Transportation Modes: An Overview

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1. A Diversity of Modes

Transport modes are the means by which people and freight are carried. They fall into one of three basic types, depending on over what surface they travel – land (road, rail and pipelines), water (shipping), and air. Each mode is characterized by a set of technical, operational and commercial characteristics:

- **Road transportation**. Road infrastructures are large consumers of space with the lowest level of physical constraints among transportation modes. However, environmental constrains are significant in road construction. Road transportation has an average operational flexibility as vehicles can serve several purposes but are rarely able to move outside roads. Road transport systems have high maintenance costs, both for the vehicles and infrastructures. They are mainly linked to light industries where rapid movements of freight in small batches are the norm.
- **Rail transportation**. Railways are composed of a traced path on which are bound vehicles. They have an average level of physical constrains linked to the types of locomotives and affected by the gradient. Heavy industries are traditionally linked with rail transport systems, although containerization has improved the flexibility of rail transportation by linking it with road and maritime modes.
- **Maritime transportation**. Main maritime routes are composed of oceans, coasts, seas, lakes, rivers and channels. However, maritime circulation takes place on specific parts of the maritime space. The Atlantic Ocean is very important since it accounts for 78% of the global trade, 68% of its value and for 75% of the maritime trade. The construction of channels, locks and dredging are attempts to facilitate maritime circulation by reducing discontinuity. Comprehensive inland waterway systems include Western Europe, the Volga / Don system, St. Lawrence / Great Lakes system, the Mississippi and its tributaries, the Amazon, the Panama / Paraguay and the interior China. Maritime transportation has high terminal costs, since port infrastructures are among the most expensive to build, maintain and improve. High inventory costs also characterize maritime transportation. More than any other mode, maritime transportation is linked to heavy industries, such as steel and petrochemical facilities adjacent to port sites.
- **Air transportation**. Air routes are practically unlimited, but they are denser over the North Atlantic, inside North America and Europe and over the North Pacific. Air transport constraints are multidimensional and include the site (a commercial plane needs about 3,300 meters of track for landing and take off), the climate, fog and aerial currents. Air activities are linked to the tertiary and quaternary sectors, notably finance and tourism that require movements of people. More recently, air transportation has been accommodating growing quantities of high value freight.
- **Pipelines**. Pipeline routes are practically unlimited. The longest gas pipeline links Alberta to Sarnia (Canada), which is 2,911 km in length. The longest oil pipeline

is the Transiberian, extending over 9,344 km to Western Europe from the Russian arctic oilfields in eastern Siberia. Physical constraints are low and include the landscape and pergelisol in arctic / subarctic environments. Pipeline construction costs vary according to the diameter and increase proportionally with the distance and with the viscosity of fluids (from gas to oil). The Trans Alaskan pipeline, which is 1,300 km long, was built under difficult conditions and has to be above the ground for most of its path. Pipeline terminals are very important since they correspond to refineries and harbors.

- **Telecommunications**. Telecommunication routes are practically unlimited with very low constraints, which may include the physiography and oceanic masses that may impair the setting of cables. They provide for the instantaneous movement of information (speed of light). Wave transmissions, because of their limited coverage, often require substations, such as for cellular phone networks. Satellites are often using a geostationary orbit which is getting crowded. High network costs and low distribution costs characterize many telecommunication networks, which are linked to the tertiary and quaternary sectors (stock markets, business to business information networks, etc). Telecommunications limit the requirement for personal movements in some economic sectors.

2. Modal Competition

A general analysis of transport modes reveals that possess key operational and commercial advantages and properties. However, contemporary demand is influenced by **integrated transportation systems** that require maximum flexibility. As a result, modal competition exists at various degrees and takes several dimensions. **Modes can compete or complement each other** in terms of cost, speed, accessibility, frequency, safety, comfort, etc. Although intermodal transportation has opened many opportunities for complementarity between modes, there is intense competition as companies are now competing over many modes in the transport chain. Modal competition thus occurs over three dimensions:

- **Modal usage**. Competition that involves the comparative advantage of using a specific or a combination of modes. Distance remains one of the basic determinants of modal usage for passengers transportation. However, for a similar distance, costs, speed and comfort can be significant factors behind the choice of a mode.
- **Infrastructure usage**. Competition resulting from the presence of freight and passenger traffic on the same itineraries linking the same nodes.
- **Market area**. Competition being experienced between transport terminals for allocating new space or capturing new markets.

As transport demand is a **derived demand** from individuals, groups and industries it can be desegregated into series of partial demands fulfilled by the adaptation and evolution of transport techniques, vehicles and infrastructures to changing needs. Moreover, the growing complexity of economies and societies linked with technological changes force the transport industry to constant changes. This lead to growing congestion, a reduction in transport safety, a degradation of transport infrastructures and growing concerns on environmental impacts.

The technological evolution in the transport industry aims at adapting the transport infrastructures to growing needs and requirements. When a transport mode becomes more advantageous than another over the same route or market, a modal shift is likely. A modal shift involves the growth of demand of a transport mode at the expense of another, although a modal shift can involve an absolute growth in both the concerned modes. The comparative advantages behind a modal shift can be in terms of costs, convenience, speed or reliability. For passengers, this involved a **transition in modal preferences** as incomes went up, such as from collective to individual modes of transportation. For freight, this has implied a shift to faster and more flexible modes when possible and cost effective, namely trucking and air freight.

The **geographical distribution of transport infrastructures and networks varies enormously**. Some regions are characterized by the coexistence of several transport modes, while in other regions only one mode can provide transport service. The evolution of transportation concerns both the infrastructure and the vehicle. The technological changes in the transport sector has permitted to **increase the performance** of existing transport modes and the **creation of new forms of transportation**, such as intermodal transportation The history of transportation (see chapter 1, concept 3) reveals that all modes of transport have surmounted many constraints of the natural environment.

3. Passengers or Freight?

With some exceptions, such as buses and pipelines, most transport modes have developed to handle both **freight and passenger traffic**. In some cases both are carried in the same vehicle, as for example in the airlines where freight is transported in the cargo holds of passenger aircraft. In others, different types of vehicle have been developed for freight and passenger traffic, but they both share the same road bed, as for example in rail and road traffic. In shipping, passengers and freight used to share the same vessel, but since the 1950s specialization has occurred, and the two are now quite distinct, except for ferries and some RORO services.

The sharing by freight and passengers of a mode is **not without difficulties**, and indeed some of the major problems confronting transportation occur where the two seek to co-inhabit. For example, trucks in urban areas are seen as a nuisance and a cause of congestion by passenger transport users. The poor performance of some modes, such as rail, is seen as the **outcome** of freight and passengers having to share routes. This raises the question as to whether freight and passengers are compatible. The main advantages of joint operations are:

- **High capital costs** can be justified more easily with a diverse revenue stream (rail, airlines, ferries).
- **Maintenance costs** can be spread over a wider base (rail, airlines).

- The same traction sources can be used for **both freight and passengers**, particularly for rail.

The main disadvantages of joint operations are:

- Locations of demand **rarely match** – O/D of freight is usually quite distinct spatially from passenger traffic.
- **Frequency of demand** is different – for passengers the need is for high frequency service, for freight it tends to be somewhat less critical.
- **Timing of service** – demand for passenger services has specific peaks during the day, for freight it tends to be more evenly spread throughout the day.
- **Traffic balance** – on a daily basis passenger flows tend to be in equilibrium, for freight, market imbalances produce empty flows.
- **Reliability** – although freight traffic increasingly demands quality service, for passengers delays are unacceptable.
- Sharing routes **favors passenger traffic** – passenger trains are given priority; trucks may be excluded from areas at certain times of the day.
- Different operational speeds – passengers demand faster service.
- **Security screening measures** for passengers and freight require totally different procedures.

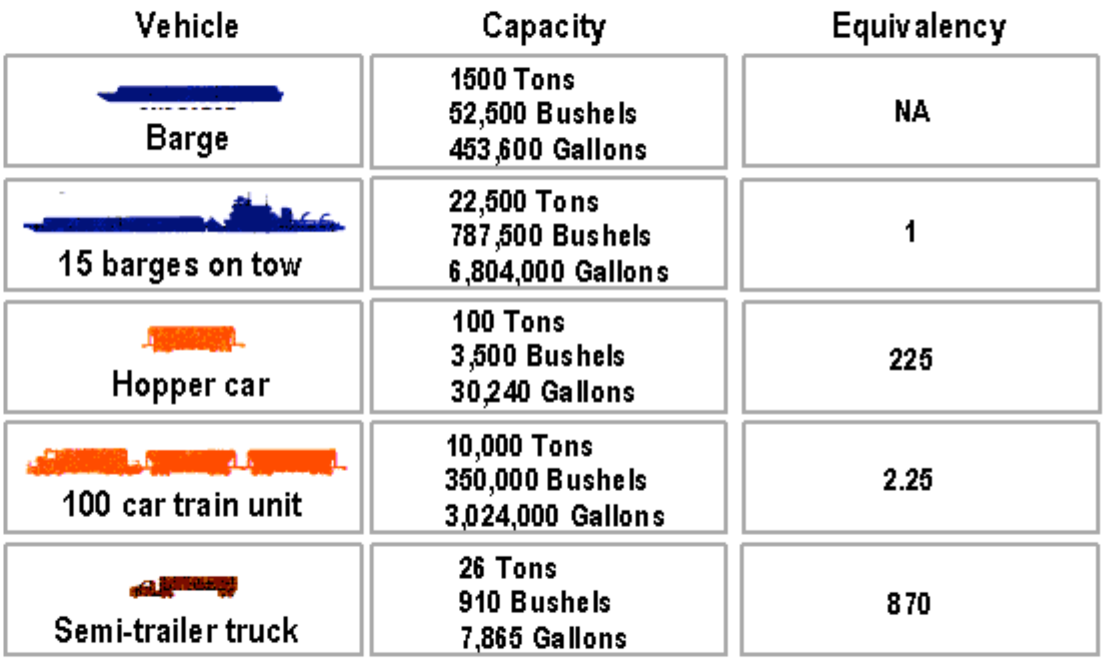
4. A Growing Divergence

In several modes and across many regions passenger and freight transport is being unbundled.

- **Shipping**. Mention has been made already how in the maritime sector passenger services have become divorced from freight operations. The exception being ferry some services where the use of RORO ships on high frequency services adapt to the needs of both market segments. Deep sea passenger travel is now dominated by cruise shipping which has no freight-handling capabilities, and bulk and general cargo ships rarely have an interest or the ability to transport passengers.
- **Rail**. Most rail systems still operate passenger and freight business. Where both segments are maintained the railways give priority to passengers, since rail persists as the dominant mode for inter-city transport in India, China and much of the developing world. In Europe the national rail systems and various levels of government have prioritized passenger service as a means of checking the growth of the automobile, with its resultant problems of congestion and environmental degradation. Significant investments have occurred in improving the comfort of trains and in passenger rail stations, but most notable have been the upgrading of track and equipment in order to achieve higher operational speeds. Freight transport has tended to lose out because of the emphasis on passengers. Because of their lower operational speeds, freight trains are frequently excluded from day-time slots, when passenger trains are most in demand. Overnight journeys may not meet the needs of freight customers. This incompatibility is a factor in the loss of freight business by most rail systems still trying to operate both freight and

passenger operations. In Europe, there are signs that the two markets are being separated. First, it is occurring at the management level. The liberalization of the railway system that is being forced by the European Commission is resulting in the separation of passenger and freight operations. This had already taken place in the UK when British Rail was privatized. Second, the move towards high speed passenger rail service necessitated the construction of separate rights of way for the TGV trains. This has tended to move passenger train services from the existing tracks, thereby opening up more daytime slots for freight trains. Third, the Dutch are building a freight only track, the Betuwe Line, from the port of Rotterdam to the German border, having already sold the freight business of the Netherlands railway (NS) to DB, and having opened up the freight business to other firms. It is in North America where the divorce between freight and passenger rail business is most complete. The private railway companies could not compete against the automobile and airline industry for passenger traffic, and consequently withdrew from the passenger business in the 1970s. They were left to operate a freight only system, which has generally been successful, especially with the introduction of intermodality. The passenger business has been taken over by public agencies, AMTRAK in the US, and VIA Rail in Canada. Both are struggling to survive. A major problem is that they have to lease trackage from the freight railways, and thus slower freight trains have priority.

- **Roads**. Freight and passenger vehicles still share the roads. The growth of freight traffic is helping increase road congestion and in many cities concerns are being raised about the presence of trucks. Already, restrictions are in place on truck dimensions and weights in certain parts of cities, and there are growing pressures to limiting truck access to non-daylight hours. Certain highways exclude truck traffic – the parkways in the US for example. These are examples of what is likely to become a growing trend – the need to separate truck from passenger vehicle traffic. Facing chronic congestion around the access points to the port of Rotterdam and at the freight terminals at Schiphol airport, Dutch engineers have worked on feasibility studies of developing separate underground road networks for freight vehicles.
- **Air transport**. Air transport is the mode where freight and passengers are most integrated. Yet even here a divergence is being noted. The growth of all-freight airlines and the freight-only planes operated by some of the major carriers, such as Singapore Airlines, are heralding a trend. The interests of the shippers, including the timing of the shipments and the destinations, are sometimes better served than in passenger aircraft. The divergence between passengers and freight is also being accentuated by the growing importance of charter and 'no-frills' carriers. Their interest in freight is very limited, especially when their business is oriented towards tourism, since tourist destinations tend to be lean freight generating locations.



Vehicle	Capacity	Equivalency
Barge	1500 Tons 52,500 Bushels 453,600 Gallons	NA
15 barges on tow	22,500 Tons 787,500 Bushels 6,804,000 Gallons	1
Hopper car	100 Tons 3,500 Bushels 30,240 Gallons	225
100 car train unit	10,000 Tons 350,000 Bushels 3,024,000 Gallons	2.25
Semi-trailer truck	26 Tons 910 Bushels 7,865 Gallons	870

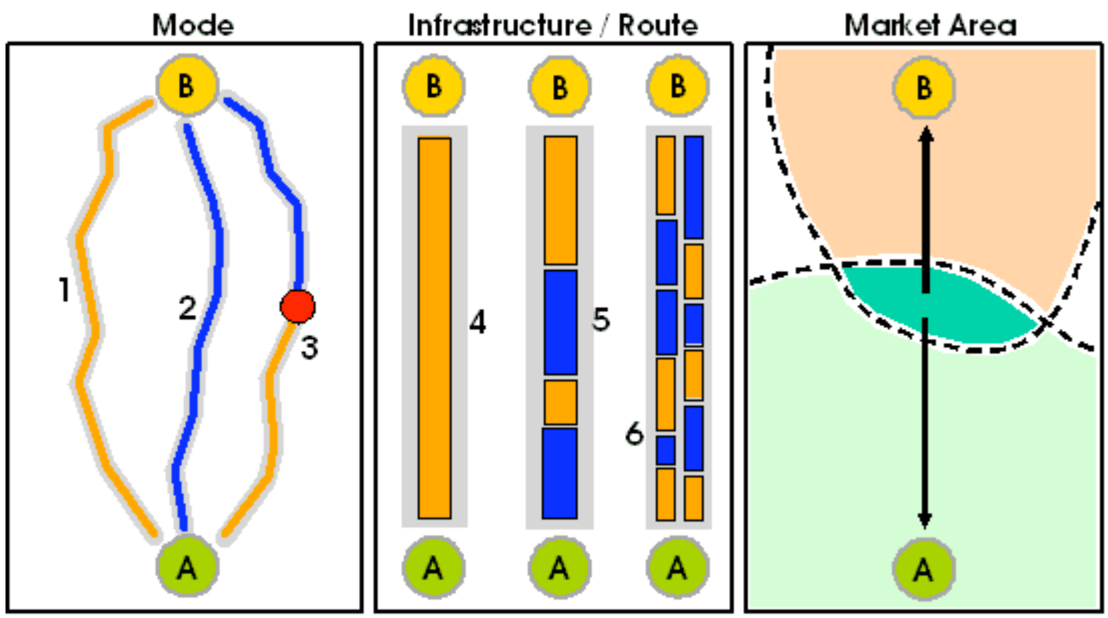
Performance Comparison for Selected Freight Modes

Because of their operational characteristics, several freight transportation modes have different capacities and levels of efficiency. While the truck is certainly the mode which has the least capacity, it has a level of flexibility (speed and door-to-door services) unmatched by rail and fluvial transportation.

Mode	Fuel Consumption	Infrastructure Capacity	Costs	Safety
Railroad	455 ton-miles per gallon	216 million tons per mainline per year	2.7 cents per ton-mile	0.61 fatalities per billion ton-miles; 12.4 incidents per billion ton-miles
Trucking	105 ton-miles per gallon	37.8 million tons per lane per year	5.0 cents per ton-mile	1.45 fatalities per billion ton-miles; 36.4 incidents per billion ton-miles

Source: Brown, T.A and A.B. Hatch (2002) The Value of Rail Intermodal to the US Economy, http://www.aar.org/pubcommon/documents/govt/brown.pdf

Comparison of the Relative Efficiencies of Rail and Trucking



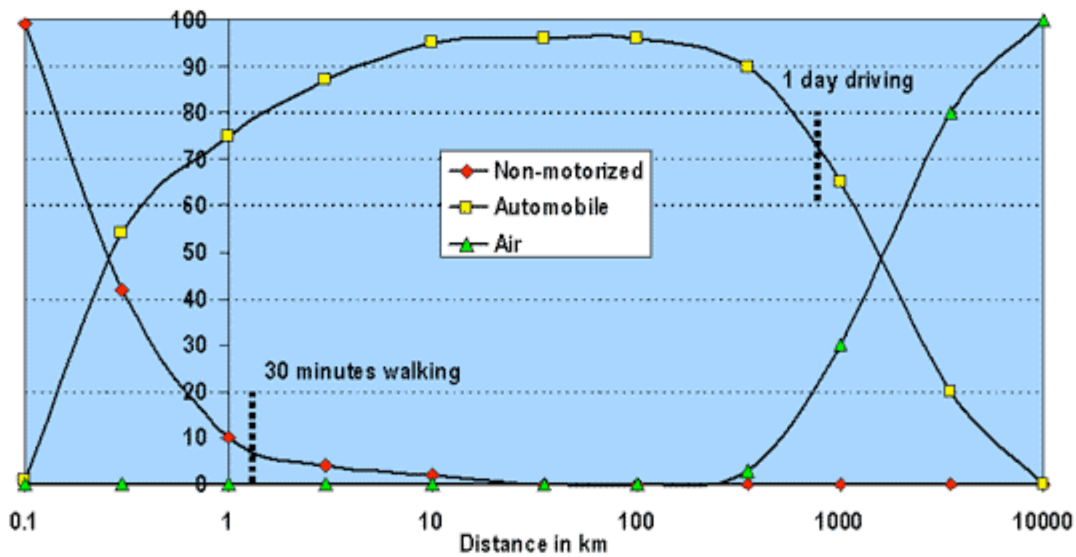
Modal Competition

Three major dimensions are of concern to depict the concept of modal competition. The above figure depicts those three dimensions for two locations (A and B):

- **Modal choice competition** is the most basic consideration in the modal competition process. On the above example, three modal choice scenarios are considered for two modes (orange and blue). The first two cases (1 and 2) are instances where only one mode is used since it represents the most efficient (or the only available) solution. This solution is derived by comparing the two available modes and choosing the one that answers the best the requirements of shipping freight or passengers between locations A and B. Case three represents another possible solution where the two modes are used in a combination of two segments with a point of transfer (red circle). This alternative is the classic **multimodal transport solution** which is increasingly been applied over transport systems. It enables to use modes over the segments they are respectively the most efficient.
- **Infrastructure or route competition** represents another dimension where modal competition occurs over the usage of a specific infrastructure or route. Three scenarios are generally possible. In the first case (4), there is simply no competition as one mode has a **monopoly** over a route, either because of technical (a subway line for instance) or regulatory (car-only expressways) reasons. The second case (5) represents an **exclusive sharing arrangement** where two modes are using the same infrastructure, but at different moments. The issue of rail passenger and freight is a relevant example, as both are using the same infrastructure but not at the same time. A decision has thus to be made about which mode gets priority. In North America, priority is given to rail freight while in Europe priority is given to rail passengers. The third case (6) illustrates a situation where two modes have a **mutual sharing arrangement**. Access to

infrastructure is generally unconstrained but the total capacity is obviously the result of respective levels of usage. Cars and trucks are commonly sharing the same road infrastructure.

- **Market area competition** is the third dimension of modal competition, which is highly tied to geographical considerations. It mainly concerns transport terminals that are drawing users and their associated flows, people and/or freight, from their surroundings. In the above example, locations A and B have their own exclusive market areas (light green and orange) over which that have a clear advantage. Competition occurs over a portion of the territory where the respective advantages of locations A and B are not clear (green); the **competition margin**. Technical improvements have increased competition margins as terminals such as ports are competing over overlapping market areas that may span whole regions.



Source: adapted from Schafer, A. (2000) Regularities in Travel Demand: An International Perspective, Journal of Transport Statistics, Vol. 3, No. 3.

Modal Split in the United States by Passenger Travel Distance, 1995

Distance remains a significant factor in modal choice. The above figure underlines two turning points for passengers modal split. The first being the 30 minutes walking threshold, representing about 2-3 kilometers. However, in a motorized society such as the United States, the automobile plays a significant role for short distances. This has a lot to do with the physical setting which tends not to be favoring walking. The second turning point is the 1 day driving threshold, at about 700-800 kilometers. Beyond this point, air transportation clearly dominates and becomes the only possible mode at distances of more than 8,000 kilometers.

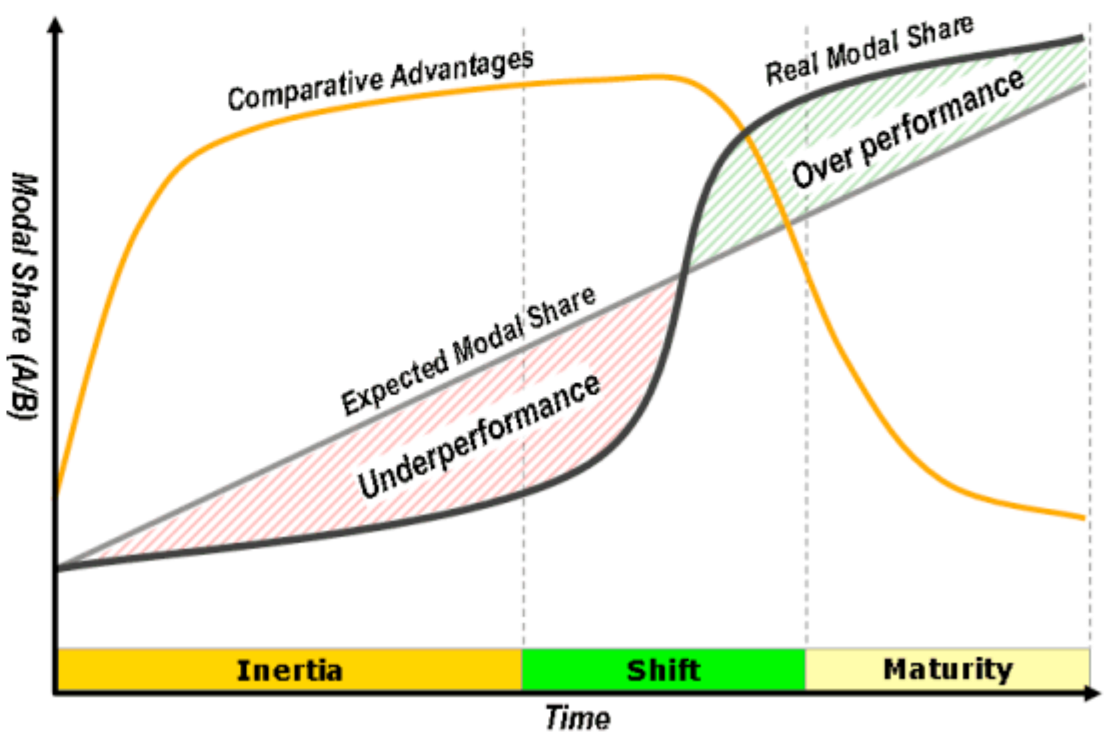
Mode	Price (one way)	Time
LimoLiner (luxury bus)	$69	4 hours

Acela (Amtrak train)	$99	3 hours
Greyhound bus	$30	4 hours
Air Shuttle	$128	1 hours (plus check in)

Source: K. Gordon (2004) “Boston to New York: Four Ways to Make the Trip”, New York Times, January 20.

Four Travel Options between New York and Boston, 2004

New York and Boston are about 200 miles apart, a distance that permits several modes to compete over this important passengers transport market. Outside using a private car, three modes are competing but over customers that are not necessarily similar. The air shuttle is obviously the fastest mode, but the most expensive. However, this short travel time does not take into account the amount of time spend getting in and out of an airport which often takes at least one hour in congested New York or Boston. Acela is a medium speed train service (150 mph) that runs between Boston and Washington, mainly used by business travelers. To complement the conventional Greyhound bus service, which is not used by business travelers, a new luxury bus service was inaugurated in 2003. It includes large seats, onboard movies and internet access.

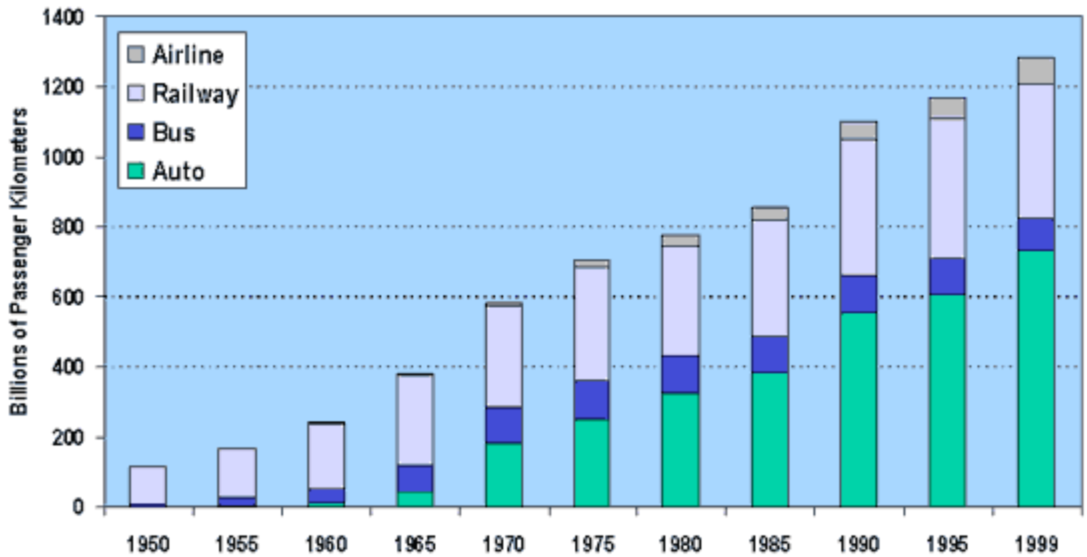


Principles of Modal Shift

A modal shift occurs when one mode (A) has a comparative advantage in a similar market over another (B). Comparative advantages can take various forms, such as costs, capacity, time, flexibility or reliability. Depending on what is being transported, the importance of each of these factors vary. For some, time is of the essence and a modal shift will occur only if the new mode offers time improvements, while for others it is mostly a matter of costs. The outcome is a series of decision made by firms (for freight) or individuals (for passengers) to shift to a more convenient mode if comparative advantages are significant enough. This process often takes place over three phases:

- **Inertia**. Initially, a strong level of inertia makes the modal shift a slow and sometimes difficult to perceive process. Only a few users will experiment with modal shift, often as part of a publicly subsidized initiative (government providing the initial funding to develop infrastructures). Inertia implies that the modal shift is often much less significant than expected, leading to a situation of underperformance. The reasons behind the inertia are linked to accumulated investments and assets in the prior mode and terminals. Thus, a corporation will be reluctant to relinquish those assets even if the comparative advantages of the other mode are significant. Management preferences also play a role as expertise was developed to manage flows on the previous mode and may be difficult to adapt to the new mode. The negotiation of new procedures and contracts are certainly tasks corporations are unwilling to undertake if the benefits are not readily apparent. The fact that the existing mode has a proven reliability, even if costly, will also play in delaying a potential modal shift. Early adopters of a modal shift are thus likely to be new transport ventures willing to risk testing an unproven distribution system for the potential rewards of being the first, enterprises facing already very high transport costs on the existing mode, or "welfare statists" receiving government subsidies to do so.
- **Shift**. The shift phase represents a fast transition from one mode to the other as the advantages are now acknowledged by the industry. The new transport mode evolves from a situation of underperformance to one of over performance. As inertia involved a modal shift taking place at a rate lower than expected, during the shift the transition rate is faster than expected. This can take users and authorities by surprise with a rush to cope with the transition with additional infrastructure investments. The significant drop in comparative advantages as the new mode gets increasingly congested and/or as the previous mode loses traffic (closing of some routes, rationalization, price cutting, etc.), triggers the end of this phase.
- **Maturity**. At this point the potential is reached and a new equilibrium in modal share is reached. Their respective comparative advantages are of lesser variance.

Thus a modal shift takes place in a context where from a macro perspective there are changes in the transport supply and from a micro perspective the decisions (behavior) of individuals (passengers) and firms (mostly for freight) is changing.



Source: Japan Ministry of Transport.

Passenger Transport by Mode, Japan, 1950-1999

The evolution of passenger transportation in Japan over the last 50 years revealed that the number of passenger-km has increased substantially and that the modal share of movements has shifted to the automobile. The automobile accounted to 57% of all passenger-km in Japan for 1999. This represents a shift from collective and inflexible modes (railways and buses) to individual travel. Both trends are related to demographic growth (in the 1960s and 1970s) and especially to growing income levels (in the 1980s and 1990s). The growth of domestic air transportation in Japan is particularly linked with this trend.