Memorandum

To: Richard Nau, AICP
Vice President
URS Corporation

From: William Troe/Stephen Osberg

Date: August 2014

Subject: Ann Arbor Connector: WATS Traffic Model Update Methodology

Overview

This document describes the process and products developed as part of ridership and vehicle forecasts prepared for the Connector Alternatives Analysis in Ann Arbor, MI. Forecasts were developed using the WATS Travel Demand Model (TransCAD) and relied heavily on WATS Travel Demand Model Improvements Technical Memoranda 1-20, describing the initial setup of the model. The forecasting process involved three steps. First, links and nodes supporting each considered alignment were constructed in the model and assigned routes representing the Connector in BRT and LRT/streetcar formats. Second, the underlying roadway network was modified to reflect changes associated with the Connector, such as the removal of driving or turn lanes. Third, the existing bus system was modified to eliminate service redundant to the Connector. University of Michigan (U of M) and Ann Arbor Area Transportation Authority (AAATA) bus routes were removed, added, or truncated.

Beyond the modifications described herein, the model was left unchanged. The model runs use 2005 as the base year and 2040 as the horizon year. While the model updates were completed by SRF Consulting, WATS performed the actual model runs in-house.

The remainder of this document describes key restrictions encountered in the forecasting process and the steps taken by SRF to update the model. It also includes the methodology for various types of analysis performed on the completed model runs.

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1 Some attributes populated into the roadway network are from two closely related fields: one representing the model’s base year and one representing updated information from 2005, the base year of the study described herein. The field names reflect the difference with the presence or absence of “.05” after the variable name (e.g., FT vs. FT_05). Updates to the model appear in both the base field and “.05” field to ensure their use in all the model runs.
Key Restrictions/Assumptions

Listed in the following bulletpoints are the key restrictions and assumptions that influence the outputs and limit the amount of analysis of the ridership and/or traffic forecasts developed through use of the WATS model:

- Socioeconomic Data Confidentiality: The base period employment dataset used in the WATS model was developed by SEMCOG and provided to WATS. The employment dataset restricts viewing the information at the TAZ or in multiple zone aggregated format to WATS staff. As a result of the confidentiality of the information, a number of analyses of the ridership results were not feasible to complete. One of these was an analysis of the potential for the Connector to influence the vehicle trips per employee in the downtown area. The Connector Project Management Committee requested an analysis of the potential for the Connector to impact parking demand in the downtown area. The identified analysis methodology included estimating the trips per employee in the No-build and the range of Build alternatives. Restrictions on reporting the number of employees in the aggregated TAZs representing the downtown restricted the ability to complete the requested analysis. Thus, it was not completed.

- Transit Use Propensity: In many metro areas where there is a premium transit mode in place (i.e. BRT, LRT or streetcar) there is an observed greater potential for using transit across most trip lengths where the premium service is logical to use. In these areas, ridership forecasting methodologies typically take into account the difference in the desire to use the premium mode over the standard (or bus) mode. As premium transit modes are not present in the WATS study area, no added use propensity factor was included. Thus, any incremental ridership observed in the build the Connector alternatives relative to the No-build alternative reflects only the change in travel time associated with higher running speeds associated with less congestion in dedicated travel lanes and fewer stops.

- No Change in Intra-university Trips from Current to 2040 Horizon: A key portion of travel that influences ridership forecasts in the Connector study area is trips between and within campuses of the University of Michigan. A key assumption of the ridership forecasting process is that trip between campuses of the University of Michigan will not increase noticeably over the planning period that runs through the 2040 horizon. Trips between campuses observed today (quantified through the April 2013 boarding and alighting count program) were not increased for use in the 2040 forecasts. This assumption was reviewed with representatives of the University of Michigan and confirmed as logical due to the assumption that enrollment is forecasted to remain stable over the period.

- Connector Fare: Within the WATS travel demand model transit ridership is impacted by six interacting factors; transit travel time relative to auto, fare charged, dwell time at stops/stations, walk time to/from the stop/station and the actual origin/destination, wait time at stops/stations, the number transfers required to make a complete trip and persons preferences for using transit versus other modes. Fare assumptions for AAATA routes are set at $0.70 for
the initial boarding, with no “fare” for a transfer. This assumption represents a “typical” fare (not necessarily the average fare) across the range of actual fares paid by users from UM students, to full fare cash riders, to seniors, to multi-ride pass users, to children, etc. The WATS travel demand model also includes UM transit routes, which have a $0.00 (free) fare. As no operator has been defined at this stage, a fare sensitivity analysis was conducted to allow quantifying the potential impacts of the likely range of fares. The result of the sensitivity analysis was a fare free system would carry approximately 10 percent more riders than a system that required the typical AAATA fare ($0.70). All of the forecasts reported in later section of this memo reflect the $0.70 fare. Thus, represent a conservative estimate of ridership.

Building the Connector

Transit Link Placement
The roadway network is a GIS line file that defines the paths upon which trips will occur in the model. The first step in updating the WATS Travel Demand Model involved adding links to the roadway network in TransCAD to represent the proposed alignments of the Connector. The alignments for the routes were constructed in new links running parallel to existing links on the roadway network to reflect the exclusive nature of the proposed alignments (i.e., the proposed BRT and LRT alternatives do not operate in mixed traffic). There are short segments (approximately one block) on Alignments A, C, and D that do operate in mixed traffic, yet they were still added to the network as separate links parallel to the existing links to allow for greater control of Connector speed and reduce the impacts of intersection delay resulting from signal prioritization associated with the concept. All three of these alignments operate in mixed traffic for only short portions of their routes.

The links provided for the Connector only interact with the roadway network’s nodes at the planned transit stops. Additional detail is provided on the stops in a later section.

Direction of Flow
All links supporting the Connector were assigned a two-way direction of flow (Dir=0, Dir_05=0) regardless of whether the links carry two-way travel. When the northbound and southbound routes travel along different roads, each direction was provided with its own set of links in the portion of the route where directions are separated. Despite some links only seeing one-way travel, the links were assigned two-way flow to minimize complications in running the model. The directionality of one-way travel in the Connector was accounted for in the model’s transit route system, as described later in this document.
Facility Type

Each link in the roadway network is assigned a facility type (“FT” field in the attribute table) that governs the modes of travel it can support. Links added to the roadway network for the Connector were assigned a facility type “Transit Only” (FT=52). This is the approach recommended in *WATS Travel Demand Model Improvements Technical Memorandum #2 – Roadway Network Structure* for use with the “modeling of transit service utilizing an exclusive right of way, such as commuter rail, light rail, or bus rapid transit” (p.8).

Connector Speeds

The travel speeds assigned to each link in the model are critical components of the trip distribution and assignment process. Freeflow speeds on links related to the Connector were entered into a transit speed override field (“TR_OR”), which was added to the network as part of the Connector forecasting work. The override field was used because the default freeflow speed employed in the model for the Transit Only facility type (FT=52) is 15 mph, below the actual speed expected for the Connector. This default speed could not be modified as part of the Connector forecasting.

Two techniques were used when populating the speed override fields for BRT alternatives. First, where possible, freeflow speeds were assigned to the Connector’s links that matched the closest roadway link traveling in approximately the same direction. It was assumed that the Connector, when occupying a lane in a street, would travel at approximately the same speed as neighboring auto traffic. In some instances, however, the transitway travels in its own right of way where there are no parallel roads whose speeds would be appropriate to duplicate (e.g., Alignment C in the former freight rail corridor near the Ross Athletic Campus). In such cases, average station-to-station speeds were calculated based on travel time estimates for BRT provided by URS. The average station-to-station speeds were input into the corresponding links in the model.

In the concept design, the LRT/streetcar speeds are assumed to be slightly faster than the BRT speeds. Over the length of the corridor, LRT/streetcar travel times were approximately five percent lower than BRT concept travel times. This five percent interval was fairly consistent along the northern and southern parts of the route. Thus, LRT/streetcar defined speeds were set at five percent higher than BRT speeds.

Connector Routes

Each proposed alignment of the Connector was assigned two routes in the model’s transit route system, one route traveling in each direction. Maps of each alignment and its stops/stations appear

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2 Default speeds for centroid connectors and transit links can be found in Table 2.10 of *WATS Travel Demand Model Improvements Technical Memorandum #2 – Roadway Network Structure* (p. 26).

3 The travel time calculations provided by URS appear in the Appendix.
in the appendix. The key route system fields requiring population in the model include the following:

- Peak and off-peak headway ("PEAK_HEADWY" and "MIDDAY_HEADWY") – Peak and off-peak headway are identical for the Connector’s routes. All BRT routes were assigned two-minute headways, and all LRT/streetcar routes were assigned five-minute headways.

- Route operator ("COMPANY") – All routes associated with the Connector were assigned to AAATA for operations (COMPANY=AATA). Identifying an operator impacts a route’s access to certain park-and-ride lots and defines transfer penalties in the model. The selection of AAATA as the operator for the Connector results in transfer penalties more consistent with similar operating systems.

- Fare ("FARE") – Fares for all Connector routes were set at $0.70, consistent with other AAATA routes in the model.

- Transfer fare ("X_FARE") – Transfer fares for all Connector routes were set at $0, consistent with all other routes in the model.

- Transfer Penalties – Requiring passengers to use multiple routes to travel between their origin and destination is generally considered a negative of transit service. In the WATS model the negative perception of requiring transfers is addressed as a Transfer Penalty. Penalties included in the base model are:
  - AAATA Routes: Seven minutes per transfer in the peak or off-peak, respectively.
  - Intra-UM: An additional two minutes of penalty time was added to the seven or nine minutes.

  To account for a shorter headway between transit vehicles (two minutes for BRT and 5 minutes for LRT) in the build the Connector scenario relative to typical bus service in Ann Arbor, a lower transfer penalty of 0.4 minutes was added to the AAATA Route Transfer Penalty.

The model dynamically adjusts trip making to account for the relative ease of making trips using travel time as a proxy. The adjustment occurs through the costs assigned to transit trips in wait times (before the original boarding and at transfers) and walk times from origins and to destinations to/from transit stops/stations. Additionally, time is added to transit trips requiring transfers in the form of transfer penalties to account for the reluctance of passengers to transfer between transit vehicles during a trip. Transit paths and mode choice are calculated in the first iteration of speed

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4 A complete list of route system variables and a more detailed description of their definitions can be found in WATS Travel Demand Model Improvements Technical Memorandum #5 – Transit Route System and Network Development.

5 To calculate average wait times for transit service, the model divides the headways in half. However, it imposes a minimum of two minutes of wait time. Thus, average wait times in the model are two minutes for BRT and two minutes thirty seconds for LRT/streetcar.
feedback in the model run, and the resultant transit skim is used in interim iterations. The transit paths and mode choice are recomputed once speed feedback convergence has been met.\(^6\)

**Stops/Nodes**

The locations of the transit system nodes representing stops/stations along the Connector are based on the “Potential Station Locations for Evaluation” in the alignment maps provided by URS.\(^7\) Many of the areas designated as potential station locations in the maps are multiple blocks long. However, stop locations in the model must be placed at specific points. Modeled stops were placed directly next to the roadway network nodes and located within the potential station location areas. Roadway network nodes designated as stops/stations were selected to maximize use of existing connections to TAZ centroids through walk connector links and the proximity to designated stops for local buses to facilitate transfers. Stop nodes were placed along the Transit Only links (FT=52) dedicated to the Connector. As with the Connector’s routes, there are separate stops assigned to each direction of travel.

**Park and Ride Nodes**

Nodes representing park-and-ride (PnR) lots were added to the north and south ends of the Connector to provide adequate drive access to the routes. Alignments C1 and E1 had a PnR node added only to the north end since their southern portions are in downtown Ann Arbor, a place where drive access to transit is less substantial. For all alignments, the northern PnR node is at the intersection of Green and Plymouth Roads. For Alignments A, B, C, D, and E, the southern PnR node is at the intersection of State Street and Hilton Boulevard. Alignment F’s southern PnR node is at the intersection of Main Street and Eisenhower Parkway.

The PnR nodes were assigned to the AAATA system (PNR=1, PNR_05=1, PNROP=AATA, and PNROP_05=AATA), which allows both U of M transit routes and AAATA routes to use them in the model.\(^8\)

**Modifying the Underlying Roadway System**

As the Connector moves through Ann Arbor, it often travels along existing rights of way. Space on the streets currently devoted to other uses must be reallocated to provide a dedicated guideway for transit travel. Uses impacted include through lanes, center turn lanes, and/or on-street parking. The portion of the street most commonly transferred for exclusive use of the Connector is on-street

\(^6\) Additional information on the speed feedback process can be found in *WATS Travel Demand Model Improvements Technical Memorandum #16 – Speed Feedback*.

\(^7\) Alignments A, B, C, D, E, and F are from figures dated January 6, 2014. Alignments C1 and E1 are from figures dated April 4, 2014.

\(^8\) Additional information on PnR nodes can be found in of *WATS Travel Demand Model Improvements Technical Memorandum #5 – Transit Route System and Network Development* (p. 8).
parking, principally in the downtown area. On-street parking does not factor into the road capacity calculations in the WATS Travel Demand Model, so changes in parking were not coded into the system. On the other hand, the number of travel lanes and the presence of center turn lanes both affect the model's capacity and congestion calculations, so alterations to those facilities were added to the roadway network of each proposed alignment.9

The travel lanes removed varied between each alignment. Alternatives included removing one lane in each direction or removing one lane in only one direction. For alternatives traveling south along State Street, including the Connector would require removing the center turn lane on the north side of Eisenhower Parkway.

**Modifying Bus Service**

**Current Route Removals**

The following U of M routes were removed entirely from the model for all alignments:10

- Commuter
- Northwood
- Northwood Express
- Bursley-Baits
- Diag-to-Diag
- North Campus
- Research Link

**Current Route Truncation**

Three bus routes were truncated in the process of adding the Connector to reduce duplicative service.

U of M Route:
- Intercampus – Retained from the North Campus Research Complex to the east only for all alignments. Stops west of the intersection of Nixon and Plymouth Roads were removed.

AAATA Routes:
- Route 6 – Truncated at Stadium Boulevard for all alignments except for Alignment F. Stops north of the intersection of Stadium Boulevard and State Street were removed.

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9 Adjustments to the roadway network are based on alignment maps provided by URS, dated January 6, 2014 and April 4, 2014.

10 The Oxford, Intercampus (labeled “UMHS_to_Arbor_Lakes” and “UMHS_to_NIB” in the model), and Med Express (labeled “Mitchell_Glazier” in the model) U of M routes were retained.
• Route 7 – Truncated at Briarwood Mall for Alignment F only. Stops north of Briarwood Circle and State Street were removed.

New Shuttle Routes Added

To support intra-campus travel, the two new U of M routes were defined in the north campus area; the Northwood Shuttle and the Baits-Stone Shuttle. Figures 1 and 2 display the routes and associated stops as added to the model.

Figure 1. Northwood Shuttle Route and Stops

Figure 2. Baits-Stone Shuttle Route and Stops
Intra-University Trip Table

A unique element of the WATS travel demand model, relative to the SEMCOG model, is addressing trips between the three primary campuses in Ann Arbor; North Campus, Central Campus and South/Ross Athletic Campus. Within the modeling structure trips between the campuses listed are contained in the Intra-university Trip Table. The intra-campus trip table includes the following:

- Trips that stay on campus made by students living in campus housing.
- Trips between classrooms on each campus made by students and faculty.
- Trips from one part of campus to another made by students, faculty and staff not related to classroom activity (for example: trips to and from recreation facilities that have an origin and a destination on campus).
- Student trips to/from on-campus jobs that start and end within the boundaries of the UM Ann Arbor campus.

Trips to/from the Medical Campus are addressed in the modeling structure, but are not included as part of the intra-university trip table.

Intra-university trips are developed using a spreadsheet-based approach outside the general and special generator trip generation and distribution structure, with these trips then being assigned consistent with other trips in the region.

During the feasibility study portion of the Connector analysis the methods, assumptions and results of how the WATS model addresses intra-university trips was evaluated and resulted in the following findings:

- Person trip generation rates borrowed from surveys at other universities are likely appropriate and adequate for the WATS model and for the Connector analysis.
- The relative interchange of trips between each of the campuses in the version of the model in place at the beginning of the feasibility study likely did not reflect actual conditions. In the feasibility study the relative travel between each of the campus pairs (Central Campus to/from North Campus, North Campus to/from South-Ross Athletic Campus, etc.) was modified based on input received from members of the project steering committee with knowledge of general interaction levels. The recommended adjustments identified in the Connector feasibility study were incorporated into the WATS model procedures and are reflected in the based condition model parameters for the Connector Alternatives Analysis.
- The intra-university mode split distribution did not likely reflect actual conditions in the unique setting of the university. The mode split model developed for the entire WATS area was also employed to convert campus-based person trips into auto driver, auto passenger, transit, walk and bicycle trips. The vast majority of trips were assigned to auto-based modes and/or walking
trips, with a very low percentage of trips being allocated to transit. Parking congestion observed through most of the day on each of the campuses and the relatively limited time between classes did not logically support a high auto mode percentage. In addition, the distance between at least the North Campus and the Central Campus and the relatively short passing period between classes did not logically support a high walk trip percentage between the campuses.

To address the concerns of whether the WATS model intra-university trip mode split reasonably reflected actual conditions an additional data collection effort to obtain information on actual travel between campuses and the mode of travel was completed. In April 2013 stop-by-stop boarding and alighting information was gathered for the six principal UM Parking and Transportation Services routes. The selected routes account for approximately 87 percent of the daily ridership. The non-surveyed routes (Research Link, Oxford Shuttle, Intercampus) each account for less than five percent of the daily ridership and they provide trips between similar origins and destinations as the surveyed routes. As the routes that were not in the April 2013 data collection effort connect similar origin-destination pairs as the surveyed routes, it was assumed the travel patterns observed from the surveyed routes would be representative of those not included in the survey. Thus, origin-destination patterns observed from the survey could be factored to account for ridership of the non-surveyed routes.

During the survey boarding and alighting information was collected in a manner that would allow for reasonable construction of an origin-destination matrix for trips between each of the current stops, including:

- Data was organized such that boardings and alightings for each run by direction over the collection period was retained in a separate file. With the limited number of stops present on most routes, a logical connection between where a person likely boarded a bus and where they likely got off the bus could be identified.

- Data collected at stops served by multiple routes was retained in unique files for each route.

- Times of the boardings and alightings were recorded to allow reconstruction and connectivity of activity at each stop to upstream and downstream stops on the same route.

Stop level origin and destination data from the April 2013 survey was aggregated to the traffic analysis zone (TAZ) level in order to allow comparison to the pre-survey inter and intra campus distribution. The April 2013 survey data required the following adjustments to provide a dataset representative of the typical weekday (which is the trip defined in the WATS model):

- Hours of the day: The survey was conducted from approximately 7:30 AM through 7:00 PM, while UM shuttles operate from as early as 6:00 AM to as late as 1:30 AM. Survey data for the approximately 12 hours was factored on a route by route basis to represent the percentage of average total daily ridership occurring over the approximately 19 hour operating day.
- Factoring to account for route not surveyed: The six routes on which boardings and alightings were collected for each run in either direction represent approximately 87 percent of the daily ridership. The account for activity on those routes not surveyed, the cumulative matrix was factored up by 13 percent to reflect the percent of daily trips on routes not surveyed.

Table 1 displays the intra-campus trips derived from the April 2013 boarding and alighting collection efforts.

The campus level trip interchanges were disaggregated for use in the WATS regional model based on the WATS trip generation estimates for each traffic analysis zone within each of the campus areas. The product of this step in the process was the final intra-university transit trip table that was inserted into the WATS modeling process. The intra-university transit trip table derived for the Connector Alternatives Analysis replaced the former transit mode intra-university trip table generated from the mode split module of the model. Intra-university pedestrian, bike and auto trips from the original WATS methodology were not revised as none of these trips are assigned to the multimodal network. Thus, they do not impact the analysis completed for the Connector Alternatives Analysis. Table 2 displays the traffic analysis zone level intra-university transit trip table derived through the Connector update. Figure 3 displays the traffic analysis zone boundaries and numbering for the zones included in the intra-university trip table.

Table 1. Trip Interchanges Between University of Michigan Campuses

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Table 2. Intra-university Transit Trip Table
Figure 3. Traffic Analysis Zones Containing Intra-university Trips
Analysis of Results

The outputs of the model runs were analyzed in several ways to better understand the relative impacts of the different alignments. This section describes the processes used in the examination and briefly summarizes the outcomes.

Boarding and Alighting by Stop

Methodology

The following steps were used to determine the daily number of passengers boarding and alighting at Connector stops for each alignment:

1. The model output file “Tasn_Day_OnOff.bin” was joined with each transit stop node file in TransCAD, and the data associated with the Connector were exported into Excel.

2. Boardings and alightings were calculated for each Connector station. Because boardings and alightings at each station are presented separately for routes representing northbound and southbound travel on the Connector, ons and offs from the two routes were summed to obtain the total number of passengers boarding or alighting at each station.

3. The number of people traveling along route segments between each Connector stop was calculated. Looking at each direction of travel separately, the number of people traveling on each segment was determined by adding the difference between passengers boarding and alighting at each station and the people onboard the segment before that station. Then, the passengers traveling in either direction were summed for each segment.

Results

The results of the ons/offs and onboard calculations appear in Tables 3 through 5.

Transit Ridership

Methodology

The model directly provides estimates of daily boardings on the Connector and total ridership for the entire transit system (including buses and the Connector). To better understand the ridership pressure on the Connector during periods of peak demand, peak hour and peak direction in peak hour boardings were estimated. In calculating peak hour boardings, it was assumed that 10.2 percent of daily ridership takes place during the peak hour of service. It was further assumed that 67 percent of passenger travel occurs in the peak direction during the peak hour.11

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11 Peak hour and peak direction proportions were derived from UM driver boarding summaries by run for the April 2013 survey period.
Table 3. BRT Ons/Offs by Station and Onboard by Segment – Alignments A, B, C, D, E, and F

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<td></td>
<td>7,130</td>
<td></td>
</tr>
<tr>
<td>Central Campus (CC Little)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Segment (E1 one-way)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downtown Ann Arbor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Segment (E1 one-way)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blake Transit Center</td>
<td>4,620</td>
<td>2,650</td>
<td>4,540</td>
<td>2,590</td>
</tr>
<tr>
<td>Segment (E1 one-way to Central Campus)</td>
<td>3,160</td>
<td></td>
<td>3,160</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>31,330</td>
<td>31,330</td>
<td>30,750</td>
<td>30,740</td>
</tr>
</tbody>
</table>
Results

Ridership forecasts for the Connector and the entire transit system appear in Table 6.

Vehicle Miles Traveled and Vehicle Hours Traveled

Methodology

Understanding the impacts of the Connector on overall travel in the region is an important component of evaluating the proposed alternatives. The model generates estimates of vehicle miles traveled (VMT) and vehicle hours traveled (VHT) for each alternative under consideration. VMT and VHT values reported for each alternative scenario represent only autos and trucks. Transit forecasts from the modeling stream provides an estimate of riders, but does not convert those riders to the number of buses needed to transport them. Thus, transit vehicles are not included in the estimate of VMT and VHT.

Results

Table 7 shows the estimated vehicle miles traveled (VMT) within the city limits of Ann Arbor for each alternative.

Zero Fare Assessment

Methodology

As noted earlier, AAATA routes were assigned average fares of $0.70, and U of M routes were assigned fares of $0.00. The Connector was designated as an AAATA route and assigned an average fare of $0.70, but one alternative was rerun with Connector fares set at $0.00 to examine the impact of fare (and operator, indirectly) on Connector and transit system ridership, VMT, and VHT.

Results

Table 8 compares the effects of fare on Connector and transit system ridership, citywide VHT, and citywide VMT for BRT Alternative E1.
Table 6. Connector and Transit System Ridership Forecasts

<table>
<thead>
<tr>
<th>Option</th>
<th>BRT</th>
<th>LRT</th>
<th>BRT</th>
<th>LRT</th>
<th>BRT</th>
<th>LRT</th>
<th>Total Transit System Ridership (Daily)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt A</td>
<td>34,700</td>
<td>33,800</td>
<td>3,500</td>
<td>3,400</td>
<td>2,300</td>
<td>2,300</td>
<td>57,200</td>
</tr>
<tr>
<td>Alt B</td>
<td>36,600</td>
<td>35,700</td>
<td>3,700</td>
<td>3,600</td>
<td>2,500</td>
<td>2,400</td>
<td>57,600</td>
</tr>
<tr>
<td>Alt C</td>
<td>35,900</td>
<td>35,200</td>
<td>3,700</td>
<td>3,600</td>
<td>2,500</td>
<td>2,400</td>
<td>57,500</td>
</tr>
<tr>
<td>Alt D</td>
<td>35,900</td>
<td>35,100</td>
<td>3,700</td>
<td>3,600</td>
<td>2,500</td>
<td>2,400</td>
<td>57,400</td>
</tr>
<tr>
<td>Alt E</td>
<td>37,500</td>
<td>36,700</td>
<td>3,800</td>
<td>3,700</td>
<td>2,500</td>
<td>2,500</td>
<td>58,000</td>
</tr>
<tr>
<td>Alt F</td>
<td>37,600</td>
<td>36,900</td>
<td>3,800</td>
<td>3,800</td>
<td>2,500</td>
<td>2,500</td>
<td>58,100</td>
</tr>
<tr>
<td>Alt C1</td>
<td>31,300</td>
<td>30,700</td>
<td>3,200</td>
<td>3,100</td>
<td>2,100</td>
<td>2,100</td>
<td>54,400</td>
</tr>
<tr>
<td>Alt E1</td>
<td>32,300</td>
<td>31,600</td>
<td>3,300</td>
<td>3,200</td>
<td>2,200</td>
<td>2,100</td>
<td>55,300</td>
</tr>
<tr>
<td>Base</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55,100</td>
</tr>
</tbody>
</table>

Table 7. Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT) within Ann Arbor

<table>
<thead>
<tr>
<th>Option</th>
<th>Vehicle Miles Traveled in Ann Arbor (VMT, Daily)</th>
<th>Congested Vehicle Hours Traveled (VHT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRT</td>
<td>LRT</td>
</tr>
<tr>
<td>Alt A</td>
<td>2,583,000</td>
<td>2,583,600</td>
</tr>
<tr>
<td>Alt B</td>
<td>2,591,700</td>
<td>2,583,000</td>
</tr>
<tr>
<td>Alt C</td>
<td>2,586,800</td>
<td>2,586,800</td>
</tr>
<tr>
<td>Alt D</td>
<td>2,585,900</td>
<td>2,585,800</td>
</tr>
<tr>
<td>Alt E</td>
<td>2,582,900</td>
<td>2,583,600</td>
</tr>
<tr>
<td>Alt F</td>
<td>2,571,400</td>
<td>2,570,700</td>
</tr>
<tr>
<td>Alt C1</td>
<td>2,590,400</td>
<td>2,589,700</td>
</tr>
<tr>
<td>Alt E1</td>
<td>2,589,700</td>
<td>2,590,300</td>
</tr>
<tr>
<td>Base</td>
<td>2,593,600</td>
<td></td>
</tr>
</tbody>
</table>
Table 8. BRT Alignment E1: Typical $0.70 Fare vs. $0.00 Fare

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Alt E1 w/ $0.70 Fare (BRT)</th>
<th>Alt E1 w/ $0.00 Fare (BRT)</th>
<th>Change</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector Boardings (Daily)</td>
<td>32,300</td>
<td>35,600</td>
<td>3,300</td>
<td>+10.2%</td>
</tr>
<tr>
<td>Connector Boardings (Peak Hour)</td>
<td>3,300</td>
<td>3,600</td>
<td>300</td>
<td>+9.1%</td>
</tr>
<tr>
<td>Connector Boardings (Peak Hour - Peak Direction)</td>
<td>2,200</td>
<td>2,400</td>
<td>200</td>
<td>+9.1%</td>
</tr>
<tr>
<td>Total Transit Ridership (Daily)</td>
<td>55,300</td>
<td>57,800</td>
<td>2,500</td>
<td>+4.5%</td>
</tr>
<tr>
<td>Vehicle Miles Traveled in Ann Arbor (Daily VMT)</td>
<td>2,589,700</td>
<td>2,587,000</td>
<td>-2,700</td>
<td>-0.1%</td>
</tr>
<tr>
<td>Vehicle Hours Traveled in Ann Arbor (Daily VHT)</td>
<td>117,600</td>
<td>115,700</td>
<td>-1,900</td>
<td>-1.6%</td>
</tr>
</tbody>
</table>

Note: Analysis completed for Alternative E1 Only. Assume relative changes are transferable to other alternatives.

Congestion

Methodology

Analysis of changes in congestion levels resulting from implementation of the Connector was performed by calculating volume-to-capacity ratios for links in the roadway network. The model uses a method of post processing described in NCHRP Report 255 to provide forecasted daily traffic estimates at the link level. NCHRP-post-processed volumes are available for minor and major arterials, expressways, and freeways only; so congestion analysis was confined to links representing these types of roads within the city limits of Ann Arbor. Two-way daily volume inputs are found in the field “TOT_FLOW_NCHRP” and were used as the volume components of the V/C ratio calculations.

Capacity is provided in the model in a one-way hourly format. It represents the point at which LOS E traffic transitions to LOS F traffic. In order to calculate V/C ratios, capacity for each link was converted into a two-way daily format. To accomplish this, one-way capacity was first divided by 60 percent to get a two-way hourly capacity representing an estimated 60-40 directional split in peak hour flow (AB_CAP/0.6).

Next, the hourly two-way capacity was converted to two-way daily capacity. Travel patterns are not equally distributed throughout the day, so it would be inappropriate to simply multiply the hourly capacity by 24 hours to get the daily capacity. Rather, the conversion must be based on the

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12 Additional information on the post processing procedures can be found in WATS Travel Demand Model Improvements Technical Memorandum #18 – NCHRP Post Processor.

13 See WATS Travel Demand Model Improvements Technical Memorandum #2 – Roadway Network Structure for more information on roadway capacity in the model.
proportion of travel occurring in the peak hour of travel. Based on traffic counts performed by the Michigan Department of Transportation, the peak hour of travel in Ann Arbor is from 5:00 to 6:00 PM. According to the counts, 9.7 percent of all travel takes place during that hour. Accordingly, the hourly two-way capacity was divided by 9.7 percent (0.097) to get the two-way daily capacity.

V/C ratios were calculated by dividing the NCHRP volumes by the calculated two-way daily capacities. Because congestion occurs at a point before LOS E transitions to LOS F, a V/C ratio of 0.9 was considered the threshold where congestion occurs.

**Results**

Tables 9 and 10 display the number of congested miles within Ann Arbor by V/C ratio for each of the proposed alignments.

**Table 9. Congested Lane Miles within Ann Arbor City Limits Alternatives A through F**

<table>
<thead>
<tr>
<th>VC Ratio</th>
<th>Base</th>
<th>Alt A</th>
<th>Alt B</th>
<th>Alt C</th>
<th>Alt D</th>
<th>Alt E</th>
<th>Alt F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRT</td>
<td>LRT</td>
<td>BRT</td>
<td>LRT</td>
<td>BRT</td>
<td>LRT</td>
<td>BRT</td>
</tr>
<tr>
<td>1.25 +</td>
<td>15.2</td>
<td>15.4</td>
<td>15.2</td>
<td>15.2</td>
<td>15.4</td>
<td>15.4</td>
<td>15.4</td>
</tr>
<tr>
<td>1.15-1.24</td>
<td>3.9</td>
<td>3.1</td>
<td>1.66</td>
<td>3.4</td>
<td>2.0</td>
<td>1.7</td>
<td>3.1</td>
</tr>
<tr>
<td>1.00-1.14</td>
<td>11.4</td>
<td>11.8</td>
<td>13.3</td>
<td>9.2</td>
<td>11.1</td>
<td>12.8</td>
<td>11.4</td>
</tr>
<tr>
<td>0.90-0.99</td>
<td>12.1</td>
<td>13.2</td>
<td>10.7</td>
<td>13.7</td>
<td>13.1</td>
<td>13.6</td>
<td>13.6</td>
</tr>
<tr>
<td>Total</td>
<td>42.6</td>
<td>43.5</td>
<td>41.1</td>
<td>41.5</td>
<td>41.4</td>
<td>43.5</td>
<td>43.5</td>
</tr>
</tbody>
</table>

---

14 See Table 14.1 in *WATS Travel Demand Model Improvements Technical Memorandum #14 – Time of Day Analysis* (p.5).
Table 10. Congested Lane Miles within Ann Arbor City Limits Alternatives C1 and E1

<table>
<thead>
<tr>
<th>VC Ratio</th>
<th>Alt C1</th>
<th></th>
<th>Alt E1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRT</td>
<td>LRT</td>
<td>BRT</td>
<td>LRT</td>
</tr>
<tr>
<td>1.25 +</td>
<td>15.4</td>
<td>15.2</td>
<td>15.4</td>
<td>15.2</td>
</tr>
<tr>
<td>1.15-1.24</td>
<td>3.6</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>1.00-1.14</td>
<td>10.9</td>
<td>11.4</td>
<td>11.3</td>
<td>11.4</td>
</tr>
<tr>
<td>0.90-0.99</td>
<td>13.6</td>
<td>13.6</td>
<td>13.7</td>
<td>13.9</td>
</tr>
<tr>
<td>Total</td>
<td>43.5</td>
<td>43.3</td>
<td>43.5</td>
<td>43.6</td>
</tr>
</tbody>
</table>

Note: The V/C ratios presented in Table 4 represent only arterial routes. Congested collector miles exist; however, they are not included in the analysis as no post-processing is done at the collector level.
Appendix A: Connector Routes and Stations
Figure 4: Connector Alignment Alternative A
Figure 5: Connector Alignment Alternative B
Figure 7: Connector Alignment Alternative D
Figure 9: Connector Alignment Alternative F
Figure 10: Connector Alignment Alternative C1
Figure 11: Connector Alignment Alternative E1
Appendix B: Connector Travel Times
### Alignment A

<table>
<thead>
<tr>
<th>Segment</th>
<th>Speeds (MPH)</th>
<th>Traffic Signals</th>
<th>Station Dwell Time</th>
<th>Times (seconds)</th>
<th>Distances (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start</td>
<td>End</td>
<td>Maximum</td>
<td>(sec)</td>
<td>Start</td>
</tr>
<tr>
<td>End of Line: Station 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Plymouth Rd - Green Rd to Station 2</td>
<td>3.433</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>Plymouth Rd - Station 2 to Murfin Ave</td>
<td>4.329</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Murfin Ave - Plymouth Rd to Station 3</td>
<td>2.47</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Murfin Ave - Station 3 to Station 4</td>
<td>2.182</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>Murfin Ave - Station 4 to Bonisteel Blvd</td>
<td>10.94</td>
<td>0</td>
<td>10</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Bonisteel Blvd - Curve to Fuller Rd</td>
<td>4.07</td>
<td>10</td>
<td>10</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Fuller Rd - Bonisteel Blvd to River</td>
<td>3.54</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>New ROW - Fuller Rd to Rainroad ROW</td>
<td>3.05</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Rainroad ROW - Curve to Station 5</td>
<td>1.32</td>
<td>10</td>
<td>10</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Rainroad ROW - Station 5 to Glen Ave</td>
<td>3.02</td>
<td>10</td>
<td>10</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Glen Ave - Curve to Station 8</td>
<td>1.23</td>
<td>10</td>
<td>10</td>
<td>55</td>
<td>1</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Honig St - Glen Ave to Station 7</td>
<td>1.015</td>
<td>10</td>
<td>10</td>
<td>39</td>
<td>1</td>
</tr>
<tr>
<td>Honig St - Station 7 to State St</td>
<td>2.31</td>
<td>10</td>
<td>10</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>State St - Huron St to Washington St</td>
<td>1.15</td>
<td>5</td>
<td>5</td>
<td>13</td>
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</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Washington St - State St to 8 Ave</td>
<td>1.22</td>
<td>5</td>
<td>5</td>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>Curve</td>
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<td>-</td>
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<td>-</td>
<td>0</td>
</tr>
<tr>
<td>9 Ave - Washington St to 8 Ave</td>
<td>1.097</td>
<td>5</td>
<td>5</td>
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<td>2</td>
</tr>
<tr>
<td>8 Ave - Station 8 to Madison St</td>
<td>1.043</td>
<td>5</td>
<td>5</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Madison St - 5th Ave to Main St</td>
<td>5.58</td>
<td>5</td>
<td>5</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
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<tr>
<td>Main St - Madison Ave to Station 9</td>
<td>2.29</td>
<td>5</td>
<td>5</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Main St - Station 9 to Stadium Blvd</td>
<td>1.25</td>
<td>0</td>
<td>5</td>
<td>39</td>
<td>1</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Stadium Blvd - Main St to Industrial Hwy</td>
<td>3.88</td>
<td>5</td>
<td>5</td>
<td>39</td>
<td>1</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Industrial Hwy - Station 10 to Stimson St</td>
<td>1.96</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Stimson St - Industrial Hwy to State St</td>
<td>5.62</td>
<td>5</td>
<td>5</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>State St - Stimson St to Station 11</td>
<td>3.39</td>
<td>5</td>
<td>5</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>State St - Station 11 to Mall Dr</td>
<td>2.79</td>
<td>10</td>
<td>10</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Mall Dr - Station 11 to Market Pl</td>
<td>4.63</td>
<td>5</td>
<td>5</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Curve</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
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### Station to Station Travel Times

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### Station to Station Travel Times (2009)

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### Station to Station Travel Times (2009)

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Alignment A

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**TOTALS:**

- **Total Distances:** 40,062 feet, 12,980 miles, 2021 seconds, 5.65 minutes
- **Average Speed:** 41.8 MPH
- **Acceleration:** 0.18 sec/ft
- **Deceleration:** 0.32 sec/ft

**Station to Station Travel Times**

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<th>Station</th>
<th>Travel Time (seconds)</th>
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<tr>
<td>11 to 10</td>
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<td>3 to 2</td>
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**TOTAL:** 2,281 seconds
# Alignment B - Estimated Southbound Travel Times

## The Connector - Preliminary Route Alternatives

### Speeds (MPH) Traffic Signals Station Dwell Time Times (seconds) Distances (Feet)

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<th>Length(ft)</th>
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<th>End</th>
<th>Maximum</th>
<th>(s)</th>
<th>(sec)</th>
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<th>Decel</th>
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### Station to Station Travel Times

<p>| Station 1 to Station 10 | 194 | seconds |
| Station 10 to Station 9 | 163 | seconds |
| Station 9 to Station 8 | 115 | seconds |
| Station 8 to Station 7 | 332 | seconds |
| Station 7 to Station 6 | 237 | seconds |
| Station 6 to Station 5 | 270 | seconds |
| Station 5 to Station 4 | 253 | seconds |
| Station 4 to Station 3 | 77 | seconds |
| Station 3 to Station 2 | 184 | seconds |
| Station 2 to Station 1 | 94 | seconds |
| <strong>TOTAL:</strong> | 1,919 | seconds |</p>
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<th>Distances (Feet)</th>
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### Station to Station Travel Times

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<td>Station 3 to Station 4</td>
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<td>Station 4 to Station 5</td>
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<td>Station 5 to Station 6</td>
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<td>Station 6 to Station 7</td>
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The Connector - Preliminary Route Alternatives

Alignment C

BRT - Estimated Southbound Travel Times

URS Corporation

12/23/2013 DRAFT
### Alignment C - BRT - Estimated Northbound Travel Times

#### Stations and Travel Distances

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<th>Segment</th>
<th>Length (ft)</th>
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<th>Maximum Speed (MPH)</th>
<th>Traffic Signals</th>
<th>Station Dwell Time (sec)</th>
<th>Times (seconds)</th>
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### Station to Station Travel Times

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<th>Traffic Signals</th>
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### Distances (Feet)

- Distances: Station 6 to Station 7
- Distances: Station 7 to Station 8
- Distances: Station 8 to Station 9
- Distances: Station 9 to Station 10
- Distances: Station 10 to Mall Dr
- Distances: Mall Dr to Market Pl
- Distances: Market Pl to Briarwood Cir

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**Total Travel Time:** 1587 seconds
## Alignment D  BRT - Estimated Northbound Travel Times

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### Speeds (MPH) Times (seconds)

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<td>20.6 ft/sec 1844 Seconds</td>
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<td>7.20 miles</td>
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### Traffic Signals

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<td>Station 8 to Station 11</td>
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<td>Station 6 to Station 5</td>
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### Station to Station Travel Times

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<td>34 seconds</td>
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### Acceleration and Deceleration Rates

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### TOTAL:

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### Alignment E - Preliminary Route Alternatives

#### Traffic Signals Station Dwell Time

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<th>Decelerate</th>
<th>At-Speed</th>
<th>Total Time</th>
<th>Accelerate</th>
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### Speeds (MPH) Times (seconds) Distances (Feet)

- **Speeds (MPH)**
- **Times (seconds)**
- **Distances (Feet)**

**End-of-Line: Station 1**
- 0 to 0

**End-of-Line: Station 11**
- 0 to 0

**TOTALS**
- 39,354 feet
- 19.4 ft/sec
- 2,033 seconds

**Station to Station Travel Times**

<table>
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<tr>
<th>Segment</th>
<th>Length(ft)</th>
<th>Start Time</th>
<th>End Time</th>
<th>Maximum Dwell (sec)</th>
<th>Accelerate</th>
<th>Decelerate</th>
<th>At-Speed</th>
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<th>At-Speed</th>
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</table>

**TOTAL:** 2,033 seconds

- **Distances (Feet):** 39,354
- **Speed (MPH):** 19.4
- **Time (seconds):** 2,033
- **MPH/sec:** 7.45
- **Minutes:** 33.89
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<thead>
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<th>Segment</th>
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## The Connector - Preliminary Route Alternatives

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