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The Worst of Both

The Rise of High-Cost, Low-Capacity Rail Transit

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EXECUTIVE SUMMARY

Most new rail transit lines in the United States and around the world are either *light rail*, including lines that sometimes run in or cross city streets, or *heavy rail*, which are built in exclusive rights of way, usually elevated or in subways. Heavy rail costs far more to build than light rail, but the capacity of light rail to move people is far lower than heavy rail. In fact, the terms *light* and *heavy* refer to people-moving capacities, not the actual weight of the equipment.

Recently, a number of cities in the United States and elsewhere have built or are building a hybrid form of rail transit that can best be described as the worst of both, combining the cost-disadvantages of heavy rail with the capacity limits of light rail. Seattle is building a three-mile subway that costs nearly six times as much per mile as the average light-rail line. Honolulu is building a 20-mile elevated rail line that costs well over twice as much as the average light rail. Yet those lines will be limited to little (or no) more than light-rail capacities.

This seems to be a worldwide trend, as new, high-cost,

low-capacity rail systems have recently opened in Mumbai, India; Panama City, Panama; Fortaleza, Brazil; and several other Asian and Latin American cities. A small number of French, German, Italian, and Spanish contractors and railcar manufacturers seem to be involved with building and supplying many of those lines.

Rail lines built at light-rail costs are questionable enough, as in nearly every case buses can move more people just as comfortably (if not more so), just as fast (if not faster), and at a far lower cost. Buses share infrastructure with cars and trucks, reducing their cost, while the use of high-occupancy vehicle or high-occupancy toll lanes would allow buses to avoid congestion during even the busiest times of day.

The willingness of many rail advocates to support high-cost, low-capacity rail lines calls into question the entire rail agenda. Supporters of low-capacity lines are not truly interested in transportation; supporters of high-cost lines are not truly interested in urban efficiencies. If they are not willing to draw the line against such projects, then there is little reason to believe their claims about the benefits of other rail projects.

“The difference between light and heavy rail is not weight but capacity: light rail is low-capacity transit while heavy rail is high-capacity transit.”

INTRODUCTION

Numerous cities throughout the world are dealing with growing traffic and congestion by building rail transit lines. Although many skeptics have questioned whether the lines are cost-effective, this hasn't stopped officials in urban areas from Valparaiso, Chile (population 900,000) to Mumbai, India (18 million) from building such lines.

Normally, there are two ways to build a new rail transit line in a city. The first is to build some or all of the line at ground level, sharing streets with motor vehicles and pedestrians. The second is to completely separate the lines from streets, either by elevating them above street level or tunneling underground. The first is commonly called *light rail* while the second is called *heavy rail*.

Despite the names, the weight of rails and railcars used for light rail are about the same or even more than for heavy rail. What differentiates the two is capacity: light or *low-capacity* rail can only move a small fraction of the number of people per hour as heavy or *high-capacity* rail. Rail transit is often sold to politicians and the public on the claim that it can move more people per hour than a multilane freeway, but in fact that only applies to high-capacity rail.

Light-rail capacities are lower than heavy rail for two reasons. First, trains running in city streets can be no longer than the length of a city block; otherwise they would obstruct traffic every time they stop. A typical light-rail car is a little more than 90 feet long. Downtown blocks in Portland, Oregon, for instance, are just 200 feet long, so trains can have no more than two cars. In Salt Lake City, blocks are 400 feet long, so it can run four-car trains. Most American cities have 300-foot blocks and so can run three-car trains.

By comparison, heavy-rail lines can run trains as long as the platforms at each station. The Washington, D.C., Metrorail system has platforms long enough for eight cars. The BART system in the San Francisco Bay Area has 10-car platforms, while some New York City subway lines have platforms long enough

for 11 cars. Longer trains mean more capacity.

Second, trains running in city streets are limited in speed for safety reasons. Such slow trains mean fewer trains can run per hour. Few light-rail lines can safely run more than 20 trains per hour. By contrast, some heavy-rail lines can run 30 trains per hour. Fifty percent more trains per hour combined with trains that can hold two to five times as many people means heavy rail can move four to eight times as many people per hour.

To be fair, typical heavy-rail cars are a little shorter, around 50 to 75 feet, than typical light-rail cars, which are around 80 to 95 feet long. But the heavy rail cars partly make up for that by being wider; they are typically 10 feet wide versus less than 9 feet for light-rail cars. Thus, a 90-foot light-rail car has just 7 percent more floor space than a 75-foot heavy-rail car. Light-rail cars typically have four doors on each side while many subway cars have only three. Light-rail cars are also divided in the middle by a center set of wheels. Those factors reduce light-rail capacities.

For example, a 75-foot Washington Metro car typically has 68 seats and is rated for 136 standees (but comfortably accommodates only about half that many). A 92-foot Portland light-rail car has 64 seats and is rated for 100 standees (but comfortably accommodates only a fraction of that number).¹

The drawback of high-capacity rail is its cost. Elevated rail typically costs two to four times as much to build per mile as ground-level rail; underground rail can easily be two to four times more expensive than that.

In short, there is a clear distinction between relatively low-cost but low-capacity light rail and high-cost, high-capacity heavy rail. In recent decades, Atlanta, the San Francisco Bay Area, and Washington chose to build the latter while Dallas, Portland, and Salt Lake City chose to build the former.

Given this distinction, the surprising and puzzling thing is that an increasing number of cities are building a hybrid between light and heavy rail. On one hand, they are elevating or tunneling to keep rail systems separated from

traffic. On the other hand, they are building short platforms and purchasing short trains that run at slower, light-rail speeds. Thus, they have the cost disadvantage of heavy rail and the capacity disadvantage of light rail—the worst of both.

Critics have questioned the social, environmental, and economic benefits of all forms of rail transit. But the fact that so many cities are building high-cost, low-capacity rail reveals the bankruptcy of the entire rail transit movement. Rail transit is not about moving people if cities choose low-capacity systems. Rail transit is not about efficiency if cities choose high-cost systems. Instead, rail transit is simply a form of crony capitalism: a way to spend large amounts of tax dollars in order to build political coalitions that have no real interest in transportation.

COMPARING CAPACITIES

Rail advocates commonly claim that a single rail line can move as many people as an 8- or 10-lane freeway. To support such claims, they usually compare heavy-rail trains running at full capacity with cars on freeway lanes operating at average capacity. A more valid comparison reveals that high-capacity rail at its peak can move more people than cars, but low-capacity rail cannot. Moreover, buses running at capacity can outperform all forms of rail transit.

A typical light- or heavy-rail car has about 50 to 70 seats and enough standing room to hold no more than a total of 150 people at levels of crowding that most Americans or Europeans would consider comfortable. Railcar manufacturers sometimes estimate much higher capacities; for example, some light- and heavy-rail cars in the Federal Transit Administration's National Transit Database are rated at holding 225 standees. This is known in the transit industry as "crush capacity." Outside of some Asian cities, railcars never come close to those numbers as people will simply wait for the next train or stop riding transit before crush conditions are reached.²

Assuming a capacity of 150 people per railcar, it is easy to calculate the capacity of a rail

line as 150 times the maximum number of cars per train times the maximum number of trains per hour (Table 1). Portland's two-car light-rail trains thus have a maximum capacity of 6,000 people per hour; Salt Lake City's four-car trains have a capacity of 12,000 people per hour; Washington's eight-car trains can move 36,000 people per hour; and New York's 11-car trains can move 49,500 people per hour.

Trains rarely operate at those full capacities, however. For one reason, few rail lines are scheduled to move that many trains per hour. When two or more rail lines merge, such as Washington's Orange, Blue, and (soon) Silver lines; or Portland's East Side Blue, Green, Red, and Yellow lines, each of the unmerged portions of the lines can operate at only a fraction of its potential capacity or it would crowd out trains from the other lines once those lines merge.

Moreover, trains are rarely full except during rush hour, and then only near the city centers. On average, light- and heavy-rail lines that operate most of the day (as opposed to only during rush hours) fill only about 40 to 50 percent of the seats, which means when standing room is counted they operate at only 20 to 25 percent of capacity.³

Although trains do not always operate at capacity, having lower capacities can mean lower ridership. For example, by almost any measure shown in Table 2, the nation's most productive light-rail lines are in Boston, yet in terms of passenger miles per route mile they are only half as productive as Boston's heavy-rail lines and less than a quarter as productive as the nation's most productive heavy-rail lines. On average, the nation's heavy-rail lines carry almost five times as many passenger miles per route mile as the nation's light-rail lines.

Table 2 shows that the use of some heavy-rail lines is well below their capacity. Based on this, cities such as Baltimore, Cleveland, Miami, San Juan, Staten Island, and Lindenwold-Philadelphia (PATH) should have never built their heavy-rail lines, as light rail easily could have moved the number of people carried by those lines. Several light-rail lines are also

“The puzzling thing is that some cities are building hybrid rail systems, with the cost disadvantage of heavy rail and the capacity disadvantage of light rail—the worst of both.”

Table 1
Transit Capacities in People per Hour

Streetcar (Portland, Oregon)	2,000
2-car light-rail trains (Portland, Oregon)	6,000
3-car light-rail trains (Most Cities)	9,000
4-car light-rail trains (Salt Lake City)	12,000
8-car heavy-rail trains (Washington)	36,000
10-car heavy-rail trains (San Francisco)	45,000
11-car heavy-rail trains (New York)	49,500
Cars on freeway lane (5 people per car, national avg.)	10,000
Single-decked buses on streets (national avg.)	10,000
Double-decked buses on streets (national avg.)	17,000
Single-decked buses on busway (national avg.)	66,000
Double-decked buses on busway (national avg.)	110,000

Source: Calculations based on railcar capacities found in the National Transit Database—see text for details.

particularly unproductive, including those in Baltimore, Cleveland, New Jersey (both the Hudson-Bergen and River lines), Norfolk, Pittsburgh, Sacramento, Salt Lake City, and San Jose.

For comparison, a freeway lane can typically move about 2,000 automobile-sized vehicles per hour, though more modern freeways have been measured moving as many as 2,200 autos per hour. At the average occupancy rate of 1.6 people per car, 2,000 vehicles per hour represents 3,200 people per hour. But this is an unfair comparison with trains operating at full capacity. Assuming that the average car has five seats, a freeway lane filled with cars at capacity can move 10,000 people per hour—

more than any two- or three-car light-rail line.

A more valid comparison to rail transit would be bus transit. Studies by Portland State University researchers have found that a single bus stop can serve 42 buses per hour.⁴ Downtown Portland bus stops are staggered so that there are four distinct stops every two blocks, potentially serving 168 buses per hour. A standard 40-foot bus has about 40 seats and room for about 20 standees. Thus, a single street with staggered bus stops can move more than 10,000 people per hour. Just two lanes of such a street would need to be dedicated to transit: one stopping lane and one passing lane. The passing lane could be opened to autos or other traffic if bus frequencies were low.

Table 2
Heavy- and Light-Rail Productivities

	Occupancy (percent of seats)	Recovery Rate (percent)	Weekday Passenger Miles per Directional Route Mile	Weekday Trips per Directional Route Mile	Weekday Trips per Stop
<i>Heavy Rail</i>					
Atlanta	39.8	24.1	14,304	2,227	6,077
Baltimore	22.0	13.6	7,303	1,470	3,570
Boston	45.9	34.4	18,127	5,079	10,351
Chicago	49.7	36.7	16,926	2,541	5,043
Cleveland	27.8	14.3	3,511	513	1,194
Los Angeles	66.0	27.1	21,271	4,449	9,483
Miami	28.5	25.3	8,134	1,099	2,786
New York (MTA)	64.0	49.6	40,323	9,998	17,729
NYC (PATH)	108.0	27.3	26,718	6,287	20,845
Oakland	36.6	50.8	19,207	1,464	8,904
Philadelphia	48.3	41.8	15,084	3,383	4,501
Philly (PATH)	27.2	35.6	8,534	964	2,847
San Juan	37.9	14.4	7,044	1,472	2,346
Staten Island	21.4	16.6	6,289	726	1,046
Washington	31.7	53.0	20,131	3,590	11,264
Total/Average	52.2	45.0	25,205	5,349	11,649
<i>Light Rail</i>					
Baltimore	22.1	8.4	3,172	490	855
Boston	74.3	38.0	9,006	3,185	3,357
Buffalo	37.6	14.4	4,691	1,691	1,590
Charlotte	46.1	19.9	8,750	1,631	798
Cleveland	33.7	14.9	1,804	298	289
Dallas	39.4	12.0	4,022	514	1,555
Denver	32.5	40.1	7,980	929	1,868

continued

**Table 2—Continued
Heavy- and Light-Rail Productivities**

	Occupancy (percent of seats)	Recovery Rate (percent)	Weekday Passenger Miles per Directional Route Mile	Weekday Trips per Directional Route Mile	Weekday Trips per Stop
Hampton	25.2	5.4	2,551	587	395
Houston	45.1	11.1	4,675	2,050	2,332
Jersey City	33.5	12.6	3,927	1,206	1,834
Los Angeles	43.2	16.0	8,436	1,245	2,561
Minneapolis	41.2	33.7	5,649	1,062	1,648
Phoenix	58.0	39.6	6,424	971	1,265
Pittsburgh	28.4	11.6	2,384	491	967
Portland	43.6	42.1	6,735	1,248	2,274
Sacramento	29.4	30.1	3,446	606	910
Salt Lake City	21.8	22.1	3,805	806	1,147
San Diego	40.7	16.4	5,660	949	1,836
San Francisco	39.7	17.4	5,322	1,843	2,457
San Jose	26.4	11.7	2,240	411	503
Seattle	35.7	25.8	5,087	675	2,000
St. Louis	33.1	20.8	4,923	547	1,425
Trenton	35.1	13.0	3,133	1,416	1,158
Total/Average	39.2	21.2	5,245	1,013	1,810

Source: 2012 National Transit Database.

Note: *Occupancy* measures the average share of seats filled by passengers. *Recovery Rate* is the share of operations and maintenance costs covered by fares. *Weekday Passenger Miles per Directional Route Mile* is the average number of passenger miles carried on a typical weekday per directional route mile, which is the number of miles of track or routes in each direction; thus, a 10-mile rail route would have 20 directional route miles. *Weekday Trips per Directional Route Mile* is the average number of trips carried on a typical weekday divided by directional route miles. *Weekday Trips per Stop* is the average number of weekday trips divided by the number of stations or stops.

Bus capacities can be nearly doubled by replacing standard 40-foot buses with 40-foot double-decker buses. With a footprint no larger than an ordinary bus, double-deckers typically have 75 to 85 seats and are rated to hold as many as 97 standees—although that is at crush capacity and 20 to 40 is more realis-

tic. Some double-decker buses are less than 14 feet tall and should be able to fit under most overpasses, wires, or other obstacles. Assuming a capacity of just over 100 people, those buses could move 17,000 people per hour on city streets with staggered stops—more than a four-car light-rail line.

Far more people can be moved on buses on a dedicated bus lane. Since full-sized buses are more than twice as long as most automobiles, a highway lane cannot move as many buses per hour as cars. Most highway capacity calculations compare the *passenger car equivalents* of trucks and buses. But buses are shorter than many trucks, and weigh less (allowing faster acceleration and braking) than most trucks, so a highway lane should be able to handle more buses than trucks. While a single bus may displace around two automobiles in mixed traffic, an exclusive bus lane should be able to handle more than half as many buses as cars.

A lane with buses traveling at 60 miles per hour with six full bus lengths between them can move more than 1,100 buses per hour. Single-decked buses can thus move about 66,000 people per hour; double-decked buses can move more than 110,000. Around 80 percent of those people—far more than a train—would be comfortably seated. In fact, just the seated passengers on double-decker buses on a single bus lane would vastly outnumber both seated and standing passengers on the highest-capacity rail lines.

SUPERBOWL TRANSIT. The advantage of bus transit was demonstrated at the 2014 Super Bowl at MetLife Stadium in the New York suburb of East Rutherford, New Jersey. It was proclaimed to be the first “transit Super Bowl” because most people were required to arrive by transit as the stadium parking lot was half occupied by security and media equipment. While a few people were allowed to pay \$150 for a parking space, most football fans paid \$50 for either a bus or train ride to the stadium.

The buses worked great. According to a local news report, “buses at Harmon Meadow came and went without incident, with fans calmly boarding three or four [buses] at a time before they took off and several minutes later replaced with more.”⁵ Rail transit, however, was a disaster, with passengers waiting in line for hours, forced to stand in overheated stations, and stuffed into overcrowded trains.⁶ After the game was over, bus passengers were able to leave the stadium quickly, but some train passengers were stuck until 1 a.m., and would have

had to wait even longer except that extra buses were chartered to relieve overcrowded trains.⁷

BUS FLEXIBILITY. With the possible exception of some Asian cities, few if any places in the world have enough travel demand to dedicate an entire lane to buses. But buses can also avoid congestion by using high-occupancy vehicle (HOV) or high-occupancy toll (HOT) lanes. The latter are open to low-occupancy vehicles willing to pay a toll, but the tolls are varied to guarantee that the lanes never become congested. This has led some to call HOT lanes “virtual exclusive busways,” but just about any number of buses (up to the capacity of 1,100 buses per hour) can use the lanes without encountering congestion.⁸

Given the capacities shown in Table 2, it would be easy to design a bus system for almost any city that would be capable of moving more people than low-capacity rail lines while building little, if any, new infrastructure. Buses could fan out from downtowns and other major employment centers on city streets and highways, using HOV or HOT lanes where available.

When entering downtown areas or other job centers, buses can be funneled onto one-way couplets with staggered bus stops. If demand for bus travel exceeds the capacity of one street with such bus stops, more than one pair of downtown streets can be designed for such stops.

Many downtowns, for example, are located at or near the crossings of two major interstate freeways, one running east–west and the other north–south. The freeways typically each have more than one exit serving different parts of the downtown. Buses could be routed off each of the freeways onto two pairs of one-way couplets. With commuters entering downtown from each of the four cardinal directions, the downtown area would have a capacity of moving 136,000 people per hour (eight streets, each moving 17,000 people per hour on double-decker buses). Since only 10 urban areas in the United States even have that many downtown jobs, buses can obviously provide adequate transit service to most cities.⁹

Some cities do not have HOV or HOT lanes and have freeways that are jammed with

“Double-decker buses on exclusive bus lanes can move more than 110,000 people per hour. Just the seated passengers would vastly outnumber both seated and standing passengers on the highest-capacity rail lines.”

“Any city with fewer than 250,000 downtown jobs can adequately be served by bus transit.”

slow-moving traffic at rush hours. In those cases, rail advocates argue that rail transit will give people an alternative to driving in congested traffic that buses cannot offer. However, the question must be asked why taxpayers should pay hundreds of millions or even billions of dollars to subsidize train rides that will only benefit a relative handful of people. For far less money, new highway capacity could be built and used as HOT lanes, offering far more people—including both auto drivers and transit riders—an alternative to congestion.

In Tampa, for example, the Tampa-Hillsborough Expressway Authority (THEA) has built new highway lanes elevated above an existing highway and supported by pillars in the median strip of the existing road. Six-foot pillars support a freeway deck that is nearly 60 feet wide. The THEA striped the deck for three 12-foot lanes plus two 10-foot breakdown lanes and uses the three lanes for inbound traffic in the morning and outbound traffic in the afternoon. But the lanes could also be striped for four lanes, two in each direction.

Either way, tolls paid by the low-occupancy vehicles could pay most, if not all, of the costs of the elevated lanes, which cost less than \$10 million per lane mile. Moreover, studies have found that HOT lanes take significant numbers of vehicles off the existing lanes and thus all travelers benefit even if they do not pay to use the HOT lanes.

Rail lines with heavy-rail capacities may be the only way of bringing large numbers of workers into downtowns that are densely packed with hundreds of thousands of jobs. Decentralization, however, has reduced the number of such downtowns in the developed world to a relative handful, while increasing auto ownership in developing nations is likely to produce the same decentralization of jobs. In any case, building high-cost rail lines with light-rail capacities to such downtowns will do little to relieve congestion or slow decentralization.

Buses on HOT lanes and downtown streets with staggered bus stops can thus serve just about any urban area as well as rail transit.

The exceptions would be urban areas with extremely high numbers of downtown workers, most of who travel to work by transit. In the United States, New York, with nearly 2.0 million jobs in middle and lower Manhattan, certainly qualifies. Three other urban areas with many downtown jobs are Chicago (about 500,000), Washington (about 380,000), and San Francisco (about 300,000).¹⁰

The notable thing about those cities is that they already have rail transit. Without rail transit, New York simply could not have that many jobs downtown, and Chicago, Washington, and San Francisco probably wouldn't either. Boston, with about 250,000 downtown jobs, and Philadelphia, with 240,000, probably could be adequately served by buses if they did not already have rail transit. Atlanta, Denver, Houston, Los Angeles, and Seattle all have between 100,000 and 200,000 downtown jobs and could adequately be served by buses. Indeed, until recently, transit in most of these cities consisted exclusively of buses. For that matter, between 1962 and 1976, downtown Washington was exclusively served by bus transit.

So there is little reason to consider it necessary or beneficial to build expensive rail transit lines into the downtowns of cities such as Minneapolis (just under 100,000 jobs), Austin (72,000), Dallas (70,000), Charlotte (63,000), or Honolulu (52,000). Buses can adequately serve those commuters, especially considering that the majority of commuters to those downtowns do not even ride transit.¹¹

TRANSIT CONSTRUCTION COSTS

In the 1970s, Atlanta, San Francisco, and Washington built new heavy-rail lines at costs of \$80 million to well over \$100 million per mile (in today's dollars).¹² Each of the lines suffered massive cost overruns and failed to attract even half as many riders as proponents had predicted.¹³ So when, in 1981, San Diego opened a new ground-level, 13.5-mile light-rail line for a mere \$86 million—just \$17 million per mile in today's money—many cities took note and began planning light-rail systems.¹⁴

San Diego used an existing rail line for most of its new light-rail line, greatly reducing construction and right-of-way costs. It also built the line without federal support, which officials said saved money by avoiding several onerous federal requirements. So when other cities began building light rail from scratch with federal funds, costs were much higher than in San Diego. Yet few people questioned whether such high-cost transit made sense, even though buses could carry more people on existing infrastructure at a far lower cost.

Table 3 shows current costs per mile of light- and heavy-rail lines that are recommended for funding in the Federal Transit Administration's 2013 *New Starts Report*. As the table shows, light-rail lines built largely at ground level cost an average of \$109 million per mile, with costs ranging from \$51 million to \$168 million per mile. Heavy-rail lines cost an average of four times as much per mile. Even deleting New York's ultra-expensive Second Avenue Subway from the list, the remaining heavy-rail lines cost an average of \$340 million per mile—more than three times the cost of the average light-rail line. The least-expensive heavy-rail line costs almost 30 percent more per mile as the most-expensive light-rail line (which includes the cost of an expensive river crossing), while it was twice the cost of the average light-rail and four times the cost of the lowest-cost light-rail line.

HIGH-COST, LOW-CAPACITY TRANSIT

The remarkable thing about the list of projects in Table 3 is the presence of several lines that appear to be hybrids of light- and heavy-rail transit. Those lines are entirely grade-separated from streets, yet they use light-rail cars or similar trains of cars on short platforms, thus combining the high costs of heavy rail with the low capacities of light rail. San Francisco and Los Angeles are building short subways for light-rail lines that otherwise operate at street level; local transit agencies say the subways are needed to resolve bottlenecks in their rail systems.

Seattle, however, is building an entire light-rail line underground from the University of Washington to downtown Seattle. When completed in 2016, the line is expected to cost \$628 million per mile, yet it will not carry any more people per hour than San Diego's original 1981 light-rail line that cost \$17 million per mile. The total cost of the 3.1-mile subway would be enough to build almost 200 miles of elevated busways at \$10 million per lane mile. Seattle's first light-rail line, which opened in 2007, was also completely separated from streets, costing \$175 million per mile (nearly \$200 million per mile in today's dollars).¹⁵

Honolulu is also building a high-cost, low-capacity rail line. The 20-mile line is expected to cost nearly \$250 million per mile, yet it will be designed to use four-car trains manufactured by an Italian company named Ansaldo. Each car is shorter than a standard light-rail car, so an entire train is only 256 feet long, or less than a three-car light-rail train. A four-car train will have 128 seats and is rated to carry 508 standees, although 300 or so is more realistic. Thus, each train will move about 450 people.

The manufacturer claims the system can move 40 trains per hour, for a total throughput of 18,000 people per hour. However, a similar system installed in Copenhagen runs no more than 30 trains per hour, for a capacity of 13,500 people per hour.

THE MUMBAI MONORAIL. The trend to high-cost, low-capacity rail is growing all over the world. For example, in February 2014, Mumbai, India, opened the first 12.1 miles of a planned 84-mile monorail line. The first line cost about \$500 million¹⁶ (adjusting for purchasing power parity increases the cost to \$1.25 billion¹⁷). Slightly more than \$100 million per mile might seem inexpensive by American standards, but it is a very high cost by Indian standards.

The Mumbai urban area has about 18 million people packed more than 15 times as densely as New York City, making it one of the few places in the world where rail transit may make sense.¹⁸ But the government rates the Mumbai Monorail as being capable of car-

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Table 3
Costs per Mile of Planned or Under-Construction Rail Lines

	Rail Line	Miles	Cost (\$ millions)	Cost per Mile (\$ millions)
<i>Heavy Rail</i>				
New York	Second Avenue	2.3	4,887	2,125
Los Angeles	Westside	8.9	5,129	576
San Jose	BART	10.2	2,218	217
Washington	Silver	11.7	3,143	269
Total/Average		33.1	16,022	465
<i>Light Rail Built Mostly at Ground Level</i>				
Phoenix	Central Mesa	3.1	190	61
Sacramento	South	4.3	262	61
San Diego	Mid-Coast	10.9	1,596	146
Baltimore	Red	14.5	2,219	153
Washington	Purple	16.3	1,926	118
Minneapolis	Southwest	15.8	1,221	77
St. Paul	Central	9.8	957	98
Charlotte	Blue	9.3	989	106
Portland	Milwaukee	7.3	1,229	168
Dallas	NW/SE	21.0	1,406	67
Houston	North	5.3	756	143
Houston	Southeast	6.7	823	125
Salt Lake	Draper	3.8	194	51
Total/Average		139.2	15,228	109
<i>Underground Low-Capacity Rail</i>				
Los Angeles	Regional Connector	1.9	1,353	707
San Francisco	Third Street	1.7	1,578	928
Seattle	University	3.1	1,948	628
Total/Average		6.7	4,869	727
<i>Elevated Low-Capacity Rail</i>				
Honolulu	Transit Corridor	20.1	4,879	243

Source: 2013 New Starts Report, Federal Transit Administration, 2012.

rying just 7,500 people per hour, which Table 1 shows is at the low end of train capacities. To add insult to injury, the trains will operate at speeds averaging less than 20 miles per hour.¹⁹

Mumbai Monorail trains are four short cars capable of carrying a total of 562 people (just 72 of them seated) at crush capacity.²⁰ The 7,500 people per hour capacity would be reached by running trains every 4.5 minutes. In actual practice, trains are scheduled every 15 minutes, for a maximum throughput of fewer than 2,250 people per hour. Even if frequencies could be increased to every 3 minutes, which is the minimum safe headway, the trains could move no more than 11,240 people per hour. As shown in Table 1, single-decker buses on city streets can move a third more people than the monorail's rated capacity of 7,500 people per hour, and double-deckers can move well over twice as many people per hour.

When the monorail opened, press reports made it clear that "the monorail hadn't offered the zippy, easy ride people thought it would." The trains' low capacities resulted in hour-long lines, overfilled cars, and shouting security guards.²¹ After opening day, ridership declined to just 15,000 people per day, well short of the systems supposed capacity of 125,000 people per day.²²

Fares currently cover less than 30 percent of operating costs and the line is losing about \$250,000 (or, after adjusting for purchasing power parity, \$625,000) per month. By comparison, Brihanmumbai Electricity Supply and Transport is a government-owned bus operator whose fares cover nearly 90 percent of costs, making up the difference with advertising revenues and rents and thereby operating without any taxpayer subsidies.²³

The Mumbai Metropolitan Regional Development Authority says that "bus services operate in crowded and narrow roads with very low average speed," and that "buses also add to traffic congestion." It adds that monorail "can easily be implemented" in places where bus-rapid transit could not fit.²⁴ But the pillars supporting elevated monorail lines effectively occupy one lane of traffic, which means that a

lane that could contribute to the movement of more than 10,000 people per hour by bus is instead dedicated to a monorail moving a tiny fraction of that number.

PANAMA CITY METRO. Opened on April 5, 2014, the Panama City Metro is the first of what Panama President Ricardo Martinelli hopes will be several metro lines aimed at improving the "quality of life" in Panama.²⁵ Built as a subway in the inner city and an elevated line elsewhere, the first 8.5-mile segment cost nearly \$1.9 billion, or \$224 million per mile. That is extraordinarily expensive, especially considering that Panama's purchasing-power parity is only 60 percent of the United States', which makes the true cost of the line more than \$370 million per mile.

Panama City has fewer than a million people, and its broader metropolitan area is less than 1.3 million, so it is not comparable to Mumbai, New York, or other large urban areas with extensive rail transit systems. While the metropolitan area is not particularly dense, the central city is, being the location for 373,000 jobs.²⁶ This is more than the downtowns of all but the three largest American urban areas (New York, Chicago, and Washington), but such job densities are typical in developing nations that have low auto ownership rates.²⁷

The Panama City rail plan is predicated on projections that downtown jobs will increase by nearly 150 percent by 2035.²⁸ However, this is extremely unlikely, as growing auto ownership is likely to lead instead to decentralization of jobs and housing, just as it has in the rest of the developed world.

In 2010, Panama residents owned about 132 cars per thousand people, well under the U.S. rate of about 800 per thousand residents. However, Panama's auto ownership rate is growing at about 4 percent per year.²⁹ At that rate, car ownership will double before 2030.

Increased car ownership invariably leads to decentralization of jobs and population. The only cities that successfully avoided this were in Soviet nations that imposed draconian policies that kept a majority of urban residents in poverty. When the Soviet governments fell,

“When the 20-mph Mumbai monorail opened, press reports made it clear the monorail had not provided passengers with the quick and easy ride they had expected.”

“Panama’s heavy investment in rail transit at a time when irreversible forces will lead to declining transit ridership is like investing in manual typewriters as microcomputers became popular.”

large numbers of people purchased cars and moved into decentralized areas, and jobs decentralized as well.

Increased auto ownership is also associated with declining or, at best, stagnant transit ridership. Panama had about the same auto ownership rate—132 cars per thousand people—in 2010 as the United States had in 1925. Transit ridership in the United States peaked at 17.3 billion trips 1926 and (except for the war years) has declined or been stagnant since, currently averaging around 10 billion trips per year. Considering population growth, per capita transit rides declined from 278 per year in 1923 to about 40 per year today.³⁰

Panama’s current auto ownership rate is similar to that found in many Western European nations in 1960, when France had 158 cars per thousand people, Great Britain had 137, Germany 73, and Spain a mere 14—compared with more than 400 in the United States. By 2000, auto ownership rates in all those European countries had gone far beyond the United States’ 1960 levels: France was 576, Great Britain 515, Germany 586, and Spain 564.³¹

Meanwhile, transit ridership in most major European cities was stagnant or declining. London trips fell from 3.5 billion per year in 1960 to 2.5 billion in 1990; Hamburg from 615 million to 563 million; Brussels from 339 million to 251 million; and Copenhagen from 311 million to 280 million. While Paris transit ridership grew from 2.5 billion to 3.2 billion, that was due solely to population growth; per capita transit trips in 1990 were the same as in 1960.³² By 2006, the average resident of Western Europe (the nations commonly referred to as the EU-15) traveled less than 100 miles per year by trams and metros, compared with 6,500 miles per year by automobile.³³

It appears, then, that Panama is investing heavily in rail transit at a time when irreversible forces will lead to declining transit ridership no matter what kind of transit is offered. That is like investing in manual typewriters as microcomputers became popular or investing in telegraphs when cell phone use was growing.

Although job decentralization is likely in

Panama City’s future, a high-capacity rail transit system could slow that decentralization just as the New York City subway system has maintained that city’s high-density job core. However, Panama City’s Metro is far from a high-capacity system. Instead, the city plans to operate trains made up of three 75-foot-long cars every 3.5 minutes. With each train capable of carrying about 600 people, the system will be able to move fewer than 10,300 people per hour.

The government argues that Panama City streets are too narrow to allow for high-frequency bus service. As noted above, however, only two street lanes—a parking lane and a passing lane—are needed to support high-frequency bus service. It would almost certainly cost far less than \$1.9 billion to modify a few streets to allow for such service, an alternative the government never examined when it decided to build the Metro rail line.

The platforms built at each station are 325 feet long, which means the government could run trains with as many as five cars. The manufacturer also says that frequencies could be increased to one train every 1.5 minutes, but that would probably require spending more money on more advanced signaling. Five-car trains at that frequency would move up to about 25,000 people per hour, which is more than double-decker buses on a city street but far less than buses on elevated highways. Rebuilding platforms to allow even longer trains would be extremely expensive, especially in the case of the eight underground stations.

The railcars in the Panama City Metro system are semi-permanently coupled together, which means it would not be feasible to add or subtract cars on a daily basis to accommodate peak and off-peak travel periods. As a result, if Panama City Metro ever gets to the point of running five-car trains, it would run them all day long, meaning they would be nearly empty most of the day. That would put extra wear and tear on the cars and require more energy to move the longer trains.

In short, Panama has constructed a low-capacity transit system that could optionally be increased to a moderate-capacity system. But

that option may never be exercised as growing incomes and auto ownership rates are likely to decentralize the urban core, removing the need for moderate- to high-capacity systems. To the extent that improved transit service is needed, it would be better provided by building elevated bus or high-occupancy vehicle lanes along major corridors outside of central Panama City and turning several central city streets into high-frequency bus corridors. Instead of carrying a relatively small number of people to work, this solution would relieve congestion for far more people at a far lower cost.

OTHER LATIN AMERICAN CITIES. Prodded by the sales representatives of European railcar manufacturers and rail contractors, the construction of new high-cost, low-capacity rail systems seems to be sweeping across Latin American cities. As shown in Table 3, at least four cities are opening their first new high-cost, low-capacity rail lines in 2014, and several more—including Lima, Peru, and Santo Domingo, Dominican Republic—are expanding existing systems.

Several Latin American cities, including Mexico City; Sao Paulo, Brazil; and Caracas, Venezuela, have true heavy-rail systems with frequent operation of trains that are six- to nine-cars long. One measure of the productivity of those systems is the daily number of people who board a train at each station or per mile.³⁴ As shown in Table 4, many of the true heavy-rail systems in Latin America attract 20,000 to nearly 40,000 daily riders per station and 23,000 to 65,000 riders per mile.

By comparison, none of Latin America's high-cost, low-capacity rail systems carry as many as 12,000 daily riders per station or per mile. The systems cost as much or more to build as the true heavy-rail systems, yet their productivities are more in line with light-rail systems that cost much less to build.

Many Latin American lines were or are being built by various European construction companies. For example, the lead company building the Panama City Metro is a Spanish company, Fomento de Construcciones y Contrats (FCC).³⁵ FCC and another Spanish company,

Grupo ACS, are the lead contractors building a \$5.4 billion extension of the Lima Metro.³⁶

European manufacturers also provide most of the railcars for Latin American rail transit lines. The lines in Brasilia, Brazil; Lima, Peru; Los Teques, Venezuela; Panama City, Panama; and Santo Domingo, Dominican Republic, for example, use cars made by Alstom, a French company. Others, including the new line in Fortaleza, Brazil, and the Lima Metro line that is now under construction, use railcars built by the Italian company Ansaldo.³⁷ Ansaldo is also building vehicles for the Honolulu rail line.³⁸ Naturally, all those companies lobby hard to see rail projects funded and built.

The World Bank is acting as an enabler for at least some rail projects in Latin America and other parts of the developing world. The bank provided a \$700 million loan for Lima to extend its high-cost, low-capacity Metro line that is being built by FCC and ACS.³⁹ It has also supported rail transit projects in Brazil, including Bele Horizonte, Fortaleza, Recife, and Salvador.⁴⁰ The bank is lending part of the funds to build an expensive, moderate-capacity (six-car) subway that is about to break ground in Quito, a medium-sized (1.6 million people) city in Ecuador that certainly does not need such an expensive rail line.⁴¹

Outside of Latin America, World Bank loans also helped fund the Mumbai Monorail.⁴² One of the justifications for World Bank loans to rail transit in China is that they will “support compact, transit-oriented urban development”—as if development in China is not already compact enough.⁴³ This suggests that the bank is applying the standards of American urban planners to places where they make even less sense than in the United States.

A HIDDEN COST OF RAIL

While the cost of constructing rail lines is often well publicized, rail proponents never acknowledge the future costs of maintaining rail lines. Instead, they often emphasize that trains have lower operating costs per passenger than buses because one train driver can handle far

“The World Bank is acting as an enabler by providing loans to build at least some of the high-cost, low-capacity transit projects in development countries.”

Table 4
Latin American Rail Systems

	Year Opened	Route Miles	Stations	Daily Riders per Mile	Daily Riders per Station
<i>Heavy Rail</i>					
Buenos Aires, Argentina	1995	47.1	78	29,010	10,890
Caracas, Venezuela	1983	32.6	48	61,350	27,660
Medellin, Columbia	1995	19.9	34	23,386	13,330
Mexico City, Mexico	1969	140.7	195	32,803	22,540
Rio de Janeiro, Brazil	1913	29.3	35	43,137	31,430
Santiago, Chile	1975	64	108	35,938	16,460
Sao Paulo, Brazil	1974	46.1	64	65,054	37,550
<i>Light Rail</i>					
Guadalajara, Mexico	1989	14.9	29	16,107	8,280
Mendoza, Argentina	2012	7.8	26	n.a.	n.a.
Mexico City, Mexico	1986	8	18	7,192	3,200
Monterrey, Mexico	1991	19.9	31	22,417	13,870
Valencia, Venezuela	2006	6.2	7	15,897	6,730
Valparaiso, Chile	2005	26.7	20	1,765	2,360
<i>High-Cost, Low-Capacity Rail</i>					
Bele Horizonte, Brazil	1986	17.5	19	8,989	8,280
Brasilia, Brazil	2001	26.3	24	5,703	6,250
Fortaleza, Brazil	2014	26.7	28	n.a.	n.a.
Lima, Peru	1990	13.4	16	10,448	8,220
Los Teques, Venezuela	2006	6.3	3	5,653	11,870
Maceió, Brazil	2014	19.9	n.a.	n.a.	n.a.
Panama City, Panama	2014	8.5	12	n.a.	n.a.
Porto Alegre, Brazil	1986	24.2	19	7,025	8,940
Recife, Brazil	1985	27.5	30	10,364	7,270
Salvador, Brazil	2014	18.6	19	n.a.	n.a.
San Juan, Puerto Rico	2006	6.3	16	3,794	1,890
Santo Domingo, Dominican Republic	2008	17	30	8,859	2,820
Teresina, Brazil	1989	9	9	1,333	1,310

Source: "List of Latin American Rail Transit Systems by Ridership," Wikipedia, 2014, tinyurl.com/m6ayyy3.

more passengers than one bus driver. The attraction of lower operating costs is further enhanced by several new rail systems, such as the Mumbai Monorail and Panama City Metro, which are entirely automated and use no operators.

Yet rails cost far more to maintain than roads, and while the cost of roads is shared between autos, trucks, and buses, most rail transit lines are dedicated exclusively to the few rail riders. Annual maintenance costs start out low, but grow over time as rail equipment and infrastructure wear out.

Most rail infrastructure wears out after about 30 years, and the cost of replacing or rehabilitating such worn-out systems is often nearly as great as the original cost of construction. Structures, signals, electrical facilities, and track work have a design-life of 30 years; railcars just 25 years.⁴⁴ Transit agencies rarely take those costs into account when planning new rail lines.

Although there is no need to rebore subway tunnels, replacing or rehabilitating tracks and other infrastructure without disrupting service is very costly. As of 2000, the Washington Metrorail system had cost \$8.8 billion to build (about \$18 billion after adjusting for inflation).⁴⁵ In 2002, the agency announced that it needed \$12.2 billion to rehabilitate older portions of the system, the oldest of which were just 26 years old.⁴⁶ None of that money was available, leading system officials to defer the work, which in turn has resulted in frequent breakdowns and service disruptions.⁴⁷

Metrorail's problems came to a head in 2009, when lack of maintenance led to a failure of signaling systems and a moving train collided with a stationary train, killing nine people. Although each Metrorail train has an operator, the trains were actually computer controlled; the operator's main job was to open and close the doors and start the train when doors were closed. The computers determined train speeds, stopped them in stations, and prevented collisions. After the accident, Metrorail managers announced that signals were malfunctioning throughout the rail system. Since then, trains have been driven without computer assistance, forcing a reduc-

tion in frequencies and less comfortable rides as operators inexpertly apply brakes to stop trains in stations.⁴⁸

The Washington Metrorail system is not the only rail system in the United States suffering from a lack of maintenance. The Chicago Transit Authority system is "on the verge of collapse" and trains in some parts of the system must slow to less than 10 kilometers per hour for safety reasons.⁴⁹ A recent crash of a Chicago train at O'Hare Airport resulted when the operator fell asleep, but officials added that at least two backup systems that should have stopped the train also failed.⁵⁰

Boston's transit agency "can't even pay for repairs that are vital to public safety," says a report that was commissioned by the Massachusetts Office of the Governor in 2009. Moreover, the maintenance backlog was growing because the system was deteriorating faster than the agency's maintenance budget could repair it.⁵¹ In 2010, the Federal Transit Administration estimated that rail transit systems in the United States faced a \$59 billion maintenance backlog and, as in the case of Boston, the national backlog was growing faster than it was being fixed.⁵²

Such maintenance shortfalls are almost guaranteed in a transport system that is not funded entirely out of user fees. Politicians love to support grandiose capital projects, especially if they can get some other level of government to fund them. That allows the politicians to bask in glory when the projects open for business. But they routinely underfund maintenance, as there is little political benefit in replacing a worn-out rail, brake shoe, or electrical signal, while accidents, delays, and other problems can always be blamed on someone else.

LOW-CAPACITY RAIL AND URBAN DEVELOPMENT

Rail advocates often claim that rail will attract new development. That may be true for heavily used heavy-rail lines, but low-capacity rail lines will, by definition, be unable to carry enough people to alter development patterns.

“Rails cost far more to maintain than roads, and maintenance shortfalls are almost guaranteed in a transport system that is not funded entirely out of user fees.”

“Urban areas that spent more on transit capital improvements in the 1990s tended to grow slower in the 2000s than areas that spent less on transit.”

Even the most heavily used rail transit systems do not increase overall urban growth. New transportation projects stimulate growth by providing transportation that is faster, less expensive, or more convenient than existing transportation. Rail transit is almost always slower, more expensive, and less convenient than driving, so it won't stimulate growth. More likely, the high cost of rail transit will reduce growth by adding to a region's tax burden.

This can be demonstrated by comparing per capita transit expenditures in the 1990s with population growth in the 2000s of the nation's leading urbanized areas. For the nation's 64 largest urban areas, spending more on transit capital improvements in the 1990s was negatively correlated with population growth in the 2000s (correlation coefficient of -0.23), while spending more on transit operations in the 1990s was even more negatively correlated with population growth in the 2000s (correlation coefficient of -0.30).⁵³ Transit is not the only factor influencing urban growth, but it appears the added tax burden of spending more on transit has a negative effect on growth that offsets whatever benefits result from having a more expensive transit system.

A Federal Transit Administration-funded report by University of California planning professor Robert Cervero and Parsons Brinckerhoff consultant Samuel Seskin found that “urban rail transit investments rarely ‘create’ new growth.” At best, they may “redistribute growth that would have taken place without the investment.” The main redistribution was from the suburbs to downtown, which explains why downtown property owners tend to strongly support rail transit projects.⁵⁴

Even if such redistribution of growth is considered desirable, it will only result from transportation systems that receive heavy use. Several studies have found that low-capacity rail systems do not carry enough people to alter development patterns unless new development patterns are supported by additional subsidies such as tax-increment financing.⁵⁵

RAIL'S POLITICAL ADVANTAGE. Except in very large, high-density urban areas, the only thing

rail transit can do that buses cannot is cost lots of money. That extraordinary spending on obsolete transit technology allows government to pick winners and losers. The winners are naturally very grateful for their gains and lobby hard to promote rail transit.

The contractors who engineer, design, and build rail lines and railcars are winners. The taxpayers who pay for them are losers. The property owners whose land is next to high-use rail stations are winners; all other property owners are losers. The people who happen to both live and work next to a rail station, or who are willing to adjust their lives to do so, are winners—and systems with low capacities can only have a few such winners. Everyone else loses because resources that could have improved transportation for everyone were spent on a few people.

Ironically, the low capacity of many rail systems ends up being used to support the expansion of such systems. Politicians will claim that crowded railcars prove that a new line is a success, so more lines should be built. In fact, all crowding proves is that planners chose the wrong technology for moving people.

CONCLUSION

Many people have questioned the effectiveness of new rail transit systems when autos and buses are potentially faster, far more convenient, and most important, far less expensive than rails. In response, rail advocates often claim that special circumstances require high-capacity trains that can move more people in less space than cars or buses on highways and streets.

There may in fact be some places where rails can move people more cost-effectively than buses. But this argument falls apart when applied to high-cost, low-capacity rail systems. Since many rail advocates continue to support such systems, the question becomes where to draw the line between a rail project that makes sense and one that does not. If rail advocates believe that it makes sense to spend (in the case of Seattle's light-rail subway) \$628 million

a mile building a rail line that cannot move as many people as buses, then perhaps all of their claims are equally questionable.

If \$628 million per mile for a low-capacity rail line makes no sense, under what circumstances would it make sense? Would \$628 million a mile be worthwhile if it produced a high-capacity rail system? Is \$200 million per mile—the cost of Seattle’s previous light-rail line—worthwhile for a low-capacity rail line? Or is \$109 million per mile—the average cost of light-rail lines planned or under construction in the United States today—worthwhile? Was the \$17-million-per-mile cost of San Diego’s 1981 light-rail line worthwhile considering that it replaced a *profitable* bus service?

One way to answer those questions is to ask whether user fees will cover the costs of operating and maintaining, if not building, the rail lines. But even the New York City subway does not collect enough fares to cover half the costs of operations and maintenance, much less its construction.⁵⁶ Few other light- or heavy-rail systems in America come close to that, and most rail advocates reject profitability as an appropriate criterion for deciding whether to build new rail projects.

A second way to answer those questions is to look at *cost-effectiveness*—that is, to determine if rail transit is the least-cost way of achieving the benefits it supposedly produces. Especially in the case of high-cost, low-capacity rail systems, but also in the case of most light-rail and even many heavy-rail projects, buses are likely to be far more cost-effective than trains. Congress requires transit agencies to evaluate cost-effectiveness as a part of the process of seeking federal funding for new rail transit projects. However, the Obama administration has rewritten the already-weak cost-effectiveness rules to allow agencies to avoid considering buses as an alternative to rails when they evaluate cost-effectiveness—meaning they won’t evaluate it at all.⁵⁷

If rail transit advocates aren’t willing to consider either profitability or cost-effectiveness as criteria for judging rail projects, then they effectively have no transportation criteria. In-

stead, they appear to support rail transit—no matter how high the cost and how low the capacity—for entirely different reasons than its value for transportation.

As in the “Marge vs. the Monorail” episode from *The Simpsons*, one major selling point of rail transit seems to be that the cities need to keep up with their peers in a totally artificial competition to be a “world-class city,” whatever that is.⁵⁸ Just as automobile salespeople use peer pressure and envy to entice drivers into buying cars that are more expensive than they really need, cities end up building transit systems that are more expensive than they need.

Automobile ads imply that if you buy an expensive car, your family will love you, your friends will respect and envy you, and you will be more attractive to the opposite sex. Rail advocates argue that if city officials agree to build expensive rail lines, their residents will vote for them, other cities will respect and envy them, and their cities will be more attractive to new businesses and jobs.

All too often the reality is that the high cost of rail lines forces cities to cut other urban services while raising taxes, which in turn leads businesses to expand elsewhere. The difference between private auto marketing and public-transit lobbying is that not every car buyer is susceptible to this sales technique, and those who are susceptible will pay the cost themselves, while city and transit officials eager to build expensive rail lines can pass the cost onto unwilling taxpayers.

Aside from politicians, rail supporters have a variety of reasons for ignoring the high cost and low capacity of many rail projects. Rail contractors and railcar manufacturers are simply interested in profitable sales. Planners and some environmentalists are interested in social engineering, hoping that rebuilding cities to high densities and with pre-automobile transport systems will lead people to drive less. Some auto drivers are misled into supporting rail transit in the hope that it will get enough other people off the road to eliminate the congestion they face in their daily commutes, when in fact few new rail lines have a significant impact on traffic.

“All too often the reality is that the high cost of new rail lines forces cities to cut other urban services while raising taxes, which in turn leads businesses to expand elsewhere.”

In the end, building new rail transit lines, at least in the Americas, is almost always a mistake. Putting the same amount of money to use in relieving congestion for everyone by undertaking such projects as coordinating traffic signals and building high-occupancy toll lanes adjacent to crowded highways would produce far greater benefits. Alternatively, providing the same transit capacity with buses instead of trains would cost far less.

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