Next Generation Traveler Information System: A Five Year Outlook

Final Report

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16. Abstract

Traveler information is in a state of significant growth and evolution. User expectations, technologies, and the roles of the major public and private participants in the transportation ecosystem are all in motion. Traditional approaches to planning for stable, long term solutions do not work well in the face of constant consumer and technology change.

This report is intended to help agencies plan the next generation traveler information system so that they stay in step with their customers and with transportation network management needs. It provides a current snapshot of status in key areas such as traveler needs, technology trends, and business models. Against this backdrop, the report provides guidance on operational and technical best practices that can be used by public agencies as they develop next generation traveler information systems (NGTIS). These best practices are designed to help agencies optimize their operational approaches to provide travelers with improved functionality and generate desired transportation outcomes.

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PREFACE

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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LIST OF ABBREVIATIONS

AASHTO ....American Association of State Highway and Transportation Officials

ATDM.. Active Transportation and Demand Management

ATIS..Advanced Traveler Information System

B2B ....Business to Business

B2C ....Business to Consumer

CAGR .... Compound Annual Growth Rate

Caltrans ....California Department of Transportation

DMS...Dynamic Message Sign

DOD.. Department of Defense

ETA.. Estimated Time of Arrival

FGDC...Federal Geographic Data Committee

GPS ....Global Positioning System

HAR .... Highway Advisory Radio

ISO .... International Organization for Standardization

ITIL ....Information Technology Infrastructure Library

ITS...Intelligent Transportation System

IVR...Interactive Voice Response

MAP-21...Moving Ahead for Progress in the 21st Century Act

NGTIS...Next Generation Traveler Information Systems

OEM..Original Equipment Manufacturer

PND..Personal Navigation Device

RTSMIP ....Real-Time System Management Information Program

RTTI...Real Time Traveler Information

SAFETEA-LU ....Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

SRTI..Safety-Related Traffic Information

TMC..Traffic Management Center

TNM..Transportation Network Management

US DOT .... United States Department of Transportation

VMT...Vehicle Miles Traveled

EXECUTIVE SUMMARY

Traveler information is in a state of significant growth and evolution. User expectations, technologies, and the roles of the major participants in the transportation ecosystem are all in motion. Against this backdrop, this report seeks to provide a current snapshot of status in key areas such as traveler needs, technology trends, and business models, and to offer guidance on best practices which may be used by public agencies to navigate this landscape as they develop next generation traveler information systems (NGTIS).

MAJOR TRENDS

Traveler information data has moved from being a siloed set of data collected for transportation uses to being part of the overall "big data" stream that flows to and from consumers. This stream now includes information about drivers, vehicles, and the network that they both move in, from driving behavior patterns to real-time traffic status on freeways and arterials.

Both smartphones and connected infotainment- and telematics-equipped vehicles have become a rich source of these valuable data for private companies, who have uncovered models for monetizing it. As a result, the private sector is moving aggressively to capture, process, and sell traveler information and the resulting services on a global scale. Major data mega-managers, like Google, have included these data in their offerings and continue to integrate it with an ever-expanding collection of new data and functionality.

Further progress in this direction should be expected, as continuing rapid adoption of smartphones and other smart devices provides a widely available platform for both collecting and sharing data and functionality with consumers. Longer term, further adoption of connected infotainment and connected safety solutions will also add to these capabilities.

RECOMMENDATIONS

As a result of these dynamic trends, the traditional role of public sector agencies in providing traveler information must be reconsidered. The outcomes of this assessment will vary from agency to agency, but it is important both to perform such assessments now, as well as to establish processes that ensure regular reviews are executed to help navigate anticipated change in the traveler information landscape over the next 5-10 years.

At the most fundamental level, there is a need for agencies to link business and technology processes more tightly together to ensure that increasingly fast evolution in the consumer and private-sector marketplaces can be quickly understood, and that public sector NGTIS business models and technology suites can effectively respond to these changes.

Additional recommendations based on current trends include:

- **Re-visit core goals.** Determine the most important objectives to accomplish as an overall Transportation Network Management provider. Document how the collection and sharing of specific transportation data supports those goals, including which data are mission-critical and which can accept varying levels of availability risk.

- **Build and monitor a roadmap.** The environment in which NGTIS functions is changing rapidly, but the actual changes to a given agency's NGTIS must be made at the right time, in the right way. Building a roadmap allows the agency to set expectations for change. Monitoring key metrics allows validation or refinement of actual changes. In particular, the cross-over points where it makes sense to enter or exit key roles, deploy specific technologies and insource or outsource parts of the overall system should be carefully considered.

- **Standardize wherever possible.** Standardization facilitates data analysis, sharing and outsourcing as appropriate. The importance of this cannot be overemphasized. Barriers to achieving economies of scale, opportunities for advanced functionality, and effective outsourcing (when appropriate) are all significantly reduced by standardizing data so that it can be easily integrated across systems.

- **Measure, measure, measure.** The only way to make data-driven decisions is to have the data in the first place. Determine the costs of collecting transportation data and delivering it to consumers. Determine how travelers are actually using the data, and measure how their behavior then impacts the transportation network.

CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

State and local transportation agencies provide traveler information to their communities using increasingly sophisticated traveler information systems. These systems are evolving quickly. The next generation traveler information systems (NGTIS) emerging in the five-year timeframe need to consider an updated variety of data and delivery mechanisms to provide travelers with improved functionality and generate desired transportation outcomes. The role of the public sector systems must also be continuously evaluated in the context of private sector activities in offering traveler information as well.

As in all such situations, resource constraints prevent perfect solutions. Decisions about developing and managing NGTIS must be based on *overall goals* and *operational outcomes*. Every state will have its own mix of "best solutions" for providing these systems – there is no single answer.

This report offers a set of best practices and information that can be used as a guide in making good decisions over time as agencies evolve their traveler information solutions. These best practices are provided in the context of current and projected information about stakeholder needs and overall industry trends, as well as business and operational models.

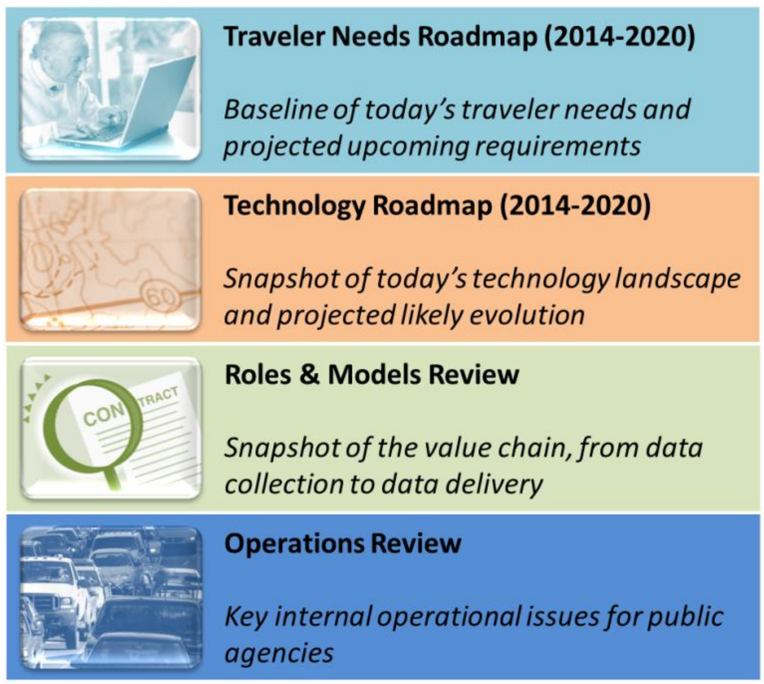


Figure 1. Chart. Report Summary (SCG)

As described in Figure 1, this report is divided into four main chapters, and concludes with references:

- Chapter 2. Traveler Needs Roadmap (2014-2020).
- Chapter 3. Technology Roadmap (2014-2020).
- Chapter 4. Roles & Models Review.
- Chapter 5. Operations Review.
- Chapter 6. References.

1.2 NGTIS BACKGROUND

As shown in Figure 2, NGTIS is a subset of both overall Transportation Network Management (TNM), the responsibility of the public agency, and Consumer Big Data, the stream of information arising from the day-to-day activities of the connected consumer. This basic relationship is increasingly important to consider, as overall trends in Big Data impact the expectations of connected consumers, and the travel-related data both provided to and received from those consumers. Instead of being a discrete set of information received from a suite of agency-run sensors, traveler information is growing to include an ever-larger set of data about every aspect of the consumer's journey, captured on everything from Twitter feeds to smartphone apps. At the same time, it is simply part of a growing trend towards constant collection of every possible type of data generated by the consumer, which is driving a whole new set of service providers and interactions. Companies like Google, for example, have built very large businesses by providing services like searching tools, and extracting value from the customer data that is shared as part of that interaction.

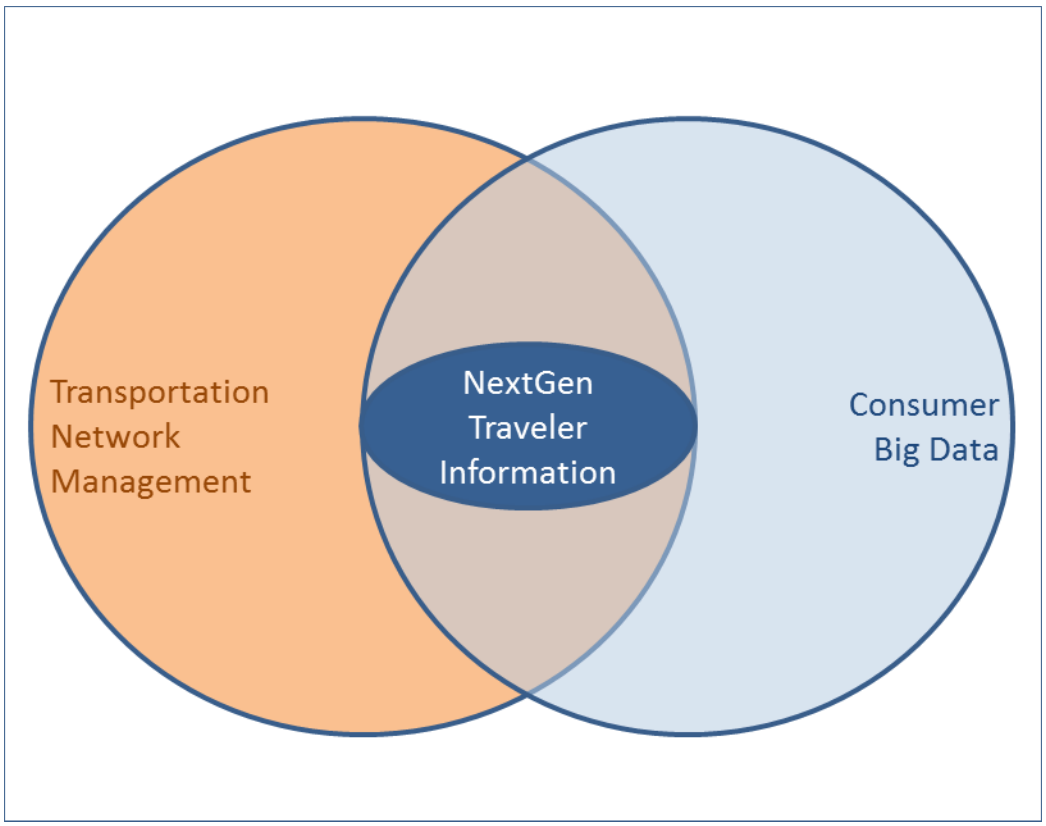


Figure 2. Chart. TNM, Consumer, and NGTIS Relationship View (SCG)

The NGTIS itself can be represented as a standard hardware/software solution stack depicted below in Figure 3, with a variety of functions occurring in succeeding layers, which build up from initial data collection through to final presentation to the user. These functions include contributing public sector capabilities and, in some cases, may also include third-party providers.

This framework will provide structure for the rest of the report as we consider the individual components of the NGTIS.

- The first layer includes all data collection activities, both insourced and outsourced.
- The second and third layers address data aggregation and data analysis, which may also include an outsourced component in some cases.
- The fourth layer involves the communication of data over various transmission technologies, such as radio, cellular, etc.
- Finally, there is the presentation layer, which encompasses a wide array of hardware and user interface solutions tailored to deliver information to specific audiences such as Emergency Responders, Traffic Management, and the Consumer. This fifth layer also includes all outsourced presentation channels for traveler information, such as TV shows, radio broadcasts, and private sector websites.

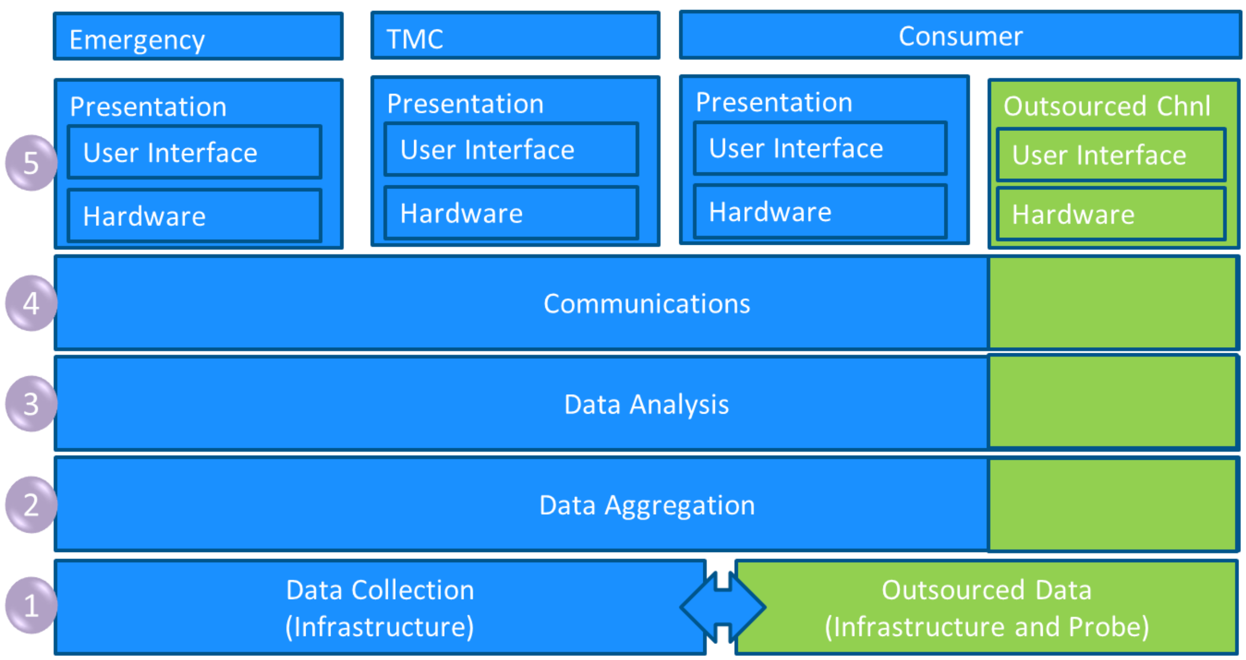


Figure 3. Chart. NGTIS Overview (SCG)

Today's public sector traveler information systems have evolved from two perspectives: a) as an outgrowth of existing traffic management activities, with traveler information seen as a useful but secondary byproduct of data collected for other uses, and b) as solutions specifically designed to support and improve individual traveler mobility. This difference in focus is important to consider when planning NGTIS evolution, as it drives the basic goals and outcomes expected from the system.

For example, if an NGTIS is designed to focus primarily on network efficiency, it might focus on the needs of freight vehicles to help reduce major blockages from freight incidents; while an NGTIS developed to impact consumer behavior and thus improve the mobility of those travelers might involve a very different suite of data, communications, and presentation solutions. This report provides a framework for considering these and many other strategic questions, for use by state DOTs in addressing their unique local needs.

CHAPTER 2. TRAVELER NEEDS ROADMAP (2014-2020)

This roadmap chapter considers today's traveler needs and projects upcoming requirements as reflected in consumer research. It focuses on the questions:

- What are the future trends of the traveler information needs, e.g., types of information, coverage, timeliness, accuracy?
- What are the trends and needs of urban versus rural areas?

2.1 WHO IS THE TRAVELER?

For agencies that choose to offer traveler-facing solutions, design starts with the end user. Who is the traveler and what functionality will they actually use? For those focused primarily on transportation network management, the same questions are important to understanding how to influence travelers to act in the way which best optimizes network efficiency.

In both cases, it is important to characterize the *traveler* and their *context.* This chapter outlines a segment analysis approach with an example set of traveler characterization factors, which can be used when considering a specific state or region, and a sample description of key high-level traveler segments.

Travelers can be characterized in a variety of different ways. This characterization, also described as 'segment analysis', is a useful tool in assessing overall user communities to determine appropriate NGTIS solutions. For example, a population which is largely rural and older may take much longer to accept new solutions than a younger urban group.

Once traveler segments are well-understood, this information can be used in considering both the required *functionality* of offerings and their *deployment timing*. Solutions for a rural community must be tailored to address the needs of longer distance travelers with fewer route and mode choices than those for a more urban group. Similarly, a community full of early adopters will quickly benefit from information delivery on the latest handheld platforms, while a more conservative community will not. At the same time, the early adopter community is quicker to move away from existing solutions in favor of the next hot option, demanding more aggressive technology deployment timelines.

These segments may also be used to test and monitor user response to NGTIS. Are specific segments adopting and responding to new NGTIS offerings as expected? Is their new behavior having the expected / desired impact on the overall transportation network? Is a new offering generating positive customer satisfaction ratings among this group?

2.1.1 Traveler Characterization Factors

In this analysis, it is helpful to review both *travel factors* and *technology adoption factors* for a target community. Travel factors provide insight into how and why people move from point to point, helping to clarify what those consumers' needs are as they do so. Technology adoption factors help shed light upon the tools people are most likely to use and benefit from as part of this process. A sample set of segment analysis factors is included in Table 1 below.

Table 1. Sample Segment Analysis Factors (SCG)

Demographics	Travel Reasons	Travel Environment	Offering Priorities
Age	Commute	Modal options	Functionality
Socioeconomic group	Social	Trip location	Effectiveness
	Errand	Average trip distance	Stability
	Repeat/one-off	Average trip length	Reputation
	Freight Delivery		Adoption behavior

It is important to note that segment analysis is not a one-time exercise. For example, as new generations emerge, and older ones mature, behavior patterns may well change within a given age group. As shown in Figure 4, today's Millennials (i.e., Gen Y with birthdates from about 1980-2000) are an excellent example of this, as they are currently trending much lower than their predecessors on car ownership (Gen X (~1960-1980), Baby Boomers (1946-1964), War Babies (~1930-1946)). As they proceed through each life stage, they may continue to diverge from prior generations or they may revert to more traditional patterns. Ongoing segment analysis is a helpful framework for taking a structured look at state and local communities to understand their needs over time.

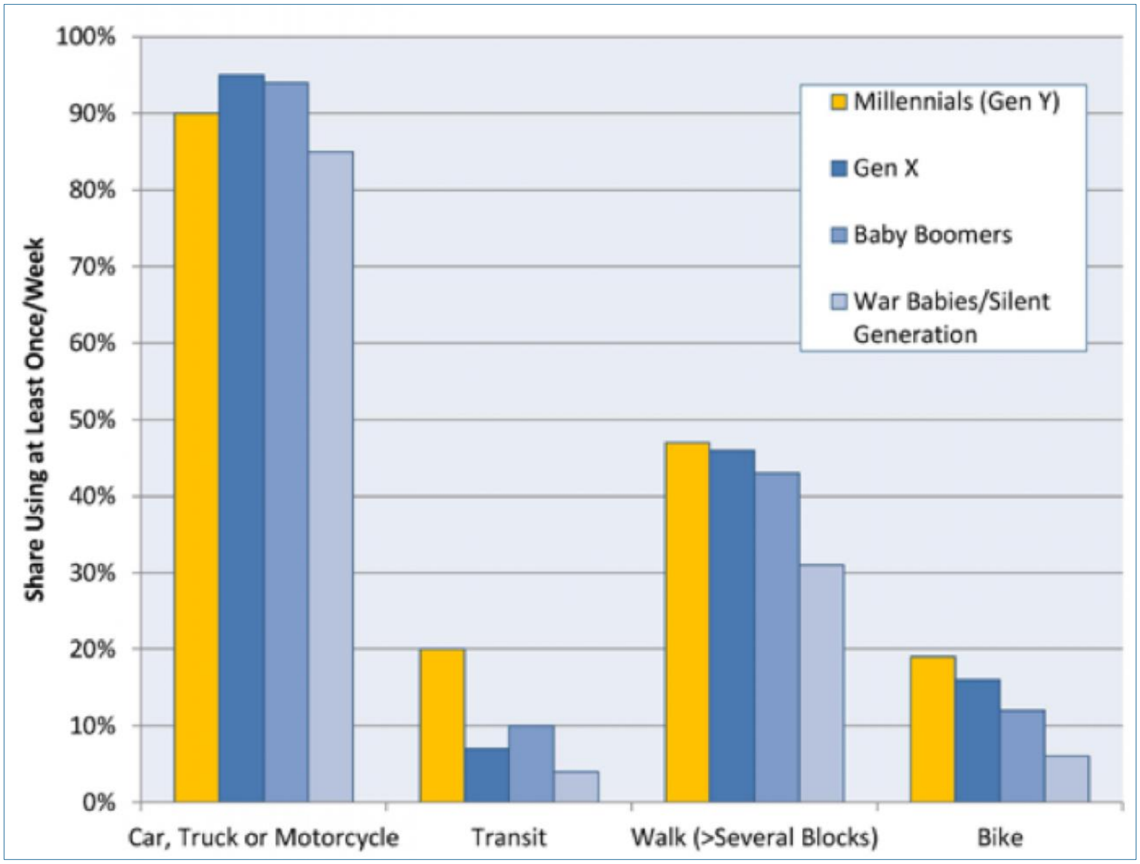


Figure 4. Graph. Snapshot of transportation mode usage by generation (U.S. PIRG Education Fund, 2014)

2.1.2 Sample Segments

It is not possible to consider every permutation of possible factors which make up a potential customer segment in this report. Instead, we have partially characterized a few high-level segments below on a national basis as a sample. Although there are many possible segments which might need to be considered by an agency, we have characterized a few high-level segments below:

- Urban commuters.
- Rural drivers.
- Truck drivers.

2.1.2.1 Urban Commuters

- Travel Reasons: This group predominantly performs local trips to and from work, which represent approximately 28 percent of all daily trips on U.S. roadways and transit systems (Dorsey, 2015).

- Trip Length: Average national trip length trends were 25.5 minutes in 2011, which did not change from average length in 2000 (Polzin, 2013).

- Modal Options: They have the largest set of modal options, with 69 percent of urban households having access to transit (as opposed to 14 percent of rural households (ASCE, 2013).

2.1.2.2 Rural Drivers

- Travel Reasons: This group largely travels in rural areas, for either business or recreational purposes.

- Trip Length: Rural trips may be *long duration,* i.e., approximately 50-100 miles, with the possibility of changing conditions over the course of the travel.

- Modal options: This group may have *reduced options* and mobility in the event of situations that impact their trip, such as closures, incidents or adverse weather (Deeter, 2009).

2.1.2.3 Truck Drivers

- Trip Distance: Truck drivers comprise 10 percent of vehicle miles traveled (VMT) in the US (US DOT, 2013). This number is increasing as e-commerce continues to grow, as shown in Figure 5 below (Smith, 2014) with the compound annual growth rate (CAGR).

- Offering Priorities: This driving community is highly time-sensitive, facing direct financial consequences for delay. As a result, the larger carriers have historically been prompt adopters of technologies with clear return on investment, although solutions must be hardened to meet the needs of both the truck driver demographic and the freight business.

- Trip Location: Truck drivers handle the bulk of interregional miles as well as an increasing percentage of urban travel.

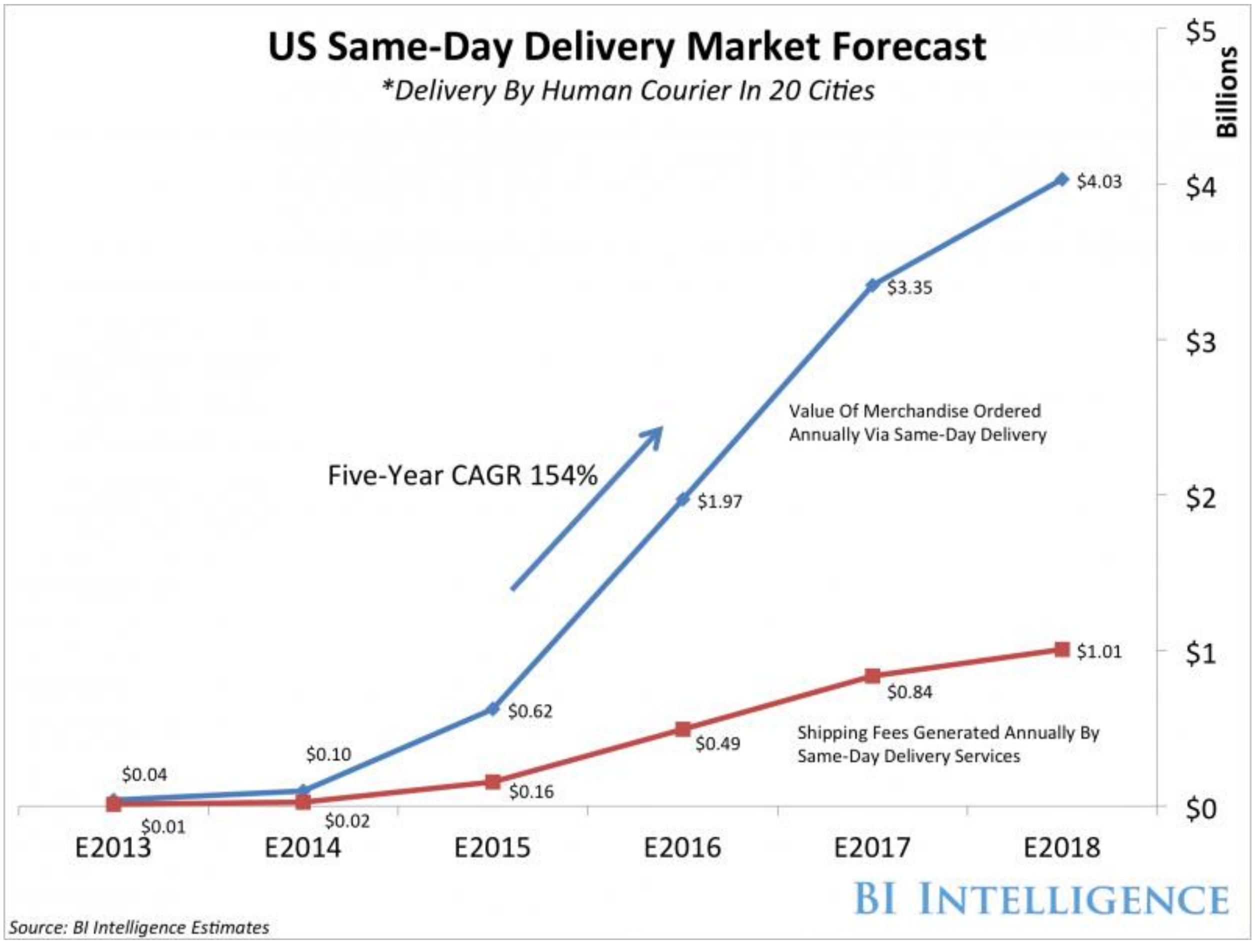


Figure 5. Graph. US Same-Day Delivery Market Forecast (Smith, 2014)

2.1.3 Overall Travel Trends

Overall VMT has decreased since about 2005. It should be noted that the timing for this shift varies regionally, and that projections of this trend to future years vary significantly. Some examples of future projections are shown in Figure 6. Researchers have posited a variety of factors driving the existing trend, but it remains to be seen which will prove to have the most impact. In the meantime, NGTIS planners and managers should monitor the situation in their area.

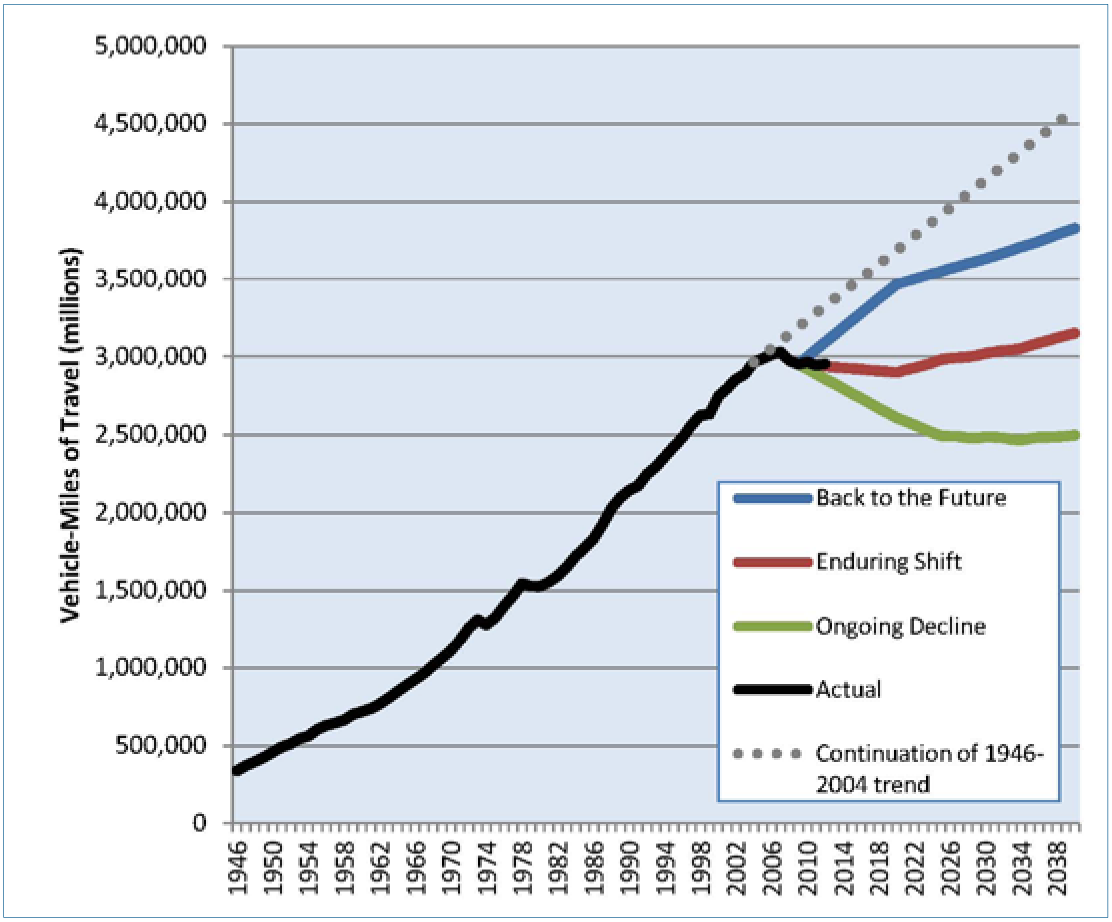


Figure 6. Graph. VMT Projections under Three Scenarios of Future Growth (U.S. PIRG Education Fund, 2014)

2.2 WHAT ARE THEIR NEEDS/GOALS?

As shown in Figure 7 below, the traveler's primary focus is simply moving from one point to another. There are a variety of sub-needs associated with that goal, including information about decisions about mode, route and departure time.

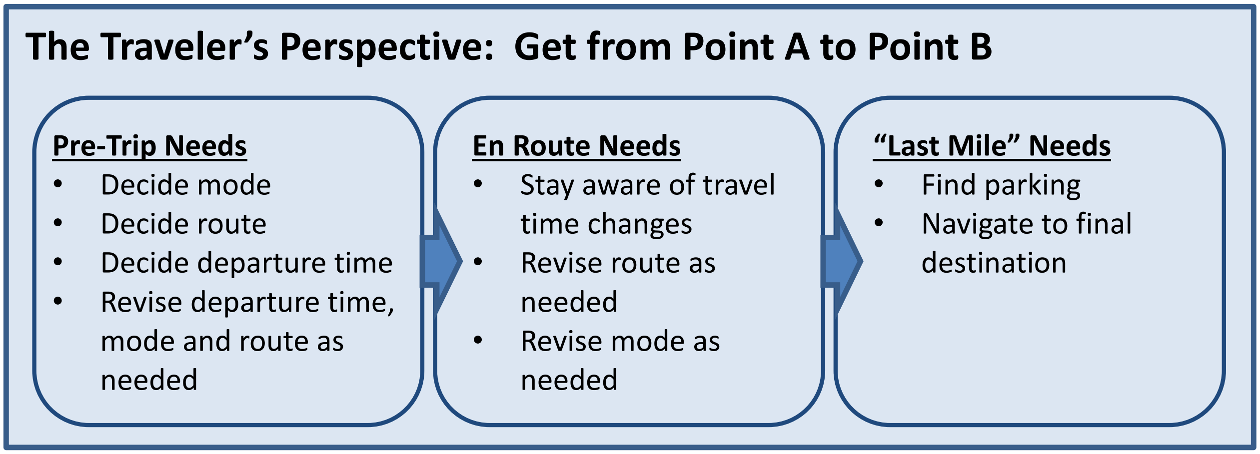


Figure 7. Chart. Traveler Perspective (SCG)

At the next level of detail, specific information needs found in recent surveys (Brydia R. E., 2015) include:

- Expected delays between major points.
- Current travel times between major points.
- Current location and status of incidents.
- Locations and times for planned lane closures.
- Projected travel times between major points during their trip.
- Availability of information (routes/maps) for necessary detour.
- Current speeds between major points or smaller segments.
- Visual confirmation of conditions at selected points.
- Coverage across the entire trip, regardless of roadway choice or jurisdiction.
- Pre-trip access to traveler information for planning (days or hours in advance).
- En route access to traveler information.
- Information of interest along route, including tolls, roadway restrictions, weather events, rest stops, food, gas, lodging, and information related to tourism.

On the transit side, needs include (Brydia R. E., 2015):

- Real-Time:
  - Transit departure/arrival time.
  - Service changes.
  - Outages.
  - Parking availability and fees.
  - Current system delays.
  - Current information on alternate modes.

- Static:
    - Schedule, fare, security, and accessibility information.
    - Transfer information.
    - Directions to/from transit locations.

2.2.1 Information Need Trends

While traveler needs as shown in Figure 7 are not changing, expectations for meeting these needs are growing rapidly, as connected consumers become used to instant access to information and services.

Figure 8 provides a high level view of the evolution in information need trends, from a focus on basic information used by humans to make travel decisions to the availability of more sophisticated collections of information which can be used by computers to automate support for traveler needs. These and other information attributes and types of information are described in more detail in the subsections below.

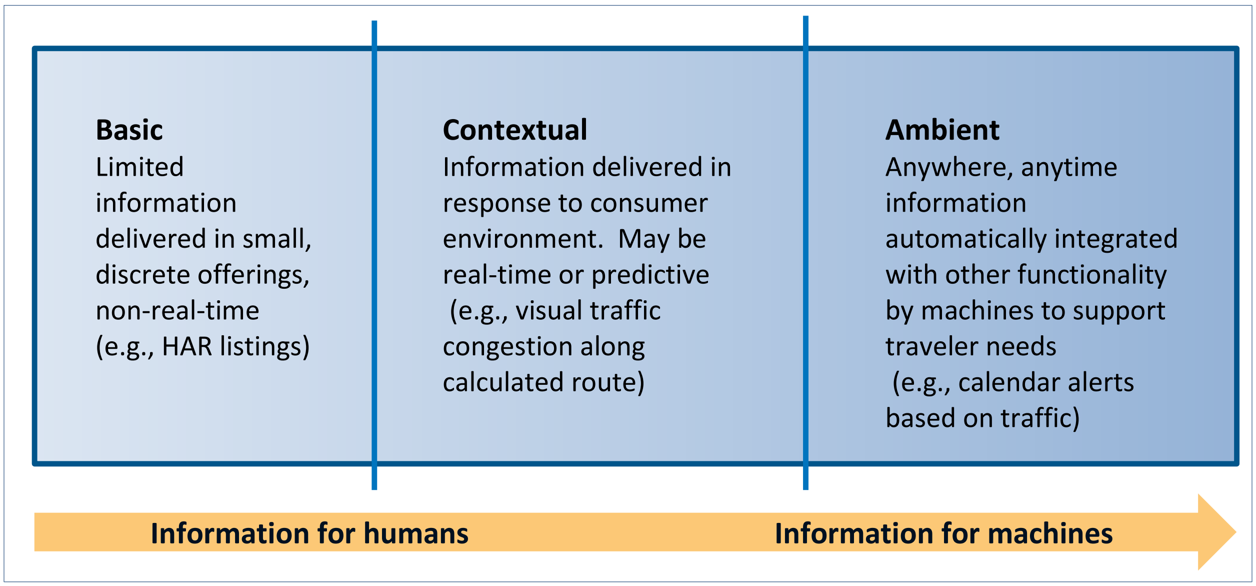


Figure 8. Chart. Traveler Information Roadmap (SCG)

2.2.1.1 Information Attributes

The core attributes, such as quality, availability, timeliness, functionality and reliability of data continue to be a focus for all providers. Key trends in this area include:

- **Anytime/anywhere availability**. Connected consumers expect to be able to access information wherever they are, on whatever device they happen to be using.

- **Contextual filtering**. Simple availability, however, does not go quite far enough. There is so much data available at this point that consumers are now asking for data and service providers to deliver only "exactly what, when, and where needed." Consumers want their data filtered for local and individual relevance and provided in their preferred format. One example of this is the interest in multi-lingual data. (Deeter, 2009) Another is the concept of safety-oriented traveler information such as real-time warnings of upcoming traffic jams to help avoid rear-end collisions with stationary queues. (TomTom, 2013)

- **Ambient data use**. (Daecher & Galizia, 2015) As the Internet of Things evolves, certain types of data become more useful when employed by machines than by humans. Current examples include map data, which is increasingly used by machines to provide directions, rather than by humans directly; and time data, which is a fundamental part of practically all automated activities. Traffic data appears to be headed in the same direction, as consumers are being offered functionality which takes the state of the transportation network into account, rather than consuming traffic incident information directly. One example would be applications which provide calendar alerts based on current or projected travel times. Another example is real estate applications which rate location suitability based on average commute times.

- **Ability to Integrate**. Fundamental to all of the previous points is the concept that traveler information is one of many types of data being processed in new ways and new combinations. It must be capable of being attached to locations, processed by calendars, and fused with multiple other data types to produce new functionality. One classic example is multimodal data – consumers increasingly expect to get information about every available mode, from bikeshare to carshare to transit, as well as related parking and traffic data, in one application.

2.2.1.2 Types of Information

The general trend for information types is simply "more", as service providers seek to deliver ever-improving functionality to their consumers. Specific data types that are receiving attention include:

- Arterial travel times. This information is required to deliver high-quality route choice functionality. Travelers want to know not only where problems are occurring, but the best ways around them. This is most practical in in areas with strong arterial alternatives to freeway travel.

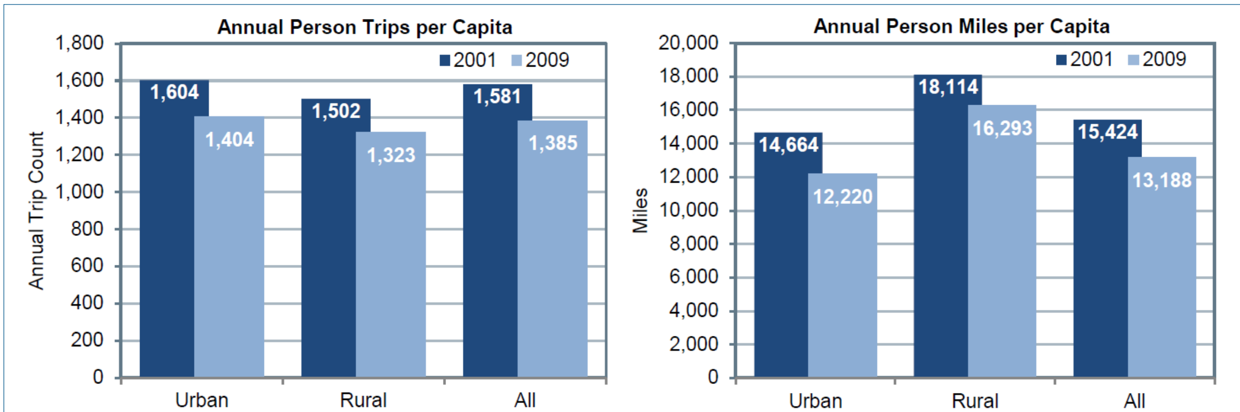
- Parking. Parking data has been available for some time, but has found its way into the spotlight over the last two years or so, with a number of new smartphone apps and their inclusion by OEMs in in-vehicle infotainment solutions. Parking data claims a variety of strong benefits in addition to consumer convenience, including reduced congestion in central business districts.

- Predictive. True, real-time, predictive data has been a holy grail for traffic providers for decades. Recent advances in data availability and integration have moved the needle forward in this area, as providers seek to deliver quality estimated times of arrival for consumer use. For further discussion on predictive data, see the section titled "Aggregation and Analysis Technologies" in the next chapter.

- Environmental. A recent symposium on probe data showed increased private sector interest in providing environmental data such as emissions and fuel costs (Hamedi, 2015). These data may be of use both to planners and to system managers who provide it back to travelers in situations such as Ozone Action Days. Data to support electric vehicles was also discussed.

Rural vs. Urban

Rural travelers need information that caters to their travel patterns. Longer trips require more en route data to keep the traveler abreast of changes during the trip. As noted previously, rural drivers may also have reduced options and mobility in the event of situations that impact their trip, such as closures, incidents, or adverse weather. Figure 9 shows the contrast between rural and urban person trips and miles per capita. Per the NHTS, person trips may include any mode of travel, but rural travel is predominantly automobile travel.



Note: The travel of children aged 0–4 is excluded from 2001 NHTS data to make it compatible with other years.

Source: 2001 and 2009 NHTS.

Figure 9. Graph. Annual Person Trips and Person Miles per Capita by Urban/Rural (US DOT, 2013)

One key item to consider is that the rural availability and adoption of some technologies has historically been slower than urban. In some areas, for example, cellular coverage is still unreliable or non-existent. Figure 10 shows the state-level estimates of no connectivity, or individuals who did not connect to the Internet and lived in a home without a computer. This means that both information and delivery solutions must be appropriate to the environment and the demographic.

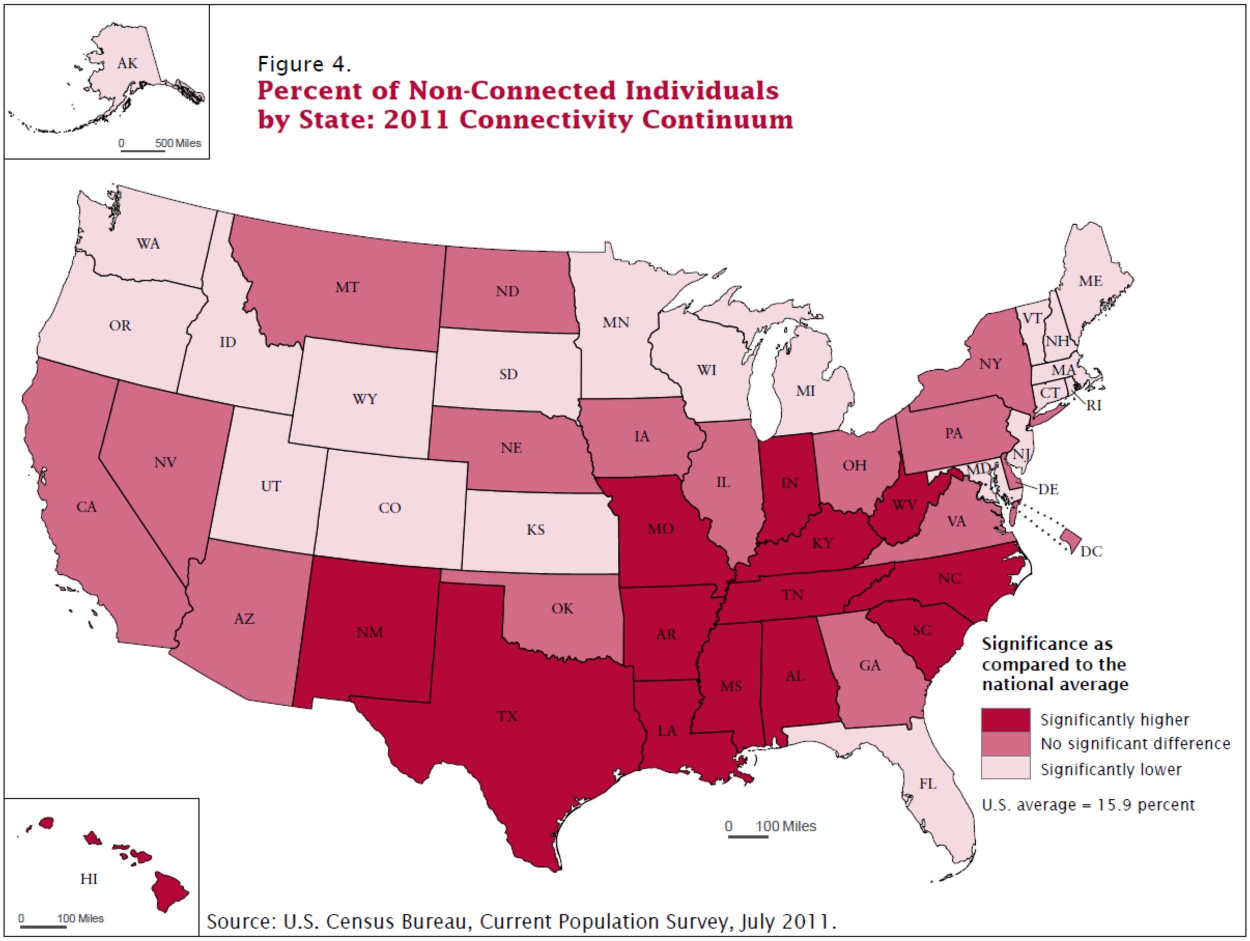


Figure 10. Map. State-level Connectivity Continuum (File, 2013)

2.3 WHAT IS THEIR DAILY CONTEXT?

It is important to consider NGTIS in the traveler lifestyle contexts in which they are used. Key trends in this area include:

- **Rapid mobile device adoption.** At this point, the majority of American adults have smartphones, and adoption rates continue to grow. A broad array of other mobile devices are also quickly becoming fixtures in consumer households, fueling the expectation that at any given moment, a screen providing information access will be ready-to-hand. From a public sector perspective, it is important to serve both the mobile device-enabled community and those who have not yet moved to this technology. At the same time, the extremely high usage levels of these new platforms among those who do have them makes it equally important to carefully consider the new platforms as they emerge. As of January 2014:

  - 90 percent of American adults have a cell phone.
  - 58 percent of American adults have a smartphone.
  - 42 percent of American adults own a tablet computer (Pew Internet Project, n.d.).

- **Traveler Information access via smartphone.** There are relatively few studies on this topic, but it is clear that travelers are using their smartphones as a routine source of travel information, with most reporting use of directions/navigation, and somewhat fewer mentioning traffic and transit information. We have not found any studies which show a direct correlation between smartphone device ownership and use of smartphones for traveler information – the studies simply note that certain percentages of smartphone owners do use their phones in this way. It is reasonable to project that in the years since these studies were done, this trend has continued upwards.

  It is important to note that many of those getting directions may also be receiving traffic data along their routes without having to ask for it separately (e.g., via Google Maps). Another item to consider is the variation in this usage among user segments, which may help an agency understand how best to serve certain communities. For example, one study shows African-Americans using their cellphones 31 percent of the time in the past month to get up-to-the-minute traffic or public transit information while whites in the same study reported using their phones in this way 16 percent of the time. (Rainie & Fox, 2012)

  - 74 percent of adult smartphone owners ages 18 and older say they use their phone to get directions or other information based on their current location.
  - In an April 2012 survey, 20 percent of users surveyed have used their phone to get up-to-the-minute traffic or public transit information to find the fastest way to get somewhere in the past 30 days (US DOT, 2015).
  - Some 65 percent of smartphone owners say they have gotten turn-by-turn navigation or directions while driving, with 15 percent doing so on a typical day. (Rainie & Fox, 2012)

- o A 2012 survey of 752 drivers along I-35 in Texas showed that 60% used traffic- or travel-related applications on their cell phone or device. (Brydia R. E., 2012).

- **Social media evolution by age group**. Social media is the focus of a great deal of attention, and continues to grow rapidly. However, it is important to note variations by user segment in this area as well, particularly age-related ones. For example, millennials are very heavy Facebook users (over 90 percent), while fewer than 40 percent use Twitter. (MarketingCharts, 2015). An alternative analysis of social media demographics is shown below in Figure 11.

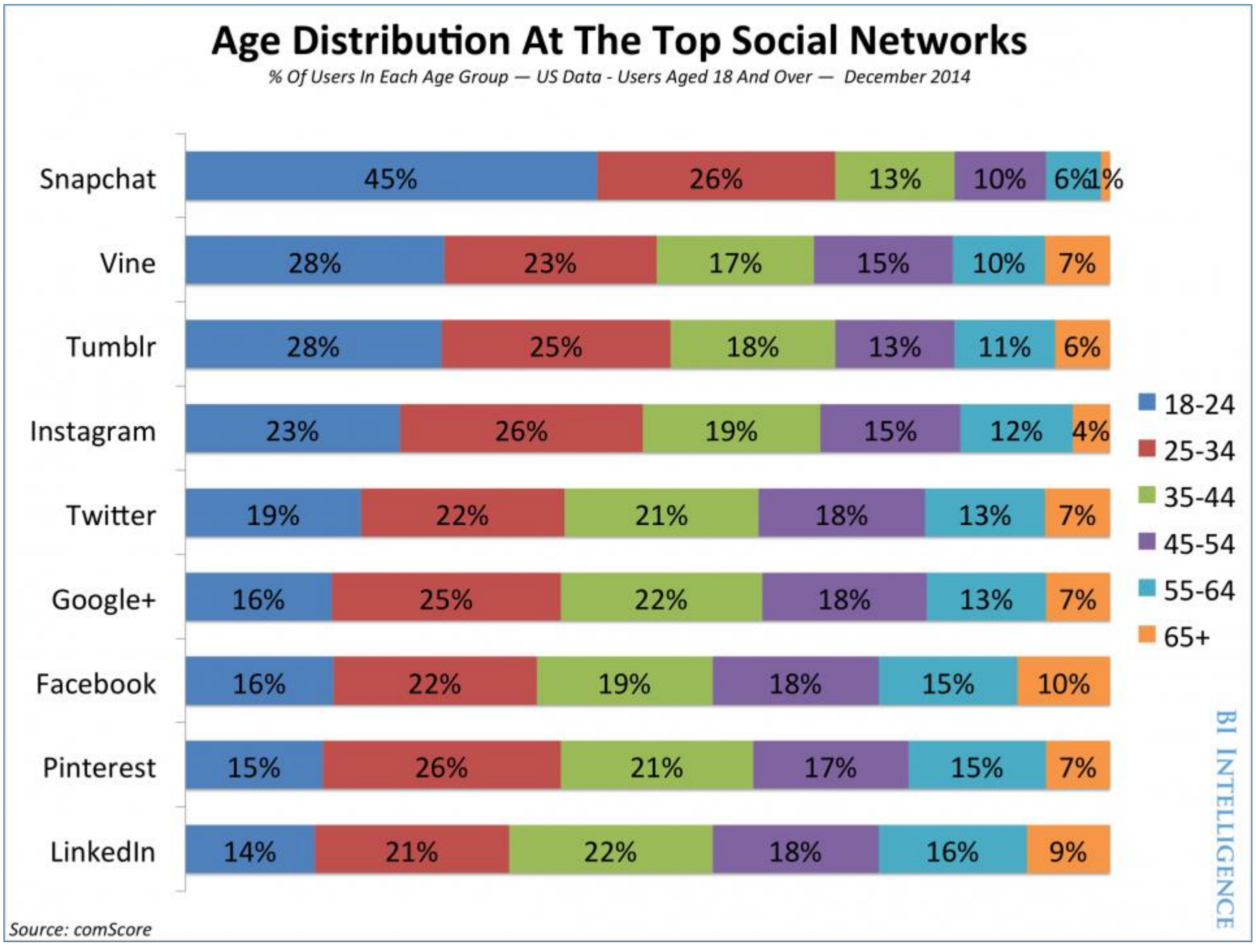


Figure 11. Graph. Demographic Composition of Social Networks (Hoelzel, 2015)

CHAPTER 3. TECHNOLOGY ROADMAP (2014-2020)

The Technology Roadmap provides a snapshot of today's technology landscape, and projects likely evolution based on emerging technologies, as well as the lifecycles and adoption of existing and new solutions. Questions considered include:

- What are the most popular ways for travelers to obtain information, pre-trip and en route?
- What are the back-end data issues with managing large data volumes?
- What is the latest on data quality standards and improvements?
- What likely impacts will technology advances have on current information delivery technology? For example, how will advances in cloud-based services and in-vehicle devices with innovative voice-based transactions and heads-up displays impact traveler information dissemination? Also, what about connected vehicles?
- Will Interactive Voice Response (IVR), Highway Advisory Radio (HAR) and 511 still be viable delivery methods in the future?
- Will social media meet the need? Will there be gaps to be filled and how?

This chapter includes:

- Offerings and Offering Trends.
- Technology and Deployment Trends.

3.1 OFFERINGS AND OFFERING TRENDS

3.1.1 Today's Offerings

The list of ways for travelers to get traveler information continues to grow, as dozens of permutations of new solutions, such as apps and social media, are added. Currently available platforms include:

- FM and AM radio, including highway advisory radio (HAR) and Radio Data System – Traffic Message Channel (RDS-TMC).
- Broadcast TV.
- In-vehicle infotainment systems (built-in and aftermarket).
- Cellphones.
- Smartphones and other smart devices (tablets, etc.).
- Desktop computers.
- Infrastructure signage such as Dynamic Message Signs (DMS) and real-time transit information signs.

While growth in newer solutions has been explosive, studies show that the more traditional means of accessing information still receive substantial use. In particular, some studies show TV, radio, and non-mobile websites are still being used the majority of the time for pre-trip review (Robinson, Jacobs, Frankle, Serulle, & Pack, 2012). En route, the leading source of information remains radio, with DMS coming in second.

Newer solutions such as mobile sites and apps are now running third for pre-trip and en route use according to several recent studies. It is reasonable to expect that growth of these tools will continue.

However, it remains critical to carefully track both actual usage and the impact of that usage on behavior in order to determine the correct timing for phasing in traveler information solutions appropriate to both key user communities and overall transportation goals. Each type of social media has its pros and cons for different operational situations. For example, when communicating transit information to users, social media may be much more helpful for services which operate every hour (or less) than those which have lower service frequencies. One detailed example of considering the potential impact on user behavior is shown in Figure 12 below (Pender, 2014). In this example, transportation system characteristics (network context, system characteristics) are mapped to social media application.

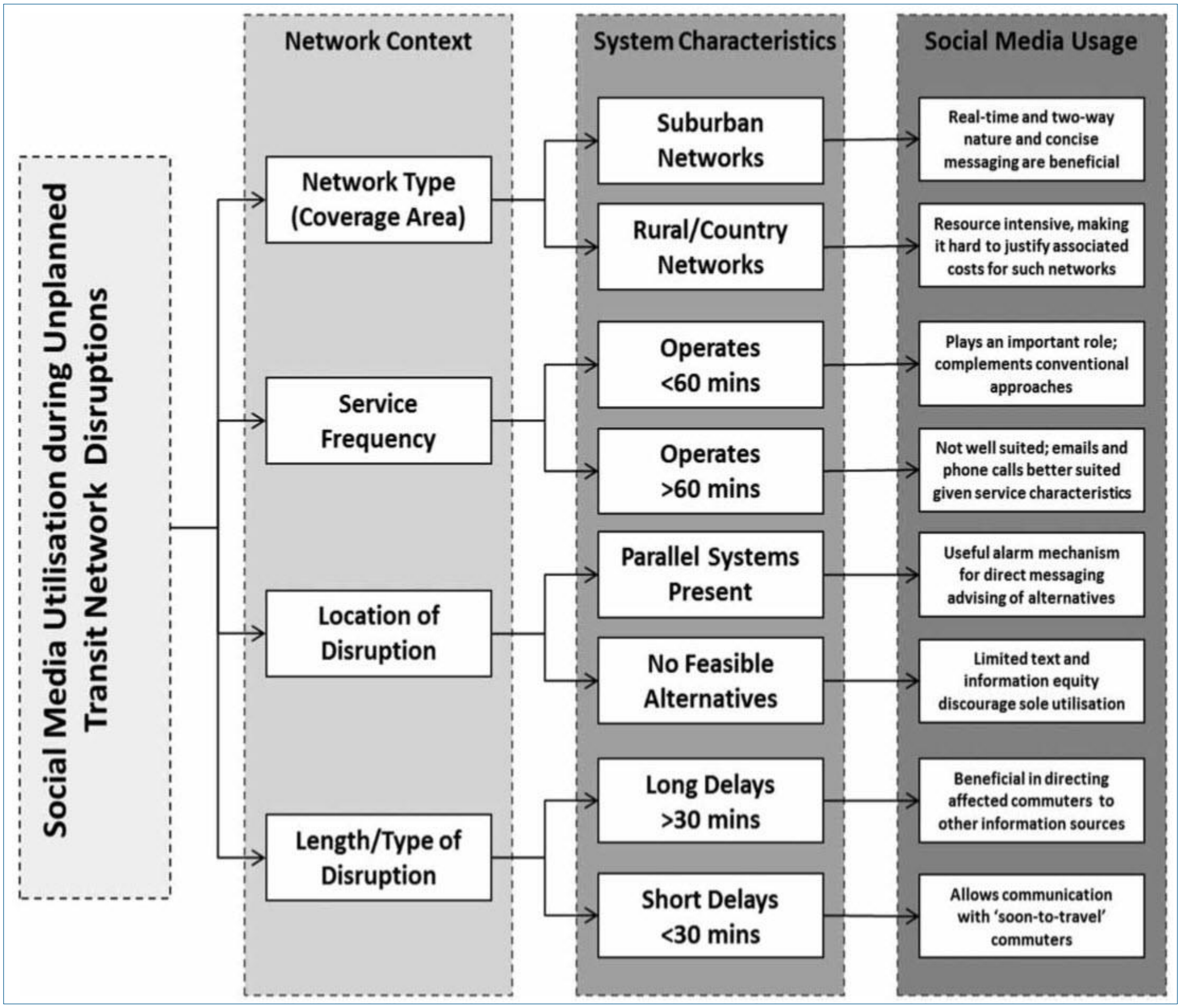


Figure 12. Chart. Impact of Social Media in Multiple Operational Contexts (Pender, 2014)

3.1.2 Offering Trends

The trend in new traveler information offerings follows the information need characteristics discussed above, as providers strive to provide functionality which supports anytime/anywhere availability, contextualized data, and machine-useable ambient data.

A few recently announced examples include:

- INRIX now offers an app that provides a "driver-friendly user interface" on certain Samsung phones. It is specifically described as making it easier to get traffic information with best routes, travel times, and estimated times of arrival (ETAs), as well as real-time en route voice alerts about incidents, nearby parking locations, and best price gas stations (INRIX, 2015).

- Google Maps now offers a "faster route" alert solution for Android and iOS (see Figure 13), which lets users know when a better route becomes available (Protalinski, 2014).

- TomTom provides real-time "Jam Ahead" warnings, to make consumers aware that they are nearing the tail of a traffic jam queue. This solution is described as a safety offering, helping travelers slow down before encountering slowed or stopped traffic (TomTom, 2013).

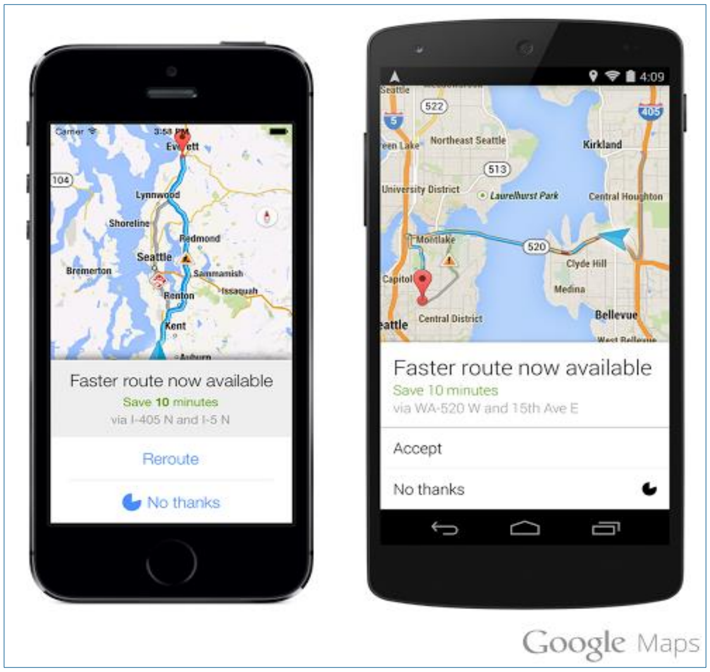


Figure 13. Photo. Google Maps "Faster Route" Feature (Google.com)

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3.1.3 Offering Gap Analysis

When determining appropriate NGTIS offerings, it is helpful to generate a baseline by considering both the overall goals of the agencies involved and the specific needs of the major traveler segments to be served. A gap analysis involves comparing existing offering functionality with this baseline to identify unmet needs, i.e., gaps. For example, if provision of high quality traffic-responsive routing is required, then arterial data availability may become a key gap to address. As is shown in Figure 14 arterial agencies are less likely to disseminate various types of traveler information.

This analysis will vary by locality, but there are some items which have been consistently identified as gaps and may serve as a useful starting point for these considerations:

- Data type issues.
    - o Are the available data sets sufficient to support desired functionality?

- Coverage issues.
  - o Is the available geographic, modal, and road classification coverage enough to enable needed capabilities?
- Integration issues.
  - o Is there sufficient cross-jurisdictional integration to support inter-regional and intermodal travel?
  - o Are various types of traveler information siloed within departments and agencies, reducing potential functionality?
  - o Is the NGTIS offering suite fragmented across platforms, making it difficult to promote availability and value to consumers?

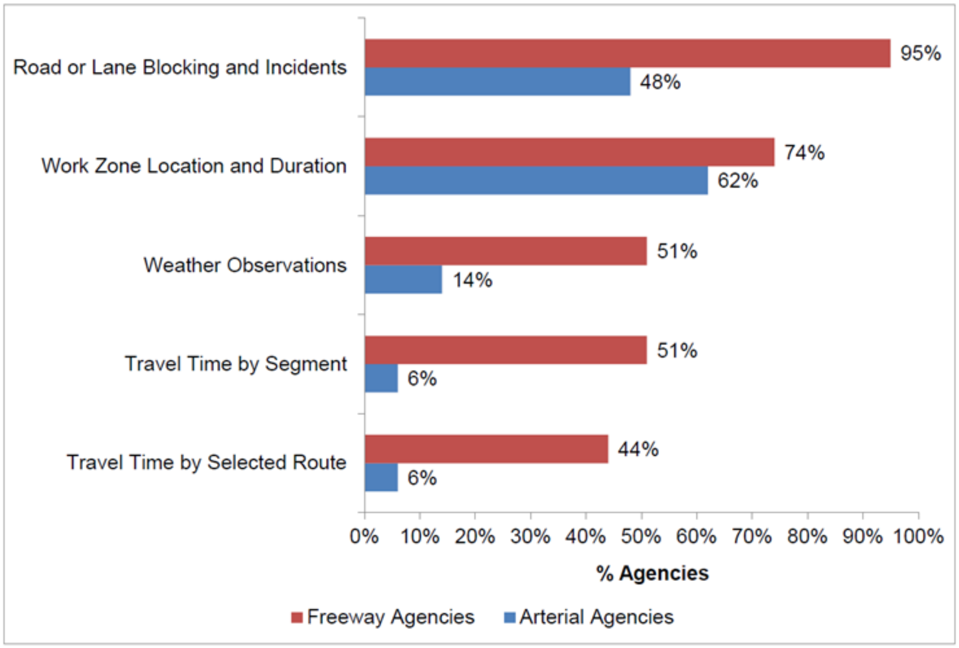

Figure 14. Graph. Information Types Disseminated by Freeway and Arterial Agencies (Gordon & Trombly, 2014)

3.2 TECHNOLOGY AND DEPLOYMENT TRENDS

Building, operating, and enhancing an NGTIS requires an increasingly complex suite of technologies, including:

- **Collection.** Solutions in this area may include everything from traditional loop detectors to modern probe and crowdsourcing.

- **Aggregation and Analysis.** Once data are collected, a rapidly expanding array of capabilities is available to combine large sets of similar and related data for transformation into high value information for use throughout the transportation management system.

- **Delivery.** A variety of mechanisms exist for transporting traveler information from sources to users, including radio, TV, and the internet, as well as providing a means for travelers to interact with NGTIS information, including websites, IVRs, apps, etc.

Each of these areas is currently quite dynamic, with new solutions emerging and costs dropping at an unprecedented rate. This section will take a look at highlights for each area.

3.2.1 Collection Technologies

Data collection has historically been based on static sensors placed at or in the roadside, such as loop detectors, cameras, toll tag readers, and more recently, Bluetooth readers which register passing cellphones. Significant deployments of these technologies are in operation, and further ones are planned. At the same time, there is a new emphasis on mobile sensors which can be rapidly and broadly deployed. These solutions include:

- GPS probes installed in various fleets.
- Anonymous or opt-in collection of consumer smartphone data.
- Anonymous or opt-in collection of consumer vehicle data.
- Citizen reporting via voice or automated tools.

These mobile solutions are particularly appealing because they have no right-of-way restrictions, and may not require that traffic collectors deploy much physical infrastructure beyond the back-end processing needed to handle the data. In fact, these solutions have done so well that some industry commenters have started to consider a future in which mobile sensors become the exclusive source of traffic data. It is unclear that such a change is feasible at this stage, but the possibility is certainly one that should be monitored closely over time using consistent metrics such as quality, reliability, and cost. A summary view of traffic data collection technologies is shown below in Figure 15.

As a result of the addition of new probe capabilities, more traffic and traveler data streams are becoming widely available. Basic issues, like cross-source location referencing and overall data security, have not gone away, but the number of real-time data points to be managed on a daily basis has soared into the billions. Particularly in the case of probe data, this significantly increases the complexity of managing this information.

Figure 15. Illustration. Traffic Data Collection Technologies (INRIX.com)

Detailed state of the practice summaries of arterial and rural solutions can be found in *Travel Time on Arterials and Rural Highways: State-of-the-Practice Synthesis on Arterial Data Collection Technology* (Singer, Robinson, Krueger, Atkinson, & Myers, 2013).

3.2.1.1 Data Quality Standards

The Real-Time System Management Information Program (RTSMIP) provides a baseline for traffic quality levels, as shown in Table 2 below. There is ongoing work to provide consensus standards for measuring this quality. The American Society for Testing and Materials (ASTM) in particular has a number of activities in this area:

- ASTM WK27028 New Test Methods for Evaluating Travel Time Data Quality.
- ASTM WK35821 New Specification for / Guide for Highway Classification Systems with User Requirements and Test Methods.
- ASTM WK35917 New Specification for Archiving Traffic Incident Characteristics and Management Data.

Older standards in this space include ASTM's series of E-standards and Federal Geographic Data Committee (FGDC), International Organization for Standardization (ISO) and Department of Defense (DOD) guidelines:

- ASTM E2759-10 Standard Practice for Highway Traffic Monitoring Truth-in-Data.
- ASTM E2259 Guide for Archiving and Retrieving Intelligent Transportation Systems-Generated Data.
- ASTM E2468 Practice for Metadata to Support Archived Data Management Systems.
- ASTM E2532 Test Methods for Evaluating Performance of Highway Traffic Monitoring Devices.
- ASTM E2665 Specification for Archiving ITS-Generated Traffic Monitoring Data.
- ASTM E2667 Practice for Acquiring Intersection Turning Movement Traffic Data.
- FGDC-STD-001-1998 and ISO DIS 19115 (metadata) guidelines for quality advanced traveler information system (ATIS) data (ITS America 2000).
- DOD Guidelines on Data Quality Management.

Table 2. RTSMIP Minimum Quality Levels (Title 23 CFR Part 511)

Category of Information	Timelines – Interstate Highways (Statewide)	Timelines –Limited Access Roadways In Metropolitan Areas	Availability	Accuracy
Construction Activities	20 minutes	10 minutes	90%	85%
Roadway or lane-blocking incidents	20 minutes	10 minutes	90%	85%
Roadway weather observations	20 minutes	20 minutes	90%	85%
Travel time/speed information	N/A	10 minutes	90%	85%

3.2.1.2 Data Quality Improvements

Public and private sector data managers are continuously working to improve data quality. One recent example is the focus on sub-TMC granularity. At a January 2015 conference, three major traffic data vendors reported that they are now able to offer sub-TMC link level data. This is a relatively new offering, and discussions are underway about access and effective operational use of this information. (Hamedi, 2015)

3.2.2 Aggregation and Analysis Technologies

The largest trend in data aggregation is the rapidly increasing ability to fuse and analyze data sets for improved NGTIS end product functionality. One area which illustrates this trend particularly well is predictive traffic.

Travel time prediction has been a major focus of advanced traveler information systems in recent years. Travelers can use travel time if accurately predicted to make informed decision both pre-trip and en route. Predicted travel time information can also be used as inputs to optimize network capacity and reduce bottlenecks using various active transportation and demand management (ATDM) strategies.

Several travel time prediction techniques have been developed. These techniques can be categorized into two approaches: (a) regression-based methods and (b) machine learning methods. The travel time data can come from various sources including toll tags, fixed sensors, and Bluetooth probes. Research also captures the effect of weather on the predicted travel time using toll tag readings as a data source (Faouzi, Billot, & Bouzebda, 2010). Specific examples include:

- TomTom claims to be the first company to use real-time weather information to calculate routes and arrival times commercially (TomTom, 2014).

- IBM's "Smarter Traveler" traffic prediction tool, developed with the help of University of California Berkeley's Mobile Millennium project team and the California Department of Transportation (Caltrans). The tool relies on predictive analytics software, crowd-sourced GPS monitoring, and permanent infrastructure sensors. The predictive system is built upon a control theory and machine learning methods. The system can offer alerts and build a custom model for each individual's commuter route (Melanson, 2011).

- Microsoft's Clearflow project focused on applying machine learning to learn how to predict the flows on all street segments of a greater city area. The algorithm is based on crowdsourcing of GPS data from volunteers, buses, and paratransit vehicles for over five years. The data was used to identify dependencies among flows based on various attributes of road network and topology in order to build predictive models. Clearflow traffic-sensitive directions were first available in the spring of 2008 and have been integrated into Bing Directions (Predictive Analytics for Traffic, n.d.).

- The Daily Commute app compiles the individual traveler's data from previous commutes to predict how long the travel time will be on a daily basis, and lets the user know how much time he/she should budget before embarking on the trip. The application builds a custom model using average values on a weekly and yearly basis and becomes more intelligent with frequent use (Commute, n.d.).

3.2.3 Delivery Technologies

Delivery technologies span a wide range of solution types and technologies. Deployment of many of these solutions has reached very high levels among freeway agencies, with transit agencies focusing primarily on web-based solutions (Figure 16 and Figure 17).

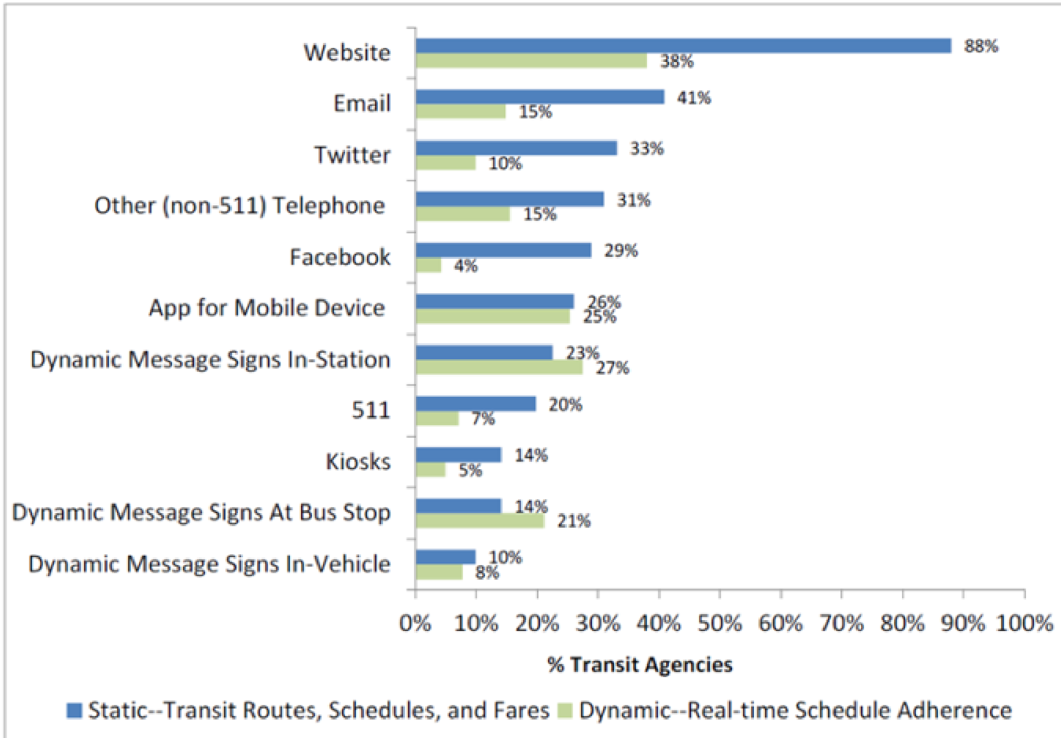

Figure 16. Graph. Media Used by Transit Agencies (Gordon & Trombly, 2014)

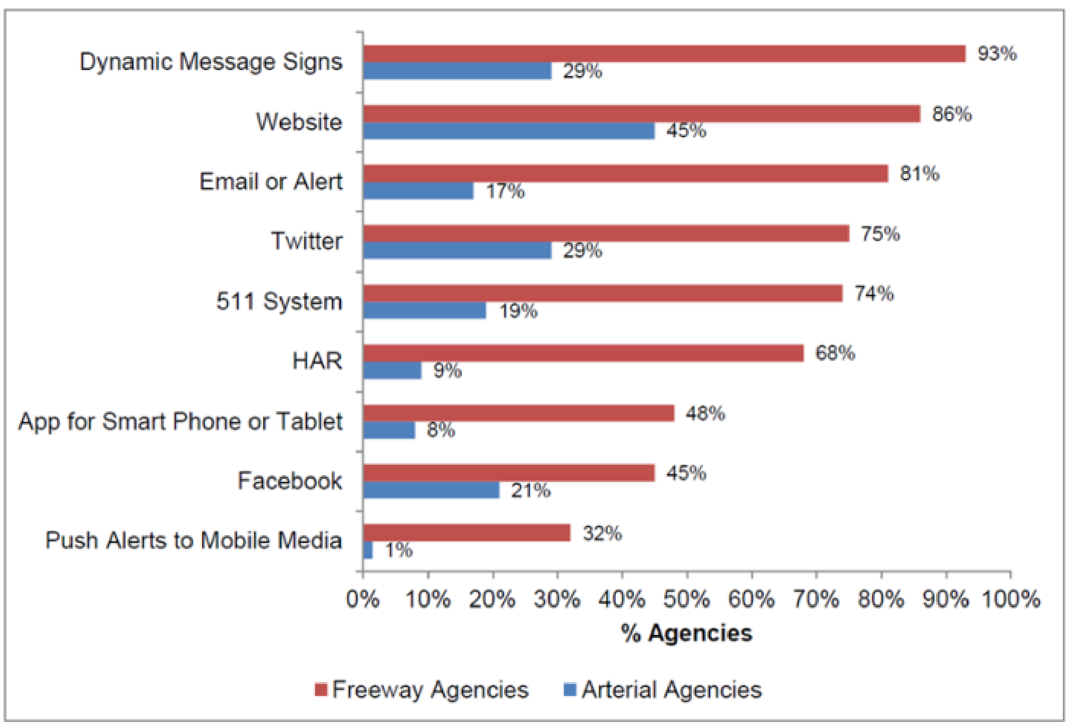

Figure 17. Graph. Traveler Information Distribution Methods – Freeway and Arterial Agencies (Gordon & Trombly, 2014)

In order to properly assess delivery options, it is helpful to organize current and emerging technologies into three categories – communications channels, hardware platforms, and presentation software – as shown in Table 3. Table 3 also highlights the relative momentum of key technologies. Further detail about these technologies is provided in the subsections below.

Table 3. Traveler Information Delivery Technology Categories (SCG)

Communications Channels	Hardware Platforms	Presentation Software	Offering Notes
Radio (AM, FM, & Radio Data System – Traffic Message Channel) Broadcast TV ● Cellular Landline telephone Cable/fiber	▲ In-vehicle infotainment In-vehicle connected safety ● Smartphones Cellphones Smart Devices Wireless roadside devices (e.g., DMS) Desk phone Desktop Wired roadside devices TV sets	▲ Vehicle-based applications ● Mobile applications ● Networked applications (e.g., social media, crowdsource) Interactive Voice Response (IVR) Website	■ Highway Advisory Radio (HAR) is AM version of this 511 as brand (vs. technology) ■ 511 (traditional landline phone-based)

● High momentum
■ Emerging
▲ Declining

3.2.3.1 Communications Channels

Looking at national trends, FM radio, TV, and landline telephone use are all declining overall, in favor of mobile device options. However, usage of these traditional media for traveler information is still quite strong, as shown in the section 3.1.1 titled "Today's Offerings" earlier in this chapter.

HAR is a more challenging area. Some studies show a user base of between 15-20 percent, but there is little recent data (Robinson, Jacobs, Frankle, Serulle, & Pack, 2012). Anecdotal reports trend towards a belief that HAR usage is steadily declining (CTC & Associates LLC, 2011). It seems reasonable to project a continued downward trend for this technology overall.

HAR is, however, a reliable emergency backup to mobile networks for certain geographic regions and traveler populations, and as such, should be carefully considered as an option in the overall NGTIS communication mix. In May 2015, for example, the Tennessee DOT reported removing HAR in urban areas, and relocating it to rural areas where clear benefits can be identified, such as areas with high crash rates, winter weather issues, etc.

3.2.3.2 Hardware Platforms

Key hardware platforms for the dissemination of traveler information include:

- **Mobile devices** have unquestionably become a key platform for the distribution of traveler information. Smartphones, cellphones, and smart devices are all enjoying rapid and widespread consumer adoption. The more advanced solutions, however, are not yet in use by all populations in all locations. Over 30 percent of American adults do not yet have smartphones (Pew Internet Project, n.d.).

- **In-vehicle infotainment platforms** are growing in availability. Car manufacturers now offer these systems in a wide range of makes and models. There are, however, ongoing issues with usability, as the rush to provide complex functionality has outstripped ease of use considerations. It remains to be seen how quickly consumers will adopt these solutions as they update their vehicles. It is also not clear exactly how often consumers are actually using these platforms to access traveler information.

- **Smartphone integration solutions** are also starting to emerge, as car manufacturers seek to manage the disparity between automotive and consumer electronics life cycles by enabling the use of the smartphone to host or connect apps for use in the vehicle. Mirrorlink, Google Android Auto and Apple Carplay solutions are now making their way into the market, although overall penetration and availability are still fairly low at this time (Connected World, 2015).

- **In-vehicle connected safety systems** are not yet available, although at least one automaker has targeted 2017 as an initial commercial release date (GM, 2014). There is significant federal government interest in accelerating the rapid deployment of these solutions, but standards and business models are still under discussion and projected timing of a potential broad deployment is not yet clear. This is an area to watch, but is unlikely to have a significant impact within the five-year timeframe of this study.

3.2.3.3 Presentation Software

From the traveler's perspective, the software used to present the information is what matters, as it controls the user experience and hopefully ensures safe en route operation. This software can reside in various places – on the vehicle, on mobile devices – and operate either individually or as part of a social network.

Within the vehicle, an increasing range of traveler information applications are now packaged as part of in-vehicle infotainment systems, or available through smartphone integration. Private sector traffic providers have now taken their place on the dashboard, as evidenced by announcements such as the INRIX / Audi offering first shown at CES 2015 (INRIX, 2015).

On the mobile side, the majority of state DOTs now support mobile platforms (80 percent). In addition, many offer mobile applications with a primary focus on traffic and traveler information (55 percent). These apps may also provide safety messages (15 percent), project updates and notifications (23 percent), and general DOT information (34 percent). A significant percentage of these apps are developed by DOT staff (more than 1-in-4) (Brown, 2014).

These public sector offerings are joined by a broad array of private sector apps and mobile websites. A summary of some widely-used traveler information applications is provided in Table 4. As can be seen from this sample set, the private sector is actively investing in traveler information offerings which draw on the latest data and data collection approaches to provide a comprehensive set of capabilities.

Table 4. Traveler Information Apps (Brydia R. E., 2015)

	Waze	INRIX	Google Maps	Sigalert	Trapster*	Scout GPS	VZ Navigator	AT&T Navigator	MapQuest
Real-time Traffic Information	●	●	●	●	●	●	●	●	●
Pre-Trip Information	●	●	●	●	●	●	●	●	●
En Route Information	●	●	●	●	●	●	●	●	●
Crowd Sourcing	●	●	●	●	●	○	○	○	○
Sensor/Probe Information	⊙	●	●	⊙	⊙	●	●	●	●
Prediction Algorithm	○	●	●	○	○	○	○	○	○
Personalized Information	⊙	●	●	●	●	●	●	●	●
Number of Users	High	High	High	Low	Med	Med	Low	Low	High
Review Rating [1]	4+	3	4	2.5	NA	3.0	3.0	2.5	3.0
Traffic	●	●	●	●	●	●	●	●	●
Regional Traffic	○	●	○	●	●	○	○	○	○
Alerts	Push	Push	Push	Email	Push	Push	Push	Push	Push
Weather	○	●	○	●	●	○	○	○	○
Police	●	○	○	●	●	●	○	○	○
Gas Station	●	●	○	○	●	●	○	○	●
Accidents	●	●	●	●	●	●	●	●	●
Road Hazard	●	○	○	●	●	●	○	○	○

Key: ● – Yes; ○ – No; ⊙ – Partial

Social media has been the recipient of enormous hype. State agencies have quickly added this tool to their arsenal of traveler information delivery tools (see Figure 18), and anecdotal evidence shows that the interactive, measurable nature of this technology is yielding benefits (Brown, 2014). However, it is difficult to tell exactly how highly to place social media in the overall traveler information solution set, as there is little usage data showing how much of the overall

[1] This rating reflects user reviews of the applications, as gathered by app stores providing these apps.

user base interacts with traveler information in this way. Total costs are also an area for further research, as initial capital outlay is quite low but operational staffing demands must also be managed over time (AASHTO, 2014).

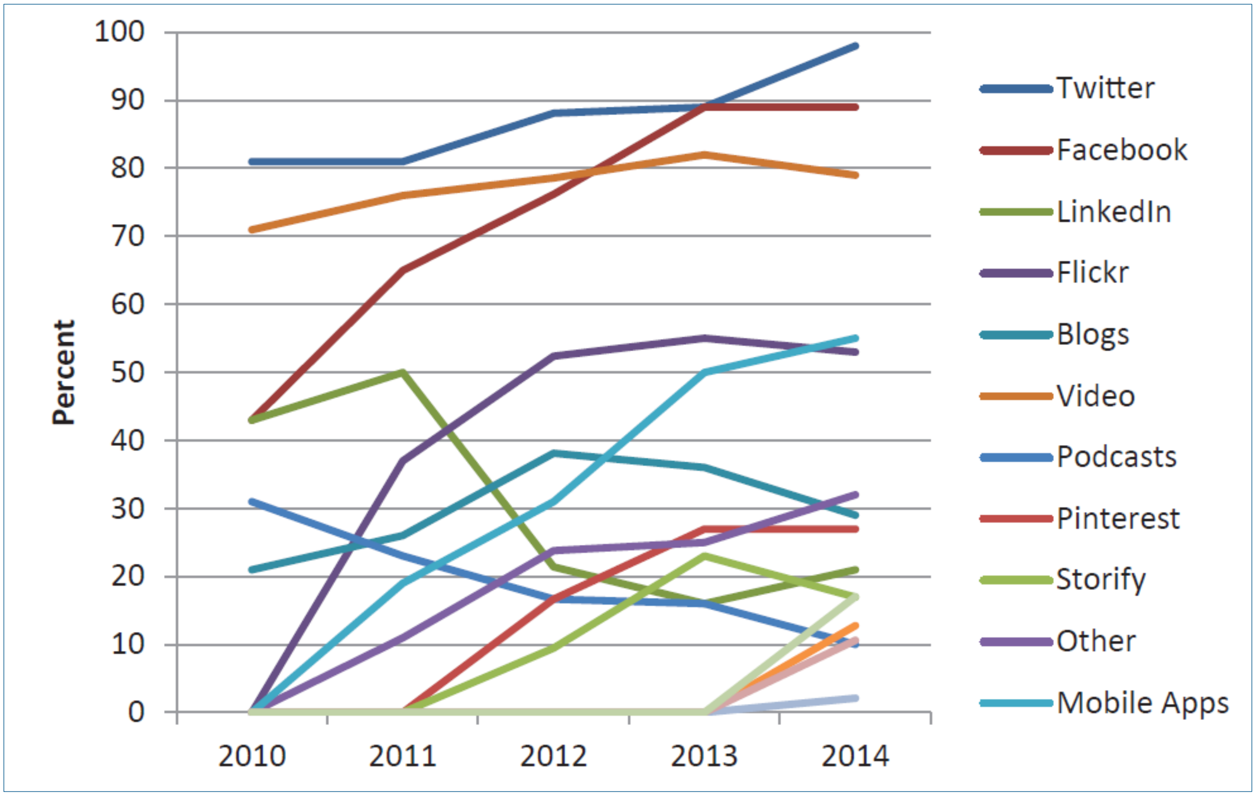

Figure 18. Graph. State DOT Social Media Adoption (AASHTO, 2014)

As new solutions become available, the overall traveler information delivery mix must be re-evaluated. What platforms are best for sharing specific types of data? Which new solutions should be deployed? Which older ones have run their course? This is a particularly critical question for older web- and IVR-based solutions. These have often been packaged under the overall brand of 511, although there is no consistent standard for what is included in a 511 offering, making it difficult to clearly assess them. For the purposes of this report, we note the following highlights:

- Some populations are still relying on IVR systems. Tennessee DOT, for example, reports that they are tracking 2000 calls/day on average.
- Overall, however, the 511 offering should be assessed, as there are some data indicating low awareness and use of such offerings. In an extensive 2012 survey, 511 ranks significantly lower than other sources for pre-trip and en route usage. A snapshot of this assessment is shown in Figure 19 (Robinson, Jacobs, Frankle, Serulle, & Pack, 2012).

- Anecdotal evidence also suggests that state DOTs are expecting changes away from 511 solutions. For example, as of May 2015, Utah and Tennessee DOTs report that they expect an eventual phase out of 511 systems.

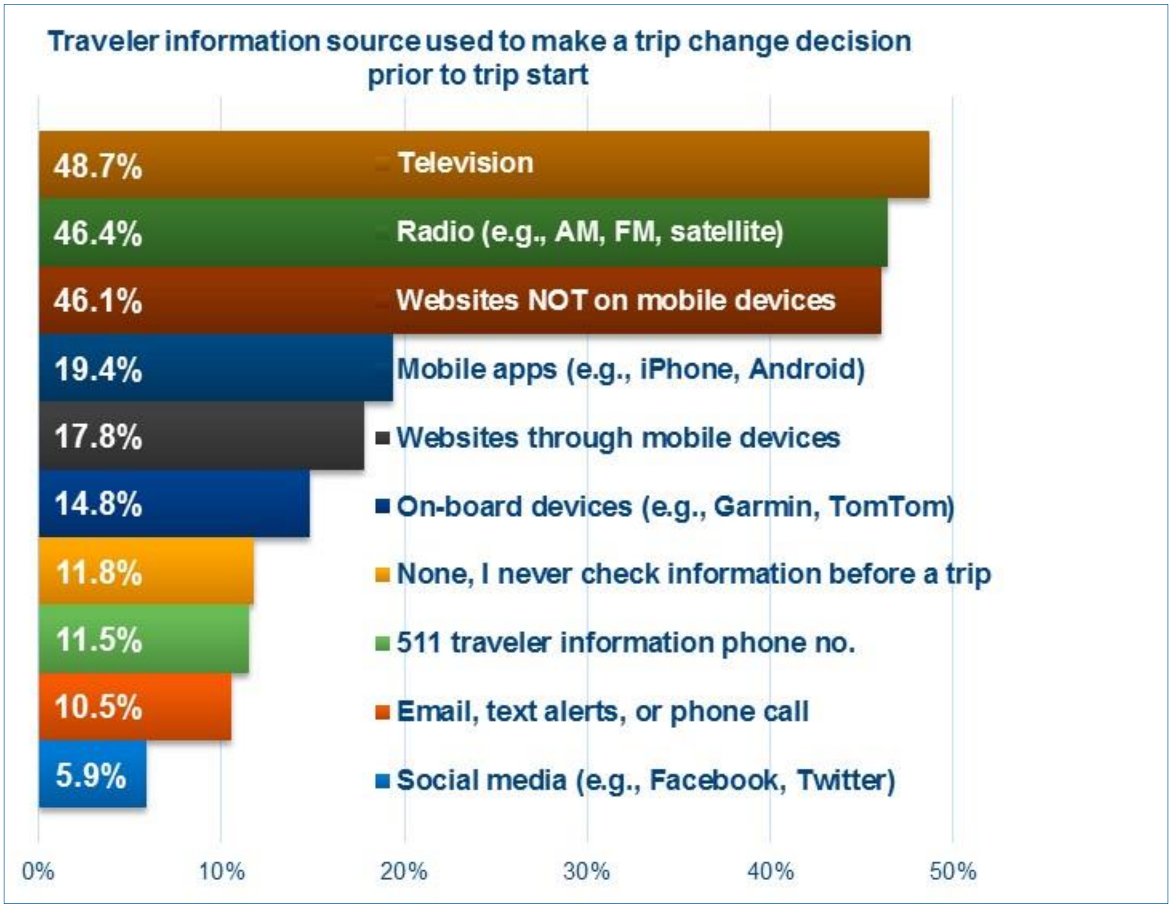

Figure 19. Graph. Pre-Trip Information Usage
(Robinson, Jacobs, Frankle, Serulle, & Pack, 2012)

Given this general direction and the quickly growing use of alternatives, it appears that 511/IVR is a technology which is starting to shift into the later phases of its lifecycle. Like all technology transitions, the exact timing is uncertain and decisions about changes will need to be made on a case-by-case basis in response to the needs of key traveler populations. This makes it critical to closely both track performance and determine quantifiable milestones for making any needed changes (e.g., phasing out 511/IVR in favor of solutions which have become more effective). A tracking framework might include the items shown in Figure 20:

- ✓ Identify the user segments using 511 phone solutions and understanding their relationship to the overall population
- ✓ Determine whether they are using 511/IVR exclusively
- ✓ Determine the actual impact of information from this source on traveler behavior (in addition to tracking usage statistics)
- ✓ Determine whether known user segments are likely to effectively transition to other solutions if offered
- ✓ Plot 511/IVR usage and impact trends against similar technologies (e.g., smartphone apps)

Figure 20. Chart. 511/IVR Tracking Framework (SCG)

This framework will help public agencies conduct a cost/benefit analysis of this technology and allow its projected lifecycle to be mapped.

3.2.4 International Trends

This section considers highlights of recent trends and activities related to NGTIS occurring around the world.

3.2.4.1 Global Case Studies

There are a variety of global activities which can serve as valuable sources of lessons learned for U.S. agencies. The following is a list of selected programs to consider, sorted by key traveler information topic:

- **Integration of public and private sector data and functionality**. These temporary public/private partnerships in support of real-time operational events might be adapted to similar situations in the U.S.:
    - Japan Probe Coordination. In response to the 2011 tsunami, Japanese automakers partnered with the public sector to generate a nationwide database of probe data from all equipped vehicles in the consumer fleet. This was a temporary partnership to help with the emergency. There are efforts to build a more permanent solution, at least in the context of disaster response.

    - In Brazil, public agencies partnered with Waze and Moovit for transportation management during the World Cup (Olson, 2014). Rio de Janeiro uses Waze data as part of its traffic management program, and will likely rely on specific assistance from Waze during the upcoming Olympics (Ungerleider, 2015).

- **Public sector access to probe data**. Private sector companies have established massive mobile probe data networks, but the public sector has had less access to this information to date. It is still early in this area, but an important one to track. The following examples of foreign agencies leveraging private information may have applicability in the U.S.:

    - Cooperative ITS Corridor. Holland, Germany, and Austria are partnering to establish a connected car corridor which will include some basic probe data capture based on messages sent out for safety reasons. The exact details of these systems are still in the works. (Ross, 2014).

    - Japan's ITS Spot system roadside infrastructure which is capable of capturing vehicle probe data from equipped vehicles has now been broadly deployed. Implementers are now working to increase the penetration rates for equipped consumer vehicles.

    - Volvo, the Swedish Transport Administration, and the Norwegian Public Roads Administration are partnering in an experiment to allow cellular-based probe data sharing via a cloud-based solution. Initial plans are to share road condition data both among drivers and with road authorities (Crowe, 2015).

    - Indonesian toll authorities are implementing probe-based traffic information collection based on Fujitsu's SPATIOWL platform. This system includes software which is put on smartphones to collect vehicle location, time and speed, and then develops information usable by TMCs (Benzinga, 2014).

3.2.4.2 European Commission Highlights

In December 2012, the European Commission funded a study regarding the provision of European Union-wide Real Time Traveler Information (RTTI) services. As this study is focused on very similar topics as this report, a summary is included here to demonstrate the global nature of the trends which are occurring in this space. Observations and findings for European Union traveler information services from this report that have implications for the U.S. market include (van de Ven & Wedlock, July 2014):

- Technological advances have changed the traveler information service landscape by enabling new ways of collecting more road and traffic data through platforms such as smartphones and personal navigation devices. Big data analytics have been instrumental to cost-efficient data processing and enrichment of available data.

- Similar to the progress of connected vehicles in the United States, technology that connects vehicles to the Internet (Connected Car), to each other, and to roadside equipment (Cooperative Technology) are expected to lead to a significant increase in available traveler information data at much lower costs.

- As more driving tasks are automated, the need for human-comprehensible traffic information will decrease, while the demand for machine-readable road and traffic data will increase. Automated vehicles will in particular require RTTI to provide them with full forward awareness of potential traffic queues and hazardous traffic situations downstream, as opposed to only within the range of vehicles' sensors and cooperative range.

- Roles in the traveler information value chain will likely change in the future. Private traffic data providers have the technology to process large volumes of new traffic data and develop profitable business models. Public authorities will, however, retain a key role in assuring societal interests in the value chain.

- Until now, most safety-related traffic information (SRTI) have been collected by public authorities. It is expected that car manufacturers, their suppliers, and/or service providers will be a primary collector of SRTI in the near future, for example, through messages from cooperative vehicles or the CAN-bus.

- It is recognized that data privacy and service liability will become key issues for increasing amounts of data originating from vehicles and communities.

CHAPTER 4. ROLES & MODELS REVIEW

Business models for making NGTIS financially viable have changed significantly in recent years. Business models are the activities associated generating value from the collection and provision of traveler information. These activities can be described in the context of a “value chain”, which describes how value is added to a product or service as different actors contribute to the end product. This chapter takes a structured look at the value chain, from data collection to data delivery. Public and private sector participants and their current and potential business models and roles will be discussed for each stage in the chain.

Questions considered include:

- What are private sector models and applications for revenue generation? What are the strengths and weakness and their relevance and appropriateness for public agency use?

- What are the roles of state and federal governments in traveler information services in the next five years? Should public agencies be the content provider? Or should public agencies become the data provider and let the private sector provide content?

4.1 ROLES AND VALUE CHAINS

Delivery of traveler information service offerings is a complex business. Public and private sector actors, working both separately and in partnership, bring a variety of agendas and capabilities to the mix. In order to understand the landscape, it is helpful to consider the entire chain of participants and the flow of value, from end-to-end (the “value chain”), as shown in Figure 21.

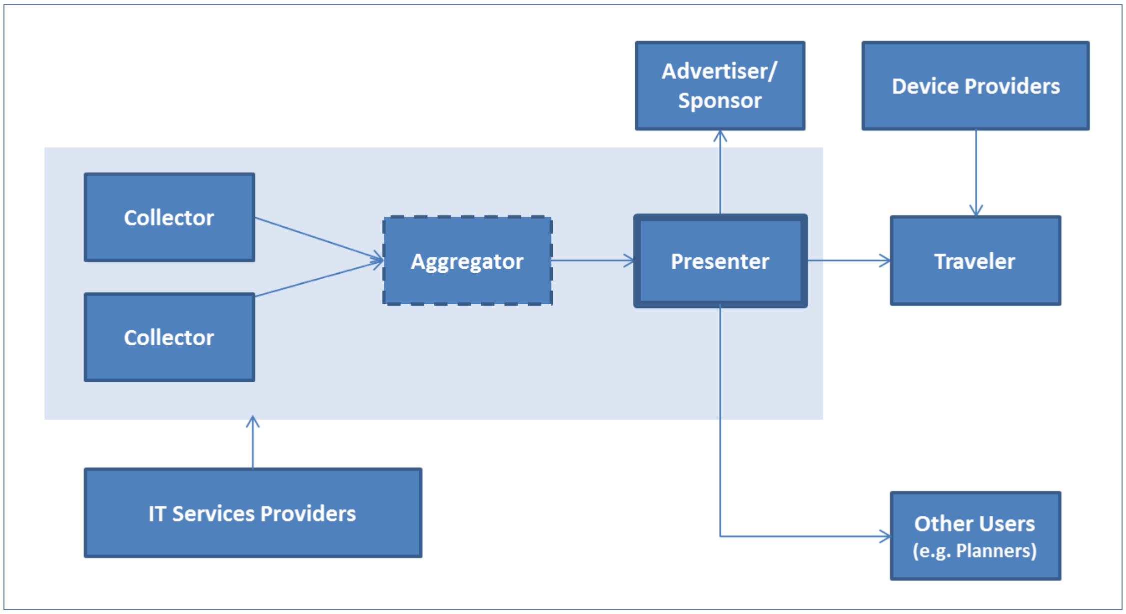

Figure 21. Chart. Traveler Information Value Chain (SCG)

Roles in the value chain include:

- **Collector.** Directly captures the traveler information data and generates data products and services.
- **Aggregator.** Combines multiple data streams and generates data products and services.
- **Presenter.** Provides the traveler information directly to the consumer. May include everyone from public agencies providing information on roadside DMS and consumer device providers, to mobile app providers and automotive original equipment manufacturers (OEMs) who provide in-vehicle infotainment solutions.
- **Device Provider.** Provides hardware used by the consumer to interact with traveler information. In some cases, also serves as a Presenter.
- **IT Services Provider.** Provides services such as software development, hosting, and outsourced operations.
- **Advertiser/Sponsor.** Links its brand with traveler information in some way to gain business benefit.
- **Other Data Users.** Specific public and private users of traveler information data, e.g., real estate industry, urban planners, etc.

4.1.1 Role Trends

As traveler information becomes more pervasive, *role boundaries* are blurring. The private sector has discovered the value of creating consumer crowdsourcing communities. Participating consumers provide much more about themselves and their environment than just traffic data. Instead, traffic is just one piece of the overall consumer Big Data business, an increasingly massive operation with global efficiencies of scale. Traffic is useful in this environment because it is "sticky" – it creates a constant stream of repeat visitors who provide value over time both as a data source and as an ad audience which can be commercialized.

As a result, there is a growing set of 'end to end' providers which handle the entire value chain. These include data mega-managers like Google/Waze. Rather than confining themselves to data collection or a particular aspect of data delivery, they have developed fully integrated solutions complete with cutting-edge end consumer offerings, which have proven very attractive in the marketplace. This places them directly in parallel with similar state activities.

Another major trend is the increasing complexity of the *data sourcing* picture. The private sector has developed a densely interconnected web of data sharing and aggregating agreements, with more layering on every day. This is partly fueled by the growth of non-infrastructure collection technology options, which has created new categories of participants and expanded the capabilities of existing ones. INRIX and TomTom, for example, have made agreements with auto companies for access to traffic data from their consumer connected car fleets (Marshall, 2014). The potential value of these data have already triggered deals from the OEM side as well, as exemplified by Porsche's recent investment in INRIX. Providers of all stripes are also eyeing the potential of data from the entire national vehicle fleet, which may eventually be mandated for vehicle safety reasons, but can also be used for many other purposes. (Lerman, 2014)

A recent snapshot showing how the data ecosystem around the vehicle has gone well beyond simple traveler information and is now part of the "connected consumer" Big Data pool is shown below in Figure 22 (Lawson, 2015). Traffic is a line item in the overall set of information sent to and received from the car and handled by a wide variety of private sector participants.

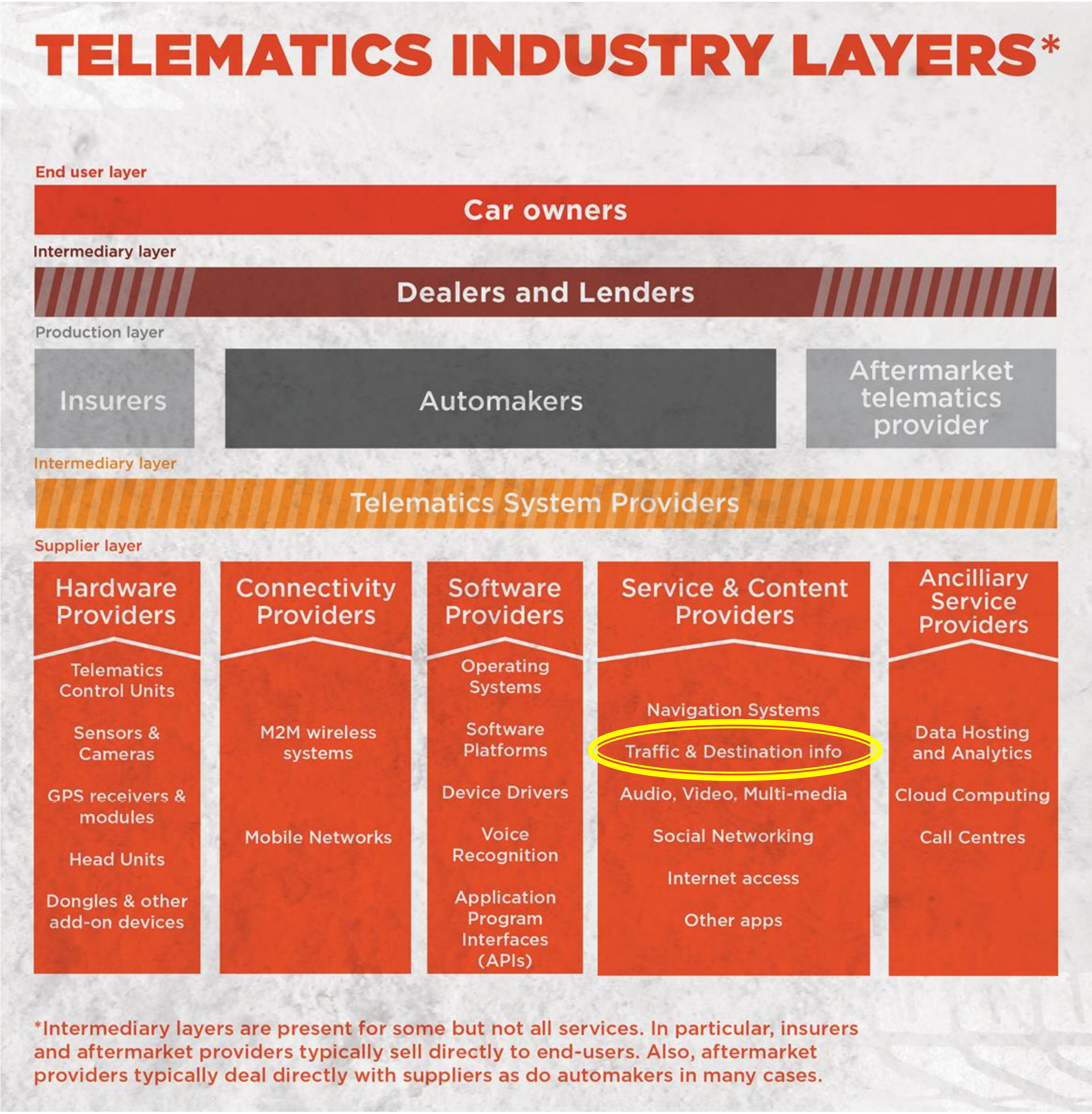

Figure 22. Chart. NGTIS / Big Data Landscape Example (Lawson, 2015)

4.1.2 Public Sector Roles

Public sector agencies currently serve in almost every role in the value chain. Given the recent evolution in private sector activities, it is important to assess future public sector roles in NGTIS. The outcome of this assessment will inevitably vary among agencies, so this report seeks to provide some key areas for consideration to assist this process.

4.1.2.1 Collector

Federal law as noted in *Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Section 1201 Real-Time System Management Information Program (RTSMIP)* requires public sector agencies to provide certain traveler information. The larger question is how much of this requirement the public sector fulfills directly (using its own infrastructure) or indirectly (sourcing the data from other collectors). Numerous public-private partnerships already show that there can be value in a variety of solutions to this question. Key factors to consider include:

- **Pricing**. What is the "per unit" cost of information collection? Who can most cost-efficiently capture each type of data? Determining appropriate metrics and tracking them over time will help to resolve this question.
- **Compliance risk**. Acceptable risk to regulatory compliance if there are contract or supply issues with outsourced vendors.
- **Delivery risk**. Acceptable risk to ongoing operations if there are contract or supply issues with outsourced vendors. This includes stability of potential vendor companies.
- **Switching costs**. Are there multiple sources for a given type of data? What will it take to switch from one data source to another?

Presenter

It is important to understand the opportunities and limitations at each point in the value chain. The Presenter has the most access to the consumer and other end users. Those further back in the chain have much more difficulty establishing a consumer brand, and can be more easily replaced by similar offerings. They also do not have direct access to consumer interactions and data.

The public sector has been moving forward along the chain, with the 511 brand and social media push taking it squarely into the Presenter space. This creates direct conflict with the private sector entities who want to own that customer interaction. As private sector data providers move aggressively to capture the traveler's limited attention, the traveler must choose between their offerings and those of the public sector.

Key questions for the public sector to consider include:

- Can agencies achieve their goals without direct customer access? Historically, the public sector has distributed information through channels such as radio and TV. Is that sort of dis-intermediated positioning still acceptable?
- How much of an audience does the direct public sector offering need to reach? Which audience segments are most important?
- How valuable is direct consumer feedback for data collection and customer satisfaction monitoring? "Value" should be measured by metrics here.
- How will the public sector compete over time with consumer-facing brands like INRIX and Google for this role?

4.2 BUSINESS MODELS

As the private sector continues to the explore opportunities in the traveler information space, corporate whiteboards fill with lists of value creation opportunities like the one shown below in Table 5. Reviewing the marketplace, practically every permutation of these is being tested somewhere. Companies are selling data for license fees, trading consumer's functionality for data, providing data aggregation as a service, etc.

Table 5. Value Creation Opportunities (SCG)

Where's the value?	What's the deal?

• Historical databases
• Real-time databases
• Predictive databases
• Apps (development or white label)
• Communications (e.g., radio)
• Development, deployment and operations
  ○ Data collection infrastructure
  ○ Data management system
  ○ Data delivery system (Application Programming Interfaces, Platforms, User Interfaces, etc.)
• Consumer hardware
• Consumer software
  ○ Apps (development or white label) – in-vehicle or mobile
	• Data licensing
	• Data swapping (barter/value trade)
	• Ad revenue (in-app, dedicated/non-dedicated website, etc.)/sponsorship
	• Subscription revenue
	• Bundled hardware fees
	• App re-selling (white label)
	• Platform licensing
	• Hosting/operating
	• Niche markets (real estate)

Shown in Figure 23 in the context of the value chain described in the prior section, these value creation opportunities vary by role. It is important to recognize that the private sector reviews both roles and the business models associated with them on a continuous basis, and that every discussion about a business deal takes place with this thinking as a backdrop.

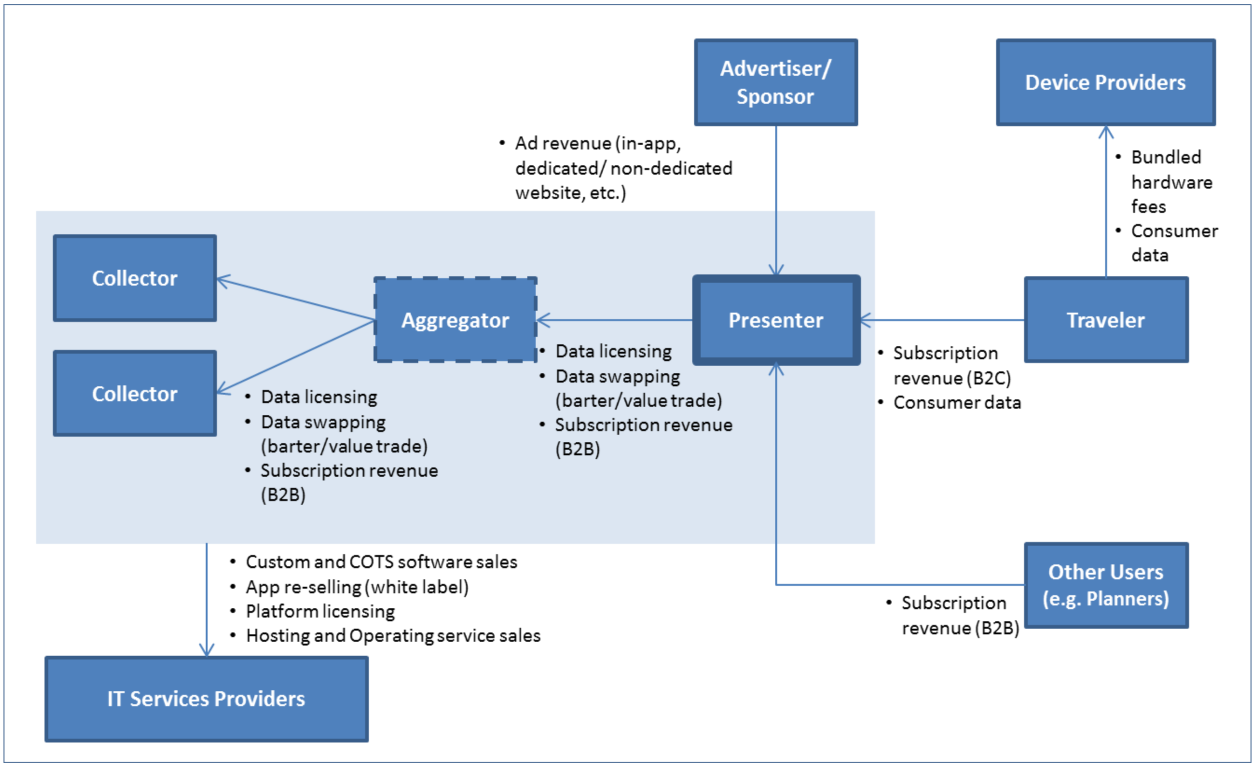

Figure 23. Chart. Value Chain / Value Opportunity Review (SCG)

4.2.1 Public Sector Business Models

The term "business model" typically refers to an approach which generates revenue. Because the public sector is different from a for-profit business, and has significant restrictions on any activities of this type, the role is to create value. In some cases, however, there may be room for some value creation. Several possible areas include:

- Selling or bartering travel data. Limited licensing arrangements, which require fees or 'in-kind' barter, may be possible for commercial use of state data. This approach only works as long as states have data which private sector cannot source less expensively on its own.

- Selling or bartering consumer data. This is a particularly difficult area, as there are major privacy concerns. However, there may be opt-in scenarios in which consumers allow sharing of some information under appropriate circumstances.

- Selling advertisements or sponsorships. Successful ad sales require large volumes of consumer exposure (e.g., traffic on a web page), or a high value niche customer base. To date, states have reported very limited success in establishing sufficiently attractive advertising opportunities (e.g., around 511 websites). This model is very well-established in the private sector, however, and should not be discarded without consideration if local regulations permit it.

- Selling or bartering access to physical assets. Public sector agencies may have access to rights of way and/or infrastructure which can be made available to private sector companies in exchange for data or other related services.

All of these models have major challenges for public sector implementers, and in many cases, regulatory and commercial realities may dictate that the public agency simply internalize the entire value equation without the expectation of external revenue or barter value being added to traditional funding sources. In these cases, business model choices revolve more around the roles taken by the agency (as discussed previously in the section titled "Public Sector Roles") and the opportunity for cost savings due to internal efficiencies and expenditure avoidance.

This last item is particularly interesting in the context of the situation which has evolved in the private sector telematics space. Automakers initially viewed telematics services as a revenue generator, but over time recognized that their primary value was in the internal use of the data captured from vehicles. From a public agency perspective, NGTIS activities may prove to work in a similar way. For example, the user feedback loop created by social media distribution of traveler information may produce valuable insights on how best to influence consumer behaviors, allowing more efficient deployment of resources.

Determining possible business models may be done using a structured process such as the "business model canvas." A detailed case study on exploring value creation opportunities in the public sector using this canvas and related tools may be found in *Business Models and Value Creation: A Case Study of the New York City Economic Development Corporation* (Chambers & Patrocinio, 2011).

CHAPTER 5. OPERATIONS REVIEW

This Operations Review will address internal operational issues for public agencies, including cross-functional data sharing and re-use, build-buy-partner decision-making, and development of an agency-level technology roadmap. As every state and local agency has a unique set of needs in this area and the operational environment continues to evolve quickly, a key emphasis of this chapter is frameworks and best practices that can be applied by specific agencies both to address today's challenges and to actively manage operational decisions over time. It is important to note that these items apply both to existing and new systems: the rapid pace of change requires a regular reassessment of core business and technical assumptions in every case.

Questions considered include:

- What are models of business planning and determining when to phase out current technology/methods?

- What are the issues, processes, and procedures for transitioning to new technology and phasing out/retiring/replacing older technology and system components?

- Some public agencies procure live traffic data from the private sector to supplement existing data collection capabilities. What are the potentials and possibilities of such services to replace existing public agencies' data collection systems (i.e. detectors, loops, etc.)? What are the risks, gains, and losses for agencies?

- How should the sharing of data between states and third parties be handled?

- What are the funding outlook, limitations, and opportunities for traveler information systems for the next five years?

5.1 BUSINESS PLANNING

Public agencies face a variety of important decisions in the NGTIS space. This requires not only initial strategy formulation, but also continuous strategy maintenance in order to ensure that the agency effectively evolves along with the overall traveler information space. This section will review a framework for strategy development and management which can be used to help make key decisions, such as determining the potential roles of state and federal governments in traveler information services in the next five years.

5.1.1 Strategy Management

As a basic framework, strategy management can be organized into five key steps shown in Figure 24:

- **Set assumptions for overall system goals.** This is a critical but often overlooked part of the strategy process. It is important to determine what the overall system needs to deliver, and how that delivery be measured. The overall goals of the public agency must be clearly articulated. Determining appropriate Key Performance Indicators which will be associated with each goal is an important part of this process.

- **Set assumptions for sub-system contribution to goals.** Once top-level goals are set, it's time to consider the sub-systems that contribute to those goals. NGTIS is one of these sub-systems. It is critical to decide how NGTIS will contribute to the overall agency goals and how this contribution will be measured. Making these decisions may require significant research into various aspects of the system, from activities at other agencies to technology trends.

- **Monitor and regularly assess performance to goals.** Quantitatively measuring performance is the most fundamental activity in ongoing strategy management. It is crucial to establish and monitor effective systems which provide the right data at the right time about adherence to goals, performance impacts and trends, etc. These data can also play a key role in communicating with stakeholders.

- **Make lifecycle and investment decisions based on results.** Armed with quantitative performance information, business planners can then make good decisions about where to focus resources. Are travelers trending away from a specific social media platform and is it time for the agency to follow suit? Are travelers changing their behavior in response to new functionality or data offered by a public agency app?

- **Review and re-assess strategy on regular schedule.** As external conditions change, it is important to re-confirm that goals at all levels are still generating the optimal results. If not, it may be time to change focus in some areas.

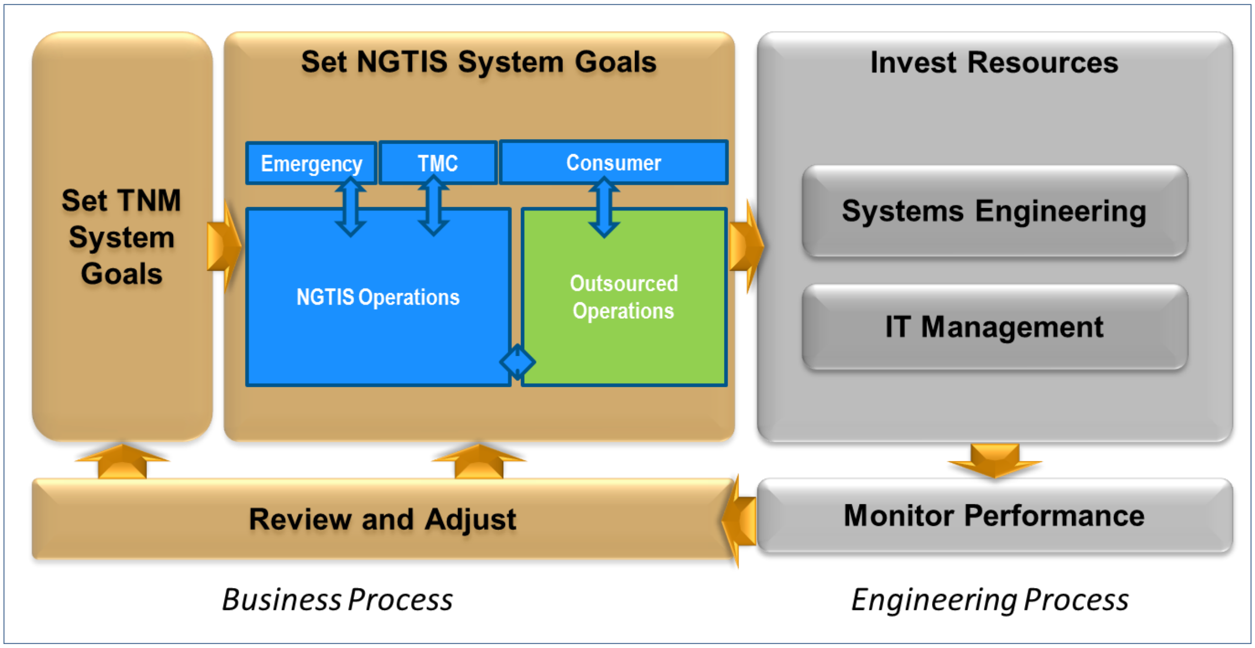

Figure 24. Chart. Strategy Framework (SCG)

As a simplified example:

- An agency might determine that its primary goal is to *optimize transportation network efficiency*, and that this goal would be measured by overall throughput of vehicles through the system per day.

- From an NGTIS perspective, this might mean that its goals are to reduce overall vehicle trips per household. The resulting operational focus might then be on providing the best possible information about transit, including highly accurate total trip times and multimodal transfer information. With those decisions in hand, planners could explore the options for delivering on these goals, which might include assessing current and potential transit usage among various traveler segments, integrating traffic and transit data for bus ETA information, providing data feeds to private sector partners for inclusion in information delivery mechanisms used by traveler segments most likely to consider using transit, etc.

- Once these various programs were implemented, overall transit use, change in transit use, and impact on private vehicle use, as well as more detailed metrics like adoption of information delivery mechanisms and use of a specific functionality, might be tracked to determine overall program performance.

- At quarterly and annual reviews of both NGTIS and overall agency strategy, these metrics could then serve as the basis for decision-making about next steps.

This example is over-simplified, but it shows how the interconnected set of goals and measurements allows continuous evolution of the system. It also serves as a valuable tool in communicating decisions and outcomes to both managers and the traveling public.

In addition, the outputs of the strategy management process can provide substantive input to funding discussions by linking investments and results. This is particularly important in light of anecdotal evidence showing that NGTIS systems are often included as part of general operating budgets rather than called out as separate programs.[2]

5.1.2 Roadmapping

In managing a dynamic system over time, it is easy for the rapid pace of change and the hype around the latest technology to make good decision-making very difficult. Roadmaps can be a valuable tool in this environment. They allow each decision to be placed in a consistent context, and by projecting and aligning trends, can provide helpful insights about when to make changes. An example of a high-level roadmap framework is shown below in Figure 25. This framework would be filled in with specific information corresponding to the various milestones identified as important by a given agency.

[2] Information shared by NV, TN, UT, and KS DOTs Spring 2015.

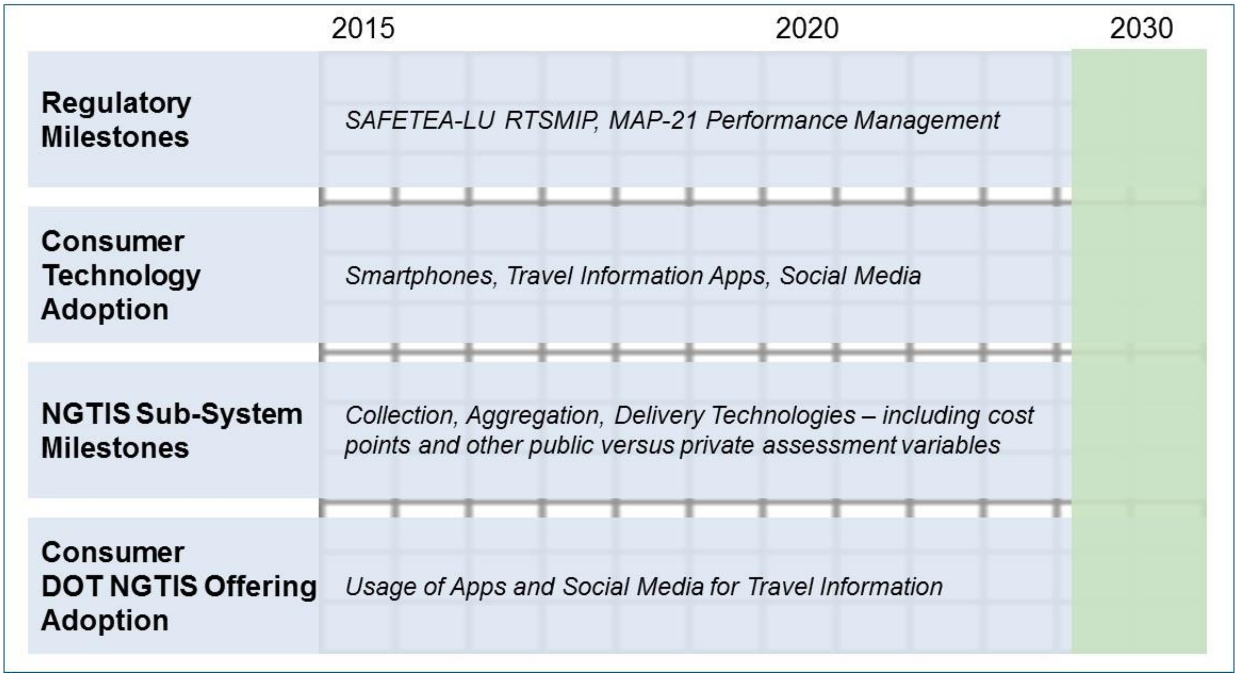

Figure 25. Chart. Roadmap Framework Example (SCG)

On the left-hand side, key tracking areas are determined. In this example, regulatory milestones which will drive specific agency activities (e.g., SAFETEA-LU RTSMIP and MAP-21 Performance Management compliance dates), consumer adoption rates for key technologies such as smartphones and specific social media, assessment points for specific NGTIS solutions (e.g., availability, cost and quality for a new type of data collection solution), and consumer adoption rates for the agency's NGTIS offerings are all tracked. For example, SAFETEA-LU requires collection of certain performance data on metropolitan "Routes of Significance" by November 2016.

Projecting and monitoring these various roadmap elements in visual parallel provides a useful set of perspectives. For example, it might be the case that cost points for data collection infrastructure are not going down fast enough to enable an agency to deploy required solutions in advance of a regulatory milestone, triggering the need to look for alternative data sources and potentially for the agency to change to a new role in the value chain. Or it might become obvious that a certain consumer technology is trending, and causing a corresponding drop in adoption of an existing NGTIS offering and a need to move to a new platform.

5.2 TECHNOLOGY ADOPTION BEST PRACTICES

Managing a dynamic environment with a range of technology lifecycles, including some very rapidly evolving ones, is a challenging discipline. As described in earlier sections, the collection, management, and provision of traveler information requires the practitioner to handle increasingly short technology lifecycles. Rather than measuring the value of deployed technology over decades, new solutions may now only be relevant for a year at a time. The need to interact with a diverse set of consumer platforms adds to this challenge, as multiple standards (or no standards) and rapid change are the order of the day.

Decision and deployment timelines are necessarily compressed in this environment. In order to effectively manage an NGTIS that is responsive to the needs of the consumer and properly enables all related transportation management activities, it is critically important to focus on a combination of business and technology processes. As noted above, these include:

- Setting business goals for systems and subsystems.
- Monitoring metrics designed to support business goal review (performance, cost, etc.).
- Building in system adaptability to enable continuous evolution.

Once clear goals have been set, classic systems engineering discipline can combine with information technology (IT) management to successfully design, deploy and operate systems, as shown previously in Figure 24 on page 48. On the systems engineering side, FHWA's *Systems Engineering for Intelligent Transportation Systems* is a proven resource. It is designed to provide an introduction to systems engineering and a "basic understanding of how it can be applied to planning, designing, and implementing intelligent transportation systems (ITS) projects." (National ITS Architecture Team , 2007) Section 4.11 provides specific information on handling system replacements. A summary is shown below in Table 6.

Table 6. FHWA Systems Engineering Retirement/Replacement (National ITS Architecture Team , 2007)

OBJECTIVES	• Remove the system from operation, gracefully terminating or transitioning its service. • Dispose of the retired system properly.
INPUT ***Sources of Information***	• System requirements (retirement/disposal requirements). • Service life of the system and components. • System performance measures and maintenance records.
PROCESS ***Key Activities***	• Plan system retirement. • Deactivate system. • Remove system. • Dispose of system.
OUTPUT ***Process Results***	• System retirement plan. • Archival documentation.
REVIEW ***Proceed only if you have:***	• Planned the system retirement. • Documented lessons learned. • Disposed of the retired system properly.

On the Information Technology (IT) side, there are also resources which may be of assistance. In particular, the private sector has established formal best practice standards which describe how to best link technology selection, deployment and management to operational needs. One of these is the IT Infrastructure Library (ITIL), an international service management standard which originated in the United Kingdom (Axelos).

ITIL is a large body of work which cannot be effectively detailed in this report. However, one specific best practice area of specific application to NGTIS (Kempter) should be noted: “The objective of *ITIL Service Transition* is to build and deploy IT services. Service Transition also makes sure that changes to services and Service Management processes are carried out in a coordinated way.” ITIL Service Transition Processes include:

- Transition planning and support.
- Change management.
- Service asset and configuration management.
- Release and deployment management.
- Service validation and testing.
- Change evaluation.
- Knowledge management.

5.3 BUILD/BUY DECISION-MAKING

In most areas of the NGTIS, there is a choice to be made between producing solutions within the agency and outsourcing. From software development to data collection, there are almost always private sector alternatives which can be considered. These decisions, however, are complicated and can have significant long term consequences.

When making decisions about data, there are three key variables to review: cost, quality, and coverage.

- Cost can be viewed in a variety of ways, but needs to be addressed consistently across both internal and external options. For example, a private sector vendor may offer freeway data at a certain cost per centerline mile. The reviewer must develop an understanding of the agency's costs using the exact same metric. This is not always simple, as hardware and software systems may serve multiple uses, but without it, there is no real way to compare costs.

- Similarly, quality must be consistently defined. This may include percentage accuracy to ground truth, percent uptime, standard capture to delivery delay, etc.

- Finally, a clear understanding of coverage allows true comparison of data sets. For example, understand how covered links are defined, and the extent of geographic and road type coverage.

When the outsourced cost is less than performing the work internally, but corresponding quality and coverage has become greater, it is time to seriously consider this alternative for a given type of data. If outsourcing becomes the more attractive option for enough types of data, it is then time to consider whether the agency needs to continue in the data collection business at all.

However, there are other major issues which must also be taken into consideration. The biggest one is availability risk. If an agency becomes dependent on an external source for a given type of data, there is always the possibility that the agency will lose access to that source. It is critical to assess what happens in that situation, which includes developing a very clear understanding of exactly how the data are used throughout the agency, and the impact of not having it. If there are other sources for the data, this risk is somewhat mitigated, although switching processes and costs must also be part of the assessment, as noted in the section titled "Collector" in the previous chapter.

A modified version of this approach can also be used to assess specific technologies. When cost, quality, and functionality of a given solution reach a certain point in comparison with another, it is time to consider switching.

5.4 PARTNERSHIPS

Public-private data sharing is a growing area. Over the next five years, it should be expected that the private sector will continue to innovate both technologies and business models, and will continue to market those offerings to both consumers and the public sector. One example of this activity is shown in Figure 26, Google/Waze is steadily building up global partnerships with specific public sector agencies. (Mgodlew, 2015); (TrafficTechnologyToday, 2015).

As a result, the public sector will have to carefully consider both its own role and the possibilities involved in partnering for solutions in every area of the NGTIS architecture. Where relationships are advantageous, it is worthwhile to give particular consideration to two areas:

> The Waze Connected Citizens program is a public/private partnership effort which is designed to facilitate the exchange of information between both sectors. In this program, Waze data reported in real-time by travelers and public sector data are combined and shared. This data includes incidents, construction, congestion and weather. Both parties can then use it for their own purposes. This program has been established in 10 US cities and 12 additional international ones.

Figure 26. Chart. Partnership Example (SCG)

- Aligning goals. There are fundamental differences in the way the two types of entities look at traveler information. As noted in the section titled "Business Models" in the previous chapter, from the private sector perspective, data and services are simply items of value to be monetized. All agreements are negotiated on that basis. Public sector entities should be very clear on the roles they wish to play, and the goals that they are seeking to meet, when performing vendor selection assessments and negotiations.

- Setting contracts. As the potential range and complexity of outsourcing arrangements grows, it becomes very important to focus on contract detail. For example, in a data contract, a key consideration might include the exact description of the data available. Data descriptions and terminology should be based on applicable standards where possible. Additional key considerations include the Service Level Agreements, the data transfer standards that are used, and the platforms that are available.

5.5 OPERATIONS CONCLUSIONS

Managing internal operational issues for NGTIS will continue to be a challenge. Traditional approaches to planning for stable, long term solutions do not work well in the face of constant consumer and technology change.

Instead, adaptability is key. Change should be expected, and every aspect of operations should be designed or evolved to provide critical data in support of regular strategic and operational reviews. This approach provides critical perspective required to make the right decisions at the right time so that agencies stay in step with their customers and with network management needs. It also allows public agencies to make good, well-justified decisions quickly, and to communicate those decisions clearly to the public and to partners.

The sections above provide a high level view of frameworks and best practices which can be of assistance as agencies optimize their operational approaches to handle the highly dynamic NGTIS landscape.

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