18.2	26.8	35.3	43.9	87.8	131.7
132	Rail	3	24.5	34.2	43.9	53.5	63.1	126.2	189.3
	Truck	6	14.6	27.4	40.2	53.0	65.8	131.6	197.4
176	Rail	4	30.1	40.4	50.7	61.0	71.3	142.6	213.9
	Truck	8	19.5	36.5	53.6	70.6	87.7	175.4	263.1
220	Rail	5	35.6	46.7	57.6	68.5	79.4	158.8	238.2
	Truck	10	24.3	45.6	67.0	88.2	109.5	219.0	328.5

Source: United States Department of Transportation Study (1), as presented in the United States Railway Association Report (2).

Table 2

Estimated Energy Efficiencies of Freight Transportation Modes for General and Inter-City Movements[a]

Mode of Transportation	Approximate Btu's Per Net Ton Mile	Net Ton Miles/ Gallon Diesel Fuel	Gallons Diesel Fuel Per 1000 Net Ton Mile
Railroad:			
General	700	198.0	5.05
30,000 gross ton unit train	330	420.0	2.38
Intercity only	500	277.0	3.61
Short, fast train	1,430	97.0	10.31
Truck:			
General	2,800	50.0	20.00
Intercity only	1,900	73.0	13.70
Local only	7,000	20.0	50.00
Inland Waterway	500	277.0	3.61
Oil pipeline	600	231.0	4.33
Air freight	42,000	3.2	312.50

[a]Due to different nature of freight, length of haul, and circuity between modes, modal comparisons are not entirely appropriate.

Source: Peat, Marwick, & Mitchell (3) as presented in United States Railway Association Report (2).

The above results indicate that trucks are only one-fourth as energy efficient as railroads in transporting freight for distances of over 300 miles. For distances of 100 miles or less, trucks may be more energy efficient than railroads, depending on the tonnage moved (Table 1).

To determine the quantity of fuel required to move freight by truck and rail between two specific points for short distances (branch lines) or long distances (intercity lines), the analyst can refer to Section IV of the Federal Railroad Administration's Manual for State Railroad Planning (9). This manual states the relevant assumptions, lists the data requirements, and gives the steps and formulas necessary for computing the fuel consumed by each mode for comparative purposes.

The discussion thus far has pertained to the energy required for transporting freight by diesel powered vehicles. But what about the energy required for transporting freight by electric powered vehicles, especially on high density railroad lines? First of all, modal comparisons of electric powered vehicles are almost impossible due to the fact that railroads are the only surface mode of transport which can easily accommodate the substitution of other fuels for petroleum (2). Second, the little data that are available suggest that the energy requirements for moving freight with electric powered trains are about the same as with diesel powered trains (2, 4). Third, electricfication of rail lines would require an initial investment of $125,000 to $200,000 miles per route mile (not including power stations or transmission lines) (2, 3). Except on the grounds of national energy considerations, it would not be economically feasible to change over to electric powered locomotives to haul intercity freight.

Energy Consumption by Passenger Modes

As in the case of freight transportation, several studies have been made which compare the energy consumed to transport passengers by various modes (5, 6, 10, 11). The results of these studies are summarized in Table 3. As can be seen, the units of comparison are Btu's per passenger mile and passenger miles per gallon. These units are relatively good measures of fuel efficiency among passenger modes because they take into account the size of the load involved.

For urban transportation, the bus and rail modes are more energy efficient than the automobile or taxi modes, especially when all vehicles are loaded to their practical maximum capacities. In most urban areas, the rail mode is not yet available. Only two urban areas in the State, Houston and Dallas-Fort Worth, hold large promise to support a viable rail transit or commuter system.

For intercity transportation, the bus mode is more fuel efficient than the other competing modes (Table 3). Rail is the second most efficient mode. In Texas, the rail mode is available only where AMTRAK operates. Presently, AMTRAK provides passenger service among the four largest cities within the State, as well as service to Mexico through Laredo and El Paso.

As in the case with freight, the energy requirements for moving passengers with conventional electric powered trains are generally about the same as with diesel or diesel-electric trains (4, 12). The electric powered unconventional or experimental high speed passenger trains are definitely less fuel efficient than the diesel powered conventional cover speed units (11). However, fuel prices and pollution requirements may ultimately cause a major shift to electric powered units over the diesel powered units.

Table 3

Estimated Energy Efficiencies of Passenger Transportation Modes for Urban and Intercity Movements

Mode of Travel	Btu's Per Passenger Mile		Passenger Miles Per Gallon	
	Actual Load[a]	100% Load	Average Load	Practical Maximum Load
Urban				
Automobile	8,100 (28%)	2,300	26	42
Bus	3,700 } (20%)	} 760	35	97
Railroad	4,100[b]		49	120
Taxi			9	-
Intercity				
Automobile	3,400 (48%)	1,600	46	79
Bus	1,600 (46%)	740	108	162
Railroad	2,900 (37%)	1,100	72	108
Aircraft	8,400 (49%)	4,100	14	-

[a]Percent loaded is in parentheses.

[b]Electric trains (Bart and NYC systems).

Sources: Hirst (6) for Btu's per passenger mile and Voorhees and Associates (10) and Christenson and Sutherland (5) for passenger miles per gallon.

POLLUTION CHARACTERISTICS OF TRANSPORTATION

Criteria for Intermodal Comparisons

Knowledge of the pollution characteristics of various modes of transportation have become very important in pollution control and transportation decisionmaking. In this study, it is particularly important to know the pollution effects of changes made in railroad service resulting from branch line abandonments and main line consolidations. Such changes may bring about intermodal shifts in freight or passenger movements, and consequently, changes the amounts of air, noise, and water pollution in the affected areas. Other changes, such as type of carload; net weight loads; type and quantity of fuel used; age; type and size of engine; type of pollution control equipment; trip distance, speed of travel; numbers of speed changes and stops; pollution standards; etc. will result in changes in the amount of pollutants emitted.

As in the case with energy consumption, it would be ideal to make pollution emission comparisons of land based modes where the same quantities and types of goods or people are transported equal distances, along parallel routes (urban and rural), and at equal times. However, it is difficult to find ideal situations to make such intermodal comparisons. The other alternative is to use pollution data developed from studies on the individual modes of transportation that can be compared on a common unit basis for generally similar conditions (urban versus rural, etc.).

For comparisons of the air pollution caused by electric powered vehicles as opposed to diesel or gasoline powered vehicles, the pollution emitted in the process of generating electricity required to operate the electric vehicles must be estimated. Also, consideration must be given to the type of fuel and location of facilities used to generate the required electric energy.

Air Pollution Emissions

Several studies estimate the gross amounts (weight) of air pollutants emitted by competing modes through the use of emission factors, based on certain assumptions or conditions (13, 14, 15, 16, 17). Air pollution emission factors are usually stated in grams or pounds per vehicle mile, per seat mile, per passenger mile, per ton mile, etc. The principal air pollutants emitted by diesel or gasoline powered engines and electric generating plants using fossil fuels are carbon monoxide (Co), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter.

Air pollution emission factors of freight and passengers transportation are presented below. For freight transportation, emissions or factors are given for intercity (long haul), branch line, and local (short haul) operations. For passenger transportation, emission factors are given for intercity and urban operations.

Freight Transportation

Table 4 shows uncontrolled air pollution emission factors for intercity ground freight transportation in the United States, as reported by Cooper, Richards, and Lam (17). The emission factors for electric trains are based on burning bituminous coal in central electric generating plants. (More details are given in the footnotes of Table 4.) The emission rates for electric generating vary considerably depending on whether they use coal, lignite, oil, gas, or uranium as a fuel source (15). However, since coal will be the most abundant fuel available for electric power generation over the next 25 to 50 years, pollution emissions from coal powered plants are used

Table 4

Uncontrolled Air Pollutant Emission Factors for Intercity Ground Freight Transportation in the United States

Transportation Mode	Pound of Pollutant per Million Net Ton Miles				
	Sulfur Oxides	Particulate Matter	Nitrogen Oxides	Hydrocarbon Vapor	Carbon Monoxide
Electric Train[a]	1,140(%S)[b]	480(%A)[b]	540	9	30
Diesel Train[c]	647(%S)[b]	124	372	244	348
Diesel Truck[c]	2,500(%S)[b]	264	6,850	684	4,150

[a]Based on burning bituminous coal in central electric generating plants, where the as-fired basis fuel heating value is 10,000 Btu's per pound, with an energy consumption requirement of 600 Btu's per ton mile.

[b]Sulfur and ash contents of fuel in percent by weight on an as-fired basis.

[c]Based on energy consumption requirements of 670 and 2,400 Btu's per gallon.

Source: Cooper, Richards, and Lam (17).

here for comparative purposes. Of the fuels used to generate electricity, uranium is by far the cleanest from an air pollution point of view. The greatest problem is storing and controlling the use of the radioactive waste materials produced by such operations. Regardless of the fuel used to power electric generating plants, the pollutants emitted are centralized in one location usually not from heavily populated areas. On the other hand, trains or trucks powered wth diesel engines pollute the air wherever they go, contributing considerably to the critical air pollution levels in densely populated areas.

As can be seen in Table 4, diesel powered trains emit less pounds of pollutants per million net ton miles of intercity freight hauled than do diesel powered trucks. Table 5 shows the increase in air pollutant emissions when utilizing diesel trucks instead of trains for branch line hauling for light, median and heavy loads (15, 18). Table 6 shows air pollutant emissions from trains and equivalent trucks hauling branch line freight according to the number and type of cars that make up a train. Trains with fewer than five cars emit more pollutants per ton mile than trucks hauling equivalent loads. Table 7 shows air pollutant emissions for short distance operations of a diesel truck, a 2-stroke supercharged switch locomotive and a 2-stroke supercharged road locomotive according to distance traveled and net shipment weight (15). For trips under 10 miles in length and carrying less than 176 tons of freight, disesl trucks emit less air pollution in pounds than do diesel trains.

Passenger Transportation

Air pollution factors for uncontrolled intercity passenger transportation are presented in Table 8 (17). Electric trains produce far more sulfer oxides and particulates per million passenger miles than do the other land modes.

Table 5

Increase in Air Pollutant Emissions When Utilizing Diesel Trucks Instead of Trains for Branch Line Hauling, by Size of Load

Pollutant	Pound of Emissions per 10^3 Ton Miles						
	Train				Increase (Train to Truck)		
	Light Load	Medium Load	Heavy Load	Diesel Truck	Light Load	Medium Load	Heavy Load
Carbon Monoxide	1.44	0.59	0.33	4.50	3.06	3.91	4.17
Hydrocarbons	1.04	0.42	0.24	0.74	None	0.32	0.50
Nitrogen Oxides	4.11	1.67	0.93	7.40	3.29	5.73	6.47

Source: Battelle Columbus Laboratories (15) as reported by the Environmental Protection Agency (18).

Table 6

Air Pollutant Emissions from Trains and Equivalent Trucks Hauling Freight on Branch Lines, by Number and Type of Cars[a]

Pollutant	Grams/Net Ton Mile											
	1 Car[b]			3 Cars			5 Cars			10 Cars		
	Hopper	Gondola	Boxcar	Hopper	Gondola	Boxcar	Hopper	Gondola	Boxcar	Hopper	Gondola	Boxcar
Carbon Monoxide												
Train	1.51	1.82	3.02	0.54	0.64	1.04	0.35	0.40	0.64	0.18	0.21	0.33
Truck	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Hydrocarbons and Nitrogen Oxides												
Train	5.56	6.71	11.18	2.00	2.37	3.84	1.28	1.49	2.35	0.68	0.79	1.22
Truck	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37

[a]Assumes the use of a 1,000 horsepower locomotive traveling at 20 mph and a 36 ton gross weight tractor trailer traveling at 30 mph with both modes having empty backloads. No allowances are made for idling time other than that included in load-speed cycles used in engine emission testing.

[b]Net tons carried: 175 for hopper, 61 for gondola, and 36 for boxcar.

Source: Battelle Columbus Laboratories (15).

Table 7

Air Pollutant Emissions for Short Distance Operation of a Diesel Truck, a 2-Stroke Supercharged Switch Locomotive and a 2-Stroke Supercharged Road Locomotive[a]

Net Shipment weight (tons)	Mode[d]	Number Vehicle Loads	Pounds of Emissions[b]			
			5 miles[c]	10 miles	15 miles	20 miles
44	2-SS	1	8.1	13.2	18.2	23.3
	2-SR	1	7.5	12.2	16.9	21.7
	MC	2	3.3	6.1	9.0	11.9
88	2-SS	2	11.5	16.9	22.4	27.8
	2-SR	2	10.6	15.7	20.8	25.9
	MC	4	6.5	12.2	18.0	23.7
132	2-SS	3	14.8	20.7	26.6	32.4
	2-SR	3	13.8	19.3	24.8	30.2
	MC	6	9.8	14.4	27.0	35.6
176	2-SS	4	18.2	24.5	30.7	36.9
	2-SR	4	16.9	22.8	28.6	34.4
	MC	8	13.1	24.5	36.0	47.4
220	2-SS	5	21.6	28.3	34.9	41.5
	2-SR	5	20.09	26.3	32.5	38.6
	MC	10	16.3	30.6	45.0	59.3

[a]Fuel consumed includes round trip.

[b]Total emissions are particulates, SO_4, CO H/C, and NO_x.

[c]I-way trip distance.

[d]Coded as 2-SS for locomotive; 2-stroke supercharged switch engine, 2-SR for locomotive 2-stroke supercharged road engine, and MC for heavy-duty diesel-powered truck.

Source: Battelle Columbus Laboratories (15).

Table 8

Uncontrolled Air Pollutant Emission Factors for Intercity Passenger Transportation in the United States

Transportation Mode	Pound of Pollutant per Million Passenger Miles				
	Sulfur Oxides	Particulate Matter	Nitrogen Oxides	Hydrocarbon Vapor	Carbon Monoxide
Electric Train[a]	3,420(%S)[b]	1,440(%A)[b]	1,620	27	90
Diesel Train[c]	1,920(%S)[b]	338	1,160	760	1,080
Diesel Bus[c]	1,875(%S)[b]	180	5,130	513	3,120
Automobile[d]	197	332	6,320	8,920	49,400

[a]Based on burning coal with an as-fired heating value of 10,000 Btu's per pound, with an energy consumption requirement of 1,800 Btu's per passenger mile.

[b]Sulfur and ash contents of fuel in percent by weight on an as-fired basis.

[c]Based on burning a fuel with a heating value of 130,000 Btu's per gallon, with energy consumption requirements of 2,000 Btu's per passenger mile for diesel trains and 1,800 Btu's per passenger mile for diesel buses.

[d]Based on 2.0 persons per vehicle and average vehicle gasoline consumption of 15 miles per gallon.

Source: Cooper, Richards, and Lam (17).

On the other hand, electric trains produce far less hydrocarbons and carbon monoxide than do the other modes. Automobiles emit more nitrogen oxides hydrocarbons, and carbon monoxide per million passenger miles than do the other modes, and they have contributed significantly to the air pollution problem in urban areas. As more and more automobiles meet the federal air pollution emission standards, the differences in pollution emissions among the passenger transportation modes will become much smaller.

Airplanes contribute little to intercity air pollution relative to the land modes. A D-9-30 carrying 115 passengers on a 300-mile trip emits the following amounts of pollutants (11):

Pollutant	Pounds per Million Passenger Miles
Sulfur Oxides	130
Particulates	50
Nitrogen Oxides	300
Hydrocarbons	560
Carbon Monoxide	730

These amounts would be doubled if the plane carried only 57 (50 percent of capacity) passengers.

Table 9 gives air pollutant emission factors for urban modes of passenger transportation with various types of engines and operations (19, 20). For automobiles, the effect of air quality standards can be seen by comparing the emission factors for 1970 and 1975 standard engines. The 1975 factors for all pollutants except sulfur oxides are considerably less than the 1970 factors. The results show that absolute levels of pollution are lower per vehicle mile for vehicles with small power plants than for those with large ones. However, if the emissions of each mode are compared by passenger mile and weighted by the relative effect of the pollutant being considered, the

Table 9

Air Pollutant Emission Factors for Urban Modes of Passenger Transportation, by Type of Engine and Operation

Mode, Engine, and Operation	Grams of Pollutant per Vehicle Mile			
	Sulfur Oxides	Nitrogen Oxides	Hydro-carbons	Carbon Monoxide
Automobile				
1970 Standard	0.27	6.0	4.6	47.0
1975 Standard	0.27	3.0	0.4	3.4
Bus, Diesel				
Arterial Street	5.2	36.3	1.7	28.3
Downtown	5.2	54.4	2.8	50.6
Bus, Gas Turbine				
Arterial Street	5.2	10.5	0.2	4.0
Downtown	5.2	12.2	1.2	6.8
Commuter Train[a]				
Roots Blown	48.0	234.0	80.0	1,040
Turbocharged	48.0	235.0	80.0	240
Rail Transit[b]				
Typical Cycle	1,030	271.0	2.7	6.8

[a]Assumed to be mainly diesel powered.

[b]Assumed to be electric powered.

Source: Liebeman (19) as obtained from Scheel (20).

results show (Table 10) that public transportation modes have lower carbon monoxide and hydrocarbon emission rates than automobile, but higher sulfur oxide and particulate emission rates (19, 20).

Noise Pollution Emissions

The impact of noise pollution emissions of competing modes of transportation depends on a number of factors, including location of and distance from transportation facilities, existence and steepness of grades, existence and sharpness of curves, condition of facilities, type and condition of transportation vehicles and equipment, operating speeds, number of stops, number of vehicles used per unit of time, etc. The perceived noise level at a particular location also depends upon the overall level of background noise. Adverse community reactions may be expected if the intruding noise level exceeds the background noise level. Widespread complaints can be expected when an intruding noise results in a noise level increase of about 17db(A) (21). Daytime outdoor residual (background) noise levels can vary widely, depending on the type of community, as follows:

- Wilderness and rural 16-35db(A)
- Suburban residential 36-45db(A)
- Urban residential 46-55db(A)
- Very noisy urban residential and downtown city 56-75db(A)

Figure 1 shows the wayside noise levels measured in decibels (db) weighted by the A-scale at 50 feet from the source of noise (21). This scale is correlated with human responses to noise.

According to Figure 1, railroad operations generate somewhat more intense noise levels than do truck operations. However, since it takes about 3.16 truck loads to be equivalent to one freight carload, a change to the truck

Table 10

Relative Effects of Air Pollutant Emissions for Urban Transportation Modes, Type of Engine and Operation[a]

Mode, Engine, and Operation	Grams per Passenger Mile					
	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides	Sulfur Oxides	Particulates	Total
Automobile						
1970 Standard	0.24	1.56	3.27	0.18	0.25	5.50
1975 Standard	0.02	0.14	1.63	0.18	0.25	2.20
Bus (Diesel)						
Arterial Street	0.02	0.10	3.50	0.52	2.08	6.22
Bus (Gas Turbine)						
Arterial Street	0.003	0.012	0.97	0.52	2.08	3.58
Commuter Train						
Turbocharged	0.004	0.08	0.58	0.o0	0.33	1.09
Rail Transit						
Typical Cycle	0.00	0.002	0.72	3.40	1.54[b]	5.66

[a]Represents the relative effect of the pollutant being considered where relative effect =

$$\frac{\text{(grams/vehicle mile) (relative effect of air quality standards concentration)}}{\text{persons/vehicle}}$$

[b]Based on 7.250g/ton (g/907kg) of coal, 10 percent of fly ash, and 80 percent collection efficiency on control equipment (by person-miles).

Source: Lieberman (19) as obtained from Scheel (20).

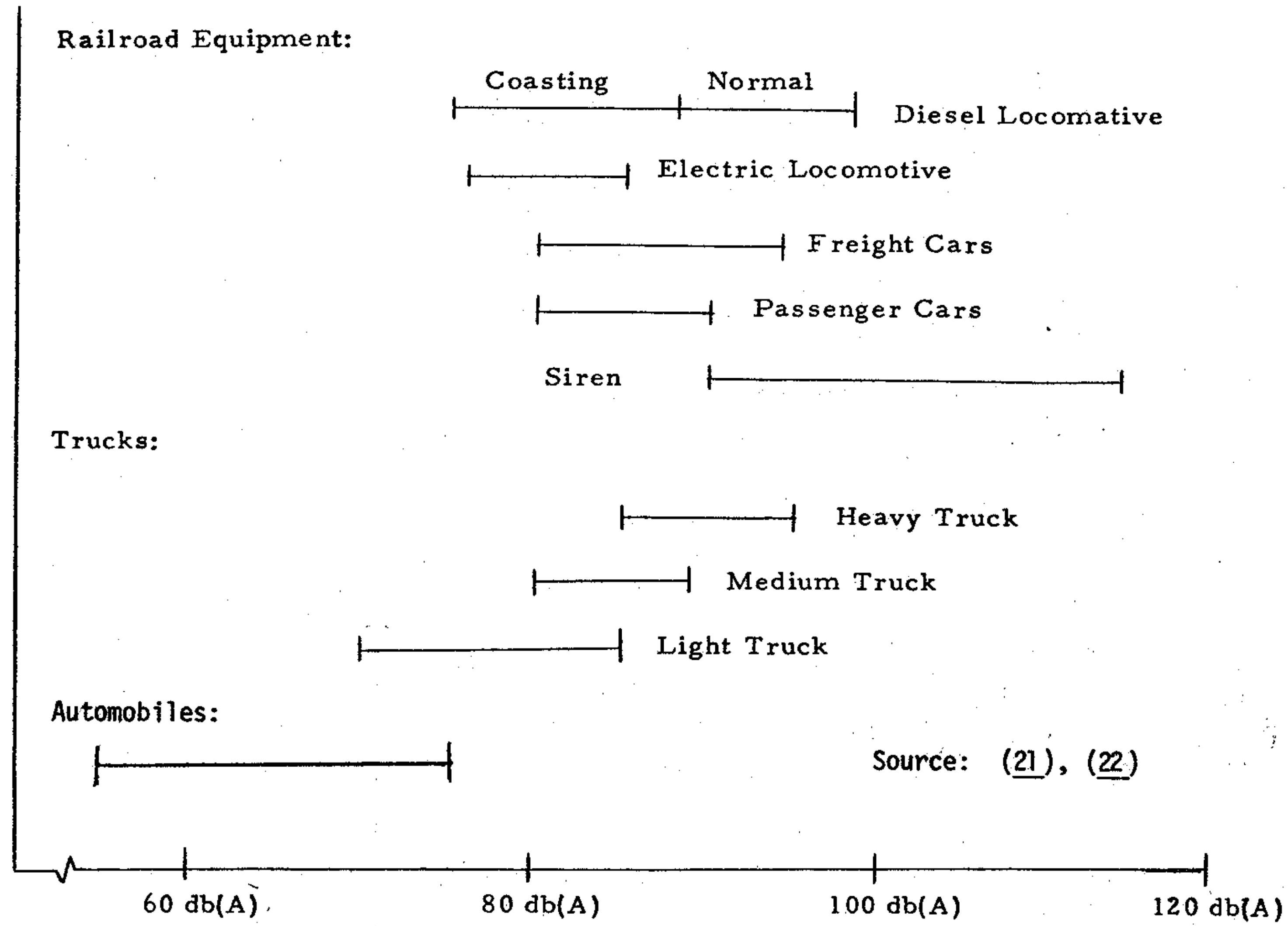

Figure 1. Wayside Noise Levels at 50 Feet from Sources.

mode of transportation may generate increased complaints about noise. Railroad noise levels decline less with increasing distances than do those of trucks (22). Also, at 500 feet, train noise will decline about 10db(A) below the 50 foot levels given in Figure 1 compared to a decline of 20db(A) for truck noise.

For the passenger modes, the noise level range of automobiles is considerably less than that of locomotives pulling passenger cars (Figure 1). The wide noise level range for automobiles is primarily due to varying densities of automobiles per mile of roadway and/or speeds (22).

As is shown in Figure 1, the use of electric locomotives would reduce the noise levels near railroads. Cooper, Richards, and Lam (17) reached the same conclusion.

Water Pollution

The operation of various modes of transportation can cause water pollution along rights-of-way and other lands used for transportation purposes. Table 11 shows the various sources of water pollution resulting from the operation of a railroad (2). It also, shows how much money that the railroad industry spent in 1972 and 1973 to control water pollution along its facilities.

As can be seen in Table 11, the railroads have been putting forth a considerable effort to control water pollution. Since trucks and barge lines use public facilities, these modes of transportation do not spend any money directly for water pollution control along the facilities upon which they operate. However, considerable water pollution is caused by these modes.

Table 11

Funds Spent by the Railroad Industry to Control Water Pollution, by Source of Pollution

Source	Funds Spent	
	1972	1973
	- - -(000) Dollars- - -	
Weed and Brush Control	20,000	20,236
Maintenance Shops	16,590	30,808
Diesel Fuel Oil Leakage	9,105	8,584
Wastewater Disposal	1,496	5,792
Hazardous Spills	1,225	—
Corrosion Inhibitors	534	218
Sanitary Waste Disposal	4,763	20,836[a]

[a]1973-74.

Source: (2) as obtained from (15).

The abandonment of a rail line may produce a slight improvement in local water quality, primarily through the elimination of herbicide leaching and runoff (3). Considerable improvement might result in railroad abandonments where the groundwater levels are shallow or where normal surface water flows are interfered with by railroad causeways (21).

Electrification of high density rail lines would eliminate water pollution resulting from diesel fuel leakage.

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