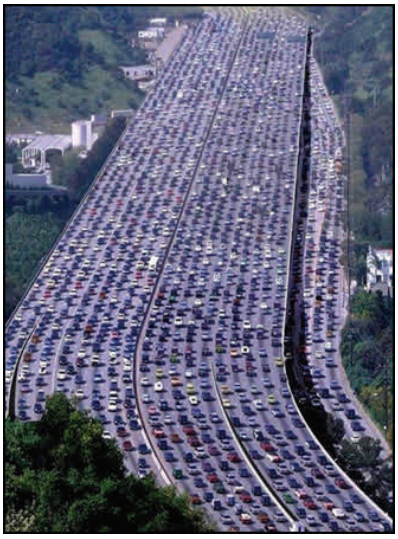
Transportation Association of Canada

Primer on

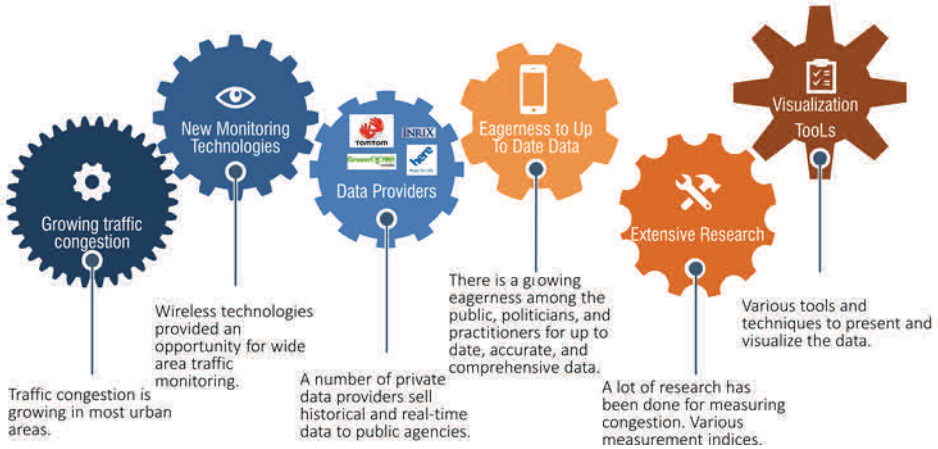
Defining and Measuring Urban Congestion

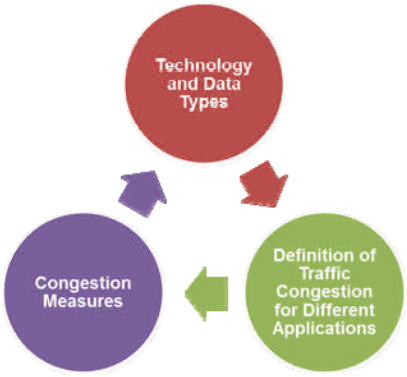


Introduction

Traffic congestion has become a major challenge in most urban areas. In recent years, the development of measures to mitigate traffic congestion has become a priority task for many road agencies. To this end, the identification of congestion characteristics is an essential step for selecting appropriate mitigating measures.

This primer is intended to address various challenges posed by traffic congestion. The primary objectives of the primer are to i) develop standards for defining and measuring traffic congestion and identifying performance measures (indices) to quantify congestion, and ii) provide guidance on how to use different data sources for measuring congestion and evaluating proposed transportation investments. The primer briefly covers contents of the TAC *Guidelines for Defining and Measuring Urban Congestion*. The Guideline is intended to promote methodological consistency among Canada's urban areas, provide guidance on how to quantify traffic congestion, how available traffic congestion data sources should be used, and inform the institutional, public and political discourse on transportation issues and solutions.

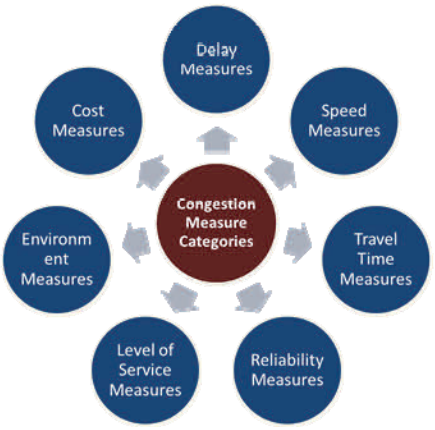




Defining Traffic Congestion

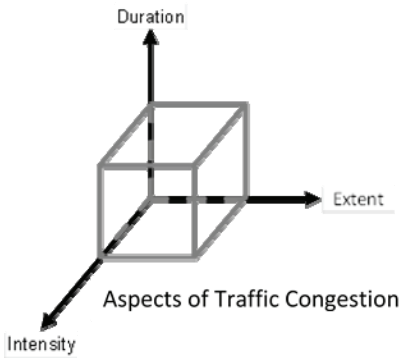
The identification of congestion and its characteristics is the first step towards selecting appropriate mitigation measures. However, the degree of congestion on urban roadways is not always measured and treated uniformly. The review of the

research studies, jurisdictional practices, as well as an online survey of jurisdictions and research institutes in North America and Europe revealed that there is no universally accepted definition for traffic congestion. The majority of studies and practices on traffic congestion showed some permutation of the following phrase in their definitions: *"Congestion is a situation in which demand for road space exceeds supply".* Although this definition of traffic congestion is valid, the complex interactions between demand and supply parameters, which lead to congestion, are not clearly discussed. As an alternative to the above perspective, many researchers and practitioners define congestion based on user's expectation: *"In the transportation realm, congestion relates to an excess of vehicles on a portion of roadway at a particular time resulting in speeds that are slower—sometimes much slower—than the expected speeds".* The expected speed can vary for different applications, time of the day, types of analysis, and jurisdictions. The TAC Guidelines provide suggestions on the expected speeds (the threshold between congested and uncongested traffic conditions) for Canadian roads.



Congestion Measures

Traffic congestion has a direct effect on the travel time, speed, delay, and quality of services and increases the emission of pollutants, fuel consumption, and travel cost. These effects are widely considered in the literature to characterize and measure the consequences of traffic congestion. Traffic congestion measures can be categorized into seven groups, including delay, speed, travel time, travel time reliability, level of service, environmental, and cost measures. Initially, around 30 congestion measures were identified. Due to the high number of available metrics, an objective procedure was devised to assess and compare congestion measures. The congestion measures were evaluated against the following factors:



- Analysis types, including government investment & policy, transportation planning models, air quality and energy models, traffic operation, etc.;
- Analysis areas, such as short road segments, corridors, and regional networks;
- Potential audiences, including traffic engineers, transportation managers, roadway users, and elected officials;
- Aspects of traffic congestion, including duration of congestion, number of people or vehicles travelling under congestion condition, the geographical distribution of congestion, magnitude of congestion, and day-to-day variations in traffic congestion; and
- Data availability and data collection methods.

The initial list of congestion measures were examined against the above factors and those covering most factors were identified. Table 1 presents the top ranked congestion measures.

Table 1 – Top Ranked Congestion Measures

MEASURE CATEGORY			
DELAY	**TRAVEL TIME**	**RELIABILITY**	**LEVEL OF SERVICE**
• Total Vehicle Delay • Total Travel-er Delay • Delay Rate	• Travel Time Index • Commuter Stress Index	• Normalized Percentile Travel Time • Buffer Time Index • Skew Index • Planning Time Index	• Lane Mile Duration Index

Attributes of each congestion measure identified in the study were summarized in a table similar to Table 2. This table shows the detailed attributes of Travel Time Index.

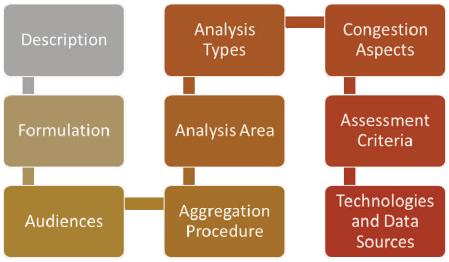


Table 2 – Detailed Attributes of Congestion Measures

Measure		Details			
Travel Time Index	Description	Travel Time Index (TTI) compares peak period travel time to the free-flow travel time. This measure includes both recurring and non-recurring conditions and is also reported in the most recent Urban Mobility Scorecard, which is prepared by the Texas Transportation Institute (Schrank and Lomax, 2015).			
	Formulation	$TTI_r = \frac{t_{(r,p)}^{obs}}{t_r^f}$ Where, TTI_r = Travel Time Index for corridor r; $t_{(r,p)}^{obs}$ = Observed peak period travel time along corridor r (min); and t_r^f = Free-flow travel time along corridor r (min).			
	Audiences	Engineers, Managers, Road Users, Elected Officials			
	Analysis Types	Government Policies	✓	Identification of Issues	✓
		Private Sector Decision	✓	Evaluation of alternatives	✓
		Land Development Impacts	✓	Assessment of traffic controls	---
		Transportation planning Models	✓	Real-time traffic management	✓
		Air quality and energy models	---	Assessment of transit systems	✓
	Analysis Area	Segment, Corridor, Region			
	Aggregation Procedure	$TTI_u = \frac{\sum_{r \in U}\left(\frac{TTI_r}{L_r} \times VKT_r\right)}{\sum_{r \in U} VKT_r}$ Where, TTI_u = Travel Time Index for the urban area u; L_r =Length of Corridor r; VKT_r = Vehicle Kilometer Traveled on corridor r; and U = Set of corridors within urban area u.			
	Congestion Aspects	Intensity			
	Assessment Criteria	Simple and easily understood	✓	Comparable	✓
		Magnitude of congestion	---	Allows aggregation	✓
		Relative to a standard	✓	Requires minimal data	✓
		Continuous range	✓		
	Technologies and Data Sources	Inductive Loop Detectors	---	Bluetooth/Wi-Fi	✓
		RFID	✓	ANPR	✓
		Dedicated Probe Vehicles	✓	Mobile Probe Vehicles	✓
		Connected Vehicles	✓	Autonomous Vehicles	✓

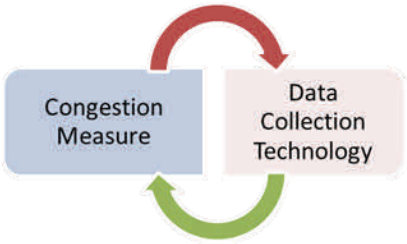
Technologies and Data Sources

The selection of congestion measures should be independent of the data collection method. However, in reality the availability of the data source play an important role in the selection process of congestion measures. Currently, different methods for acquiring traffic data are available in the market, namely fixed-point technologies (e.g. inductive loop detectors, Bluetooth and Wi-Fi Technology), dedicated GPS probe vehicle technologies, and cell phone location identification techniques from private data providers. It is noted that not all data collection methods are fully capable to measure different traffic indices. Therefore, a number of criteria were considered in evaluation of technologies and data sources, including data collection methods, type of available data (raw vs. processed data), historical and/or real time traffic data, sample size, accuracy, coverage, and limitations. In summary, a correlation between the congestion measures and data collection methods was created in a matrix format (Table 3). The symbols in this table are defined as follows:

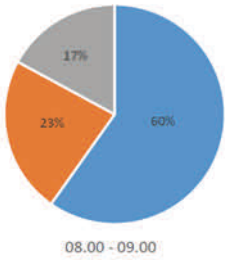
- ● The data collection technology can fully estimate the congestion index.
- ◑ The data collection technology can be used as a supplement for estimation of the congestion index.
- ○ The data collection cannot be used in estimation of the congestion index.

Table 3 – Congestion Measure and Data Collection Matrix (Sample)

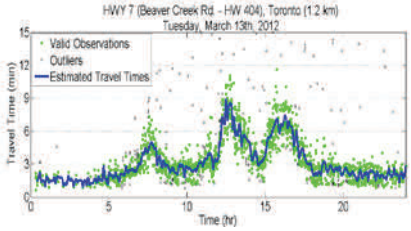
MEASURE CATEGORY	CONGESTION MEASURE	DATA COLLECTION TECHNOLOGIES					
		FIXED POINT				PROBE VEHICLE	
			AVI				
		INDUCTIVE LOOP DETECTORS	BLUETOOTH	RFID	ANPR	DEDICATED PROBE VEHICLES	MOBILE PROBE VEHICLES
Delay	Vehicle Delay	◑	◑	◑	◑	◑	◑
	Traveler Delay	◑	◑	◑	◑	◑	◑
	Delay Rate	○	●	●	●	●	●
	Relative Delay Rate	○	●	●	●	●	●
	Delay Ratio	○	●	●	●	●	●
	Congestion Severity Index	◑	◑	◑	◑	◑	◑



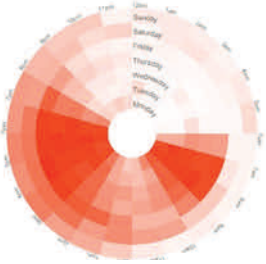
Bar and Column Charts



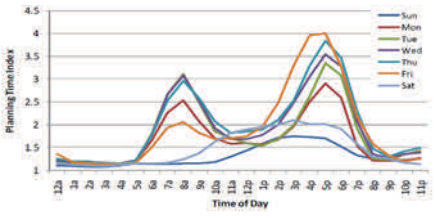
Pie Chart



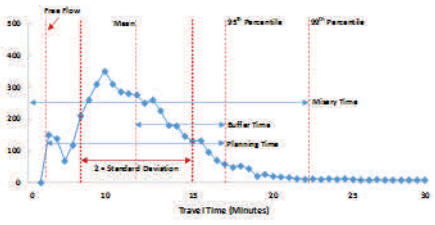
Scatter Plot



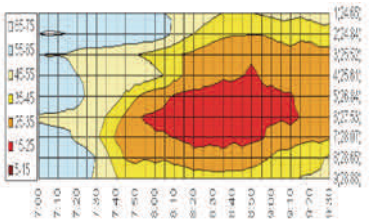
Spiral Chart



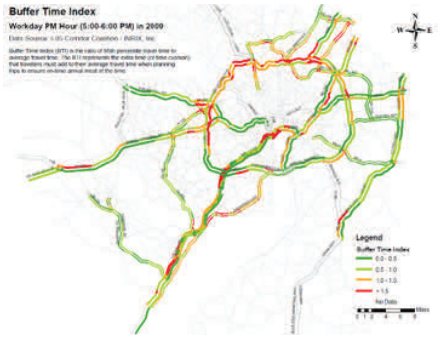
Line Graph



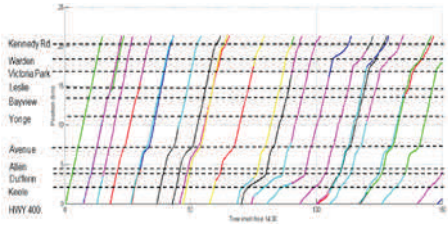
Histograms



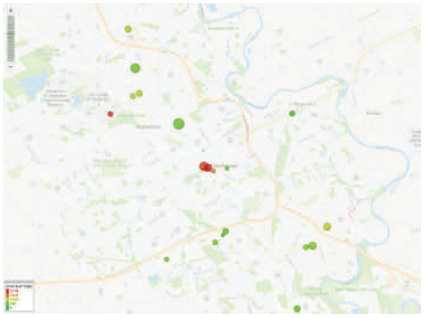
Contour Plot



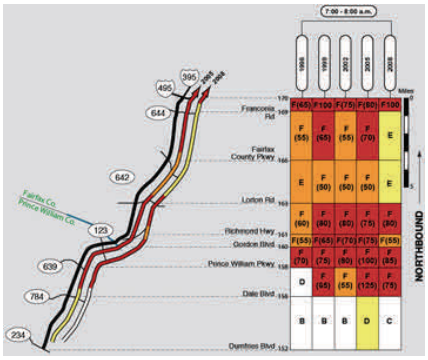
Heat Map



Space-Time Diagram



Bubble Map



Infographic

Congestion Visualization

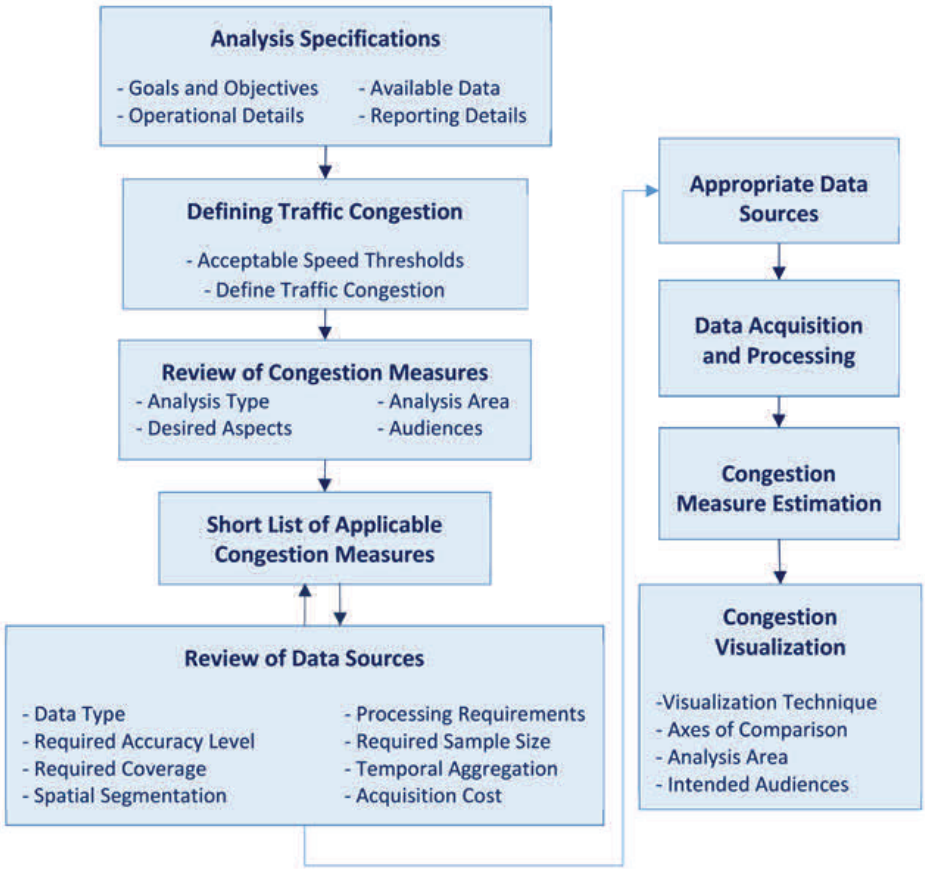
Visualization is an effective tool for presenting transportation performance data and information in ways that can be understood by various audiences. A wide range of different types of visuals can be used to present the congestion indices. Examples of such visualization tool are presented in the sidebar. Depending on the goals and objectives of the study, intended audiences, and the availability of data and resources, a diverse set of visualization techniques may be considered for different congestion management applications. In summary, the following observations can be made for different visualization techniques:

- Most of the visualization techniques are applicable to delay, speed, travel time, and LOS measures, except pie charts and frequency distributions;
- Spiral charts, frequency distribution, contour plots, and heat maps are the best techniques for visualizing reliability measures;
- The applicability of infographics to different congestion measure categories varies depending on their design scheme and included information;
- Most of the presented visualization techniques are suitable for engineers and managers, while bar and column charts, pie charts, line graphs, scatter plots, heat maps, and bubble maps are appropriate visualization techniques for road users;
- Most of the visualization methods are applicable to road segments. The only exceptions are contour plots, heat maps, and bubble maps; and
- Contour plots and space-time diagrams can fully address time & space comparisons. Moreover, spiral charts, heat maps, and bubble maps can partially address time & space comparisons.

Decision Support

As a summary of the primer, a decision support process was prepared for users of the Guideline to choose appropriate definition of congestion, congestion measures, data sources, and reporting and visualization methods based on goals and objectives of the study as well as other constraints and considerations. Figure 1 illustrates an overview of the decision support process.

Figure 1 — Traffic Congestion Measure Monitoring — Decision Support Process



More Information

This primer is based on the Transportation Association of Canada publication *Guidelines for Defining and Measuring Urban Congestion*, which readers can purchase from TAC's online bookstore at www.tac-atc.ca.

Disclaimer

Every effort has been made to ensure that this primer is accurate and up-to-date. The Transportation Association of Canada assumes no responsibility for errors or omissions. The primer does not reflect a technical or policy position of TAC.

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