# THE WORLD BANK

## ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT

**Transportation, Water & Urban Development Department**

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# Railways, Energy and Environment

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## ABSTRACT

This paper addresses the question whether rail transport should be preferred over road based modes because of its superior environmental characteristics, presumed to exist because rail is more energy efficient than road modes and uses, or can use, less polluting forms of energy. We examine the considerations which determine the relative energy intensity of modes (paras 1-2), the other cost and quality factors that determine the economic choice of mode (paras 3-4), and the environmental consequences (paras 5-6). Finally we conclude with suggestions for the way in which the Bank should approach the issue (paras 7-10).

# RAILWAYS, ENERGY AND ENVIRONMENT

## IS RAIL TRANSPORT ENERGY EFFICIENT?

1. If energy conservation were the **only** policy objective, the **theoretical potential** of rail transport would be clear. A recent report of the Commission of the European Communities[1] showed that, with full passenger occupancy, a gasoline car requires 2.5 times more energy per passenger kilometer than an inter-city train (though only 1.25 times as much as for a high speed train). In the freight market a simulation study of a number of corridors by the U.S Federal Railroad Administration concluded that rail could be more energy efficient than truck transport in all the specific situations examined.[2] A large number of other studies have generally reached roughly the same conclusion.

2. In *practice*, however, the potential advantage of rail in energy consumption per ton-km is diminished by some inherent characteristics of rail operations, namely;

- **indirectness** (the lower network density and constraints of topography make actual point to point travel distances average up to 20% more by rail than road),
- **inflexibility** (the larger unit of movement makes it more difficult and costly to maintain high load factors),

[1] Commission of the European Communities *The Impact of Transport on the Environment : A Community Strategy for Sustainable Mobility* COM(92) 46 final, Brussels, February, 1992.

[2] *Rail vs Truck Fuel Efficiency: The Relative Fuel Efficiency of Truck Competitive Rail Freight and Truck Operations Compared in a Range of Corridors* U.S. Department of Transportation. Federal Railroad Administration. Report DOT/FRA/RRP-91/2, April 1991.

- **technical inefficiency** (the typically larger company size and public sector monopoly position of railways often leads to somewhat less effective and market-responsive operation, particularly for freight services).

## WHAT OTHER VARIABLES PLAY A ROLE IN MODAL CHOICE BESIDES ENERGY EFFICIENCY?

3. Cost matters. Even where rail does have an advantage in fuel efficiency, this advantage is not always sufficient to alter the choice of mode. For example, fuel cost is only a relatively small proportion of the total money cost incurred by land transport operators (rarely more than 25%). More importantly, as presently organized, rail transport has significant elements of *fixed* costs which largely determine the money cost of carrying specific traffics.* It is these fixed costs, rather than lower variable costs—such as fuel—which restrict the use of rail to certain domains.

- **track costs**—which mean that only with high track utilization can the full potential be obtained (hence the cost advantage of rail over road in "high density" corridors),
- **terminal and transfer costs**—which mean that the cost of multiple transfers can be lowered significantly per kilometer only if spread over a larger number of kilometers (hence the cost advantage of rail over road for "long hauls"),

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*Railways have traditionally been built and managed as comprehensive entities which provide both right of way and operating equipment. Thus, "fixed costs" appear high by comparison with trucking, for example, because even where fuel taxes are adequate to force trucks to 'pay their' "full" cost, the cost is paid as a variable cost (per liter) rather than as a fixed cost independent of traffic volume.

- **locomotion costs**—which do not increase as rapidly in proportion to hauled weight and speed as for trucks (hence the cost advantage of rail over road for "bulk consignments").

It is in the other "domains" (low density, small consignments, high value, short distances) that road haulage has a clear economic advantage. In general, these other domains account for a larger proportion of total freight and passenger movement *revenues* (as opposed to tons) than the domains in which rail has a clear advantage. Finally, there is a relatively limited range of circumstances in which the modes are closely competitive (see Table 1). It is in this range that there may be scope for providing incentives to tip the balance in favor of rail use.

4. Quality of service is also important. The natural "domains" of the different modes of transport also depend on characteristics other than money costs, such as travel time, frequency of service, accessibility of the network to the origin and destination points to be served. In the *freight market* the trends toward "just in time" logistic systems emphasize the importance of precisely those quality of service attributes for which road transport has an advantage over rail. Differences in the characteristics of the products transported thus further sharpen the distinction between the "natural" markets for rail and road haulage (see Table 2). In the *passenger market* travellers' valuation of travel time, comfort, reliability and flexibility increases as income increases. Because road transport usually has an advantage in these dimensions there is a tendency for the dependence on road transport to increase with income growth. The main areas of exception to this are for long journeys

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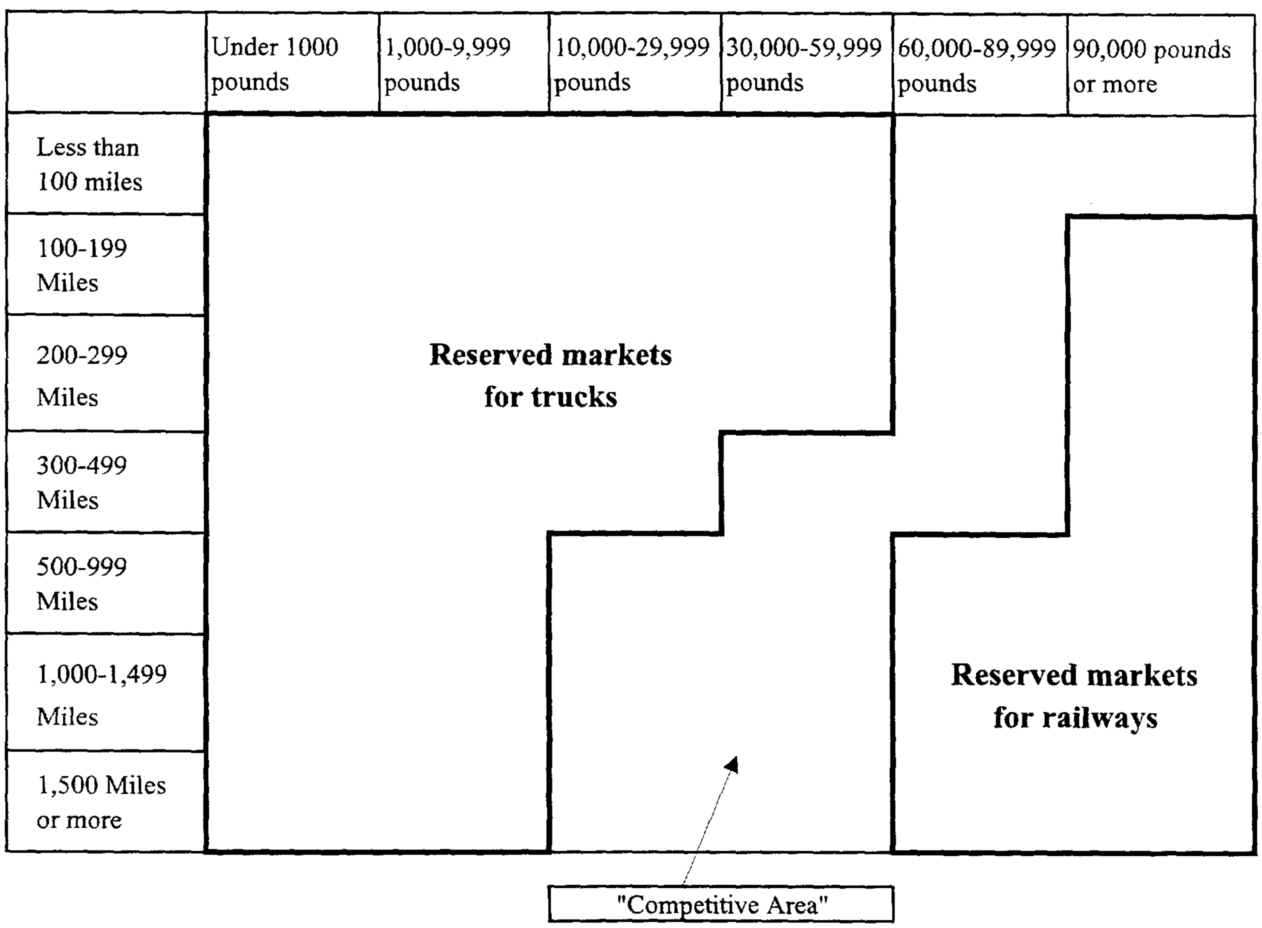
where higher speed rail alternatives are available (but where air transport also competes) and in some very large conurbations where road congestion makes the private car slower and less pleasant than public transport.

**Table 1**
**Reserved Markets* and Competition Areas as Function of Hauling Distance and Size of Shipments**




(Source: Road Transport Research, "Technico-Economic Analysis of the Role of Road Freight Transport." OECD: 1986. p. 78)

* This is the term used in the source document. It means "markets in which a specific made has an overwhelming cost advantage." It does not imply that there is, or should be, any regulatory reservation of traffic.

## Table 2
## Transport Requirements: Shippers in Production – Consumption Chain

| RAIL DOMAIN | IN–BETWEEN DOMAIN | ROAD DOMAIN |
|---|---|---|
| ***Position in Production Consumption Chain*** | | |
| Raw Materials | Processing, Construction or Production Lines | Assembling Industries or Dealers/Shops/Consumer |
| ***Characteristics of Flows*** | | |
| High Volumes<br>Large Shipments<br>Regular Destinations<br>Larger Inventories<br>*Higher Volume JIT** | Smaller Volumes<br>Smaller Shipments<br>More Irregular Destinations<br>Just–in–Time Production<br>Small Inventories | Smallest Volumes<br>Smaller Shipments<br>More Irregular Destinations<br>Just–in–Time Production<br>Small Inventories |
| ***Characteristics of Materials*** | | |
| Few Articles Per Production Unit<br>Bulk<br>Cheaper Per Tonne<br>Large Transport Share of Price<br>*Readily Containerizable** | Hundreds of Articles<br>Big and Small Objects | Thousands of Articles<br>Small and Refined Object<br>Expensive Per Tonne<br>Small Transport Share of Price |
| ***Typical Modal Choice Variable*** | | |
| Price | Reliability of Arrival | Speed |

Note: 1 tonne = 2,205 pounds

(Source: Road Transport Research, "Technico–Economic Analysis of the Role of Road Freight Transport." OECD: 1986. p. 79)

*/ *Added to original chart by the authors.*

## In What Ways Does Rail Have an Environmental Advantage Over Other Modes?

5. Environmental impacts of transport come in many forms. Global warming effects of $CO_2$ are directly proportional to hydrocarbon fuel consumption and independent of the location of consumption. A shift of traffic from road to rail is most environmentally beneficial where it involves a move away from hydrocarbon fuel as the primary energy source and where the railway is electrically powered and underutilized. However, hydrocarbon fuel use can also be reduced *without* a shift of traffic from road to rail if the power plant of autos and trucks could be converted to alternative fuels (e.g., electrically or hydrogen powered vehicles). Significant commercial introduction of such vehicles is still a decade away and full fleet conversion could take another one or two decades. This point is important only in so far as creating adequate rail capacity—where it does not already exist— could take as long as introducing the less polluting automotive technology.

6. In contrast, noise and other air pollutants, such as CO, $NO_x$, Pb, $SO_2$, etc., have much more localized effects, are less directly proportional to hydrocarbon fuel consumption, and can be suppressed in various ways without changing the primary energy source. For local air pollutants electrically-driven railways may have an advantage because pollution (if any) at the power source (and away from population centers) is easier to control than at multiple, mobile sources (within population centers). However, even though the environmental friendliness of the rail mode can be accentuated by the greater use of electric traction for rail transport, the advantage of rail electrification can be misunderstood. The economic attractiveness of electric traction to railways arises in large part from the reduction in locomotive maintenance costs and the greater acceleration potential that it offers, and to a lesser extent from energy cost savings. In fact, electric propulsion

does not usually have any large advantage in terms of overall efficiency of conversion of basic energy into effective work. Electrically-driven railways are, therefore, environmentally more friendly only where electricity can be generated (i) in a less polluting way (e.g., from renewables such as solar or hydro sources), or (ii) where pollution impacts can be more easily controlled through comprehensive abatement measures at the power source. This cannot always be presumed to be the case. For example, the electricity for China's electrified railways is generated largely from coal, which is not yet subject to comprehensive abatement measures.

## HOW SHOULD TRANSPORT POLICY REFLECT THE POTENTIAL ENVIRONMENTAL ADVANTAGE OF RAIL?

7. As summarized above, the issue is complex. The *actual* achievement of energy saving and environmental benefit by rail transport depends on the effectiveness of *rail use*. But use effectiveness depends on the existence of a market-proven superiority of the rail mode in meeting customer demands, whether for freight or passenger movement. And that is not universal; it only appears to occur in well defined domains of business. In other cases, customer demand is not often sufficiently large or concentrated to generate commercially viable rail traffic flows.

8. The question thus arises as to whether government powers should be used to increase the level of rail use, given that such "forced" transfers imposes costs on users. Government intervention may indeed be justified where the money costs to the operator do not properly represent the true economic costs. This may be so in three categories of circumstance:

- Where **road user charges** fail to cover the real costs of road infrastructure. Unfortunately, there is little empirical data on whether roads are implicitly subsidized and what the size of this implicit road subsidy might be. To the extent there is a subsidy, getting the charges for road use right is preferable to the introduction of compensating distortions of private choice by subsidizing rail. Only if road charges cannot be implemented and the implicit subsidy to roads is significant enough to alter relative prices might there be a case for a subsidy to rail. (The more difficult it is to raise general public revenues the more difficult it will be to sustain the two sets of subsidies—implicitly to roads and explicitly to rail.)

- Where **urban road congestion exists**, but pricing solutions are considered practically and politically too difficult to implement. In such cases, urban rail projects, particularly *in the context of comprehensive urban transport management plans*, may help reduce the rate of growth of road congestion. Sustaining a reduction in road congestion, however, is unlikely to be feasible without ultimately imposing some form of congestion pricing of roads.
- Where **environmental impacts of transport** can be significantly reduced. There may be a case for favoring rail transport infrastructure investment, irrespective of whether rail is a more energy efficient mode or not, if electric rail traction is a means of redistributing or suppressing environmental effects (such as air and noise pollution).

9. The practical difficulty is that we may not know how to quantify benefits or determine the "right" price for externalities. Even in European countries, car ownership and miles travelled are increasing more rapidly than travel by rail despite the fact that (i) good alternatives to automobile travel exist—in the form of a well-developed rail network and a railway that pays particular attention

to passenger traffic— and (ii) the cost of travelling by automobile is relatively high—as a result of high taxes on gasoline. In addition, the share of freight transported by road is growing, because trucks and airlines do a better job of integrated, inter-European traffic management than railways. There is reason, therefore, to be cautious in our expectations of the magnitude of passenger or freight traffic that can be shifted from road to rail. Moreover, the net economic effect depends on the economic costs of achieving the modal transfer. This can only be established by investigation on a case by case basis. There remains no good case for a global preference for rail investments independent of these careful calculations.

10. The Bank experience must be seen in this light. The Bank has long been willing to invest in railways, having supported about 171 railway projects since 1949, accounting for one quarter of lending for transport and 3.3% of total Bank lending. However, one third of the rail projects reviewed by OED have been rated unsatisfactory, and many have failed to achieve their stated objectives. This can be largely attributed to the unsatisfactory policy and institutional framework within which most railways operate.[3] In particular, railways are very management intensive and good management is a very scarce resource at early stages of development. To invest in railways which do not attract traffic is not only uneconomic but environmentally useless. The emphasis should thus continue to be on securing the institutional reforms necessary to fully realize the potential of rail transport, including its benefit for the environment.

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[3] A.C. Galenson and L.S. Thompson. *The Bank's Experience with Railway Lending: An Evolving Approach* TWUTD, forthcoming.