Chapter 28

Urban Public Transportation

Urban Public Transportation

Next we consider urban public transportation in a continuation of our treatment of traveler transportation. We will focus on United States public transportation, although many of the fundamental concepts we will discuss will have international applications.

LOS Variables for Urban Travelers

To begin, we review our level-of-service variables for travelers. Travel time, reliability, cost, waiting time, comfort, safety, and security are all examples of level-of-service variables that are relevant to any traveler transportation mode. We have characterized the automobile mode, with which public transportation is in direct competition, as very convenient. One rides in the comfort of a climate-controlled automobile listening to the stereo; the concept of waiting time for service is nonexistent—one goes when one wants to go. The cost of using an automobile may even be low, especially if one does not consider the capital cost of the vehicle, as people have a tendency not to—"I have to own the automobile anyway."

How Public Transportation Measures Up

Public transportation tends to falter on several of these dimensions. For example, comfort in a crowded rush-hour subway car is not high; one has to wait for service depending on the service frequency of the mode one is considering. Travel time may be greater or less than that of an automobile, depending on the circumstances.

A hard-to-quantify level-of-service variable is self-image—how one feels about oneself as a function of the mode you use. In much of Western society there is a very positive self-image associated with driving and a much less positive self-image associated with taking public transportation.

Security is another concern. For example, crime in the New York City subways gets a very high profile in the *New York Times*, although recent rashes of car-jacking make automobile transportation subject to some security concerns as well.

Availability of service is a question; some urban subway systems shut down during the late night/early morning hours. The Paris Metro does exactly that. Many urban bus services do not run during late evening hours. This makes the lives of night workers very difficult if they need to depend on public transportation.

Safety is another level-of-service variable. Again, while auto, judging by aggregate statistics, is a less safe mode than transit, people tend to discount that statistical difference, feeling that they, in control of their own vehicle, can drive safely. Travelers tend to focus on the occasional major transit accidents as evidence of a lack of safety in public transportation modes.

Accessibility to Service

Of particular importance is the question of accessibility to service. Earlier, we considered the Federal Transit Administration's (FTA) perspective on their difficulty in serving the very spread-out land-use patterns developed in suburban America. This is a critical concern. With urban sprawl, population densities are such that viable public transportation, which depends on consolidating the demands of many users to provide economies-of-scale, is virtually unachievable. So the development of public transportation is very much impeded by the urban structure that has developed in the United States in the post-World War II era.

Accessibility to public transportation service takes on another dimension, if we consider an intermodal car-public transportation journey. Commuters who would like to park-and-ride are constrained by parking availability in parking lots at stations. Drivers complain that if they arrive at the parking lot after 8:00 a.m., the parking lot is full. An option is satellite bus services that would circulate through the suburban neighborhoods, picking up people and bringing them to the suburban stations by van, as a mechanism for overcoming the parking constraint.

This illustrates the systemic nature of transportation. One has to consider more than the simple line-haul characteristics of, say, the rail system, which in itself may provide excellent service. To think about one's customers' needs more broadly, one has to recognize that the customer has to get to the system. And in this instance, limitations on parking lot size is preventing that from happening.

Types of Urban Public Transportation Service

Let's talk about the various services that we include in urban public transportation.

Conventional Bus

We start with the conventional bus. These services typically operate on fixed service routes, with stops specified. A typical urban bus would have a total capacity of about 60 passengers. Technologies would include internal combustion engines, diesel engines, and what are called trolley buses—buses that run on electric power.

Para-Transit

A second service is para-transit. Para-transit is a catch-all phrase for nonconventional services, often using smaller or specially-equipped vehicles. For example, para-transit services would include special services for the elderly and handicapped. These services would typically pick up and deliver people from their home to some destination like an elder-care facility.

In some cities, there are less formal modes of transportation that can be characterized as para-transit. For example, in San Juan, Puerto Rico, there is a system of públicos. These are van-type vehicles, often operated by an individual entrepreneur, which do not go on a fixed route but rather pick up passengers and deliver them to their destination, informally providing ride-sharing among groups of passengers with disparate origins and destinations.

Públicos often provide "one-to-many" service. A público could wait outside of a transit station and pick up travelers heading for the same general area of the city. The público driver would then travel in some efficient manner to provide a reasonable travel time at a reasonable cost. In some cities, these services are called "jitneys." Sometimes they run on semi-fixed routes, deviating from the routes occasionally. Often, they are totally free-form.

Demand-Responsive Service

There are demand-responsive urban transportation systems. A traveler would call for service, perhaps from his or her home or office, indicating the origin and destination, and a dispatcher, perhaps assisted by a computerized system, would route a vehicle dynamically to pick up and deliver the passengers in an effective manner. This is ride-sharing; the hope is that these services achieve some economies-of-scale through shared capacity while providing a "taxi-like" level-of-service. Indeed, we can consider conventional taxi service as a public transportation service.

Rail Systems

So far, we have introduced highway-oriented public transportation modes. Fixed-rail systems are important as well.

Subways

Large urban areas often have rail systems categorized into "heavy rail" and "light rail." The MBTA here in Boston, the MTA in New York City, the Washington Metro, and the CTA in Chicago are examples of major subway systems in the United States. These heavy rail systems, which are typically a combination of underground, grade-separated, and above-ground infrastructure, have the capability of transporting large numbers of people very efficiently along fixed corridors. Light systems often operate at grade and are lower-capacity and lower cost compared with heavy rail.

Some of our cities are virtually inconceivable without urban rail. New York City has been brought to its knees by subway strikes. Other cities like Los Angeles, a more automobile-oriented city, has functioned without a rail system for many years. Today the Los Angeles subway system is marginal, serving a very modest area of a quite spread-out metropolitan region.

It is worth noting that if one looks at total public transportation ridership in the United States, New York City represents half that total ridership. Talk about industry concentration! Half of public transportation ridership in the United States is in one urban area, in which perhaps 7% of the nation's population resides.

Commuter Rail

Also, we have commuter rail. These are typically trains from suburban areas into downtown. Commuter rail typically extends further into the suburbs than do urban metro systems. Cities like New York and Chicago are particularly dependent on these commuter rail services, with people often commuting distances in excess of forty miles to work downtown in these cities.

Intermodal Services

Another service type is intermodal, the conceptual equivalent of freight intermodalism. It has real relevance in the urban traveler domain. We have bus services serving as feeders to fixed rail systems. We have already introduced park-and-ride, with people driving to public transportation, parking their car, and taking the public transportation system into the urban area. There are any number of opportunities here. The key, as it was in freight, is proper coordination among the modes. The idea of intermodalism is to use the inherent advantages of various modes, but those inherent advantages can be quickly dissipated if the transfer between modes is poor. So coordination and careful scheduling is critical to success in intermodalism.

Public transportation has tried to redefine itself in recent years. Brian Clymer, who was the FTA administrator in the Bush administration (1988–1992), took the strong position that public transportation is everything that is *not* single-occupancy vehicle (SOV) automobile transportation. So he considered carpools, van pools, and the development of HOV lanes as an appropriate part of the transit domain. In our car- and highway-oriented society, that is a pragmatic position for a public transit administrator to take. Operate within the highway-dominated system as best one can to try and reduce SOV transportation.

Public Transportation Patronage

Figure 28.1 shows the trends in public transportation patronage since the beginning of the 20th century.

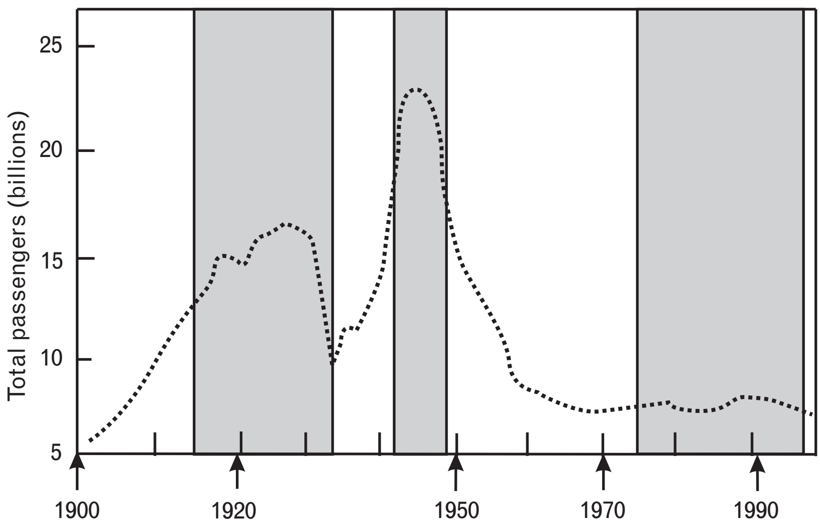


FIGURE 28.1 *Public transportation patronage in the United States (Source: APTA 1999 Transit Fact Book, American Public Transit Association, Washington, D.C., 1987).*

At the start of the twentieth century, passenger patronage was about 6 billion riders per year. To set this in time, the MBTA in Boston had been in operation for several years, as was the New York City subway system. Various kinds of streetcars and horse-drawn vehicles were part of the public transit fleet at that time.

In the next quarter century until 1925, the transit industry grew steadily to a peak of 18 billion passengers annually. This was a period of substantial urban growth in the United States. It represents a time in United States history when the nation shifted from an agrarian to a manufacturing economic base. People by the millions migrated from farms into urban areas for better paying manufacturing jobs. At the same time, automobile ownership was for only the richest in society. Public transportation was the only option for large numbers of people in urban areas.

Beginning in the late 1920s and into the 1930s, transit ridership dropped off precipitously, reflecting an economic depression of unprecedented proportions. People had no jobs; therefore there was no journey to work, and transit ridership reflected that. As the country came out of the depression in the mid-1930s, transit ridership grew again. And with United States participation in World War II, transit ridership grew substantially to a peak of 24 billion in 1945. Jobs were plentiful on the homefront and automobiles were again virtually unavailable because war-time manufacturing had turned to tanks and planes, not private automobiles. Tight fuel rationing held down automobile use as well.

However, with the end of World War II, pent-up economic demand, explicit government policies to develop the highway system, and the desire of many for a single-family home in the suburbs led to the urban land-use patterns that we discussed earlier. The 24 billion passengers carried in 1945 turned out to be the high watermark for public transportation in the twentieth century. Public transit use fell off precipitously beginning at that time and currently is at a level of about 10 billion passengers per year. This is modestly up from the bottom of the mid-1980s, but not significantly. So the current transit industry in the United States is about 40% the size of its post-war, 1945 peak, and unlikely, in the current environment, to grow significantly.

Importance of Bus Services

On a national scale, about two-thirds of the current transit patronage is carried by buses. For those of us who are large-metropolis- and rail-oriented, this comes as somewhat of a surprise. But when you think about it, the number of cities with subway systems is not large. Virtually all public transportation in cities of less than several million is by fixed-route bus and, even in cities like New York, a substantial fraction of riders go by bus.

Temporal Peaking and Its Implications

Peaking is of particular importance in urban public transportation. There is tremendous peaking in demand during the morning and afternoon rush hours, more so than the peaks that occur on the highway network. Transit ridership is dominated by the journey-to-work which causes this peaking phenomenon. While frequent service is the rule during the peak hour, vehicles are often very crowded, and passengers are not very comfortable.

Now in any kind of service operation, during the period of peak demand you require peak staffing. The problem in the transit industry is that those peaks occur on the order of eight hours apart. To have an adequate number of drivers on hand for both peaks would suggest that people would work a "split-shift." Simply put, this means they would work in the morning, go home during the middle of the day when the demand is low, and return for the afternoon peak. Of course, people tend not to like those kinds of shifts. For that and other reasons, absenteeism is a chronic problem on transit properties across the country.

Simply put, these kinds of jobs are not viewed as particularly desirable, given the stress of operating in rush-hour conditions, and the relatively low pay and status.

So, labor productivity is one of the key issues that transit managers face. And one could argue that this is a direct result of the strong peaking in the demand for public transportation.

Characteristics of the Public Transportation Industry: A Personal View

Let us proceed now to characterize the industry, recognizing this is the personal (and possibly biased) view of the author.

The public transportation industry is:

1. Financially marginal. The industry is heavily subsidized. The MBTA pays only about one-third of its operating costs from the farebox. This does not include investment costs for new vehicles or infrastructure. While all transportation is subsidized to some extent, the United States transit industry is more heavily subsidized than most other modes. This leads to a chronic under-investment in physical plant and chronic deferred maintenance of both vehicles and infrastructure.
2. Not very innovative. Adoption of new technologies by public transportation agencies is not aggressive. Now perhaps—maybe almost certainly—this can be attributed to their financial condition. But, whatever the reason, new technology tends not to be adopted very quickly.
3. Public-sector dominated. While there have been some recent attempts to privatize public transportation, particularly bus services, for the most part public transportation continues to be operated by government. In this milieu, salaries tend to be lower, and it is more difficult to attract first-rate people to manage these properties.
4. Subject to political pressure. As part of the public sector, there are political pressures on the industry that are substantial. Decisions on a variety of matters—operations, staffing—are often made on a political rather than a service and cost basis.

5. Subject to poor labor relations. These are endemic to the industry. Absenteeism in the public transportation industry is among the highest of any industry in the United States, public or private.

6. The victim of a public image problem. Public transportation is viewed as a low-service-quality, low-efficiency industry, taken usually only by captive riders—people who have no other option, such as automobile. Few boast about taking public transportation to work (outside of the academic world, of course).

7. Not especially active in market development. Marketing in public transportation is currently more a research area than it is an active part of management. Recently, market studies have been undertaken, aimed at identifying what travelers really think about public transportation and how services could be designed that would be attractive to them [1]. This is not a new idea in American business, but it has not been developed in any major way in public transportation organizations. Again, one could argue that this all derives from the financial woes of the industry.

8. Marginalized by low-density land-use patterns in United States cities. This dominant issue may well prove intractable.

The picture is bleak. While new technologies are helping many transportation industries, their deployment in public transportation is modest. Land-use patterns have developed that make public transit a less-than-useful mode in many urban areas. Political pressures are critical and the industry is chronically highly-subsidized and underfunded.

In this environment, it is a brave manager indeed who can push towards efficiency and effectiveness, but there are some out there in American industry. First-rank public transportation organizations exist in Houston, Texas; Portland, Oregon; Seattle, Washington, among others; and New York City, for all its woes, transports an extraordinary number of people to and from their jobs and other origins and destinations every day—perhaps not in the greatest comfort but from a throughput point of view, it is difficult to fault.

Putting aside this bleak picture, we now take a look at some modeling approaches to understanding some of these issues. (These approaches can be used for other modes as well.)

Life-Cycle Costing

We have talked about the financial woes of transit causing under-investment in infrastructure and vehicles and under-maintenance of vehicles and infrastructure as well. Let us use the idea of life-cycle costing to understand these issues. Figure 28.2 shows a flow of costs, both capital and maintenance, over time for a transportation infrastructure facility.

We invest at the beginning of a project with capital and then maintain it over a period of years. Here we show a flow of maintenance costs designated by M_n, which may vary from year to year. There is always a trade-off between capital and maintenance costs. High capital costs often lead to lower maintenance costs and vice versa.

In life-cycle costing, we use the concept of discounted cash flow, which incorporates the time value of money into an overall cost for a property.

$$DCF = C_C + \sum_{n=1}^{\infty} \frac{M_n}{(1+i)^n}$$

where C_C is the capital cost and i is an interest rate or "discount rate" that reflects the time value of money as well as a risk factor.

Keeping the discussion simple, we will not worry about the flow of "benefits" or "revenues" in this discussion.

Maintenance costs can be represented by the following equation:

Maintenance Costs = f(Quality of initial construction,
current state of infrastructure,
wear-and-tear caused by traffic)

Think of infrastructure as shown in Figure 28.3.

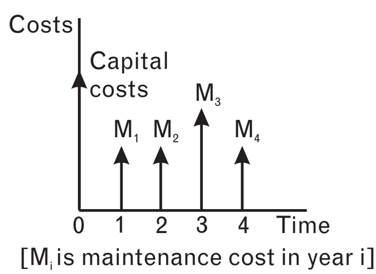


FIGURE 28.2
Life-cycle costs.

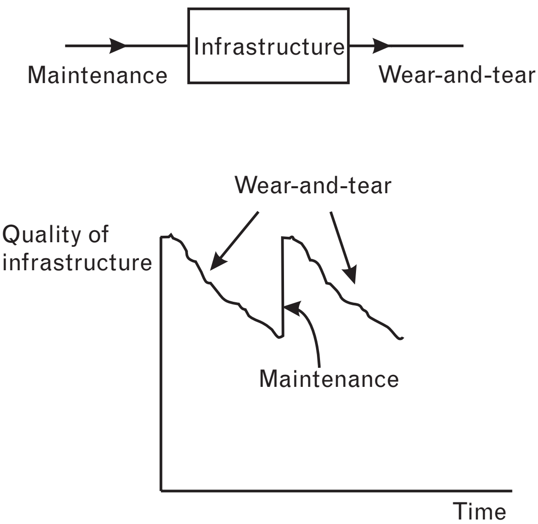


FIGURE 28.3
Infrastructure quality.

Wear-and-Tear and Maintenance

The quality of the infrastructure at any time is degraded by accumulated wear-and-tear caused by use—traffic—and improved by maintenance. So we plot quality of infrastructure as a function of time, as shown in Figure 28.3.

There are several factors in considering a maintenance strategy. First, the value of a dollar of maintenance expense is a function of the current quality of the infrastructure. If you have a well-maintained facility—it has a high dollar value—the benefits of one dollar of maintenance are higher than if one has a poorly maintained facility. This is shown in Figure 28.4. The benefit of $M of maintenance would slowly decrease with time, as shown in Figure 28.5.

The Problem with Deferred Maintenance

So delaying—or deferring—maintenance, which is a strategy often used in the stringent economic times characteristic of the transit industry, is a problem. If we delay maintenance, the "value" of the infrastructure goes down and the benefit of a maintenance dollar goes down as well.

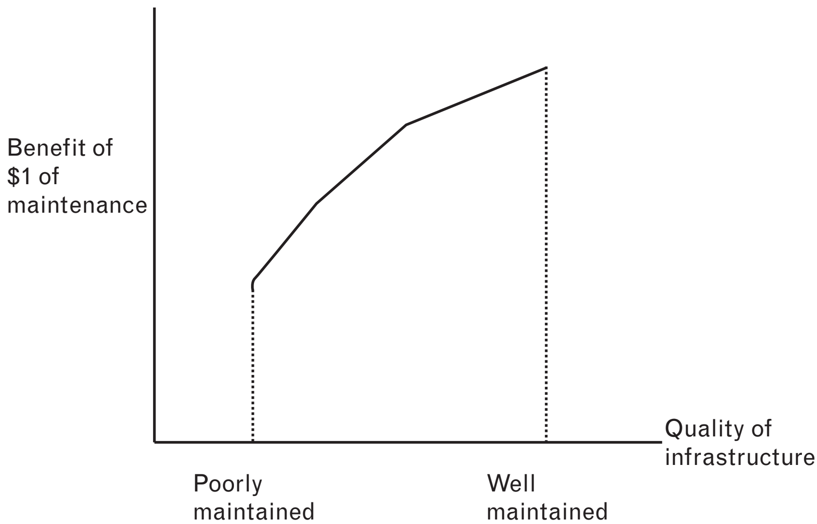


FIGURE 28.4 *Benefits of maintenance as a function of infrastructure quality.*

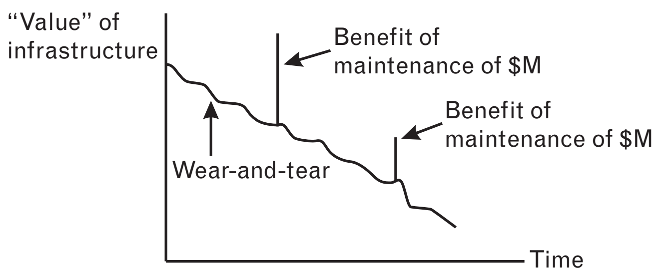
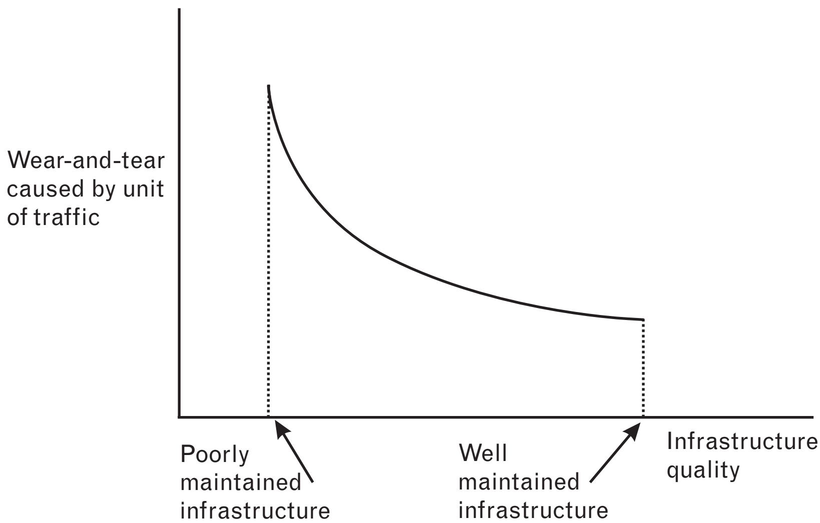


FIGURE 28.5 *The impact of delaying maintenance.*

However, it is even worse than that. There is empirical evidence to show that the amount of wear-and-tear caused by a unit amount of traffic increases as the "quality" or "value" of the infrastructure decreases. For example, for a fixed rail system, if you have a right-of-way in poor shape, the amount of wear-and-tear caused by a single train is greater than if you have infrastructure in good shape subject to that same train. (A right-of-way in poor shape also causes more wear-and-tear on the vehicle, also, but that is another story). This is illustrated in Figure 28.6.

So, if we delay or skimp on maintenance, the quality of our infrastructure goes down more quickly. We buy less for our maintenance dollar. Further, traffic causes more damage. More wear-and-tear is caused by a fixed amount of traffic.

Figure 28.6 *Wear-and-tear as a function of infrastructure quality.*

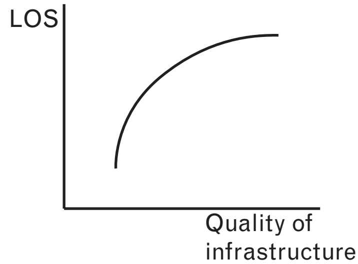


Quality of Infrastructure and LOS

But, it gets still worse. There is a relationship between the level-of-service as observed by customers and the quality of the infrastructure. As quality of infrastructure deteriorates, trains go more slowly—perhaps they derail—then the level-of-service deteriorates, as shown in Figure 28.7.

So, as the quality of our infrastructure deteriorates, level-of-service deteriorates, and considering the equilibrium framework, traffic volumes will deteriorate. So revenue goes down and there are even fewer dollars to spend to improve our infrastructure by counterbalancing the effects of wear-and-tear through maintenance.

Figure 28.7 *LOS as a function of quality of infrastructure.*



The Vicious Cycle

This is often and appropriately called "the vicious cycle." Once things start to get bad, it is very expensive to make them right again. This is true in many different kinds of systems. It has particular impact in the transit industry where money is always so chronically short and political pressures often dominate reasonable management decisions.

Service Design

We consider service design for public transportation. Service design includes routes, vehicles, frequency of service, hours of service, level and structure of fares, and supporting services, such as parking and station configuration. Service design will differ depending upon the technology being used. Clearly if one has a fixed rail system, the ability to change routes is much more limited than it is for an urban bus system.

Fare systems vary around the industry. For generations, the New York City subway system has had a flat fare system, with one fare regardless of distance traveled. Other systems, like the Washington Metro, have a fare structure in which one pays as a function of the distance traveled and also the time of day. More advanced technology is increasingly in use in transit services for collecting fares. The Washington Metro has had a fare card for many years, as has BART in San Francisco. And New York is deploying that technology as well. This enables fare structures to be more sophisticated than the simple flat fare system, and can include bulk discounts for frequent users.

An important consideration in fares is the extent to which they encourage intermodality. For many years, New York City had its infamous 2-fare zones in which travelers paid a fare to ride the bus, which took them to the subway, so they could then pay an additional fare for the subway ride. Many systems encourage intermodality by having an integrated fare system where one pays no additional fare or a modest additional fare for use of the second mode.

Network Structure

A very important service design question is that of network structure. In their excellent text, Gray and Hoel [2] discuss a number of different network structures for public transportation, including radial patterns, grid network, radial criss-cross, and trunklines with feeders.

The Vehicle Cycle

The vehicle cycle is a fundamental design element of transportation systems and public transportation is no exception. An important problem in transportation systems design is the sizing of a fleet—how many vehicles do we need to supply service at some service frequency on a particular route? Frequency is expressed in terms of the number of vehicles per hour on a particular route. From the point of view of the traveler we speak of headway, which is the time interval between consecutive vehicles. Frequency and headway are of course the inverse of one another.

The basic equation for sizing a fleet is as follows:

$$NVEH = \frac{VC}{HEADWAY}$$

where *NVEH* is number of vehicles in the fleet; *VC* is the vehicle cycle on this route—the time it takes the vehicle to traverse the entire route; and *HEADWAY* is the scheduled time between consecutive vehicles.

Alternatively,

$$NVEH = FREQUENCY \cdot VC$$

where *FREQUENCY* is the number of vehicles per unit of time passing a point on the route. Note this is identical to the calculation of the number of freight cars in the fleet in Chapter 16's section on Fleet Size Calculation.

A Simple Example

Suppose we have a route that goes from east to west and then returns from west to east, with the travel time being one hour in each direction, as shown in Figure 28.8. *VC* in this case is two hours.

Suppose we want a service frequency of four vehicles per hour. From the passenger's—our customer's—viewpoint, this means a

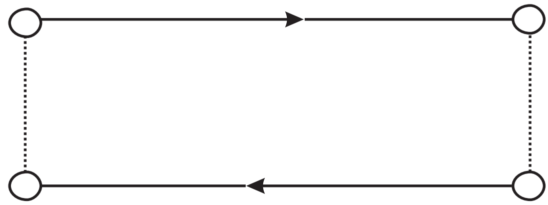


Figure 28.8
Vehicle cycle.

headway of 15 minutes or .25 hours. Using the above equation, the required number of vehicles would be eight.

How can you reduce the number of vehicles needed in this service? First, we could have less frequent buses running, say, at a headway of .5 hours rather than .25 hours. The number of vehicles required goes down to four.

Another method could be to shorten the vehicle cycle. Suppose we had fewer stops along the route and the vehicle cycle dropped from a total of 2 hours to 1.5 hours. In this case, the number of vehicles we would require would go down to six.

Of course, it is not as simple as all this. Given stochasticity and the propensity of such systems to get out of balance, we observe some interesting behavior in these systems.

Bus-Bunching: An Explanation

For example, one phenomena that has been much commented upon is bus-bunching. The traveler waits a long time for a bus to arrive and then the buses come in a convoy of two or three. Think about why this might happen.

Let us assume that people arrive uniformly over time at a bus stop. If the transportation service is frequent enough, people will not try to "catch" a particular bus, but will arrive uniformly. Figure 28.9 shows the uniform build-up of people at a particular bus stop.

We assume that people begin to arrive as soon as the previous bus departs and the number of people waiting at the stop builds up linearly over time. When the bus arrives, people depart from the bus and the people at the bus stop get on the bus. The amount of time the bus spends at the stop—the dwell-time—is proportional to the number of people getting on and off.

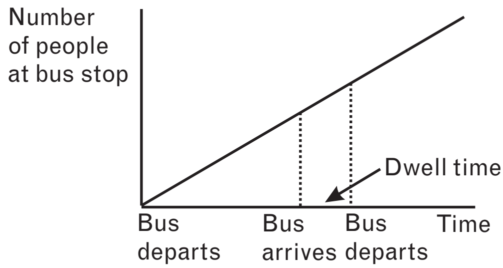


FIGURE 28.9 *Why buses bunch.*

Now let us suppose that a bus departs the terminal a few minutes earlier than it should have according to the schedule, which is designed to achieve uniform headways. What will happen now is that the interval between that bus and the following bus will be greater than normal. There will be more people waiting for the second bus at each of the bus stops. The dwell-time at each of the bus stops will be longer. The third bus departs according to schedule, but the second bus is slowed by excessive dwell-times—remember during longer dwell-times still more people arrive—and the third bus soon catches up to the second bus, leading to the bus convoy or bus-bunching idea.

The Vicious Cycle: Another Example

This is another example of the vicious cycle that we encounter in systems with feedback. We used this idea in describing the relationship between infrastructure maintenance in public transportation and level-of-service. The same kind of phenomena operates here. The more out of balance a system gets, the stronger the forces are to force it still further out of balance, with service deteriorating.

Needless to say, bus drivers who chronically leave the terminal early are not well-liked by their peers, who pay the price by arriving late at the opposite terminal and having a very crowded bus along the route to boot. So there is some peer pressure to retain schedules and proper spacing.

Control Strategies

Let us now discuss some strategies that transit properties—here using rail as an example—can use to improve operations. We call these *control strategies*.

Holding Trains

This strategy at stations is a mechanism for making headways more uniform (the previous example illustrated why uniform headways is an important characteristic of such systems). Holding trains is easy to implement and is more common than the strategies described below.

Station Skipping

Under this strategy a train will skip a particular station as a mechanism to make headways more uniform and to improve the overall throughput of the system. This is shown in Figure 28.10. Station-skipping illustrates the fact that individual passengers gain and lose as a result of various operating strategies. If you were one of the passengers that wanted to get off at the station that was skipped, you would have to get off the train at a previous stop and wait for another train that was not going to skip that station. On the other hand, passengers who were not intending to get off at that station will have a better trip. And the system as a whole will operate closer to optimum.

Short Turning

In this strategy a vehicle will not go all the way to the east-most terminal, in Figure 28.11, but will rather stop short of that terminal and come back the other way. Again, this would be used as a mechanism to

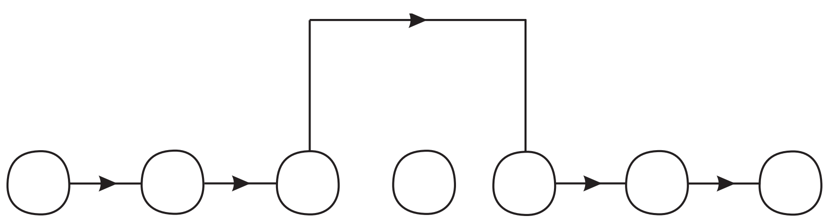


FIGURE 28.10
Station-skipping.

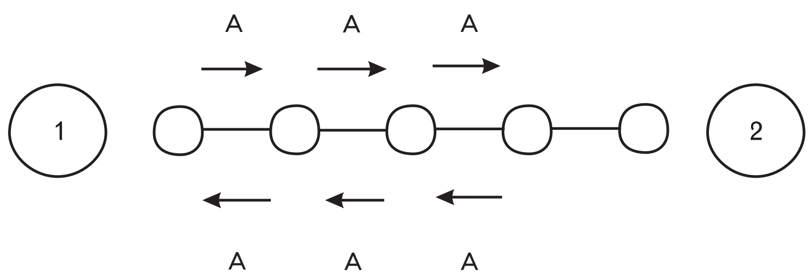


FIGURE 28.11
Short-turning.

improve the overall throughput and vehicle spacing on the route. "A" is a short-turning train, which returns to "1," without reaching the east terminus "2."

As with station-skipping, short-turning may be inconvenient for particular passengers. If you are traveling in an easterly direction and want to go to the end of the line, you have to get off and wait for the next train to take you there. On the other hand, the operators are presumably optimizing the system for passengers on the whole. Of course, in fixed rail systems we can only turn where it is physically possible to do so, given the track layout.

Need for Real-time Information

All of these approaches suggest a need for real-time information. The operator needs to know where the trains are. We would like to know the passenger loadings on trains and the number of people waiting at particular stations in order to make the above kinds of decisions in a reasonable way.

ITS—Public Transportation Applications

The ITS concept, described in Chapter 24, can be applied to public transportation. These applications, known collectively as Advanced Public Transportation Systems (APTS), include such technologies as automatic vehicle location and automatic passenger counters, which can provide the basis for more efficient fleet management systems, both in fixed rail and bus systems [3].

Intermodal Transfers

Another important ITS application is technologies that expedite transfers between vehicles (be they of the same or different modes). As with freight systems, transfer points often cause inefficiencies and service problems. ITS has the potential for providing the management control so that schedules are coordinated, as well as the traveler information to expedite transfers and make service better.

Traveler Information Through ITS

Traveler information is important—the idea here is to provide user kiosks or information at home or work that would give real-time information about actual vehicle schedules. This is information that would be updated frequently to allow passengers to know exactly what they could expect and also help them with routings through complex transit networks.

Tying these thoughts together, the overall notion is that there are operating strategies that would allow transit systems to operate more effectively. These strategies are information-driven and ITS technologies can be a boon to the transit industry both in improving operations and service and in providing timely information to travelers. The latter in and of itself could be an important market initiative for the public transportation industry.

The ITS community is certainly hopeful that the transit industry will use some of these ideas, and some of the more innovative properties have already begun to do so. However, given the financial stresses on the transit industry nationwide, there is some pessimism about how quickly they can take advantage of these new technologies.

Fares, Ridership, and Finance

Let us now consider the relationship between setting of fares in transit and the overall financial situation that the transit property faces. The overall relationships are shown in Figure 28.12. Revenues are simply the product of the fare multiplied by the volume in riders (assuming a flat fare system). In this analysis, we assume that costs are not a function of volume to a first approximation. That is, the trains or buses operate pretty much the same, independent of volume carried, for "small" changes in volume.

The financial situation of the transit property is governed by "profit," which is simply equal to the total revenues minus the total operating cost. This suggests certain strategies. One could, for example, cut fares and raise volume—the number of riders. Depending upon the form of the demand curve—the function that relates ridership to fare—it is possible that cutting fares may lead to a better financial situation for the transit property.

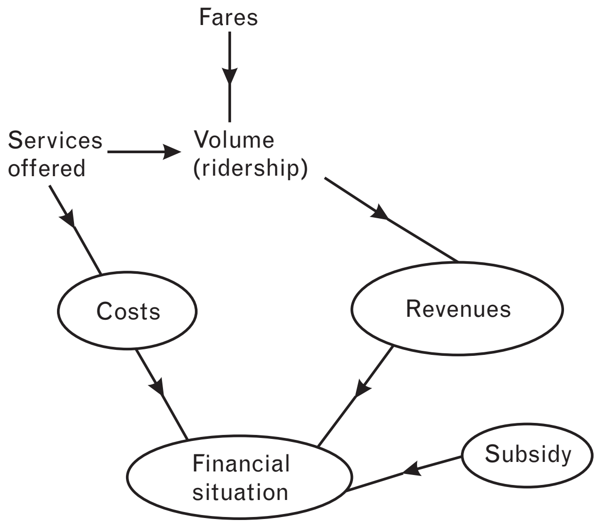


FIGURE 28.12 *Fares, ridership, and finance.*

Various Demand Functions

Consider several different hypothetical demand functions.

Linear Demand

We begin with the linear function shown in Figure 28.13. The equation for this straight line can be written as follows.

$$V = -\left[\frac{V_0}{F_{MAX}}\right] \cdot F + V_0$$

Define R as revenue.

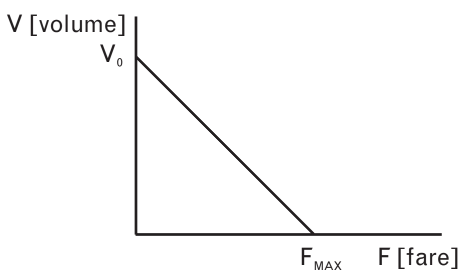


FIGURE 28.13 *Linear demand function.*

$$R = F \cdot V = F\left[\frac{-V_0}{F_{MAX}}\right] \cdot F + V_0 F$$

Choose F such that R is a maximum.

$$\frac{dR}{dF} = 2F\left[\frac{-V_0}{F_{MAX}}\right] + V_0 = 0$$

So, the level of fare that optimizes revenue F_{OPT} is as shown below:

$$F_{OPT} = \frac{F_{MAX}}{2}$$

Obviously the optimal level of fare depends upon the functional form of the demand relationship.

Parabolic Demand Curve

If we chose a parabolic demand curve, as shown in Figure 28.14, we would have a different optimal level of fare.

In mathematical terms:

$$V = k(F - F_{MAX})^2$$
$$\text{if } F = 0, \quad V = V_0$$
$$V_0 = kF_{MAX}^2$$
$$k = \frac{V_0}{F_{MAX}^2}$$
$$V = \frac{V_0}{F_{MAX}^2}\left[F - F_{MAX}\right]^2 ; 0 \le F \le F_{MAX}$$
$$\frac{dV}{dF} = 0 \text{ when } F = F_{MAX}$$

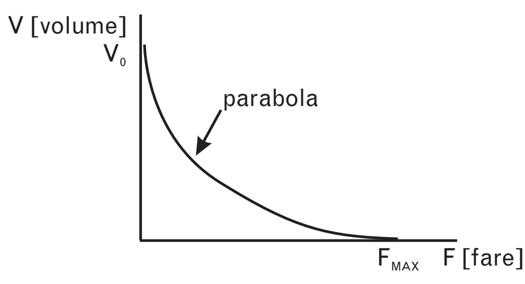


Figure 28.14
Parabolic demand function.

Recalling that R is revenue,

$$R = F \cdot V = F\left[\frac{V_0}{F_{MAX}^2}\right]\left[F - F_{MAX}\right]^2$$

$$\frac{dR}{dF} = \frac{V_0}{F_{MAX}^2}\left\{\left[F - F_{MAX}\right]^2 + 2F\left[F - F_{MAX}\right]\right\}$$

$$\text{For } \frac{dR}{dF} = 0$$

$$F_{OPT} = \frac{F_{MAX}}{3}$$

"Real" Demand Function

What do you think the demand function really looks like? Many in transit management believe it looks as shown in Figure 28.15.

The horizontal line would reflect little or no change in demand (inelastic demand) as a function of fare for some range of fares. So why not simply raise fares and hence revenue?

Equity

Even if management is right about inelastic demand and the fare increase leads to greater revenues because people are captive, the equity issues remain. Who is being negatively affected by a fare rise? Often it is the most disadvantaged people in society.

If management is wrong, and as a result of a fare rise volume goes down, as shown in the lower right-hand branch of Figure 28.15, revenues go down, exacerbating the system's financial condition. There may be broader macro-economic impacts on the region as

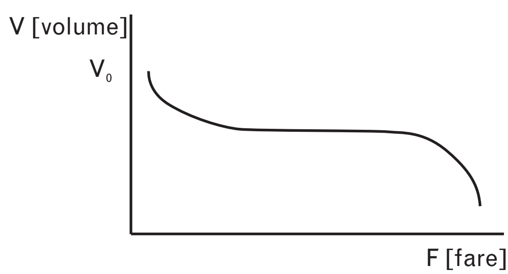


Figure 28.15
Inelastic demand function.

people find it more difficult to get to work and perhaps do not go to work as a result.

Air Quality

There will be air quality issues if more driving occurs. There are safety issues as people shift to the less-safe auto mode from the more-safe transit mode.

Vicious Cycle

Further, if revenue goes down and we under-maintain, the vicious cycle when service quality goes down as well has already been introduced. Certainly the issues in this kind of analysis are subtle. Making predictions in the complex socio-political milieu that we face is difficult indeed. Modeling can help us understand these issues but, as always, understand that modeling is just part of the answer. The results of models must be tempered with professional judgment, recognition of political reality and even some good old common sense if we are to come up with a practical solution or decision in a complicated situation of the sort that we deal with. The fact that we have a sophisticated model that produces an answer does not necessarily mean we have a usable answer for the real world.

Some Other Approaches

We conclude our urban public transportation discussion by noting some approaches that experts in the industry have advanced as a way to improve public transportation and, we would hope, the lot of urban America more generally speaking.

The idea of dedicated busways has been applied. This is basically highway infrastructure that is limited to public transportation vehicles—in this case, buses. The politics here can be difficult in that SOV drivers will note the "under-utilized" infrastructure. Whether it is underutilized on a travelers-per-hour basis is less clear—and that is the point.

David Jones, a transit expert, talks about the need for structural change for transit [4]. He has a recipe for improvement of the industry.

He includes development of new more flexible fare structures, and a market-oriented organizational structure—an area in which transit has badly lagged. Jones speaks of the need for a different mix of vehicles, ranging from large to small, and the provision of a wider diversity of service offerings. He does not feel that the "one-size-fits-all" ethic of the transit industry works in modern society. Providing the services that people need is the mechanism for getting people from their automobiles onto transit service.

Jones also comments on the need for a new relationship with labor. The management-labor friction in the transit industry is legendary. There is much fault that one could find on either side. Jones suggests that a new contract between labor and management would be fundamental in allowing the public transportation industry to play the role he feels it needs to play for our urban areas to flourish.

Conclusion: Public Transportation

The view presented here is not particularly optimistic. Urban public transportation has fallen on hard times with some bright spots partially as the result of national policies here in the United States. From the federal public expenditure viewpoint, funds in the post-World War II era have been primarily allotted to highways and airports. The tax deductible status of the home mortgage and the American dream of a single family home has led to land-use patterns that are difficult for public transportation to serve. So public transportation has an uphill fight.

Some of the more innovative public transportation operators and administrators have recognized that a broadening of the definition of the very term "public transportation" and a focus on getting people out of SOVs is an appropriate strategy. Certainly our cities will be more viable if public transportation can accommodate to the current reality of finance and land use. But it will take many innovative and dedicated operators and managers to make that happen.

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