

Getting to High School in Baltimore: Student Commuting and Public Transportation

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Getting to High School in Baltimore: Student Commuting and Public Transportation

This report is the first publication of a multi-year project examining the relationship between student commutes using public transportation and on-time arrival and absenteeism. This report begins to develop a basic understanding of how students commute to high school in Baltimore with a focus on those using public transportation. We initiated this project after hearing a compelling story of one student's commute on public transportation that aired on WYPR in February of 2015 (<http://wypr.org/post/no-yellow-buses-here-one-students-mta-commute>).

This report is structured as a series of questions and our answers to those questions. We developed a model of the public transportation network in Baltimore using geographic information systems (GIS) software. From this network, we estimated the most efficient routes to school (routes that took the shortest overall time) for all high school students who lived in Baltimore City and were enrolled in a public high school during the 2014-15 school year. While we cannot know with certainty how well our estimated routes match actual student behavior, we believe that they are a reasonable approximation, especially in the absence of other means of observing student commutes. The methodological appendix at the end of the report explains our models, assumptions and data in more detail.

It is especially important to develop an understanding of student commutes now, given the upcoming significant changes to the public transportation system that will be fully implemented by the summer of 2017. The Maryland Transit Administration's (MTA) BaltimoreLink Plan represents a major overhaul of the of the local bus system in Baltimore. The primary goals of BaltimoreLink are to improve the reliability of the system, increase access to high-frequency transit, strengthen the connection between the bus and rail systems, and increase service to job centers in the metropolitan area. The initiative also includes funding for transfer facilities, dedicated bus lanes, signal priority, and signs.

It may seem odd to describe students as “commuters,” but the description is apt for several reasons. In some sense the main “job” of a young person is going to school. Further, given the system of high school choice in Baltimore there are no automatically assigned high schools based on residence and every student must choose a high school. This means that students are free to select schools that best match their preferences, even if those schools are across town. Thus, as this report makes clear, high school students in Baltimore rely extensively on the existing public transportation infrastructure to get to their school of choice.

- The average student commute to high school using public transportation is estimated to take 36.2 minutes. Commuting to school via public transportation for students is very similar to adult commuting to work.
- We estimate that approximately 13,000 high school students (6 out of 10) rely on public transportation to commute to school. These students represent a large public transportation user group, especially during peak transit times on school days.
- High school student commutes are likely to be more complicated than the average trip of a public transportation user. Notably, we estimate that 2 out of 3 (68%) high school students will need at least one transfer to get to school; this differs substantially from estimates of the entire system (47%).

- One third of students who use public transportation to get to school (33.5%) do not feel safe during their commutes. While this is higher than students who use other modes of travel to commute to school, overall, 30% of students do not feel safe going to and from school, regardless of how they get there.
- The last portion of student commutes, the distance from the last public transportation stop to school, may present challenges for students at many schools.
- If all students were to attempt to arrive at school exactly on-time the transit system would not have the capacity to meet this demand.

The report begins with basic information about where schools and students are located and the public transportation system in Baltimore to orient the reader to the basic structure of both systems and how they intersect spatially. The remainder of the report explores questions related to key aspects of commuting to school using public transportation such as travel times, the complexity of routes to school and student safety.

Where are high schools?

To begin to understand how students get to high school in Baltimore it is important to understand where high schools are located. As can be seen in Figure 1, high schools, and high school seats are not evenly distributed spatially across the city – some areas of the city have relatively few high schools with few seats (Southeast Baltimore) while others have many (West Baltimore).

All of Baltimore’s high school buildings were built many decades ago - the median building age is 53 years (oldest = 121; newest = 35). For the most part these buildings were intended to serve their local communities. Universal choice allows students and families to freely choose their high school unconstrained by attendance zone, thereby making the location of the chosen school and the transportation required to get to that school more salient.

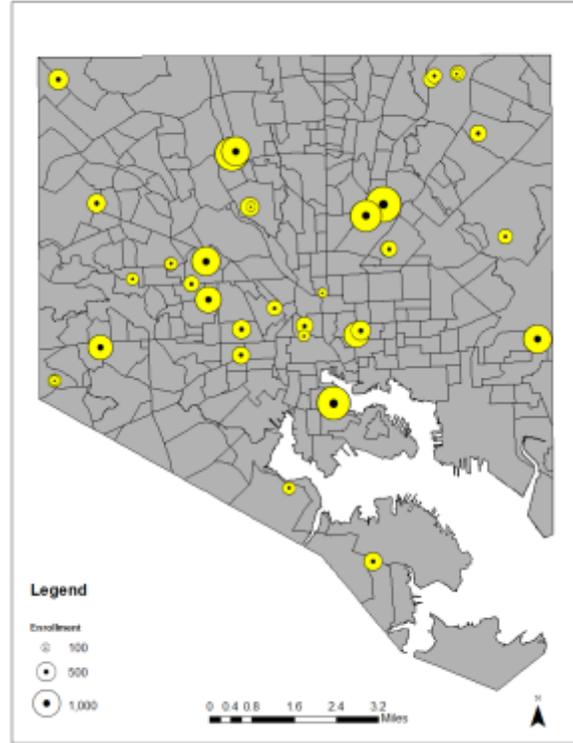


Figure 1: High school locations by enrollment Size. *Note:* Icon size proportional to school enrollment

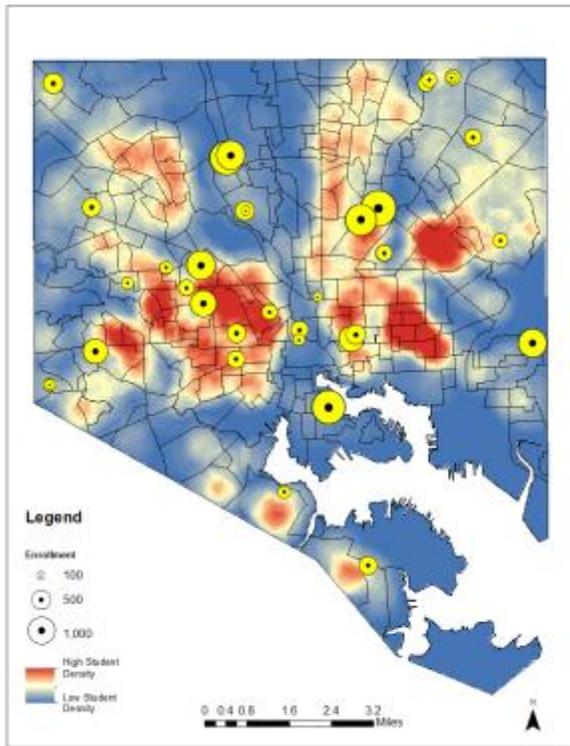


Figure 2: Distribution of high school students. *Note:* Icon size proportional to school enrollment

Where do high school students live?

Figure 2 presents a heat map of where high school students live in the city. While the relative density of students presented on the map is influenced by the housing density of a given area, the map provides a good picture of where students live.

City Schools’ high school students live across the city but are more highly concentrated in several areas of the city such as Belair-Edison, east and west Baltimore, the Edmondson Village area, Park Heights and the Greenmount Avenue /York Road corridor with noticeable concentrations in communities of Lakeland, Cherry Hill and Brooklyn in the south.

Figure 2 also highlights that communities vary in the extent of high school and seat availability within close proximity.

Where are high schools in relation to public transportation?

Most public transportation in Baltimore is provided by the Maryland Transit Administration (MTA) which operates subway (Metro), light rail (Light Rail), and bus service in the metropolitan area. MTA operated bus routes (Figure 3, black lines) include local routes, routes with limited stops, and express routes that provide service to surrounding counties. The Metro and Light Rail (Figure 3, blue and red lines respectively) run predominately within the northwest quadrant of the city and in a corridor to the south. In 2014, buses accounted for the majority of public transit trips (75.8 million trips) followed by the Metro (14.6 million trips) and the Light Rail (8.1 million trips).

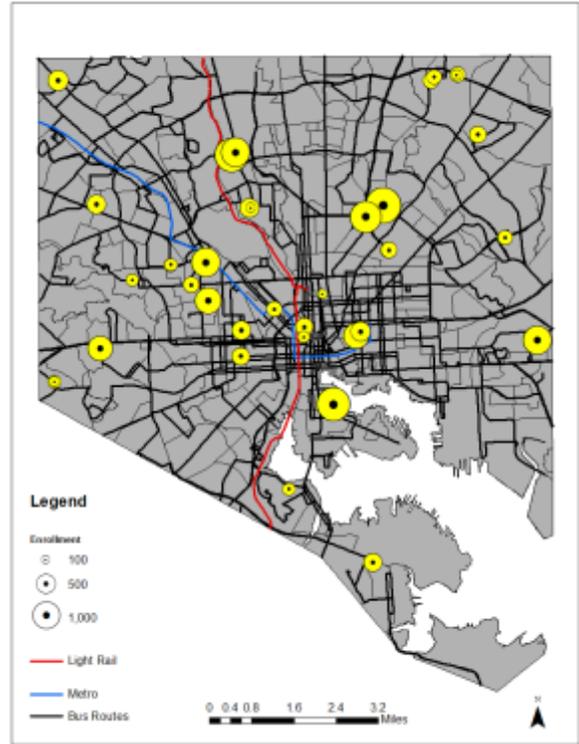


Figure 3: Baltimore’s public transportation network
 Note: Icon size proportional to school enrollment

As shown in Figure 3, all high schools appear to be on or near at least one transit line. As Figure 3 also shows, however, some high schools are in areas that are serviced by a denser network of routes. Thus, we would expect, all else equal, schools that are located centrally in the public transportation network (downtown central core) will have shorter average travel times than schools at the edges of the network. Further, a school that enrolls students from across the city will have longer average commute times than a school that enrolls students from more local neighborhoods.

What are the options for high school students in Baltimore?

City Schools operates a range of high school programs within a system of universal high school choice, whereby all students must actively choose their high school as there are no defined enrollment zone schools. This “portfolio” model makes every school in the district available to every student, provided that he or she can gain admission. With the exception of a few high schools that admit students using idiosyncratic processes (e.g., interviews or auditions) and some charter schools, Baltimore students enroll in high school using a centralized process. Schools are broadly divided into three tiers by admissions criteria that are based on a student’s composite score which captures academic performance and/or attendance: four selective academic schools, three selective career and technical education (CTE) schools, and all other schools that have no entrance criteria and enroll by random lottery.

Figure 4 shows the commute sheds for all Baltimore high schools (Panel a) and separate commute sheds for the two types of selective high schools (Panels b and c). Areas that have substantial nonresidential components are shaded in gray (e.g. industrial zones, parklands,

university campuses). Commute sheds describe areas of the city that can reach a school in a given amount of travel time (our figures present 15-minute travel bands). Generally speaking, most areas of the city can access at least one high school within 30 minutes using public transportation, according to our models (Panel a, Figure 4). Often when schools are considered in discussions of public transportation a metric of this type is discussed. For example, “From a given place a student could reach X number of schools in Z amount of time.” This however obscures the fact that schools are not strictly interchangeable; it neglects to account for the portfolio of options available to students through school choice and their relative attractiveness to individual students and families.

We highlight this point by noting that the commute sheds for the selective schools are quite different from the overall commute shed. The three selective CTE schools are located along a central axis of the city running from the southwest to the northeast (see Panel b, Figure 4) while three of the four highly selective high schools are in the northern part of the city (see Panel c, Figure 4).

Taken together there are large swaths of the city where the trip to a selective school is expected to take at least 45 minutes. In communities in South Baltimore such as Westport, Lakeland, Cherry Hill, Brooklyn and Curtis Bay the commute to any of the seven selective high schools is expected to take up to an hour or more, each way, every day.

In summarizing the previous sections we feel there are several key points that should be considered when thinking about public transportation and high schools:

- Transit networks and systems have largely been designed to link adult residents to employment locations that historically were concentrated downtown.
- High schools rarely change locations and are, therefore, fixed points in space which vary in their access to the transportation system.
- Families can choose to live in different parts of the city, but at any given time student residential locations are a fixed point in space. As with school locations, residential locations vary in their access to the transportation system and concomitantly vary in their access to high schools through that system.
- High schools vary, sometimes greatly, in the programs they offer and their attractiveness to students and families. Consequently, high schools should not be treated as interchangeable.
- Taken together, these facts create potential spatial mismatches between students and desired high schools, resulting in highly varied commute times for students, especially if they choose high schools outside their immediate communities.

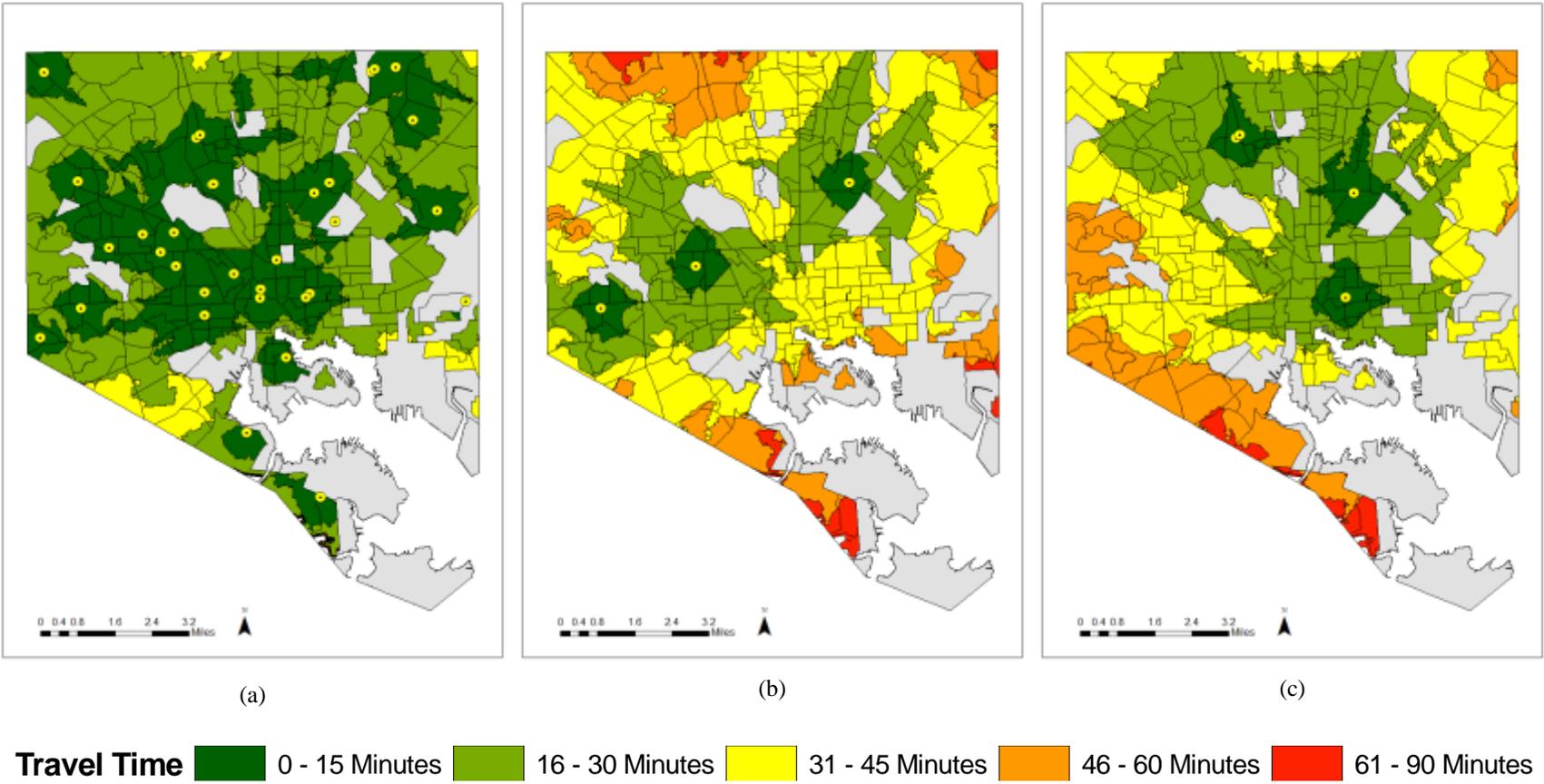


Figure 4: Commute sheds for (a) All high schools, (b) Selective CTE high schools; (c) Highly selective high schools.

Note: Nonresidential areas shown in grey.

How do Baltimore City high school students get to school?

The previous sections have implicitly assumed that high school students in Baltimore rely on the public transportation system to get to school. We explicitly show in this section that this is indeed the case.

High school students who attend City Schools and who live more than 1.5 miles from the school they attend are eligible for transportation services. City Schools contracts with MTA to provide transportation for these students. Students eligible for transportation can take the local bus, light rail, and metro services. During peak travel times, MTA provides extra buses along existing bus lines to accommodate the increased student demand; these “school tripper” buses include stops directly at the destination schools.

In our sample, approximately 9 in 10 Baltimore City high school students are eligible for transportation passes (n = 16,586; 86.8 percent).

What is our best estimate of how many high school students use public transportation regularly? In 2014-15 high school students reported on their primary mode of commuting to school on a survey administered by City Schools. While overall response rates are low (42.4 percent) these responses provide the best available estimate of high school students’ primary mode of transportation to school.

As shown in Table 1, students report that their primary mode of transportation to school is public transit (58.2 percent) followed by car (29.9 percent), walking (8.0 percent) and school bus (3.9 percent). Extrapolating out to the total City Schools’ 2014-15 high school enrollment (n = 22,341) approximately 13,000 high school students in Baltimore City would rely on public transportation to get to school. To put this number in context, the 2014 American Community Survey (5-year estimates) estimates that approximately 46,000 adults in Baltimore use public transportation to get to work.

Table 1
High School Students’ Primary Mode of Transportation to School

Travel Mode	Survey Responses	Pct.	Implied Users
Public Transit	4,871	58.2	12,994
Car	2,504	29.9	6,680
Walking	670	8.0	1,787
School Bus	330	3.9	880
Total	8,375	100.0	22,341

Source: City Schools’ School Survey 2014-15

To put the number of high school students using public transportation to commute to school in context, it is important to understand the proportion of MTA’s customer base that is likely to be made up of students during school days. Transportation systems express the number of users with a metric known as *ridership*, which measures the total number of passenger trips that occur on a given mode of transit over a period of time. A passenger trip is defined as a trip taken by a single user on a single vehicle; a student who used two buses to commute to school one way would count twice towards ridership in the morning and twice towards ridership in the evening. This student would contribute four passenger trips for the day.

We created two estimates of *high school student MTA ridership* based on this definition (see Appendix for details). The first estimates ridership from our estimates of the number of high school users and the number of transit vehicles they would need to commute to school (see Table 2, Column “Estimated Users”). The second discounts the first estimate by taking into account the average daily attendance of high school students in City Schools during the 2014-15 school year.

MTA reports average weekday ridership on buses, Metro and light rail by month. To estimate average weekday ridership on a typical school day during the 2014-15 school year, and to smooth out monthly variation, we took the average of the estimated average weekday ridership from September 2014 to June 2015 (329,689 passenger trips). We estimate that high school students represent between 16.2 and 13.2 percent of MTA’s weekday ridership during this period.

In other words, approximately 1 out of 6 to 1 out of 8 MTA passenger trips during this period was a high school student on his or her way to or from school.

Table 2
Estimated Average Weekday High School Student MTA Ridership for the 2014-15 School Year

Est. Num. of Transit Vehicles Needed per Day	Estimated Users			Adjusted for Attendance		
	n	Daily Passenger Trips	% of MTA	n	Ridership	% of MTA
Two	4,136	8,272	2.5	3,392	6,783	2.1
Four	4,083	16,332	5.0	3,348	13,392	4.1
Six or More	4,774	28,647	8.7	3,915	23,491	7.1
Total Est. Users	12,994	53,251	16.2	10,655	43,666	13.2

Note: The average MTA weekday ridership on buses, metro and light rail during the period September 2014 to June 2015 was 329,689 (source <https://data.maryland.gov/Transportation/Weekday-Ridership/uvhc-kf4p>). “Estimated Users” scenario uses our estimates of the total number of vehicles needed to commute to school to allocate the estimated 12,994 high school students who primarily use MTA to get to school. “Adjusted for Attendance” scenario discounts the counts in the first scenario for the high school average daily attendance rate in City Schools during the 2014-15 school year (82 percent).

It is also important to remember that high school ridership in the morning occurs in a window of time determined by school start times. City Schools operate on a staggered opening bell schedule in 15 minute increments from 7:30 a.m. to 9 am. The majority of schools in our sample start at either 8 a.m. or 8:15 a.m. (26/37 schools, 14,345 students) which leads to a high school student rush hour that likely overlaps with the rush hour of adults commuting to work.

How long does it take to commute to school?

Our travel time estimates represent a best case scenario in that our models assume strict adherence to the MTA schedule (perfect reliability) and that students strictly prefer routes that minimize total travel time. Actual travel times as experienced by students who use public transportation are likely to be higher than what we estimate.

- Mean estimated travel time for students using public transit is 36.2 minutes.
- Mean estimated travel time for all students (walking and public transit) is 34.2 minutes.
- 1 in 4 students' estimated commutes by public transportation would take longer than 45 minutes (25.1 percent)

To put these estimates in context, according to the 2014 American Community Survey (5-year estimates) the mean travel time to work (all travel modes) for Baltimore workers at least 16 years of age who do not work at home was 30.1 minutes. Workers in Baltimore who use public transportation take on average 46.4 minutes to commute to work. This estimate is not directly comparable to students in that more than one-third of adult workers who commute by public transportation take longer than one hour to get to work, reflecting workers commuting outside of the city for work. Comparing the travel time distributions of students and adults who have public transportation commutes less than an hour we see that, broadly speaking, students and adult commutes appear quite similar with respect to travel times.

Table 3
Estimated One-way Commute Travel Times (less than 60 minutes)
on Public Transportation for Baltimore Adults and Students

Total Travel Time	Adults	Students
Less than 15 minutes	5.5	5.1
15 - 29 minutes	26.0	32.7
30 - 44 minutes	43.6	41.8
45 - 59 minutes	25.0	20.5

Note. Adult estimates come from the 2014 American Community Survey (5-year estimates). Adult n = 46,067
Students n = 17,322. Adults and students with estimated travel times greater than 60 minutes have been omitted from calculations

How complicated are student commutes to school?

Given the design of the public transportation system in Baltimore and the varied origins (home) and destinations (schools), most student commutes will involve making connections (transfers) between transit vehicles. Transfers are necessary because direct service from all potential origins to all potential destinations is impossible. While connections make for more efficient transit networks, they also increase the complexity of commutes and increase commuters’ exposure to travel delays due to late buses. The cost to riders of late buses is increased wait times and longer overall commute times. For students, increased commute time due to unreliable service may lead to late arrival at school.

Based on our modeling assumptions, we estimate that student routes to school are nearly equally divided among zero (31.8%), one (31.4%), and two or more transfers (36.7%). The student distribution differs substantially from estimates for the entire MTA system (see Table 4). In particular, students are expected to take substantially fewer direct or point-to-point trips without transfers and substantially more trips with two or more transfers. Notably, the MTA estimates that a majority of all trips (53%) can be conducted on a single vehicle without a transfer. We estimate that 68% of students will need at least one transfer to get to school.

Table 4
 Estimated Number of Transfers Needed for High School Student Commutes to School Compared to MTA Estimates of System-wide Number of Transfers Needed

Transfers Needed	Students		MTA
	n	Pct.	Pct.
None	5,514	31.8	53.0
One	5,443	31.4	35.0
Two or More	6,365	36.7	12.0

Note: MTA estimates of the number of transfers needed come from MTA community presentations about the proposed BaltimoreLink plan. These estimates are not expected to deviate more than 2% from the average transfer rate under the current system. See for example: https://mta.maryland.gov/baltimorelink/images/library/community_meeting_presentations/BaltimoreLink-PPT-Community-Meeting-Presentation---Presentation_Charles-Village_Complete.pdf

A common transportation metric of service reliability is on-time performance (OTP), which for MTA is defined as arrival of a transit vehicle one minute before to five minutes after the scheduled arrival time. The MTA goal for the OTP of local bus service is 85 percent, which it has achieved in recent quarters. Late buses directly increase the total travel time for a commuter in a number of ways. First, by directly increasing the total travel time by number of minutes the vehicle is late. Missed transfers due to an initial late bus or delayed departure of the second or third bus can greatly increase total travel time. Further, unreliable service can create pent up customer demand, which could lead to buses reaching capacity and not letting on any additional passengers.

Given the need for most students to make at least one transfer, unreliable service is likely a key factor in how students navigate and use public transportation to get to school and needs more study to fully understand its impacts on students.

How safe do students feel commuting to school?

Students who use public transportation to commute to school must navigate the city unsupervised. For many students commuting to school can be marked by difficulty, frustration and in some cases, concern for personal safety (see <http://news.wypr.org/post/getting-school-harder-you-think#stream/0>, <http://wypr.org/post/no-yellow-buses-here-one-students-mta-commute>, and <http://www.tdpbaltimore.org/blog-1/2016/2/17/traveling-in-a-students-shoes> for examples).

In addition to asking students about their primary mode of transportation to school the City Schools’ School Climate Survey also asks high school students about their level of agreement with the following statement, “I feel safe going to and from school” -- 30 percent of students, regardless of travel mode, disagreed (see Table 5).

There are many reasons a student may not feel safe during his or her commute to school. For example, students who take public transit must walk through their neighborhood to reach the bus stop and then wait for the bus to arrive. Any real or perceived hazards that the student encounters during this time would likely be included in their perceptions of feeling safe during commuting. These concerns are likely to be shared by all students regardless of travel mode. That said, 1 in 3 students who use public transportation to get to school do not feel safe compared to 1 in 4 students who get to school in a private car. Further study is warranted to understand student perceptions of safety going to and from school and how these perceptions vary as a function of travel mode.

Table 5
Percent of students who disagree with the statement
“I feel safe going to and from school” by travel mode

Travel Mode	I Feel Safe Going to and from School: Strongly Disagree/Disagree
Public Transit	33.5
Walking	29.4
Car	25.1
School Bus	23.8
Total	30.3

Source: City Schools' School Climate Survey (2014-15); N = 8,196

Bottlenecks and Last-Mile Problems

A “bottleneck” is a well understood metaphor for conditions or other physical impediments that can cause delays. For our purposes we are using the term bottleneck to refer to places in the transportation network where congestion may occur that could impede a student from arriving to school on time.

The “last-mile” problem, a term used in telecommunications, transportation and logistics, is based on the observation that the last leg of service or package delivery is often the most difficult and inefficient. With respect to student commuting, the last-mile problem is related to how students navigate the final leg of their commute. For some students the final leg may require only a short walk from the last transit stop; for others the last mile might be more difficult.

Digital Harbor High School (Digital) is a case study of these problems. Compared to other high schools, Digital is physically located near the center of the transportation network in the Federal Hill neighborhood just south of downtown and the Inner Harbor. Both the MTA (Routes 1, 10, 64) and the Charm City Circulator (Purple, Banner) operate bus routes within walking distance of Digital (between .25 and .33 miles).

Digital is also served by morning and afternoon “tripper” bus service – as previously noted a tripper is a bus that deviates from its normal route to add a stop close to a school during peak travel times. We have listed the published tripper departure (from the Light & Redwood St. southbound bus stop) and arrival times in Table 6 as well as estimated travel times for walking and driving a car. In Figure 5 we have mapped Digital (noted as a yellow circle) in relation to the MTA routes and bus stops in its vicinity. The morning tripper (Route 64) is highlighted in green.

Table 6
Direct Travel Options between Light & Redwood St. and
Digital Harbor High Schools Before 8 a.m.

Mode	Depart	Arrive	Time
Tripper	7:34	7:38	4
Walk	7:35	7:59	24
Tripper	7:38	7:42	4
Tripper	7:41	7:45	4
Tripper	7:44	7:48	4
Tripper	7:47	7:51	4
Car	7:49 - 7:55	7:59	4 - 10

Note. Depart = Light & Redwood bus stop. Arrival = 1100 Covington St. (Digital). The table presents routes that are direct to the school. There are other routes (MTA 1 and 10, Circulator Purple and Banner) that run in proximity to Digital but would require additional walking to arrive at school. For sake of brevity we have omitted these routes from the table.

According to the published MTA schedule during the time period under study, the travel time from the Light and Redwood St. southbound bus stop (noted as a yellow star in Figure 5) is 4

minutes (see Table 6). This is unrealistic, however, as it would be very difficult for a bus to travel the 1.2 miles through this heavily congested area during morning rush hour in that amount of time.

As can be seen at the top of the map in Figure 5, downtown to the north and west of the Inner Harbor is a major nexus of the MTA transportation network – numerous bus lines and the Metro converge. In fact, the MTA system is specifically designed to deliver passengers into this area. Virtually all Digital students who live to the north of the Inner Harbor will have to navigate this area during their commute to school.

Further, while the network is dense in the downtown core, the last mile to Digital is relatively sparse with respect to transit options (see Figure 5 and Table 6).



Figure 5: Digital HS bottleneck and last mile problems

These factors simultaneously create a bottleneck and a last-mile problem for students commuting to Digital through downtown – students must compete with adults and other students for limited transit seats or decide to walk the remaining 1.2 miles to school.

Our route modeling allows us some visibility on the potential magnitude of these issues. Because our models assume that students are taking the most time efficient route that delivers them all at the starting time (Digital starts at 8 a.m.), we can observe the extent to which students end up on the same transit vehicle on the last leg of their commute. In the case of Digital, three final transit vehicles are used in our route estimates, however, one is overwhelmingly favored by our models.

If every student followed the exact route we modeled for them, the final morning tripper that is scheduled to arrive at Digital at 7:51 would have 1,141 students on it (85.7 percent of Digital students who take MTA). If we assume that this bus is filled exclusively with students with a standing-room-only capacity of 80 passengers, it would take 15 buses to meet this demand ($1,141/80 = 14.3$).

Digital is not unique among high schools in the likelihood of bottlenecks and last-mile problems. Again, assuming every student followed the exact route we modeled for them, 28 out of 37 high schools in our sample would have final vehicles that could be filled with high school students; most far above the 80-seat capacity. While we know that not every student commutes to school the way our models suggest, the thought experiment is still worthy of consideration. If every high school student attempted to get to school on-time, just before the morning bell, would the transportation system be able to handle the demand?

Summary

Obviously, many factors contribute to arriving to school on time, being ready to learn and succeeding in school. Transportation, however, is seldom recognized as one of them. Based on our modeling and the descriptive data presented in this report, Baltimore students appear to experience long and complicated commutes to school. These commutes are likely to be challenging, just as they are for adults, and are likely have consequences for valued student outcomes.

In many respects this report brings up more questions than it answers. What is the impact of commuting on student timely arrival at school? How stressful is commuting on students? Does commuting stress impact student physical and mental health? How does commuting impact student readiness to learn and academic outcomes? What underlies students' perceptions of safety going to and from school? What role does transportation and access to transportation play in student and family high school choice decisions? How might improvements to the transit system positively impact student commutes to school?

Ultimately no one – ourselves included – knows what the daily experience of commuting to school is like for all of Baltimore's high school students; the data simply does not exist and the research has not yet been done. In the near future we hope to bridge this gap through continued modeling, examination of secondary data sources and the collection of new primary data.

We believe that one thing is clear from these analyses – each and every day high school students must successfully navigate the city and its public transportation system on their way to school. Most of them manage it daily. It is critical that work be done to understand the developmental and academic consequences of this effort on students.

Methodological Appendix

We used administrative records of student home addresses and enrolled school during the 2014-15 school year to estimate routes to school, total travel time and number of transit vehicles required for the given route. These estimates were created using geographic information systems (GIS) software (ArcGIS) and schedule information (General Transit Feed Specification [GTFS] data) from the Maryland Transit Administration (MTA). GTFS is a standardized and widely used format for public transportation schedule information.

We began by geolocating students' residential locations from administrative data provided by City Schools. We limited the sample to 9th through 12th grade students who lived within Baltimore City and were not enrolled in one of the seven alternative or separate public day schools (e.g. special education schools) during the 2014-15 school year. Our final analytic sample involved 19,108 students enrolled in 37 high schools.

We created an estimate of each student's optimal route in terms of overall commute time from their residential address to their enrolled school using the Network Analyst tool suite in ArcGIS. Our models currently only consider two modes of commuting: walking or public transportation. Once the optimal routes were calculated, we ran the Copy Traversed Source Features (with Transit) tool (Morang & Stevens, 2016). This tool allows the capture of GTFS schedule information (e.g. vehicle type, time) of individual route edges that comprise a specific route.

As with all modeling exercises, the quality of the results depends on the assumptions used in the modeling. Our overarching assumption was that all students intend to arrive at school on time through the most direct and time efficient route. Specifically we assumed:

- Routes were estimated based on the MTA schedule for April 1, 2015
- Time of arrival was set to the opening bell time for each school.
- The published MTA schedule was strictly followed and assumed on-time.
- Walking speed was set to 3 miles per hour. This is considered to be the preferred walking speed of normal-weight adults (Browning, Baker, Herron, & Kram, 2006)
- We added 30 seconds to each trip every time a student would enter or exit a transit vehicle. Actual speeds of entry and exit can vary widely depending on crowding and speed of fare collection. We felt that a time cost of 30 seconds for entry and exit was a reasonable approximation of this potential variability.

From these data we created transit variables for each student in our analytic dataset. First a dichotomous variable *transit* captures whether a student's optimal route to school would require only walking or some form of public transportation. Our second transit variable, *vehicles*, captures the total number of transit vehicles (e.g. bus, subway) used for each route. This variable captures some of the complexity of a given transit route in that routes that require more vehicles, by definition, require students to navigate connections between vehicles and are more likely to expose students to external factors (e.g. heavy traffic, accidents, breakdowns) that could prevent a student from arriving at school on time or in extreme circumstances failing to arrive at school at all.

High school students who live more than 1.5 miles away from their high school are eligible to receive a monthly pass for transportation to school on MTA. Under these guidelines, approximately 9 in 10 Baltimore City high school students in our sample are eligible for transportation passes (n = 16,586; 86.8 percent). Our models indicate a similar percentage of students would need to use at least one transit vehicle during their commute school (n = 17,322; 90.1 percent).

Ridership

The first estimate of student ridership (see Table 2, Column A) uses our estimates of the number of transit vehicles needed by students to commute to school (see Table 4) to apportion our estimated number of high school public transportation users (see Table 1) into one of three categories based on the number of vehicles needed to commute to school. Based on the definition of ridership given in the narrative, we multiplied the number of students in each category by the number of vehicles needed (1, 2 or 3). Assuming that students will make a round trip from home to school each day, we multiplied this number by two and then again by five to arrive at the estimated weekday ridership of high school students. Our second estimate (see Table 2, Column B) discounts the student counts by a factor of .82 based on the average daily attendance rate (82 percent) for City Schools' high school students during the 2014-15 school year.

Student Surveys

Our estimates of high school students' mode of transportation used to commute to school and perceptions of feeling safe going to and from school come from a school survey administered to 6th through 12th grade students by City Schools during the 2014-15 school year. We limited responses to 9th through 12th grade students who were enrolled at one of the 37 high schools that formed the basis of our route modeling. Under these criteria there were a total of 8,664 surveys collected from a total of 20,419 enrolled students for an overall response rate of 42.4%. This response rate is very low and caution should be used in interpreting results based on this survey. That said, this survey represents, to our knowledge, the only available source of data on Baltimore City high school student travel modes and perceptions of safety going to and from school.

Sources

Browning, R., Baker, E., Herron, J., & Kram, R. (2006). Effects of obesity and sex on the energetic cost and preferred speed of walking. *Journal of Applied Physiology*, 100(2), 390-398.

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