



## Regional Thoroughfare Network Performance Measurement Report

Prepared by:



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## 1.0 INTRODUCTION

This report serves as the deliverable associated with Task 4 of the Scope of Services for the Strategic Regional Thoroughfare Plan (SRTP) completed for the Atlanta Regional Commission (ARC). The purpose of the SRTP is to identify a network of surface roadways, called the Regional Thoroughfare Network (RTN), that are most critical in providing regional mobility and connecting major activity centers throughout the Atlanta region and develop policy guidelines to maximize their overall functionality. As such, the RTN will also serve as the Atlanta region's priority network for its Congestion Management Process policies and procedures.

This report describes specific measures that can be used to monitor and evaluate the performance of the RTN as part of a continuous network management process, and proposes performance targets for RTN segments based on an analysis of the distribution of current and forecast segment characteristics.

To some extent the definition of specific measures and targets has been constrained by the types of data currently available. However, the report also discusses how the performance measurement framework can be updated in a coherent way as more and different types of data become available over time.

### 1.1 Report Organization

This report outlines the steps taken to develop the performance measures and their targets for the Regional Thoroughfare Network. This report is organized as follows:

- Chapter 2.0 – Thoroughfare Network Evaluation Framework
- Chapter 3.0 – Performance Measure Development
- Chapter 4.0 – Performance Measure Analysis and Targets
- Chapter 5.0 – Updating the Performance Measures and Targets

## 2.0 THOROUGHFARE NETWORK EVALUATION FRAMEWORK

This chapter provides an overview and framework of the performance measures developed to evaluate the Regional Thoroughfare Network (RTN). Following a brief discussion of the background to this analysis of performance measures and targets, it then describes the general guidelines, performance criteria types, and comparison of the other regional performance measurement definitions throughout the region.

### 2.1 Network Identification and Classification

Initial activities associated with the SRTP focused on identifying the specific facilities to be included in the RTN. This involved an intensive process of data collection and analysis; development of criteria for assessing the inclusion (or not) of particular facilities; application of the criteria to the collected data to identify two contrasting thoroughfare network candidates; outreach and presentation to the various stakeholder groups interested in the RTN definition; and final selection of facilities for inclusion in the RTN.

In order to develop a mechanism for more detailed analysis, performance monitoring, and management of the RTN network, a thoroughfare classification framework was developed. The purpose of the classification scheme was to enable the development of transportation and land use management strategies that are oriented to specific community and corridor contexts and that can be used to protect mobility and system efficiency along RTN facilities.

Thoroughfares have an intermediate position in the hierarchy of road types. They provide both mobility (through connections to other transportation facilities in the network) and accessibility (through connections to trip generating land uses). The relative importance of these two roles for an individual facility depends on its role and location within the network and in relation to land uses.

Consequently the performance of an arterial relates to:

- How well it serves the travel movements that use it (although typically for only a portion of their total trip);
- How well it facilitates connections to “higher” facility types (limited access facilities, connectors);
- How well it facilitates connections to adjacent and nearby land uses and to the “lower” facility types (other arterials, distributors/collectors, local streets, access facilities) that serve them; and
- How well it serves different travel modes and trip types.



Accordingly, based on the work accomplished in the RTN network identification process, coordination with ARC's PLAN 2040 activities, and feedback from key stakeholders, a four-part framework was developed to classify individual RTN segments (relatively short and homogeneous stretches of roadway). The following dimensions were seen as critical to classifying the RTN segments:

- **Mobility for People and Goods** – this dimension reflects the overall regional significance of the facility as evidenced by its importance to freight movement as well as its service for commute trips. The idea of “trip mix intensity” or extent to which the facility is playing a major role in a combination of regional person travel and freight movements is reflected in this part of the framework.
- **Land Use Connectivity** – this dimension reflects the critical importance of the RTN connecting major regional activity centers, including core cities, town centers, transit-oriented developments, regional industrial/logistics centers, and other regionally-significant locations.
- **Network Connectivity** – this dimension focuses on the role the RTN segments play in serving as freeway-to-freeway connectors, connectors to other limited access roadways, or connectors to other State-owned facilities to provide regional mobility.
- **Multimodal Functionality** – this element reflects the extent to which a roadway facility serves travel modes other than single-occupant vehicles, including various modes of transit, such as regional bus services and bus rapid transit (BRT) lines, regional bicycle and pedestrian facilities, etc.

Building on these classification dimensions, the SRTP study assigned to each RTN segment an ordinal level (I, II or III) indicating its overall degree of contribution in these different dimensions of thoroughfare service, in order from high (I) to low (III).

## 2.2 General Guidelines for Developing Performance Measures

The next step in the SRTP study was to develop performance measures that could be used to evaluate and monitor the thoroughfare network. A number of issues and principles were adopted to guide this work, as discussed in the following paragraphs.

The ARC thoroughfare classification framework identifies factors that relate thoroughfare identification and typology to connectivity, function and use. To ensure consistency and coherency across the different tasks of classifying and evaluating RTN segments, it was determined that the performance measures should be related to these factors as much as possible.

Some performance measures should be able to be used to diagnose aspects of facility characteristics or performance levels that are potentially “deficient” compared to target values, and that can be corrected by suitable engineering or operational improvement actions.

However, some of the classification framework factors do not directly lend themselves to defining performance measures for individual facilities (trip mix intensity, for example). Nonetheless, these factors can provide very useful additional information for monitoring the evolution of the RTN over time, for combining with other measures, or for prioritizing improvements that are identified using other factors. Accordingly, it was decided to include not only performance measures that are “actionable” (i.e. for which some engineering or operational improvement can be undertaken to improve a deficient value), but also others that are “informative” but that cannot be readily changed through engineering or operational interventions.

Because of the great variety of possible application contexts, measures developed to assess thoroughfare performance need to be scalable in a consistent way across:

- Empirical data from observations of roadway features and characteristics;
- Data generated by the ARC regional travel forecasting model;
- Data generated by a regional or sub-regional DTA model; and
- Data generated by a corridor or facility-specific micro-simulation model.

Similarly, the likely future availability of entirely new types of performance-related data makes it imperative to ensure that the set of performance measures can evolve to encompass new data types in a way that meshes consistently with the measures already defined.

For the purpose of defining performance measures, the distinction between urban, suburban and rural may be most useful for fine-tuning the measure definitions (variations on the measures that would be more applicable to each area type). The performance measure target values that will be defined in the next phase of work will in general vary by area type.

## 2.3 Criteria Types

The starting point in the consideration of potential performance measures was the set of RTN segment classification criteria described above:

- Mobility: service to travel on the facility;
- Network connectivity: service to medium- or longer-distance movements;
- Land Use connectivity: service to specific UGPM land use classes as well as to the general activities and uses that generate travel demand on the facility/in its corridor; and
- Multimodal functionality: mix of service types that a facility provides to travel on it.

Different categories of potential measures were sketched out for each criterion, as described in the following subsections. The most promising of these were then developed into actual quantitative measures, as discussed in Chapter 3 further below.

### 2.3.1 Mobility Criteria

These measure categories consist mostly of conventional traffic engineering and transit operations metrics, such as:

- Volume and characteristics of travel service on a thoroughfare segment: total volume; truck volume; VMT; VHT; speed; transit ridership;
- Quality of service on a thoroughfare segment: LOS; vehicle-hours of delay; transit service frequency and speed; and
- Reliability (a particular aspect of service quality): historical crash counts and measures of crash-related delays; model-based measures of VHT and delay impacts of capacity reductions.

### 2.3.2 Network Connectivity Criteria

These measure categories consider the nature and performance of a thoroughfare's connections to "higher" facility types, such as:

- Inventory type quantity and characteristics information about connections: location; type of connections: interchange, intersection, traffic controls, movement capacities; and
- Level of service provided by the connections: operational LOS-type data characterizing the functioning of the movements to/from the higher-type facilities.

### 2.3.3 Land Use Connectivity Criteria

These measure categories consider the nature and performance of a thoroughfare's connections to "lower" facility types, such as:

- Inventory type quantity and characteristics information about connections: location; type of connections: intersection, traffic controls, movement capacities; and
- Level of service provided by connections: operational LOS-type data characterizing the functioning of the movements to/from the lower-type facilities.

Measures corresponding to this criterion would also consider the nature and performance of service to nearby demand-generating activities and uses such as characteristics of the service via curbs-cuts or connections to local streets.

These measures would extend further to indicators of the quality of service to particular land use types identified by the UGPM:

- Regional, town centers; industrial, freight and logistics hubs; and
- For specific land uses of these types, average speed on the thoroughfare facility vs. average speed on access links.

#### 2.3.4 Multimodal Functionality

Measures in this category consider the availability and quality of multimodal options:

- Absence / presence /quality of premium, regular, para-transit services;
- Absence / presence /quality of ITS infrastructure and services;
- Absence / presence /quality of bike and pedestrian facilities; and
- Absence / presence / quality of freight service (most likely measured as truck traffic volume or truck % of traffic).

## 2.4 Comparison to Other Regional Performance Measurement Definitions

The performance measures established for the thoroughfare network evaluation should be consistent with and not contradict other performance measures established for transportation infrastructure in the Atlanta region. Below are brief descriptions of some of the other regional performance measures currently in use.

- IT3 performance metrics: these tend to be higher-level metrics than those considered for the regional thoroughfare plan. However, there is some commonality of concerns between the two sets of measures. For example:
  - Jobs access (IT3) / land use connectivity (SRTP); and
  - Number of people taking reliable trip (IT3) / reliability measures (SRTP).
- Final Recommended HB 277 Criteria for the Atlanta Region: These goals, outcomes and principles are much more general than the SRTP performance measures.
- Plan 2040: Some project-level measures used in Plan 2040 come reasonably close to the SRTP performance measures under consideration. However, the Plan 2040 project measures are defined against more generic network development objectives, and are not particularly focused on thoroughfares.



### 3.0 PERFORMANCE MEASURE DEVELOPMENT

In this chapter, the generic performance measure types for evaluating the thoroughfare network, as presented in Chapter 2, are refined into candidate performance measures. The following sections present a discussion about potential performance measure concepts, the possible data sources available to calculate performance measures, and a description of candidate performance measures to consider for the evaluation of the thoroughfare network.

#### 3.1 Identify Performance Measure Concepts

Chapter 2 discussed the performance measurement criteria for evaluating the thoroughfare network. The next step in developing performance measures was to derive more specific concepts regarding quantities that could potentially be measured to capture thoroughfare performance as regards each of these criteria.

The following tables display these performance categories and concepts, with **Table 1** presenting them for the Mobility criteria, **Table 2** presenting them for the Network Connectivity criteria, **Table 3** presenting them for the Land Use Connectivity criteria, and **Table 4** presenting them for the Multimodal Functionality criteria.

**Table 1 - Mobility Performance Categories and Concepts**

<i>Category</i>	<i>Concept</i>
Characteristics of service	
	Highway volume
	Highway utilization
	Highway speed
	Transit ridership
Quality of service	
	Highway LOS
	Highway congestion
	Transit service frequency
Reliability	
	Incident/crash occurrence
	Incident/crash impacts on service



**Table 2 - Network Connectivity Performance Categories and Concepts**

<i>Category</i>	<i>Concept</i>
Nature of connection	
	Location of connections
	Type of connections
	Number of interchanges
	Number of intersections
	Number of controlled intersections
	Movement capacities
Quality of connection	
	LOS of movements to/from higher-type facilities

**Table 3 - Land Use Connectivity Performance Categories and Concepts**

<i>Category</i>	<i>Concept</i>
Connections to "lower" facility types	
Nature of connection	
	Location of connections
	Type of connections
	Number of interchanges
	Number of intersections
	Number of controlled intersections
	Movement capacities
Quality of connection	
	LOS of movements to/from lower-type facilities
Connections to demand generators	
Nature of connection	
	Number of curbcuts
	Connections to local streets
Connections to UGPM land uses	
Nature of connection	
	Number of regional/town center connections
	Number of freight/logistics hub connections
	Speed differences between thoroughfare and local facilities



**Table 4 - Multimodal Functionality Performance Categories and Concepts**

<i>Category</i>	<i>Concept</i>
Transit	
	Presence of conventional transit service
	Frequency of conventional transit service
	Presence of premium transit service
	Frequency of premium transit service
	Presence of paratransit service
ITS	Presence of quality ITS
Bike	Presence of quality bike facilities
Pedestrian	Presence of quality pedestrian facilities
Freight	Presence of quality freight service

### 3.2 Identify Available Data Sources

As was noted above, the data used to evaluate thoroughfare segment performance may potentially originate from any of four general sources, and the defined measures should, to the extent possible, scale in a consistent way across the different levels of detail of data from these sources. The data sources and their features are:

1. Empirical data sources, which reflect characteristics that can be observed. Because of this, they tend to be more applicable to current conditions although, in some cases, future improvement plans may be able to serve for this purpose;
2. The ARC regional travel forecasting model, which can provide static measures of transportation performance for current and future years;
3. Dynamic traffic assignment (DTA) or mesoscopic models, which introduce a dynamic element into the measurement of transportation performance, and can be used to identify measures such as the duration of highly congested conditions in current and future years; and
4. Microscopic traffic simulation models, which can provide fully dynamic measurements of transportation performance. However, due to their extensive data requirements and level of computational effort, such models can only be applied at the corridor or facility level in current and future years.



The availability of suitable data from these sources must be considered when defining specific measures for each concept. An extensive clearinghouse of data was compiled as part of this project, and some of these data items can serve as sources for calculation of the performance measures. In particular, databases of observed road and traffic characteristics, together with the ARC regional travel forecasting model, provide the information needed to calculate some of the performance measure targets.

### 3.3 Candidate Performance Measures

Building upon the performance measure concepts, the work effort defined a range of specific performance measures that elaborate and quantify the concept in different but compatible ways, depending on the available data sources. This elaboration approach applies most directly to mobility-related measures, and LOS-type measures of network and land use connectivity. Where the data needed to evaluate a performance measure does not derive from model outputs at potentially different levels of detail, this approach is less relevant and the defined measures do not vary.

It will be noted that some of the performance measurement concepts refer to specific locations, whereas others refer to a stretch of roadway. While the point or linear nature of a performance measure concept does not relate to its usefulness as a measure, we document this property in order to support the more detailed implementation and application of performance measures.

Similarly, it will be noted that some performance measure concepts are actionable while others are only informative. As noted above, informative measures are useful in trying to understand the performance of a thoroughfare, but no direct actions can be taken to alter their value. Actionable measures are those for which direct actions can be implemented to alter their value. Ultimately, the actionable measures are most useful for setting performance targets, identifying deficiencies and developing appropriate responses. But informative measures are also useful in monitoring thoroughfare performance more generally, and in helping to identify priorities.

The following tables present the candidate performance measures, with **Table 5** presenting the candidates for the Mobility criteria, **Table 6** for the Network Connectivity criteria, **Table 7** for the Land Use Connectivity criteria, and **Table 8** for the Multimodal Functionality criteria.

**Table 5 - Mobility Performance Measure Candidates**

Category	Concept	Point or Linear	Actionable or Informative	Specific Measure			
				Empirical/Availability	ARC model	DTA model	Microsim model
Characteristics of service							
	Highway volume	P/L	I	Counted AADT	Forecast AADT	Input AADT	N/A
				Counted peak hour volume	Peak period volume	Peak of peak volume	Peak of peak queues
				Counted truck volumes	Forecast truck volumes	Input truck volumes	Input truck volumes
	Highway utilization	L	I	Calculated VMT	Forecast VMT by day or period	Forecast VMT by period	N/A
				N/A	Forecast VHT by day or period	Forecast VHT by period	N/A
	Highway speed	L	A	Average daily speed	Forecast average daily speed	Forecast average daily speed	N/A
				Measured peak hour avg speed	Forecast peak period avg speed	Forecast peak of peak avg speed	Peak of peak speed distribution
	Transit Ridership	L	A	Route level patronage	Forecast route level ridership	N/A	N/A
Quality of service							
	Highway LOS	L	A	Calculated LOS	Peak period LOS	Peak of peak LOS	TBD
	Highway congestion	L	A	Calculated veh-hr of delay	Forecast peak period VHD	Forecast peak of peak VHD	TBD
	Transit service frequency	L	A	Actual frequency	Input frequency	N/A	N/A
Reliability							
	Incident/crash occurrence	P/L	A	Actuals	N/A	N/A	N/A
	Incident/crash impacts on service	L	A	Actual incident delays (?)	Model computed delays	Model computed delays	Model computed delays



**Table 6 - Network Connectivity Performance Measure Candidates**

Category	Concept	Point or Linear	Actionable or Informative	Specific Measure			
				Empirical/ Availability	ARC model	DTA model	Microsim model
Nature of connection							
	Location of connections	P	A	Field observation	Model data for most connections	Model data for most connections	Model data for most connections
	Type of connections	P	A	Field observation	Model data for most connections	Model data for most connections	Model data for most connections
	Number of interchanges	L	A	Field observation	Model data for most interchanges	Model data for most interchanges	Model data for most interchanges
	Movement capacities	P	A	Field observation	Limited	Limited	Implied
Level of service of movements to/from higher-type facilities							
	Movement LOS	P	A	Calculated LOS	N/A	N/A	TBD



**Table 7 - Land Use Connectivity Performance Measure Candidates**

Category	Concept	Point or Linear	Actionable or Informative	Specific Measure			
				Empirical/ Availability	ARC model	DTA model	Microsim model
Connections to lower-type facilities							
Nature of connection							
	Location of connections	P	A	Field observation	Model data for most connections	Model data for most connections	Model data for most connections
	Type of connections	P	A	Field observation	Model data for most connections	Model data for most connections	Model data for most connections
	Number of intersections	L	A	Field observation	Model data for some intersections	Model data for some intersections	Model data for all intersections
	Number of controlled intersections	L	A	Field observation	Model data for some intersections	Model data for some intersections	Model data for all intersections
	Movement capacities	P	A	Field observation	Limited	Limited	Implied
Level of service of movements to/from lower-type facilities							
	Movement LOS	P	A	Calculated LOS	N/A	N/A	TBD
Connections to demand generators							
Nature of connection							
	Number of curbcuts	L	A	Field observation	No	No	Model data for most curbcuts
	Connections to local streets	L	A	Field observation	Model data for some connections	Model data for some connections	Model data for all connections
Connections to UGPM land uses							
	Number of regional/town center connections	L	I/A	Field observation	Model data for some connections	Model data for some connections	Model data for all connections
	Number of freight/logistics hub connections	L	I/A	Field observation	Model data for some connections	Model data for some connections	Model data for all connections
	Speed differences between thoroughfare and local facilities	L	A	Field observation	Forecast peak period speeds (where available)	Forecast peak of peak speeds (where available)	Forecast speed distributions



**Table 8 - Multimodal Functionality Performance Measure Candidates**

Category	Concept	Point or Linear	Actionable or Informative	Specific Measure			
				Empirical/ Availability	ARC model	DTA model	Microsim model
Transit service							
	Presence of regular transit service	L	A	yes, from array of shapefiles collected for project	Model input	Model input	Model input
	Regular transit service frequency	L	A	yes, from array of shapefiles collected for project	Model input	Model input	Model input
	Presence of premium transit service	L	A	yes, from array of shapefiles collected for project	Model input	Model input	Model input
	Premium transit service frequency	L	A	yes, from array of shapefiles collected for project	Model input	Model input	Model input
	Presence of para-transit service	L	A	yes, from agencies	Model input	Model input	Model input
ITS							
	Presence of quality ITS	L	A	Field observations	Possibly	Possibly	Probably
Bike							
	Presence of quality bike facilities	L	A	Field observations	No	No	Possibly
Pedestrian							
	Presence of quality pedestrian facilities	L	A	Field observations	No	No	Unlikely
Freight							
	Presence of quality freight service	L	A	Field observations	Probably	Probably	Probably

## 4.0 PERFORMANCE MEASURE ANALYSIS AND TARGETS

In this chapter candidate performance measures are transitioned into the actual performance measures and targets. More specifically, this chapter discusses the data sources used to derive the performance measures, the preparation of the performance measures, the analysis of the performance measures, and the identification of performance measure targets.

### 4.1 Available Data Sources

As previously discussed, a number of data sources were available to the work effort to calculate performance measures. As will be discussed below, other potentially interesting and useful data sources were not ready to be processed as part of the work undertaken here. The following specific data sources were ultimately used to develop the performance measures investigated as part of this work:

- ARC regional travel demand model, which provided information for many of the mobility performance measures;
- UGPM land use database;
- ARC roadway crash database;
- GIS bike/pedestrian network, as developed for the ARC Atlanta Region Bicycle Transportation & Pedestrian Walkways Plan Study; and
- Truck route GIS network, which was established for the Atlanta Strategic Truck Route Master Plan.

### 4.2 Data Assembly

The data sources described above were obtained in GIS form. Each GIS layer was then related to a layer that defined the RTN thoroughfares and segments. For performance measures that were derived from the ARC regional travel forecasting model, all model links located along a given thoroughfare were identified, and the performance measures were computed using data from all of those links. In this way, data values for each potential performance measure were compiled. Linear features on other GIS layers (such as bike and pedestrian facilities, crash data and designated truck routes) were also related to the RTN layer to establish the referencing to thoroughfares and segments, and the corresponding data was again compiled. The UGPM GIS layer was handled slightly differently because it consists of area features. RTN segments and corridors were therefore referenced to UGPM features based on proximity.

In most cases, the compilation was carried out at the level of individual RTN segments; in a few cases (noted below), however, it was felt that the measures were more



representative of a thoroughfare as a whole rather than of the individual segments along it, so values for these variables were compiled at the thoroughfare instead of the segment level.

### 4.3 General Process

The approach to select performance measures and targets relied heavily on graphical data analysis.

For a candidate performance measure, a histogram showing the empirical distribution of its data values across segments or thoroughfares was prepared. In many cases, the histogram was presented in a way that showed 5% quantiles of the empirical distribution, and that highlighted the upper and lower 25% of the distribution. The histogram was then examined to determine if the spread of values was such that different levels of performance could clearly be distinguished. If so, the corresponding variable was a strong candidate to be retained as a performance measure, and some appropriate quantile of the distribution was chosen as a target; otherwise, the variable was deemed unsuitable for use as a measure.

In some cases, an additional graphical analysis was performed. In this analysis, the correlations between candidate measures for each performance criterion were visually assessed. Uncorrelated measures present information about different aspects of segment or thoroughfare performance. Conversely, there would be little point in selecting strongly correlated performance measures, since the facility performance information that is conveyed by each measure would be very similar. Thus, where multiple candidate measures were seen to be strongly correlated, only one was retained.

### 4.4 Performance Measure Analysis and Target Definition

The following pages present scatterplots that show the correlations between candidate measures within some of the performance criteria, and histograms showing the distribution of values of the various candidate performance measures. The figures are presented in groups, according to the different performance measure criteria.

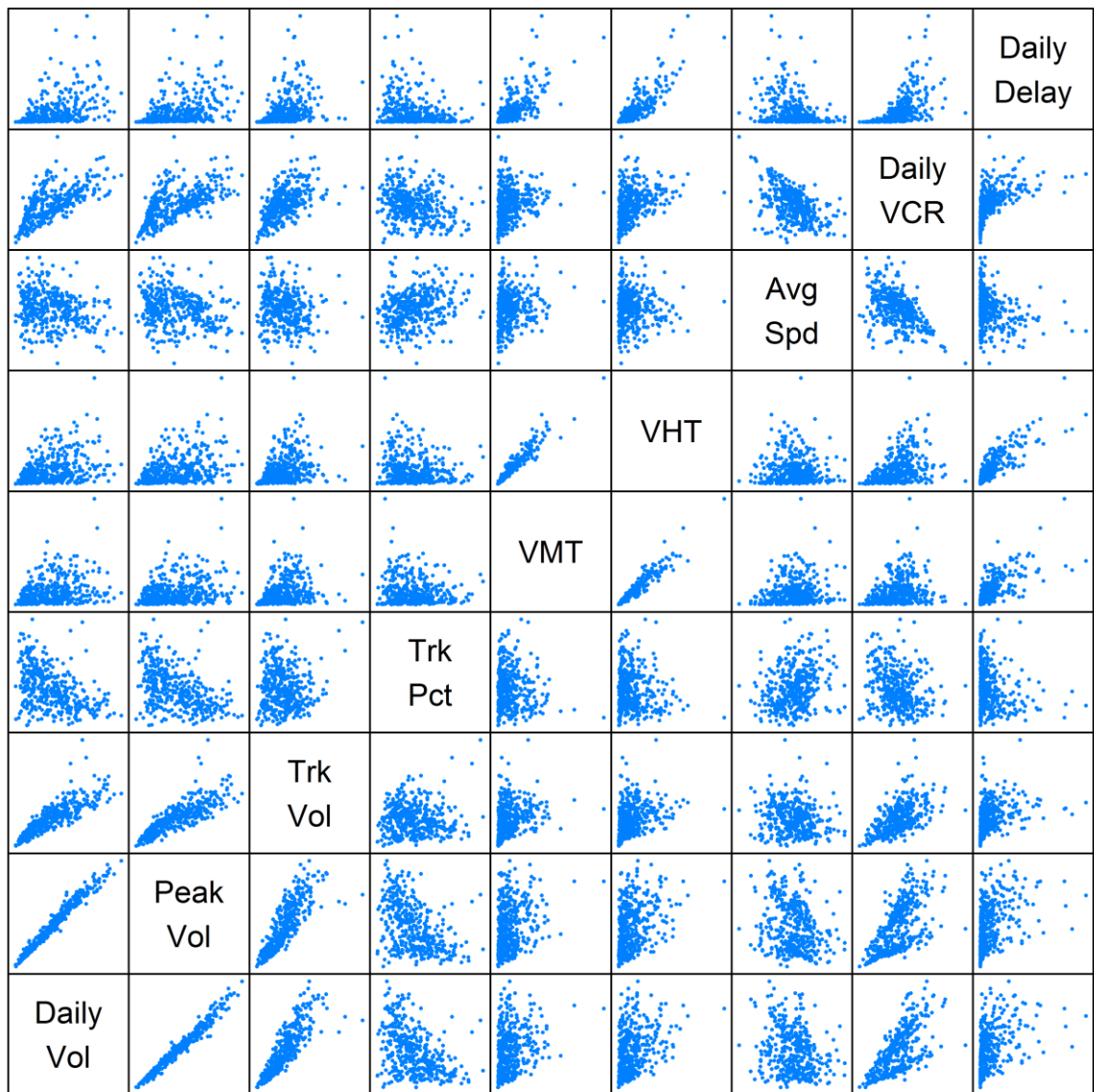
#### 4.4.1 Mobility Performance Measures

Within the Mobility criterion, a number of performance measures were evaluated. The data used for the measures was derived from ARC regional forecasting model runs for 2010 and for the 2040 long-range transportation plan. The initial review of some of these measures showed a high degree of correlation. Scatterplots were prepared to display the correlation of the mobility performance measures.

**Figure 1** displays the candidate Mobility measure correlations using data for 2010. The figure is set-up with the Mobility performance measures defined along the diagonal, and includes a set of individual plots. Each plot shows the scatter of values of a pair of performance measures, with the x-axis representing the performance measure that is listed in the same column as the plot and the y-axis representing the performance measure that is listed in the same row as the plot. Within an individual plot, a scatter of observations that is closely arrayed along a straight line indicates a strong (positive or negative) correlation between the corresponding measures. It can be seen that there are groups of correlated performance measures, notably the Daily Volume, Peak Volume, and Truck Volume variables in the bottom left side of the figure, and VMT and VHT towards the middle of the figure.

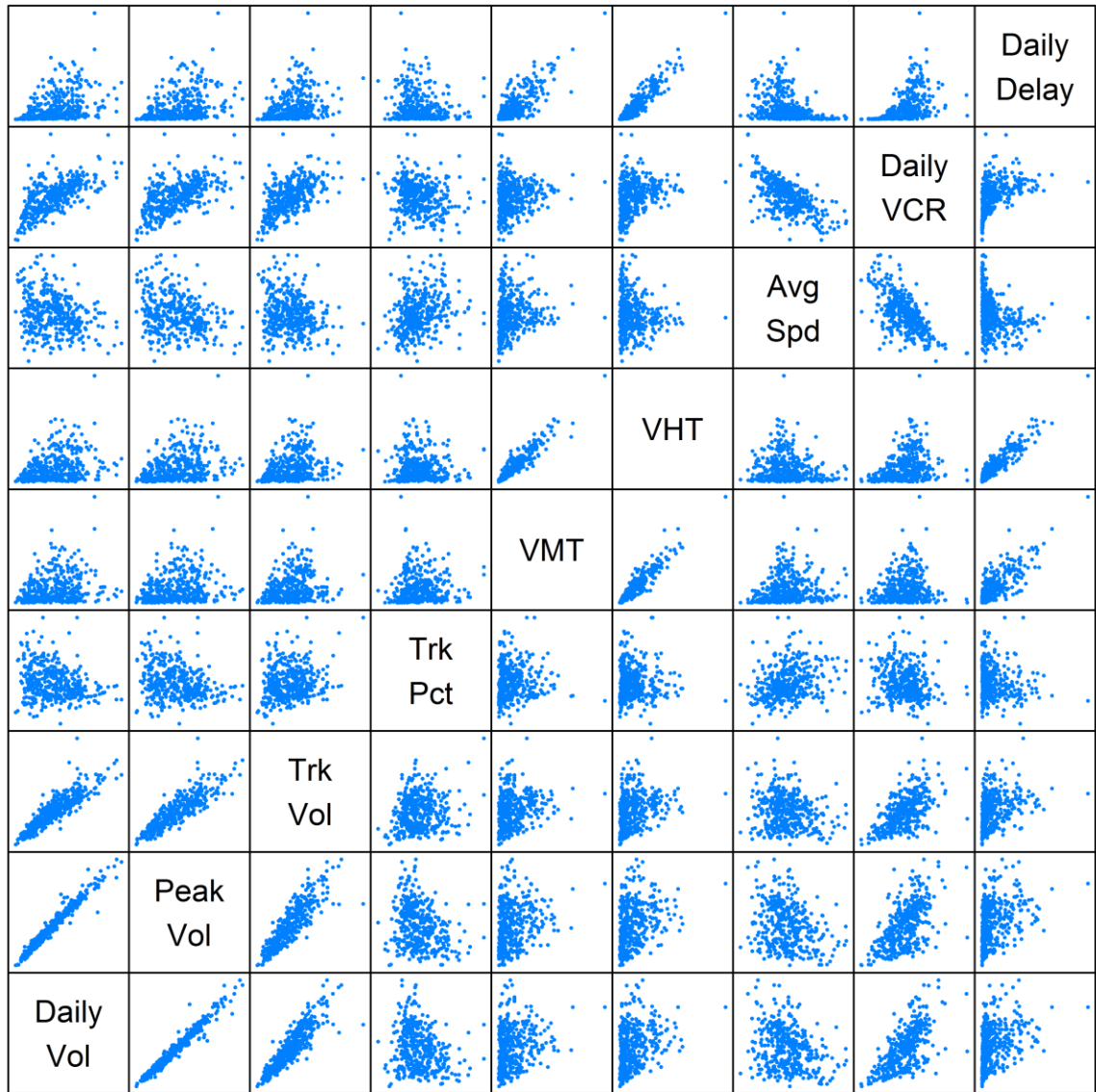
**Figure 2** presents the corresponding Mobility performance measure correlations for 2040 and displays similar correlations (or lack thereof) between individual candidate performance measures.

Figure 1 - 2010 Mobility Performance Measure Correlations



Correlations of Mobility Measures, 2010

Figure 2 - 2040 Mobility Performance Measure Correlations



Correlations of Mobility Measures, 2040

**Figure 3** displays a histogram of the distribution of daily traffic volumes. Since it is the first graphic of this type shown here, it will be described in detail. Many of the histograms presented below follow this general pattern; exceptions will be noted where they occur.

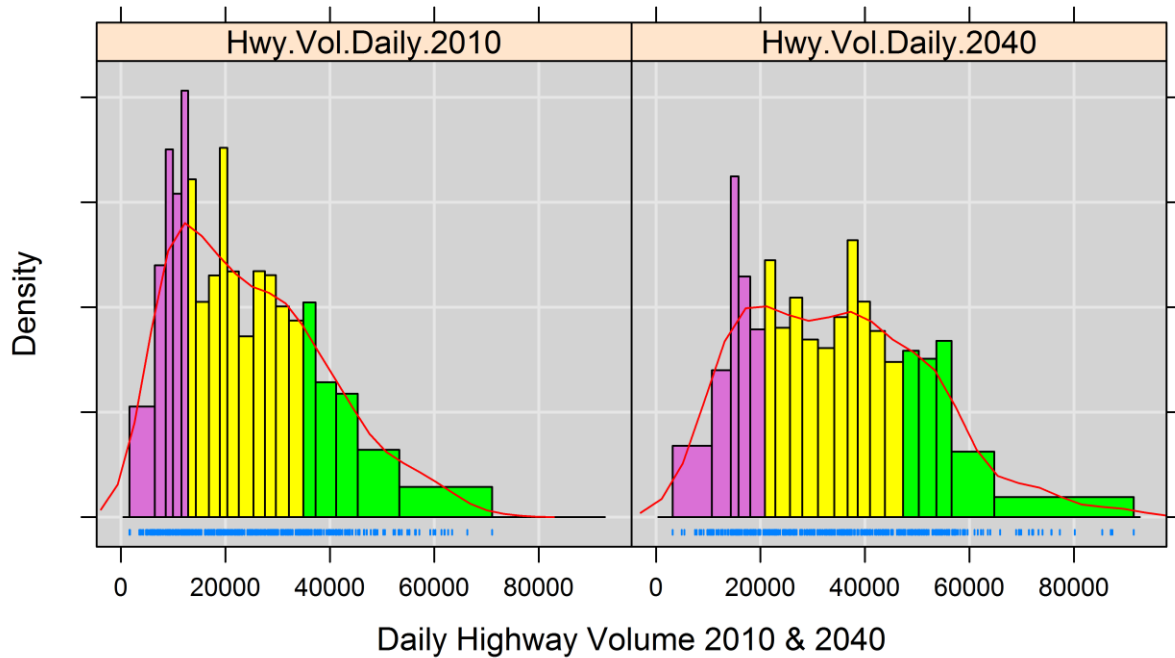
The x-axis is the specific candidate performance measure variable shown in the graph: daily traffic volume in the case of this figure. The figure shows two histograms, corresponding to the distribution of daily traffic volume values in 2010 and in 2040, respectively. When pairs of plots are presented together, as in this instance, the horizontal axes of the two plots are identical, as are the vertical axes. The “rug” of blue ticks above the x-axis shows the actual values of this variable in the dataset (although no attempt was made to account for overplotting of multiple identical values); among other things, the rug can be useful for identifying outlier data points that may distort the empirical distribution.

Each successive colored bar in the histogram represents 5% of the number of observations, with the pink bars representing the bottom 25%, the yellow bars representing the middle 50%, and the green bars representing the top 25% of observations.

The y-axis represents the density of observations, having the property that the total area (computed from the density heights and plotted variable widths of each of the histogram bars) of the histogram equals 1; the specific density values themselves have no intrinsically meaningful interpretation here. The red curve is a kernel density estimate of the probability distribution that underlies the observations and histograms; it can be thought of as a “smooth” version of the histogram that eliminates some of the arbitrary discontinuities and spikes introduced by the cutoff values for the histogram bars.

In this particular figure it will be seen that in 2040 the histogram exhibits a wider range of daily volumes and a greater number of segments having larger volumes. Daily traffic volume is clearly an informative performance measure rather than an actionable one.

Figure 3 - Daily Traffic Volume

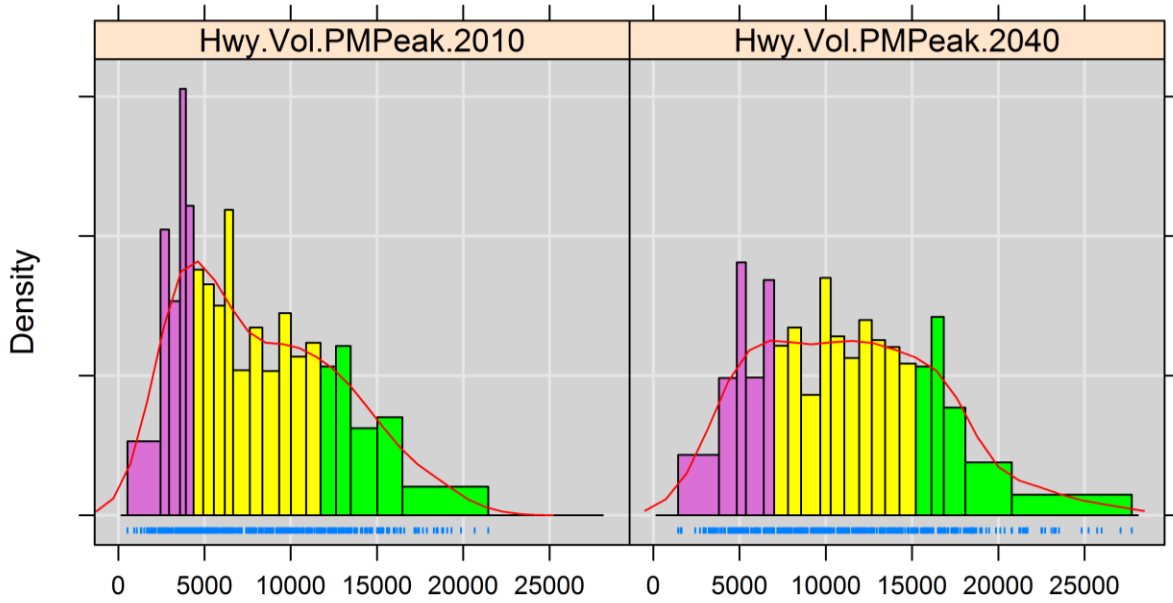


Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 4** displays the PM peak hour traffic volumes for 2010 and 2040. Similar to the daily volumes, this figure shows that the PM peak hour volumes increase by 2040 with a wider distribution of values. The distribution adjusts from skewed to the left in 2010 to a more symmetrical distribution in 2040, as can be seen from the correlation scatterplots in **Figure 1** and **Figure 2**.

Figure 4 - PM Peak Period Traffic Volume



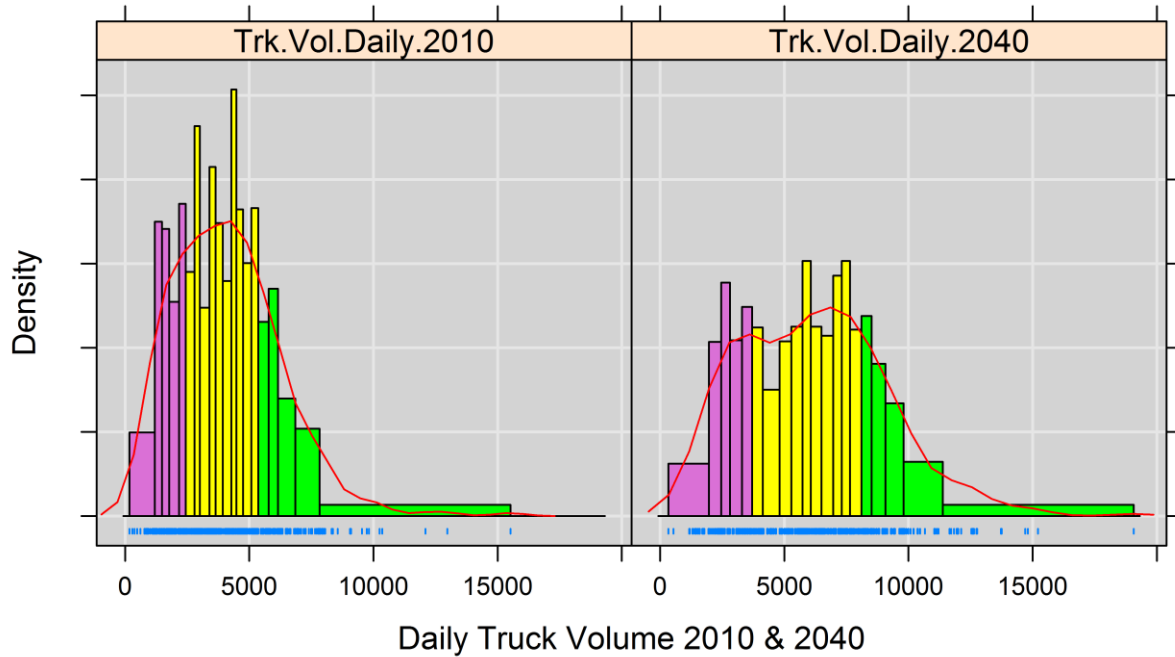
PM Peak Period Highway Volume 2010 & 2040

Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

Figure 5 presents the daily truck volumes for 2010 and 2040. It also shows that truck volumes increase from 2010 to 2040 with a wider distribution of values in 2040 including two peaks (consistent with the kernel density estimate).

Figure 5 - Daily Truck Traffic Volume

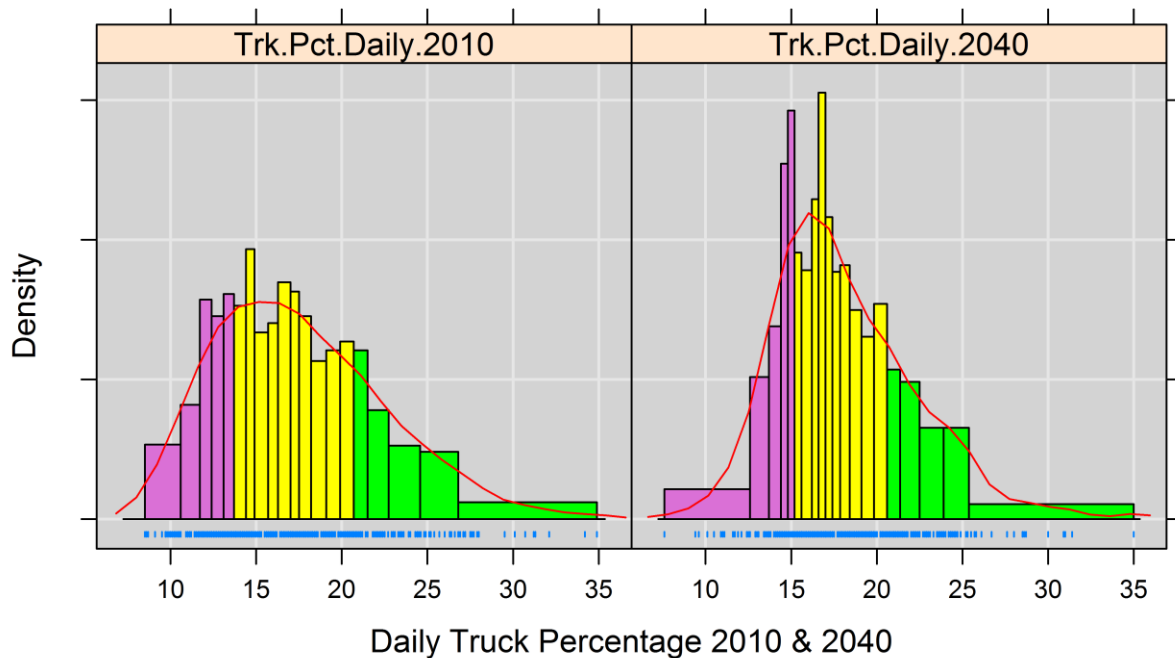


Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

The truck share of total traffic in 2010 and 2040 is presented in Error! Not a valid bookmark self-reference.. It can be seen that the distribution of truck percentage tightens from 2010 to 2040 with the bottom 25<sup>th</sup> percentile cutoff changing from around 14% to around 16%. In both years a few segments have truck compositions as high as 35%, but most segments are in the 10% to 25% truck composition range. Again, this is essentially an informative performance measure.

**Figure 6 - Truck Share of Daily Traffic**

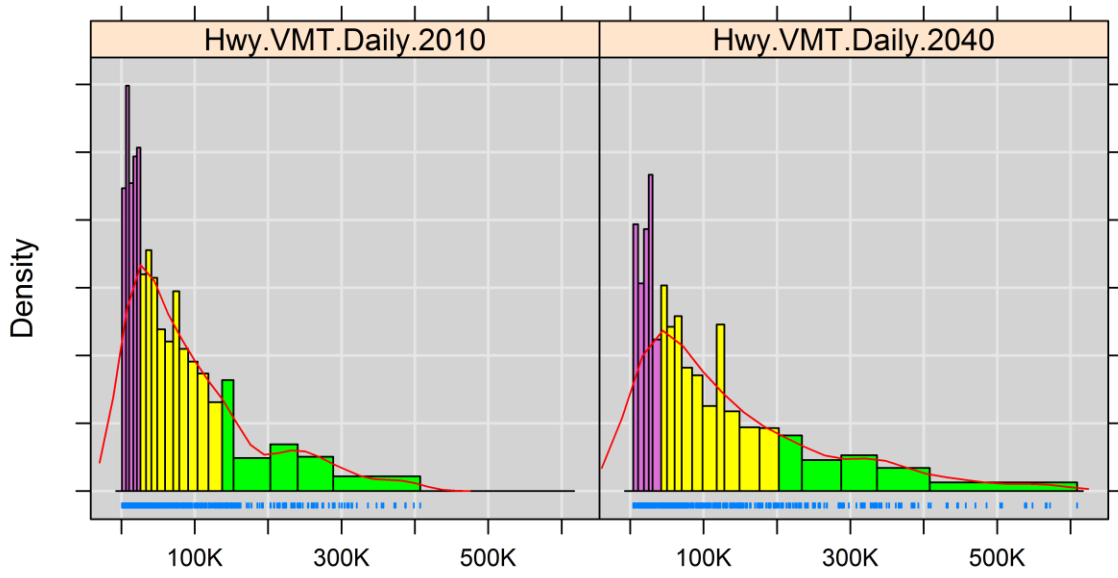


Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 7** displays the distribution of daily vehicle miles traveled (VMT) while **Figure 8** presents the distribution of the daily vehicle hours traveled (VHT). The VMT and VHT histograms eliminate outlier values higher than 700,000 vehicle miles and 30,000 vehicle hours, respectively. Both figures reveal increases in travel levels from 2010 to 2040.

**Figure 7 - Daily VMT**

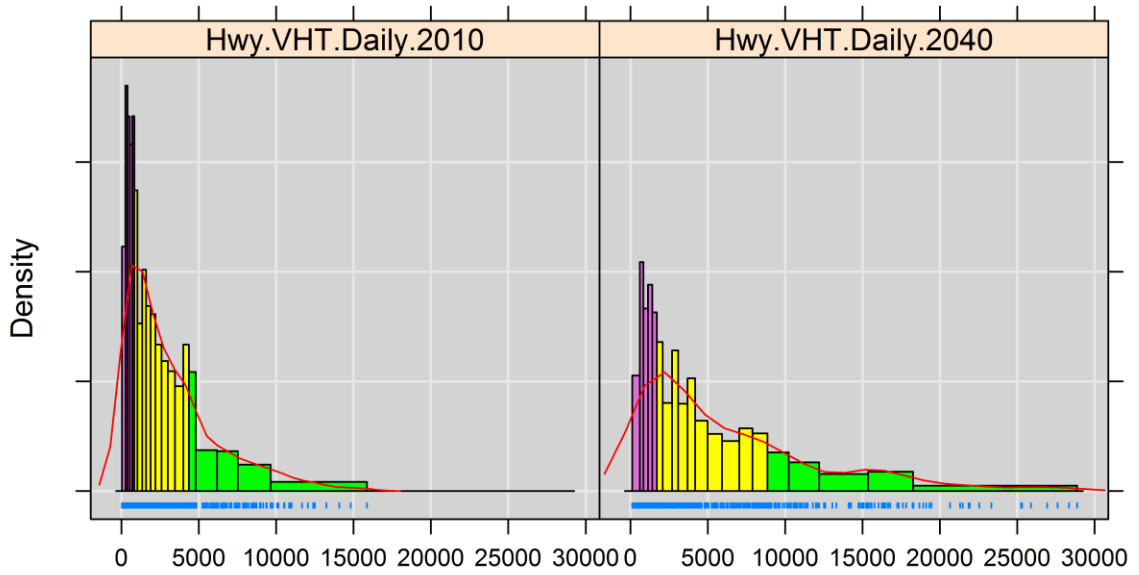


Daily Highway VMT 2010 & 2040

Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 8 - Daily VHT**



Daily Highway VHT 2010 & 2040

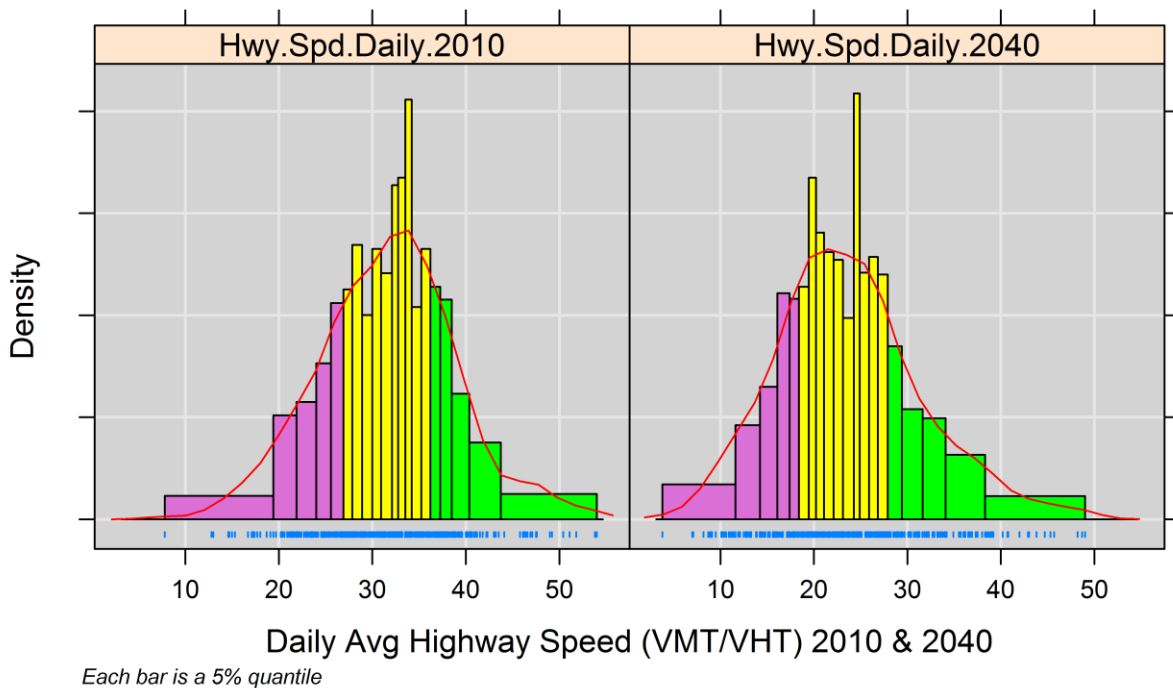
Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model



“Average daily” travel speeds were calculated by dividing the daily VMT by daily VHT, and are presented in **Figure 9** for 2010 and 2040. The figure shows that the speeds decrease from 2010 to 2040. In 2010, the cutoff for the bottom 25<sup>th</sup> percentile is around 27 mph, while in 2040 the cutoff for the top 25<sup>th</sup> percentile is around 28 mph. Average travel speed is an actionable performance measure, since engineering and/or operational improvements can be made to thoroughfare facilities to improve travel speed. Accordingly, a target can be set for thoroughfare network performance for this measure. Given the performance level of 2010, an average daily speed (computed as described above) of at least 25 mph is recommended as a draft target.

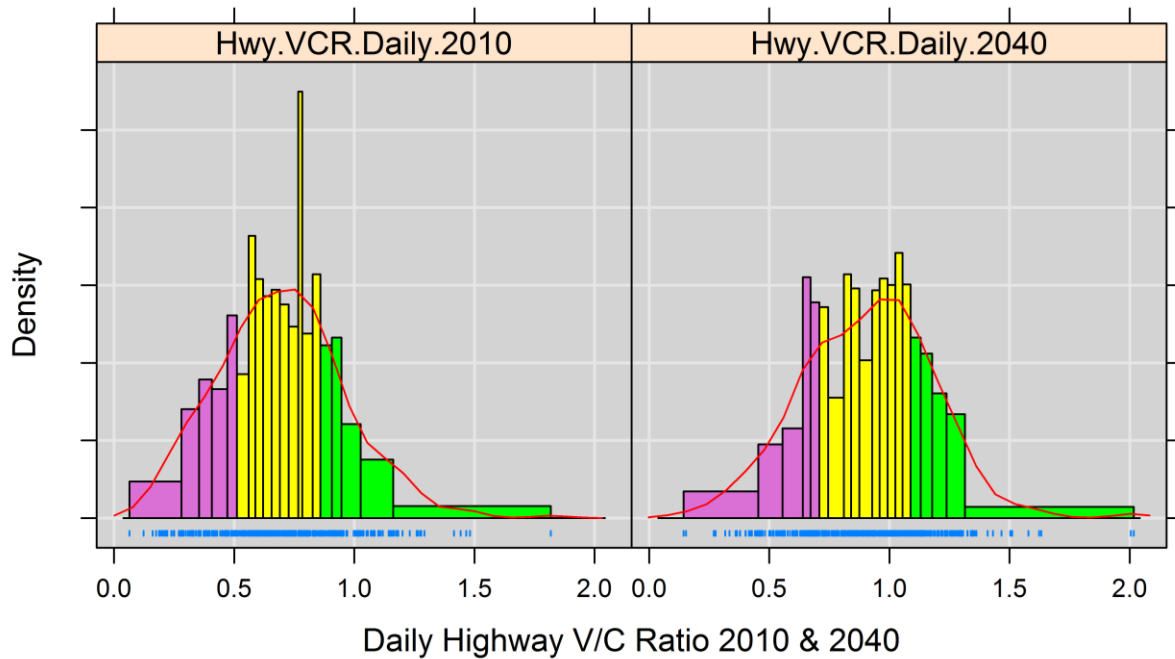
**Figure 9 - Average Daily Highway Speed**



Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 10** presents the distribution of daily volume/capacity (V/C) ratios. As would be expected from the decrease in average speed from 2010 to 2040 noted above, V/C ratios increase over the same period. While the cutoff for the top 25<sup>th</sup> percentile was 0.9 in 2010, it increases to 1.1 in 2040. This measure is in principle actionable through capacity-enhancing roadway improvements; however, the correlation scatterplot shows a (weak) negative correlation between average daily speed and V/C ratio, so the average speed target discussed above will be retained.

**Figure 10 - Daily Highway V/C Ratio**

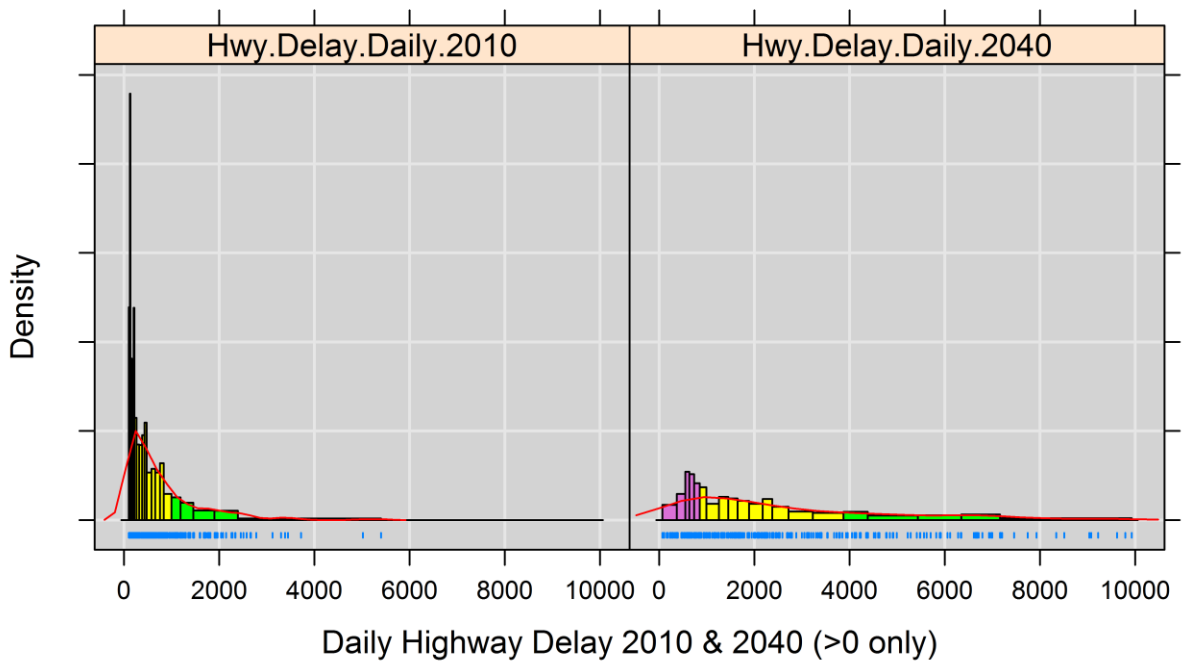


Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 11** displays the distribution of daily hours of delay (the difference between the VHT actually experienced on a link and VHT that the link’s traffic would experience under free flow conditions) for 2010 and 2040. It shows that the daily hours of delay are increasing from 2010 to 2040 with the cutoff for the top 25<sup>th</sup> percentile increasing from just over 1,000 hours in 2010 to around 2,500 hours of delay in 2040. The histogram includes only segments having positive delays and eliminates outlier segments with over 10,000 vehicle hour of delay.

**Figure 11 - Daily Highway Delay**



Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

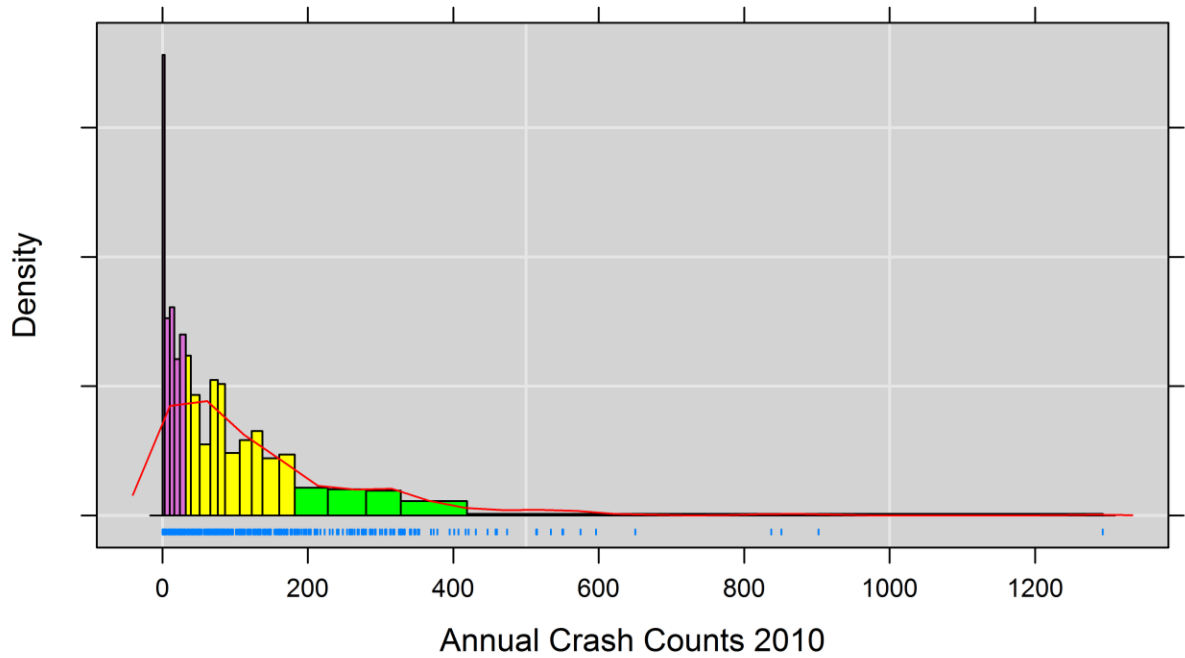
**Figure 12** displays the distribution of the number of annual crashes per segment in 2010 while **Figure 13** presents the number of annual crashes normalized per VMT; the ARC crash database was the source of the data used in this analysis. Note that this database includes roadway crashes of all types (fatalities, injuries, property damage only), so the statistics presented here cannot be directly compared with, for example, data on roadway crash fatalities available from other sources.

It is interesting to consider both of these safety performance measures. **Figure 12** shows that the top 25% of thoroughfare network segments have over 180 annual crashes or on average about 1 crash every other day. A reasonable draft target for the annual number of crashes would be to shift the top quartile cutoff to 100 annual accidents. **Figure 13** shows that the top 15% of segments roughly 15 or more crashes per million VMT. A draft target of only 10% of segments having more than 15 crashes per million VMT also seems reasonable.

Again, these targets refer to crashes of all kinds as per the source crash database used for the analysis. A next step would be to refine these measures and targets by type of crash; available data did not allow this to be done as part of this effort.



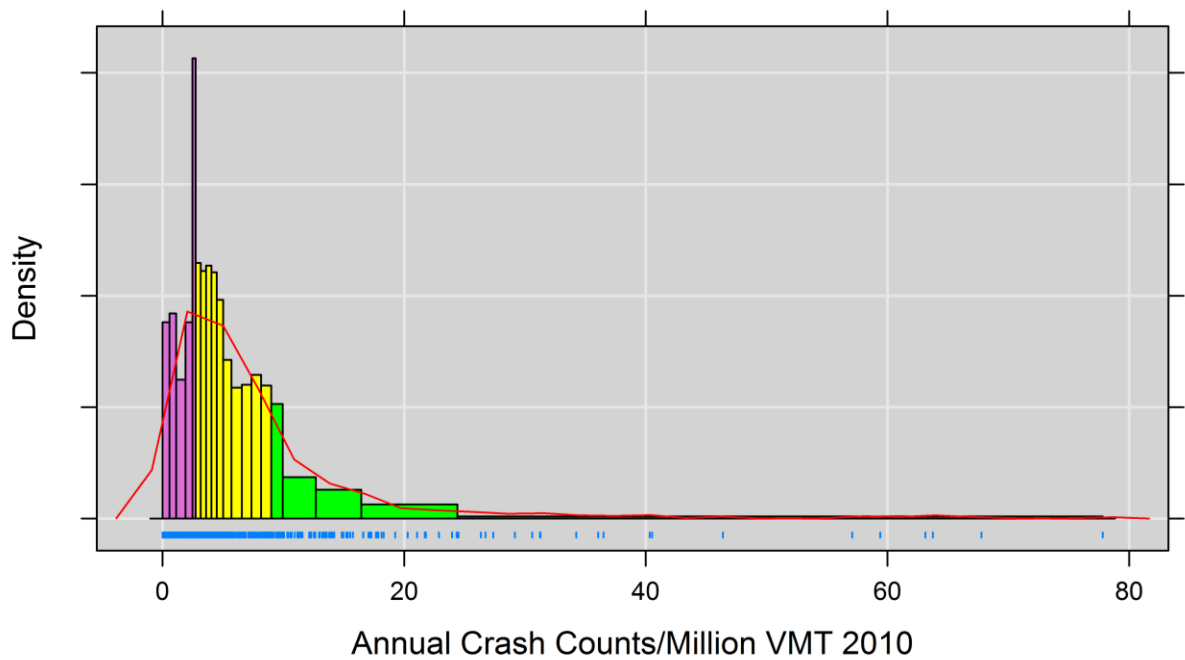
**Figure 12 - Annual Number of Crashes (All Types)**



Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC Crash Database

**Figure 13 - Number of Crashes (All Types) per Million VMT**

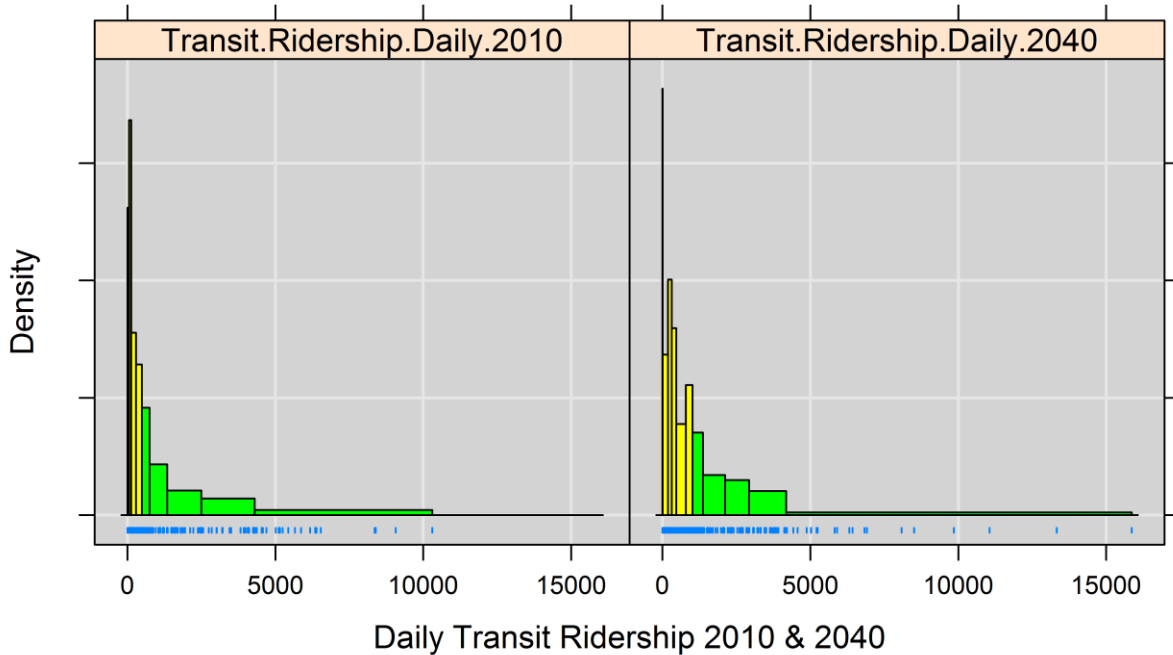


Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model and Crash Database

In addition to the highway-based performance measures presented above, several transit-related mobility performance measures were also investigated. Figure 14 presents the distribution of daily transit ridership by segment, showing a shifting of the 75<sup>th</sup> percentile cutoff from around 500 to 1,500 daily ridership.

**Figure 14 - Daily Transit Ridership**

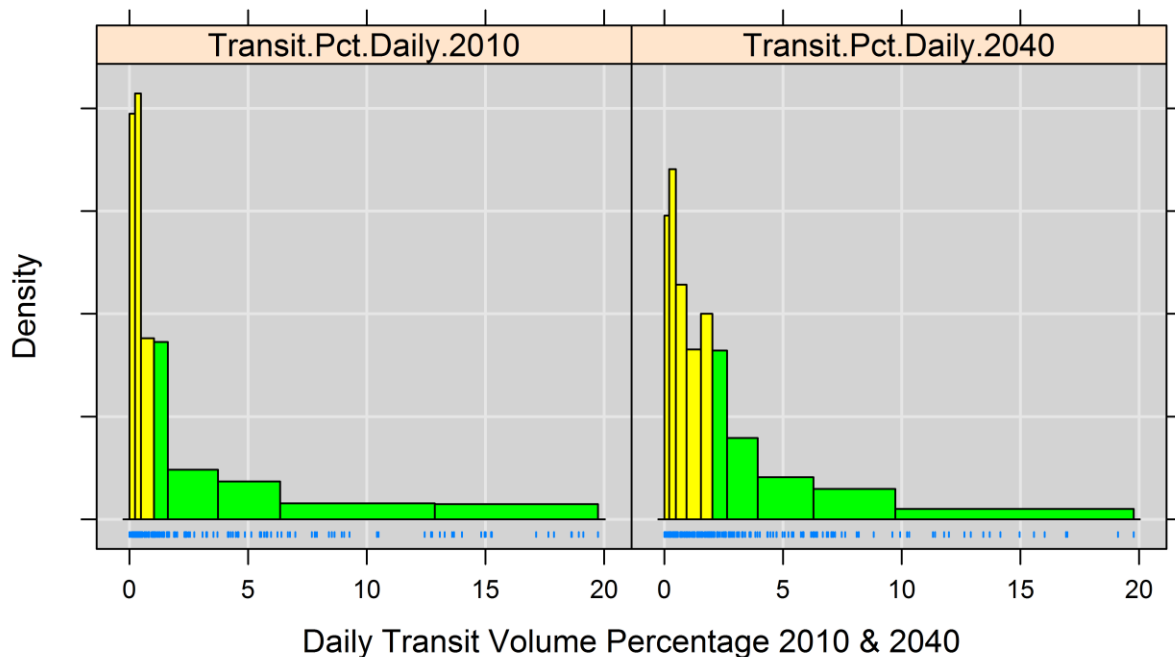


Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 15** combines the daily transit ridership with the daily traffic volumes to determine the percentage of daily passenger travel that uses transit. In the calculation of this performance measure, an average auto occupancy of 1.2 was assumed. This figure shows a small decrease in the transit percentage of total travel between 2010 and 2040, which is likely explained by a disproportional increase in auto travel compared to transit travel.

**Figure 15 - Daily Transit Ridership as Percentage of Segment Passenger Travel**



Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model

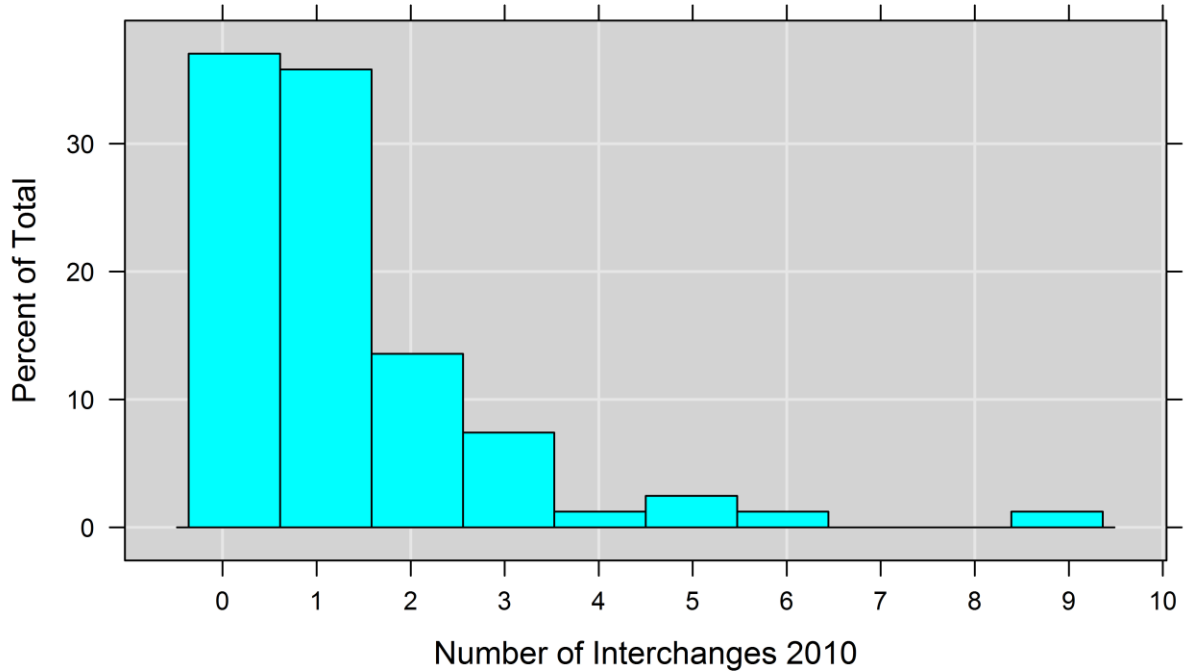
#### 4.4.2 Network Connectivity Performance Measures

Within the Network Connectivity criterion, there is a single performance measure which is available to calculate. **Figure 16** presents the distribution of the number of connections (interchanges) to higher-type facilities. Because of the relative infrequency of interchanges on thoroughfares, these connections are counted along an entire thoroughfare, unlike the Mobility performance measures, which were computed at the thoroughfare segment level. This histogram is in standard format, with each bar representing a percentage of the total distribution for a discrete value. The figure shows that it is most common (with over 37%) for a thoroughfare to have no



connections to higher-type facilities; however, this means that over 60% of thoroughfares in the RTN have at least one connection to a higher-type facility.

**Figure 16 - Number of Connections with Higher-Type Facilities**



Source: Steer Davies Gleave analysis of ARC regional travel demand model

**4.4.3 Land Use Connectivity Performance Measures**

Within the Land Use Connectivity criterion, a number of performance measures were evaluated.



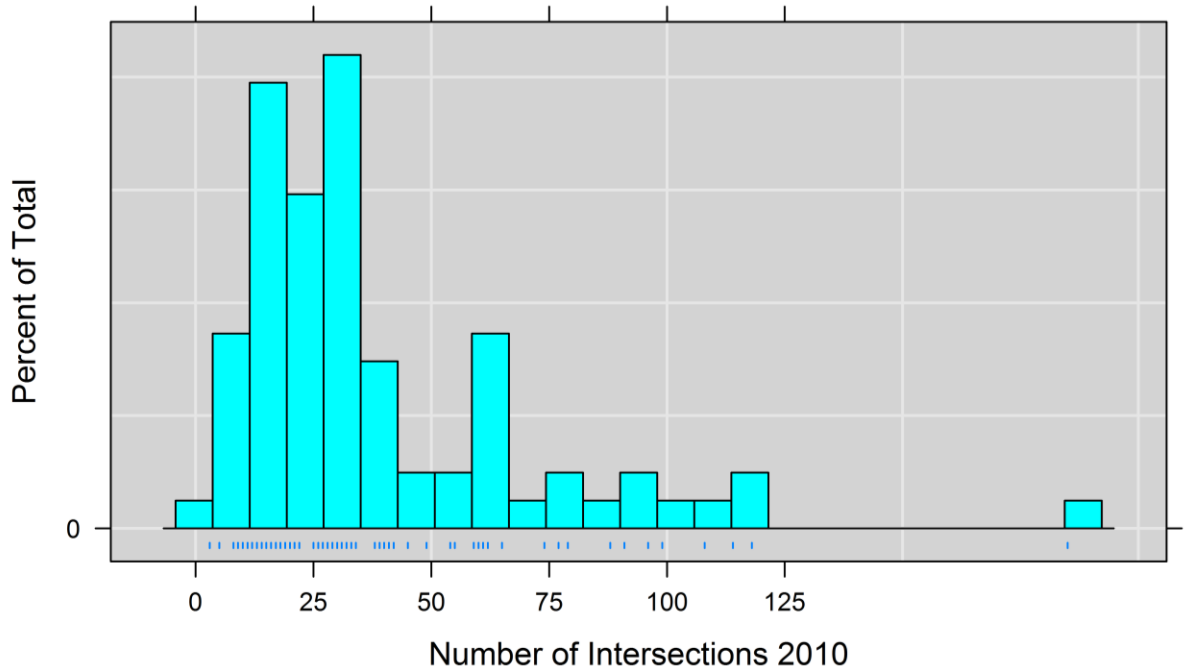
**Figure 17** displays the distribution of the number of connections with lower-type facilities and **Figure 18** displays the distribution of the connections on a per-mile basis. These connections were determined by counting the number of intersections along a thoroughfare as per the ARC regional travel forecasting model network coding; centroid connectors were included in this count. As was the case for the Network Connectivity measures, the unit of analysis for this performance measure was an entire thoroughfare.



**Figure 17** shows that there are some thoroughfares having over 100 intersections with lower-type facilities, while **Figure 18** shows that most thoroughfares (over 50%) have one intersection per mile. Note that these figures are in a standard histogram format.

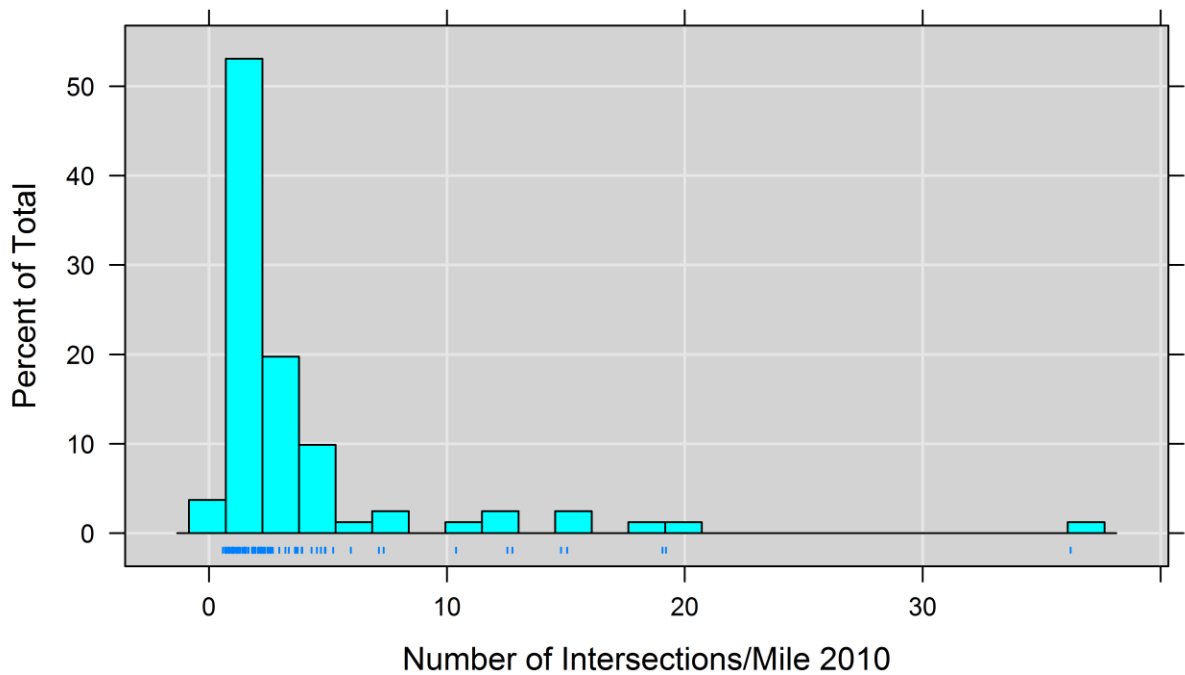


**Figure 17 - Number of Corridor Connections with Lower-Type Facilities**



Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 18 - Number of Corridor Connections per Mile to Lower-Type Facilities**

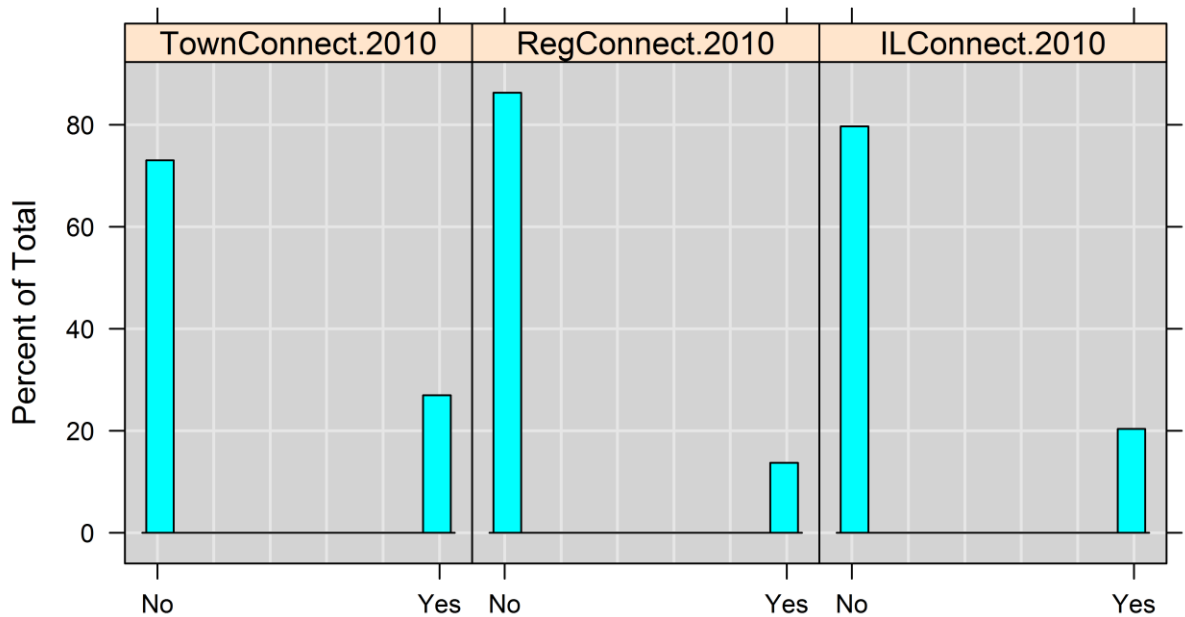


Source: Steer Davies Gleave analysis of ARC regional travel demand model



**Figure 19** presents the connectivity of thoroughfares to particular UGPM land uses. Specifically, the left plot of the figure shows that over 25% of thoroughfare segments are within 2 miles of a UGPM Town Center, the center plot indicates that almost 15% of segments are within 2 miles of a UGPM Regional Center, and the right plot indicates that 20% of segments are within 2 miles of an Industrial/Logistics Center.

**Figure 19 - Connections to UGPM Land Uses**



Connectivity to UGPM Town, Regional and Industrial/Logistics Centers 2010

Source: Steer Davies Gleave analysis of ARC UGPM GIS

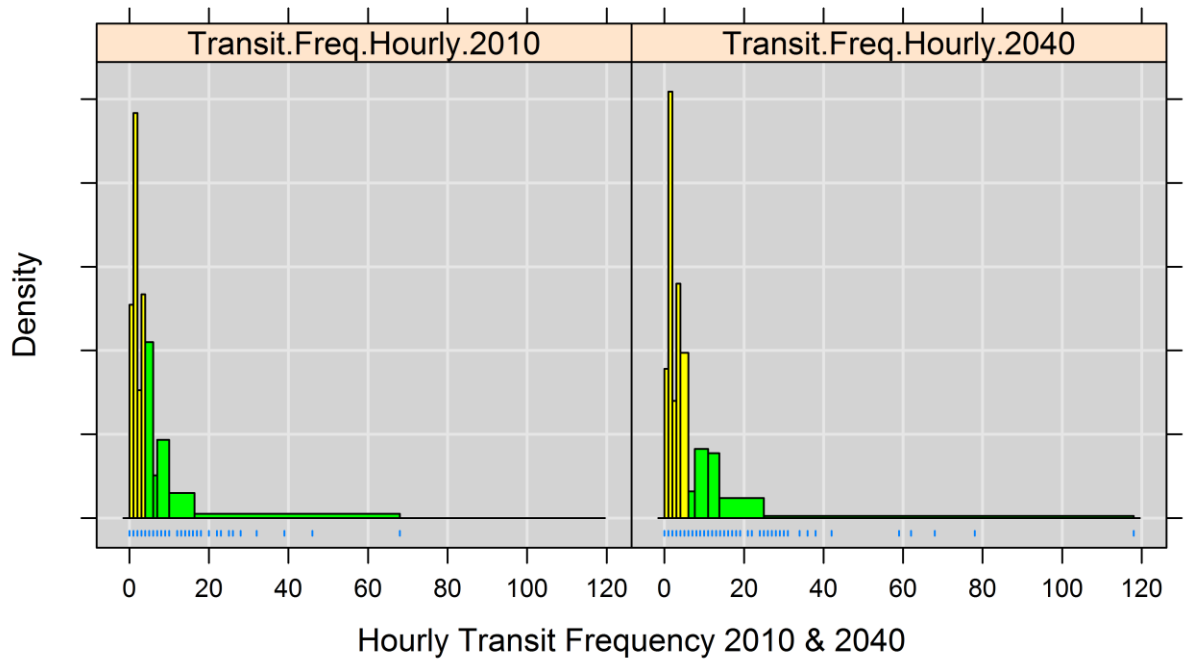
#### 4.4.4 Multimodal Functionality Performance Measures

Within the Multimodal Functionality criterion, a number of performance measures were evaluated. The first set of these performance measures are simply those indicating the performance of segments. The second set combine elements of Land Use Connectivity with Multimodal Functionality.

The first group of the segment performance measures are transit-related ones. **Figure 20** displays the distribution of total hourly transit frequency on thoroughfare segments. It shows a slight increase in transit frequencies in 2040 compared to 2010. One interesting element for both years is that there are number of segments with very high hourly frequencies. These tend to be the segments along transit transfer centers, such as Civic Center Station, Five Points Station, the Marietta Transfer Center and the Cumberland Transfer Center.



**Figure 20 - 2010 Hourly Transit Frequency**

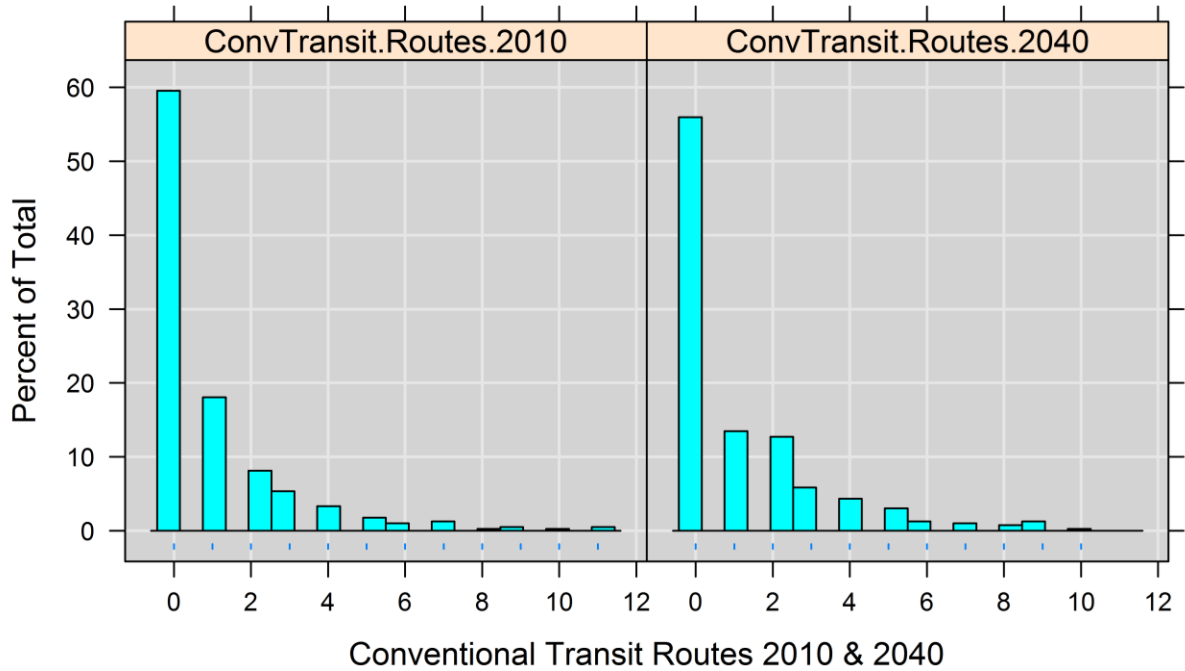


Source: Steer Davies Gleave analysis of ARC regional travel demand model

**Figure 21** presents a standard histogram distribution of the total number of conventional transit routes running on each segment while

Figure 22 presents the distribution of the number of premium transit routes in each segment. These figures show that the number of conventional and premium transit routes on the segments increases from 2010 to 2040.

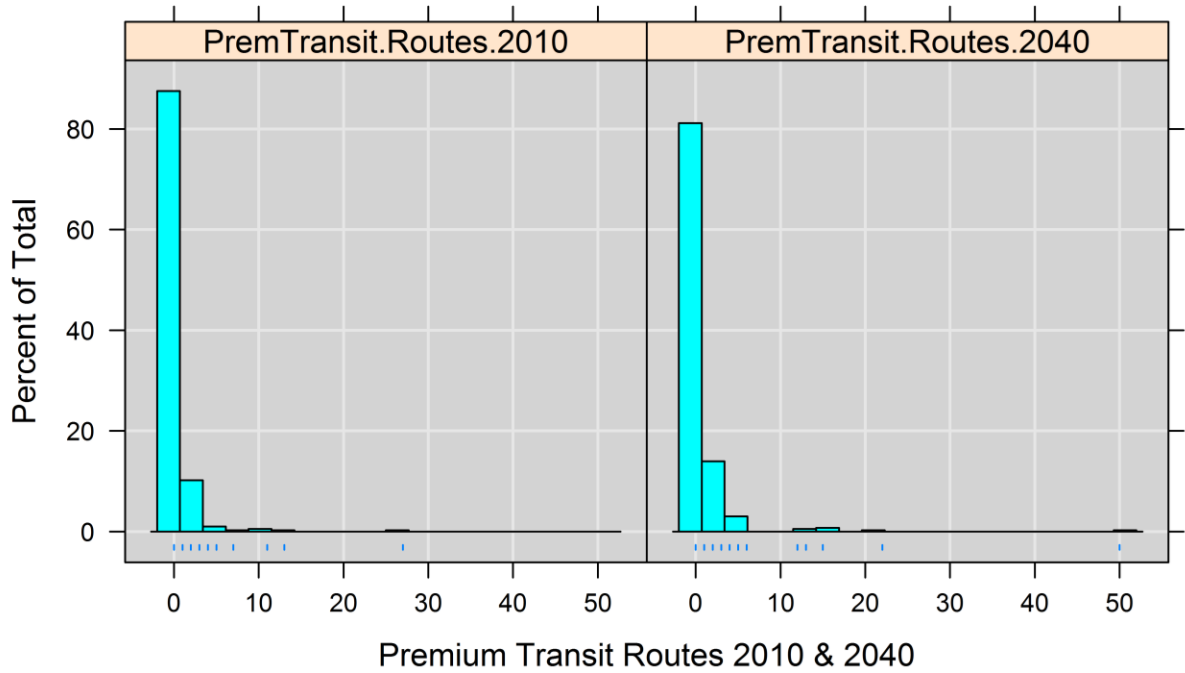
**Figure 21 - Number of Conventional Transit Routes**



Source: Steer Davies Gleave analysis of ARC regional travel demand model



Figure 22 - Number of Premium Transit Routes



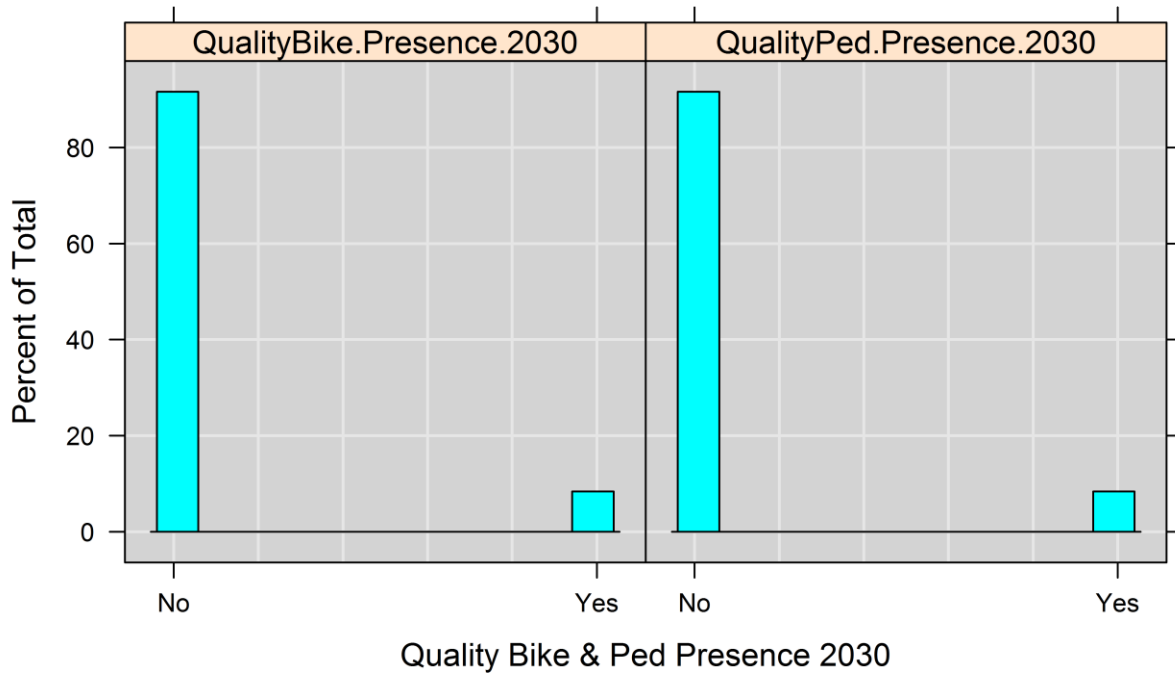
Source: Steer Davies Gleave analysis of ARC regional travel demand model



**Figure 23** presents an indication of whether each RTN segment has bicycle infrastructure and pedestrian infrastructure. Both of these performance measures come from the identification of the bicycle and pedestrian network identified in the ARC Atlanta Region Bicycle Transportation & Pedestrian Walkways Plan Study.



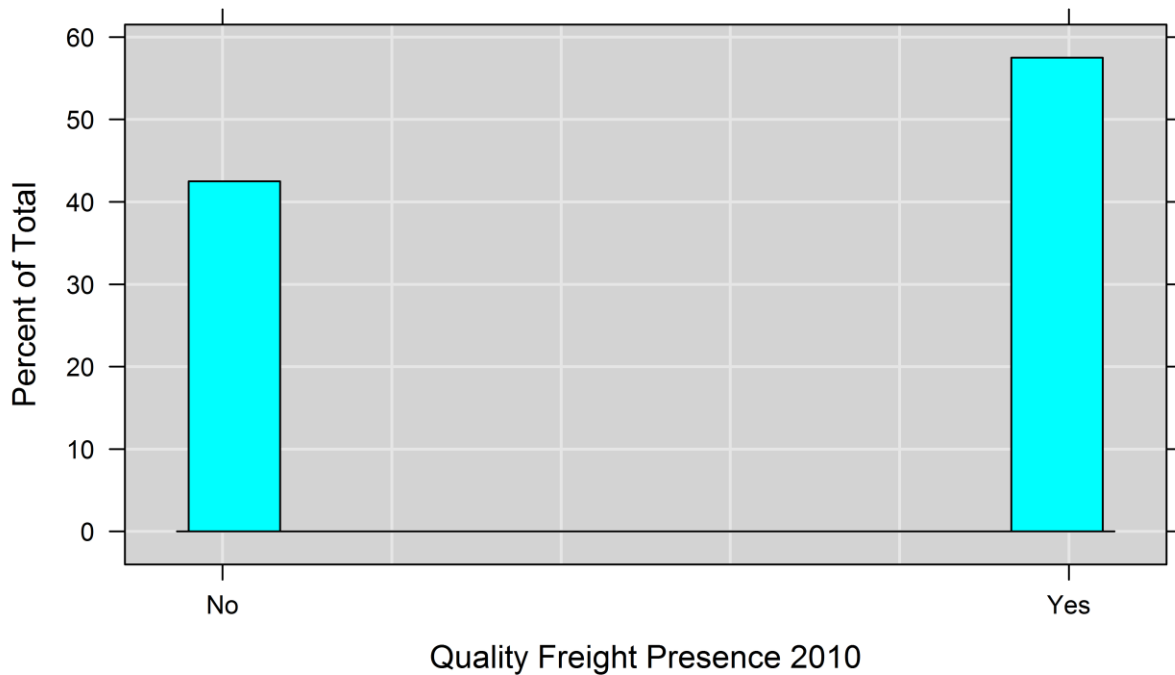
**Figure 23 - Presence of Bicycle and Pedestrian Infrastructure**



Source: Steer Davies Gleave analysis of ARC Bicycle and Pedestrian GIS Network

**Figure 24** displays a standard histogram indicating that almost 60% of RTN segments are designated freight corridors according to the Atlanta Strategic Truck Route Master Plan (ASTRoMaP).

**Figure 24 - Designated Freight Corridor**



Source: Steer Davies Gleave analysis of ARC ASTRoMaP GIS truck network

In the second set of Multimodal Functionality performance measure plots, the histograms display the distribution of values for an actionable performance measure over a subset of the segments that is selected based upon the value of an informative performance measure. Put differently, an informative performance measure is used to select a subset of all RTN segments, and the histograms then show the distribution of an actionable performance measure over this subset of segments.

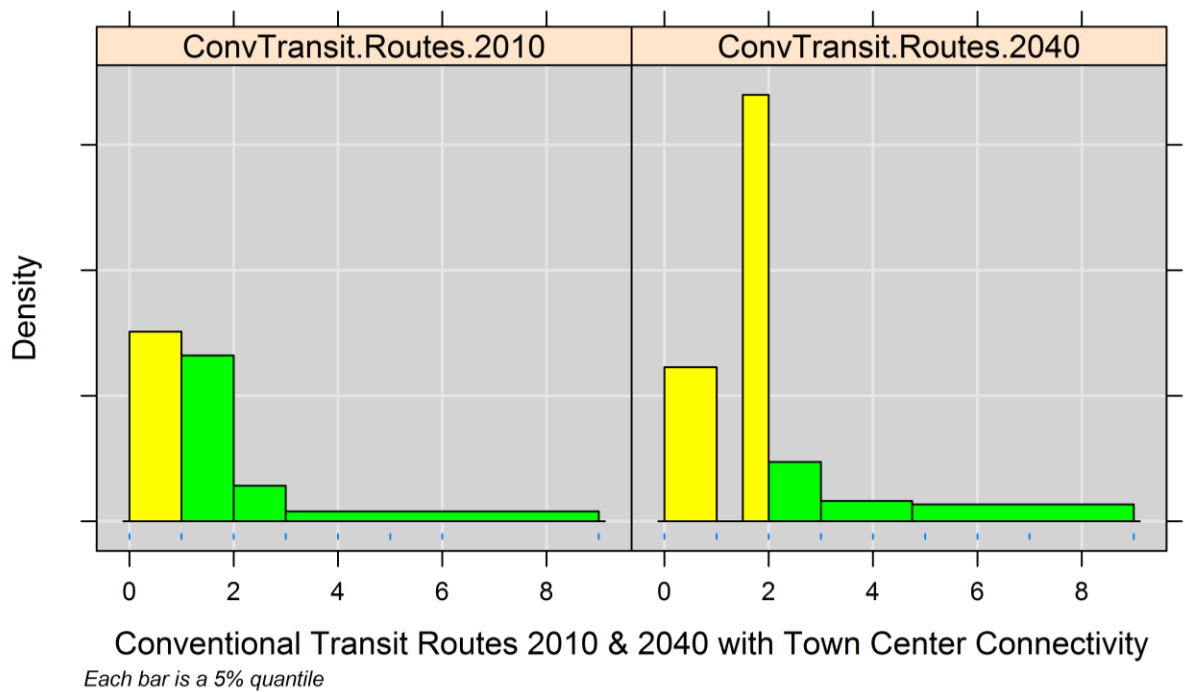
**Figure 25** through **Figure 27** consider the distributions of various actionable performance measures over the subset of segments that are within 2 miles of UPGM Town Centers (an informative performance measure). For transit service to segments within 2 miles of Town Centers, **Figure 25** shows the distribution of the number of conventional transit routes, indicating that 36% of these segments have at least one conventional transit route, while **Figure 26** shows the same for premium transit, indicating that 10% of segments have at least one premium transit route. The number of conventional and premium transit routes are of course actionable performance measures.

Draft targets have been set for RTN segments within 2 miles of Town Centers, specifying that at least 75% and 25% of these segments should have at least one conventional and one premium transit route, respectively. Note that this and similar targets apply more at the level of the RTN as a whole rather than individual segments or thoroughfares. Ultimately the decision to provide or not provide transit service on a

particular route depends closely on the properties of the potential service area; however at the RTN level it makes sense to require that 75% of segments located close to UGPM Town Centers should be served by some form of transit.

Similarly, **Figure 27** shows that 8% of RTN segments within 2 miles of Town Centers have quality bicycle and pedestrian infrastructure. Draft targets for these particular segments have been set, specifying that 15% of segments within 2 miles of Town Centers should have quality bicycle and pedestrian facilities.

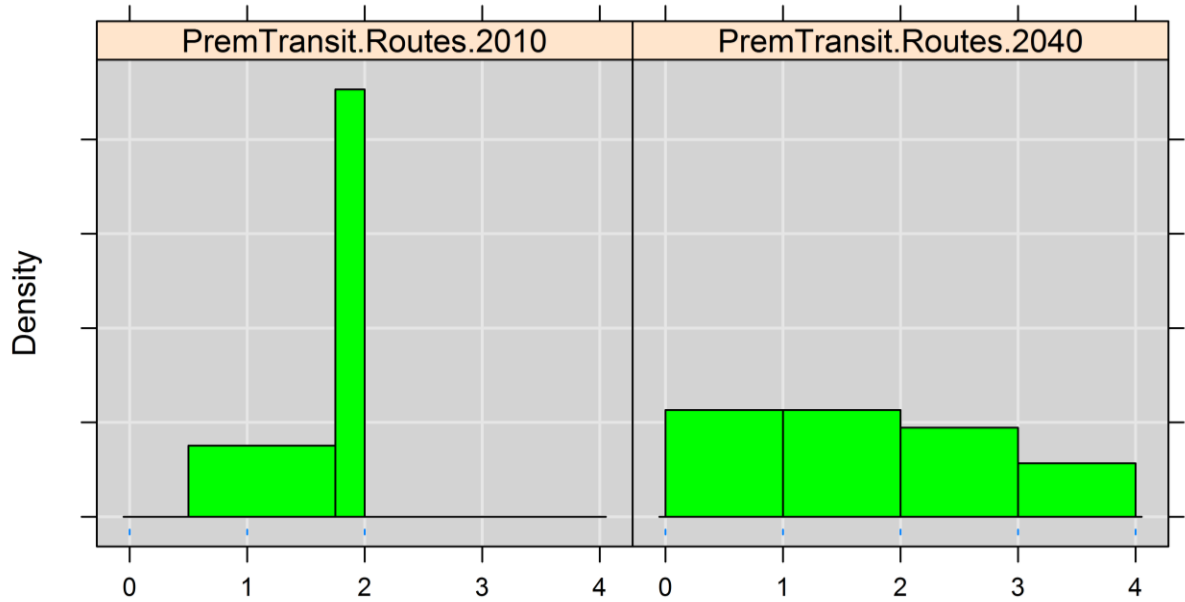
**Figure 25 - Number of Conventional Transit Routes for Segments within 2 Miles of Town Centers**



Source: Steer Davies Gleave analysis of ARC regional travel demand model and UGPM GIS



**Figure 26 - Number of Premium Transit Routes for Segments within 2 Miles of Town Centers**

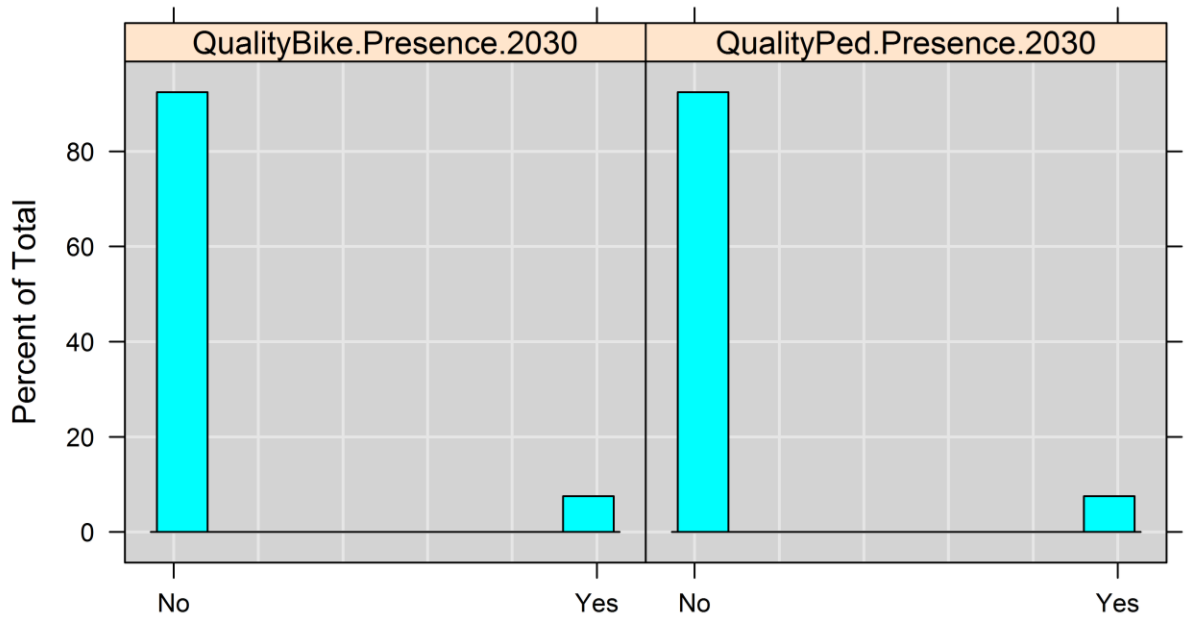


**Premium Transit Routes 2010 & 2040 with Town Center Connectivity**

Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model and UGPM GIS

**Figure 27 - Bike/Ped Infrastructure for Segments within 2 Miles of Town Centers**



**Quality Bike & Ped Presence 2030 with Town Center Connectivity**

Source: Steer Davies Gleave analysis of ARC Bicycle and Pedestrian GIS Network and UGPM GIS



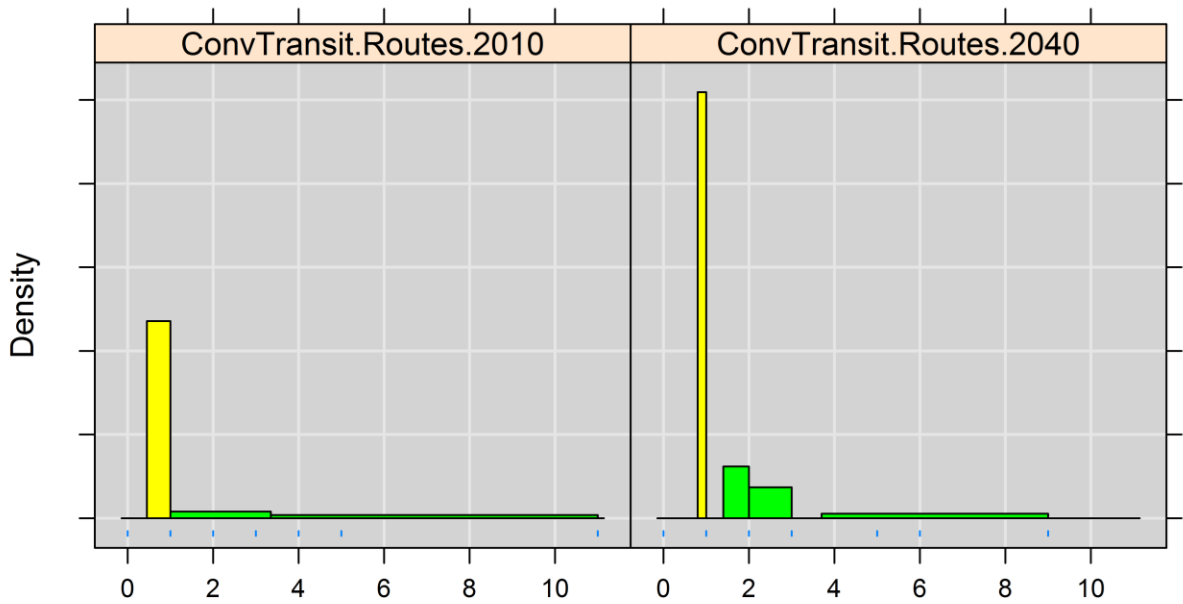
**Figure 28** through **Figure 30** consider the distributions of actionable performance measures based upon the subset of RTN segments that are within 2 miles of UGPM Regional Centers.

**Figure 28** shows the distribution of conventional transit routes on RTN segments within 2 miles of UGPM Regional Centers, indicating that 35% of these segments have at least one conventional transit route.

**Figure 29** shows the same for premium transit service, indicating that 15% of segments have at least one premium transit route. For RTN segments within 2 miles of Regional Centers, draft targets of providing conventional transit service to 75% of segments and premium transit service to 25% of segments have been set.

**Figure 30** shows that 13% of RTN segments within 2 miles of Regional Centers have quality bicycle and pedestrian infrastructure. Again for these specific segments, draft targets of 20% of segments having quality bicycle and pedestrian infrastructure have been set.

**Figure 28 - Number of Conventional Transit Routes for Segments within 2 Miles of Regional Centers**

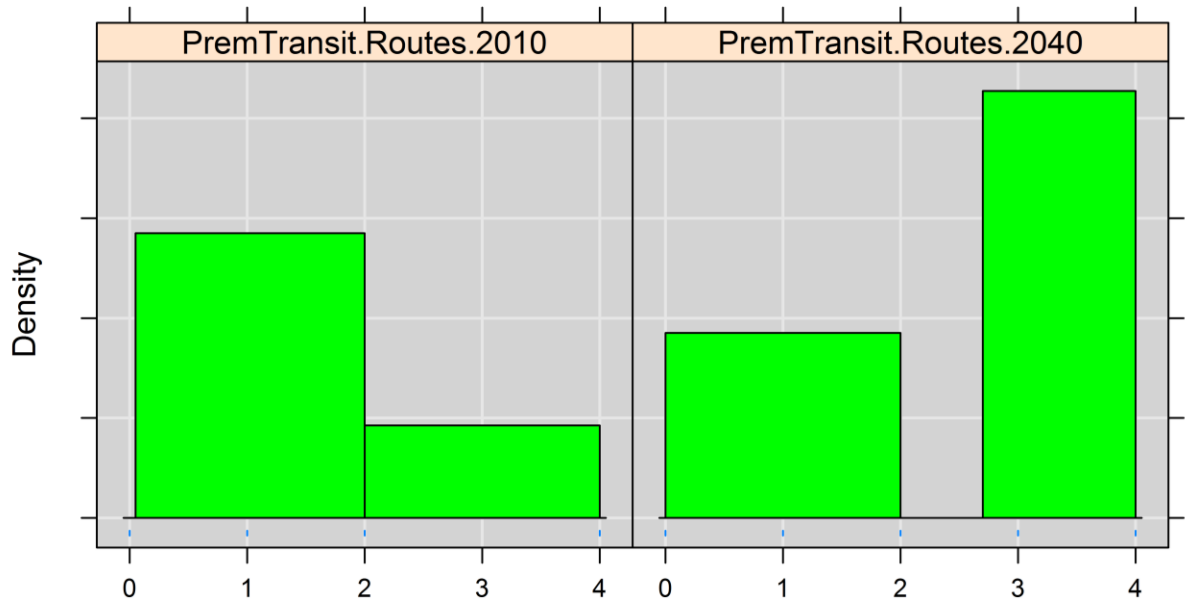


Conventional Transit Routes 2010 & 2040 with Regional Center Connectivity  
 Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model and UGPM GIS



**Figure 29 - Number of Premium Transit Routes for Segments within 2 Miles of Regional Centers**

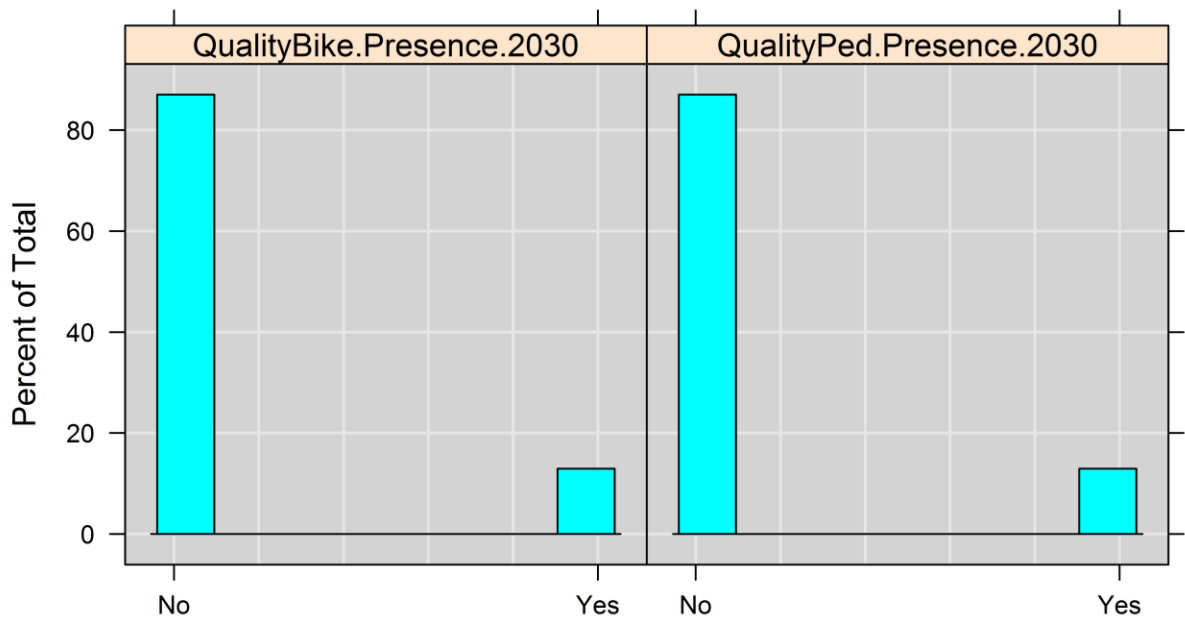


Premium Transit Routes 2010 & 2040 with Regional Center Connectivity

Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model and UGPM GIS

**Figure 30 - Bike/Ped Infrastructure for Segments within 2 Miles of Regional Centers**



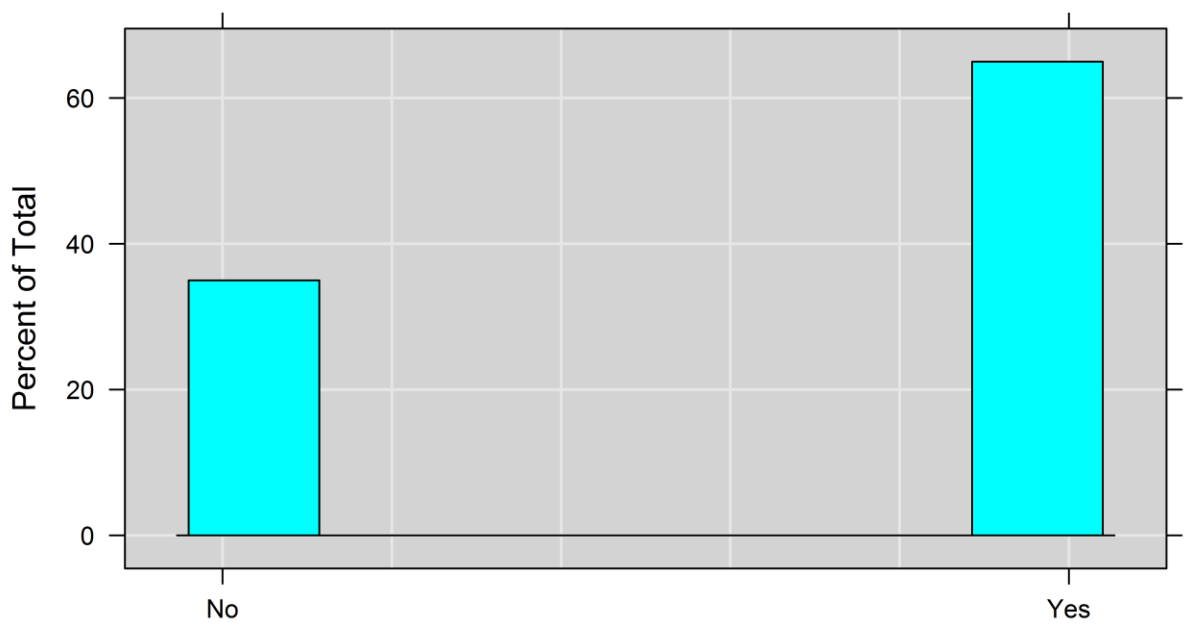
Quality Bike & Ped Presence 2030 with Regional Center Connectivity

Source: Steer Davies Gleave analysis of ARC Bicycle and Pedestrian GIS Network and UGPM GIS



**Figure 31** and **Figure 32** display distributions of freight-related measures for RTN segments that are within 2 miles of UGPM Industrial or Logistics Centers. **Figure 31** shows that 65% of segments within 2 miles of Industrial/Logistics Centers are designated as freight corridors. A draft target that 80% of all segments within 2 miles of Industrial/Logistics Centers be designated as freight corridors has been set. **Figure 32** shows the distribution of truck shares for these segments within 2 miles of Industrial/Logistics Centers.

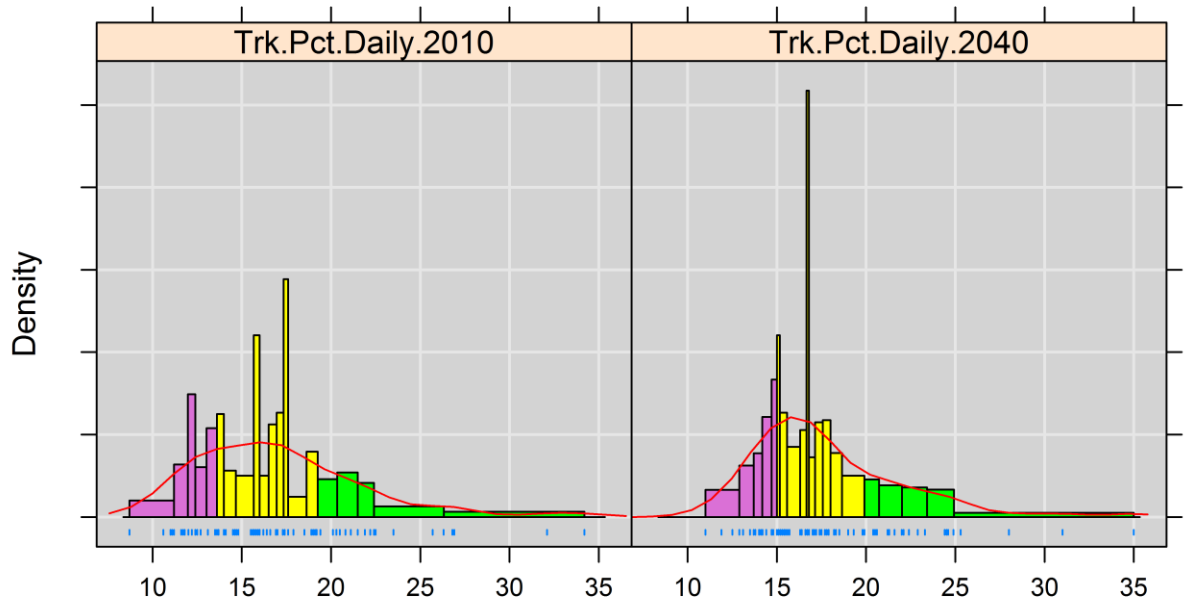
**Figure 31 - Freight Corridor for Segments within 2 Miles of Industrial/Logistics Centers**



Quality Freight Presence 2010 with Industrial/Logistics Center Connectivity

Source: Steer Davies Gleave analysis of ARC ASTRoMaP GIS truck network and UGPM GIS

Figure 32 - Daily Truck Percentage for Segments within 2 Miles of Industrial/Logistics Centers



Daily Truck Percentage 2010 & 2040 with Industrial/Logistics Center Connectivity  
 Each bar is a 5% quantile

Source: Steer Davies Gleave analysis of ARC regional travel demand model and UGPM GIS

#### 4.4.5 Summary of Draft Performance Measure Targets

During the discussion of the prior section, a number of draft performance measure targets were presented. **Table 9** summarizes those targets.



**Table 9 - Draft Performance Measure Targets**

Performance Measure	Target
Average Speed	>25 mph
Crashes (all types)	100 crashes cutoff for top 25th percentile
Crashes (all types) per Million VMT	Less than 10% of segments with greater than 15 crashes per million VMT
Conventional Transit within 2 miles of Town Center	75% of segments
Premium Transit within 2 miles of Town Center	25% of segments
Bike & Pedestrian Infrastructure within 2 miles of Town Centers	15% of segments
Conventional Transit within 2 miles of Regional Center	75% of segments
Premium Transit within 2 miles of Regional Center	25% of segments
Bike & Pedestrian Infrastructure within 2 miles of Regional Centers	15% of segments
Freight Corridor within 2 miles of Industrial Logistics Centers	80% of segments



## 5.0 UPDATING THE PERFORMANCE MEASURES AND TARGETS

### 5.1 Discussion of General Issues

As was mentioned previously, the set of performance measures and targets presented here has been designed to be both scalable and extensible:

- **Scalable** means that different measures can be consistently applied, with appropriate modifications, to different levels of data detail. In particular, the design described above considers measures that apply to data from conventional static travel forecasting models (e.g. the current ARC regional model), dynamic (mesoscopic) traffic assignment models, simulation (microscopic) simulation models, as well as empirical observations of roadway, land use and traffic data.
- **Extensible** means that the set of measures can grow as new types of performance data become available and readily accessible. Again, the intent is that the addition of new measures will not disrupt the already-defined measures, but instead will be incorporated with them to provide a coherent evaluation of the performance of the thoroughfare network.

These two characteristics are important in order for the performance measures and targets to provide a useful time series of observations on segments, entire thoroughfares and the network as a whole, suitable for:

- **Monitoring** the performance status of thoroughfares over time; and
- **Diagnosing** thoroughfare deficiencies that may be amenable to improvement through suitable engineering or operational actions.

### 5.2 Likely Future Data Availability

As will have been noted from the preceding sections, work in this effort has focused on data available from the ARC regional travel forecasting model, as well as limited sources of empirical data (e.g. crash counts). Several examples may serve to illustrate the potential that other soon-to-be-available data sources hold for future development of the system of performance measures and targets.

#### 5.2.1 Dynamic Traffic Assignment Models

As is well known, conventional static travel forecasting models predict average or steady-state travel demand and network conditions over an extended period of time, typically a peak or off-peak period that is several hours in length. This is generally sufficient for long-range planning purposes, and provides useful summary indications of network performance: a number of the mobility-related performance measures discussed above derived from outputs of the ARC static regional travel forecasting model, for example.

However, the lack of resolution of small time scales seriously limits the applicability of static models to more detailed planning or operational purposes. For example, static models cannot directly represent traffic flow phenomena such as queuing or spillbacks, or demand phenomena such as the peak of the peak or surges at the end of major sports events.

Dynamic traffic assignment (DTA) models have been developed in an attempt to capture time-varying network demand and supply effects within a traffic assignment framework. These models divide a model period into a succession of short time intervals (say 15 minutes long), and represent origin-destination travel demand, as well as traveler decisions, vehicle flow and resulting network conditions in each such interval, taking account of the carry-over from one interval to the next. Originally the focus of cutting-edge academic research projects, a number of commercially-available software packages now provide DTA capabilities. These models are computationally very demanding, however, and earlier generations of personal computer and workstation hardware were not able to run realistic DTA models in reasonable computing time. As the capabilities of computer hardware increase, and software is designed to take better advantage of these capabilities, DTA model computing time is becoming less of an issue, however. The challenge now is to develop accurate DTA models over a useful geographic and network extent.

A “proof of concept” DTA model has recently been demonstrated for the 20-county region, using the ARC static regional model to estimate (but without the benefit of empirical backup) the more detailed values required for the DTA. The resulting model was able to run to completion in a reasonable amount of computing time, but of course the outputs have only illustrative value because the DTA model has not been calibrated or validated. In many respects, DTA models are considerably more challenging to develop and validate than are static assignment models. However, the fact that a proof of concept DTA model has successfully run suggests that a project to develop a validated DTA model for the 20-county region will soon be opportune. The availability of such a model will provide considerable quantities of time-varying model data that will be suitable for incorporation in the thoroughfare performance measures, generalizing the current measures that are based on the static ARC model.

### 5.2.2 INRIX Travel Time Data

As part of the ARC’s Congestion Management Process (CMP), a dataset of travel time measurements covering large portions of the Atlanta regional network was licensed from INRIX. This dataset provides travel time estimates on roadway segments defined by the Atlanta Traffic Management Center (TMC) by 15-minute interval. For each included TMC segment, this data is available for one complete day per month over a 12-month period. INRIX estimates these travel times from a variety of data sources, and fuses the raw data using proprietary methods. However, the resulting estimates are generally felt to be reliable, and in fact INRIX data is widely used in real-time traffic condition reporting.



The availability of estimates of actual travel times at a detailed time resolution makes possible a number of detailed empirical measures of travel time and travel time reliability. For example, it will be possible to identify thoroughfares or segments having unusually high travel time variability; these might not attain the corresponding reliability performance targets, and might be the subject engineering or operational actions to improve their reliability.

It was unfortunately not possible within the timeframe of the SRTP effort to work with the INRIX data: the license to the data was only recently obtained, the dataset itself is quite large and requires some familiarization, the cross-referencing from TMC segments to thoroughfare segments or other referencing system (see below) will take time to establish, and there are some thoroughfare segments for which INRIX data is not available. Thus, this rich dataset will need to be processed in the future to establish detailed time- and reliability-based performance measures. This promises to be a very useful extension of the current set of measures.

### 5.2.3 Linear Reference System

As a follow-up to the latest CMP efforts, a linear reference system (LRS) is being developed by ARC that offers a geo-referenced data set of roadway attributes, which could include the following:

- Number of lanes;
- Speed limits;
- Presence of traffic signals/intersection control;
- Location of school zones;
- Presence of divided/undivided roadways; and
- Other existing data sources (e.g., transit automated vehicle locator (AVL) data).

The purpose of the LRS is to provide the foundation for a data clearinghouse for use by the ARC, its member local government jurisdictions, and planning partners (GDOT, GRTA, et. al.) in transportation system planning, operations, and management efforts.

To this end, the ARC has researched potential data subscriptions that could be integrated into the LRS. The data will allow the ARC and its partners to compare real time and historical travel time to identify congested locations and the level of congestion along corridors throughout the region. The LRS could be used to identify bottlenecks, conduct temporal/seasonal analysis, and/or calculate unnecessary delays. This would help to focus CMP efforts and transportation investments.

It is recognized that even with the LRS, data will still be needed from local jurisdictions to identify operational deficiencies along specific segments or to update/validate the data within the LRS. The LRS will allow the uploading of link traffic counts, intersection turning movement counts, roadway attributes, and travel time data.

### 5.3 Description of the Updating Process

Given the potential variety of new data types and sources, it is not possible to describe in specific terms the way in which new measures and targets should be incorporated. However, the overall framework of measures and targets suggests a general approach for carrying out this update.

#### 5.3.1 New Temporal or Geographic Scales of Measure

The availability of new data sources may make it possible to establish new measures that are more detailed in a temporal or geographic sense than those in the current set. For example, the availability of DTA model outputs (for base and future years) will provide a level of temporal detail that is currently lacking in ARC static regional model outputs and in the performance measures derived from them.

In such cases, the new measures should be defined in a way that relates directly to already-defined measures via a process of aggregation or averaging. For example, measures related to DTA travel time outputs at 15-minute intervals should be related, as much as possible, to the corresponding time measures over the corresponding longer time period in the ARC static regional model.<sup>1</sup> The more detailed outputs of the DTA model will of course make possible the definition of measures that have no counterpart in the static model outputs, such as travel time variability (e.g. standard deviation), but again these should be computed over the corresponding static model time periods (e.g. AM and PM peaks, mid-day and nighttime off-peaks).

#### 5.3.2 New Types of Measure

The objective of performance measure extensibility means that the set of measures must be able to grow to accommodate new types of data from sources that may not have been available when the measures were originally defined.

In this case, potential measures associated with the new data source will need to be associated with one of the measure types (mobility, network connectivity, land use connectivity, multimodal functionality) and, to the extent possible, related to other measures of that type. The nature (informative or actionable) of potential measures should be determined, and the possibility of using informative measures to condition potentially actionable ones (as was done above, for example in the analysis of conventional and premium transit routes on segments that serve UGPM-identified town or regional centers). Overlapping (i.e. highly correlated) measures do not contribute useful information to the performance measurement process and should be

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<sup>1</sup> In some cases, this exercise may highlight inconsistencies between the “average” conditions for a period output by the static model, and the corresponding sequence of short-interval outputs. This would be a problem with the models, not with the measures *per se*.



avoided. Conversely, new measures that provide a contrasting or additional perspective on something already included in part (e.g. travel time variability as an additional perspective on average travel time) should be explored in detail.

### **5.3.3 Setting Performance Targets**

The process of setting targets for measures at a new scale or involving new data will be quite similar to the process followed here. The empirical distribution of measure values (as determined through histogram plots, for example), can be used to identify logical cut-offs for “typical” values vs. outliers. Use of appropriate quantiles of the distribution, as was frequently done in the work reported here, is a reasonable approach. A suitable choice of target quantiles can be made based on an examination of the empirical distribution of the data values. In some cases, it may be advantageous to combine an informative performance measure with an actionable one to establish the targets.

## APPENDIX A

### Histograms of Mobility Measures by RTN Segment Classification Level



The following histograms present the various mobility criterion performance measures separately for each of the three RTN segment classification levels and for 2010 and 2040. As will be seen, for a given performance measure the differences between the histograms associated to the different classification levels are generally relatively minor and in any case do not appear to have a straightforward interpretation. Moreover, the lower number of data points (observations of performance measure values on an individual segment) in each level tends to create artifacts (such as spikes) in the distributions because of the way that the quantiles are computed. The kernel density estimates smooth out these spikes and other artifacts to some extent.

It is likely that additional and more detailed types of data will need to be available for the definition of performance measures in order for measures that usefully distinguish between thoroughfare and segment performance characteristics at the three levels of classification.

