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HISTORICAL TRANSPORTATION DEVELOPMENT

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The main tasks for this overview of transportation development are the provision and interpretation of information on the unfolding of the transportation systems. What have been the processes at work? What explains the similarities and differences from here to there and among systems? Big questions! But they are eased by ways systems are products of experiences, as will be seen when the paragraphs immediately following summarize early experiences. Life support systems, sustainability, and social development topics will be mentioned.

After examining their immediate precursors, the discussions in the sections to follow will treat roads, airports, trains, trucks, buses, ports, automobiles, firms and agencies, and other features of modern transport infrastructure. Although the cost, quality, and mix of services vary from here to there, services are available most everywhere. Indeed, nation to nation and big city or isolated rural area the services available have many similarities.

1.1. Transportation Enabled Revolutions

There has always been trade, human interaction, and transport for almost no society has ever been purely subsistence in character. Expanded trade and the exertion of political power have asked for more, and there have been surges of transport improvements associated with the expansion of empires. Overland and river routes served the trade of Mesopotamia five millennia ago. Roman roads supported Roman hegemony as roads did for Persian, Chinese, and New World rulers. Not much later the grain trade of the

Mediterranean flourished, as well as Orient-European linkages. Eventually, Iberian, Dutch, French, and English empires were based on transport and trade.

Looking for the thoroughgoing changes in transportation that accompanied the evolution of the modern world, a wave of these were seen in Europe in the centuries just before 1300 where a network of trade centers emerged replacing feudal economies. An explanation for change was the Crusades, which broke the many feudal barriers to movements of individuals and trade. Charlemagne's wandering armies plundering here and there between his soldiers planting and harvesting seasons illustrate the increasing movement by the Ninth Century as barriers were being reduced, often forcefully. His wandering also illustrates that ideas move easily, for in addition to ill gotten loot, Charlemagne returned with ideas about building bridges and large buildings. By the 11th Century road transport had adopted existing technologies such as iron shoes and harnesses for draft animals, swiveling front axles for wagons, and bridge building techniques. But because road transport costs were high, coastal and river transport served most movements. Europe was advantaged because it was and is a well watered peninsula of peninsulas.

There were improvements in navigation technologies aiding the ocean trades, ports were chartered by governments and mechanical aids to material handling evolved, and ocean going ships designed mainly for merchant purposes appeared. Portuguese Atlantic ventures began in the 1430s. River improvements began as did the construction of canals. The 1648 Treaty of Westphalia increased access of users to the rivers of Germany. Eventually, extensive canal systems threaded Europe and these were followed by improved road systems incorporating toll roads in many places.

Another surge of development began almost 200 years ago when steam engines were applied to water and land transportation. Beginning about 100 years ago, developments building on those modes followed through to the modern world served by varieties of air, marine, and land transportation.

1.1.1 Integration, Coupling, Transactions

The recipes for advances seen in past centuries continue today. The pre 1300 advances integrated resources and markets. Advances were achieved by decreasing barriers to movements and by expanding and

improving networks. Institutional and political arrangements aided trade, for example, alliances such as those among the cities of the Hanseatic League in the Baltic region between 1200 and 1400. Indeed, the Hanseatic League has been termed the first of the multinational corporations. Integrating resources and markets increased the variety of consumption options, and it increased the varieties of inputs and markets available to producers.

In addition to continuing such integrating improvements, the centuries prior to 1800 saw improvements in coupling technologies, for instance, ports coupling land and sea modes. In addition to facility improvements, the movements of money and information demanded by trade were enabled by advances in banking and currency exchange. Instruments such as bills of sale and letters of credit supported market transactions. Bills of lading and way bills were evolved to document what was shipped and how it was to be moved. Stock companies financing ships and cargo and insurance carriers emerged in the maritime trades.

Systems of tariffs were created, and warehouse, freight forwarding, and freight consolidation actors began to aid transactions among shippers and receivers of goods.

1.1.2. Enabling Development

There were certainly surges of advances. Should they be thought of as revolutions?

They may be thought of as revolutions when the relations of transportation and social and economic development are considered. It was pointed out that improved access to resources and markets increased choices available to producers and consumers. Beyond that there was improved access to the worlds of ideas and knowledge, a point that many writers remark on in discussions of the Crusades. Ideas are light baggage and they move wherever there is travel and trade.

Improvements in knowledge and access to markets enabled the specialization of production. Brussels became a center for cloth production, England exported wool and leather, and the Baltic grain trades flourished. Trade supported the great cities of Northern Italy, and by the 12th Century Venice and

Florence each had achieved populations of about 100,000 and Paris was soon even larger. And as trade and allied services such as banking grew, London, Amsterdam, and other port cities grew.

Increasing trade and contact with information and ideas of all sorts brought about new expectations and aspirations for individuals and changed power relations. A long story, but eventually merchant, artisan, and other classes began to gain power and push aside royalty and the church, as well as the large land holdings class. New ideas including those of science and engineering began to circulate and concepts of democracy and freedom also bloomed.

It is fair to say that transportation advances working with other advances, such as the printing press, enabled thoroughgoing changes, revolutions. It is just as important to say that transportation's advances were conditioned by social environments and markets, as is always the case for technologies.

Finally, it is important to note that decades and centuries were required and that social upheavals accompanying change were real and often bloody. As is the case today, change was often resisted by those displaced or otherwise affected by technological changes and advances.

1.2 Life Support Systems

Although the early record is blurred by lack of data and differences among regions, there is no doubt that societies faced difficult conditions time and again. For instance, plagues and highly variable weather occurred in the 1300s and in the Century that followed. Later, a little ice age extended for two centuries followed by warming beginning in the late 1800s. Famine and disease took their toll on population growth. It was negative in some periods, and settlements disappeared in some areas. Wars and social strife surged throughout Europe, and the great ages of exploration and conquest elsewhere brought their varieties of tears and cheers.

How well did transportation serve society? It served by enabling the growth of cities and many other things, and it served well enough that demand continued to grow. Its failings, such as not transporting food to distressed areas in times of famine, may have been partly due to lack of system capability, but seem largely a matter of lack of social organization and will, a situation that although moderated continues today.

Some ask if transportation is sustainable. It was during the period reviewed for it survived in spite of adversarial conditions. There were problems. Wandering Goths destroyed Roman Road services. There were decades in which services to Iceland and Greenland were blocked by storms and ice, the freezing of the Baltic Sea caused problems, and the farmland required to produce feed for horses competed with food production. (Roughly, 1 horse required 4 to 6 acres (1.6 - 3.2 ha) for hay.)

Another question asks how well transportation will serve in the future. This discussion will say that, as in the past, today's systems are the building blocks for future systems. The question is that of our ability to use the building blocks wisely.

1.3 Plan for This Discussion

Striving to overview the development of services, the discussion to follow will expand on the precursors to the modern modes, treat the emergence of modern rail and marine services, comment on regional and national differences in development paths, and highlight repeating historical themes and recipes when discussing recent developments. To begin, the major systems/modes will be reviewed in the context of English and European experiences. It will be seen that the modes are products of experiences and pragmatic decision making.

Seeking generality and to ease the burden of treating the details of changes, this discussion will give snapshots of events such as the emergence of steam ship services. It will use these snapshots as examples or metaphors that mirror the logics of development.

2. Building Blocks for the Modern Systems

The modes or systems (the words will be used interchangeably) emerged sometimes in a serial fashion and sometimes more or less in parallel. The recipe for emergence was much the same everywhere and for each mode, although recipes and outcomes were tempered by differences in geographical and political circumstances. Europe, and England in particular, was the venue for early developments, and this is the reason for the English-European emphasis in the discussion to follow.

Looking around Europe just before the industrial revolution, say in the middle 1700s, the Atlantic was a pond connecting old and new world ports. Ocean and coastal ships served ports and penetrated inland to heads of navigation. Roads and trails served overland and improvements were underway, especially in France. Already, canal service was available in Italy, France, and the Netherlands, and rapid canal construction would soon begin in England, Russia, and elsewhere.

The modern systems emerged from the services available in those years; they served as building blocks for the modern ones. Their stories are very rich but briefness is required here.

2.1 River Improvements; Canals

The low value of many of the commodities moved and the high costs of land transportation urged movement of water craft as far inland on rivers as practicable. But river navigation posed some physical difficulties. There were large tides, low water levels during some seasons, and dredging needs. There were use conflicts. Mill operators had dams and resisted releasing water for navigation. Owners with riparian rights claimed tolls for improvements or for the use of embankments for pulling boats or transshipment. They sometimes resisted river improvements.

There was government involvement early on. The City of London started developing the River Thames in 1179, and by 1500 several city corporations had been given river development authority. Upstream, the Crown gave development authority to local landowners who put forward specific development and toll schemes.

The river experience yielded the first institutional form for canals, and there were carry over technological experiences. River development utilized dredging, flash boards, and a few locks. The flash board system required a good water supply as boards were removed and flood water raised boat levels, and canals could not be so wasteful of water. Lock technology, in particular, could carry over directly as could dredging technology. Also, there was learning about construction. William Smeaton, later a famous canal engineer and recognized as the Father of British civil engineering, obtained his first experience on river projects.

The beginning of the English canal era was marked by the Duke of Bridgewater's 7.5 mile (12 km) canal from coal mines on his estate at Worsley to Manchester. Construction began in 1759, and the canal opened 6 years later. Bridgewater's canal had some interesting technological features. It tied into his mine drainage scheme, and the boats ran into the mine for loading. Although the canal could accommodate larger boats, the within-mine operations kept the beam of the boats to about 7 feet (2.2m); they were 50 feet (15m) long. In order to hold water, the canal was lined with puddled clay, and to avoid extensive lock construction, an aqueduct was constructed over the River Irwell.

This canal caught the imagination of the public. As a financial success it motivated developers and investors. It served as a model for subsequent construction and about 3,000 miles (4,800 km) of canals were opened in the next 90 years. Waves of canal building followed in Europe and North America. Systems expanded in France and the US to about the size of the English system.

There was a flurry of inland navigation acts between 1759 and 1794. Most of these were for narrow canals, using the 7 foot beam boat design from Bridewell's canal. Adoption of the 7 foot boat kept construction costs down and saved water, a problem for many canals. Boats ran 70 feet (21.4m) in length, and could carry about 30 tons and be hauled by a horse or mule moving along a tow path alongside the canal. Canal building yielded much experience with earth moving, lock structures, bridges, aqueducts, tunnels, etc. Firms were organized for contract construction and engineers, managers, and laborers gained experience.

Although navigation acts were private acts, the policy-institutional aspects of canal building began to fall into a pattern. Canal companies were organized and issued stock. There was carry over of rights of use from roads, and acts began to require that anyone could operate a boat if tolls were paid. Companies emerged to offer canal plus pick up and delivery services.

Where the terrain was difficult and/or water in short supply, incline planes were constructed. Building on the fringe of the feasible pressed for suitable technologies, and some small tub canals were

constructed. Commodities were moved in trained, 6-10 ton "tubs." Each could be moved by a horse on a near-level tramway, and they could be handled relatively easily on inclines.

By about the second decade of the 1800s the era of canal building in England was over. In part, the system was "built out" in that the feasible canals had been built. Also, rail competition came along.

The modern modes owe much to canals. They demonstrated the pay-offs from capital intensive transportation improvements. They increased construction know how and institutional experiences. They also provided management, financial, and operating experiences and related institutions. There was also important learning by the public--learning about investment opportunities and about the off-system developments induced by transportation improvements.

2.2 Roads

In England as elsewhere local roads and trails were everywhere available. In the very early days they were alignments and paths that shifted depending on seasonal stream flow and the quality of footing and grades desired by walkers, pack horses and mules, carts, and cattle drives. The English local parish road system involving statute labor began to be strained in the 1500s because of the growth of through traffic (roads no longer a local matter) and the breakdown of the manorial organization of life. Bridges were a technical and fiscal problem, and the 1537 Statue of Bridges was the response. Next, there was the Highways Act of 1555, resulting in the election of surveyors to plan and supervise the 4 days of statute labor per year, soon raised to 6 days. With revisions, this system served until the 1830s. Surveyors were given powers to requisition materials, and parishes were empowered to tax for road improvements. Labor could be hired.

However, the mismatch between regional travel and local responsibility remained, and policy had not responded to technical questions such as how to best build roads. Radical changes began to emerge as local governments attempted to deal with those problems. Some started charging tolls on heavy vehicles to raise money for repair, others set maximum weight limits for vehicles. Local governments worked together to develop toll and road programs. There was effort to increase the widths of wheels on large vehicles. In the

meantime, traffic of all types continued to grow; stagecoaches and mail wagons emerged in the early 1600s. Pack horses and mules were less and less used; wagons increased in size and weight.

The bridge problem became acute. The Act of 1537 has done no more than put the responsibility for bridge maintenance on the parishes, and it had few teeth in it. Technical problems had to do with the narrow width of bridges, unsuitable timber construction, and steep access and egress.

The stage was set for considerable revision of highway policy. One revision allowed and encouraged turnpike developments, beginning about 1650, but taking-off at about 1700. Another was a restatement of the responsibilities of the parishes.

The parishes first. Policy emerged in the 1760s and '70s with a rationalization tone. There was effort to define the technologies needed: for example, town access roads were to be at least 20 ft (6m) wide. Efforts to control weights and vehicle configurations expanded. For instance, the more the horses the wider the wheels, and six horse teams hauled wagons with wheels six inches across. Cross and little used routes could be abandoned. Taxes were graded so that those who used the roads the most paid the most. Ills were dampened, but poor construction, drainage, and bridge problems remained.

2.3 Toll Roads

The toll road or turnpike was the answer. Such roads predate the canal era, as mentioned, and early ones (e.g., in the 1600s) were ad hoc extensions of the parish system--several parishes would work out a joint project using the surveyor and obligated labor arrangement.

Although development of turnpikes was slow in the first one half of the 1700s, a pattern of development had emerged by about 1750. Trust organized and town centered sums it up. The effects on roads of traffic to London and provincial centers required action, and successful acts and schemes prior to about 1750 yielded a map of rather disconnected, urban centered routes. By then there were 143 trusts managing about 3,000 miles (4,800 km) of road. Later acts then filled in the map--by 1830, there were more than 1,000 trusts and 20,000 miles (32,180 km) of road.

Road trustees were local men and women of substance. Enabling acts specified powers, accounting and meeting requirements, and provided for posts of treasurers and surveyors. The early pattern was for tolls to be collected at gates (by toll farmers), and after expenses were met, reinvested in repair. After experience, mortgage funding guaranteed by gate income began to be common.

Toll schedules were very complex. They reflected geographical equity, the principle that those who occasion costs ought to pay, and attempts to protect roads from damage. The latter yielded high charges on excessive loads and on vehicles with narrow wheels.

The technical view was that roads needed protecting. At the national level, the General Turnpike Act of 1773 contained 28 clauses relating to wheels, weights, etc.

Robert Telford became involved with the technology of road construction in 1803 when Parliament considered the problem of roads in the highlands of Scotland. A development scheme was initiated--Parliament would pay one-half the costs if local politicians would propose schemes and pay the remaining costs. Telford surveyed needs and developed engineering designs to be used--geometry, pavements, and drainage. Telford had much experience in canal work, and, except for bridge construction, this was the first English road engineering of note. He also worked on the Hollyhead (London-Portsmouth) road offering a London-Ireland connection. Study there led to recommendations for gradients, maximum about 4 percent.

John L. Macadam obtained experience serving on trusts in the 1790s, and he interested himself in both technology and administration. He is best known for his technology--the macadam surface for roads--but he made major contributions to the improvement of the management of trusts.

By the 1820s much of the road system had been improved to macadam or similar standards. There were extensive organized coach service offering 10 mph (16 kph) velocities, mail wagons and mail service, and freight had emerged in two classes of service--fly wagons or vans for fast freight and heavy slow wagons hauling about 10 tons.

2.4 Tramways

The technology is old, having evolved first in the metal mines of central Europe and in the copper, lead, and zinc mines of England. There was a natural extension from these beginnings to hauling coal from mines to water. Propulsion was provided in near-level situations by horses. Sharp lifts were accomplished by horses turning capstans, and by steam power when rotary power could be obtained from steam engines (about 1780).

The rail evolved from iron strips fastened to wood through plates and L-shaped plates to forms that begin to look like today's T-shaped rail.

Because the early tramways were associated with mines, they were financed, owned, and operated by mine operators. As demand for coal and canals expanded, tramways expanded. At first this resulted from the new opportunities for mining. Later, tramways were incorporated in canal designs--some served as feeders where canals could not be practically extended, and some served as sections of canals, as illustrated by the Pennsylvania portage road-canal oriented east-west across central Pennsylvania.

2.5 Maritime and Port Developments:

The tonnages involved in the English open sea trades had increased very rapidly during the 1700s and shifted in composition. There were early imports of Baltic grain, flax, hemp, tar and Portuguese wines with reverse movements of leather, wool, and some minerals, especially copper and tin. Later, the fish and cotton trades evolved with North America and sugar trade with the Caribbean; there were reverse flows of manufactured products. Ship sizes pushed toward 180 tons in the North America trades in the late 1700s; Indiamen were larger.

If port traffic was limited in size, cargo handling was often managed by lightering. A ship would anchor in a bay or river, and lighters of row boat size or small barges would move cargo to and from shore. There might be on and off loading of river barges to reach upriver points. Landing stages accommodated lighters or small barges at the river side.

Increased movement of goods warranted investment in quays. One reference refers to 1,500 feet (457 m) of quays in London by the year 1700 and remarks on their crowding and needs for additional

facilities. Other cases differed depending on trade growth and local circumstances. In Hamburg, for instance, there was early use of warehouses on small shallow canals. But as ship sizes increased, river anchoring and the use of lighters became common. Eventually, ships anchored to large barges for cargo handling and storage, and lighters worked the barges. That system continued until the 1880s.

First investment in Liverpool commenced in 1709 when an enclosed dock was constructed. The enclosed dock was built to deal with relatively high tides, the alternative would have been very deep quays. The facility was built using a small estuarial pool (Liver Pool), and it provided 18 feet (5.5 m) of water. Occupying 4 acres (1.6 ha), it could accommodate 100 of then sized ships. Pools or basins began to be constructed in London some years later. The West India Docks opened in London in 1802 enclosed some 30 acres (12 ha).

Companies or local governments provided financing and exerted control, subject to enabling actions by central governments and to customs control and other operational matters of interest to central governments. Navigational aids were generally provided by local organizations. The City of London, for example, provided dredging and channel markings.

The theme in England was quasi-government or private institutions financing, constructing, and operating facilities. That theme continues for air and water ports in many parts of the world.

As ports grew, there was potential for grasping economies of scale. But a factor limiting the capturing of economies of scale was ship size, and ship sizes were not increasing very rapidly. Because of slow cargo handling, the "dead time" in port was long, disadvantaging large, expensive ships. As ships upscaled, the number of sails and requirements for crew increased in an almost linear way, as did the expense and difficulty of construction. (Rule of thumb called for three crew members per sail on a square rigged ship.)

For centuries, general cargo ships were measured on register tonnage, with one register ton representing 100 cubic feet of space. Net register tonnage is tonnage so measured minus space used for machinery and crew quarters. Large wooden sailing ships in the early 1800s were as large as 600-700 tons.

In Portugal and Spain, one register ton equaled two large kegs. In English ships the measure seems to have evolved in the Baltic trades where one ton of Russian wheat occupied 100 cubic feet. (This discussion will refer to measurement tons where appropriate. It will not take note of differences between metric and english measurement system tons because they are reasonable approximations for each other for the purposes of this discussion.)

Cargo handling was "by-hand," with simple mechanical aids. In the 1700s a dock might have a manual capstan used for warping ships, but that's all. Steam engines were available in the 1700s, but were not used on the docks. They were stationary and could not be well employed alongside ships for off and on loading or when handling small quantities. Where the topography was favorable, gravity flow of bulk commodities emerged.

There were some manual cranes. A few specialized docks had walking cranes (1750-1850). The crane was powered by laborers walking in a large, say, 16 foot drum geared to an external boom and hoist. Powered hoists were not used until the mid 1800s. A central steam engine pumped water to a large storage tower, and the pressure head drove hydraulic crane motors (or water was pumped to an accumulator under pressure).

3. The First of the Modern Modes: Rail and Water

Information in books, building plans, photographs, and accountant and legal records on the innovation and evolution of the modern modes is available from many sources, and the discussion to follow provides "snapshots" of large and well documented stories. It strives to give the flavor of these stories and make the ingredients in evolutionary recipes come alive. Recipes involved people, places, building blocks, trial and error, learning, pragmatic decision making, use of experience, and enthusiasms.

3.1 Railroads

Steam powered locomotives hauling cars on iron rails or strips on wood beams had a several decade history by the time the Stockton and Darlington opened in 1825. Even so, some say it was the world's first railway/railroad and its development serves as an instructive metaphor. This 25-mile (40 km) line connected

coal fields near Darlington with Stockton on the River Tees. Transhipped to coastal vessels, coal moved from Stockton to the London market.

The Stockton and Darlington began as rather ambitious project. The Pease family owned coal deposits in the Auckland coal fields in the vicinity of Darlington. The market for coal was increasing, but to develop and market Auckland coal, a considerable and risky investment in transportation was required. Edward Pease decided to take the risk, and secured an enabling Act for construction in 1821.

The proposal was for a tramway. Wagons drawn by horses or mules were to be pulled along rails fastened to stone or wood chairs. Rails at the time were either made of wood faced with an iron strip or iron plates with no wood backing. Where grades were steep, a fixed steam engine hauled cars using ropes; if not so steep, self acting planes were used (up direction car tied by a rope through a pulley at the top of the grade to a down direction car).

The investment was risky because the tramway was to be long relative to tramways of the times. Also, the high elevation of the coal fields and the topography of the route were unfavorable--lots of up and down grades. In light of these difficulties, Pease's problem was to find an engineer who could keep construction and operating costs to a minimum.

He found that engineer in George Stephenson, a self-taught mechanic with an excellent reputation. Stephenson did a superior job of engineering. Cuts and fills were balanced to reduce material hauling costs. Improving on best practice of the times, there was a combination of near level grades and short, sharper grades to be worked with self acting planes or steam engine-driven rope haulage.

Stephenson had experience with steam engines at coal mines (lifts, pumps), and he had also rigged some locomotives. Two locomotives were ordered. Just as a horse could, they were to pull 3 to 6 ton wagons on level or near level ground.

The Stockton and Darlington began operations in 1825. It was the first railroad in a partial technology sense. It made use of locomotives and edge rail. It demonstrated that large volumes of bulk

traffic (500,000 tons per year) could be moved at low cost. Most rail routes move upwards of 10-times that volume today and coal hauling routes 100-times more.

Many looked at the Stockton and Darlington and read the easy lesson--tramways could be built at larger scale than had been imagined before. Perhaps partly as a consequence, fifty or so tramway proposals emerged in the decade after the Stockton and Darlington opened. Most proposed powering by stationary steam engines and cables, both for incline and flat running; some were to be mainly locomotive powered. The idea extended to the Continent. The Saint-Etienne railway near Lyons is said to be the first French railway. It was a tramway that was converted to steam power in 1844 using locomotives built on the English model.

The Stockton and Darlington was a success in a larger way. It demonstrated that a well thought out design could be a money maker. The competitive movement of coal to the London market showed that clearly. It also showed that locomotives were a very effective substitute for horses and that wagons could be connected in trains.

Success was quickly emulated.

There was a proposal for a Liverpool-Manchester cableway, and William James had begun surveys in 1822. The market situation called for increased capacity. Manchester was a major mill town. In 1824, it had 30,000 power looms and was importing 400,000 bales of cotton. Canal/river facilities linking Manchester with Liverpool were strained, and Manchester businessmen sought congestion relief.

George Stephenson replaced James in 1824, and his plans went to Parliament in 1825. After overcoming much opposition from landowners and canal interests, an act was passed in 1826 and construction began.

Cable haulage was sure to work, and it had to be used in a steep grade and limited ventilation tunnel connecting the station in Liverpool with the docks. But there was concern about its use on the main line. It would provide much excess capacity if traffic was light in the early days. Locomotives could be provided to pace the build-up of traffic. But would they be reliable and have the necessary power?

To test the promise of locomotives, trials were held at Rainhill. Locomotives were to run at not less than 10 miles per hour (16 kph), haul cars of three times their weight, adhere to a weight limit, and run the route without adding fuel or water. Stephenson's Rocket easily met the requirements and won the trials.

Running at about 20 mph (32 kph), the 31 mile (50 km) line was opened to passenger service in 1825 and to freight service in 1825. Both services were an immediate success.

The railroad attempted to arrange passenger service provision by a coach operator and freight service by a canal operator. The operators seemed not to have been interested. Considering the opportunity for car training and the desire for scheduled operations, the railroad elected to operate services, a major break from canal and road traditions.

Freight cars were built from tramway wagon experiences. First class passenger cars were, essentially, three road coach bodies mounted on a flat car. Second class cars were open sided cars with roofs. If one wanted to travel in their own road-coach, it was mounted on a flat car.

Given answers to the questions of what railroads would be like and what they could do, deployment was very rapid. The London and Birmingham opened in 1825, and twelve years later there were 2.2 thousand miles (3,530 km) of route in England, and 15.5 (25,000 km) by year 1837. There were 17.9 thousand miles (28,800 km) of route by 1840, and the miles of route continued to grow into the 1850's, reaching 21.8 thousand (35 km) by 1850.

Nothing succeeds like success, and railroad construction boomed elsewhere. A railroad opened in Belgium in 1835 and in Austria in 1838. The Baltimore and Ohio obtained a charter in 1827, and it opened to Harpers Ferry in 1831. By that year, 14 short railroads had opened in the U.S. The first was the Pontchartrain Railroad, opened in 1825; it was followed by the Charleston and Hamburg (South Carolina) in 1833. The Champlain and St Lawrence opened in Canada in 1836.

One remarkable thing about the Stockton and Darling was the way it confronted conventional wisdom. A critic of the times might have said that it had no prospects. Existing transportation systems were built-out and mature. Canals, tramways, and roads had been built where the topography was reasonable and

the economics was right. The task was that of managing what had been constructed and making marginal improvements. Indeed, publications of the time were addressed to just that. They were mainly addressed to road pavements (especially macadam surfaces and the need for drainage) and toll road management, just as most planners and politicians see maintaining and financing as today's priorities.

3.2. Inland Waterway and Maritime Developments

Canal and maritime uses for the steam engine appeared as steam engines were refined. One use was pumping water for lock operations during times of water shortages. Dredging was an application, and steam tugs were developed to aid sailing ships approaching and leaving harbors. Steam engines found applications where canals used incline planes, as was the case for the portage road oriented east-west across much of Pennsylvania, which was described as one half canal and one half incline plane.

Early ship and tug applications used side paddle wheels, an application of the water wheel technology used at mill dams. Partly in response to concerns about damage to riverbanks by wave action from side wheel paddles, paddle wheels mounted at the stern of vessels emerged. Later there was application of screw propellers as these were developed along with suitable rudders. Storm damage to paddle wheels was a concern for ocean sailing.

3.2.1 Steamships on Atlantic Routes

Many managers and mechanically minded tinkerers were important actors in the emergence of modern maritime services. Although he was one of many, the discussion to follow will review Marc Isambard Brunel's activities because his efforts were in the right directions and showed how improvements might be achieved. Today, Brunel might be described as an out of the box thinker.

Brunel was the chief engineer and a major promoter of the Great Western Railway when it was organized in 1835. The route from Paddington Station in London to Bristol was opened in 1841. Afterwards, Brunel constructed or purchased links and built a system to serve the west.

Brunel was sensitive to the economies of scale achieved by building larger equipment and suitable facilities. The Great Western was built with mainly double track at 7-foot (2.134 m) gauge. Inverted U-

shaped rails were used. Where there was overlap with standard track gauge (4 ft 8.5 in; 1.435 m) railroads, as on the Oxford-Birmingham route, three rails were used.

Passenger cars ran 80 feet (24.4 m) in length, and drawings of freight and passenger cars suggest that they were two to three times the size of cars on standard gauge railroads. At first, Brunel placed the body of the car within the wheel gauge for safety and ride quality reasons. Later, the bodies were raised above the wheels and made wider, enabling passengers to sit four on each side of the aisle.

The Great Western got along fine for a while using its gauge, but gradually shifted to standard gauge, achieving this in 1891.

At the time of the start of the railroad, Brunel went into the steamship business. Brunel designed the SS Great Western which entered service in 1837, steaming to New York in 19 days. The Great Western, a wooden paddle wheel steamer with sails, was not the first of its type in service. But sized at 1340 tons, it was two or more times as large as the few previous paddle steamers. Unlike previous steamers, its size permitted it to carry sufficient coal for full-time steaming and thus schedule-keeping.

Liner coal consumption was not very efficient. At the time, sea water was used in the boilers, and it was thought that low pressure should be used to reduce scaling in boiler tubes. With low efficiency low pressure boilers, lots of coal was needed for steady-steaming; a large ship was needed. (As a rough approximation and for a given velocity, the power required to move a ship increases with the square of ship size; capacity increases with the cube of size.)

The SS Great Britain followed in 1843. Although continuing the convention of sails, this was an iron ship with a screw propeller, sized-up to 3270 tons. (A somewhat similar ship, the Rainbow at 500 tons, was constructed in 1836 and had been successful in the European trades.) The Great Britain ran aground in 1846. Refloated and reengined, it was used in the Australian trade until 1886.

Similar to Stephenson's accomplishments on the Stockton Darlington, Brunel's accomplishments serve today as an instructive metaphor and at the time as an imagination stretcher. The Great Western and the Great Britain were neither new, strictly speaking, nor very successful. Further crafting of designs would

be required before an appropriate ship technology emerged. Even so, they stretched imaginations and energized the development of modern liner shipping.

The 227 foot length (69m) City of London constructed in 1854 is viewed as the first truly modern design. However, it disappeared on its first voyage with 480 passengers aboard, presumably the victim of an iceberg.

3.2.2 Riverboats and Ferries

Even before steam and iron ships were providing services on the Atlantic, application of the steam engine and appropriate ship and boat designs were emerging in many market niches. By 1816 there were steamboat applications in Sweden, on the Hudson River in the US, and in cross channel services linking England and France. By 1821 channel services were operating on schedules.

Robert Fulton was one developer. He introduced Albany-New York steam boat service on the Hudson River in 1807 and it was an immediate success. Competing with slower sailing vessels, it provided scheduled service and shortened trip times.

Very different in background from Stephenson and Brunel, Fulton had moved from Philadelphia to London when a young man where he studied and made his living as a painter. Interested in mechanical things, he promoted tub canals and his plans for a submarine. Finding the English uninterested in building a submarine to destroy blockaded ships in French harbors, Fulton journeyed to France only to find the French uninterested in building a submarine to break the blockades. Earl St. Vincent of the English Navy accused the submarine of promoting a kind of warfare unacceptable to naval officers, and this mode of thinking may have played a role in the rejection of Fulton's concept.

Fulton was also unsuccessful in promoting his river boat concept in France where his steamboat was burned by bargemen. Relocating to New York he introduced services there. Next, Fulton sought to replicate his successful introduction of Hudson River services in the Pittsburgh, Pennsylvania-New Orleans, Louisiana market. But his low pressure steam boat proved unsuccessful--too small and not enough power for upstream services. Recognizing an opportunity, in 1816 Captain Shreve constructed a high pressure

steam engine, double deck on a barge-like hull boat which was successful and became the prototype for the Mississippi River steamboat.

Designs fitting technology and institutions to natural conditions and markets occurred on other inland waterway systems.

4. Logics of Development

Early developers such as George Stephenson and Robert Fulton are sometimes referred to as blind giants: their developments were major yet they did not recognize the consequences of their actions. In the long sweep of history the expression works very well, yet a pessimists of the times could rightly question innovations on energy efficiency, cost, safety, and limited market terms, and there were questions about public acceptance. Indeed, the Bavarian College of Physicians said in 1832 that the rapid movement of trains would generate *delirium furiosum* a brain disease in travellers and exposed onlookers.

There were also canal and railroad manias as optimistic folks had their say.

This section will look beyond the simplifications of the pessimists and optimists to how and what questions: (1) how the systems were developed and (2) what were their characteristics that gave them their robust and adaptable characteristics and that triggered enthusiasms and clamor for deployment?

4.1 Flexible and Robust Technology

A brief relook at development processes will underscore the factors supporting success and rapid deployment.

4.1.1 Use of Available Building Blocks

The modes arranged building blocks in new formats, as stressed. The railroad used canal construction experience, the service formats that had emerged on canals and roads, management and investment capabilities from those sources and others, and steam engines. As also stated, modern maritime services emerged as steam replaced sails and iron and steel were used as building blocks. Already, there were ship owning, insurance, and warehousing/freight management procedures and these were improved by the adoption of cable communications. The experiences sum as borrowing and mixing and matching.

Innovation was by design, so to speak. It was the designs, the ways that things were put together, that were new. Old things were used to make new services. Indeed, often the building block technologies would not have been regarded as leading edge or state of the art. Fulton's steamboat, for example, used an inefficient low pressure steam engine as did Stephenson's locomotives although locomotives had been built with high pressure engines as early as Richard Trevithick's 1808 products.

Another feature of the technology was its rough approximation character. Modifications were required as workable technologies were sought. Because of modifications made as the technology evolved, many refer to the London-Birmingham as the first modern railroad and the Liverpool-Manchester and Stockton Darlington as learning steps along the way.

Brunel proceeded by trial and error using wood and then iron, paddle wheels and then propellers, and variations in ship sizes. There were failures. Brunel's third large ship, the Great Eastern, was 680 feet (1,000 m) in length and overshot in a sense. It was not to be exceeded in size until the Twentieth Century. It was too large for the market and too slow compared to competitors.

Similar to other innovators, Brunel took advantage of knowledge. Newton had studied the resistance of bodies moving in a fluid and had proposed the "principle of similitude." William Froude, working for Brunel, used the principle (for the first time in ship studies) to apply the results of physical model studies to predict the roll behavior of the Great Eastern. Froude had some ideas of resistance/propulsion relations, yet the Great Eastern was underpowered.

This knowledge was the base from which Brunel acted. Relative to earlier ships the Great Eastern was long and narrow and its profile was followed by subsequent liners. There was a double hull, and high bulk heads with no doors between them: 15 transverse and 2 longitudinal through the boiler and engine rooms. The Great Eastern was a near unsinkable ship, probably more so than the Titanic of iceberg fame. Yet it was big and expensive and was a titanic failure in its market.

As the application of work by Froude illustrates, developers took advantage of the technological knowledge available, but there were many gaps. Metal fatigue wasn't much recognized nor was the

difference between static and dynamic loads. Indeed, Stephenson, whose knowledge was experience-based, was embarrassed when a bridge he had designed and tested under a static load collapsed when a dynamic load was applied. Although the steam engine has been in use for years, thermodynamics was yet to be established as a systematic field of knowledge.

4.1.2 Robust Structure

Both rail and marine operators utilized equipment that was expensive to maintain and repair. Scheduled services required control of movements and the dangers of collision and natural hazards also asked for control. Predictability is an aspect of control, will another train be on the track? Will the ship arrive on time?

With these requirements it is not surprising that marine and rail institutions were modeled on the precedents set by military organizations. Military organizations were guided by rules suited to any situation. Such organizations were large for the times and workers (soldiers, sailors) often operated out of sight of officers.

The successful, work in any situation, characteristic of transportation institutions eased their deployment in varied situations and their recovery after man made or natural disasters. Today, there are general rule books applicable to all situations and special rules, such as those found in railroad employees time tables, for particular situations. Everyone knows what to do and what others will do.

Another aspect of robustness stems from ways the systems adapted to circumstances when using the building blocks at hand. This was especially important for railroads. For example, wood was readily available in the US, so locomotives with large fireboxes designed for wood burning were developed. Relatively rich in energy (wood) and land and short on construction resources, curves and grades and rough track were the norm in the US. English locomotives with four powered wheels were modified by adding a swiveling steering truck, and swiveling trucks on rail cars and locomotives were soon a feature of US railroads. Indeed, the two axle swiveling truck and four powered wheels locomotive became known as the American Locomotive. It and its derivatives dominated locomotive manufacturing for decades.

Designs to match market and topographic situations are illustrated by variations in track and clearance gauge. Stephenson's gauge became known as standard gauge, but other gauges were used. Five feet (1.52 m) track gauge was adopted in places, as was narrow gauge, usually 3.5 feet (1.07 m). In addition to gauge, options about construction costs, double tracking, yards, acceptable grades, stations and sidings, locomotive powering, and length and frequency of trains were available to rail builders and operators. Designs to match markets and sailing conditions were, of course, common in open seas transport, as well as in coastal, river, lake, and canal situations.

4.2 Deployable Institutions

In addition to incorporating the rule based, command characteristics of the institutions on which modern rail and water services were modeled, systems had a self contained character. Sailing ships carried carpenters, iron workers, and supplies and could replace masts, repair leaks, replace small boats that had been lost, and do many other things. Armies had a similar self contained character. Once equipped with cannon, gunpowder and finances, the organizations moved on their own, sometimes purchasing food and feed to augment supplies.

Rail and maritime institutions carried these traditions forward as a matter of necessity as well as tradition. There was necessity because except in the industrial areas of England and similar areas on the continent and the eastern shore of the US, supporting services were very limited. Make if less expensive than buying is the practical rule, but it is useful only if there is some place to buy and making was often the only option for railroad and maritime operators.

Rules, command protocols, and high levels of self sufficiency gave the rail and water modes characteristics that enabled their deployment. These were not hot house flowers; they could and did flourish in harsh environments, so to speak.

4.3 Self Energizing Systems

Market niches have been emphasized and by definition, niches are places where profits may be made. But the water and land modes did more than that. They were profitable enough to energize investors and users, and their services set off clamors for deployment and services.

One key to market energizing was cheaper, faster, better services, and that case is illustrated by the way steam services displaced sail. Iron and later steel ships and steam propulsion had big advantages. A main disadvantage of wood was that connections were difficult, and, for the loads to be carried, structural pieces were large relative to iron. The form of the wooden ship was also limiting. Obtaining thrust from sails, forces had to be carried through the masts, rigging, and ship structure to overcome the resistance of water to ship movement. Ships had to be broad if they were to be stiff under heavy press of sail.

Graphs showing the percentages of sail versus steam ships from 1840 to 1900 display a typical predator (steam) prey (sail) relationship. Sail tonnage grew by a factor of 3.5 between 1800 and 1880, but the tonnage in 1920 was about the same as it was in 1800. Actually, a better sense of the displacement of sail would be given if the tonnage of steam was inflated by a factor of about 4--the working capacity of a steamer was about 4 times that of sail vessel.

In the case of liner services, freedom of the seas had been established as principle; excepting coastal trade, anyone could sail in any service and anywhere. Beginning about 1812 and, in part, as a consequence of the 1812 war between Britain and the US, a system of independent ship operators had emerged. Previously, shippers had tended to carry their goods on their ships.

After the first crossing of the Great Western, the British offered mail contracts to support service. This led to the development of the Cunard Line, which soon dominated the trade. In 1840, the Peninsular and Orient (P & O) Line was given a contract to carry mail to Egypt and India. This use of mail contracts was very common, and use was emulated as other modes emerged: for example, mail contracts were used to aid US railroads and air line companies.

4.4 Innovative People

Innovation is a people story, for innovative entrepreneurs, technology tinkers, risk takers, and promoters are involved. So are actors who recognize and exploit a new service once it is available, actors such as the great railroad and steamship line builders. Actors who innovate new uses are also important players. Many are ordinary folks who change the things they do and do new things. Some entrepreneurs organize new business and social activities. Thomas Cook of Cook's Tours fame is an example. He began to organize railroad-based tours just a few years after service became available.

Innovative folks work in varied styles. Some are nonconformists, others work in a try and try again serial fashion. Watt who refined the steam engine was an instrument maker, Fulton a dreamer, promoter, and painter, Brunel an opportunity seeking engineer and promoter, and Pease a risk taking businessman.

Brunel was a visionary when he saw the advantages of large ships early on. He seemed willing to question conventional opinion. For example, he used a screw propeller when wisdom said such propellers had no future. As Sir William Symonds, Surveyor of the British navy, stated in 1837 "...even if the (screw) propeller had the power of propelling a vessel, it would be found altogether useless in practice, because the power being applied in the stern it would be absolutely impossible to make the vessel steer." Fulton? Perhaps he could be described as an untiring promoter; designer might be another descriptor. Indeed, Fulton saw designs as the essence of innovation and made unsuccessful efforts in his later years to convince the US Patent Office that its definition of new should scope to designs.

5. Diffusion and Improvement of Rail and Marine Systems

The discussion in this section will first treat the diffusion of rail and marine services. That's a matter of growth--their worldwide spread and increased use. It will then turn to development--the ways services improved on quantitative and qualitative dimensions.

5.1 Diffusion of Services

By about 1840 a trader in London or elsewhere in England had much room for optimism. Inland coal fields were fueling manufacturing. The world was within reach and development was rapid. Competition from bankers on the Continent had been weakened by the Napoleonic wars. American port

cities were competitive in several ways, but the US would soon turn investment and commercial interests inland. Germany and other European nations would emerge as competitors, but serious competition was decades away. Britain ruled the maritime trade waves, and as late as 1890 Britain held about half of the ocean going ship tonnage.

The situation was ripe for the diffusion of marine and rail services and the industrial, agricultural, financial and other activities they enabled. Diffusion took place in space and time. Space was organized around the shores of the oceans as marine services provided links to improved land and inland water services. The time required for diffusion was partly determined by the necessity of organizing institutions and financing, building physical infrastructure, and investing in equipment and operations. But other factors were important, including the displacement of precursor services.

Commenting on service in the US, a writer in the 1880s remarked that everywhere the railroad went, science followed. His reference was to mechanized agriculture and the use of fertilizers, the telegraph, public education, improved water supply, industrial technologies, banking, and other features of the commercial, agricultural, and industrial revolutions. These developments took time for they required the accumulation of knowledge, experience, and changes in the distribution of population--nation to nation and rural to urban.

5.1.1 Diffusion of Maritime Services

In the decades just after 1819 when the Savannah crossed the Atlantic aided by steam propulsion, steam displaced sails in packet boat services on the North Atlantic and by the 1870s steam powered liner services were available in all major markets. But displacement of sail was neither easy nor quick. For a time fast sailing US built clipper ships remained competitive. The first clipper ship, the Rainbow, was designed by John Griffiths and built in New York in 1845. For about two decades wooden square rigged clipper ships served well in the long distance trades, such as China-California and Australia-Britain. But to achieve speed they had reduced draught and cargo space and they gradually gave way to larger iron ships. Most of the iron

ships were steam powered, but sail power lived on for decades in fore-and-aft rigged iron-built schooners, some with as many as seven masts. Capacities ran as high as 7,000 tons.

Unlike scheduled liner passenger and priority cargo services, tramp services, movements from port to port seeking and serving cargos when they became available, were slower to convert to steam. Sailing ships were serving lower value cargos and depending less on speed and it wasn't until the 1890s that steam tonnage overtook sail. The opening of the Suez Canal in 1868 advantaged steamships in the Australian trade where sailing ships had some advantage from the favorable winds of the high southern latitudes.

The Suez Canal shortened trip times, so fewer ships could serve demands. This overcapacity accelerated the retirement of obsolete ships, as did changes in ship technology.

During the Nineteenth Century larger and larger quantities of foodstuffs and raw materials moved to the ports of Europe and products of manufacturing were exported. The development of refrigeration enabled exports of meats and dairy products from New Zealand, Australia, and Argentina, and the grain trade increased as Canadian, Argentine, Australian, and US products flooded Europe. The availability of cheap grain in Europe reduced food prices and supported rapid urbanization. But cheap imported grain impacted the livelihoods of many farmers. Rural unrest was increased, and out migration also increased.

Great Britain's largest trading partner in the 1855-1900 period was the US, and the total value of trade increased by about 300 percent during that period. Australia ranked as the 7th trading partner in 1855 and had risen to 3rd in rank by 1900. With the decline of the US shipping industry during this period, as indicated by the decrease in the imports and exports carried in US bottoms from about 80 to about 12 percent, Britain became the predominant supplier of shipping services. It had an early start and was also advantaged by the availability of coal for export which aided the balance of tonnage on out bound tramp ships.

5.1.2 Diffusion of Rail Services

Railroad expansion marched to the same clock as did maritime improvements and the growth of industry and trade. From lots of starts here and there, expansion was accelerating rapidly at about 1850 and

continued until about 1920 or 1930. The US and European systems were essentially built out by about 1920, expansion of systems in late-starter nations on the periphery continued until later.

In areas where narrow canals with horse or mule drawn boats had served, railroads displaced most canal services. In instances, railroad developers purchased canals in order to acquire right of way and/or feeder services. In other cases, canals were enlarged to enable the use of motorized barges or tows.

Some long distance wagon services continued for decades; the Oregon Trail in the US was in use until about 1900. But in the main wagon and coach services on roads were realigned to serve as feeders to rail services. The driving of cattle to markets along roads gave way to live animal shipments in stock cars to final markets and then to processing yards as refrigerated rail cars became available.

The sweep of industrial, trading, and transportation system developments may be thought of as maritime-railroad enabled globalization. Today, it is not surprising that the US and Europe are served by well developed rail networks and that the rail and port development of nations on the then periphery mirror the ways they participated in that sweep of development. China, for example, had limited involvement. Its first rail line opened in 1880, 30 years after the first line opened in India. Compared to other nations on size and population dimensions, China has a very limited rail system today.

The rail system of Japan developed slowly because of competitive inter island and coastal marine services and resistance to foreign influence. The situation changed with the Meiji period beginning about 1868, and a 29 km Tokyo to Yokohama railroad was begun in 1870 and opened in 1872. The Tokaido main line (606 km) between Tokyo and Kobe was opened in 1889. Because of the late start, the interruption of World War II, and financial constraints, expansion of the rail network continued into the 1960s. Trains were operated on 3.5 ft (106mm) track gauge, but expecting increased traffic which could be better served by standard rail gauge, many lines were built to standard clearance gauge in order to leave room for rail gauge widening.

Although Japan centered, many features of its development pattern were typical. It was motivated by commercial interests (Yokohama was an open port), but also by the desire to assure the political

dominance of Tokyo. Bonds were sold in London, and equipment was purchased from the UK. Managers were hired from the UK including, interestingly, brothers Francis and Richard Trevithick grandsons of Richard Trevithick who had built and operated a pre Stephenson locomotive on iron rails. The establishment of an engineering college in 1877 in Osaka initiated the development of domestic expertise.

5.2 Improvements

Rail and marine services enabled developments of many sorts in the activities of the users of transportation services. Many of these involved the diffusion of knowledge, technologies, and attitudes from already developed areas and others were the results of local innovations. These developments are the subject of the Technological Changes and Transportation Developments Chapter following and will not be treated here.

Rather, the present short section will highlight improvements of the modes as they were diffused and traffic grew. Some improvements were primarily of a technical sort and others were primarily organizational and management in character.

5.2.1 Institutional Improvements

In both the maritime and rail modes labor was divided into officers and men and tasks and responsibilities were organized around crafts. Discipline was maintained in a pseudo military fashion. For example, well into the 1900s the railroads held court marshals to determine guilt and penalties on matters such as the derailment of a train. Also, and as mentioned, the use of rules imposed discipline and predictable actions even when labor was not directly supervised by management.

Opportunity and necessity shaped organizational communications. The telegraph provided the opportunity. It enabled headquarters control of far flung operations organized in divisions. Train control by departure and meet (instructing where one train will meet an overtaking or passing train) orders were sent by telegraph and ocean cable traffic provided for ship movement and other maritime management matters. Indeed, today's highly developed train control and ship operations systems mirror and build from yesterday's.

The railroad, in particular, is said to have provided the model for modern industrial organizations. There is a central headquarters that undertakes planning and manages financial matters. Operations are scattered here and there and are monitored by headquarters that makes judgements about levels and mixes of outputs.

Railroad organizations specialized services to markets and equipment was specialized. This was also the case in maritime activities where tramp and liner services were augmented by tanker, dry bulk, and many other varieties of services.

In addition to the firms providing services, a large number of special purpose institutions became involved in rail and maritime activities. Insurance companies, owners and lessors of rail freight cars or ships, professional and standards setting organizations, tariff setting conferences, bureaus of shipping that inspect and certify the conditions of ships, and shippers organizations are among the many private institutions.

Governments also have industry related institutions. Safety regulation is found everywhere, there are labor relations activities, and economic regulation has far from completely disappeared. Industry experience was the basis for public utility law and it taught governments how to engage in safety and economic regulation. In the US is no accident that the railroad designated inspector system in which employees of railroads serve as government safety inspectors is replicated in air transportation and that air transport labor relations are cast in the rail mold.

5.2.2 Technological Improvements

Dating from the first trials of a new mode, there are periods of twenty to thirty years during which the predominant form of the technology emerges. During this period, technology development has a trial and succeed or fail character. Once the predominant technology is found, incremental improvements become the rule accompanied by input substitution. These patterns held for the rail and maritime modes.

Input substitution included steel for iron in ship construction and for wood in rail car construction. In both locomotives and ships, fuel oil began to be substituted for coal in the early Twentieth Century. By

the middle of the Twentieth Century, diesel-electric propulsion was substituted for steam in many locomotives and ships. Some electric locomotives collecting power off board began to be used by 1900, and their use spread after World War II, especially in Europe and Japan.

A long list of improved techniques may be identified. The use of welding in place of rivets in equipment construction is one. Nowadays sensors report the depth of water under ships and the air brake pressure in the last car of freight trains. Train control has profited from a series of improvements as uses of sensors and computers has expanded.

Scale increases have been important. Traffic growth has enabled increased train, railroad car, and ship sizes, lowering costs and increasing fuel efficiency. There have been improvements in materials handling at ports and train loading facilities. Inland water and port facilities have been dredged deeper and deeper, enabling larger ships and tows. Very large crude petroleum carriers are in service. Unit costs have decreased and decreased.

Traffic growth also enabled more and more specialized services. Specialized rail cars, trains, and ships often both decrease costs and improve services.

5.2.3 Diffusion Versus Concentration

During the period of diffusion and subsequently institutional and technological changes yielded cheaper, faster, better services. But even as improved services became ubiquitous, they were more and more concentrated in specific markets and trades. Economy of scale plays a role here, and there are other considerations.

Nowadays service providers often find it economical to go the long way around, so to speak. And by concentrating traffic on routes, operators achieve both facility and operations economies. There are route economies of scale.

Looking around today the results of this process are quite apparent in the air transportation system where hub airports are connected using large aircraft and smaller higher unit cost aircraft serve feeder functions.

Processes with similar outcomes were at work as rail and maritime modes were diffused. They continue today. Instead of sorting and remaking freight trains in yards spaced 100 miles (160 km) or so apart, nowadays cars are sorted in large hub yards where economies of scale are important and trains operate on mainlines where traffic density warrants improvements keeping unit costs low.

Prior to displacement of passenger liner services by air services, large fast passenger liners called at major ports served by land or water feeder services. Nowadays, container liner services have begun to use hub ports.

Scale and agglomeration economies in the industrial and service sectors of modern economies have also affected transportation service concentration, as has urbanization. Competition from newer modes has also been a factor. These forces increased as the modes and the industrial and commercial developments enabled by them were diffused. One result was the abandonment of some marine and rail services even while the network was still expanding. Contraction continues today. The situation differs from nation to nation depending on whether freight or passenger services are at issue, the levels of competition from alternative modes, and political efforts to maintain services.

6. Settings for the Further Development of the Modern Modes

The discussion of the diffusion of the rail and maritime modes began with England and then touched on some world wide examples. Experiences differed region to region. As mentioned, one broad consideration shaping differential diffusion was the receptivity of peripheral areas to the complex of agricultural, industrial, and commercial developments enabled by improved transportation services. This section will add two other broad considerations: urbanization and political conditions.

6.1 Urban Settings

Urbanization accelerated during the decades in which the rail and maritime modes were deployed. By 1900 more than half of the population of Great Britain resided in urban areas and about one half the US population was in urban areas by 1920s. Urbanization patterns differ nation to nation and protocols for classification of urban versus rural populations also vary. No matter. Today's world is in a large measure an

urban world, and the question for discussion is that of the diffusion of rail and marine services in urban areas.

6.1.1 Cities as Connecting Places

Looking at the city with historic perspective, early key places, the location and activities defining places, were where the water and roads met. For freight transportation those places were sites for markets and warehouses, for shipbuilding, and for other industries. Wet docks and canals were built to accommodate ships and to increase the sites for port activities. New York City has its canal street built on the site of a canal, for example. In addition to aiding commerce, canals were places where ships could be protected from storms and defended by cannon.

The places where road and water modes met made the support of urban populations possible. But there was much more. They formed hinges, in a sense, for forces of ideas and cultures from different sources met and merged, in addition to the meeting of products of industry and commerce. Meeting and merging played roles in cities becoming centers of learning, the arts, ideas, innovation, and imagination.

Snapshots provide examples of transportation's imprints. New York City's Manhattan Island is oriented North-South and the east-west streets are more closely spaced than the north-south ones. There are many reasons, but street spacing is partly because the east west streets gave access to water transportation for the movement of people, building materials, and food stuffs. In London at an earlier time, Sir Walter Raleigh's Durham house acquired in 1583 as a gift from Queen Elizabeth I was described as a pile of Norman stone but praised for its redeeming feature of a water gate on the River Thames. Raleigh is remembered for promoting colonization of Virginia in the New World and for promoting the use of tobacco in England.

When railroads entered cities they created more hinge points, passenger stations, freight depots, and yards where freight was interchange with wagons (teaming yards), in addition to serving dock areas. Rail service patterns differed depending on topography, markets, and the size of the already built up area. In many cases rail stations and yards were located at the edge of the already built up areas. The several

passenger stations in Chicago, Paris, London, and elsewhere are a result. (The Central in the name of New York Central Railroad's Central Terminal is from the name of the railroad, fringe or edge better describes the station's original location.) The railroads also served places here and there where factories, stock yards, warehouses, and other activities were developed.

6.1.2 Serving Intracity Demands

The rail and mechanized marine modes also served intracity travel and freight shipment demands. Serving commuter-like functions, steam powered passenger ferries were utilized in places suited for them. Freight moved by powered scows and freight cars moved on car ferries. Railroads began to offer commuter services. But other services were limited. At the time small steam engines were not nearly as efficient as large ones and steam was not much liked because of smoke and noise and the way it frightened horses.

Alternative street railway services emerged. Their immediate precursor was the horse car line, a tramway arrangement where horses pulled cars on rails. Horse cars had succeeded the omnibus where traffic warranted. (The horse drawn omnibus was wagon-like with an entrance in the rear and seats along each side.) From beginnings in New York and New Orleans, by the 1850s horse car services were available in major US cities. Similar services evolved elsewhere. Their advantage over the omnibus was somewhat increased speed and the ability of horses to work more efficiently as cars rolled on rails.

But the use of horses in tiring work required a change out of teams every four hours or so and their retirement after four or five years. This was aggravated in hilly areas where demands on horses were very high. They were subject to diseases, and the Great Epizootic of 1872 in the US killed many horses, especially in urban areas where the respiratory disease spread quickly.

Although living with horses on city streets went with the times, there were increasing problems. Manure and the insects accompanying it was one. Urine was sprayed about and made for uneasy walking both for horses and humans. Dampness and slippery surfaces discouraged pavements other than cobble stones.

Seeking more efficient and improved services, operators began to invest in rope hauled systems-- cable car services. They adapted cable/rope/chain systems that been used at mines and even to haul canal boats on rail cars over steep grades in funicular designs where ascending and descending cars counterbalanced each other. A street application in London in the 1840s had used a natural fiber and then wire rope; it was replaced by locomotive haulage as traffic increased. An 1870 subway under the River Thames had used cable power, as did an elevated line along 5th Avenue in New York. A.S. Hallidie opened a cable car line in San Francisco in 1873, and although his application wasn't a first and his technology was modified by others, he is generally recognized as the innovator of the cable car.

The cable car on steel rails obtained power by gripping a cable running in a slot. Gripping and ungrinding the cable allowed for starting and stopping. A steam engine in a powerhouse moved the continuous cable at about 10 mph over distances of a mile or so in a typical application. Cars were able to climb hills and operate regardless of weather. The cable car found a ready market and was profitable for developers, and it began to be deployed in city after city in the US and in Portugal, New Zealand, France and Great Britain.

But deployment was cut short by the development of a successful electric street car design. The cable car's problems were many. The slot track arrangement was expensive and the slot could be clogged by debris. The crossing of one line by another created construction and operations problems. Operations required a gripmen and a conductor, and the wire ropes were expensive to maintain and replace.

Alternatives to the steam engine powered endless cable were available and improvements were sought. E. W. von Siemens had demonstrated an electric railway in Berlin in 1870, and Thomas Edison had work underway by about 1880. Battery power, compressed air, and chemical generation of electricity had been explored.

Several electric street car systems had been build with limited success before Frank J. Sprague perfected the concept in 1888. He mounted a light weight 500-volt DC motor between the car frame and the driving gear. He solved the problem of a satisfactory voltage (later increased to 600-volts in most

applications) for power distribution and management on board the car. Also Sprague's nose mounted motor avoided the problems of axle mounting (heavy unsprung weight and damage to motors) and car mounting using difficult to use and maintain gears or belts to send power to the axles.

Although pre Sprague electric street cars were inferior to cable cars, Sprague cars were a considerable improvement and except in areas with steep grades, cable cars were soon replaced. Costs were at least halved and speeds increased somewhat.

After an unsuccessful first trial in Richmond, Virginia, Sprague worked out the difficulties there and systems were soon under development or deployed in many cities, large and small. The growing electricity production and distribution industry encouraged investments and sometime participated in development. The power distribution lines required for street cars served to enlarge customer areas and although individual cars drew power intermittently, the power drawn by the systems helped even loads, especially during the daytime when home lighting and cooking loads were low.

By 1900 there were about 5,000 (8,000 km) miles of street car lines in the US. Mileage had increased by a factor of about six by 1925 when bus service began to substitute for street cars. There were about 4 billion transit trips in 1900 in the US, and trips rose to about 17 billion by 1930 when the average urban dweller was making about 120 trips per year by transit of all sorts.

The streetcar and related subway and elevated systems made possible the expansion of cities by increasing the land available for development. In addition to making possible centers of employment of some size and diverse functions, they enabled museums, theaters, universities, legal centers and new ways to array and sell consumer goods.

Even so, urban transit services began to lose market share by the 1920s and private sector investments decreased. Many say that services gave way to the automobile but the matter is much more complex. There was regulatory inflexibility. Franchised and controlled by city governments, institutions lacked pricing and investment flexibility and thus could not adjust well to changes in their markets. As trucks influenced the location of industry and warehousing employment and enabled logistics support for

shops at scattered locations, transit was unable to serve many new markets. Recreation travel shifted to the automobile, and weekend travel demand dropped. The investments and services oriented to rather even demand seven days a week were not so efficient when changes in demand required serving rush hour travel five days a week.

6.2 Political Settings; Government Roles

It was just stated that fates of US streetcar firms were affected by the political context of American cities at the time, and political contexts influenced all of transportation, in all environments, and at all times. Examples are everywhere. For instance, Member of Parliament John Lambton desiring to keep Auckland coal non competitive to his coal in the London market had imposed his desires for high tariffs on the Stockton and Darlington. But questions are not so much about the political influences on particular decisions as they are about broad policy influences on the direction and pace of development.

To cover the range of effects, the discussion to follow will contrast statist and capitalistic extremes and variations on these extremes.

6.2.1 The French Experience

The emergence of the modern modes in France differed from experiences elsewhere because of its strong central government and its traditions of scientific work, rationalization, and professionalism. When railroads emerged, the French differed because canals and railroads were seen by the State as complementary rather than competitive and it acted according to that view. This style of taking State action had a long history.

Beginning in 1716, State highway engineers prepared standardized maps for provinces, with centralized planning of roads beginning in 1747. In addition to capacity addition plans, standards were developed for bridges and other aspects of the physical plant. Similar steps were taken as the canal movement began. The decision to adopt standards suited for Flemish boats (300 tons) was taken in 1810, and a general plan for the canalization of France was adopted in 1820. (Another plan was developed and implemented in 1880, at a time when most canals were pretty much obsolete.)

State engineers had maps for the entire country, and they saw the need for a plan with everywhere-similar facilities, regardless of local physical conditions and markets.

Plans were implemented. The public capital was there. The French government had been exercising considerable taxing powers, in part because of the military needs of the central government. The vision and power were there too. Jean-Baptiste Colbert, Louis the XIV's minister of finance, developed a plan for the orchestration of national life through the use of canals and roads for commercial and military purposes. A vision sometimes called Colbertism emerged--in essence, the State has the wisdom, resources, and power to do the best and most just things.

A high quality, State planned, financed, and operated, free road system centered on Paris had been developed prior to the emergence of the railroad. That was at a time when English major roads were toll roads and folk in many other places usually had not much more than strips of mud or dust.

Railroads were next, and central government planning responded. The Legrand Star plan was produced about 1830, a plan centering railroad service on Paris. Engineer Claude-Louis Navier saw speed as the advantage of rail, and railroads were to move passengers and priority freight in a fashion complementary to canals. He felt that others, especially the Americans and Germans, were not building to high enough physical standards, and the plan called for limited curvature and grades.

But there was a problem. In spite of taxing power, public capital wasn't available for the high quality railroads. The compromise was that the government would create the fixed facilities and that private companies would provide financing for equipment, stations, etc. There would be private operations for 99-years, at which time the properties would revert to the State. In practice, there was some compromising of standards to reduce facility costs. Twenty-eight companies were created and eventually consolidated into six regional monopolies. To meet the requirements of the plan, main routes cross subsidized the operation of routes in small markets.

The routes were planned by State engineers, and there were complaints from places not well served. State financing was partial, as mentioned. Private companies could and did build feeder lines, as was the

case with toll roads built in the regions. However, freight tariffs and passenger fares (and to an extent, service) were established by State engineers. Details aside, the point is that the central government took actions in an absolutism way in the spirit of Colbert.

These accomplishments were not made without great debate, and there were periods when antistatist, antielite, liberal forces held power. Antistatist folks argued that the time value of money made high quality facilities inefficient and that marginal cost ideas should take priority over State determined prices and cross subsidies. The authority of government engineers versus engineers in the private sector was also debated, with cheaper and better argued for private sector engineers. But even with these debates, absolutism continued. This was in spite of the Revolution and Napoleonism.

Many critics say that France overexpanded its rail facilities and invested in canals long after they were not competitive with rail. High standards for canals resulted in expensive facilities, they did not fit instances where water and/or traffic was in short supply. Others say that France developed very fine systems as a result of the professionalism of the central government and the engineers uses of science.

Bismarck's invasion of France in 1870 brought the Paris centered rail system into question, for the French could not move troops to the front as quickly as the Germans could. As a result, a grand plan was produced in 1880 resulting in the northeast rail corridor.

6.2.2 Comparisons

The French policy context may be labeled absolutism or statism--all decisions turned on what was taken to be good for the State and were made by the State. Plans were made by the State, instead of by firms as in England. The same was true of tariffs (rates, fares). There was State financing (partial) instead of private capital. Operations had heavy State input. There was to be eventual State ownership of facilities.

Striving to characterize situations elsewhere requires broad brush remarks for which there are many exceptions. Also, situations changed as systems grew and developed. First, broad brush remarks.

The term entrepreneurial capitalism captures English policy in the early days of the modern modes. English policy had a hands off character, and this seems to have flowed from the notion that the national

interest was best served by competitive, independent firms creating jobs and wealth. Government did press for the setting of through rates by agreements among connecting firms, rates high enough to result in profitable firms. There was a bit of welfare motivated tempering by government--e.g., railroads were required to operate low fare workmen's trains and publish freight tariffs and handling charges. Also, Parliament's careful examination of requests for charters may have protected existing properties and investors from poorly developed schemes.

US policy doesn't summarize so easily. Early on, local and state mercantilism makes a good label. Publics clamored for the development that would accompany the spread of facilities. In response governments granted charters and took other actions to accelerate facility development. Owning vast amounts of land but cash short, the federal government assisted the westward expansion of railroads using land grants. Loans and direct payments were sometimes used.

Policy was modified in the 1880s when regulation of railroads was initiated. Many considerations pushed for regulation. Shippers complained of uneven treatment place to place and commodity to commodity. Railroads had problems enforcing agreements on joint tariffs and managing what they viewed as unfair competitive pricing practices. Regulation was forged in response to these and other voices, and competition was constrained to protect the interests of regions, shippers, and service providers.

In Germany the kingdoms and states authorized private railroad development, with the only early state railroad being in Bavaria. As a result there were about 50 rail companies by 1850. Rail development was market driven, and standards varied according to what markets warranted and could pay for. Several railroad centers emerged in addition to Berlin.

Railroad beginnings in Japan were state directed and sponsored. But as the economy began to grow, policy tended toward the capitalistic model.

6.2.3 Exceptions

Every context and development history is different for many reasons. Two ask for special mention.

Nations and regions have had different experiences with difficult to implement development schemes. The upland canal problem provides a metaphor. To explain, recall that canals were first built in rewarding market niches, usually watersheds here and there. To expand required building across uplands from watershed to watershed where the local upland area market might be limited and costs of construction and water acquisition and management might be high. Building roads in the highlands of Scotland, a canal across Ohio linking the Great Lakes and Ohio River watersheds, the trans Siberian railroad, and railroads across the arid west in the US posed upland canal-like problems.

The Ohio-Mississippi River context for inland waterway improvements had a somewhat different slant. In addition to high capital requirements for improvements, improvements were orphaned without a responsible parent in a sense because the rivers formed boundaries of states and individual states avowed responsibility for improvements. Responsibility, national policy goals, capital requirements, and risk were the issues. The development of waterway (and later flood control) programs of the statist-style US Corps of Engineers was the answer.

Today's versions of upland canal-like situations include the tunnel joining France to England, Danish bridge-tunnel projects such as the Oresund crossing, expansion of high speed trains in thin markets, and efforts to provide air services to remote areas where markets are limited. Today as yesterday, political imperatives energize facility expansion and the policies of state subvention of construction costs, purchase of bonds, and subsidy of operating costs have a statist cast.

So far attention has been on policy contexts for the deployment of systems. Do changes or exceptions arise once systems are deployed and operations are at issue?

Perhaps there are changes in attitudes as rewards from obtaining services fade from memory and day to day services have a more of the same character. Perhaps ills become more apparent--as the saying goes, familiarity breeds contempt. Perhaps the high fixed cost, decreasing average cost, time valued product character of systems creates problems. As a result users have always paid different tariffs for seemingly

similar services as one observes today in coach sections of aircraft. Monopoly power real or imagined may be in the equation.

Shifts from prosperity to depression and competition from new modes have also changed the context of systems. Fiscal crises have forced varieties of nationalization and regulation. Perhaps it was the accumulation of stresses and ills that lead Howard Darling, the Dean of Canadian policy analysts, to remark in 1980 that railroad policy is "... a kind on witchcraft ... a combination of incantatory spells, proprietary gifts, and rites of exorcism ..." Looking around today, his words often apply to those modes mainly energized and steered by political imperitives.

Seeking a broad brush characterization, constrained entrepreneurial capitalism seems to summarize the result of today's attitudes and policy environments. Although experiences and policies have differed, the spirit of entrepreneurial capitalism is most every where. It's a product, a social contract, or a philosophy that has emerged regardless of experiences from different beginnings. Of course there are exceptions arising mainly from political imperatives. But even so, differences nation to nation seem to be running less and less deep.

7. The Late Comers, Planes, Trucks, Autos...

Struggles over political philosophies, wars, and the antics of the rich dominated the reports in the press and other literatures during the first decade or so of the Twentieth Century. But there was room for transportation, and the reactions when looking around ranged widely. The technology enthusiast saw airplanes, varieties of steamships, lighter than air ships, and automobiles and trucks coming along. Even space travel was imagined. The records set by larger and faster ocean liners were acclaimed by all. Deluxe train services were expanding. Radio would soon allow communication from trains, as well as listening entertainment on board.

The realist saw built-out railroad, waterway and canal, streetcar, and maritime systems and directed attention to needs for their improvements. The race to build networks had resulted in duplicating lines and railroad and streetcar operators needed to rationalize networks--consolidate properties and abandon

duplicating lines. There were public concerns about monopolies and monopolistic behaviors. At the same time, there was need for massive investments on subway systems in the larger urban areas.

In addition to concerns about stagnating technology and slowing productivity growth in the rail and maritime modes, the pessimist saw failing mass transit systems and railroads. As Arthur Wellington put it in his seminal late 1800s book on railroad location, many properties were bleeding and oozing from every pore. Cartel arrangements limited competition in ocean services. Glamorous developments in air and liner services were for the few and rich. Automobiles and fancy trains and ships were rich men's toys guaranteed to increase tensions between the upper and lower classes. The massive sums of money needed to improve roads was unthinkable. As the Great Depression of the 1930s took hold, many critics held the view that production capability had overshot demand, and permanent retrenchment of production and urbanization was in order.

In many nations imports of petroleum were threatening the balance of payments and producing nations such as the US were concerned about exhausting petroleum resources. Indeed, the US Navy established petroleum reserves to assure fuel for its oil burning vessels. But by the 1930s the discovery of petroleum resources in Oklahoma, California, and Texas had eased the situation in the US. To dampen fuel imports, some nations used taxes to discourage the use of large engines in automobiles.

Through these and later decades of the Twentieth Century the historic recipe for transportation development soldiered on. The modes to be treated now will be examined in that template-recipe. It says what to look for when back and looking around.

7.1 Air Services

The innovation and improvement of aircraft take center stage in most discussions of the emergence of air transportation services.

Powered flight in France using airships dates from 1903, and in that same year Orville Wright made a short sustained control airplane flight in North Carolina. Possibilities were seen, and by the end of that decade "firsts" were established time and again as airships and planes broke speed and distance records.

Military uses were imagined and bombs dropped in practice. Already, air mail service was begun and recreational flight also.

There were longer and longer flights, and scheduled passenger services were established by the late 1920s. Enthusiasms ran high. Responding to enthusiasms and seeking industry development and political goals, governments established weather forecasting services and an International Convention for the Regulation of Air Navigation was adopted by the League of Nations early on.

The League of Nations action was modeled on maritime traditions and those traditions and policy priorities colored the actions of individual nations. Air mail and other subsidies were everywhere. Services to colonies and trading partners loomed large in Europe. The US followed marine port policy, and airports were a local government or private matter. The US government did provide mail subsidy and aids to navigation in the maritime tradition and become involved in safety matters as it was in other modes. Something new occurred when the US established the National Advisory Committee for Aeronautics in 1915. That Committee made important contributions to aerodynamics and was a successful example of government aid to industry through knowledge development.

7.1.1 First Round of System Building

By the middle of the 1930s the ingredients for air system development were in place. Governments were playing supportive roles and firms had explored markets and accumulated operations experience. Public and private airports had been constructed along with aids to navigation (AM radio beacons and lighted airways) and the beginnings of airspace traffic management. There were engine and airframe suppliers and large firms providing financing and insurance.

Markets had been explored. There were over water routes where flying boats and rigid airships competed with passenger liners. There were overland city to city services where air services competed with trains. Recreation flying was building a market. Aircraft designs oriented to niche markets were emerging-- the Piper Cub and the Gypsy Moth for recreation flying and the Norseman for arctic conditions for example.

The Soviet Government was developing large aircraft for its routes. There was a large military market, especially in Europe and the Soviet Union.

The emergence of the Douglas Corporation's 21 passenger Model 3 (DC-3) met many of the needs of passenger service in the US and similar markets. It was an all metal, retractable undercarriage, two engine state of the art design. It differed mainly from immediate precursors (Boeing 207 and Douglas Model 2) on larger size and longer range dimensions. It could fly non stop at about 170 mph (273 kph) from New York to Chicago and between many of the major population centers in Europe. (At about that time, 24 passenger Short Empire flying boats and similar aircraft served well for a few years in over water market niches.)

The DC-3 and the emergence of the modern system again highlight system design. The aircraft itself was a design incorporating elements from other aircraft and improving on previous designs. The system was built of existing developments such as airports and their methods of construction and financing and firms and their route structures. As stated, governments were involved in safety regulation and provided subsidies of various kinds. Economic regulation dampened competition and aided in attracting capital for investment.

7.1.2 Second Round of Development

The arrangement of airports, firms, national interests, and markets established in the 1930s and before held for another 20-30 years while the utilization of air services increased. The per capita miles of travel by commercial aircraft in the US increased from about 8 (13 km) in 1940 to 120 (193 km) in 1955 and growth rates were sharp elsewhere where travel also increased from a small base. Growth also describes changes in airport and firm sizes and activities of the air traffic control system.

World War II and its aftermath ran their courses and the world was in turmoil during much of this period. Although many say that the War accelerated aircraft development, that seems doubtful. By and large designs were frozen and 1930s models of military and commercial (for military use) aircraft were produced in large numbers during the war years. Its true that jet and rocket engine work was accelerated, but this work did not translate quickly to commercial uses. Indeed, the Gas Turbine Committee of the US National

Academy of Sciences advised in 1940 that "... the turbine could hardly be considered a feasible application to airplanes ..."

In the years just after WWII aircraft grew in size, cruise velocity, and range. Cabin pressurization enabled flying at increased altitudes with increased passenger comfort. These improvements enabled competition in new markets over water and world wide. Air services were beginning to substitute for passenger liner services on many routes and the demise of the passenger liner was in view.

However, propeller driven aircraft technology seemed to be pressing against size and efficiency limits. The newer aircraft, such as the DC-7, were achieving increased range and velocity only with increased seat mile costs. The transition to jet power was sought, at first by British and French equipment manufacturers. But as is sometimes the case, first efforts were not very successful and provided lessons for competitive latecomers.

The development of jet passenger aircraft by the Boeing Corporation began when it attempted to introduce a passenger aircraft based on a military jet tanker design. Although that attempt was only modestly successful, Boeing and other companies were soon producing somewhat larger aircraft, and by the 1960s a B-707-type round of development was underway. (The Tupolev Model 114 turboprop was produced in the Soviet Union.) Early models of Boeing and competitive aircraft evolved into very large versions, long range versions, smaller and shorter range versions, and many other versions suited for different market niches including supersonic service. Today, Airbus and Boeing compete in the large passenger aircraft market and Russia and the US market large freighter aircraft. Many other suppliers compete in other markets.

The aircraft part of the story is very visible, but there are other important parts. Larger heavier jet aircraft played a discordant note in the system they were entering. Their cost strained the fiscal viability of many carriers. The aircraft asked for stronger and longer runways and for revisions to airways and local area flight control protocols. Terminals needed to be revised to accommodate larger wing spans, as well as increased fluxes of passengers on departing and arriving aircraft. Jet fuel had to be accommodated. Noise

became a problem and although quieter aircraft were produced, it worsened as the number of flights increased. One result of these stresses was increased central government participation in airport matters.

Jet service was in a sense force fit because it strained the existing system design. Difficulties were great enough that many critics were pessimistic about its future. Indeed, there were several studies that concluded that jet aircraft would be successful in only a few market niches. The situation was chancy, and the Boeing Airplane Company's decision to manufacture the 707 was misguided.

The market was the force that trampled difficulties. Once jet service became available, ridership began to grow at an accelerating rate. Again referring to the annual average miles of travel per capita in the US, travel increased by about a factor of about 10 between 1960 and 2000. The competitive factors that were at work when DC-3-like services diverted business and recreational travels from trains were again at work when B-707-like services captured even more passengers from the railroads and travel across the oceans from passenger liners.

Going beyond substituting one mode for another, travel demand was driven by qualitative and quantitative changes in the ways governments ruled, international importers and exporters made and executed contracts, tourism offered new experiences, and investment and financial markets expanded their scopes. Air transportation services grew as they became essential tools for living and working in increasingly integrated global and national markets. Along with communications and new varieties of freight transport, including air freight, air services changed patterns of production and consumption.

7.2 Highway Based Services

Treatments of highway based services usually focus on the automobile but the story is much larger because truck services loom large in the history and status of the mode. Also, and similar to the evolution of air transportation, many building blocks served as the clay from which the system hardened.

Experiences with motorized road vehicles date from the early days of the steam engine when steam tractors pulled passenger cars and there were also vehicles with engines and passenger and freight on board. For one of many examples, in 1840 Frank Hillis operated a steam powered vehicle between London and

Hastings and maintained a speed of 25 mph (40 kmh) for 125 miles (200 km). Mobile steam engines were driven from farm to farm to provide power for harvesting equipment. Trucking services using steam powered vehicles emerged in limited markets, and batteries and sails were tried and much talked about.

Something new was imagined, enthusiasms were great, and many "firsts" were claimed. America's first electric vehicle was built by William Morrison in 1887, and in that same year Ransom Olds built a steam car using gasoline (naphtha) as a fuel. At about that time (1886) Karl Benz developed a 3 wheel car using an internal combustion engine and G. Daimler and W. Maybach a four wheel car. There were exhibits and fairs and automobile and motorcycle races. Automobile clubs were established and the French-coined word automobile was in wide use.

About 20 years later Henry Ford built his Model-T, and during those 20 years the race among the internal combustion engine, steam, and electric power was settled. In spite of Thomas Edison's claim to Henry Ford that he would soon have a battery assuring the future of electric vehicles, battery limitations confined electric vehicles to small market niches. Steam had many advantages such as simplicity and high torque at low velocity, but the time required to heat the boiler and the necessity to make up boiler water frequently were overriding disadvantages. (If today's quick heating flash boilers and steam condensers had been available, the outcome might have been different.)

Road improvement programs expanded. As cities grew, farms serving nearby urban markets increased market garden activities and farmers asked for improved roads. To serve New York and Philadelphia markets, as well as in-state markets, the State of New Jersey adopted a road improvement program that provided partial financing for local government activities in 1900 and other states in the US soon followed suit. Intercity carriage of mail by road had been diverted to rail, but the delivery of mail in rural areas asked for road improvements. The farmers supplying fluid milk for urban consumers wanted all weather routes to milk train stations. The popularity of the bicycle played an important role in the demand for road improvements.

The International Road Federation promoted improvements and designs, some of which asked for the physical separation of walking, automobile, horse, streetcar, and bicycle traffic. As wheelmen (bicyclist) and auto enthusiasts pressed for road improvements the good roads in France were held out as a model.

Street planners in urban areas adopted concepts of local access and arterial roads. The demand for pavements to reduce dust and mud was high in cities, and in US cities the protocol that local roads were funded by taxes on abutting properties and arterial roads by the general public provided a financial mechanism for improvements. Urban public works departments were created to implement street, drainage, flood control, and other projects.

7.2.1 Many Beginnings; Diffusion

During the first decades of the Twentieth Century, there were many automobile service beginnings. Europe had about 10,000 cars in 1900, and that number had grown to about 200,000 by 1910. Rich men's sports cars and rich folks substitutes for horse and carriages characterized vehicles and their uses, but that is a very rough characterization for there were many varieties of vehicles and uses.

The Panhard et Levassor company had placed the engine in the front of the vehicle in 1896, and some other modern features of vehicles had begun to emerge. Even so, vehicles varied: gasoline, steam, or electric propulsion; three wheel, four wheel, or more; tiller or steering wheel; many or a few seats; throttle or no throttle; and every color in the rainbow. Vehicles were expensive and most did not have all season capabilities.

These kinds of vehicles and their uses were in mind when Woodrow Wilson speaking when President of Princeton University commented that automobiles were worsening the divisions among social classes. Actually, Wilson did not seem to be autophobic. When President of the US he made afternoon (chauffeured) rides for recreation on a regular basis.

The situation changed when Henry Ford built his Model-T in 1908. Once production accelerated the car was marketed as an inexpensive one, much less expensive than competitors. As the economy responded to preparations for and WWI, the vehicle was more and more affordable for many farmers and others. It was

simple to drive and maintain and repair. With a high clearance and strong frame it was suited to the rutted rural roads of the time. With room for four or five passengers it was a family car. With the ability to power accessories such as saws and truck-like capabilities (truck versions were also marketed) it found a ready market in rural areas.

The Model-T offered users unprecedented freedoms, and it found markets world wide. Shipped in kits for assembly, it was produced in many nations.

Wilson-type social concerns continued and others were added. The automobile (bicycle and motorcycle) increased social opportunities and changed the nature of courtship. The automobile was referred to as the Devil in God's country because of its effect on Sunday activities.

In spite of world wide beginnings, the wave of automobilization ran fastest in the US and Canada. It was not until after WWII that there was comparable accelerated take off in Western Europe and elsewhere, and many of those areas have just about caught up. By the 1990s there were 400 cars per thousand members of the population in Western Europe. (In Switzerland, Italy, and the former West Germany about 500 per 1,000.) In the US there are about 600 cars and 100 small trucks per thousand members of the population, about 1.75 per household and one for each driver.

The integrated assembly line production method used by Ford was a model for the production technology that emerged in the automobile manufacturing industry, and his marketing through factory owned and independent dealers and financing methods for purchasers were also. However, the predominant vehicle technology did not emerge until the 1930s: streamlining, all metal bodies with seating forward of the rear axle, synchromesh gearing, hydraulic brakes, and, soon, high compression engines.

As heavy duty trucks became available they found ready markets in construction work, moving and storage applications, coal distribution, and other applications. The examination of historical publications such as *Wheels of Time* oriented to trucking services illustrates the variety of vehicles and uses in cities in the 1920s. Services included collection of goods for delivery to warehouses and rail spurs and the delivery of goods from those sites. The literature also shows how equipment and services were specialized to

markets. Circus, storage and moving, refuse, liquid bulk, and other varieties of trucks were developed. Uses of horses and wagons continued in light duty delivery-type uses in the US into the 1940s and a decade or so longer elsewhere.

Trucks suited for intercity services were available in the 1920s and their use was becoming widespread and well established by the 1930s. By the 1930s diesel engines, air brakes, and tractor-trailer combinations were in use.

Some services were developed by railroads that used trucking as a collector/distributor service. Others were created by firms serving niche markets or providing common carrier services. The mixes of geographic scales of services and specializations found today was established by the 1930s. Also established were government regulatory activities, industry associations, and the patterns and services provided by owners operating their own trucks (owner operators). Mixes of institutions and activities vary nation to nation, of course, depending on traditions, markets, and regulation and deregulation actions.

Truck services grew as traffic was diverted from railroads. In the US market share capture began in the late 1920s and tapered in the 1960s and '70s. Nowadays, the railroads are serving heavy haul markets where moves are, say, 400 miles (650 km) or more and intermodal markets where traffic is dense. Pipelines and coastal and inland water have their services, and trucks monopolize local moves and compete with air transport for the longer distance moves of valuable products, including packages and mail.

The motor bus and its services evolved along with autos and trucks. The rural market grew rapidly as buses competed with trains in passenger and priority package delivery services. There were for hire services in recreational markets, as well as sightseeing services in larger parks.

Buses supplemented and then replaced street car services in most urban areas as lower costs and increased flexibility gave the bus advantages.

7.2.2 Road Facilities; Accessibility

A key factor in the adoption and diffusion of the automobile in the US and many other places were improvements of highway infrastructure. For example, as late as 1945 intercity routes in Japan were of very

poor quality, and it is not surprising that the surge of intercity truck, bus, and auto activities occurred along with highway improvements. The same situation was true in the US before the Federal-aid to the states and state and local programs began to produce results in the late 1920s and 1930s.

The situation was highly interactive. Users demanded road improvements and supported financing either from fuel and related use taxes or from general revenues. Road improvements enabled users doing old and new things they valued and increased demand. (See the Chapter following, "Technological Change and Transportation Development.)

There is a long standing view that the presence of facilities stimulates traffic growth and associated developments such as those realized as outlying warehouses, industrial plants, recreational activities, and housing. This view has supported rural road development programs dating at least from Parliament's support of the funding of highland roads and the US support of the National (Cumberland) Road across Appalachia to the Lake States in the early 1800s. It has continued recently in US Appalachian and World Bank developing nation programs.

Today the presence of facilities is equated to accessibility. There are debates between those who advocate increased accessibility to increase opportunities and those who would limit accessibility in order to preserve present arrangements by limiting traffic growth and its effects. Missing in the debate are references to yesterday's experiences that say that accessibility turns on the ability of individuals and organizations to do old and new things. Such capabilities and the values of doing old and new things are not upfront in debates.

7.3 Maritime and Railroad Adjustments

The diffusion of the modern air and highway modes has occasioned adjustments in rail and water modes, just as those modes impacted their precursors.

Threatened by modal competition, do better was one adjustment. Another was to emphasize functions that could be performed well and surrender other functions to the competition. There were also searches for new business and technological formats.

Achieving specialization and economies of scale were tools for doing better. Growth in traffic was permissive as movements could be consolidated for specialized bulk handling. Maritime neobulk shipments such as wine in tankships and automobiles in auto carriers are examples. Automobiles that used to move a few at a time in a box car or in a tramp ship are now placed on specialized auto transporter rail cars or ships, and instead of hauling wheat in sacks in box cars, specialized gondolas are now used.

As mentioned in a previous section, rail networks have been decreased in length and traffic concentrated on routes and in large hub yards. Larger maritime ports and hub services have emerged in maritime services.

Working with trucking and railroad carriers, container liners have continued and enlarged the freight services once offered by passenger/freight liners. There are also domestic container services and many combinations of air, truck, and maritime services.

8. Transportation Systems as Life Support Systems

The situation today seems similar to situations at the dawning of the Nineteenth and Twentieth Centuries. There are systems in place with robust institutions and ever improving user friendly services. The systems serve in differing environments, they have adjusted to changes and have enabled development. As was the case yesterday, some folks are pessimistic and others are optimistic. But regardless of inclination, many critics ignore the recipes for past changes, as well as the ways yesterday's building blocks and social and economic environments shaped today's systems. They implicitly assume that a Darwinian sorting out of possibilities has yielded the best of all possible services and that so much investment is in place that change is not possible. Consequently, the task is to constrain, polish, and bend systems to conform with changing environments.

But looking back reminds us that today's systems evolved from old building blocks in the milieu of the Nineteenth and Twentieth Centuries, and in some ways they are obsolete. While their institutional and technological forms have evolved and been modified, the systems mirror yesterday's capabilities, spatial

structures, resource uses, and expectations. They mirror the technological capabilities and the industrial and commercial activities of the times, the activities they nurtured and diffused.

So the question of how well systems will serve as future life support systems is only partly about controlling, steering, or modifying them. That's a difficult task because the systems are entrenched and interested parties may resist change or bend change to their ends. They refuse to imagine retrenchment or graceful decline. Placating stakeholders and preserving and investing in obsolete services may place high costs on change. As Bjorn Linn at the Royal Institute of Technology in Stockholm put it, "The combination of highly permanent construction and lack of realism in its conception is one of the worst legacies our time is leaving to posterity."

The question of serving in the future surely turns much more on the activities that future systems will enable and the markets they will serve. It turns on recognizing the nature of change and building new systems out of old ones. The history of transportation development has much to say on those subjects.

SUMMARY

England in the early 1800s was the venue for the emergence of the modern maritime and rail modes/systems. These built from the technological and institutional features of Eighteenth Century canals, docks, ships, tramways, and roads. The steam engine, iron and then steel, and the telegraph also served as ingredients or building blocks in the recipes for the emergence of the modern modes. The recipes are illustrated by Stephenson's contributions to railroad building and Brunel's to steam powered iron ships. Their work and subsequent developments illustrate the roles of market niches, design, innovative persons, and robust institutions in the evolution of new systems.

The modern rail and maritime modes were diffused worldwide by about 1920. In addition to increasing service areas and utilization, there were service improvements as the modes honed their technologies, concentrated traffic on routes, and specialized their services.

Diffusion took place in both urban and rural areas. Urban areas served as terminals for maritime, inland waterway, and rail services. Electric streetcar service expanded beginning in the 1880's. Diffusion

also took place in varied policy environments, as contrasts among statist, capitalistic, and mercantilistic behaviors indicate.

Airplanes, trucks, and automobiles emerged in the early 1900s as workable designs and markets were found. The diffusion of aircraft services accelerated in the 1930s followed by a second surge of growth beginning in the 1960s. The diffusion of automobile and truck services began earlier and services are approaching saturation in many markets.

The modern modes emerged in the 1800's and 1900's and are the products of those times. Twenty-first Century innovators and policy makers have the choice of concentrating on further constraining and refining those modes or using them as building blocks for modes more suitable to present times and new futures.

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