Data-Driven Urban Performance Measures: A Case Study Application in the District of Columbia

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ABSTRACT

Performance measures are typically used by transportation agencies to measure progress towards organizational goals. As cities have reoriented their transportation priorities toward people over cars and have put more emphasis on multimodal transportation options, relatively few studies have identified measures that capture the urban context and are sensitive to the multimodal nature of urban transportation systems. Moreover, some of these studies focus only on the measures without fully considering the available resources necessary to capture these measures and the limitations in data. This often hampers the implementation of performance measures and prevents agencies from creating a sustainable and reliable performance measurement program.

The objective of this research is to define a data-driven framework for monitoring mobility performance for urban transportation systems through a case study application in the District of Columbia, conducted as a part of an overall study to better understand the state of the District's transportation system. The study attempts to identify multimodal measures that can be repeatable over time and are supported by readily available, attainable, and reliable data sources. Measures that are common and can be compared across modes were considered as part of the initial selection process. The initial list was then refined and prioritized based on the data inventory considering the availability and quality of data sources. Twelve multimodal measures that can be supported by valid, usable, and reliable data sets are recommended in the final metric list to evaluate multimodal mobility in the District.

INTRODUCTION

Performance measurement is used by transportation agencies to monitor trends in system performance over time and measure progress towards organizational goals and objectives. A successful performance measurement program plays a key role in improving efficiency, making the decision-making process transparent, and fostering accountability with decision makers and the public. In addition, Federal Highway Administration (FHWA) has recently established national performance management measures and requirements for State departments of transportation (State DOTs) and Metropolitan Planning Organizations (MPOs) (*1*). As a result, especially with the latest advancements in data collection and the growing availability of data, measuring performance is increasingly becoming useful and needed in the United States. According to the Performance Measurement of Transportation Systems Conference Proceedings published in 2013, most transportation agencies already employ performance measurement and 18 states have mature performance management programs (*2*). Another study conducted in 2010 showed that 23 out of the 39 surveyed DOTs have used performance measures to gauge success on achieving their strategic goals and objectives (*3*). This number is higher today as additional state and local DOTs have been increasingly focused on performance measures.

There is a very broad set of measures identified in the literature to evaluate transportation system performance. Traditionally, the vast majority of the measures have been highway-focused (*4, 5*). Over the last couple decades, cities in the United States have reoriented their transportation priorities toward people over cars and have put more emphasis on non-motorized, multimodal transportation options. As a result, several recent studies identified measures that are able to capture the urban context and multimodal nature of urban transportation systems (*6*, *7, 8*). However, a main drawback of these studies is that measures were often selected without fully considering the available resources and the limitations in data (e.g., complexity in data requirements or data accuracy issues). This often hampers the implementation of performance measures and prevents agencies from creating a sustainable and reliable performance measurement program.

This paper builds upon continuing work by the District Department of Transportation (DDOT) and Kittelson and Associates, Inc. (KAI) to assess, quantify, and communicate the current state of system performance for multimodal transportation users in the District of Columbia (‘the District’ or ‘DC’). The “District Mobility” study responds to DDOT’s need to better understand multimodal congestion and to communicate accurately with the public how well the transportation system is performing. In addition, DDOT aims to identify potential gaps in the transportation network, assess the effectiveness of ongoing projects, and develop a framework to incorporate data to aid in decision making, project planning and prioritization. To achieve these goals, it is critical to identify measures that can be recalculated over time from sustainable and reliable data sources.

Figure 1 illustrates the proposed prioritization process and describes the vision for the District Mobility study.

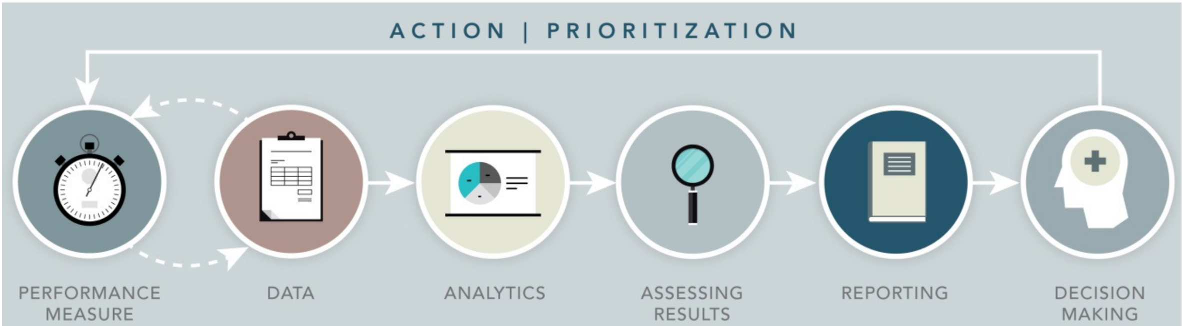

Figure 1. Proposed Prioritization Process

This data-driven urban performance measures research attempts to specifically address the following:

- Developing a data-driven framework for monitoring performance for urban transportation systems through a case study application in the District,
- Identifying measures for multimodal systems in the urban context that can be repeatable over time and supported by readily available, attainable, and reliable data sources, and
- Addressing future measures that are critical for the performance assessment of urban systems as the data becomes available and reliable.

The framework presented here also provides guidance for other agencies on the development of measures for assessing performance of urban transportation systems. It is important to emphasize that this paper mainly focuses on the performance measure and data portion of the prioritization process. A companion paper will address other components including assessing results, reporting and communication methods, and leveraging data-supported decision making for internal project planning and coordination (*9*).

FRAMEWORK FOR SELECTING MEASURES

This framework was developed in response to a need to identify the most applicable measures that would allow for ongoing performance reporting. The resulting framework incorporates an iterative stage that aligns data to measures. The general process is as follows.

To begin with, the project team must define the scope of what is to be measured, both in terms of what can and should be managed, and in terms of the context and geography of the study. The adage that "what gets measured gets managed" is a reason to do performance measurement but also an important consideration when framing out a performance measurement tool. The choice of what to measure should reflect what the organization is seeking to manage and communicate.

Similarly, the context of the study affects the measure selection. How data is aggregated and reported will be different for a corridor versus an entire metropolitan area or state, or for a year versus a single day or month. Urban context, climate, and history are all other factors that might alter the study framing and selected measures.

With this base established to inform the rest of the process, the next step is set up the iterative process of selecting measures by inventorying possible measures and available data. To identify the universe of possible performance measures, a scan of the literature and measures in use by other agencies form the base of this, supplemented by a list of what the agency is already measuring on this topic and by ideas from within the project team based on the project goals. On the data side, it is important to assess the availability of data but also its quality, accessibility, reliability, repeatability, and usability/complexity.

In order to create an effective performance measurement program that can be maintained over time, it is important to select measures not only based on the goals and objectives of agencies, but also considering the availability and quality of data sources. As shown in **Figure 1,** the first step in the iterative process is to identify whether data exists to obtain the desired performance measure. Where data is available, data analytics are performed to evaluate whether the data can support the identified performance measures in a reliable and systematic way. Then, based on the outcomes, the initial performance measures are prioritized and revised.

Once the list of final measures have been developed and data analytics completed, the framework moves on to the development of the final reporting mechanism(s), which then helps develop a transportation system management plan and monitoring plan for decision making. The rest of this paper describes how this framework was applied to the District Mobility project.

SETTING THE SCOPE

DDOT's study resulted from a request from the DC Council to assess the state of congestion for all surface modes in the District (automobile, bus, bicycle, and pedestrian). In order to address the Council's request and measure congestion, DDOT had to define what congestion encompasses for all modes. Examining the District and agency objectives and needs, DDOT made the decision to broaden the focus of the study beyond congestion to cover system performance from a mobility perspective. This decision broadens the range of strategies available to address congestion and better reflects the agency and District's options. Three general categories of system mobility performance were identified:

- Travel Time Reliability: this category captures the variability in travel times and the resulting uncertainty experienced by travelers. Unreliability in travel time can be far more frustrating than recurring congestion. Managing travel time variability improves travelers' experience and makes the overall system function better.
- Accessibility: this category measures the ease of reaching valued destinations or opportunities (e.g., jobs, hospitals, shopping, etc.). A second formulation of this category measures the ability of a traveler to use a particular mode. Accessibility provides a way to make comparisons between modes and, more importantly, factors in the role of land use in transportation. Improving accessibility more directly addresses the fact that people travel to get places. Modal access also improves system resilience by increasing modal redundancy for more people.
- Intensity of Usage: this category measures system capacity and is what is most commonly understood as congestion. Discussions of congestion often focus on the intensity of travel during peak periods as more users in a system degrade system performance. This category can include a focus on overall person throughput or on measuring the costs of congestion as well as the intensity of congestion.

Traditionally, the measures of intensity of usage tend to focus on traffic congestion using level of service (LOS), congestion duration, or travel time indices. However, in an urban environment, measures including more than just auto travel may also be considered. Furthermore, it is important to note that in areas where trips are generally short but experiencing higher levels of congestion, intensity measures may not matter as much since higher levels of accessibility can be achieved within those short trips.

UNDERSTANDING THE CONTEXT

The scope of the DDOT study is to address congestion and mobility throughout the District on all surface modes. System performance measures therefore need to reflect the urban environment and be applicable across the jurisdiction.

The District of Columbia is at the center of the seventh largest metropolitan area in the United States. The District has a population of nearly 660,000, but has a daily influx of over 500,000 commuters and visitors (*10, 11, 12, 13*).

The District's transportation system comprises over 1,100 miles of roadways, of which less than 15 miles are freeways (**Figure 2**). Therefore, the efficiency of the transportation system is dictated to a large extent by how effectively the arterial roadways operate. The District has a very robust transit system, bikeway network, and a bikeshare program, resulting in one of the most multimodal transportation systems in the nation. Based on the American Community Survey (ACS) 2014 data, among cities, the District has the fifth highest percentage of non-vehicle mode share (*10*).

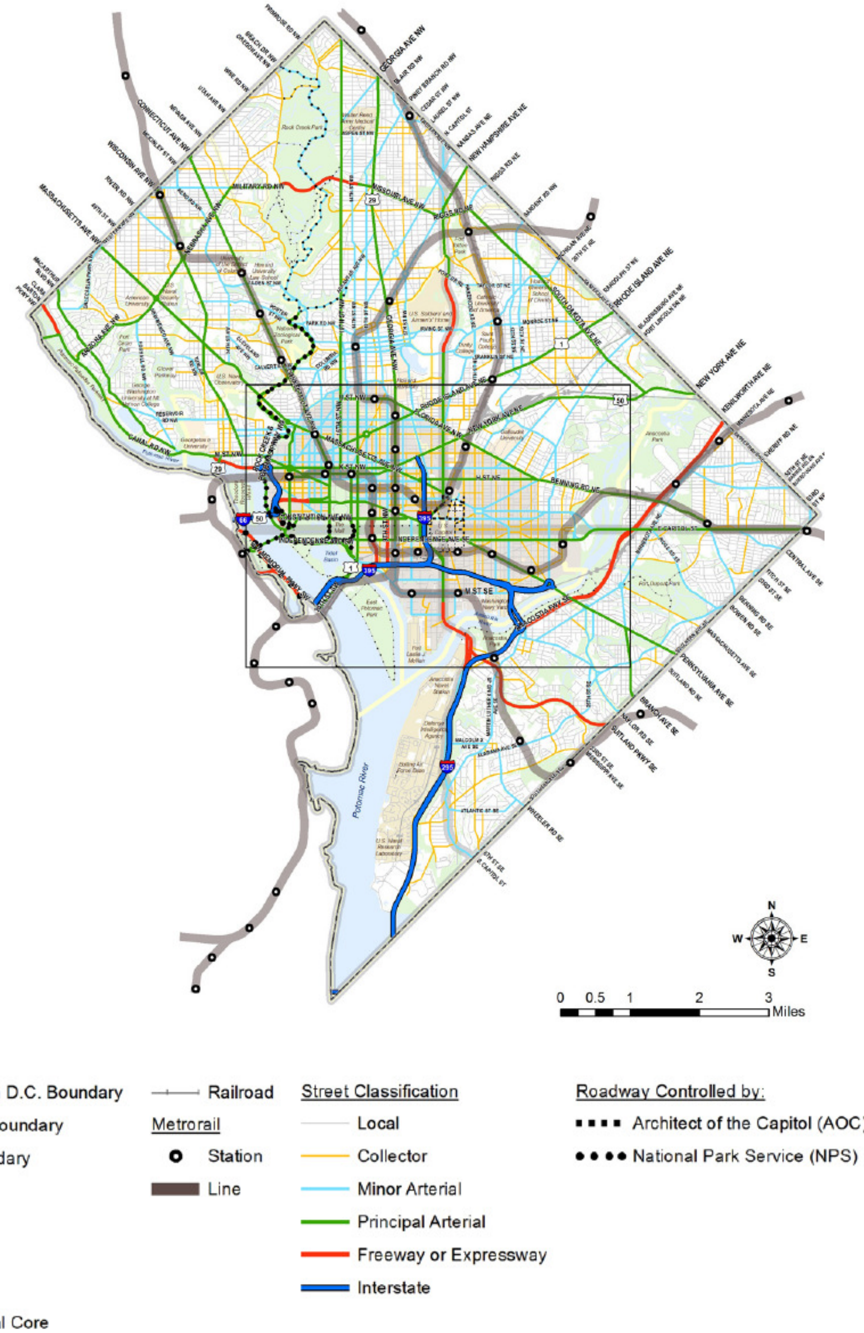

Figure 2. Existing Roadway Functional Classification for the District (*12*)

Despite the fact that the percentage of District residents driving alone to work is relatively low (*12*), the freeways in the District consistently reach capacity during the peak hours. This can be partly attributed to heavy cut-through traffic but also to the fact that the share of drive alone commuters is higher among workers who live outside the District. One out of every four vehicle trips entering the District "cuts through," that is, they do not have a destination within the District, and two of three vehicles in the District during peak hours are from out of state.

The DC region is consistently ranked poorly on traditional congestion measures. According to the *Urban Mobility Report*, the Washington, DC metropolitan area is reported as one of the most congested regions in the country (*4*). However, DC's poor ranking may not be accurate or reflect the "true" system performance for multiple reasons:

1. The scoring is based on the automobile congestion and therefore fails to capture the urban multimodal context of the District, and may not capture the experience of most individuals living in the District.
2. This metric is for the entire region, which includes cut-through traffic. As a result, the results may not entirely reflect the transportation patterns for the District itself.
3. This metric uses congestion delay for the ranking process and does not take into account median travel time. This approach undervalues compact cities such as the District that tend to have shorter trips, but likely with higher intensity of congestion.

Hence, developing measures that are sensitive to the multimodal nature of the travel is critical to providing a well-balanced assessment of the District's transportation system.

INITIAL PERFORMANCE MEASURES

Measures in the Literature and in Practice

An extensive review of the literature was conducted, which indicated that there is a very broad set of measures used to assess system performance and mobility. The selection of the appropriate measures is typically made based on the different overarching goals in describing multimodal congestion (*14, 15*). Some of these goals include safety, accessibility, reliability, environmental quality, and reduction of congestion. **Table 1** shows the set of key performance measures by mode identified as part of the literature review (*16, 17, 18, 19, 20*).

Table 1: Key Performance Measures Identified in the Literature by Mode

Mode	Performance Measures	
Pedestrian	Sidewalk availability Sidewalk congestion Walkability index Route directness Pedestrian safety	Pedestrian network connectivity Pedestrian volume Pedestrian signal delay Pedestrian commute mode share
Bicycle	Number of bicycle trips Bicycle level of traffic stress Bikeshare availability Bicycle commute mode share Average bikeshare trips per resident	Bikeshare system coverage area Miles of bike lanes/cycle tracks Route directness Bicycle safety
Transit	Ridership Service frequency On-time performance Vehicle crowding Farebox recovery Passenger accident rate Transit to auto travel time ratio	Transit service coverage Bus speed Headway adherence Passenger miles/passengers per mile Transit commute mode share Vehicle accident rate
Auto	Vehicle miles travelled Vehicle hours of delay Travel time index Duration of congestion Average vehicle occupancy Vehicle crash frequency/rate Vehicle miles traveled in congestion	Level of service Auto speed Planning time index Cost of congestion Single occupancy commute mode share Incident clearance time

The review of the literature and interviews with peer agencies indicated that performance measures are a growing technical area with agencies reporting on a wide range of metrics such as vehicular volumes and transit on-time performance. Congestion performance measures for automobiles are well-established within transportation agencies and consistently popular with the public and policymakers. A primary reason that automobile performance measures are well established is due to a maturity in vehicular data collection techniques and technologies. Automated detection systems provide reliable and sustainable data to allow for agencies to measure and report automobile performance measures. Similarly, performance measures for transit systems also are relatively mature with continued integration of data collection technologies on transit vehicles. Conversely, pedestrian and bicycle performance measures are limited and this can be attributed to more limited data collection technologies and techniques. As a result, comprehensive multimodal mobility performance measures have been applied in fewer contexts. Further, many agencies do not dynamically communicate the results of any measures they have to the public, nor assess internally how they are performing in terms of improving mobility.

Refined initial list

For the selection of the initial performance measures, the researchers focused on metrics that are applicable for all types of modes. Appropriate metrics are typically overarching and can provide meaningful comparisons across modes. In addition to the common measures across modes, mode specific measures that can address multimodal needs of the District's transportation system were prioritized. Finally, measures focusing on *reliability, accessibility,* and *intensity of usage* were considered in the initial list.

Table 2 shows the initial performance measures identified for the study based on the broad literature review and indicates the performance category each metric falls under. The initial measures were selected to help DDOT assess how the transportation system is functioning in a more holistic manner and assist in capturing the balance between different mode users, while also leaning on the state of the practice for urban performance measurement.

For this project, a distinction was made between "transit" and "bus." When the word "transit" is used, it indicates that the analysis will include both heavy rail (i.e., Metrorail) and surface transit (thus includes the bus mode), while "bus" indicates only buses are considered. Metrorail plays a crucial role in service coverage and accessibility, thus accessibility related measures were included. However, Metrorail operates on a separate network and DDOT does not have a direct influence on day-to-day Metrorail operations and performance, while DDOT can much more directly influence bus operations. DDOT recognizes rail (commuter, passenger, and Metro) has a significant impact to overall system performance and that future efforts will engage the regional partners to examine the interrelationships within the system. This initial effort was focused on facilities that DDOT owns, operates, and maintains, which serves as a baseline for the future incorporation of other modes.

Table 2. Initial Performance Measures Identified for the District Mobility Project

Metric	Mode	Reliability	Accessibility	Intensity of Usage
Commute Mode Split	All*	✓	✓	✓
Commute Time	All*			✓
Accessibility to Jobs	All*		✓	
Safety	All*	✓		✓
Travel Time Reliability	Bus/Auto	✓		
Person Throughput	Bus/Auto			✓
Travel Time Index	Auto			✓
Transit System Coverage Area	Transit		✓	
Bus Ridership	Bus			✓
Bus Speed	Bus			✓
Bus On-Time Performance	Bus	✓		
Bus Overcrowding	Bus	✓		✓
Bicycle System Coverage Area	Bicycle		✓	
Number of Bicycle Trips	Bicycle			✓
Bicycle Level of Traffic Stress	Bicycle		✓	
Pedestrian Congestion	Pedestrian			✓
Pedestrian Friendliness**	Pedestrian		✓	

*All indicates auto, transit, bicycle, and pedestrian modes

**Based on the methodology described by Parks and Schofer (*21*)

DATA INVENTORY AND MEASURES PRIORITIZATION PROCESS

This section summarizes the data sets reviewed and discusses the data inventory process for the prioritization of initial performance measures.

Summary of Data Sets Reviewed

Multiple data sets from various data sources were evaluated to provide an assessment of data quality. The data reviewed are categorized in three different areas and summarized in the next sections.

DDOT Owned and Collected Data Sets

DDOT owned data were the first data sets reviewed as part of the data inventory process. The collected and reviewed data included the following:

- Base map shapefile,
- Roads and highways shape files,
- Crash data,
- Manual intersection turning movement counts,
- Historic annual roadway tube counts,
- Usage data from Capital Bikeshare (regional bikesharing system),
- DC Circulator data (DDOT-operated high frequency bus service in downtown DC and adjacent neighborhoods), and
- Manually collected bicycle counts at certain locations.

Other Government Data Sets

Additional data needed to be gathered from the regional transit operator and commute information from survey sources, including the following:

- Washington Metropolitan Area Transit Authority (WMATA) route and schedule data,
- WMATA automatic passenger count (APC) data to measure bus ridership by routes and stops,
- WMATA automatic vehicle location (AVL) data measuring average bus travel time and speed by route and by trip between WMATA time points,
- WMATA on-time performance data measuring lateness and earliness of buses,
- Metropolitan Washington Council of Governments (MWCOG) commute survey data, and
- United State Census commute data

Third Party Data Sets

Third party data collected or considered from other sources for the data inventory included:

- INRIX travel time (speed) and origin-destination data,
- General Transit Feed Specification (GTFS) data,
- Map and routing information from Google Maps Application Programming Interface (API) and OpenStreetMap data,
- Ride hailing and carshare data (e.g. Uber, Lyft, Split, Car2Go),
- Strava data for non-motorized modes, and
- AirSage cellular phone data.

Data Inventory for Prioritization

For each performance measure listed in **Table 2**, a data inventory was conducted to evaluate the quality of data required for each metric. The following factors were considered in the assessment:

- Data availability:
  - Whether the data is readily available and accessible to obtain the desired performance measure or whether it can be purchased for a reasonable price
- Data usability/complexity:
  - The complexity in obtaining and analyzing the data, and whether the data has any limitations
- Data reliability
  - Accuracy and completeness of the data
- Data repeatability:
  - The data is recurring, regularly updated and the quality of the data is maintained over time
- Data coverage:
  - The data covers a wide area of the District's transportation network

Figure 3 explains the cost and complexity of data sources based on the data quality assessment. It should be noted that cost and complexity relate to staff resources as well. Data analysis skills are required and often may not be readily available within a transportation department, which may result in the need to utilize outside resources. If outside resources, such as a consultant, are required, then costs increase and the data source may not be considered as sustainable over the long term. Alternatively, an agency may choose to develop staff resources to analyze the data internally, which requires training and dedicated time. Thus, staff skill sets is another layer that could be considered in the prioritization process.

The assessment of the data indicates that mobile probe travel time data such as INRIX or TomTom are generally expensive data, however relatively easy to analyze and display since they are pre-processed and aggregated. On the other hand, high-resolution origin-destination based data typically require specialized skills to analyze, thereby limiting their use in practice.

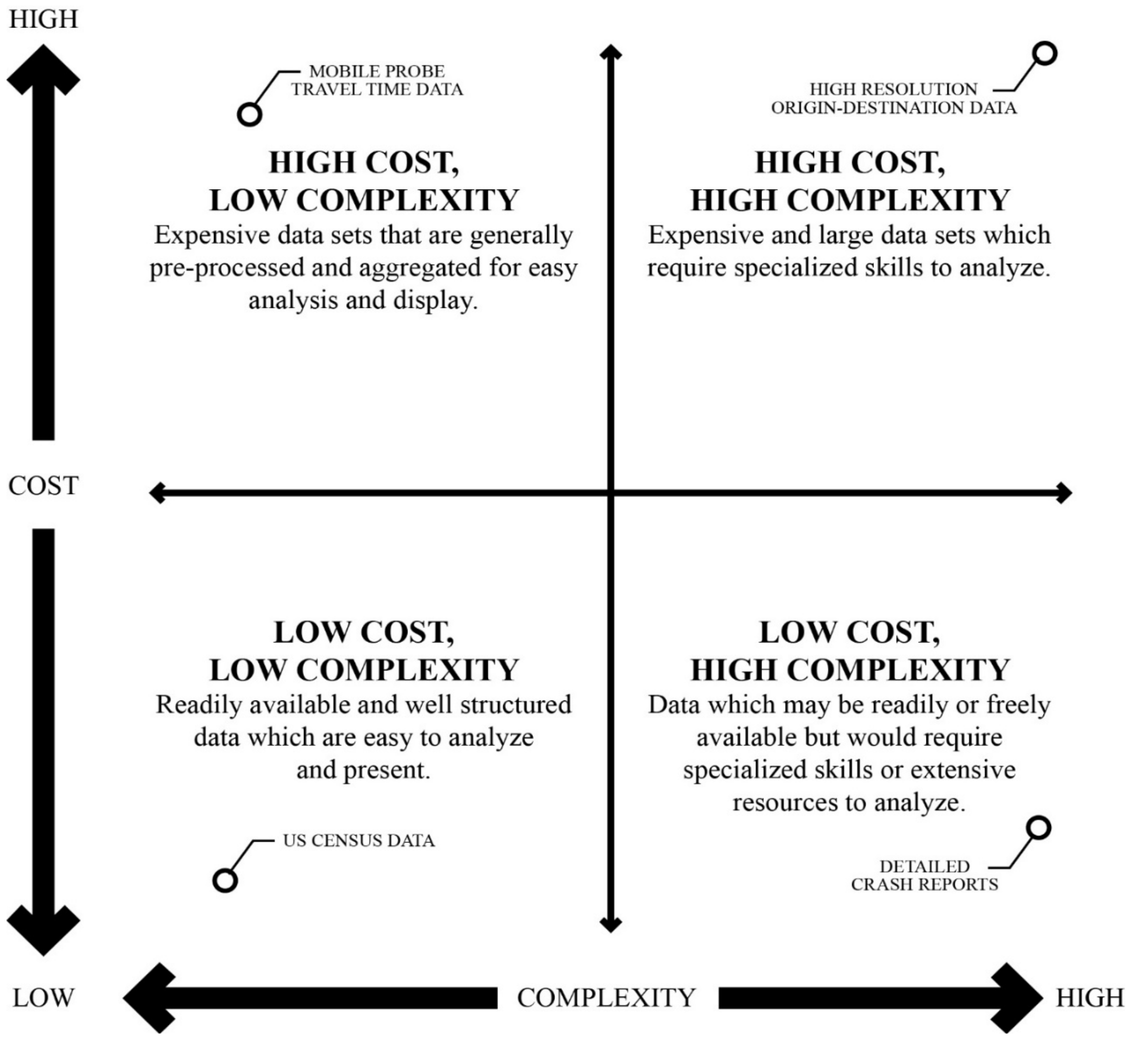

Figure 3. Cost and Complexity of Data Sources Reviewed

The next section provides detailed information regarding the selection of the recommended measures based on the data quality assessment.

RECOMMENDED DATA-DRIVEN PERFORMANCE MEASURES

This section first discusses the measures that are eliminated from the initial list due to the limitations in data availability and/or quality. Then, it provides the recommended list of measures to assess urban system performance for the District.

Measures Eliminated from the Initial List

Pedestrian Congestion

Pedestrian congestion is becoming more pronounced in large cities due to the increase in walking trips. The issue of pedestrian congestion is exacerbated and becomes more critical in the District as every year DC welcomes approximately 20 million visitors (*11*).

Evaluation of pedestrian congestion typically requires pedestrian volume counts. While it may be possible to do manual data collection at spot locations fairly easily, it is not practical to conduct District-wide pedestrian counts to perform a quantitative analysis of pedestrian congestion, and the District does not have automated pedestrian counters. It is important to note that the recent National Cooperative Highway Research Program (NCHRP) Report 797 describes methods and technologies for counting pedestrians and bicyclists, with a focus on automated technologies to address non-motorized data collection issues (*22*). However, resource limitations still prevent agencies from collecting data over an extended period of time at all locations.

Person Throughput

Person throughput is an important measure for urban systems as it assesses the number of people served by a facility regardless of the particular travel mode used. A person throughput measure is generally calculated by conducting manual vehicle counts, corresponding occupancy counts (or assuming an average auto occupancy), and transit data including transit frequency and average load of people using transit. Similar to the pedestrian congestion metric, data collection to measure person throughput for the District corridors over time would require considerable resources and could be burdensome for agencies. Thus, person throughput measure is not considered in the final list.

Number of Bicycle Trips

Total number of bicycle trips can provide insight regarding the evolution of bicycle use in the system and trends over time. This metric can also be used to conduct before and after studies to assess the change in bicycle volumes after a bicycle facility is implemented.

For cities with a bikeshare program, bikeshare data is typically used to indicate the level of bicycle activity. However, focusing only on bikeshare trips has limitations as bikeshare data can only capture a specific sample ridership. Moreover, the data is generally limited to the stations (unless GPS-enabled bikes are available), which does not allow capturing bike activity on specific bicycle facilities.

Strava Metro has been increasingly used by transportation planners to estimate the number of bicycle trips and determine what routes cyclists are using. Strava is a leading provider of mobile apps to track athletic activity using GPS data. As part of this study, a dataset of bicycle and pedestrian activity was provided as a pilot from Strava Metro.

In order to explore whether the Strava Metro can be used to estimate bicycle trips in the District, an analysis of the relationship between Strava bicycle counts and counts recorded manually by DDOT staff at a select number of locations was conducted. In total, 32 locations with 96 peak period manual counts from 2015 were used for this comparison. The analysis found that the Strava data captured between zero and five percent of the DDOT manual counts, with an average of approximately two percent. Key findings included:

- The variability in capture rate does not allow for a single multiplier factor that can estimate total bicycling activity at a given location within a reasonable range without substantially more analysis and refinement to the data used in the analysis (e.g. limiting Strava data to peak periods and conducting regression analysis that factors in contextual variables).
- Order of magnitude estimates from the Strava data may be feasible, particularly for long time frames (e.g., daily estimates) and for area-wide spatial aggregations, but additional validation would be needed to make these estimates.

As a result, the number of bicycle trips metric is not included in the final recommended performance measures and separate additional exploration will occur.

Safety

Congestion and unreliable travel time result from the interaction of many different factors, some of which include high traffic demand, traffic incidents such as crashes and vehicle breakdowns, and poorly timed traffic signals. A study conducted by Federal Highway Administration (FHWA) developed rough estimates of the sources of congestion and indicated that nationally, 25 percent of the congestion can be attributed to traffic incidents (*23*). While the impact of incidents may be lower for systems that can offer alternative route or mode options, it is clear that safety is an important part of system performance, in particular reliability, that needs to be addressed.

Most safety performance measures focus on increasing safety, rather than improving safety for congestion/incident-reduction reasons. Moreover, slower vehicle speeds in congested conditions can improve safety outcomes by reducing the severity of crashes. The District has a stated "Vision Zero" goal to eliminate fatalities and serious injuries on the transportation system by 2024. Even though safety is part of system performance, this project acknowledged concurrent efforts led by the Vision Zero initiative, and thus did not include safety metrics in the final performance measure list.

Selected Performance Measures

Table 3 shows the selected performance measures and indicates the mobility category each metric falls under, the desired outputs obtained from each measure, and the temporal and spatial variations for the outputs.

TABLE 3 Selected Performance Measures and Outputs

Category	Measure	Outputs	Temporal	Modes	Geography
Commuting	Commute Mode Split	Percent of commuters using mode (% commuters/mode)	Daily average	Pedestrian Bicycle Transit Auto	District Block / Ward
	Commute Time	Average commute time by mode (avg. minutes/commute) Commute time distribution	Daily average	Pedestrian Bicycle Transit Auto Overall	District Block / Ward
Reliability	Auto Travel Time Reliability	Planning time index (ratio of 95th percentile travel time to travel time in light traffic) for arterials and freeways	Over the day (by time period*), weekends and weekdays	Auto	District
	Bus On-Time Performance	Runtime difference (scheduled vs. actual runtime) for all bus routes in the District	Over the day (by time period*) for weekdays	Bus	District

Intensity of Use	Roadway Congestion	Auto travel time index (ratio of congested travel time to travel time in light traffic)	Over the day (by time period*), weekends and weekdays	Auto	District
	Bus Ridership	Average stop level ridership by time period (ridership per stop) Route level ridership (ridership by line)	Over the day (by time period*) Daily	Bus	District
	Bus Overcrowding	Average of the maximum load observed per route, by time period, on roadway links	Over the day (by time period*)	Bus	District
	Bus Travel Speed (Time)	Average bus speeds (speed between timepoints) per route	Over the day (by time period*)	Bus	District
Accessibility	Transit System Coverage	Walksheds to all transit service (0.5 miles to Metrorail, 0.25 miles to bus) Walksheds to high frequency transit service**	Over the day (by time period*), weekends and weekdays	Transit	District Ward
	Bikeshare System Coverage	Walksheds to bikeshare stations (0.25 miles)	N/A	Transit Bicycle	District Ward
	Walkability Index	Scores based on walkability methodology	N/A	Pedestrian	Ward Neighborhood (ANC)***
	Bicycle Level of Traffic Stress (LTS)	LTS score by roadway network link***	N/A	Bicycle	District Ward Neighborhood (ANC)***

*Time periods are: early morning, AM peak, midday, PM peak, early evening, late night
**High frequency transit service is defined as headways of less than 10 minutes for bus service and less than 5 minutes for Metrorail service
*** Four types of cyclists popularized by the City of Portland (24)
***Advisory Neighborhood Commissions (ANCs) are a sub-ward level of political oversight in the District

The selected measures will help DDOT evaluate the multimodal system performance of the District and make investment decisions that balance the needs of different users of the system. In addition, the measures can be supported by attainable and reliable data sources, which will allow updating the measures over time without requiring major investment in resources.

CONCLUSIONS AND FUTURE DIRECTIONS

Comprehensively measuring urban transportation system performance is becoming more critical as most cities in the United States are putting more emphasis on non-motorized, multimodal transportation options. As a result, several recent studies reported performance measures that can address the multimodal nature of urban transportation systems. However, some of these studies focus only on the measures without taking into account the challenges in collecting, analyzing, and using data. This often results in ineffective performance measurement practices or programs that are initially successful but cannot be maintained over time.

This paper presents a data-driven framework for monitoring urban transportation system performance through a case study application in the District. Twelve measures were selected to assess urban mobility system performance. The following criteria were employed for the selection of the measures:

- Measures that are common and can be compared across modes as well as sensitive to the multimodal nature of travel were prioritized,
- Three performance categories are defined in this study to assess multimodal system performance: *reliability, accessibility,* and *intensity of usage*. Metrics that fall under these three categories were included, and
- Measures that can be supported by data sets that are valid, usable, and reliable over time were recommended in the final list.

A wide range of performance measures are prevalent for bus and auto modes, however it was realized by the project team that system performance measures and supporting data for non-motorized modes were limited. As a result, the pedestrian and bicycle performance measures focused on accessibility with respect to the state of the infrastructure. As data sources mature for pedestrian and bicycle, the District intends to include the appropriate performance measure to assess mobility for non-motorized users.

Future Directions

Performance measurement and management is relatively mature in the sense that many agencies are utilizing performance measures as part of their activities, yet there are many opportunities in this evolving and growing area. Three further opportunities have been recognized through this effort:

1. The first opportunity is the need for expanded reliable data sources to support performance assessments and decision making. Some of the performance measures, particularly the non-motorized related metrics, were not included in the final list due to the data limitations. However, these measures play an important role in assessing the operations of multimodal systems. There are future opportunities to develop and expand a data collection program for the non-motorized performance measures as technologies and techniques become more mature. In the near-term, the District is focusing efforts to quantify and qualify the built environment with goals to ensure that the infrastructure is established for the non-motorized users.
2. A second opportunity is the continued development of multimodal system performance measures that integrate modal performance. A majority of performance measures focus on specific modal performance but a few performance measures are able to be compared across multiple modes. This phase of the project did not allow for the team to explore opportunities for comparable assessment due to the tight schedule. However, it is desired to continue the effort and include this in future reporting rounds. Additional input and

technical community insights may allow for evolved approaches to multimodal performance measures.

3. The last opportunity is refining the decision-making process based on the data resolution behind the performance measures. Performance measures based on high resolution data can be used to inform decision making at a more nuanced project level. For example, greater spatial resolution (e.g., probe vehicle data) can provide in-depth information for an intersection or corridor and could be used to inform the specific strategies to employ in specific areas. On the other hand, performance measures that utilize data that is of lower resolution temporally (e.g., Census data that is updated annually) or spatially (e.g., system coverage measures) may be more valuable for tracking the longer term effects of system changes or for identifying general areas of need for additional evaluation.

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