# Are High Speed Rail Customers Really Speed Demons?

## (or Performance-Based Technology Scanning for Intercity Rail Passenger Systems)

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*Dear Customer, Would you like the Cadillac, the Porsche, or the SUV?*
(Amtrak F-40 #280 and AEM-7 #901 at Boston South Station, Mass.)

# THESIS

- Technological Research need to go beyond High Speed Rail.

# OUTLINE

- How the travel-time is spent is important. Values of time is different for different parts of the trip.
- Improving passenger utility is a much better objective than trying to increase train speed or door-to-door travel time.
- Utility analyses should go to a level of detail not commonly considered in state-of-the-art models.
- Research should focus on technologies with the most cost-effective impact on passenger utility.
- Ease of access, efficient terminals, and opportunities to make better use of time in trains and in stations require much more than traditional rail technologies.
- This may seem obvious, but take a look at DOT research budgets and State DOT rail plans…!

# ACKNOWLEDGEMENTS

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# HIGH SPEED IS THE SILVER BULLET?

**The Cost of High Speed Rail.** The world is slowly coming to terms with the enormous costs of constructing fixed-guideway ground transportation operating at above about 90mph. The track geometry required to operate at such speeds often require much earthwork, whatever the technology. British Rail pursued the incremental approach, yet struggles to dominate the Anglo-Scottish key flows. SNCF and JR pursued the dedicated infrastructure approach, but like some airports, needed (and continues to require) tremendous infrastructure subsidy to maintain operations. Does Passenger Rail have a future?

**How high is High Speed?** *(How tall is a Skyscraper? How long is a Piece of String?)* One would be foolish to claim that the same "high-speed" is required in all locales to be competitive. Dependent on variable such as values of time, relative distances between metropolises, and the extent to which other modes have been developed, different rail speeds would be appropriate for different economic circumstances. In some countries, capacity or safety upgrades are much more desperately needed than higher speeds.

## The need for Speed: **Solution *sans* Problem?**

*I'm not convinced that higher speed is really what we need here. People might fall off the train if it went any faster.*
**Photo:** Nand Sharma, MIT Center for Transportation Studies.

*Transportation Systems are complex, large, integrated and open systems. When increasing speed, we should be mindful of its effect on reliability, cost, and other performance indicators.*
**Photo:** Lexcie Lu, MIT Center for Transportation Studies

High speed rail, and many other "advanced" rail technologies, appear to be solutions in search of a problem. The technologies will solve some problems, but not all. Application of the wrong technologies for a particular situation will at best generate little benefit, and may even make matters worse or divert scarce resources from other potentially important projects. A methodology is needed to identify what the potential problems (or service improvements sought) are, evaluate the potential solutions (technological or otherwise), and steer technological research and development towards the solutions that would be most effective in the widest range of circumstances, or solutions that would benefit a large number of people in specific implementations.

In determining research priorities, we should be aware of the phenomenon of "surrogate customers". Especially in large infrastructure projects, sometimes the needs of the actual customers (i.e. the travelling public) is neglected as the majority of the investment is not coming from the user but a state entity. Detailed market research, along with development of appropriate models to estimate what the customers want, what is their vision, and to what extent it is economically sustainable, should form the basis of strategic planning for research and development.

# QUICK POLL (WRITE YOUR OWN RESULTS)

**What Kind of Technologies are most Popular?** The most popular technologies, presumably, are ones that are likely to sell, and therefore are likely to be leveraged. After all, Sam Walton didn't build his empire by sourcing the absolutely best premium goods in the industry. In any case, what is "best" depends very much on what each individual customer is looking for. This logic would suggest that there are a number of performance measures – trade offs between cost, reliability, speed, accessibility, comfort, and other attributes that customers would evaluate when purchasing transportation services.

What is needed, thus, is a way of modelling these evaluation decisions in quantitative terms, and a framework for translating the technological developments into likely performance increases. We use this process to determine the leveraged technologies, where a small change (or a small investment) will lead to a large "performance" increase. This is what we call "Performance-based Technology Scanning", or PBTS for short.

## **Leveraged:** Small Investment, Big *Performance* Bonus

Let us illustrate this with an example:

| **Type of Vehicle** | *Cadillac* | *Porsche* | *S.U.V.* |
|---|---|---|---|
| *Speed* | 80 mph | 200 mph | 60 mph |
| *Cost* | $500,000 | $750,000 | $200,000 |
| *Capacity* | 4 paxs | 2 paxs | 6 paxs |
| *Demand?* | | | |

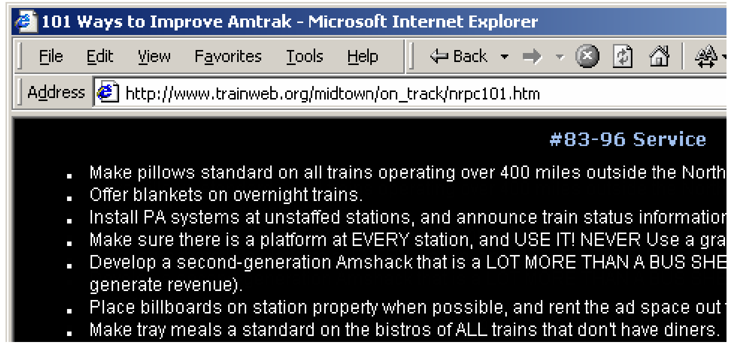
Clearly, not everybody in this room would choose the Porsche, even if the high cost is not a constraint. Some prefer to travel in style, while others require higher carrying capacity. The same logic applies to choice of what type of train service to provide, and consequently the type of technologies that would generate the greatest impact (or benefit the largest number of people, or generate the most revenue).

| **Type of Train** | The *Royal Scotsman* | Tokaido *Shinkansen* | Amtrak *Superliner* |
|---|---|---|---|
| *Speed* | 75 mph | 186 mph | 110 mph |
| *Capacity* | 33 paxs | 1,324 paxs | 228 paxs |
| *Seat pitch* | Large | 960 mm | 1,295 mm |
| *Demand?* | | | |

On the other hand, if this room comprised of entirely Japanese businessmen, or Indian peasants, or British steelworkers, the results may have been drastically different. Thus, PBTS is a local exercise; something which national railroads or private railroad companies can conduct for a particular market segment that they are targeting (or for a particular local culture). Of course, it is a two-way street, since service and technology can influence customer expectation and willingness-to-pay. However, the technologist should not assume just because something is high-tech, customers would be willing to pay for it, or it will be appropriate for every customer's needs. Analysis appropriate for one part of the world may not be appropriate elsewhere. Modelling performance from a customer-centric perspective is key to deploying technologies in an appropriate way.

# LISTEN TO THE CUSTOMERS

**What Service Improvements are Needed?** Is it more frequent service? Is it faster service? Is it cheaper service? The answer may surprise you. The customers are a great resource – many will air their opinions quite openly. Some are more informed than others:



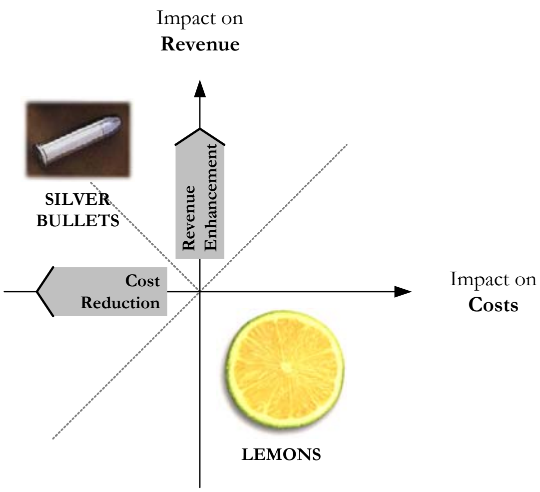

Customers usually have a poor understanding of the costs involved in providing certain amenities, and usually expect carriers to pay for them out of already very-thin (or negative) profit margins. However, the informed customer base clearly understand vehicle cycles and other elementary concepts in transportation. Many of their suggestions could be valid.

## **Customers:** a *Resource* in Technology Scans

Customer requirement or aspiration alone is not a reason to implement a new technology or a new service. The new service must also be *effective*, i.e. the customers must be either willing to pay for the new service, or derive benefits greater than the costs of providing such a service. Nonetheless, by starting with customer input, we can understand the customers' utility function better, and perform analysis and determine whether the customers' suggestions is in fact effective. We may even learn about possible market segmentation and possible pricing strategies. The customer is an equally important resource as the technologist in the search for passenger railroad technologies.

# UNDERSTANDING TECHNOLOGIES

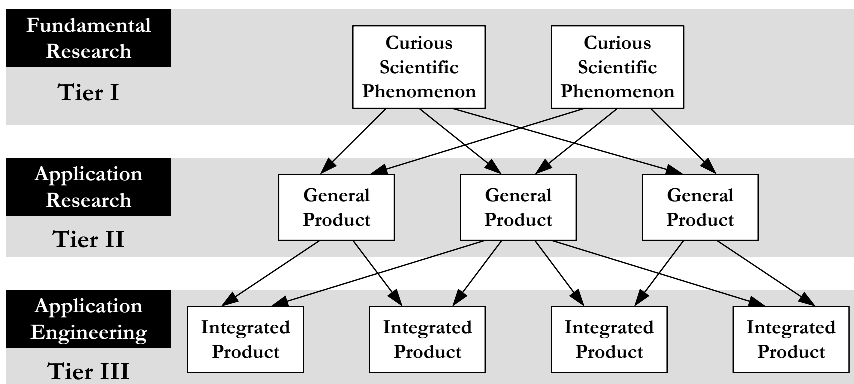
**What Impacts will a New Technology have?** To understand the impacts of new technologies, we developed a three-pronged framework for thinking through how technologies might be deployed, and what their impacts on various performance attributes might be if deployed in a particular manner.




**Classification by Financial Impact.** Technologies may be divided into two broad categories: its impact on revenue, and on costs.

- *Cost-Cutting Technologies* (Type A) are predominantly designed to provide the same service at lower costs (e.g. cheaper rails & ties).
- *Revenue-Enhancing Technologies* (Type B) are predominantly designed to provide better service to generate more revenue (e.g. on-board internet service).

However, service and cost-base are invariably tied. The goal of the railroad management is to promote technologies in the northwest quadrant of the graph shown, and to reject technologies in the southeast quadrant.




**Classification by Fundamentality.** Technologies may be classified into three distinct segments, Tiers I thru III.

*Tier I* Research are simply discoveries and preliminary investigation of scientific phenomenon which may or may not lead to an application. *Tier II* Technologies are at a stage when an intermediate product prototype has been developed but does not yet serve useful purpose from the consumer's point of view until it becomes possible (and economically desirable) for the technology to be integrated into a *Tier III* Product – which represents ultimately what the consumers will pay for directly.

Understanding technologies from a technologist's perspective allows us to accurately predict what the potential impacts might be (and prompts creative applications which might otherwise have been overlooked).

## *Three-Pronged* **Approach:** Financial, Fundamentality, Functionality.

**Classification by Functionality.** Finally, we can think about technologies from the ultimate customer's (i.e. the travelling public's and freight shippers') perspective. How will the technology impact the customer? Which market segments will benefit the most? Which the least? Are there distributional issues?

In general, technologies have four major functions: **1.** improve operations (speed, frequency for existing customers); **2.** improve accessibility (increase customer base); **3.** improve en-route services; **4.** improve network operations (coordination and consolidation). Of course, other categories are possible. The aim is to create categories that are fairly general so that they are not attached to particular kinds of technologies.

# UNDERSTANDING PASSENGER UTILITIES

**How to Compare Different Technologies?** Using the three-pronged approach, we can identify a number of technologies that are potentially important and assess their impacts. But how do we translate these expected impacts into a quantitative measure of how the customers will view them?

| **Utility for Intercity Travel** | | | | | |
|---|---|---|---|---|---|
| C.D. Martland 11/28/01 | | | | | |
| | **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 | $4.00 | $4.00 | $4.00 | | $4.00 |
| Fare - fixed | $100.00 | $50.00 | $25.00 | | |
| Fare/mile | $0.50 | $0.40 | $0.30 | | |
| Expenses/trip | | | | | $40.00 |
| Expenses/mile | | | | $0.30 | $0.05 |
| Expenses/day | | | | | $40.00 |
| Access to destination | | | | | |
| Parking per day | $20.00 | $20.00 | $20.00 | $20.00 | $20.00 |
| Total | $269 | $214 | $152 | $123 | $178 |
| Time for trip | | | | | |
| Access to station | 0.75 | 0.75 | 0.50 | | 0.50 |
| Buffer for access unreliability | 0.25 | 0.25 | 0.20 | | |
| Process time | 0.10 | 0.15 | 0.00 | | 0.25 |
| Queue time | 0.25 | 0.35 | | | |
| Available time in station | 0.50 | 1.50 | 0.25 | | |
| Boarding time | 0.20 | 0.40 | 0.20 | | 0.20 |
| Travel time - fixed | 0.75 | 1.50 | 0.20 | | |
| Travel time - per 100 miles | 0.20 | 0.20 | 1.25 | 2.00 | 2.00 |
| Total travel time in vehicle | 1.25 | 2.10 | 3.64 | 5.50 | 5.75 |
| Travel time - work % | 0.75 | 0.75 | 0.75 | 0.00 | 0.00 |
| Travel time - entertainment % | | | | 0.10 | 0.10 |
| Travel time - rest & other % | 0.25 | 0.25 | 0.25 | 0.90 | 0.90 |
| Travel time - work | 0.94 | 1.58 | 2.73 | 0.00 | 0.00 |
| Travel time - entertainment | 0.00 | 0.00 | 0.00 | 0.55 | 0.58 |
| Travel time - rest & other | 0.31 | 0.53 | 0.91 | 4.95 | 5.18 |
| Exit time from vehicle | 0.20 | 0.40 | 0.20 | 0.00 | 0.25 |
| Exit time from station | 0.25 | 0.25 | 0.10 | | |
| Access to destination | 1.00 | 1.00 | 0.50 | 0.25 | 0.25 |
| Buffer for access unreliability | 0.50 | 0.50 | 0.50 | 0.25 | 0.25 |
| Total time | 5.25 | 7.65 | 6.09 | 6.00 | 7.45 |
| Risk | | | | | |
| Exp. fatal acc. per mill. m. | 0.005 | 0.01 | 0.015 | 0.025 | 0.05 |
| Consequences of fatal accident | $2,500,000 | $2,500,000 | $2,500,000 | $2,500,000 | $2,500,000 |
| Estimated risk | $3 | $8 | $10 | $17 | $36 |
| **Value of time** | | | | | |
| 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 |
| **(Dis)Utility** | | | | | |
| Direct Costs | $269 | $214 | $152 | $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 |
| Total travel time cost | $43 | $21 | -$183 | $213 | $306 |
| Total cost | $324 | $247 | -$19 | $336 | $490 |

The concept of utility as applied to transportation has been discussed since the 1960s, in pioneering work by Moshe Ben-Akiva and others. However, such traditional models are heavily laden with assumptions, some of which has been generally accepted, but may be incorrect. For instance, utility models generally view journey time as bad (a disutility). However, a longer journey time may be advantageous for a business traveller who values the productive work he could get done on-board a train. If an overnight traveller would otherwise be asleep in a hotel or at home (and not moving), journey time for movement that takes place during sleep may be cost-neutral.

**We conducted a very detailed study of Values of Time.** Productive work done during the rail trip shows a positive value because the passenger produces billable work; time spent riding the subway and reading the papers might be netural, while time spent in unscheduled delays at an airport might be negative.

These values-of-time are different for different market segments, both because of the differences in wage rates and also how the customer is likely to view the journey time. In general, long-stretches of in-vehicle time tend to be more positive than short bursts of time spent in queues or other unproductive activities.

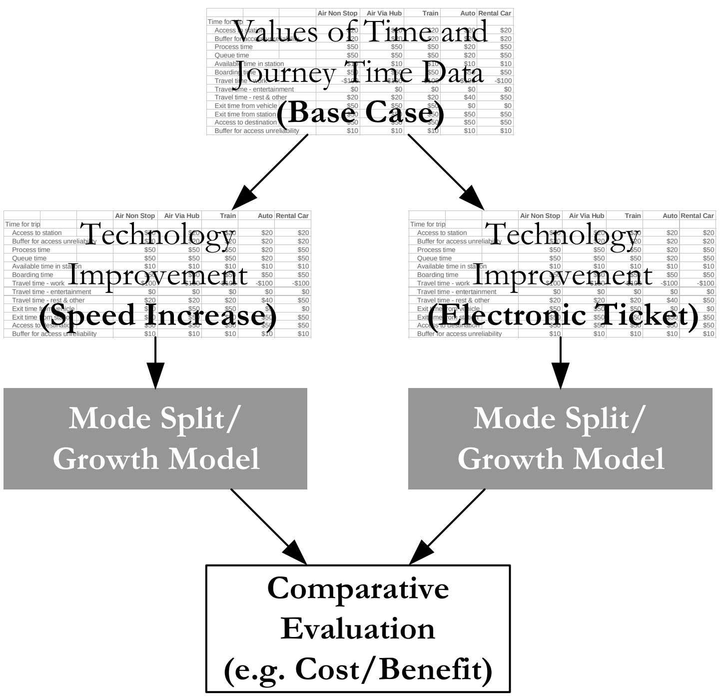
## **How Much** do you Value *your* Time?

**Demand Studies** seldom approach the level of detail necessary to address the effects of technology on the *quantity* and the *quality* of time spent specific activities. We hypothesize that passenger make much finer distinctions concerning utility than have thus far been captured. We assumed that time and comfort utilities can be expressed in monetary terms and compared directly to fares and other out-of-pocket costs. This enables us to compare the impacts of different technologies on a level playing-field – through the customer's lens.

By summing the out-of-pocket costs and the value that the customer generate (or expend) during the trip, we may predict if the customer will choose to make the trip, and by what mode.

# APPLICATION TO TECHNOLOGICAL EVALUATION

**We are Now Ready to Evaluate Technological Proposals.** We understand how the technologies will affect the customer's travel experience, and we understand quantitatively how the customer will perceive these changes in travel experience. It is now possible to pitch one technological proposal against another to see which one is more *leveraged* – produces the greatest increase in passenger utility for the least cost.




Firstly, the values of time and journey time data using existing technologies are collected. Secondly, we consider a number of technological alternatives: e.g. investing in high-speed technologies may lead to a 25% reduction in in-vehicle time, while investing in the e-ticket capability may lead to a 50% reduction in queue time when arriving at the train station.

We then consider what the impact of these time-reductions would be for each market segment. Internet-savvy consumers would benefit from the zero queue time e-ticket while other travellers would benefit from the reduction in queue time. However, higher train speed will affect all passengers, regardless of their ticketing arrangement.

Having determined the impact of the technology on the mode split or revenue growth, some standard evaluation methodology could be used to determine which technology should be pursued.

## **Technology** changes the *Quantity* and *Quality* of Time

**Who Captures the Benefits?** In a commercial environment, it is important to distinguish between benefits captured by the carrier, the user, and a third party. The traveller is the decision-maker in most cases, and carrier revenue depends fairly strongly on the decision of the user. However, in some cases it is impossible to recapture the benefits resulting from technological investment through fare increases. In some other circumstances, e.g. a business traveller on a salary, any work done by the traveller in fact benefits the company but not the individual, while the individual is the person making the transportation carrier choices.

From a public policy perspective, the distributional issues do not matter – positive externalities generated by the technological investment are captured by the general public and perhaps third parties. However, it is important to be *explicit* in considering these positive externalities, since technological investments should *not* be made until the cost of the technology is sufficiently low to make it effective. Political support for investment schemes would also be stronger if the benefits are made explicit.


*Amtrak's QuikTrak machines attempt to reduce a part of total travel time which many perceive as undesirable – time spent standing in-line waiting to purchase a ticket. When implementing such technologies, it is important to evaluate if the consumer benefit exceeds the cost of the technology.*

**Photo:** Washington State DOT, Amtrak Cascades Official Site.

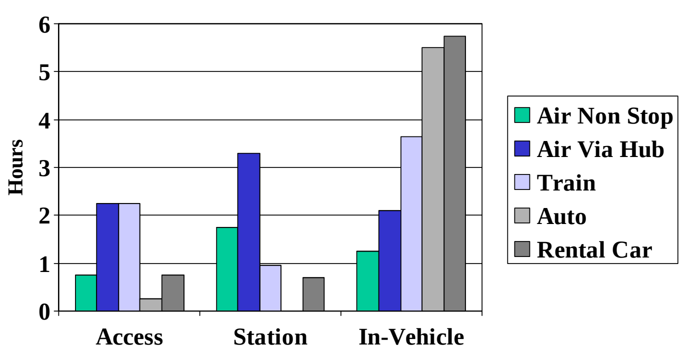
# OUR HYPOTHETICAL EXAMPLE

**To Demonstrate the Power of Performance-Based Tech Scan,** we invented a business traveller with an average billable rate of $100/hour and a salary of $40 per hour. Using the prototype spreadsheet model shown in slide 5, we analyzed the effects of various competitive scenarios and impact of technology changes on his trip utility. With a typical 250-mile trip, we found that a business-shuttle service could be a formidable competitor if well-managed. To compete, the best technological improvement for the railroad is not in cost-cutting nor in higher speeds. Making access more convenient and easier in fact produced the highest market share in a competitive environment.

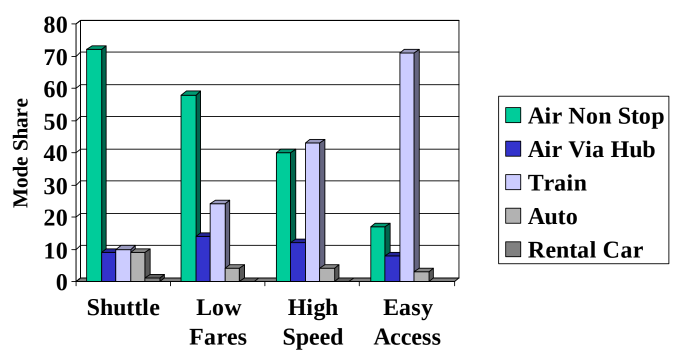
| | Air Non Stop | Air Via Hub | Train | Auto | Rental Car |
|---|---|---|---|---|---|
| Base Case | 2% | 1% | 67% | 29% | 1% |
| Discount Air Fares | 18% | 3% | 56% | 22% | 1% |
| Business Shuttle | 72% | 9% | 10% | 9% | 1% |
| Lower Rail Fares | 58% | 14% | 24% | 4% | 0% |
| High Speed Rail | 40% | 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% |

Cheaper or higher speed did *not* produce better market share than **Enhanced Access**

**How the Time is Spent is Important**
(Hypothetical 250-mile Trip)

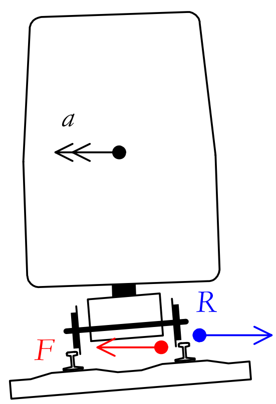



**How Rail might Respond to Low-Fare Airlines** (250 miles)



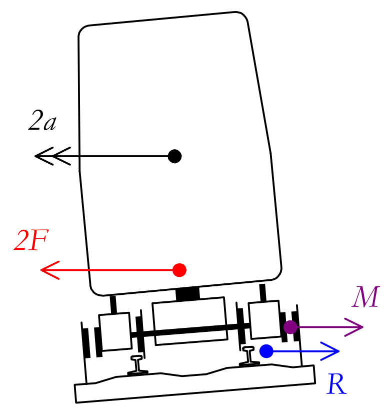
# INCREMENTAL HYBRID MAGLEV

**Technologies have achieved widespread acceptance generally through backwards compatibility.** Part of the reason Maglevs have consistently failed to sell can be attributed to the high up-front infrastructure investment required. If Maglevs could be engineered such that they are backwards-compatible with existing railroad systems, the railroad can take advantage of Maglev's guidance capabilities to conquer ruling grades and sharp reverse curves, without having to construct long stretches of expensive infrastructure through open space where steel-wheels and steel-rails are perfectly capable of delivering the desired speed.




**Conventional Train**

Speed Limited by
Superelevation, Reaction
Forces, Passenger Comfort




**Hybrid Maglev Tilting Train**

Speed Limited only by
Passenger Comfort.

*Track is Freight Compatible!*

**Maglevs** have consistently failed to sell due to its high C*onstruction Costs*

In constrained urban rights of way, speed is often the slowest and speed enhancements are often the most expensive. Given the relative ratios of vehicle versus infrastructure costs in interurban service, the bulk of the investment should be made on the vehicle. The tilting element of the hybrid maglev train maintains passenger comfort; the steel-wheels, steel-rails component supports the weight of the railcar and provides part of the guidence; the magnetic element holds the truck in place and prevents it from derailing, thus allowing trains to operate over track at speeds which would cause a derailment without magnetic guidance.

The expensive magnetic infrastructure is only necessary over constrained parts of the right-of-way. The track can be superelevated for a balancing speed of 40mph (thus remaining compatible with double-stack freight), with passenger trains operating at much greater speeds held in place by magnetic rather than reaction forces.

# CONCLUSING OBSERVATIONS

- Technological advances will be rapid – but they will *not* be driven by needs of railways
- Highway and air transportation will likely benefit more directly from R&D
- Accessibility, comfort, and productivity of time can be major assets for railways
- "High Speed Rail" is a limited and possibly a limiting concept. What's needed is:

  **"Competitive, Integrated, Effective Rail"**
- This may seem obvious, but take a look at DOT research budgets and State DOT rail plan


*Technology scanning and infrastructure investment decision making can cause friction between customers from different market segments – beneficiaries should be made explicit and costs allocated accordingly.*

(CSX unit-coal train powered by GE4400AC No.324, on the ex-B&O mainline as seen from Amtrak Train #29, the Capitol Limited.)