2 Is Transit Useful? Key Indicators
Ridership Arises from Usefulness

Ridership is an important goal for many reasons other than fare revenue. It measures how many people benefit from the service, and how effective it is at providing alternatives to the private car and other less space-efficient modes.

Public transit ridership arises mostly from service that is useful to as many people as possible, for as many trips as possible. There are some geometric facts about how networks do this, which this chapter briefly reviews.

A helpful way to illustrate the usefulness of public transport is to visualize where a person could get to using public transit and walking from a given location. Figure 28 shows an isochrone map of the access available from 4th Street and Oregon Avenue at noon on a weekday. From the selected point, the map shows where someone could be, on public transit combined with walking, in 15, 30, 45, or 60 minutes.

A more useful service is one in which these isochrone areas are larger, so that each person is likely to find the service useful for more trips. We can quantify this by counting how many destinations—jobs, shopping, etc.—are inside these areas, and how those numbers grow or shrink depending on the network design.

Even beyond usefulness, an isochrone shows the level of personal freedom and opportunity afforded by the public transport network. If someone at 4th Street and Oregon Avenue chooses to rely on transit, they will be constrained by where transit can readily take them, and will experience the blobs in this map as walls around where they can go and what they can do. For someone to choose to rely on transit, and especially for them to decide not to own a car or to share a car, these blobs have to contain enough of the places that make people’s lives complete like education, shopping, services, social opportunities and jobs.

Expanding this freedom and opportunity is foundational for ridership growth. While other factors also affect ridership, this measure of freedom and opportunity isolates the aspect of ridership that network design can influence. This calculation can be made without recourse to assumptions about human culture or behavior, whose effects are not predictable.

How can we help more people get to more places sooner, so that they can do more things?

To maximize liberty and opportunity for the greatest number of people, a network of routes must optimize:

1. Frequency,
2. Span,
3. Connections,
4. Speed,
5. Reliability, and
6. Capacity,

and follow favorable patterns in the built environment.

The rest of this chapter and Chapter 3 will focus on the six elements identified above. Chapter 4 will focus on the patterns of development in Philadelphia. Together, network design and development patterns will illuminate the geometric facts that define the possibilities for the Philadelphia transit network.

From 4th St and Oregon Ave, where could I travel to on weekdays at 12 pm?

Figure 28: Map of travel time isochrones for walking and transit from 4th St and Oregon Avenue.
Frequency Comes First

Riders respond to many features of a service, including speed and reliability, but the dominant factor is frequency. Frequency is the elapsed time between consecutive buses (or trains, or ferries) on a line, which determines someone’s maximum waiting time.

People who are accustomed to traveling by car often underestimate the importance of frequency, because there is not an equivalent in driving. A car is ready to go when you are, but public transit is not available until it comes.

High frequency means public transit is coming soon, which means that it approximates the feeling of liberty you have with a private vehicle—namely that you can go anytime. Frequency has three independent benefits for the passenger:

- **Frequency reduces waiting**, which is everyone’s least favorite part of a trip. The basic sensation of being able to go when you want to go is the essence of frequency.

- **Frequency makes connections easy**, which makes it possible for a cluster of transit lines to become a network. A transit line without good connections is useful for travelling only along that line. A network of frequent lines can make it easy to travel all over the city. This massively expands the usefulness of each line.

- **Frequency is a backup for problems of reliability**. If a vehicle breaks down or is late, frequency means another will be along soon.

Many people assume that today, with real-time transit arrival information and smartphones, nobody needs to wait for a bus anymore, and frequency therefore does not matter. If a bus only comes every 30 minutes, that is fine, because your phone will tell you when it is a few minutes away and you should start walking.

Despite smartphones, realtime information and other new technologies, frequency still matters enormously because:

- **Waiting does not just happen at the start of your ride, it also happens at the end. You may not need to leave the house much before your departure, but if your bus is infrequent, you have to choose between being very early or too late.**

- **Many of the places we go do not let us hang out until our bus’s arrival is imminent. We can easily do this when leaving home, but it is more awkward when leaving a restaurant or a workplace that is closing.**

We can see the effect of frequency on ridership by looking at how existing services perform.

Figure 29 shows a dot for each SEPTA bus and trolley route within Philadelphia, with the horizontal axis indicating frequency and the vertical axis indicating productivity, which is ridership divided by the quantity of service provided. High frequency means a short elapsed time between consecutive trips, so it is to the left on these diagrams. Service quantity is measured in hours, where a service hour represents one bus on the road for one hour.

The highest frequency routes, like Routes 11, 52, and 23, tend to be the most productive. Route 11 is the highest productivity route of all with 73.6 boardings per service hour on weekdays.

Low frequency routes, like Routes 1, 68 and 77, tend to have the lowest productivity. Route 27, despite being a 30-minute frequency route, has the lowest productivity at 17.6 boardings per service hour on weekdays.

The relationship between route productivity and frequency and outlier cases will be further explored in Chapter 5.

Figure 29: Frequency and productivity relate for SEPTA bus routes in Philadelphia.
Figure 30 shows the similar relationship between productivity and frequency for hundreds of routes in 23 North American cities plus Philadelphia routes (shown with green dots). The individual points for the other 23 cities are grouped into hexagonal bins, to prevent them obscuring one another; darker-colored hexagons contain more routes.

In Philadelphia and beyond, **higher frequency is generally associated with higher productivity**. The larger dataset shows the pattern very strongly, including the upward curve indicating an exponential payoff of very high frequencies. More frequent services tend to have higher productivity (ridership per service hour), even though providing high frequency requires spending more service hours.

While a higher frequency increases the denominator of the productivity ratio, the higher ridership more than makes up for it.

This is how we know that high frequency contributes to high ridership, rather than simply representing a responsive transit agency that raises frequency where ridership is high. If higher frequencies were not causing higher ridership, then the dots on this chart would be a flat horizontal cloud, instead of a curve upward to the left. When a transit agency increased the frequency on a route, its ridership would increase proportionally, and its productivity would remain unchanged. Instead, higher frequency is associated with higher productivity.

This happens because frequent service is the most useful and convenient service for riders; thus, transit agencies typically target this most expensive service towards their strongest markets. When frequent service is available to people in a suitably dense, walkable environment, high ridership is a common result. This illustrates the power of frequency to deliver more ridership than would be expected by the increase in service hours.
Span: Is transit there when you need it?

For transit to be useful, it must be there at the time of day that you need it. The times of day that transit operates is called the span of service. In Philadelphia, many routes provided by SEPTA run late into the evening and start early in the morning. But the frequency of service varies greatly by time of day.

The network maps on pages 20–26 show the frequency throughout the midday. Frequencies are generally even better during the peak. But on most routes, the frequency drops significantly in the evening. This is a normal response to a drop in demand, but because frequency is so important for quick and reliable connections, this can cause a very abrupt drop in usefulness. The freedom and liberty that transit provides often arises from using two frequent routes together, so the value is only present when both are running frequently.

Of the role of frequency outlined above, this can cause a very abrupt drop in usefulness.

Figure 31 shows the 20 routes with the longest spans of high frequency service. Only four routes have a 15-hour span (e.g., 6 am to 9 pm) of frequent service. Frequent service begins in the 6 am hour for most routes. But there is no consistency in when frequent service ends in the evening. They also differ in the beginning and ending times of service.

The lack of consistency in when frequent service transitions to less frequent service means that riders must consult a schedule for trips in the evening or if they are traveling on weekends. While they may have a quick trip with a minimal wait in the morning, their return trip may be much longer because their transfer may involve a much longer wait.

Figure 31: Frequency and span of service for the 20 SEPTA routes with the longest spans of frequent service. Only four routes have frequent service for 15 hours a day or more.
Frequent service is highly inconsistent on weekends as well. Figure 32 shows the same 20 routes with their span and frequency of service on Saturday and Sunday. Of these 20, 19 routes have some period of frequent service on Saturdays, but most have fewer than 12 hours of frequent service. And there is little consistency in when frequent service begins and ends for each route. Route 52 is frequent for most of the day on Saturday, from 8 am to 9 pm. But as a crosstown route it would be even more useful if the connecting radial routes, like the trolleys or Routes 21 and 42, had frequent service in the mornings and evenings.

Service levels on Sundays are even lower than Saturdays. Only eight routes have any period of service that is frequent, and only Route 52 has a period of frequent service more than eight consecutive hours.

Figure 32: Frequency and span of service on Saturday and Sunday for the 20 SEPTA routes with the longest spans of frequent service. Most routes are not frequent on Sunday.
Frequent Service Standards

An increasing number of transit agencies use standardized spans for all frequent routes, usually in the context of branding their frequent network to help people see where transit is most likely to be coming soon. Figure 33 provides some examples of the frequent service standards used by other major transit providers in North America. Portland uses a standard of 15-minute frequency or better for at least 14 hours on weekdays. Others provide at least 15 hours. These agencies also maintain frequent service on weekends for these branded routes, at higher frequency and longer spans than SEPTA does.

Many agencies are also developing specific maps and bus stop signs to brand and market their frequent service. Figure 34 shows the frequent network map and an example of a bus stop served by the frequent network in Portland.

The limited nature of the frequent network in Philadelphia is well illustrated by the set of maps in Figure 35 on page 37. At noon on weekdays, the frequent network covers much of the city. By 7 pm, however, the frequent network is severely limited. By 9 pm, the frequent network consists of just the BSL, MFL and Route 52. The frequent network at noon on Saturdays is similar to the weekday network, but less comprehensive, while at noon on Sundays it is quite limited.

Evening and weekend service is relatively inexpensive to operate compared to peak period service, and it is also crucial to a large segment of transit riders. People who work in most retail and entertainment sectors have to work on weekends and often late into the evening. Having some transit then is important to making it possible for them to rely on transit at all.

Houston recently had great success with a network redesign that extended evening service and expanded Saturday and Sunday service to be the same level as weekday service, but without the peak period. In the first year of their new network, Saturday ridership increased 13 percent and Sunday ridership increased 34 percent.

We would like to recommend improved frequency in the evening and on weekends for Philadelphia as part of its network redesign process, but without new resources it would require cutting the weekday network too deeply. Bringing evening and weekend service up to a similar standard to the examples noted above would increase annual costs by about 15 percent. Additional evening and weekend service should be a top priority for any new resources.

Figure 33: Frequent service standards in four North American cities

<table>
<thead>
<tr>
<th>FREQUENT BRANDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREQUENCY</td>
</tr>
<tr>
<td>FREQUENT NETWORK</td>
</tr>
<tr>
<td>WEEKDAYS</td>
</tr>
<tr>
<td>SATURDAYS</td>
</tr>
<tr>
<td>SUNDAYS</td>
</tr>
<tr>
<td>HOUSTON, TX</td>
</tr>
<tr>
<td>MONTREAL, QC</td>
</tr>
<tr>
<td>SEATTLE, WA</td>
</tr>
<tr>
<td>PORTLAND, OR</td>
</tr>
</tbody>
</table>

**FREQUENCY**

- under 5
- 5 - 9
- 10 - 15
- 16 - 25
- 26 - 40
- over 40

Figure 34: Portland’s TriMet is one of many agencies that promotes the Frequent Network as a distinct product with bus stops (left) and a map (right).
The scope of the frequent network is relatively broad during weekdays and Saturdays at noon. But it is very limited in the evenings and on Sundays.
Connections

The SEPTA bus system in Philadelphia has an efficient grid network across most of the city that provides easy connections between most routes and between buses and other transit modes. This structure and will be discussed more thoroughly in Chapter 5 on page 69.

Buses are Getting Slower

SEPTA bus speeds in the City of Philadelphia are typical for a dense and congested urban area, but speeds have been declining. As shown in Figure 36, below, scheduled speeds have declined since 2014 and average less than 12 miles per hour during most of the day. Many factors affect bus speeds, including overall traffic congestion, ridership levels and the number of stops. An unfortunate reality is that increased ridership will tend to decrease average speeds, as longer dwell times are required to board and alight more passengers. But ridership has declined on SEPTA since 2014, so one would expect, absent other changes, to see an increase in average speed. Thus other factors, like general traffic congestion, must be slowing down buses.

Another factor that slows buses is the density of signals and stop signs. Figure 37 shows the density of signals and stop signs along major north-south routes through North, South and Center City Philadelphia. Route 45 trips coming into Center City have 29 signals and 17 stop signs over about four miles, averaging eleven signals or stops per mile.

In addition, bus stop spacing within the city is typically every block at the near-side of intersections. This results in a stop about every 500 feet. This is consistent with the current SEPTA stop spacing standards (detailed further on page 93) but it is not in line with current best practice for bus stop spacing, which is to space stops as follows:

- Space stops more widely in dense areas, where there are likely to be people waiting at every single stop, and where it is relatively safe and easy to walk a few blocks to a bus stop.
- Space stops more closely in low-density, outlying areas, where ridership is lower and so it is unlikely that there will be people waiting at every stop. The closely-spaced stops therefore do not affect areas, so more closely spaced stops also reduce the impact on passengers who might have walk to on streets without sidewalks, crosswalks and lighting.

Connections across most of the city that provides easy connections between most routes and between buses and other transit modes. This structure and will be discussed more thoroughly in Chapter 5 on page 69.

Buses are Getting Slower

SEPTA bus speeds in the City of Philadelphia are typical for a dense and congested urban area, but speeds have been declining. As shown in Figure 36, below, scheduled speeds have declined since 2014 and average less than 12 miles per hour during most of the day. Many factors affect bus speeds, including overall traffic congestion, ridership levels and the number of stops. An unfortunate reality is that increased ridership will tend to decrease average speeds, as longer dwell times are required to board and alight more passengers. But ridership has declined on SEPTA since 2014, so one would expect, absent other changes, to see an increase in average speed. Thus other factors, like general traffic congestion, must be slowing down buses.

Another factor that slows buses is the density of signals and stop signs. Figure 37 shows the density of signals and stop signs along major north-south routes through North, South and Center City Philadelphia. Route 45 trips coming into Center City have 29 signals and 17 stop signs over about four miles, averaging eleven signals or stops per mile.

In addition, bus stop spacing within the city is typically every block at the near-side of intersections. This results in a stop about every 500 feet. This is consistent with the current SEPTA stop spacing standards (detailed further on page 93) but it is not in line with current best practice for bus stop spacing, which is to space stops as follows:

- Space stops more widely in dense areas, where there are likely to be people waiting at every single stop, and where it is relatively safe and easy to walk a few blocks to a bus stop.
- Space stops more closely in low-density, outlying areas, where ridership is lower and so it is unlikely that there will be people waiting at every stop. The closely-spaced stops therefore do not affect areas, so more closely spaced stops also reduce the impact on passengers who might have walk to on streets without sidewalks, crosswalks and lighting.
On-Time Performance Is Poor

Reliability of bus service can be measured in a few different ways but is commonly measured by either on-time performance or headway reliability.

On-time performance measures the percent of trips that arrive within a given window around the scheduled arrival time. SEPTA standards define the “on-time” window as 0 minutes to 5 minutes and 59 seconds late. By this standard, a bus that arrives at a timepoint 6 minutes behind schedule would be counted as late. A bus that arrives 5 minutes behind schedule would not be considered late.

This definition is relatively strict by the standards of US transit agencies. Any bus that arrives even one minute early is considered not on-time and would count against this metric. More typical standards allow a window of up to one minute early before counting an arrival as not on-time.

Figure 38 shows the on-time performance of most SEPTA routes in Philadelphia. SEPTA performance standards call for buses and trolleys to achieve 80% on-time performance. As the figure clearly shows, the majority of routes are not achieving this standard today. 54 of the 83 routes analyzed do not meet this standard.

But this raises a critical question about the value of this metric for most SEPTA routes in Philadelphia. Route 47, for example, achieves only 73% on-time performance. Yet the route is scheduled to operate at least every 10 minutes or better from about 6 am to 6 pm. When measuring high frequency services, of 10 or 15 minutes or better, earliness and lateness relative to the schedule is usually a poor measure of reliability. Earliness and lateness matter if somebody is really going to expect the bus at 10:10 am. But on high-frequency services almost no one does that. They just go out to wait for the next bus and trust that it will be along soon. So the thing most customers care about is the maximum wait time, not earliness or lateness compared to the schedule.

Figure 38: A majority of SEPTA routes are not achieving the 80% on-time performance standard (conventional measure). For frequent services, this measure of on-time performance is not what matters.
Better Measures of Reliability

Suppose that at a particular stop on a particular day, buses are scheduled to come every 10 minutes as shown in Figure 39. There are three ways to describe this situation:

- **Conventional on-time performance**, also called schedule adherence, would be 14%, because only one of the seven buses is on time. The others are all six minutes late.
- **Headway regularity** would be 86%. Only one of the buses is more than 10 minutes behind the one in front of it.
- **Probability of waiting** no longer than the scheduled 10 minutes would be 90%. If people appear evenly throughout the 60 minutes of the hour, only 10% of them will arrive at a time when the next bus is more than 10 minutes away.

Headway regularity is about how often a headway (the elapsed time between consecutive buses) is what it should be. Probability of waiting translates this into the customer experience: How likely am I to be affected by a delay?

With recent upgrades to AVL and communications systems, SEPTA now has the technical capabilities to track and manage the reliability of frequent service in this way. Changing to a new standard, however, would require significant adjustments in policy and the culture of how operators, supervisors, dispatchers and others cooperate in the daily management of service.

A key factor in changing this policy is that the individual driver cannot be held responsible for it. A driver is only responsible for when her bus gets to the stop, but she obviously does not control the buses in front of her and behind her. But an aggressive operations management, using current tools such as GPS to tell them where every bus is, can monitor these things, giving the necessary real-time direction to drivers about how to adjust their operations to keep buses more evenly spaced.

An example of more aggressive operations management would be to more regularly instruct operators to switch to drop-off only when they start falling behind the regular headway of the bus ahead of them and the bus behind them is approaching quickly. This will upset some riders, who will get skipped by that bus, but the overall system will function better as the aggressive management of headways will reduce bus bunching and even out passenger loads.

Judging service on earliness and lateness is an easy measure to apply to vehicles. This means that operations management has an easier time monitoring performance on a route and dealing with disruptions. Changing to a headway reliability standard would shift the onus to active management because success is the result of teamwork rather than individual vehicle performance. Changing work and management habits is a major cultural shift and bus operations managers may not have the training, or the tools, to do it that way. However, many transit agencies are seeking to make this transition, because the conventional on-time performance measure just does not describe what matters in frequent bus operations.
Probability of Waiting at SEPTA

Figure 40 describes the reliability of frequent routes in the SEPTA system by a “probability of waiting” standard. The figure shows system-wide performance for frequent routes (those that average every 15 minutes or better) during different time periods of the day, because those are the routes where this standard is relevant. The analysis is limited by the small number of days included in the analysis and missing vehicle locations, but it helps illuminate where reliability problems are greatest.

Unlike the abstract example above, we use a standard of 1.5 times the scheduled headway. Thus, if the scheduled headway is 10 minutes, a wait of up to 15 minutes would be considered acceptable. This helps reflect the normal variability due to traffic signals, slow boardings, etc., that is impossible to prevent even in the most optimized network.

The probability of waiting at least 1.5 times the headway is more than 6% from 4:00–6:30 pm and more than 5% from 2:00–4:00 pm. For trips in the PM peak, a rider should expect to wait at least 1.5 times the headway one or two workdays a month. A delay of twice the headway or worse could be expected every other month.

The results of this “probability of waiting” analysis suggest that performance is much better than one might think when reviewing the results of the official SEPTA On-Time Performance analysis in Figure 38. SEPTA is achieving better than 95% headway reliability on high frequency routes in the AM, Midday, and Evening.

Nevertheless, performance could be improved. The PM Peak and Mid PM (or afternoon) reliability levels are lower than many customers might like. Imagine being a shift worker trying to get home to pick up your child from day care. Late pickups more than twice a month would likely get your child dropped from typical day care centers. This forces riders to leave earlier than they want so they can avoid a missed pick up—or a missed shift. It adds wasted time to their day, takes away from time with family, and takes away some of their freedom to do what they wish.

Chapter 3 describes key steps that could be taken in this direction.

1 These headway reliability measures probably underestimate the real impact on customers. Many scheduled time-points were missing from the data. For missing timepoint crossings it is impossible to know if they were missing because the bus did not make that trip or because the AVL system failed to detect the time that a bus crossed a timepoint. Since each missing observation causes uncertainty in the actual headway experienced at a stop, we dropped the affected headways from the analysis. Detection failures may be especially common when on-time performance is poor, introducing bias into reliability measures.
All door boarding

There are a range of things that can be done to improve bus speed and reliability. Most of these require cooperation with the City of Philadelphia, but there is one important area where SEPTA can lead.

Many transit agencies are looking at ways to reduce the amount of time that buses dwell at stops. A potential solution is to allow customers to board at any door, rather than requiring all customers to board through the front and interact with the driver. San Francisco does this on all bus services citywide, and many other big-city transit agencies are using it on major lines or Bus Rapid Transit services. It is nearly universal on light rail; in fact, SEPTA’s trolleys are one of the few rail services that does not use the method.

The key challenge of all-door boarding is fare enforcement. Staff must be assigned to randomly ride buses and check fares, issuing citations to those who are not holding a valid proof of payment. Fare inspection is a challenging job that is part law enforcement and part customer service. Careful management is required to ensure it is done equitably, but many cities are finding that the benefits of all-door boarding are worth the effort.

The Trolley Modernization project also envisions new longer trolleys that will also use all-door boarding, so fare enforcement will be needed there as well. Since SEPTA will be expanding its fare enforcement capacities anyway, it should consider extending all-door boarding across much of the bus system.

On some systems, particularly those with few stops and relatively high levels of infrastructure, ticket machines on platforms can further reduce the need to pay cash, and some systems, including most light rail lines, require tickets to be purchased in advance. This approach may be appropriate for trolleys, Direct Bus services, and stops with high numbers of cash boardings throughout the system.

But ticket vending machines are not essential. In the simplest version of all-door boarding, customers board at the front door only if they need to pay cash. SEPTA Key validators would be installed on rear doors so that passengers using the card, or carrying some other prepaid fare, could use any door.

The National Association of City Transportation Officials (NACTO) recently released a white paper on the subject, looking at the experience of San Francisco, New York, Seattle, Chicago, Austin, Minneapolis, and Vancouver.1 San Francisco’s dwell time per boarding passenger dropped by 38% when all-door boarding was introduced. This translated into a 2% average increase in speeds, which would amount to reversing the last three years of SEPTA’s speed losses. Benefits would be highest on the busiest corridors and times of day. All-door boarding on New York’s Select Bus Service routes caused dwell time per boarding passenger to drop by 42-51%.

All-door boarding also reduces the variability in boarding time. This translates into more evenly spaced buses, which reduces bunching and thus more evenly distributes customers across buses.

SEPTA is already studying all-door boarding for Boulevard Direct service, but the agency should also consider the evolving experience on local buses, especially San Francisco’s and consider extending the idea to major routes across the city.

---