1 DISTRICT MOBILITY DATA ANALYSIS METHODOLOGY

1.1 Data Sources and Performance Measure Methodology

Table 1 summarizes the performance measures and data sources for District Mobility's performance measures. The following pages describe each data source and summarize the methodologies applied to each data source to measure multimodal performance. Links are provided to access and download each publically available data source.

Table 1: Performance Measures and Associated Data

Mobility Story	***Performance Measure***	***Mode***	***Data Source***	***Years Reported***
Time spent commuting	*Commute Time*	*Multiple*	*American Community Survey (ACS)* *TIGER/Line Census Tract Shapefiles*	*2010-2014 (five year average)*
How we are commuting	*Commute Mode Split*	*Multiple*	*American Community Survey (ACS)* *TIGER/Line Census Tract Shapefiles*	*2010-2014 (five year average)*
Travel during the week	*Travel Time Index*	*Auto*	*INRIX*[1]	*2015, 2016*
How many people ride the bus	*Bus Ridership*	*Transit*	*Automatic Passenger Count (APC)*	*October 2015, October 2016*
Which bus stops serve the most riders	*Bus Ridership*	*Transit*	*Automatic Passenger Count (APC)*	*October 2015, October 2016*
Which bus routes are most crowded	*Bus Overcrowding, Bus Speeds*	*Transit*	*Automatic Passenger Count (APC)*	*October 2015, October 2016*
How reliable are our roads	*Travel Time Reliability (Planning Time Index)*	*Auto*	*INRIX*[1]	*2015, 2016*
Bus reliability	*Bus On-Time Performance*	*Transit*	*Automatic Passenger Count (APC)*	*October 2015, October 2016*
Transit Coverage Area	*Transit Coverage Area*	*Transit*	*The General Transit Feed Specification (GTFS)*[2] *District Geographic Information System (GIS)*	*October 2015 – April 2016, October 2016 – April 2017*
Bicycle Comfort Network	*Bicycle Level of Traffic Stress*	*Bicycle*	*District Bike Layer* *District Centerline Layer* *Business District Layer*	*2010-2015*, 2010-2016**
Pedestrian Environment	*Pedestrian Friendliness Index*	*Pedestrian*	*District Centerline Layer* *District Census Block Layer* *District Sidewalk Layer* *District Census Block Centroids Layer*	*2010-2015**

* The reporting period varies based on the District Layer used for the analysis

[1] http://inrix.com/xd-traffic/ [Accessed September 2016]
[2] https://developers.google.com/transit/gtfs/ [Accessed September 2016]

C2 - Commute Mode Split

Performance Measure Summary	District worker's perceptions of congestion vary by the mode(s) people choose. This measure highlights the modes that District residents use get to and from their place of work.
Applicable Mobility Story	How we are commuting
Applicable Modes	Automobile, Transit, Bicycle, Walk
Metric and Units	Commute Mode Split (% commuters): (Sum of Commuters Using X Mode)/(Total Commuters)
Data Source	American Community Survey (2010-2014) TIGER/Line Shapefiles
Source Summary	The **American Community Survey (ACS)** is an ongoing statistical survey by the U.S. Census Bureau. The U.S. Census Bureau releases new ACS data every year in a variety of tables, tools and analytical reports. ACS data can be accessed via the website *American Factfinder*, and is available in 1-, 3- and 5-year estimates. **TIGER/Line shapefiles** are spatial extracts from the U.S. Census Bureau's MAF/TIGER database, containing features such as legal and statistical geographic areas. Tiger/Line shapefiles contain geographic entity codes that can be linked to the Census Bureau's demographic data.
Analysis Methodology	1. Select desired geography (Census Tract) and download the appropriate shapefile from TIGER. 2. Obtain ACS data for the "Means of Transportation to Work by Age (B08101)" variable for the selected geography in the District of Columbia. 3. Tabulate the data by mode for each census tract 4. Join the results to the geographies selected in Step 1 and display in GIS as follows: **(Sum of Commuters Using X Mode)/(Total Commuters)**

C3 - Commute Time

Performance Measure Summary	The time that it takes District workers to commute to and from their place of work affects their perception of congestion. These perceptions of congestion vary by the mode(s) people choose. This measure reports the average time DC residents spend commuting to work by mode.
Applicable Mobility Story	Time Spent Commuting
Applicable Modes	Automobile, Transit, Bicycle, Walk
Metric and Units	Average Commute Time for X Mode (minutes): (Aggregate Travel Time Using X Mode)/(Total Travelers Using X Mode)
Data Source(s)	American Community Survey (2010-2014) TIGER/Line Shapefiles
Source Summary	The **American Community Survey (ACS)** is an ongoing statistical survey by the U.S. Census Bureau. The U.S. Census Bureau releases new ACS data every year in a variety of tables, tools and analytical reports. ACS data can be accessed via the website *American Factfinder*, and is available in 1-, 3- and 5-year estimates. **TIGER/Line shapefiles** are spatial extracts from the U.S. Census Bureau's MAF/TIGER database, containing features such as legal and statistical geographic areas. Tiger/Line shapefiles contain geographic entity codes that can be linked to the Census Bureau's demographic data.
Analysis Methodology	1. Select desired geography (Census Tract) and download the appropriate shapefile from TIGER. 2. Obtain ACS data for the "Means of Transportation to Work by Travel Time to Work (B08134)" variable for the selected geography in the District of Columbia. 3. Calculate the average travel time for each mode by census tract as follows: **(Aggregate Travel Time Using X Mode)/(Total Travelers Using X Mode)** 4. Join the results to the geographies selected in Step 1 and display in GIS.

D2 - Travel Time Index

Performance Measure Summary	Travel time index (TTI) is measured as an indicator of auto congestion in the District. TTI is defined as the ratio of peak period (congested) travel time to travel time under "light" or "free-flow" conditions. For example, a TTI of 1.5 indicates that a trip that would normally take 20 minutes under free-flow conditions takes 30 minutes (or 50 percent longer) as a result of traffic congestion.
Applicable Mobility Story	Travel during the week
Applicable Modes	Automobile
Metric and Units	Travel Time Index (unitless): (Travel Time for TMC Location Code)/(Free-flow Travel Time for TMC Location Code)
Data Source	INRIX Traffic Data (2016)
Source Summary	INRIX provides real-time and historical travel time and speed data to users. INRIX uses standard Census Bureau information to define the geographical boundaries for road analysis in the United States, and Traffic Message Channel (TMC) location codes and referencing to define road segments.
Analysis Methodology	1. Archive INRIX data for one year. Use the following time periods to categorize INRIX data: AM Early (4:00 AM – 5:59 AM), AM Peak (6:00 AM – 8:59 AM), Midday (9:00 AM – 2:59 PM), PM Peak (3:00 PM – 6:59 PM), Early Night (7:00 PM – 10:59 PM), and Late Night (11:00 PM – 3:59 AM). 2. Define the Travel Time Index (TTI) baseline. For District Mobility, the daily 95th percentile speed was the baseline for automobile travel time index calculations. 3. Calculate the TTI for each TMC location code in each time period, as follows: **(Average Travel Time for TMC Location Code)/(Daily 95th percentile speed for TMC Location Code)**
Mobility Map Threshold Methodology	1. Map all non-interstate roadways with a TTI score higher than 2.0 in the AM and PM Peak Periods

D3 - Route-Level Ridership

Performance Measure Summary	Route-level ridership measure includes line ridership, which is the average weekday boarding along all routes within a Metrobus Line by time period.
Applicable Mobility Story	How many people ride the bus
Applicable Modes	Transit
Metric and Units	Line ridership (passengers): Sum of monthly average boardings for all stops within a bus line
Data Source	WMATA Automatic Passenger Count (APC) **WMATA Bus Line Shapefile**
Source Summary	WMATA's **Automated Passenger Counter (APC) System** reports arrival time, and passenger boardings and alightings at bus stops for each bus. This allows for the calculation of load, speed, runtime, and schedule deviation. The data is reported as an average across the month. The **WMATA Bus Line shapefile** is a polyline shapefile containing WMATA bus lines, including regular and pattern routes.
Analysis Methodology	1. Use the following time periods to categorize route-level ridership data: AM Early (4:00 AM – 5:59 AM), AM Peak (6:00 AM – 8:59 AM), Midday (9:00 AM – 2:59 PM), PM Peak (3:00 PM – 6:59 PM), Early Night (7:00 PM – 10:59 PM), and Late Night (11:00 PM – 3:59 AM). 2. For bus line ridership, sum the monthly average boardings by time period for all stops within a line by day. Join the calculated average boardings to the WMATA Bus Line shapefile.

D4 - Stop-Level Ridership

Performance Measure Summary	The stop-level ridership, which is the total number of people boarding buses at each stop by time period.
Applicable Mobility Story	Which bus stops serve the most riders
Applicable Modes	Transit
Metric and Units	Stop Ridership (passengers): Sum of monthly average boardings per stop
Data Source	WMATA Automatic Passenger Count (APC) **WMATA Bus Stop Shapefile**
Source Summary	WMATA's **Automated Passenger Counter (APC) System** reports arrival time, and passenger boardings and alightings at bus stops for each bus. This allows for the calculation of load, speed, runtime, and schedule deviation. The data is reported as an average across the month. The **WMATA Bus Stop shapefile** is a point shapefile containing WMATA regional bus stop locations, including bus stop identification, location, and inventory information.
Analysis Methodology	1. Use the following time periods to categorize stop-level ridership data: AM Early (4:00 AM – 5:59 AM), AM Peak (6:00 AM – 8:59 AM), Midday (9:00 AM – 2:59 PM), PM Peak (3:00 PM – 6:59 PM), Early Night (7:00 PM – 10:59 PM), and Late Night (11:00 PM – 3:59 AM). 2. For bus stop ridership, the monthly average boardings for stops within a scheduled arrival time within the same time period are summed to get stop-level ridership by time period. Join the calculated boardings to the WMATA Bus Stop shapefile.
Mobility Map Threshold Methodology	1. Map the top ten *"non-interior circulation"* bus stops with highest number of all-day boardings per trip during weekdays

D5 – Bus Speed

Performance Measure Summary	Bus speed includes average bus speed for WMATA buses between time points on all routes within the District.
Applicable Mobility Story	Which time points have the lowest average bus speeds
Applicable Modes	Transit
Metric and Units	Bus Speed (miles per hour): Runtime between time points / Distance
Data Source	WMATA Automatic Passenger Count (APC) **WMATA Bus Line Shapefile**
Source Summary	WMATA's **Automated Passenger Counter (APC) System** reports arrival time, scheduled runtime, actual runtime, speed, for every stop on every trip. This allows for the calculation of runtime. The data is reported as an average across the month. The **WMATA Bus Line shapefile** is a polyline shapefile containing WMATA bus lines, including regular and pattern routes.
Analysis Methodology	1. Use the following time periods to categorize stop-level ridership data: AM Early (4:00 AM – 5:59 AM), AM Peak (6:00 AM – 8:59 AM), Midday (9:00 AM – 2:59 PM), PM Peak (3:00 PM – 6:59 PM), Early Night (7:00 PM – 10:59 PM), and Late Night (11:00 PM – 3:59 AM). 2. Bus speeds were calculated based on the runtime between the timepoints and the distance travelled. The APC data only provides the time between the time point and the previous stop. Thus, timepoint-to-timepoint runtimes were calculated based on the difference in arrival time between timepoint along the same trip. The distances traveled between timepoints were calculated in ArcGIS based on the shapefile of WMATA routes.
Mobility Map Threshold Methodology	1. Map the timepoints where average bus speed during peak periods (combined AM and PM) is lower than 4 miles per hour (mph).

D5 - Bus Overcrowding

Performance Measure Summary	The District Mobility Project analyzed bus overcrowding using the ratio of the average of the maximum number of passengers on the bus over the course of a month to the seated capacity of the vehicle. This was done by time period. WMATA set the standard for overcrowding using a ratio of 1.2 passengers to seats.
Applicable Mobility Story	Which bus routes are most overcrowded
Applicable Modes	Transit
Metric and Units	Bus overcrowding (passengers per seated capacity of bus): (Average of the maximum number of passengers on a bus over the course of a month)/(seated capacity of bus)
Data Source	WMATA Automatic Passenger Count (APC) **WMATA Bus Stop Shapefile** **WMATA Bus Line Shapefile**
Source Summary	WMATA's **Automated Passenger Counter (APC) System** reports arrival time, and passenger boardings and alightings at bus stops for each bus. This allows for the calculation of load, speed, runtime, and schedule deviation. The data is reported as an average across the month. This sample had undergone a WMATA data cleaning process and reported the seated capacity and average and maximum load on board at each stop by time period. Type of vehicle (e.g., articulated bus) is also considered to reflect the actual seating capacity The **WMATA Bus Stop shapefile** is a point shapefile containing WMATA regional bus stop locations, including bus stop identification, location, and inventory information. The **WMATA Bus Line shapefile** is a polyline shapefile containing WMATA bus lines, including regular and pattern routes.
Analysis Methodology	1. Use the following time periods to categorize bus overcrowding: AM Early (4:00 AM – 5:59 AM), AM Peak (6:00 AM – 8:59 AM), Midday (9:00 AM – 2:59 PM), PM Peak (3:00 PM – 6:59 PM), Early Night (7:00 PM – 10:59 PM), and Late Night (11:00 PM – 3:59 AM). 2. Average the maximum passenger load by time period with the other days in the month. Divide the average of the maximum load by the average number of seats on the vehicles driven on that route to establish the load to seat ratio. Use the WMATA Bus Stop Shapefile and WMATA Bus Line shapefile to create a new "Stop to Stop Route Segments" shapefile. Create the shapefile in ArcGIS using an automated process that splits WMATA routes at stops that have a matching "Route_ID" and "Direction" and fall within 100 feet of the route. Join the calculated ratio of average daily maximum vehicle load to seated capacity by time period to the new "Stop to Stop Route Segments" shapefile.
Mobility Map Threshold Methodology	1. Map the top ten routes with v/c ratio > 1.3 for the highest number of consecutive segments during peak periods (both AM and PM)

E2 - Travel Time Reliability (Planning Time Index)

Performance Measure Summary	Planning Time Index (PTI) is a measure of reliability defined as the ratio of 95th percentile travel time to travel time in light or free-flow traffic. A PTI of 2.0 indicates that for a trip that takes 20 minutes in light traffic, a traveler should budget 40 minutes to ensure on-time arrival 95 percent of the time (i.e. on-time arrival about 19 days out of 20).
Applicable Mobility Story	How reliable are our roads
Applicable Modes	Automobile
Metric and Units	Planning Time Index (Unitless): (Travel Time for TMC Location Code*0.95)/(Free-flow Travel Time for TMC Location Code)
Data Source	INRIX Traffic Data (2016)
Source Summary	INRIX provides real-time and historical travel time and speed data to users. INRIX uses standard Census Bureau information to define the geographical boundaries for road analysis in the United States, and Traffic Message Channel (TMC) location codes and referencing to define road segments.
Analysis Methodology	1. Archive INRIX data for one year. Use the following time periods to categorize INRIX data: AM Early (4:00 AM – 5:59 AM), AM Peak (6:00 AM – 8:59 AM), Midday (9:00 AM – 2:59 PM), PM Peak (3:00 PM – 6:59 PM), Early Night (7:00 PM – 10:59 PM), and Late Night (11:00 PM – 3:59 AM). 2. Define the Planning Time Index (PTI) baseline. For District Mobility, the daily 95th percentile speed was the baseline for automobile travel time index calculations. 3. Calculate the PTI for each TMC location code in each time period, as follows: **(95th Percentile Travel Time for TMC Location Code)/(Daily 95th percentile speed for TMC Location Code)**
Mobility Map Threshold Methodology	1. Map all non-interstate roadways with a PTI score higher than 3.0 in the AM and PM Peak Periods

E3 - Bus On-Time Performance Index

Performance Measure Summary	The District Mobility project analyzed the difference between the scheduled runtime and the actual runtime it took a bus to traverse between two points (known as time points) by time period. A weighted average runtime deviation for each time point was then calculated accounting for the absolute runtime difference and percent run time difference.
Applicable Mobility Story	Bus Reliability
Applicable Modes	Transit
Metric and Units	Bus on-time performance index (minutes): (Scheduled runtime – actual runtime)* $\frac{scheduled\ runtime - actual\ runtime}{actual\ runtime}$
Data Source	WMATA Automatic Passenger Count (APC) **WMATA Bus Stop Shapefile** **WMATA Bus Line Shapefile**
Source Summary	WMATA's **Automated Passenger Counter (APC) System** reports arrival time, and passenger boardings and alightings at bus stops for each bus. This allows for the calculation of load, speed, runtime, and schedule deviation. The data is reported as an average across the month. The APC dataset provided to measure on-time performance included records for all stops along all routes. The **WMATA Bus Stop shapefile** is a point shapefile containing WMATA regional bus stop locations, including bus stop identification, location, and inventory information. The **WMATA Bus Line shapefile** is a polyline shapefile containing WMATA bus lines, including regular and pattern routes.
Analysis Methodology	1. Subtract the average runtime between timepoints from the scheduled runtime to calculate how many minutes the bus has deviated from the scheduled time. 2. Calculate the percent runtime difference by dividing the runtime difference to the actual runtime 3. Multiply the average runtime difference calculated in Step [1] with the percent difference calculated in Step [2] to obtain weighted average runtime deviation. 4. Manually split the shapes for each route to produce a timepoint-to-timepoint line segment shapefile. 5. Join the calculated timepoint-to-timepoint weighted average runtime deviation to the timepoint-to-timepoint line segment shapefile.
Mobility Map Threshold Methodology	1. Map the top ten earliest and top ten latest segments for non-supplemental (i.e., school) routes with the on-time performance index (weighted average runtime deviation)

F2 - Transit Coverage Area

Performance Measure Summary	The District Mobility project identified bus walksheds and metro walksheds in its analysis of District transit coverage. For bus walksheds, the project identified areas in the District that were within a 1/4 mile walking distance (based on roadway and non-motorized network) of high frequency Metrobus service. Ten minutes or better was set as the threshold for high frequency service. For Metrorail walksheds, the project identified areas in the District that were within a 1/2 mile walking distance (based on roadway and non-motorized network) of high frequency Metrorail service (station entrances). Five minutes or better service was set as the threshold for high frequency service.
Applicable Mobility Story	Transit Coverage Area
Applicable Modes	Transit
Metric and Units	Transit Station Headways (vehicles per hour): (Total Trips per Time Period)/(Hours of Service in that Time Period) Transit Coverage Area (miles): Use ArcGIS Network Analyst to create network buffers around stops/stations
Data Source	WMATA's **General Transit Feed Specification (GTFS) database** is a record of the transit schedule for Metrorail, Metrobus, and DC Circulator and is arranged by stop, routes, and trips. It also includes the latitude and longitude which was used to map the data. **WMATA's Station Entrance shapefile** is a GIS shapefile that reports the location of each metro stations escalators and elevators. **TIGER/Line shapefiles** are spatial extracts from the U.S. Census Bureau's MAF/TIGER database, containing features such as roads, trail and bike paths. Tiger/Line shapefiles contain geographic entity codes that can be linked to the Census Bureau's demographic data.
Source Summary	WMATA's **General Transit Feed Specification (GTFS) database** is a record of the transit schedule for Metrorail, Metrobus, and DC Circulator and is arranged by stop, routes, and trips. It also includes the latitude and longitude which was used to map the data.
Analysis Methodology	1. Calculate the total number of trips at each bus stop or metro station per time period and the span of service at that bus stop on an average weekday. 2. Calculate the headway at each bus stop or metro station as follows: 3. (Total Trips per Time Period)/(Hours of Service in that Time Period) 4. Geocode the bus stop locations from the GTFS. 5. Join the headway data to the metro station entrance GIS file. 6. Create network buffers around the stops and station using ArcGIS Network Analyst. The tool uses The TIGER /Line shapefile's road, bike, and trail networks to approximate ¼ mile walking distance from the bus stops and ½ mile walking distance from the metro station entrances.
Mobility Map Threshold Methodology	1. Map the Metrorail stations with poor pedestrian access to the station. Pedestrian access is defined as the ratio of potential service area (accessibility using radial distance) divided by the actual walkshed using street network.

F3 - Bicycle Level of Traffic Stress

Performance Measure Summary	Level of Traffic Stress (LTS) [3] evaluates the impact of traffic on a bicyclist's experience and its analysis results classify streets into one of four "stress levels" for bicycling: • Streets Suitable for All Bicyclists (LTS 1): a level of traffic stress that most children can tolerate • Streets suitable for most bicyclists (LTS 2): the level that would be tolerated by the mainstream adult population • Streets suitable for some bicyclists (LTS 3): the level tolerated by American cyclists who are "enthused and confident" but prefer dedicated space for riding • Streets suitable for few bicyclists (LTS 4): a level tolerated only by those characterized as "strong and fearless"
Applicable Mobility Story	Bicycle Comfort Network
Applicable Modes	Bicycle
Metric and Units	Street-level Level of Traffic Stress Score (unitless)
Data Source	**District Bicycle Lanes Shapefile** **District Centerline Shapefile** **District Land Use Shapefile** District Roads and Highways Route Feature Class
Source Summary	The **District Bicycle Lanes Shapefile**, **District Centerline Shapefile**, and **District Land Use Shapefile** are GIS shapefiles that report the location and type of bike facilities in the District, functional classification of roadways in the District, and land uses in the District, respectively. The **District Roads and Highways Route Feature Class** is composed of linear features for all roads and highways in the District, which are overlaid with linear "lane events" that store characteristics of individual roadway lanes, including street width.
Analysis Methodology	For further information; please access the Bicycle Level of Traffic Stress Technical Memorandum.
Mobility Map Threshold Methodology	1. Map all census blocks with accessibility scores within the bottom 10% of all census blocks (Accessibility Score: number of accessible census blocks within 3.3 miles of the origin census block on the low stress bicycle network). For further information; please access the District Mobility LTS Strategies Memorandum.

[3] **Mekuria, Pd.D., P.E., PTOE, et al. 2012.** *Low-Stress Bicycling and Network Connectivity.* San Jose : Mineta Transportation Institute, 2012.

F4 - Pedestrian Friendliness Index

Performance Measure Summary	The Pedestrian Friendliness Index (PFI)[4] characterizes the walkability of neighborhoods based on network design, sidewalk availability, and building accessibility, and its analysis results assign neighborhoods a score indicating how "friendly" they are to pedestrians compared to surrounding neighborhoods. The PFI method recognizes that pedestrians are sensitive to the built environment, and are less likely to walk for transportation if their trip cannot be completed comfortably and efficiently.
Applicable Mobility Story	Pedestrian Environment
Applicable Modes	Pedestrian
Metric and Units	"Walkability" of Census Tracks (unitless): 0.270 + (-0.00046*St. Dev. Block Length) + (0.00501*Census-Block Density) + (0.153*4-way Ratio) + (0.0772*Sidewalk Ratio) + (1.96*Avg. Inverse Setback)
Data Source	**District Centerline Shapefile** **District Census Blocks Shapefile** **District Intersection Points Shapefile** **District Sidewalk Shapefile** **District Building Footprints Shapefile**
Source Summary	The **District Centerline Shapefile** reports the functional classification and length of all roadways in the District. The **District Census Blocks Shapefile** reports the location of all 2010 Census Block Boundaries in the District. The **District Intersection Points Shapefile** reports the location of all intersections in the District. The **District Sidewalk Shapefile** reports the location and shape of all sidewalks in the District. The **District Building Footprints Shapefile** reports the location and shape of all building footprints in the District.
Analysis Methodology	The PFI method scores the "friendliness" of a neighborhood based on three elements: network design, the pedestrian environment, and the roadside built environment. Each element is assigned a score based on a range of one to three variables, and the combined scores from all three elements make up the overall PFI score for the neighborhood. In the District's case, neighborhoods were defined as census blocks, and a PFI score was calculated and assigned to each census block. The analysis variables and their relation to the three key elements are detailed in Error! Reference source not found.. For further information; please access the Pedestrian Friendliness Index Technical Memorandum.

Pedestrian Facilities	**Roadside Built Environment**	**Network Design**		
Sidewalk Provision	*Building Setbacks*	*Census Block Density*	*Block Length*	*Four-way Intersection Ratio*
(Linear Feet of Sidewalk)/(Linear feet of roadway)	*Inverse mean of setbacks of buildings fronting the street*	*(# of census blocks)/(neighborhood area)*	*Standard deviation of road segment lengths*	*(# of four-way intersections)/(total intersections + dead-ends)*

Table 1: PFI Analysis Variable

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Parks, James and Schofer, Joseph. 2006. *Characterizing neighborhood pedestrian environments with secondary data.* Evanston : Northwestern University, 2006.