PERFORMANCE-BASED TECHNOLOGY SCANNING FOR INTERCITY RAIL PASSENGER SYSTEMS

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Abstract

Performance-Based Technology Scanning (PBTS) is a methodology for identifying areas where new technologies can have greatest performance benefits in terms of reducing costs, increasing market share, and achieving higher profitability. New technologies, however exciting, are germane only if important improvements in performance are realized. Utility analyses quantify the impact that technology change will have on performance from the customer's viewpoint. Improving utility is a much better objective than trying to increase train speed or door-to-door travel time. It may be easier to save time by improving access than by increasing speed, and it may be easier to increase utility by providing services than by saving time. The railroads should stay focused on the main issue – transporting passengers and express freight from origin to destination - and invest in technologies for greatest return.

1. Introduction

Improved technology can undoubtedly help railroads and other transportation companies improve their competitiveness in specific market segments. “Performance-based technology scanning (PBTS)” is a methodology for identifying where new technologies can have the greatest payoff in terms of reducing costs, increasing market share, or achieving higher prices *(1)*. PBTS can also help the rail industry structure more effective strategies for research and development (R&D) and for technology-related investments. This paper applies performance-based technology scanning to intercity passenger services, drawing upon research conducted for the UIC (Union Internationale de Chemins de Fer) *(2)*.

The role of rail in intercity transportation varies widely around the world *(3)*. In countries like China, India, and Russia, where incomes are low and the rail network is extensive, rail has the largest market share for intercity travel. In much of Latin America, bus is the preferred mode even for distances greater than 1,000 km. In the most developed countries, railways must compete with air for longer distance travel and autos for shorter distance travel. Still, when railways are able to offer service on the order of 150 km/hr along 300-500 km corridors, they can capture more than half the non-auto market. Examples include Paris-London, Stockholm-Gotenburg, and Rome-Bolgna. Where railways offer service in excess of 200 km/hr, they can dominate such markets, e.g. Paris-Brussels, Paris-Lyons, and Tokyo-Osaka. In the US, passenger rail services are highly competitive only for the Northeast Corridor, and rail market share is very low elsewhere *(4)*. While there is certainly interest in expanding high-speed rail services in the United States *(5)*, there is even greater concern about curtailing Amtrak’s costs *(6)*.

As incomes rise, people want to travel more and further using the fastest modes. Whether or not these people choose rail will depend upon the structure of the rail, air, and highway networks, the prices charged, and the quality of the service that is offered. Ultimately, the role for rail within any region of the world will depend in large part upon the transportation technologies that are developed and implemented.

This paper describes PBTS as a method for identifying the types of technologies that could help railways compete for intercity passenger traffic over a 20-30 year time horizon, i.e. sufficient time for new systems to evolve and land use to adjust. PBTS is a method that helps provide a comprehensive view of technology by considering how customers perceive performance and how current technologies limit performance. Technological opportunities arise from R&D, and they become effective through sustained investment programs. The best technological opportunities will be those that have the greatest impact on customers’ utility. If R&D is too narrow, or if investment is concentrated upon relatively ineffective or overly expensive technologies, then the rail industry will not achieve the full potential of new technology.

Section 2 describes various categories of rail passenger systems and the types of technologies that might help improve performance. Section 3 shows how to relate changes in performance to passenger utility and market share for various markets. Section 4 presents general conclusions concerning PBTS and technological opportunities for improving rail passenger service.

2. Technological Opportunities for Rail Passenger Systems

2.1 Categorizing Rail Passenger Systems

Rail systems serve distinct markets, within unique competitive environments, with specific technological needs and opportunities. Technologies that work well for one system may not be important for others. Therefore, it may be useful to consider various ways of characterizing both rail systems and rail technologies. Looking at a rather broad range of systems can assist in benchmarking as well as in technology transfer. Passenger systems can differ in terms of:

- **The rail system**: equipment, infrastructure, operations, and organizational structure. Networks can be quite diverse at both system and metropolitan levels (Figure 1). Some systems emphasize frequency and reliability; others emphasize train speed or accessibility.
- **The competitive and regulatory environment**: in some countries, rail is the only mode available for most trips for most people; prices may be low, but service, capacity, comfort, safety, and security are likely to be problems. In developed countries, multiple modes compete with many combinations of price and service.
- **Economic geography**: population density and distribution, personal income, and other determinants of demand.

Performance, which will depend upon interactions among these three sets of characteristics, can be measured in terms of service, capacity, traffic volumes, safety, environmental impacts, profitability, or other measures. Some systems will be most interested in technologies that increase capacity, while others may be more concerned with technologies to improve service or safety.

Technological development can be directed toward systems with specific network structures, patterns of metropolitan stations, operating strategies, or competitive environments. New technology is not the only option for improvement; equivalent results may be gained through technology transfer, operating or management improvement, institutional change, or elimination of barriers to innovation. Such barriers could relate to finances, institutions, human resources, or technical matters.

2.2 International Contrasts

International comparisons and benchmarking can help discover the best uses of technology or innovative ways to overcome barriers to innovation. They can also stimulate thought about new applications of technology. As part of our research for the UIC, we found marked differences among rail passenger systems around the world. For example:

- In Britain, highway competition is pervasive for the dense rail network. Passenger traffic dominates rail operations, as short distances favor trucks over rail freight. Recent restructuring separated ownership of track from operations and increased competition, but complicated trade-offs among track, equipment, operations and safety.

- In much of the US and Canada, passenger rail travel is not considered a serious mode of intercity transportation, whereas freight systems are highly developed. There have been efforts to revive high-speed service, but progress is slow in comparison to Europe and Japan.

- In India and China, where there are extensive rail networks and large populations, freight traffic is as important as passenger traffic. In India, capacity and safety are overriding concerns. Fares are low, and investment capabilities are limited, resulting in line congestion and crowded trains.

- In China, pricing and investment policies have maintained a reasonable balance between supply and demand for passenger services. Moreover, the railways have been losing market share to other modes and there is a concern for improving service to retain market share.

- In Europe and Japan, high speed rail systems are highly developed and the railways are investigating ways to increase speed, safety, and convenience of passenger services.

Comparison of the technologies used in these systems can yield useful insights. For instance, the majority of high-speed rail systems in Europe operate with push-pull trainsets in fixed formations, which Amtrak also uses in its Acela service on the Northeast Corridor. Greater use of push-pull operation could provide substantial economies in terminal operations and vehicle utilization.

Benchmarking is not limited to comparisons between similar systems in different countries, since comparing dissimilar systems may suggest technological opportunities worthy of exploitation. For example, Maglev and conventional High-Speed Rail (HSR) are usually viewed as competing systems, where Maglev has higher infrastructure costs, but superior engineering performance. Benchmarking uncovered many examples of hybrid vehicles, suggesting to us that Maglev/HSR hybrids would be worth investigating. Such a vehicle could use conventional, relatively low cost HSR to cross the “wide open spaces”, then switch to Maglev to achieve high speeds up grades. The ability to climb very steep grades would allow more direct routes through mountains or steeper routes that avoid environmentally sensitive regions. The costly infrastructure for Maglev would only be installed in critical areas, with some of the added infrastructure expense recouped through use of a shorter, less disruptive route.

a. Classifying Technologies

There are three major dimensions that can be used to classify technologies relevant to passenger rail: performance objective, sub-system targeted, and intended competitive strategy. Technology can be used to enhance any aspect of performance, including travel time and reliability, comfort and convenience, safety and security, and environmental impacts. Technologies can also target any of the major elements of the major rail systems: trains, the passenger environment within the trains, track & structures, communications & control, stations and intermodal transfers, and even passenger access & distribution. Innovations can be intended primarily to reduce costs while maintaining other performance levels or to improve performance in order to expand revenue or profit potential. Cost-reducing strategies may seek better components for or better management of any of the sub-systems. Revenue enhancing innovations may seek better market share through higher speed & frequency of operations, better on-board service, greater accessibility, or superior stations.

Cost-reducing technologies are normally (1) mass produced, (2) cheap, (3) omnipresent, and (4) standardized, with innovations introduced through a process of steady state renewal. This type of technological development could be useful for cross-country systems, low cost commuter services, or high capacity services, where they can be applied across the board. For these markets, attempts to increase market share through enhanced service are likely to fail because competition is based upon cost, not service.

Revenue enhancing technologies are normally (1) specialized, (2) expensive, (3) custom-built, and (4) proprietary. If there is potential for increasing market share, capital enhancements and upgrades may be justifiable. These technologies may be best for corridor systems or leisure services, where better service is needed to compete with other travel and leisure options.

3. PBTS: Finding the Best Opportunities for New Technology

3.1 Overview

Competition for intercity passenger services is based upon cost, time, and quality of the available services, which can be modeled using the economic concept of utility. Travelers' utility can be increased by reducing costs, increasing speed, or improving the quality of their experience. Travelers will choose the mode that allows them to reach their destination with the greatest utility. Technological change can improve utility for potential customers and therefore increase market share, as demonstrated in this section.

3.2 Preliminary Models for Competing Modes

Air, bus and auto are the primary modes competing with rail for intercity passengers. For air, the key factors are the time required at the terminal and the number of stops, as well as the actual flight time. For rail competitive trips (i.e. less than 1,600 km (1,000 miles)), flight time is at most several hours, often less than half the total trip time. Fares, access time, terminal processing, and time and hassle associated with connections are key elements affecting travelers' utility.

Bus is much simpler than air or rail, as the terminal time and amenities are both minimal. The average trip time is dependent upon highway conditions and the number of stops. Travel by bus allows opportunities for work, and seats in the best buses are at least as comfortable as coach class on most planes. Design of bus networks is extremely flexible and readily integrated with air or rail networks.

Auto travel is the most flexible, in some ways the most comfortable, and often appears the cheapest. Most people ignore depreciation and treat insurance and taxes as fixed or sunk costs, worrying only about out-of-pocket costs (fuel and tolls for personal automobiles, plus daily and mileage fees for rental cars). Auto competition varies greatly across the world, in terms of availability, service, and cost. Where roads are poorly developed or extremely congested, auto is too slow for anything but short trips. Where auto ownership is high and highways well-developed, auto is a convenient, cheap option for traveling quite long distances. In Europe and Japan, out-of-pocket costs are high because of tolls and fuel taxes. In China, railways are losing mode share to autos and especially buses as the highway network is expanded.

3.3 The Utility of Time

Economists use the concept of utility as a means of understanding how people make economic decisions. People are assumed to make choices that maximize their utility, perhaps unconsciously, thus providing a basis for understanding and modeling the way people make choices. In principal, utility can encompass cost, travel time, comfort, and other factors. Surveys and statistical methodologies can be used to develop models of utility based upon user choices or their stated preferences. Assuming that such models exist, we can compare the utility associated with using rail, air or other modes. If utility is identical for two modes, then we would expect travelers to be indifferent to which mode they use. If utility varies with distance, there may be a breakeven distance at which mode shares will be equal. For example, Hall estimated that the breakeven distance for rail and air within the European Union would be 528 km (330 miles) for a 125mph rail service; if the rail speed increased to 301 km/h (188 mph), then the breakeven distance would increase to 960 km (600 miles) *(7)*.

Some general insights concerning utility have been gained from research on travel demand:

- Trip times and reliability are important factors in addition to out-of-pocket cost
- Value of time is related to, but less than, the hourly wage and may depend upon mode or trip purpose
- Time spent in different activities is valued differently; time spent moving in a vehicle is generally less onerous than time spent waiting in the terminal
- Ease of access and ease of using the mode are important
- Time of day, trip purpose, and service frequency affect choice of departure and arrival times.

Results garnered from various studies *(8)* indicate that the value of time as a percentage of average wage is highest for air travelers (149%) and lowest for auto travelers (only 6%), with rail in the middle (54% for low income travelers and 69% for high income travelers). These results document great variations in value of the time for different groups of people in various activities. A study of intermodal facilities *(9)* for intercity rail, bus, and transit facilities, suggested using 1/3 of the prevailing wage for the travel time from home to work, 1/6 of the prevailing wage for non-work travel, and 200% of the prevailing wage for work-related travel. Safety and security can also be included in utility analysis.

It is possible to go into great detail in utility analysis. Slagmolen *(10)*, in a study of demand for inter-city rail trips in the Netherlands, examined “adjustment time”- added trip time required because schedules do not perfectly conform to travelers’ needs. An extra minute of adjustment time was equivalent to about 1.5 minutes in the train; adding a transfer was equivalent to adding 15-20 minutes of “adjustment time”. Relative weightings of travel time, adjustment time, and transfers varied for major categories of customers: school children, business travelers, shoppers, and elderly travelers.

Studies of demand typically use rather general independent variables, possibly separating trip time into in-vehicle and out-of-vehicle time. FRA’s recent study of high speed rail, for example, used trip time, fares, and frequency of service in developing demand models for various market segments *(11, p. 5-10).* That study addressed the potential markets for high speed rail as an alternative to air and auto travel; it defined service to be total trip time, without attempting to distinguish among the utility associated with different trip segments.

It was beyond the scope of this research to calibrate utility or mode split models for different classes of passengers. Our intent was to describe and motivate an improved approach to technology scanning that is based upon an understanding of passenger utility. As noted above, there are already many studies supporting several general conclusions relevant to assessments of technology. However, demand studies seldom approach the level of detail necessary to address the effects of technology on the quantity and quality of time spent time spent in specific activities.

We therefore hypothesize that passengers make much finer distinctions concerning utility than have yet been captured by demand models. In order to demonstrate the power of PBTS, we assumed that time and comfort utilities can be expressed in monetary terms and compared directly to fares and other out-of-pocket costs. We then made assumptions concerning utilities for different segments of a trip in order to illustrate the relative importance of these segments and the opportunities for technological improvements. The main point is that different trip segments have markedly different utilities for the traveler, ranging from highly positive to highly negative. The main implication for technology scanning is that saving a few minutes in travel time by introducing faster trains may not be nearly as beneficial as using better IT to save the same few minutes in terminal processing or providing in-vehicle communications and entertainment to make travel time more productive. It is well worth considering how technology might be used to increase the utility of various trip segments and how improvements in utility will influence travel decisions.

3.4 A Preliminary Model of Passenger Utility

A simple example will demonstrate how the utility concepts can be applied. A business traveler with an average billable rate of $100/hour and a salary of $40 per hour might view an air trip as follows:

- Drive to airport, including buffer time required because of access unreliability: unproductive time valued at 50% of the average salary or $20/hour
- Process time: standing in lines, checking-in, going through security, and boarding are not only unproductive, but uncomfortable and stressful, so this time is valued at $50/hour
- Extra time at the airport: conceivably useful for shopping, eating, or reading, but likely broken into segments too small to be productive; valued as somewhat better than driving at $10/hour
- Time on the plane resting, eating (peanuts), waiting: similar to the time in the car, probably negative, but at something less than average salary, so this is valued at $20/hour
- Time on the plane having fun: time spent watching a movie, eating (a real meal), or reading a book may be indistinguishable from time spent at home, so some of the time could be considered neutral, i.e. $0/hour
- Time on the plane working: this is billable time with a positive value of $100/hour

This individual would presumably associate similar utilities with the corresponding segments of a trip by rail, bus or automobile, although the duration of similar segments could be quite different for each mode. If we break the competing travel options into logical trip segments and use consistent values of time for each activity, then we can estimate the utility associated with the various options available for any trip.

Let’s begin with a 400-km (250-mile) trip, a distance long enough for rail to be competitive with auto and short enough to be competitive with air. Tables 1.1 to 1.3 give representative inputs for evaluating trip utility. Table 1.1 shows sample inputs for calculating out-of-pocket costs. . Air is the most expensive ($289 one-way), automobile is the least expensive ($123), and rail is in the middle ($162). The table also shows the time required to make a reservation, which is not an out-of-pocket expense, but which will affect utility. Table 1.2 shows the factors used to estimate total travel time, including access, terminals, and buffers sufficient to cover likely delays. Non-stop air is the fastest, requiring 5.25 hours; rail and auto are nearly an hour longer. Table 1.3 shows hypothetical values of time that might be reasonable for a business traveler in the United States for the various activities specified in Table 1.2; the final row shows the value per hour for the extra time gained by using the fastest mode. Most likely, the extra time is a net benefit to travelers at something close to their average value of time. However, it could be more or less. For a business traveler, the extra time might be spent with the client, leading to a higher probability of having a successful meeting. Table 1.3 therefore shows that the extra time is worth $150/hour, 50% higher than the value of work time for our hypothetical traveler. Other travelers might have completely different perspectives on the value of this extra time. For a student traveling home for the holidays, extra time on the train might be valuable time to finish an assignment – or it might mean missing the start of a great party. A vacation traveler might lose 2% of the daylight hours available on the beach during the vacation – or gain time to finish up work before relaxing on the beach.

With these detailed inputs concerning travel time and the value of time, it is possible to estimate our traveler's utility for each mode (Table 1.4). Time is shown as a "disutility" so that it has the same sign as cost – the mode with the lowest disutility is therefore the preferred mode. The quality of time spent traveling is clearly important; ranking the available options in terms of their disutility gives much different results than ranking by either out-of-pocket costs or time. In particular, rail looks much better, because there is extra time for work and less for processing and access. Although rail takes an hour longer, its disutility is less than the disutility of flying. For someone who can work on the train, driving is not a good option. Renting a car, which looks good in terms of direct cost, is by far the worst choice; it takes time to rent the car and it is usually impossible to work in the car, so the disutility of the time is quite high relative to train or plane.

This particular example emphasizes the importance of "work time" to the decision and shows that the cumulative benefits of lower terminal time, easier processing, and greater accessibility help rail relative to air travel (but hurt rail relative to driving your own car). It also suggests a framework for comparing technologies. Any intercity market will have groups of travelers with diverse needs and values. Some people may be able to think effectively when driving, so they may look forward to having several quiet hours in a car. Vacation travelers are concerned with baggage handling facilities – but day trippers are not. Self-employed businessmen undoubtedly view time and costs of travel far more carefully than corporate travelers, whose personal finances are unaffected by their travel choices. The value of terminal services depends upon the expectations of the customer. Hungry students devour fast food, as long as it is cheap and plentiful; wealthy couples en route to a resort prefer to pass an extra hour enjoying a fine meal; a "road warrior" might grab a quick snack, a beer, and check e-mail. The next section considers how passengers in four market segments might respond to various changes in mode or trip characteristics.

3.5 Estimating Mode Share

Given the utilities (or disutilities) for each available mode, it is possible to estimate mode shares using a logit model. The mode share for mode j is calculated as follows:

$$\text{Mode Share} = (e^{-\text{disutility mode j/scale factor}}) \;/\; (\sum e^{-\text{disutility mode k/scale factor}})$$

The scale factor was assumed to be 25% of the average disutility of the mode with the lowest disutility for each market segment. This factor determines how strongly mode shares vary with the relative costs. If the disutility of two modes is within 5 or 10%, they each have a sizeable market share; if the disutility of one mode is much greater, then it has a very minor share of the market.

The base case for the sensitivity analysis added three market segments to the example from the prior section: general business, vacation, and student. The latter three market segments have values of time that are 50%, 25%, and 10% of the values for the executive considered above. Each market segment was assumed to have an equal number of travelers.

3.5.1 Sensitivity Analysis

Six cases were investigated in addition to the base case (Table 2). The first two consider airline strategies:

> **Case 1 – Discount Air Fares**: a new carrier enters the market, halving air fares, but doubling processing times. Rail retains more than half the market, because the trip is too short for air speed to make much difference. Since business travelers expect to be productive, the rail option still looks good.
>
> **Case 2 – Business Shuttles**: major airlines introduce a service aimed at business travelers. Fares match the discount airlines, but processing, queuing and wait times are halved. This service captures more than 90% of the business market. Vacationers also appreciate the time savings; more than half switch to air. Students, still searching for the best deal, divide fairly evenly among the two air modes, rail, and auto. Overall rail market share plummets to 10%.

The next three cases address possible rail responses to the business shuttle. Each helps retain market share, with the greatest benefits for this particular example coming from improving access:

> **Case 3 – Lower Rail Fares**: railways respond to the shuttle by cutting fares by 20%. Executives don't even notice the change; the other groups increase their rail mode share to a quarter or a third. Overall, the rail share recovers to 24% of the market.
>
> **Case 4 – High Speed Rail**: average rail operating speed is 240 km/h (150mph) rather than 128 km/h (80mph). This is more successful than simply lowering fares, and rail is projected to gain 43% of the market. However, a major effort would be needed to achieve such high speeds and it is unclear if prices could remain unchanged.
>
> **Case 5 – Easy Access**: the average speed is again 128 km/h (80mph), but times are halved for rail processing, access, and reservations, while better on-board seating and services increases the value of time by 20% for business travelers. The value of terminal and on-board entertainment time is increased for everyone with more entertainment, retail and culinary opportunities in the stations and better food and services on the train. Executives are assumed to increase their working time from 70 to 80% of the trip time. The results are very strong for the railways, which become dominant in the first three markets and capture a third of the students.

Sometimes a group is traveling:

> **Case 6 – Two Travelers**: travelers share the cost of auto trips or cab rides. The dominant result is to make driving a very good option, with almost all air traffic and more than 20% of the rail traffic diverting to auto. Rental cars also improve, increasing their share from 1 to 4% and becoming a good option for vacationers and students. Clearly, if a family is going on vacation with children, the automobile will look better for even longer distances. Likewise, if three or four people are traveling together on business, then renting a car may look better, particularly if they can conduct some business while driving.

Distance is obviously another key factor for sensitivity analysis, as rail works best for distances that are rather long for highway travel, yet rather short for airlines. "Easy Access vs. the Air Shuttle" was used as the base case. For the 200-km (125-mile) trip, rail captured 69% and autos took 20% of the market. For the 400-km (250-mile) trip, the highway modes essentially drop out and direct air flights capture 17% of the market. As distances increased to 600-, 800, and 1000-km, the rail share drops steadily, while the air share grows. Air travel via a hub is increasingly attractive for the longer distances, as the cost savings become large enough to justify the additional time.

Improvements in cost and service by rail can also lead to increased travel demand. The amount of induced demand will be greatest in markets where rail already has a competitive advantage or where technological improvements enable rail to offer significant improvements over existing services. Induced demand can play an especially important role where advances in technology transform what was previously an intercity trip into a feasible commuting trip. Local circumstances will indicate whether induced demand is more likely to be vital or insignificant. A recent study of potential diversions to high-speed rail or maglev recommended using conservative estimates for this portion of demand *(11, p. 5-11)*. The study cited estimates of induced demand amounting to 16% of total travel on France's TGV in 1984 and 6 to 28% of total travel on Japan's Shinkansen system, but the authors elected to limit estimates of induced demand to 10% or less of the demand diverted from other modes. As the diversion from another mode approached 100%, the assumed that induced demand would approach 10% of the diverted traffic.

3.5.2 Implications for Carriers and Terminal Operators

The implications of utility analysis are generally well understood. There is value in reducing travel time, in minimizing process time, and in increasing passenger comfort. There is value in providing a variety of ways for travelers to spend their time and their money. Carriers attempt to capture this value by offering premium services at higher prices. First class and business class travelers enjoy quicker check-in, comfortable and productive waiting areas, larger seats and better food – and they are willing to pay a premium of $100-$200 per flight hour for these privileges. This premium is high compared to the coach fare, but not unrealistic when compared to executive salaries or consulting rates. Carriers also advertise their on-board services, including telephones, movies, games, magazines, and shopping opportunities.

Terminal operators may have been slower to understand the importance of time and utility, but they have certainly responded well over the past 10-20 years. New airports feature greatly enlarged shopping opportunities, food courts, fine restaurants, lounges, TVs, and other amenities that make waiting time more valuable to the traveler (and more profitable to the terminal owner). Government agencies and airlines are also concerned about airport access, recognizing the importance of time and comfort to the user as well as the costs of the infrastructure. Similar trends have affected some major train stations, which now offer varied retail and dining opportunities

3.5.3 Implications for Technology Scanning

The implications of utility analysis are less well understood as a technique for planning R&D or investment strategies, where it is quite possible to focus too narrowly on high speed rail or improvements in traditional rail technologies. This example shows how markedly different technologies can be compared in terms of their potential effects on passengers' utility. The most striking comparisons are among the three generic responses to the business shuttle for the 400-km (250-mile) trip (Cases 3-5). Lower fares could be interpreted as representing any of the many technologies that might reduce cost while leaving service and access unchanged. High speed rail is of course a dominant theme in the evolution of rail technology, in rail R&D, and in proposals for rail investment. Easy access relates to entirely different technologies, including terminal processing and terminal access. For this example, access is somewhat more important than train speed, and much more important than cost reduction. In general, saving time in access and processing or allowing more productive use of time may be more effective – for the customer – than saving time by running faster.

3.6 Discussion of Other Markets

Utility analysis can be applied to any market segments. The most effective technologies will be the ones that have the greatest improvements in utility, taking into account changes in cost, service, and other elements of performance. In overnight and intermodal markets, which are discussed below, different types of technologies will be suggested by the utility analysis.

3.6.1 Overnight Rail

For overnight train travel, since the trip must be long enough to allow reasonable time for sleeping, comfort and convenience may be more important than speed. Timing of departures and arrivals are critical in terms of how the train trip fits into travelers' schedules. The overnight train experience involves factors related to comfort, the total time available for sleep, and the specific times of day made available for sleeping. Sleeping on a train is not like sleeping in your own bed – but it may be preferable to getting up at 5am to catch a 7am flight. And departing at 10pm on an overnight train may be preferable to departing work at 5pm to catch a 7pm flight to get to the next city at midnight in hopes of getting 7 hours sleep at a hotel.

Reasonable speed and a smooth ride are prerequisites for good overnight service, so a solid, though not necessarily high-speed track structure is essential. Higher average speeds will certainly increase the maximum competitive distance vs. airlines, but at a considerable cost because of the long distances. Hence, the relevant technologies relate to train handling, train operations, interior accommodation, and cost-effective infrastructure.

For services that operate along a common trunk line, economies of train density are realized, though dedicated point-to-point services are required as sleep is easily disrupted by general train movements and switching activities. Speed is not as important a factor as in corridor services; some origin-destination pairs may even require a "sleeping siding" stop so that people could use the service without arriving too early at their destination. The quality of the sleeping compartment is a more important concern. Showers and breakfast are essential – conceivably at the station rather than on the train.

There are some markets in the United States in which overnight rail is potentially viable. The main markets are likely to occur between clusters of major metropolises that are separated by relatively open spaces. The cluster of metropolises is linked by a "pick-up" corridor, followed by an overnight line-haul segment through open spaces, and "drop-offs" in another metropolitan corridor. For example, a set of overnight trains could conceivably link the Northeast, the Midwest Industrial Heartland, and the Florida Peninsula *(12)*.

3.6.2 Air-Rail Intermodal

The main idea of the intermodal option is that rail may be better off cooperating with air and bus services rather than competing with them. Air is much faster and bus is much more flexible, and either may dominate rail in their preferred markets. However, the intermodal combination can be more effective than a single mode – if the terminal environment and the connection processes are well-managed. For the rail-air connection to work well, the railroad needs to serve the airport directly, so that the traveler views the train trip as indistinguishable from a connecting flight. Rail can easily be as fast as air for a 300~500 km (200~300 mile) trip. Rail networks could be structured with airports as major nodes.

Rail connections are available at some airports, but these are generally designed for moves from the airport to the nearby city center. A recent study of rail connections to airports identified 12 major airports where rail services achieve at least a 20% market share for ground access *(13)*. The best rail connections and the highest market share (43%) were found at Oslo, where the airport is 48 km (30 miles) from downtown; an express rail service operates on 10-minute headways, with half the trains continuing beyond Oslo. Narita, Geneva, and Zurich each achieved about a 33% market share rail, all with connections that are part of the intercity network.

As airports move away from the city center (as is happening around the world), they eventually begin to serve multiple cities and the rail links could become critical. Air travelers already go through hubs to get cheaper fares, so it is easy to imagine that travelers would utilize air-rail hubs. At an airline hub, the minimum connection time is approximately 30 minutes, which allows a small buffer for late planes plus enough time to walk to the next gate for processing. Passengers also have various retail and eating options. For air-rail intermodal to succeed, similarly easy connections will be essential. Off-site baggage and check-in facilities, IT for customer service, and automated people-movers are among the technologies that will be needed *(13)*.

Airlines could eliminate short-distance flights and integrate their plane schedules with train schedules. Information technology can facilitate intermodal transportation at several levels: marketing and reservation, coordination to preserve connections, and yield management (in favour of the most efficient mode). The train could also be an extension of airfreight services. Handling systems for airline containers, loading and unloading equipment, sorting cars where packages could be sorted would all facilitate package express services. The railroad could, in effect, provide space for certain functions that would otherwise need valuable space at the airport itself.

3.6.3 Bus-Rail Intermodal

The bus-rail connection aims at a different set of issues. Frequent stops hinder the average speeds that can be attained by high speed rail, but infrequent stops hinder the accessibility of rail service. Well-coordinated rail-bus services will allow faster average speeds on the rail network while maintaining accessibility using the bus services. As with air-rail systems, coordination between modes is critical. Cross platform transfers, with scheduled 10-minute connections would be very convenient. Providing amenities in the rail-bus terminal reduce the disutility associated with terminal times and compensate for longer connection times.

Rail and bus services are well-integrated in some countries. An excellent example is the “Swiss Rail+Bus 2000” plan that aims to provide an auto-competitive intercity public transportation service *(14)*. This service uses a “fixed interval, timed-transfer” strategy for a multiple-hub rail network. There is a regular schedule that is set up to facilitate reliable transfers between trains at many hubs; the more hubs, the more city-pairs that can be served. Links with bus services further improve the coverage provided by the system.

3.7 Summary of Utility Analysis

There are many potential intercity markets where rail can be competitive, including overnight and intermodal services as well as the traditional, medium distance air- and auto-competitive markets. In each market, travelers make choices based upon utility, which combines aspects of cost, travel time, and quality of time. In general, market shares will be very sensitive to local conditions, traveler characteristics, and mode capabilities; price, speed and convenience will all be important.

The implication for technology scanning is that improvements in any of these areas can be helpful in attracting customers. Attempting to improve utility will be a much better objective than trying to increase maximum train speed, average train speed, or even door-to-door travel time. It may be easier to save time by improving access or reducing processing times than by increasing train speed, and it may be easier to increase utility by providing services than by saving time. The utility analysis suggests that individual railroads need to evaluate their own circumstances and that the rail industry needs to ensure that its technology scanning and research programs are broadly-based, rather than focusing too narrowly on one attribute of service.

4. Discussion

The rail industry and public agencies are well aware of the potential for high-speed rail systems to attract traffic from congested airports and highways, and extensive R&D and investment programs are in place to advance such systems. In the U.S., the “next Generation High-Speed Rail Technology Demonstration Program” was funded at more than $25 million annually in fiscal 2001 and 2002, exceeding the rest of the FRA’s budget both passenger and freight R&D *(15).* However, as demonstrated in this paper, higher speed is not the only way to reduce travel time or to enhance travelers’ utility, and quite different technologies may be equally effective in enhancing rail competitiveness.

The research summarized in this paper some general conclusions relevant to technology scanning, R& D opportunities and investment priorities:

1. New technology can help railroads increase their market share by changing the rail system so as to increase any of the many factors that affect passengers’ utility during any portion or their trip.

2. Utility is more important than average door-to-door speed, which in turn is more critical than maximum speed. The time spent in the vehicle is likely to be perceived as having less disutility than time spent in access and terminal processing; in vehicle time can even be perceived as being positive. This means that station locations, network design, frequency of service, connection times, access, and passenger amenities may be more important than achieving higher speeds.

3. Dramatically better integration with air and bus services is possible, but better connections will be critical. Technologies are needed to support joint ticketing and check-in, simplify baggage transfer, allow more rapid security checks, and ease movement within the intermodal facilities.

4. Infrastructure costs can be high for dedicated passenger lines; it is critical to achieve economies of scope and density by combining various passenger markets, by achieving higher volumes of passengers, or by developing technologies that better integrate freight and passenger services.

5. Information technology is clearly a major consideration for customer service, entertainment, passenger productivity, intermodal coordination (marketing, customer service, operations), and operations control.

6. Carriers, terminal operators and planners can use focus groups and surveys to obtain information concerning the utility of the time spent by different types of passengers in various trip segments.

7. It is essential to consider the potential impacts of technology on passenger utility before committing to major expenditures for R&D or for new systems. Performance-based technology scanning provides a methodology for comparing the effectiveness of performance improvements gained from markedly different technologies as they might be applied to different elements of the transportation system.

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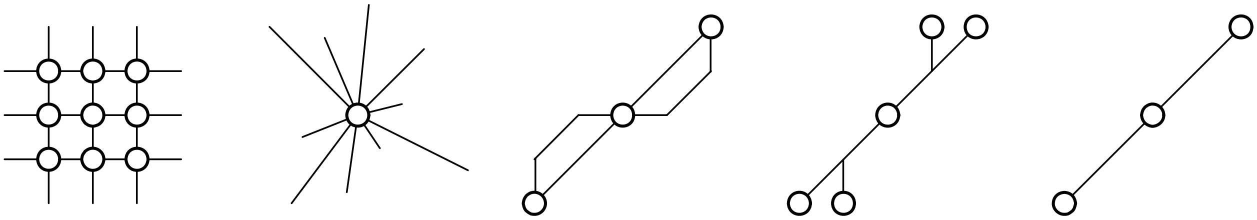
Figure 1.1: Typical Network Structures for Intercity Passenger Rail Systems



Grid
(e.g. Germany)

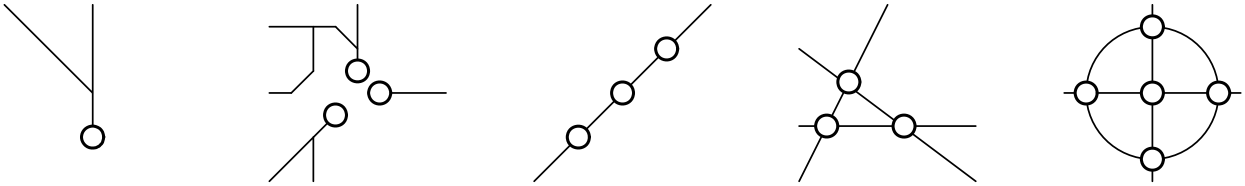
Hub & Spoke
(e.g. France)

Corridor with loops
(e.g. Britain)

Corridor with branches
(e.g. Shinkensen)

Plain Corridor
(e.g. Northeast Corridor)

Figure 1.2: Typical Metropolitan Structures for Intercity Passenger Rail Networks



Union Station/Stub-end
(e.g. Washington)

Multiple stub-ends
(e.g. London, Boston)

Suburban Stations
with mainline corridor
(e.g. Philadelphia)

Parisian
(e.g. Paris, Warrington UK)

Ring-road
(e.g. Tokyo)

Table 1.1: Calculating Out-of-Pocket Cost, by Various Modes

	Air Non Stop	**Air Via Hub**	**Train**	**Auto**	**Rental Car**
Circuity	1	1.2	1.1	1.1	1.15
Distance 1 way	250	300	275	275	287.5
Days at destination	2	2	2	2	2
Reservations (hours)	0.25	0.25	0.25	0	0.1
Cost (1-way)					
Access to station	$4	$4	$4		$4
Fare – fixed	$100	$50	$25		
Fare/mile	$0.50	$0.40	$0.30		
Expenses/trip					$40
Expenses/mile				$0.30	$0.05
Expenses/day					$40
Access to destination	$20	$20	$10	$0	$0
Parking per day	$20	$20	$20	$20	$20
Total Out-of-Pocket Cost	$289	$234	$162	$123	$178

Table 1.2: Calculating Total Trip Time, by Mode

	Air Non Stop	**Air Via Hub**	**Train**	**Auto**	**Rental Car**
Time for trip					
Access to station	0.75	0.75	0.5		0.5
Buffer for access unreliability	0.25	0.25	0.2		
Process time	0.1	0.15	0		0.25
Queue time	0.25	0.35			
Available time in station	0.5	1.5	0.25		
Boarding time	0.2	0.4	0.2		0.2
Travel time - fixed	0.75	1.5	0.2		
Travel time - per 100 miles	0.2	0.2	1.25	2	2
Total travel time in vehicle	1.25	2.1	3.64	5.5	5.75
Travel time - work %	75%	75%	75%	0%	0%
Travel time - entertainment %	0%	0%	0%	10%	10%
Travel time - rest & other %	25%	25%	25%	90%	90%
Travel time - work	0.94	1.58	2.73	0	0
Travel time - entertainment	0	0	0	0.55	0.58
Travel time - rest & other	0.31	0.53	0.91	4.95	5.18
Exit time from vehicle	0.2	0.4	0.2	0	0.25
Exit time from station	0.25	0.25	0.1		
Access to destination	1	1	0.5	0.25	0.25
Buffer for access unreliability	0.5	0.5	0.5	0.25	0.25
Total time	5.25	7.65	6.09	6	7.45

Table 1.3: Hypothetical Value of Time, by Mode and Type of Activity

	Air Non Stop	**Air Via Hub**	**Train**	**Auto**	**Rental Car**
Reservations	50	50	50	50	50
Time for trip					
Access to station	20	20	20	20	20
Buffer for access unreliability	20	20	20	20	20
Process time	50	50	50	20	50
Queue time	50	50	50	20	50
Available time in station	10	10	10	10	10
Boarding time	50	50	50	50	50
Travel time - work	-100	-100	-100	-100	-100
Travel time - entertainment	0	0	0	0	0
Travel time - rest & other	20	20	20	40	50
Exit time from vehicle	50	50	50	0	0
Exit time from station	50	50	50	50	50
Access to destination	50	50	50	50	50
Buffer for access unreliability	10	10	10	10	10
Extra travel time	150	150	150	150	150

Table 1.4: (Hypothetical) Disutility of Travel, by Mode

	Air Non Stop	**Air Via Hub**	**Train**	**Auto**	**Rental Car**
Direct Costs	$289	$234	$162	$123	$178
Reservations	$13	$13	$13	$0	$5
Travel time					
Access to station	$15	$15	$10	$0	$10
Buffer for access unreliability	$5	$5	$4	$0	$0
Process time	$5	$8	$0	$0	$13
Queue time	$13	$18	$0	$0	$0
Available time in station	$5	$15	$3	$0	$0
Boarding time	$10	$20	$10	$0	$10
Travel time – work	-$94	-$158	-$273	$0	$0
Travel time - entertainment	$0	$0	$0	$0	$0
Travel time - rest & other	$6	$11	$18	$198	$259
Exit time from vehicle	$10	$20	$10	$0	$0
Exit time from station	$13	$13	$5	$0	$0
Access to destination	$50	$50	$25	$13	$13
Buffer for access unreliability	$5	$5	$5	$3	$3
Extra travel time	$0	$360	$126	$113	$330
Total travel time disutility	$43	$381	-$58	$326	$636
Total disutility	$344	$627	$117	$448	$820

Table 2: Sensitivity Analysis for Mode Share

	Air Non Stop	**Air Via Hub**	**Train**	**Auto**	**Rental Car**
Base Case	2%	1%	67%	29%	1%
Discount Air Fares	18%	3%	56%	22%	1%
Business Shuttle	72%	9%	10%	9%	1%
Lower Rail Fares	58%	14%	24%	4%	0%
High Speed Rail	40%	12%	43%	4%	0%
Easy Access	17%	8%	71%	3%	0%
Two Travelers	2%	0%	54%	40%	4%
Easy Rail & Business Shuttle					
125 miles	7%	4%	69%	20%	1%
250 miles	17%	8%	71%	3%	0%
375 miles	35%	12%	51%	1%	0%
500 miles	56%	16%	27%	0%	0%
625 miles	68%	19%	13%	0%	0%