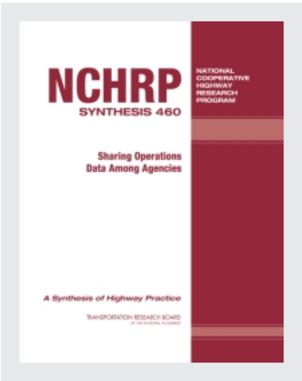

Sharing Operations Data Among Agencies

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AUTHORS

Pack, Michael L.; and Ivanov, Nikola

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 460

Sharing Operations Data Among Agencies

A Synthesis of Highway Practice

Consultants
Michael L. Pack
and
Nikola Ivanov

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TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Academies was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

The opinions and conclusions expressed or implied in this report are those of the researchers who performed the research and are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

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FOREWORD

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, “Synthesis of Information Related to Highway Problems,” searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Tanya M. Zwahlen
Consultant
Transportation Research Board

This report identifies the current state of the practice regarding sharing operations data. A primary objective of this study is to document both the qualitative and quantitative business cases for sharing data among agencies. The study also documents the institutional, legal, and technical challenges that can inhibit data sharing.

Information used in this study was acquired through a review of the literature, and a survey of state and local transportation operations individuals as well as transit service providers, law enforcement, emergency management agencies, private sector data providers, private sector traveler information providers, and other agencies responsible for transportation operations.

Michael L. Pack and Nikola Ivanov collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable with the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SHARING OPERATIONS DATA AMONG AGENCIES

SUMMARY

This synthesis will inform transportation-related agencies of the current state of practice in the sharing of operations data, document both the qualitative and quantitative business cases as to why agencies share data, and document institutional, legal, and technical challenges that can inhibit the success of sharing operations data between agencies, the private sector, and the public.

A survey was distributed to more than 250 state and local transportation operations' individuals in all 50 states and nearly 650 transit service providers, law enforcement, emergency management agencies, private sector data providers, private sector traveler information providers, and other agencies responsible for transportation operations. Forty-one of the 50 state departments of transportation responded to the survey, as did many transit providers and a limited number of law enforcement and public sector representatives. The literature review, survey responses, and follow-on interviews show that the majority of state departments of transportation are sharing some form of operations data with other agencies, the private sector, and/or the public. Although this is encouraging, other survey findings, along with the follow-on interviews, suggest that the bulk of the data being shared is basic—vehicle speeds, accident types and locations, and closed circuit television images. A number of challenges remain that can potentially impede an agency's willingness and ability to share its data—the primary being concerns of being judged, perceived legal issues, and, to a lesser extent, funding and technical challenges—especially with respect to more detailed operations data such as responder locations, notifications, on-scene arrival times, computer-aided dispatch from law enforcement, and even real-time signal timing plans. Although less likely to be shared with other agencies, these highly detailed operations data have the potential to have even greater operational benefits.

Many agencies continue to struggle with quantifying the benefits of operations data sharing; however, a recent study related to multi-state operations in the Washington, D.C., metropolitan region revealed how hundreds of thousands of dollars in benefits can be realized for just a single large-scale incident of which there are hundreds every year. At the time of this study, two Integrated Corridor Management demonstration sites in Dallas, Texas, and San Diego, California, were attempting to do direct benefit-cost studies showing the performance, safety, environmental, and financial benefits of their programs that are the direct result of information sharing. Anecdotally, many other agencies referenced within the report identified significant internal cost savings with respect to receiving data from others.

Specifically, this report notes that the coordination and sharing of operations data may:

- Enable the coordination of signal timing plans between jurisdictions;
- Improve coordination of commodity flows for shippers;
- Enhance interagency transit and mode coordination;
- Free agency staff to work on other tasks;
- Help agencies coordinate work zones and lane closures;
- Improve information flow and coordination between all jurisdictions and agencies involved in an incident;
- Enhance the understanding of joint priorities and restrictions by all agencies with responsibility for an incident;

- Provide a single set of objectives for those working to resolve an incident—a collective approach to develop strategies to achieve traffic incident management objectives; and
- Optimize the combined efforts of all agencies as they perform their respective assignments to mitigate the impacts of incidents—all of which leads to significant benefits in terms of:
  - Safety,
  - Congestion reduction,
  - The environment, and
  - Cost savings to the agencies and the public.

Agencies referenced in the report have observed similar or even greater cost savings through their efforts to provide their own data to others by means of real-time automated feeds, specifically noting that the provision of data to external entities in electronic feeds helps to reduce internal workload and improve coordinated incident response.

The findings of this synthesis also suggest that there are additional factors that can significantly impact the value of operations data including:

- Human factors associated with how operations data from other agencies is presented to the user to strike a healthy balance between information overload and hiding information from users deep within complicated systems.
- The level of detail that is presented to traffic management operations personnel or first responders. Simply stating that an incident has occurred has inherent value; however, informing a user that an incident "has occurred, police are on the scene, fire and rescue are 2 minutes from arriving, chlorine gas is leaking at the scene, and queues are backing up 5 miles and growing" is significantly more useful in coordinating a response.
- The speed at which information is provided to other agencies and third parties is critical. Agencies that wait excessive periods to "confirm an incident" usually reap fewer benefits than those who share openly even "suspected" incidents prior to verification.
- The bureaucracy and overly burdensome legal reviews necessary for those agencies that simply want to formalize an agreement related to providing data to third parties or acquiring information from third parties can have significant impacts on an agency's willingness and ability to enter into agreements, thus diminishing opportunities for collaboration.
- The types of agreements that are required by certain agencies can have adverse effects. Agencies that are constrained by state laws or internal policies to develop full data use agreements with legal sign-off from the state attorney general can sometimes find that partner agencies are unable to agree to certain terms and conditions.

This synthesis provides critical information to support agencies in making a strong business case for sharing agency operational data and encourage greater interagency cooperation.

Further research is needed to help identify the benefits of individual data elements so that data sharing initiatives can be prioritized effectively. Research is needed to standardize the way benefits are measured and reported for the sake of consistency and repeatability. Lastly, more research into the understanding of how agencies perceive and respond to concerns over liability, open data initiatives, and interagency performance analysis may be warranted to help understand the effects these concerns have on an agency's ability to share information with others.

CHAPTER ONE

INTRODUCTION

BACKGROUND

Agencies responsible for the safety and efficiency of mobility and freight movements continue to produce ever-increasing amounts of real-time data. What began as just a few deployed systems in only major metropolitan areas—consisting of volume and speed detectors, cameras, and incident logs—has now blossomed into significant deployments of seemingly ubiquitous amounts of data related to incidents, traffic flow, video images, weather, transit, computer-aided dispatch (CAD), radio transmissions, probes, connected vehicles, signal systems, and more.

Despite this wealth of data, it is rare that any single agency is the sole collector, provider, or steward of all of these important data elements. Instead, most agencies operate independently—with separate budgets, missions, infrastructure, and information systems. For example:

- Law enforcement, fire, and rescue agencies usually have control over 911 systems, CAD, and their radio systems—all of which are highly sought after by the transportation operations community because they frequently represent the "first notice" of an incident.
- State departments of transportation (DOTs) are generally the collectors of data emanating from traditional intelligent transportation system (ITS) deployments including vehicle speeds, volumes, travel times, queues, event logs (including lane status), road weather sensor data, video, etc., primarily on freeways and major arterials.
- Local transportation agencies, including cities, counties, municipalities, etc., are usually the holders of real-time data emanating from arterials—the smaller capacity streets that feed directly into businesses and homes. The data from these agencies often contain information about signal timing plans, signal status, construction projects and water main repairs, camera feeds, etc.
- Transit providers (bus and rail) generally collect and manage their own data related to schedule adherence, asset locations, fares, maintenance issues, etc., although this can also regularly translate to travel time data and disabled vehicle information.
- Private sector data providers have become more prevalent in recent years through proliferation of technologies that provide traffic information without the need for use of the state's right-of-way or other resources.
- Private sector traveler information providers are also important partners in transportation management. These for-profit partners provide information on traffic conditions directly to motorists through television, radio, web, mobile, and in-vehicle systems. In some instances, these private sector providers will be co-located with traffic management center (TMC) or other agency operations personnel.

With the amount of data available, the real-time sharing of operations information has become a more important aspect of multi-agency transportation operations, especially in large metropolitan areas where agencies and jurisdictions overlap, share responsibilities, or are otherwise expected to work together to ensure consistent information to the public and seamless transitions across adjoining boundaries.

Regional collaboration and coordination are often cited as primary reasons for data sharing and center-to-center interaction; however, these are high-level goals that are not easily quantifiable or defendable. Although many tout the anecdotal benefits of data sharing, there is a need to document business cases, cost-benefit analyses, and effective practices that support data sharing, especially given current budget constraints and other issues that sometimes restrict agencies from sharing information.

STUDY OBJECTIVE

The objective of this study was to synthesize the current state of practice with respect to operations data sharing; more specifically, to identify:

- Business cases for sharing operations data,
- Successful multi-agency operational data sharing practices,
- Examples and case examples of operational improvements resulting from sharing, and
- Other challenges that continue to impede data sharing.

STUDY APPROACH

The information included in this synthesis was collected through

1. A literature review, the results of which were used to help guide the questions used in the web-based

screening survey, identify gaps, and consolidate existing knowledge about the state of practice.

2. A web-based screening survey, the purpose of which was to understand the implemented state of information sharing throughout the country at various agencies, but also to identify agencies worthy of additional analysis and follow-up interviews. The survey was distributed to more than 250 state and local transportation operations' individuals in all 50 states and nearly 650 transit service providers, law enforcement agencies, emergency management agencies (EMAs), private sector data providers, private sector traveler information providers, and other agencies responsible for transportation operations.
3. Telephone and in-person interviews with distinctive agencies: the information gathered through these interviews was then used to document the various benefits, costs, governance, and technical and legal issues that either drive operations data sharing or hinder it.

ORGANIZATION OF THE REPORT

This synthesis report consists of six chapters. This introductory chapter provides an overview of the project, including background information. Chapters two through five contain summaries and relevant tables and figures of the findings from the literature, surveys, and in-depth interviews.

- Chapter two—Literature Review
- Chapter three—Survey Results
- Chapter four—Synthesis of Current Business Cases
- Chapter five—Synthesis of Issues Affecting Operations Data Sharing.

The final chapter of the report (chapter six) is a summary of key findings, including remaining gaps and issues to be considered for future research.

It is important to note that the observations from the literature, surveys, and case examples throughout this report are those of the authors, survey respondents, and interviewees.

CHAPTER TWO

LITERATURE REVIEW

The literature review was used to identify current, documented knowledge of the benefits of operations data sharing. This chapter references the relevant documents that were discovered and was crucial in establishing a solid foundation upon which to develop the web-based survey and the interview questions.

DATA TO SUPPORT THE OPERATIONS MISSION

Introduction

Transportation operations is a means to optimize the performance of existing transportation networks through the implementation of various incident management, congestion management, traveler information, and other multi-modal, cross-jurisdictional systems, services, and projects (*1*). Operations often involve the deployment of sensors, systems, traffic control devices, first responders, and many other programs—all of which aim to gather information, support decision making, and lead to more effective use of existing road networks. Examples of transportation operations programs and projects include:

- Active traffic demand management
- Arterial management
- Electronic toll and fare collection
- Freeway service patrols/emergency response units
- Freight management/commercial vehicle operations
- High-occupancy vehicle (HOV) or high-occupancy tolling lane development
- Integrated corridor management (ICM)
- Regional signal systems coordination
- Regional transit coordination
- TMCs
- Traveler information dissemination
- Road weather management
- Special events management
- Traffic incident management (TIM)
- Work zone management
- Any combination thereof.

While transportation operations by itself is not the focus of this synthesis, the sharing of data that enables these types of programs and projects and the value that comes from the sharing of this information between agencies is.

Participants in the FHWA's TIM Program-Level Performance Measures Focus States Initiative developed the following key objectives for traffic operations (*2*).

Safety Goal
- Reduce the number of secondary incidents and the severity of primary and secondary incidents.

Temporal Goals
- Reduce incident notification time (defined as the time between the first agency's awareness of an incident and the time to notify needed response agencies).
- Reduce roadway clearance time (defined as the time between awareness of an incident and restoration of lanes to full operational status).
- Reduce incident clearance time (defined as the time between awareness of an incident and the time the last responder has left the scene).
- Reduce recovery time [defined as the time, following an incident, from when all lanes are open until normal traffic conditions are achieved and traffic has returned to a steady state (pre-incident conditions)].
- Reduce time for needed responders to arrive on the scene after notification.

Internal Goal
- Develop and ensure familiarity with regional, multi-disciplinary TIM goals and objectives and supporting procedures by all stakeholders.

Communication Goals
- Improve communications between responders and managers regarding the status of an incident throughout the incident.
- Provide timely, accurate, and useful traveler information to the motoring public on a regular basis during an incident.
- Regularly evaluate and use customer (road user) feedback to improve TIM program assets.

All of the above-stated mission objectives cannot be met without data, and the data needed are rarely attainable by one agency. Data from many partners and multiple agencies are needed to meet these objectives. This is especially true in metropolitan regions that share borders and jurisdictions.

Types of Data Being Shared

The following were identified as examples of the types of data being shared, or desired to be shared, by operations personnel in pursuit of the overall operations mission:

- **Traffic volume, speed, class, and occupancy from point and probe data sources.** This information is collected by agencies and third parties from roadway sensors that could include inductive loops, side-fired sensors (acoustic, microwave, etc.), radar, and video. Data from probe-based systems—either agency-owned or third-party supplied—are also included in this category.

- **Event, work zone, and incident information.** This consists of information entered by each agency into its own incident management system. Data typically include incident location, type, severity, information about the vehicles involved and their status, to whom are notifications made and which responders are on-scene, lane closures, response plans or detours, and messages on dynamic message signs (DMS) or Highway Advisory Radio.
- **Weather data.** Weather alerts and radar data from the National Weather Service, third parties, the media, etc. Also included are weather and pavement surface conditions that agencies gather from their roadway weather information systems.
- **Device operational status.** Data on the operational status of roadway devices from each agency. These include traffic detectors, DMS, traffic signals, highway advisory radio, roadway weather information systems, and closed circuit television (CCTV) cameras, where available.
- **Managed lane status.** The status of HOV, high-occupancy toll, and reversible lanes.
- **Surveillance video.** Live CCTV feeds focused on roadways, assets, or pedestrians.
- **Transit alerts.** Transit alerts, service disruptions, and other information transmitted by transit providers—both public and private.
- **Automated vehicle locations (AVLs).** The locations and status of freeway service patrols, transit vehicles, or other assets equipped with AVL hardware.
- **Signal status.** This includes the operational status of signals at intersections or ramp meters such as operational, maintenance mode, flashing, or offline.
- **Signal timing plans.** Signal timing plans, current or future timing schemes.
- **CAD information.** Data from public safety CAD systems such as fire, EMS, and law enforcement. These data can include dispatch requests, incident types, severity, responder requests, or even lane status.
- **Static, descriptive information.** This can include any information on roadway infrastructure, evacuation routes, business locations, permanent asset locations, or transit characteristics. For transit this includes schedules, routes, and stops. For roadways it includes information such as number of lanes, weight and height restrictions, speed limits, evacuation routes, and location of ITS devices.
- **Decision-support response plans.** This can include the various actions that the DOTs are likely to take to help minimize congestion impacts and clear roads more quickly. These response plans could include pre-programmed DMS messages, signal timing plans, traveler information strategies, detours, etc., that are grouped together into a single, cohesive "plan of action" ready to implement. The sharing of these response plans can help agencies to better coordinate so that one agency's response plan is not in conflict with another's.
- **Parking data.** This can include the location of parking facilities, the number of remaining available spaces, the current fees, restrictions, and data on how to reserve a space.
- **Travel time.** Often a derivative of speed data, travel time data represents the number of minutes it should take a vehicle to travel from one location to another. Travel times are often broken down into road segments where the start and end point of the segments are often intersections or key features (such as bridges or tunnels). Travel time data can be derived from point sensor speed data, can be directly measured by probes (such as license plate recognition, toll tag transponders, Global Positioning Systems, and cell phone tracking) or it can be estimated and predicted from other data sources.
- **Freight movements.** This can be a mix of data related to the origin–destination (OD) of various shipments or types of shipments, statistics on the type of goods being shipped, the mode by which the goods are shipped, value of the goods, quantity of goods, type of shipping container, and safety records of the shippers.
- **O–D data.** Considered relatively difficult to collect because of privacy concerns, passenger vehicle OD data tells operations personnel and planners where trips begin, end, and sometimes even the routes that are taken. This information can be valuable for planning purposes, but is also useful for real-time operations when trying to measure the impact of various traveler information strategies and the impact of incidents on arterials and other secondary roads.
- **Routing data.** Data that can be used by both emergency first responders and the traveling public to determine the fastest route, shortest path, etc., from one point to another. This type of data is comprised of road network data, turning restrictions, speed limits, and other information related to route types and distances.

All of the above-mentioned data are particularly relevant to real-time operations and are considered critical to effectively managing traffic.

VALUE OF OPERATIONS DATA SHARING

There is surprisingly little documentation that explicitly quantifies the direct value of interagency transportation operations data sharing. The 2004 *NCHRP Report 520: Sharing Information Between Public Safety and Transportation Agencies for Traffic Incident Management* (*3*) states that "Interagency exchange of information is the key to obtaining the most rapid, efficient, and appropriate response to highway incidents from all agencies. More and more, such information must be shared across system, organizational, and jurisdictional boundaries." However, the report also stated that

> Most local officials interviewed were strongly supportive of sharing traffic incident information and employing multiagency teams to manage traffic incidents. However, no location visited during this study could formally quantify the benefits of information sharing. Moreover, most locations had no data to measure how other TIM practices affected detection, notification, response, clearance time, responder safety, or other metrics of performance.

This observation remains mostly unchanged today. Although many reports note that data sharing is key to realizing certain operational goals, the bulk of the documents fail to quantify those benefits and the implications of not sharing.

Many agencies produce well-thought-out performance summaries of their transportation operations programs—some documenting direct benefit-cost summaries (*4–7*), and FHWA has even produced a desk reference on providing guidance to practitioners in the analysis of benefits and costs of management and operations projects (*8*); however, the vast majority of these reports review the individual programs and do not consider the impacts on the program resulting from data coming from other partner agencies or data being provided to partner agencies. That said, there are a few limited studies that have evaluated programs that only exist because of data sharing (*9–18*). Although the studies do not directly cite particular individual data elements as being more valuable than the others, the implications are still relevant.

The following are notable documented cases where shared operations data has resulted in financial and other benefits.

Multi-State Operations

One notable example of the direct quantifiable benefits of operations data sharing is an evaluation of the Metropolitan Area Transportation Operations Coordination (MATOC) program conducted in 2010 (*10*). This internal document specifically evaluated the benefits of "coordinated regional incident management"—the combined efforts of the Virginia Department of Transportation (VDOT), the Maryland Department of Transportation, the District of Columbia Department of Transportation (DDOT), and the Washington Metropolitan Area Transit Authority (WMATA) to share operations information and how that sharing of information between agencies has a positive impact on user delay, queues, emissions, etc., in actual numbers. A broader discussion of the detailed benefits and the methodologies used within this evaluation are presented in chapter four under "Multi-State, Multi-Agency Data Sharing in the National Capital Region."

Other reports and case studies on multi-state or multi-region/multi-agency programs such as Transcom (*19–21*) and Niagara International Transportation Technology Coalition (NITTEC) (*22*, *23*) have been produced with compelling anecdotal benefits of regional and multi-agency collaboration; however, these reports rarely quantify the benefits in terms of reduction in delays, emissions, or benefit-cost ratios. Instead, the focus is on effective story telling; using specific examples of construction coordination, major incident coordination, etc., as case studies of how the agencies worked together to better serve the public and avoid conflicts. These case studies are effective for most operations proponents; however, they do not carry the same weight as formal benefit-cost studies that quantify the results of coordination in terms that are more easily accepted by management, decision makers, and the public. That said, because the hundreds of agencies that participate in each of the above-mentioned programs are willing to dedicate their own time and, in most cases, their own funds to these regional programs, shows an inherent understood benefit of the programs. However, without firm numbers, the senior executives in charge of these programs are constantly under scrutiny to justify these budgets to their funders, especially when resources are scarce for traditional transportation infrastructure projects.

Integrated Corridor Management

In 2006, FHWA and FTA co-developed a generic Concept of Operations (ConOps) for ICMS (*24*). The central objective of the ICMS concept was that "independent, individual network-based transportation management systems and their cross-network linkages could be operated in a more coordinated and integrated manner, thereby increasing overall corridor throughput and enhancing the mobility of the corridor users." Within this ConOps it was noted that for an ICMS to be successful, three primary items would need to be addressed:

1. Agencies would need to integrate operations between modes and departments including the sharing of information and cross-network coordination.
2. Agencies would need to integrate institutional responsibilities and control functions—essentially implying that each agency would need to adopt new governance structures and change approaches to shared responsibilities.
3. Technical integration between each agency system and interface would need to occur. This includes communication links, standards by which information is shared, etc.

Note that in two of the three critical items for successful ICMS, information sharing is front and center. ICMS is only possible if and when agencies share their operations data with one another. The anticipated benefit-cost ratio of ICMS in certain metropolitan regions is anticipated to be as high as 22:1 (*25*). These values are based on preliminary modeling and simulation efforts used by FHWA to evaluate the potential effectiveness of ICM in three separate metropolitan regions.

Freight Data Integration

In 2003, FHWA completed an evaluation of the benefits that shippers could realize through better integration of various operations information systems (*13*). The project developed a Freight Information Highway to serve as the backbone for data sharing related to asset tracking and cargo visibility. The primary benefits came from increasing the efficiency of modal shifts from rail to truck, reducing errors in data entry and shipment mishandling, limiting customer service and tracking costs, and reducing penalties and delays. Estimated benefits for shippers using an integrated shipment, equipment, and freight status information system equate to a 6.2% reduction in shipment costs from the following factors:

- Increased modal shift (truck to rail);
- Reduced emergency transloads (shifting to a more expensive transport mode to meet customer needs);
- Reduced inventory carrying costs and outages;
- Improved collaboration;
- Reduced data entry and shipment mishandling;
- Reduced customer service and tracking costs; and
- Reduced penalties and delays.

This equated to approximately $28.66 saved per shipment.

Other studies (*26*) have evaluated how the trucking industry can make better use of real-time operations data from public agencies to make better decisions about when to ship, where to ship, and what routes to take.

Signal Systems

NCHRP Synthesis 420: Operational and Institutional Agreements That Facilitate Regional Traffic Signal Operations notes that Regional Traffic Signal Operations Programs (RTSOPs) are one more tool that regions can use to improve traffic flow especially at or near jurisdictional boundaries (*27*). Several studies (*28, 29*) were cited to show that RTSOPs have produced significant reductions in travel times, stops, delays, fuel consumption, and vehicle emissions. RTSOPs often achieve their program goals through the direct sharing or integration of operations data (*30*)—signal timing plans, detection, and maintenance activities. Still, 38% of RTSOPs conduct no formal evaluation reports documenting the effectiveness of their programs.

Another study (*31*) looked at the direct impacts of real-time passenger information and bus signal priority. Average passenger wait time has been reduced significantly, with an estimated a cost savings of $0.70 per passenger trip.

Operations Data to the Public

The 2012 Texas Transportation Institute Urban Mobility Report found that congestion cost the U.S. economy $121 billion in 2011 (*32*). Simply providing better, more reliable traveler information to the public can reduce congestion on the roadway in significant and cost-effective ways (*33–36*). By providing information to motorists they can:

- Change their routes when incidents block their paths;
- Quickly chose parking locations based on real-time availability, thus limiting “search time” as well as reducing energy consumption, costs, and emissions;
- Decide to remain at work longer in the evening to avoid adverse conditions;
- Make different mode choices;
- Decide to telecommute if travel conditions are not safe; and
- Ease motorist frustration and annoyance.

A number of studies have been conducted to try to quantify the benefits of sharing information with the public. The bulk of these studies examine how traveler information helps motorists make better decisions about when to take trips, what routes to choose, and which mode to select.

- Transit providers have determined that better real-time information provided to customers increases ridership and satisfaction (*37*).
- Robust multi-modal trip planning websites have been shown to influence users to try transit services that they might not have normally tried (*38*).
- A study in the Washington, D.C., area found that regular users of pre-trip traveler information reduced their frequency of early and late arrivals by 56% and 52%, respectively, resulting in meaningful cost savings (*34*).
- Travelers that used in-vehicle devices to alert themselves of freeway traffic congestion were reported as saving an average of 30 minutes each time they used the information to change their travel routines (*36*).

Just as the commuting public is dependent on the transportation system for its daily commute to work, the trucking industry is dependent on a reliable roadway network to pick up and deliver goods to its customers. In their written testimony to the U.S. House of Representatives Committee on Transportation and Infrastructure, UPS estimated that at any given moment, the economic value of the goods and services moving in the UPS supply chain equates to 6% of the U.S. gross domestic product and 2% of the global gross domestic product (*39*).

Because carriers make time-sensitive deliveries that need to fall within a certain delivery window, obtaining information about changing roadway network conditions, especially when the network is operating at reduced capacity because of an incident, construction, weather, etc., is of significant importance to truckers. This industry is acutely dependent on accurate and timely traveler information.

UPS has calculated that if every one of their delivery vehicles is delayed just 5 minutes each day, it would cost the company an additional $105 million annually. These costs equate to excess fuel consumption, diminished air quality, increased shipping rates, additional trucks on the road that lead to further congestion, etc. UPS suggests in their testimony that the various transportation agencies and modes in the United States are too siloed and need to be better integrated. The availability of timely information across borders is deemed sufficiently critical that state DOTs are taking on freight-specific truck traveler information efforts.

Traveler information, whether to the public or directly to shippers, is dependent on integrated and open data feeds from agencies and the private sector. The recent NCHRP web-only publication *Document 192: Deployment, Use, and Effect of Real-Time Traveler Information Systems* (*33*) concluded that the future of successful traveler information depends on several items including the availability of ubiquitous real-time data. This conclusion is a direct correlation between data sharing and the success of traveler information strategies.

Transit Operations Data

Based on five case histories of public transit agencies, researchers at the Transparency Policy Project have published a study that examines the process by which some transit agencies have disclosed their operations data to the public (*40*). The results of this study, which reviewed information flows from Portland's Tri-County Metropolitan Transportation District (TriMet), Boston's Massachusetts Bay Transportation Authority (MBTA), Chicago's Chicago Transit Authority (CTA), Washington's WMATA, and New York's Metropolitan Transportation Authority (MTA), found that an agency's disclosure of operations data improved upon prior customer information systems. The study hypothesized that agencies would notice operational performance improvements based on the sharing of data with the public and third-party developers. The researchers noted that few studies have been conducted that assess system performance since the release of large amounts of publicly available data on the included agency systems.

> Perhaps a reason why we find so few efforts at assessing system performance by comparing transit schedules to actual arrival information is that once real-time data are available, schedules become a less important source of information. If at some point in the future, all riders can consult real-time location and arrival information along an entire transit network, the notion of 'on-time-performance' may no longer be based on schedules, but rather on some expectation of service regularity that meets customer demand. It may be that with the availability of real-time information, transit riders are adapting their use of transit to a system 'as is' rather than to the expectation set by schedules.

If true, this could be a unique case of where improved operational data sharing to external private sector information service providers, commonly referred to as ISPs, could actually decrease operational costs, decrease the publics' desire to measure performance in terms of schedule adherence, and improve customer satisfaction and ridership.

LITERATURE IN PROGRESS

Although not ready for publication at the time this report was written, there are several on-going NCHRP projects and other reports that are relevant to quantifying and enabling operations data sharing, including:

- NCHRP 03-108: Guidance on Quantifying Benefits of TIM Strategies. This document will provide guidance on how to determine and/or compute economic benefits of TIM programs and the use of information in various evaluation and decision-support systems.
- White paper on Interagency Agreements to Support Regional Transportation System Management and Operations. This paper is being prepared for FHWA and covers more than 20 different types of memoranda of understanding (MOUs), memoranda of agreement, cooperative agreements, and other data sharing and collaboration agreements between agencies, and in some cases, the private sector.
- *NCHRP Synthesis 447: Active Traffic Management for Arterial* (Topic 43-10) has several sections dedicated to system and data requirements associated with implementing the strategies as well as the measured benefits of the various strategies.
- U.S.DOT is in the process of completing a report titled *Making the Connection: Advancing Traffic Incident Management in Transportation Planning—a Primer.* Among many other operations and planning insights, this document will reference how information sharing among agencies can improve the efficiency and effectiveness of the transportation system.

FHWA is also currently undertaking a multi-year evaluation of two demonstration ICMS projects—one in Dallas and one in San Diego. A significant portion of these evaluation reports will focus on data sharing initiatives that enable ICM along with actual measurements related to improved operations resulting from information sharing and decision-support systems. Each of these reports will have a number of relevant components that will lead to a better understanding of how to effectively measure and understand the direct and indirect benefits of operations data sharing among agencies and to the public.

SUMMARY OF LITERATURE REVIEW

It is clear from the existing literature that while many agencies appear to agree that there is value in sharing operations data, almost all agencies have been unable to directly quantify those benefits. Even the agencies that have attempted to quantify benefits have done so in an inconsistent manner. Agency X's evaluation methodology and terminology is often different from Agency Y's methodology and definitions, making it difficult for U.S.DOT to post meaningful benefits to its ITS Joint Program Office online benefits database, which can be found at http://www.itsbenefits.its.dot.gov/.

The FHWA Office of Policy is currently working on a project called "Evaluating Congestion Mitigation and Active Traffic Management Strategies," which is examining various ways in which agencies have represented benefits and costs for their projects. Although still in its early stages, the project is looking at potential recommendations for how benefit-cost studies are written up in a common format to make it easier for agencies to interpret the results of studies, understand the potential variance in anticipated benefits, and understand any regional implementation criteria that may have affected the benefits. The results of this project could potentially help to improve agency approaches to reporting on the benefits they measure in a more uniform and consistent manner.

CHAPTER THREE

SURVEY RESULTS

Based on the findings of the literature review, a brief survey was administered to a targeted audience of traffic management agencies, transit providers, and first responder communities. The goal of the screening survey was to:

- Generate meaningful statistics regarding current agency data sharing practices;
- Identify specific organizations engaged in, in consideration of, or in opposition to, operations data sharing;
- Identify barriers to data sharing; and
- Identify agencies worth interviewing for additional details and insights.

AUDIENCE AND SURVEY ADMINISTRATION

The target audience for the survey included state, county, city, and local DOTs, metropolitan planning organizations (MPOs) that had operational roles, and transit agencies. The survey was also administered to law enforcement agencies, private sector data providers, and companies involved in the provision of traveler information to ensure adequate coverage and breadth of perspectives.

The online survey was distributed by e-mail to a list of 200 state and local TMCs in the United States and Canada. FTA helped compile a list of more than 600 transit providers, and the International Association of Chiefs of Police was asked to distribute the survey to its membership. Private sector, MPO, and select university respondents were chosen from a mix of literature review findings and steering committee input.

The complete survey questionnaire can be found in Appendix C, and the detailed survey results are in Appendix D.

STRUCTURE

The survey was divided into three main sections:

1. **Respondent information:** This section collected basic information about survey respondents including their contact information, organization, title, role, etc., providing insight into differing perspectives from respondents that may be representing the same organization, but may have a different role and attitude toward data sharing.
2. **Providers of information:** This section contained questions related to:
   - The types of data being shared,
   - Sharing methods and frequencies,
   - Organizational agreements, and
   - Reasons for or against the sharing of operations data.
3. **Recipients of information:** This section contained the same questions as in section two, but from the viewpoint of those who receive information from other agencies:
   - The types of data being received from others,
   - The method and frequencies by which data are provided,
   - Organizational agreements,
   - Reasons why the agency wants access to the data or does not want access to the data, and
   - Types of data agencies would like to receive if it was available.

SURVEY RESULTS

Two hundred and thirty-nine (239) survey responses were received; 178 of these were complete, and 61 partially complete. After the removal of duplicates and unusable responses, it was determined that there were 198 valid survey responses. State DOTs, bus transit providers, transportation/transit/port authorities, and local agencies represented the largest group of respondents (Figure 1). Respondents were able to select multiple answers to all questions, resulting in total response counts that are larger than the number of survey responses. For example, many respondents designated their organization to be both a state DOT and EMA; therefore, their response counted twice. This explains why there are total of 239 responses on the graph, but only 198 respondents.

The survey was distributed to multiple contacts at agencies, and respondents were encouraged to share the survey with their colleagues, resulting in multiple responses from individual agencies. The goal was to collect data from different jurisdictions, districts, divisions, and organizational groups to determine if there are differences in the way larger or more decentralized organizations share operations data. Additionally, even responses from the same groups differed between respondents with different functional titles. For example, the state of New Jersey was represented by 36 respondents. Of those 36 respondents, 31 belonged to New Jersey DOT; however, the respondents ranged from traffic engineers, project engineers, and information technology specialists, to communication

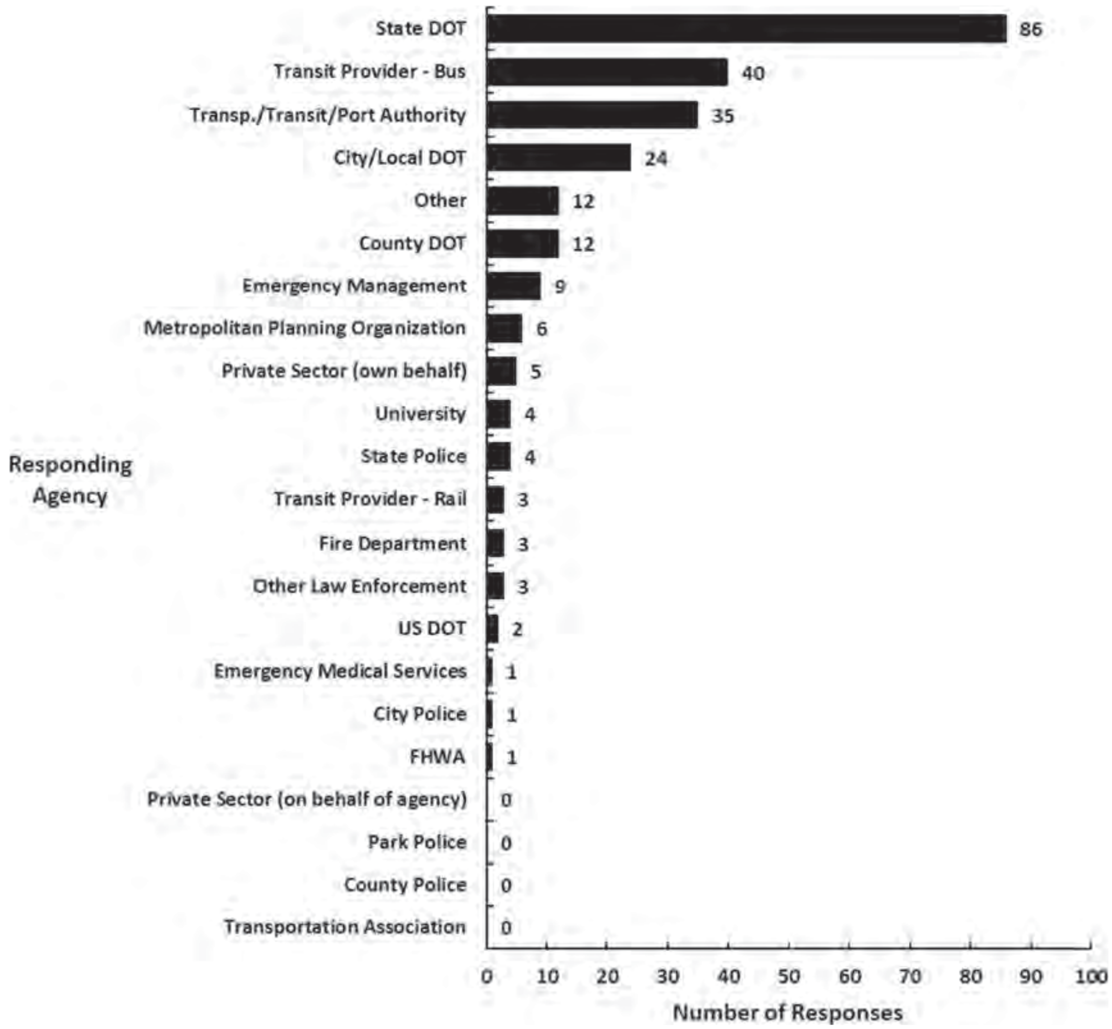

FIGURE 1 Agencies participating in the survey—198 responses (Question 1).

officers and executive directors. Many of these were located in different parts of the state and were members of different divisions, such as Mobility Systems Engineering or Traffic Operations South.

In the case of Pennsylvania, of 15 respondents, nine belonged to Pennsylvania DOT, with each reporting from a different district. Owing to the decentralized nature of Pennsylvania DOT, each district in Pennsylvania could be implementing different operations data sharing procedures. The remaining six respondents were members of individual townships, emergency management centers, and planning organizations such as the Delaware Valley Regional Planning Commission.

Only nine state DOTs declined to provide any input into the survey or interviews (Figure 2).

AGENCIES THAT SHARE

One hundred and seventy-four of 198 respondents reported that their organization *provided* data to others, 124 of 198 reported that their organization *gathered* data from others, 19 were unaware of their agency's current capacity to gather operations data from others, and nine were unaware of their agency's data providing practices (Figure 3).

It is worth noting that 118 of 198 respondents reported that they both provided and gathered operations data, and only nine did not.

The survey divided the data types into major categories and subcategories similar to those mentioned in chapter two, including incident-related data, detector data, probe vehicle data, other ITS-generated data (CCTV, DMS, etc.), AVL, weather, CAD, and signal system data.

Incident Data

Most frequently shared incident data included event type, event location, lane closures, construction schedules, and notifications. The trends in providing and gathering of these data were similar. Most of the respondents (127 of 198) provided event type information (Figure 4).

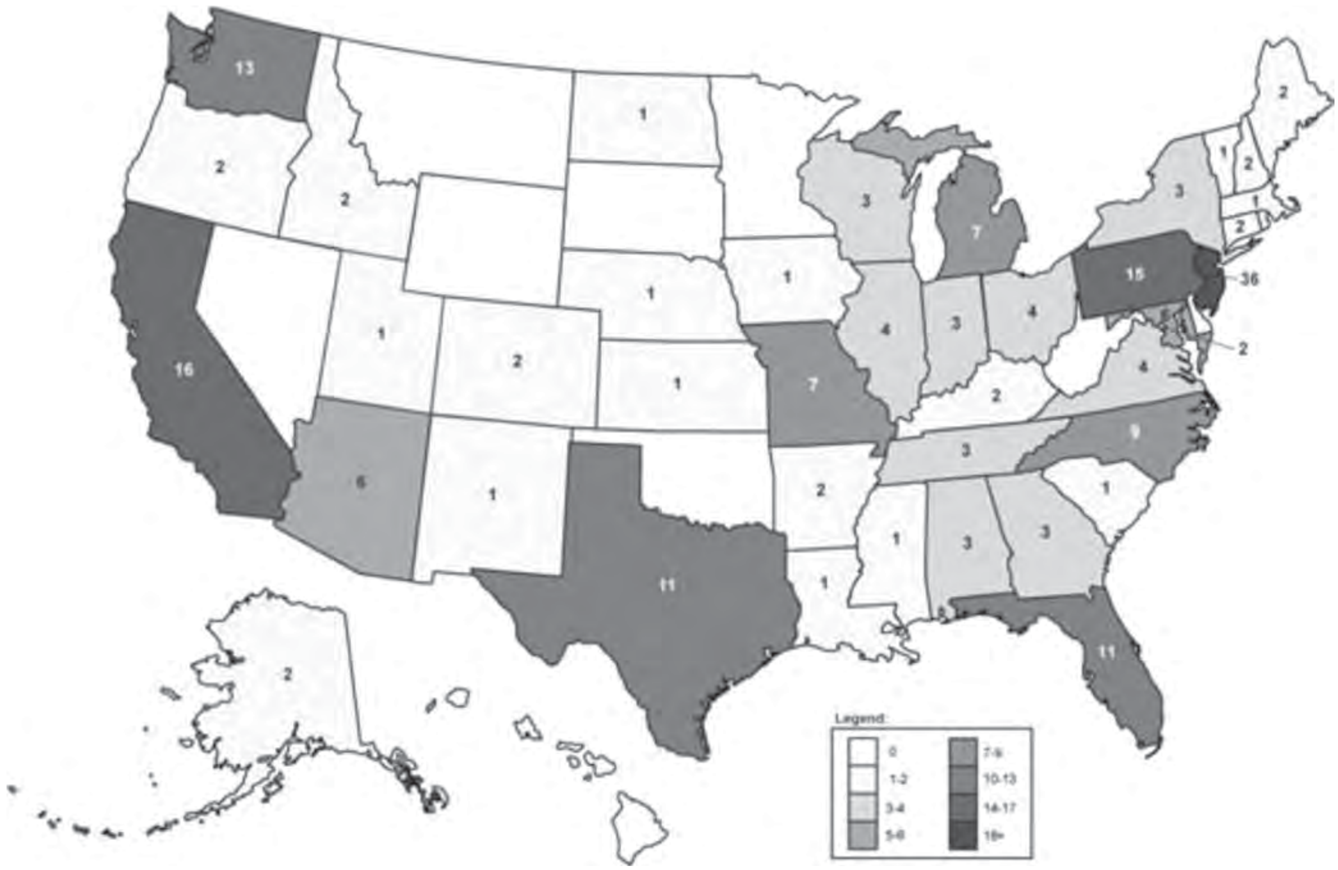

FIGURE 2 Number of respondents by state.

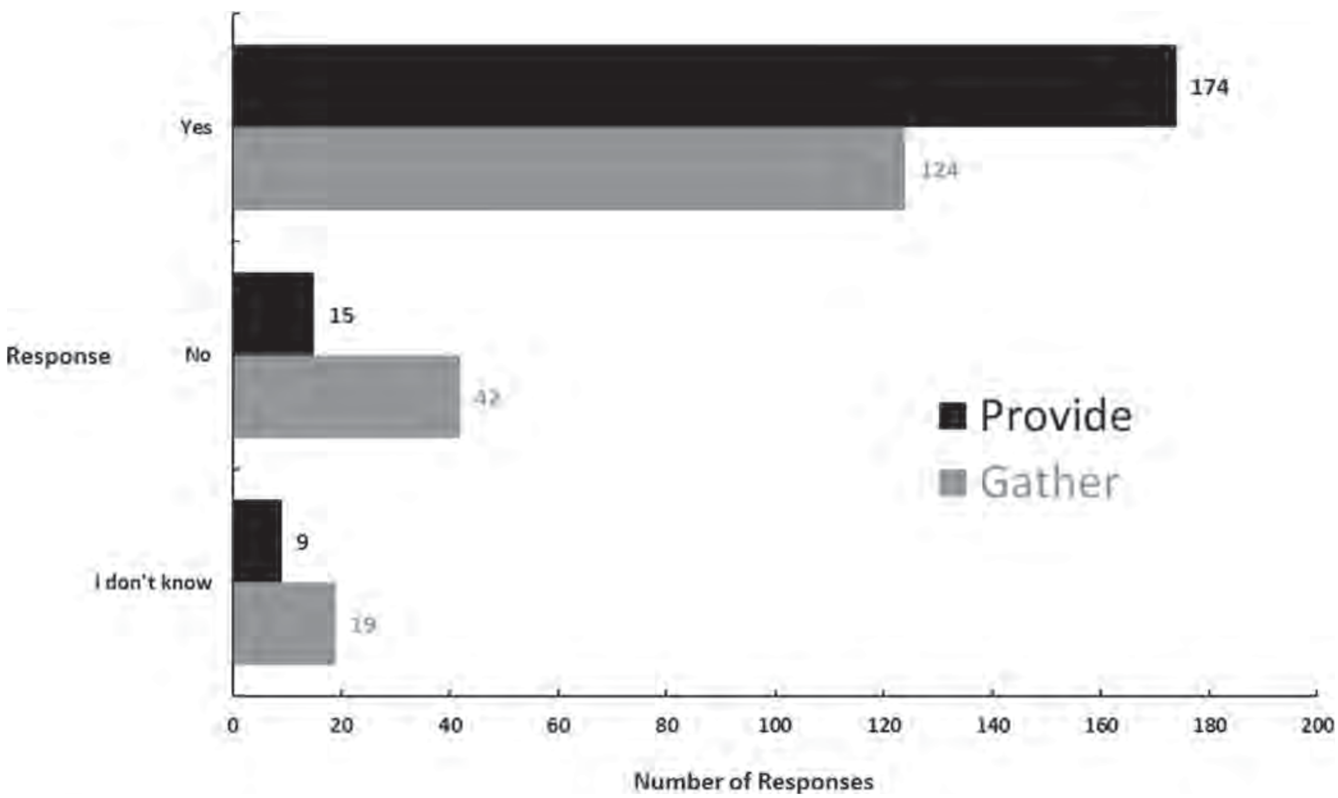

FIGURE 3 Agencies providing and gathering operations data—198 responses (Questions 3, 12).

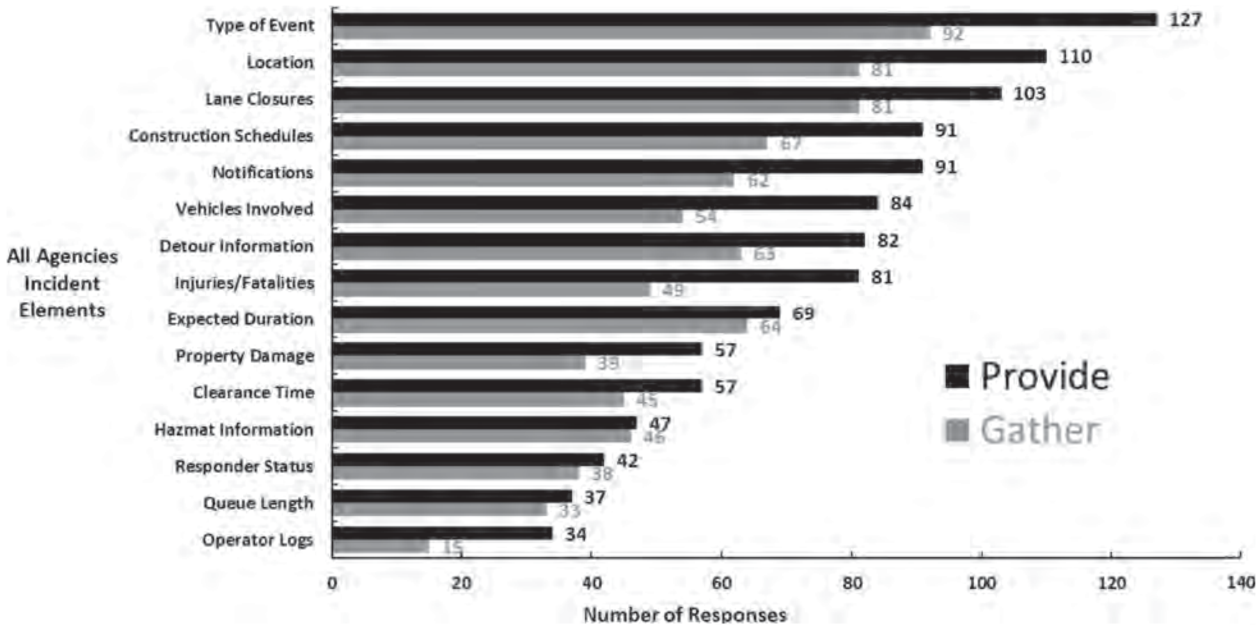

FIGURE 4 Incident elements shared by agencies in general—198 responses (Questions 4, 13).

Although state DOTs and transportation/transit/port authorities exhibited similar sharing trends to those shown in Figure 4, bus transit providers were significantly more focused on providing injury/fatality, vehicles involved, and property damage information related to incidents (Figure 5).

Detector Data

Sixty-one of 198 respondents reported that they provided speed data generated by traffic detectors and 59 of 198 that they provide volume data (Figure 6).

Although state DOTs and transportation/transit/port authorities were focused on providing speed and volume data, county and local agencies were more aggressive in providing volume information, with seven of 12 county DOTs (Figure 7), and five of 24 city/local DOTs providing volume data (Figure 8).

Probe Vehicle Data

Fifty-three of 198 surveyed agencies reported that they provide travel time and 47 of 198 provide speed information generated by probe vehicles. In addition, 41 of 198 gather

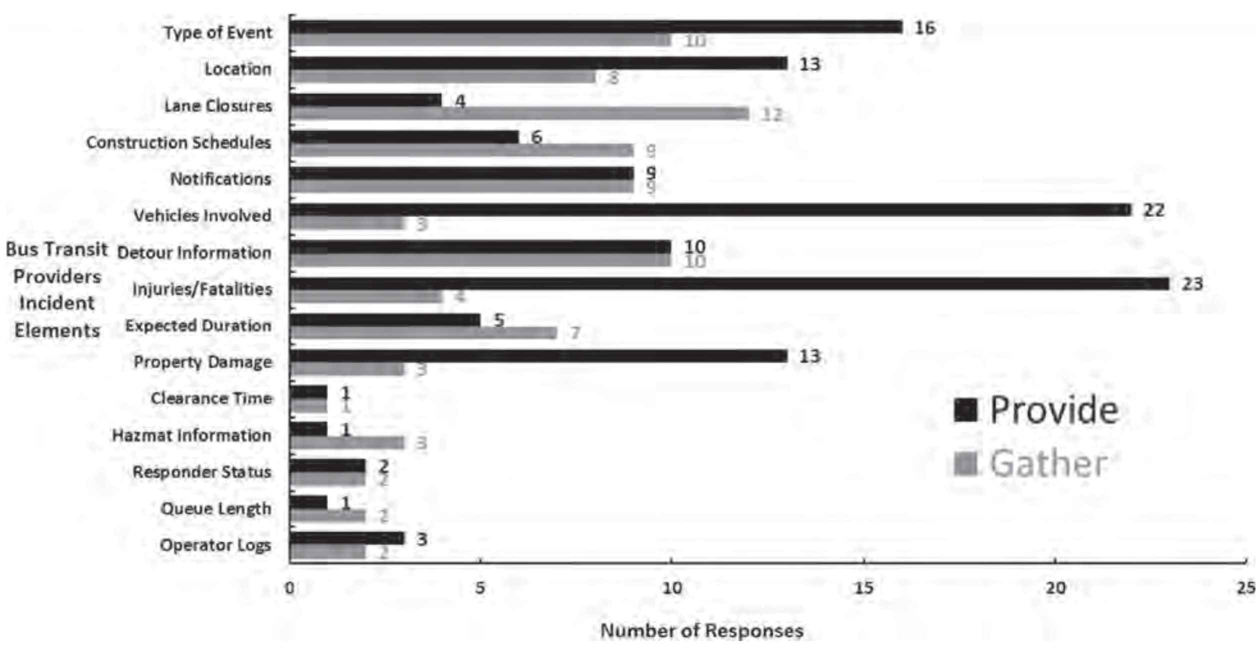

FIGURE 5 Incident elements shared by bus transit providers—40 responses (Questions 4, 13).

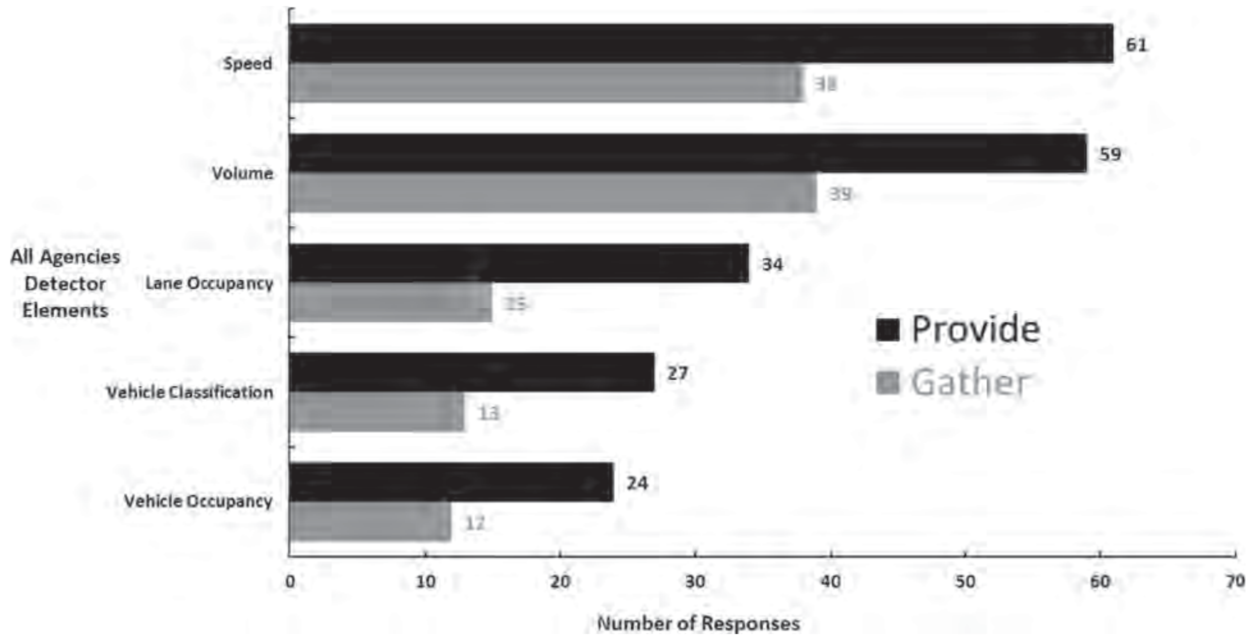

FIGURE 6 Detector elements shared by agencies in general—198 responses (Questions 4, 13).

travel time and 34 of 198 gather speed information generated by probe vehicles. Several respondents indicated that they provided and gathered other probe-related data, but did not specify what specific data elements (Figure 9).

Automated Vehicle Location Data

AVL data sharing trends appear to differ significantly from event, detector, and probe data sharing trends. This is a result of AVL technology only recently becoming more integrated in the state DOT operations, while transit providers have been utilizing some version of this technology to track their vehicles for several decades. Bus transit providers were most active in providing transit AVL, with 20 of 40 respondents providing these data (Figure 10), whereas only 23 of 86 state DOT respondents provided AVL data related to maintenance vehicles (Figure 11).

Weather Data

Most of the survey participants that dealt with weather data were more likely to gather weather data than to provide it (Figure 12). This is most likely because, while important in

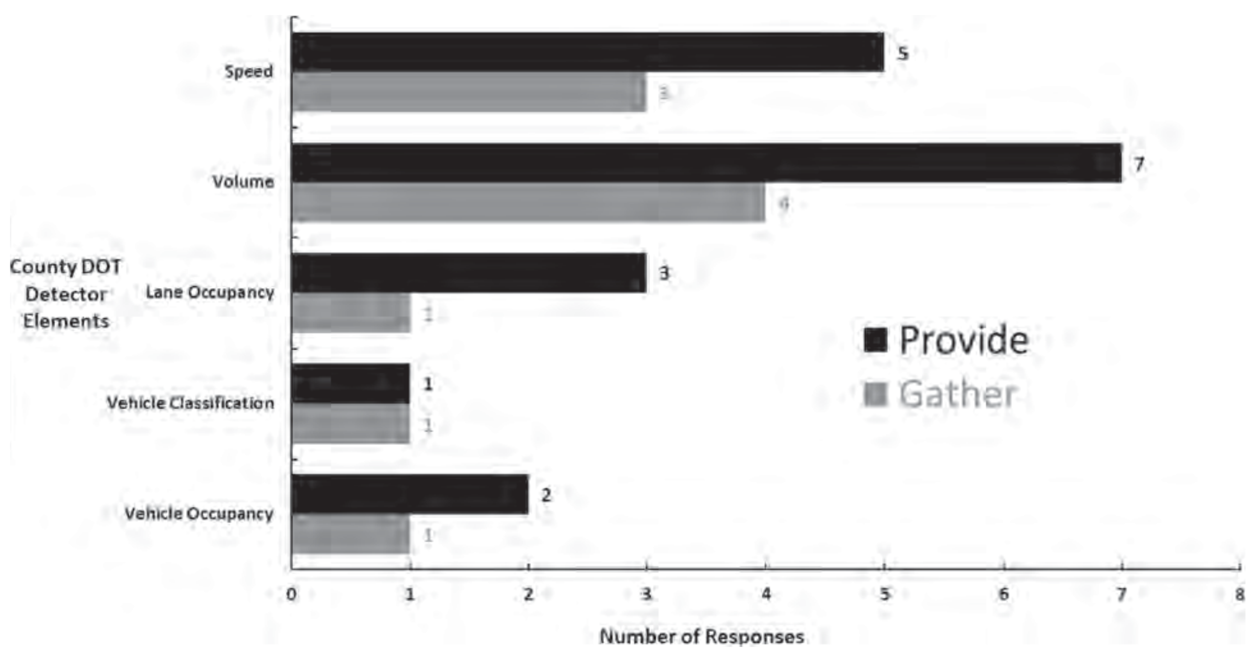

FIGURE 7 Detector elements shared by county DOTs—12 responses (Questions 4, 13).

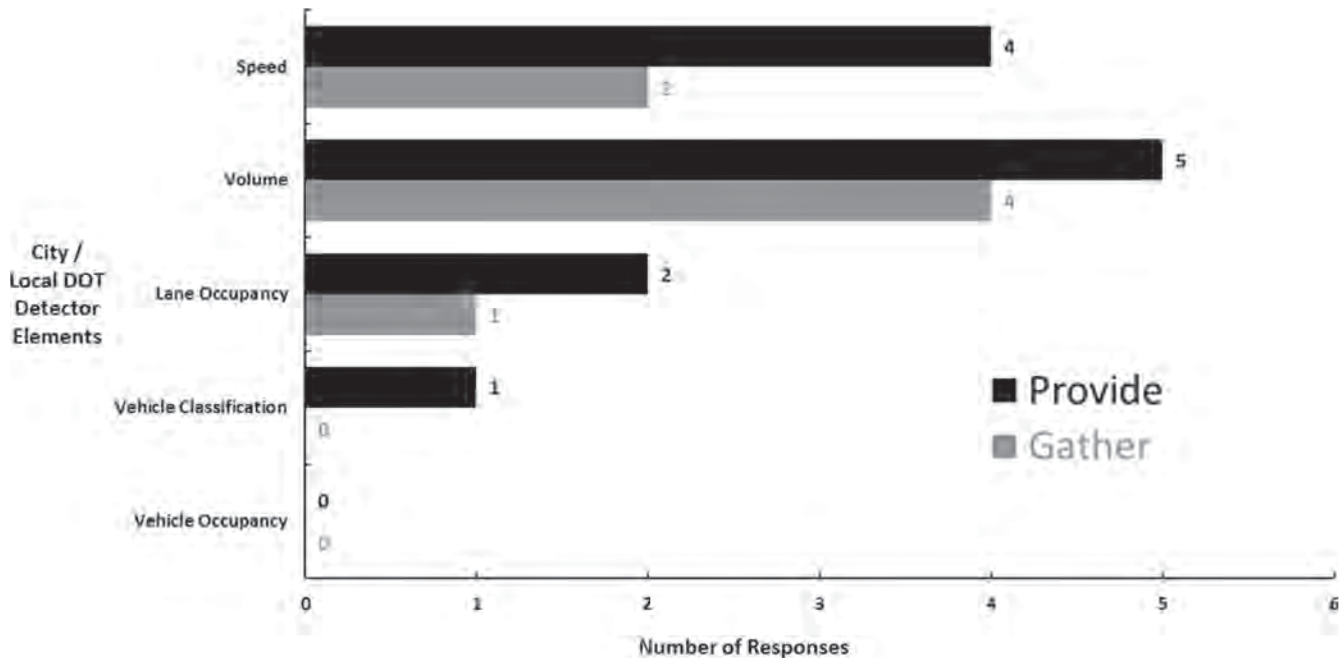

FIGURE 8 Detector elements shared by city and local DOTs—24 responses (Questions 4, 13).

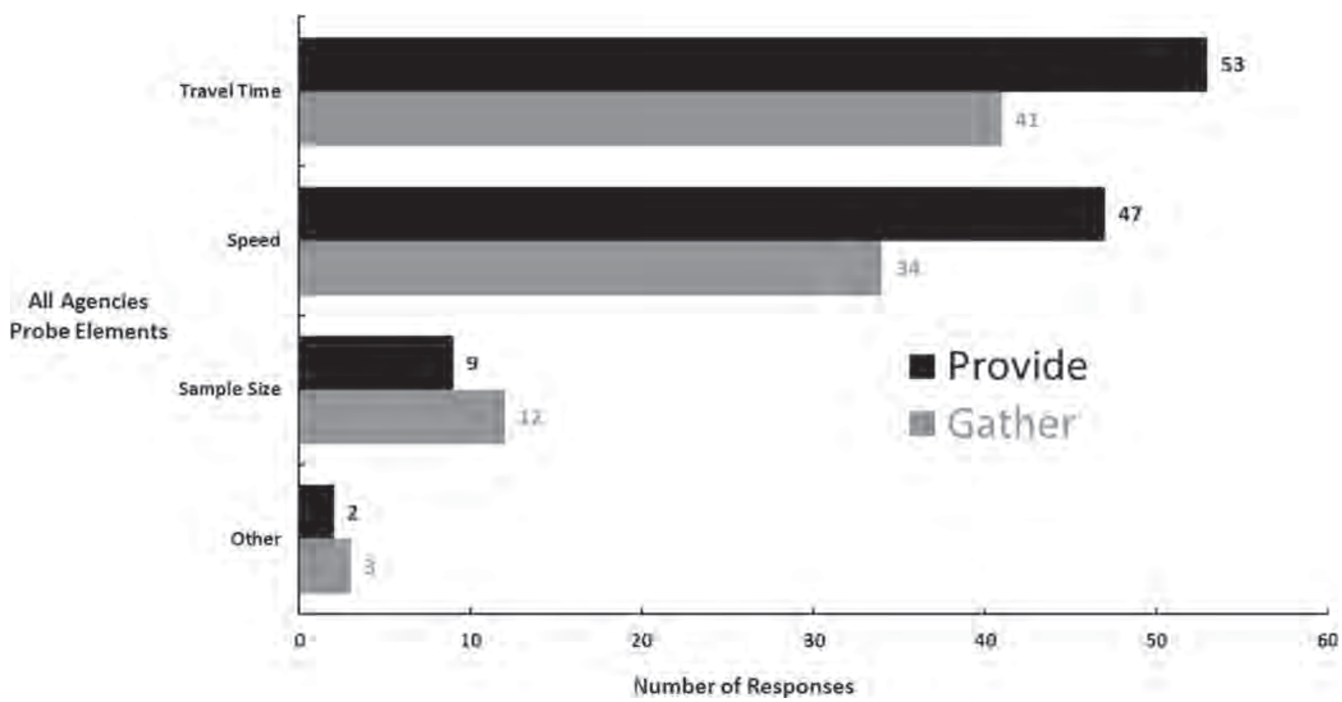

FIGURE 9 Probe vehicle elements shared by agencies in general—198 responses (Questions 4, 13).

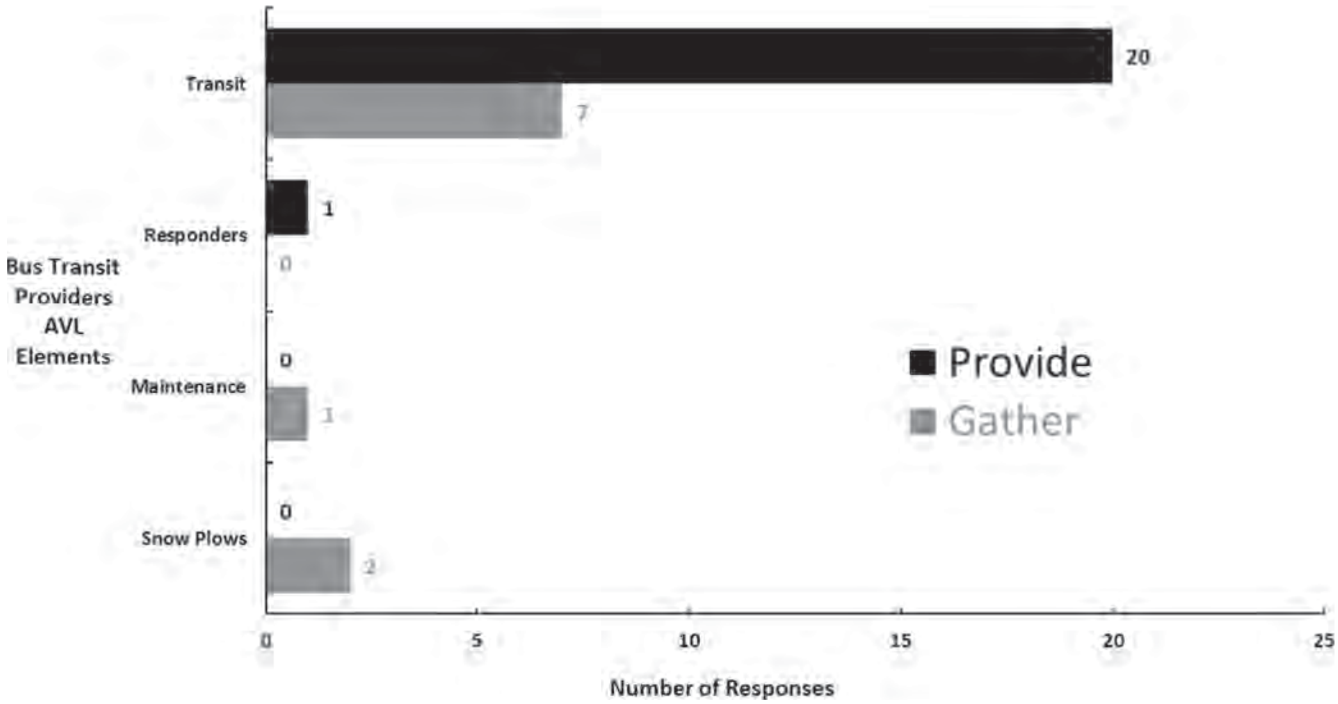

FIGURE 10 AVL elements shared by bus transit providers—40 responses (Questions 4, 13).

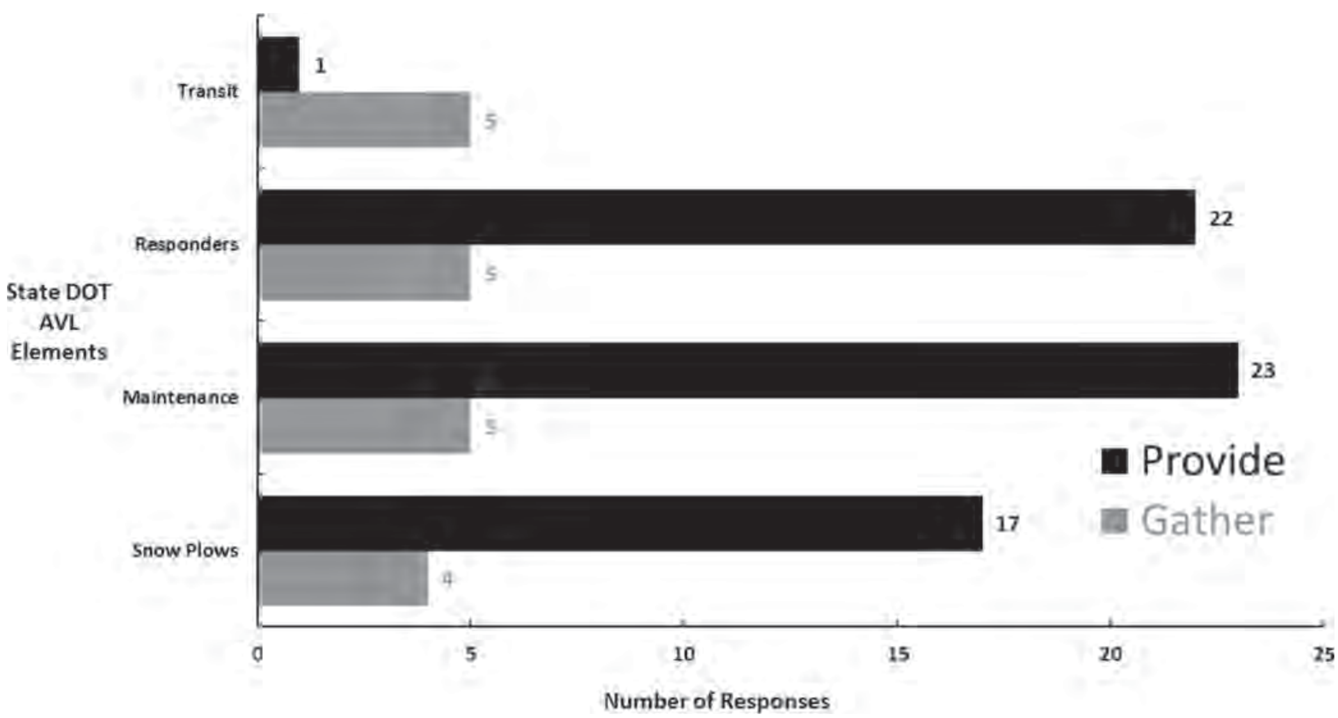

FIGURE 11 AVL elements shared by state DOTs—86 responses (Questions 4, 13).

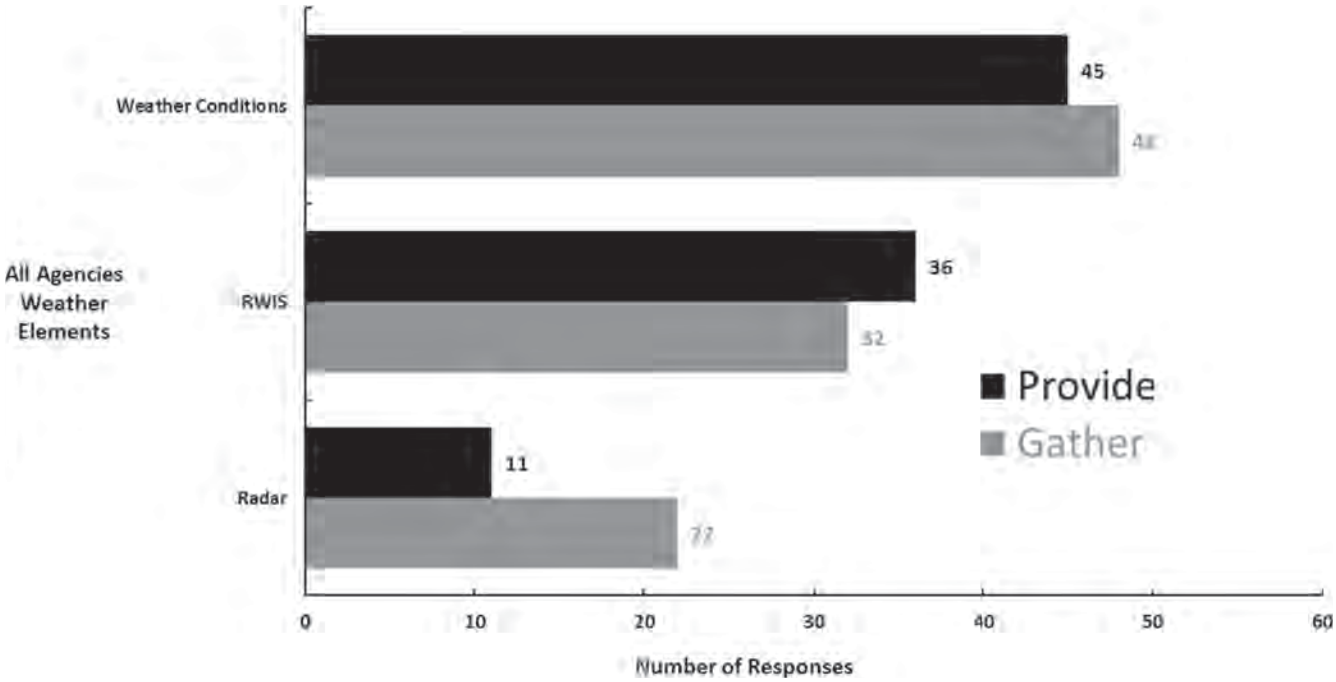

FIGURE 12 Weather elements shared by agencies in general—198 responses (Questions 4, 13).

transportation operations, weather data are mostly generated by other sources and then integrated by the transportation community for enhanced situational awareness.

Computer-Aided Dispatch Data

Similar to weather data, most of the survey participants were consumers of CAD data. The CAD data of most interest was supplied by law enforcement, primarily as a result of its relation to transportation operations, as well as on-going work on integration of law enforcement CAD with Advanced Traffic Management System (ATMS) in some states (Figure 13).

Not surprisingly, three of the four state police respondents reported that they provided more CAD data than they acquired from others (Figure 14).

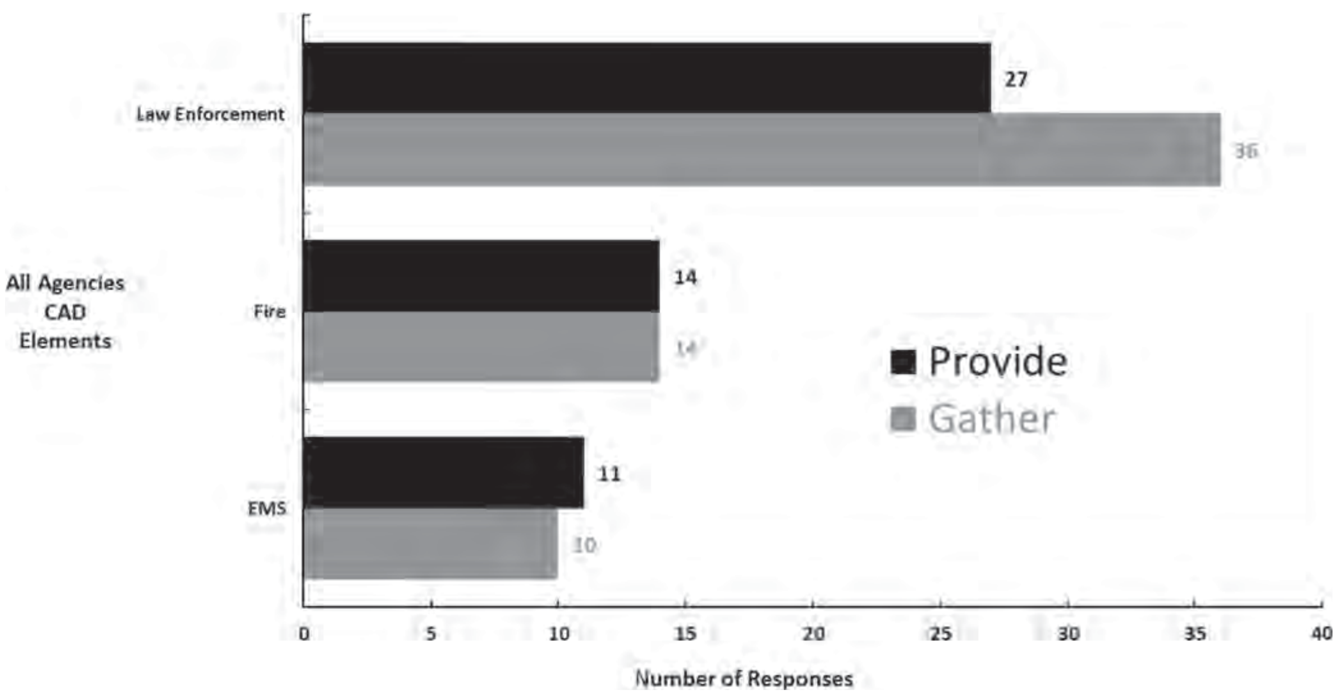

FIGURE 13 CAD elements shared by agencies in general—198 responses (Questions 4, 13).

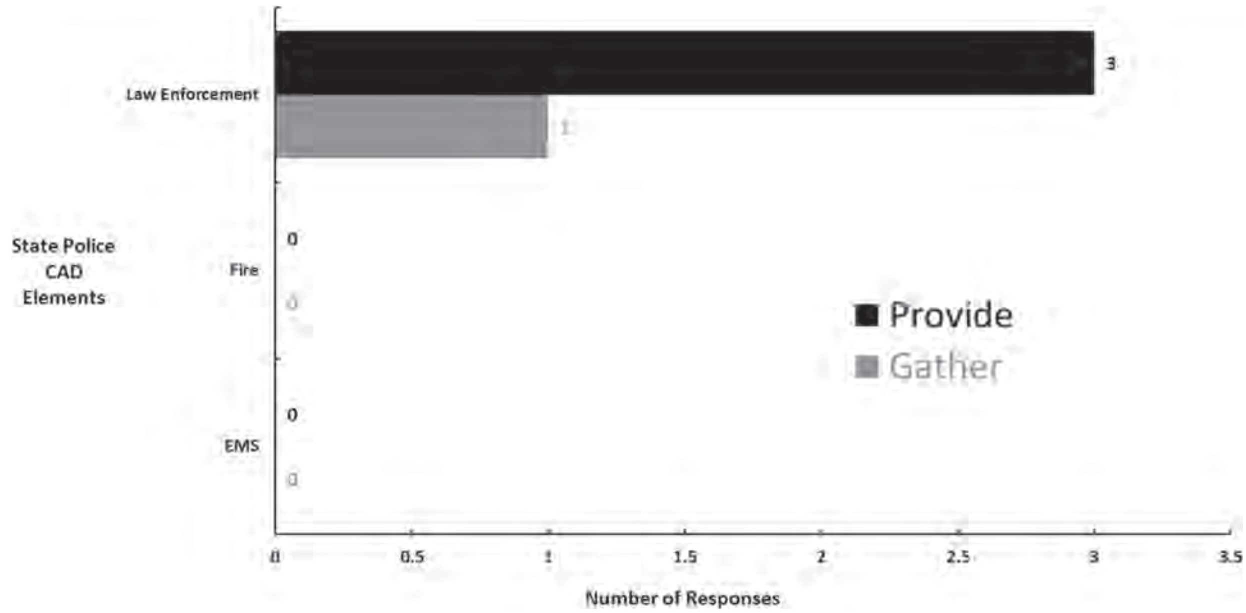

FIGURE 14 CAD elements shared by state police—4 responses (Questions 4, 13).

Signal System Data

City and local agencies were the most active in supplying signal system data, followed by county and state DOTs (Figure 15). Primary consumers of signal system data included bus transit providers and MPOs.

DATA EXCHANGE METHODS AND FREQUENCIES

The survey examined the different methods organizations use to provide data to and gather data from others. These methods ranged from complex Center-to-Center (C2C) feeds to more traditional telephone and radio communication and hard copy forms. Most organizations used multiple methods to provide data to others, with many still relying on e-mail communication as their primary means (Figure 16). E-mail was unintentionally not offered as a possible data gathering method, resulting in no information related to gathering data by means of e-mail to appear in associated figures.

Bus transit providers in particular relied on e-mail, with 30 of 40 respondents reporting that they use e-mail to send data to others (Figure 17).

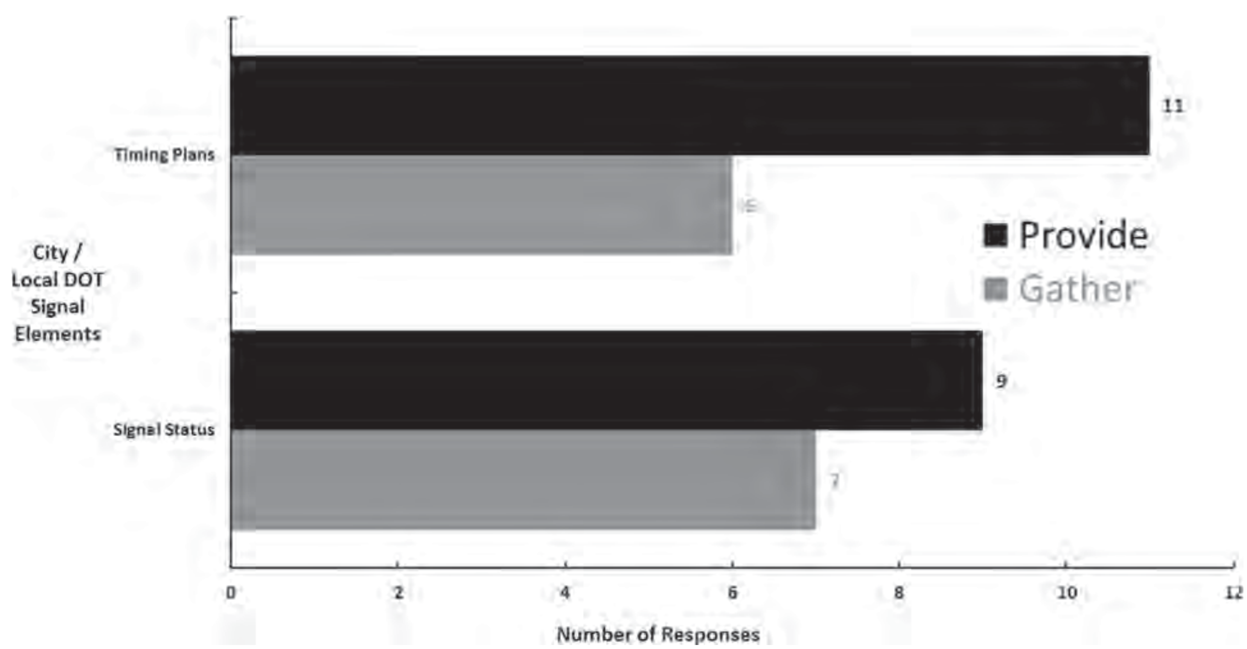

FIGURE 15 Signal elements shared by city and local DOTs—24 responses (Questions 4, 13).

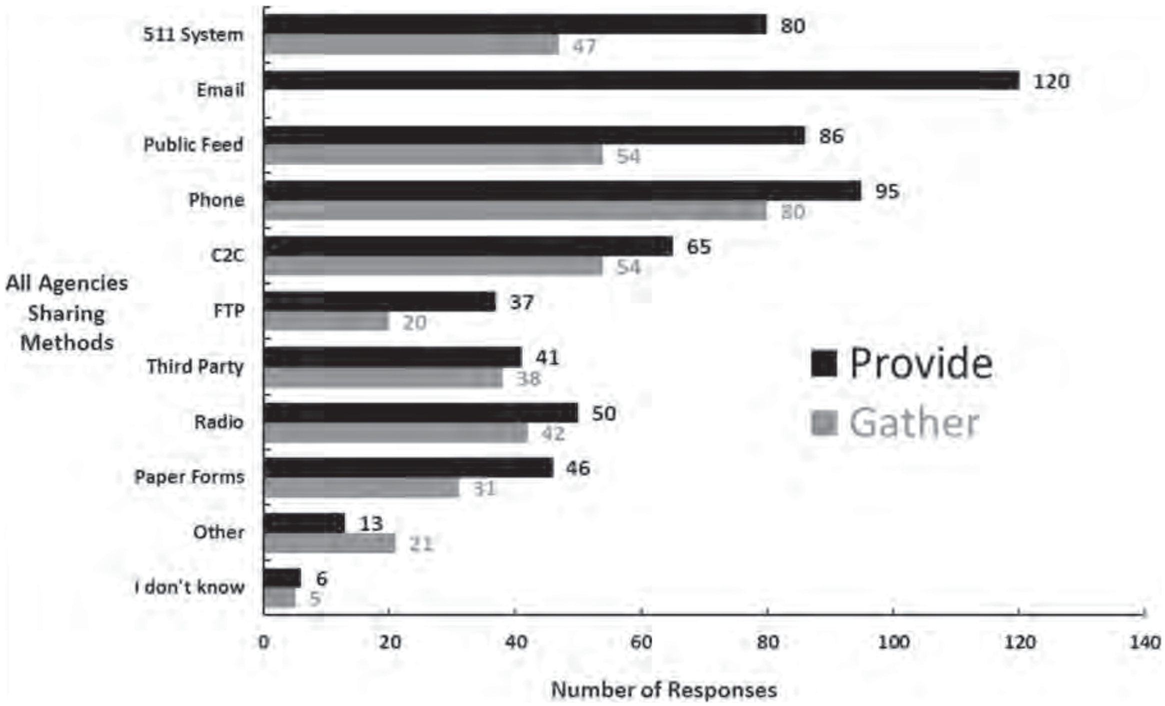

FIGURE 16 Sharing methods utilized by agencies in general—198 responses (Questions 5, 14).

Public feeds, C2C, and 511 systems were often listed together as the means of providing the data. Surveyed county DOTs were more progressive in using C2C, with 6 of 12 respondents reporting this to be one of the methods of providing data. State DOTs relied on 511 systems (61 of 86) and public feeds (47 of 86) to distribute data (Figure 18). Despite major developments in digital data feed technologies, telephone and radio were still the most common methods of providing information to other organizations.

Other methods identified by survey respondents included text alerts, surveys and reports, social media, and face-to-face

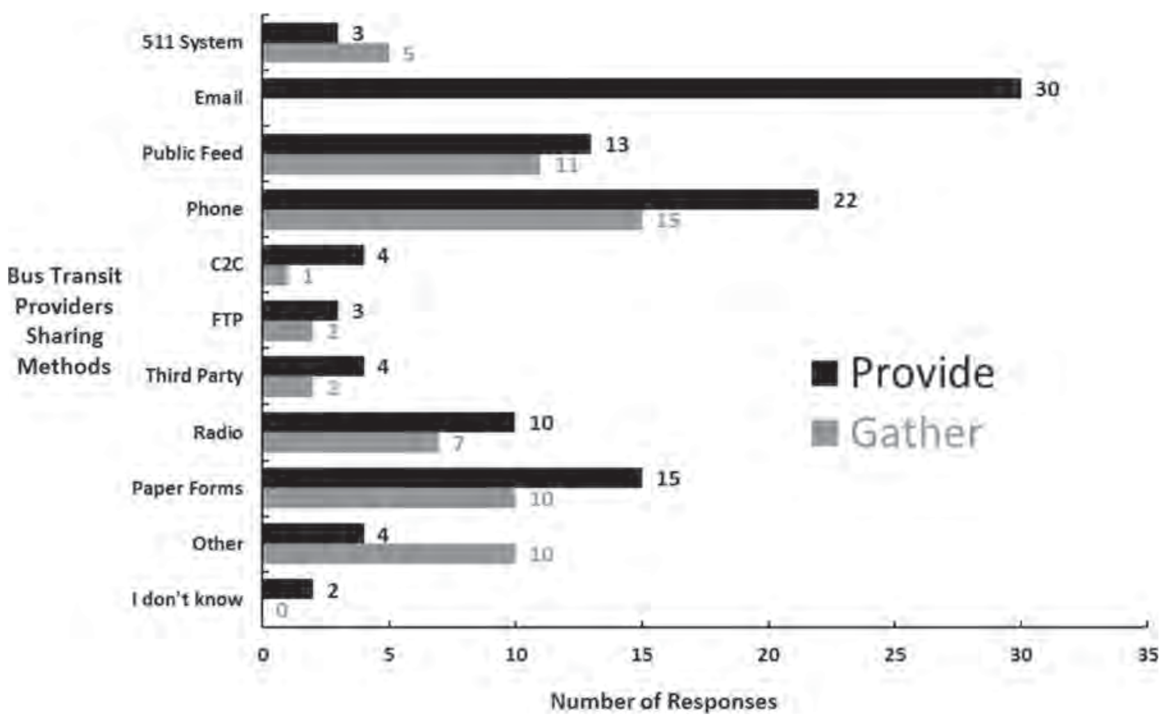

FIGURE 17 Sharing methods utilized by bus transit providers—40 responses (Questions 5, 14).

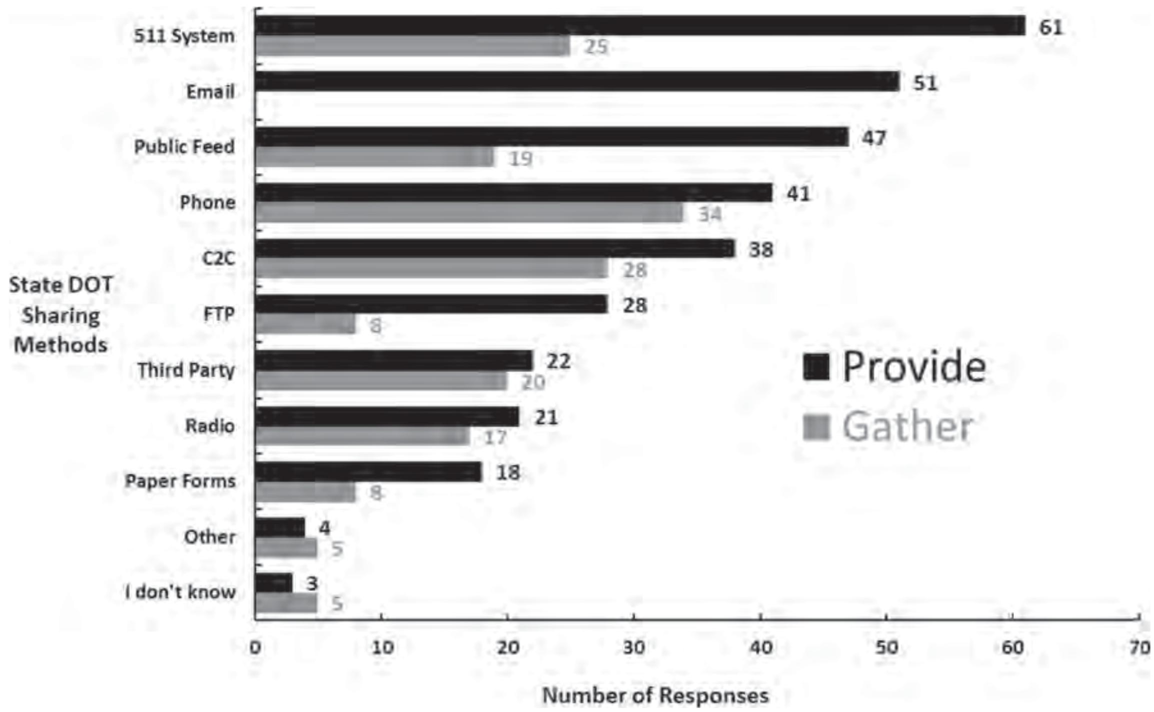

FIGURE 18 Sharing methods utilized by state DOTs—86 responses (Questions 5, 14).

exchanges. Maricopa County DOT in Arizona and the MATOC program in the National Capital Region were the two organizations that reported they utilize social media to distribute information to others even though follow-on interviews suggested other agencies were starting to increase their use of social media.

Slightly less than half of the survey respondents (89 of 198) provided data continuously through some form of real-time or near real-time feeds. In addition to real-time and near real-time frequency, organizations often published reports and created data summaries on monthly, quarterly, and yearly intervals as well. Unlike state DOTs (Figure 19),

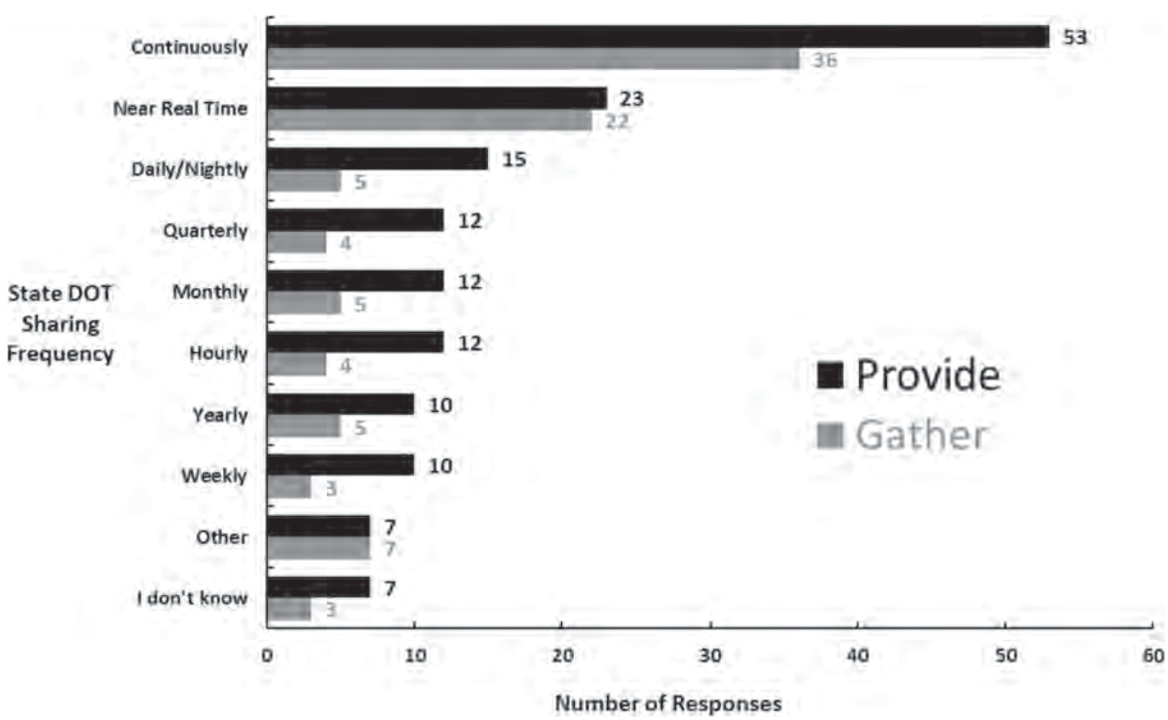

FIGURE 19 State DOTs data sharing frequency—86 responses (Questions 7, 16).

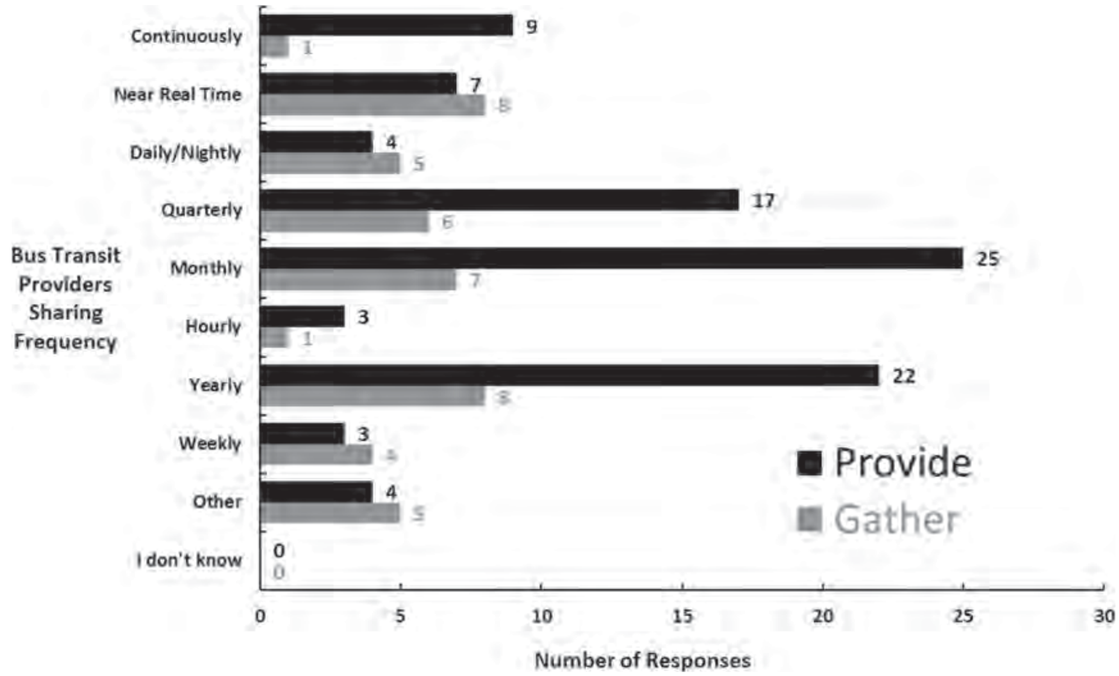

FIGURE 20 Bus transit providers data sharing frequency—40 responses (Questions 7, 16).

most bus transit providers reported that they supply data in monthly (25 of 40), quarterly (17 of 40), and yearly (22 of 40) periods (Figure 20). Several respondents mentioned that they provide data only on request or as a part of other activities, such as the development of emergency preparedness plans, research, or during regular operating hours.

DATA SHARING AGREEMENTS

The survey showed that the majority of data sharing efforts are fairly informal with respect to organizational agreements. Most organizations provided data to others either with no formal agreements, implied good faith, or with use of MOUs (Figure 21).

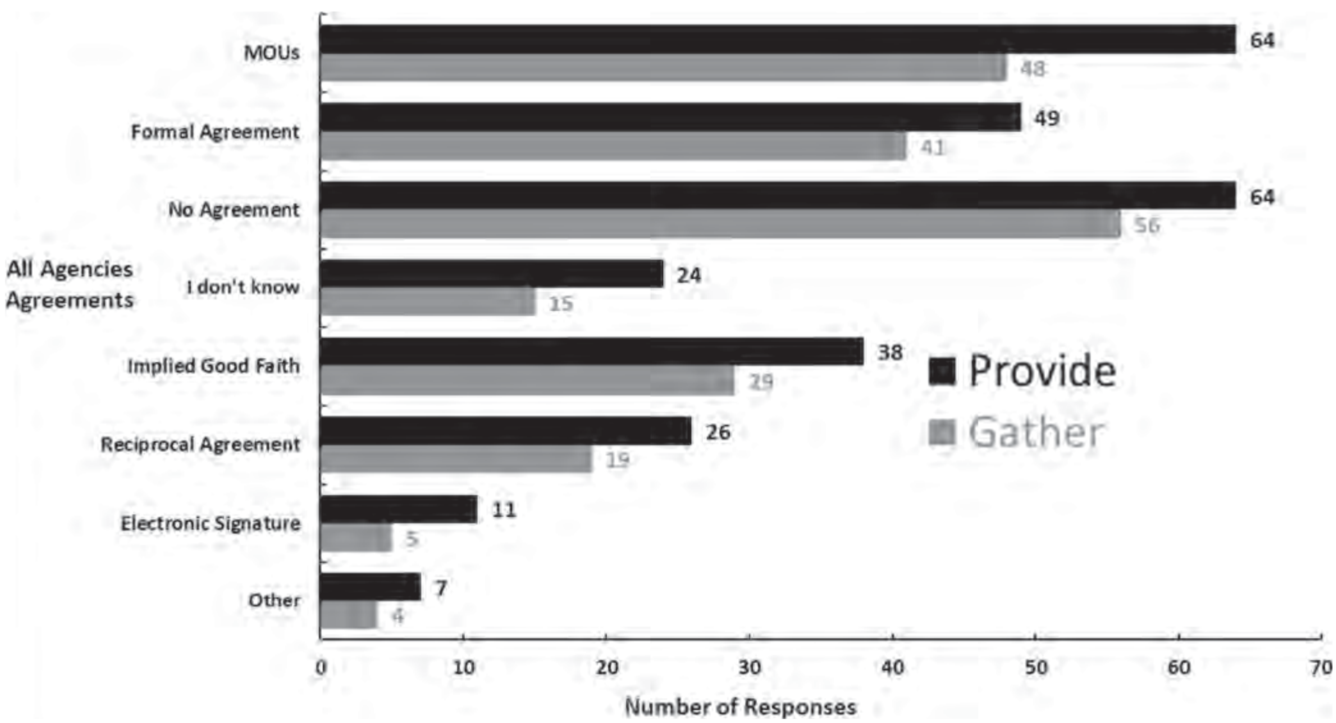

FIGURE 21 Agreements utilized by agencies in general—198 responses (Questions 6, 15).

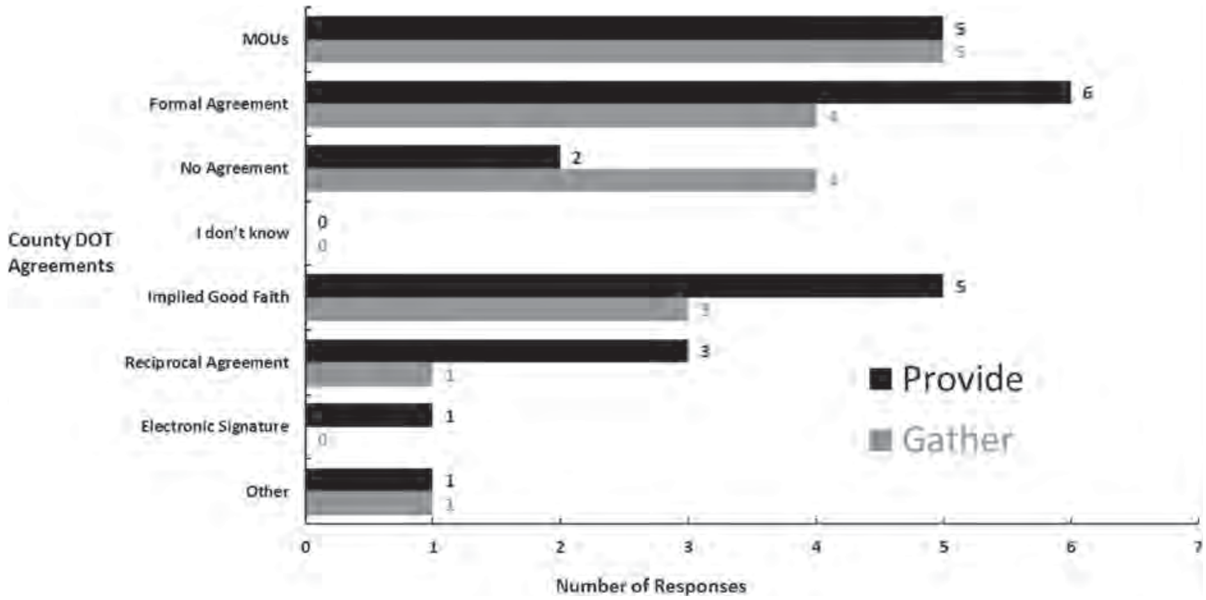

FIGURE 22 Agreements utilized by county DOTs—12 responses (Questions 6, 15).

County DOTs were most likely to require formal data use agreements (DUAs) (six of 12), followed closely by bus transit providers (18 of 40), as seen in Figure 22.

Similarly, most organizations gathered data from other organizations with no formal agreements, with implied good faith, or with the use of MOUs. It is important to note that organizations that provided data in informal ways to other agencies also had formal DUAs with their data consumers. Several survey respondents identified other guidelines for data sharing, including National Transit Database Rules of Behavior, Joint Operations Policy Statement agreements, and regional operations guidelines (as in case of AZTech in Arizona).

PERCEIVED BENEFITS OF PROVIDING DATA

When asked to identify reasons for providing data to others or gathering data from others, most organizations noted multiple benefits, with 125 citing traveler information and 109 safety as the primary reasons. Economic benefits to the traveler, performance measurement, and enhancing the visibility of the program were other reasons organizations used to justify providing data to others (Figure 23). Several respondents noted that grant requirements, general regional coordination, and even simply "because they can" as reasons for providing data to others. One agency stated that they gather data for the sake of "reconciliation of funding agreements in other MOUs for reimbursement."

PERCEIVED OBSTACLES TO PROVIDING DATA

The survey asked participants to identify obstacles to providing operations data to others. Most respondents found this question not applicable because they were already providing "all the data they have." However, other respondents cited a lack of funding, sensitivity of operations data, and "no data requestors" as primary obstacles (Figure 24). Local agencies and bus transit providers reported that a lack of requestors was one of the main reasons they may not provide data. On the other hand, county DOTs generally struggled with a lack of funding and technical challenges.

Despite these optimistic survey responses, the large number of follow-up interviews resulted in slightly different perspectives on the severity and depth of the obstacles—all of which are discussed in chapter four.

Several respondents offered less traditional obstacles, including delays in executing agreements, internal institutional issues in receiving organizations, and organizational policies. Additional technical issues such as data incompatibility, data format inconsistencies, outdated technology, proprietary encoding, and the ability to transform incoming data into meaningful information were also mentioned and are discussed further in chapter four.

DESIRED DATA ELEMENTS

The survey asked respondents to identify data elements their organization would be interested in acquiring if available. Overall, travel time, incident clearance time, and probe-generated speed data were top three elements (Figure 25). Law enforcement CAD data were cited by 46 of 198 respondents, making it one of the top ten desired elements, even though the survey showed that CAD data were one of the least available data elements.

Desired data element patterns varied by each category of respondents with state DOTs; county, local, and city agencies;

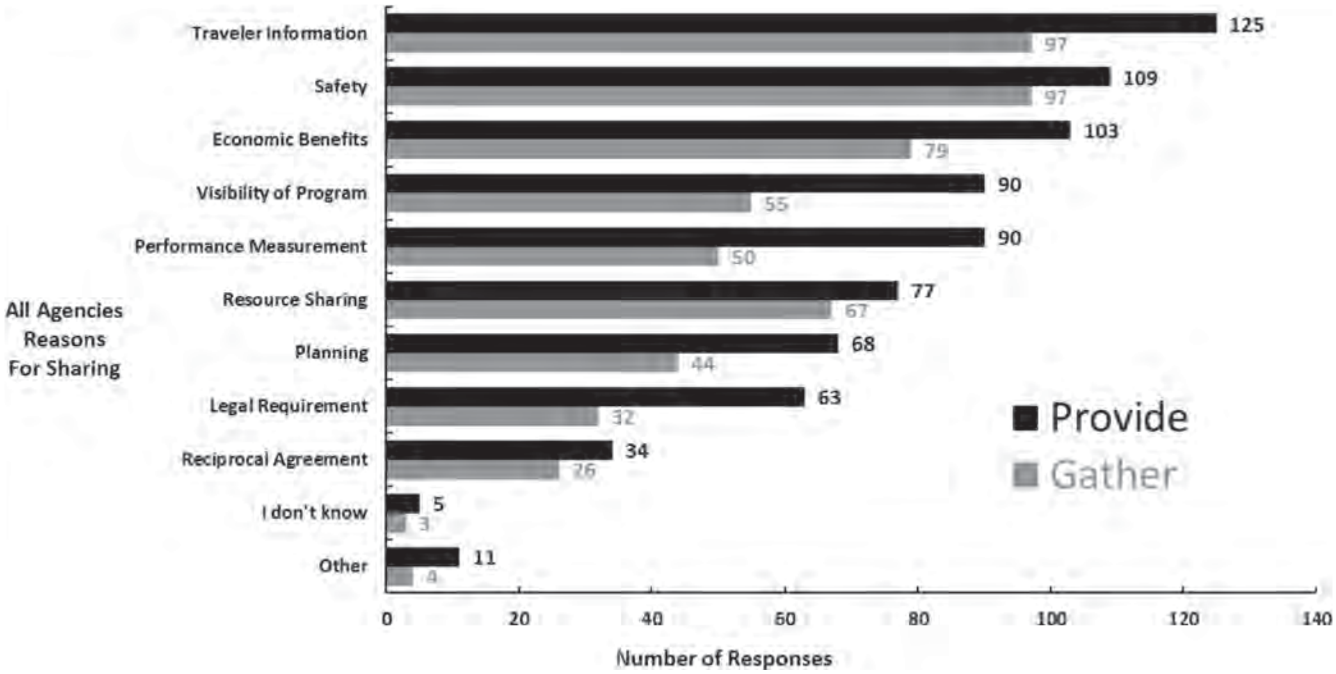

FIGURE 23 Reasons for sharing by agencies in general—198 responses (Questions 9, 18).

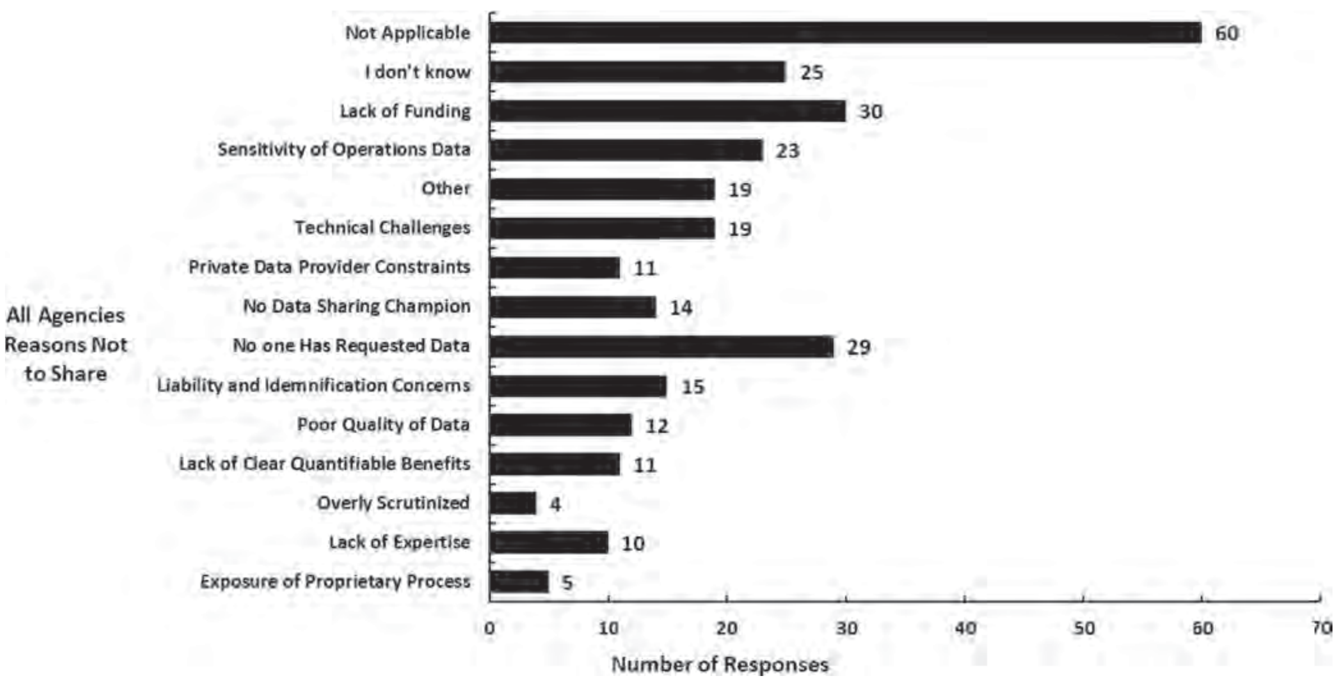

FIGURE 24 Data sharing barriers for agencies in general—198 responses (Question 10).

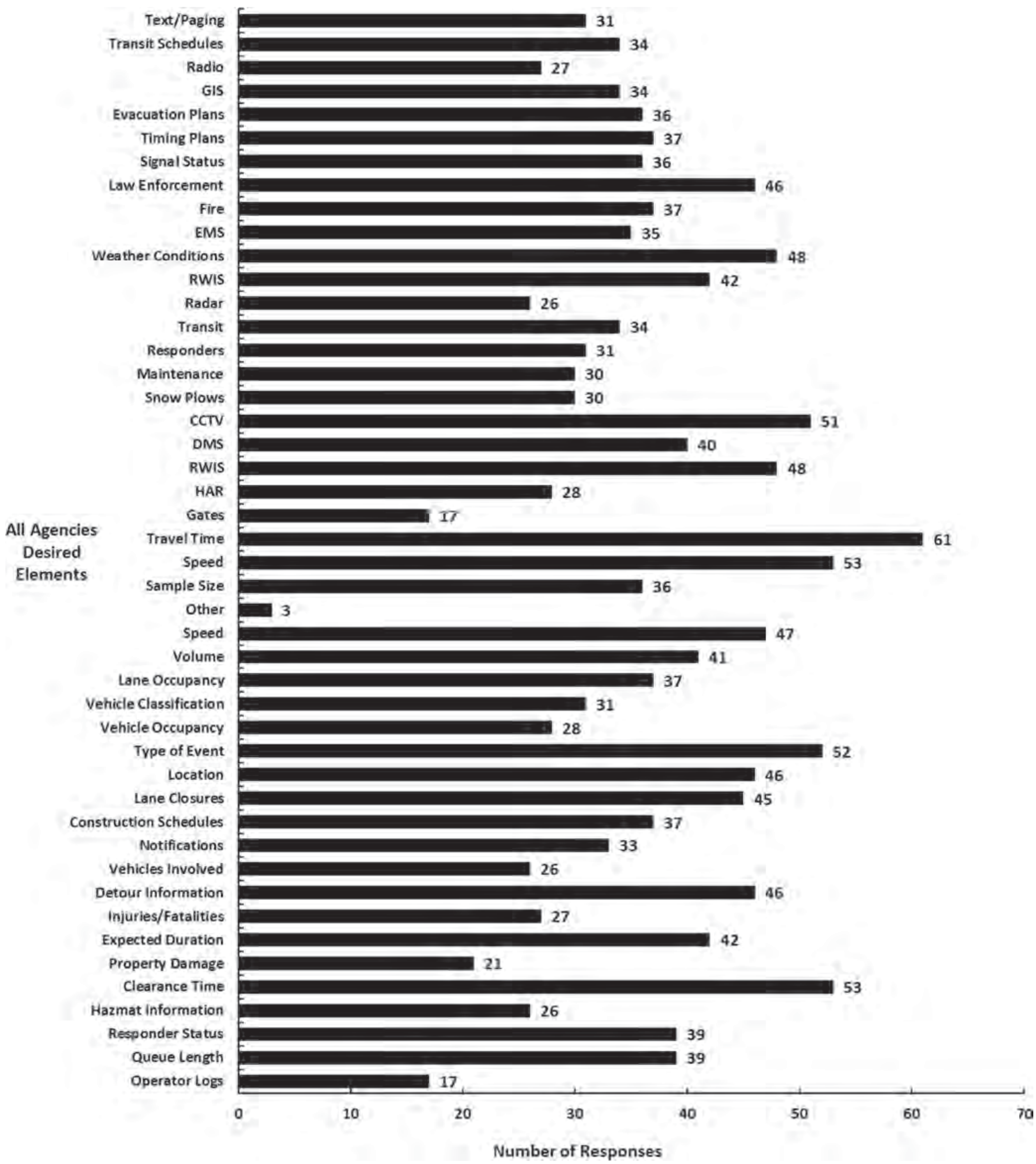

FIGURE 25 Desired data elements in general—198 responses (Question 19).

and transportation/transit/port authorities primarily interested in travel times and speeds, while bus transit providers were primarily interested in transit schedules, and MPOs were looking for CAD data generated by the law enforcement, fire departments, and EMS. For detailed results of Question 19 refer to Appendix D: Detailed Survey Results.

SUMMARY OF SURVEY RESULTS

The survey was distributed to a wide audience and resulted in 198 acceptable responses. All but nine states were represented, with respondents originating from state DOTs; county, local, and city agencies; police agencies; and transit providers.

The most common data elements provided by state DOTs included event types, event locations, lane closures, CCTV video, and other event-related information. Unlike state DOTs, transit agencies primarily provided AVL data. Local and county agencies differed from state DOTs in that they provided more signal systems-related data.

The second most common elements state DOTs provided were ITS device-generated data such as DMS messages, vehicle speed, and traffic volume. According to the survey, the least frequently provided data included CAD information, although CAD data were ranked high on the list of "wish to receive" by most respondents. However, it is important to note that law enforcement, fire and rescue, and EMS, all of whom are primary CAD data providers, were underrepresented in survey responses; only 11 of 198.

For agencies gathering data from others, the most common data included expected incident durations, weather conditions, hazmat information, and law enforcement CAD data. Transit agencies most often gathered lane closure information, detour information, and construction schedules, all of which are critical to on-time performance for buses and rail.

Most of the data sharing efforts occurred in real time or near real time with no formal agreements. Most frequently agencies shared data under implied good faith or MOUs. Transit agencies were more likely to share data in monthly, quarterly, or yearly cycles. Agencies cited traveler information and safety as primary reasons for sharing data. The most frequent obstacles to sharing included a lack of funding, sensitivity of operations data, and "no data requestors."

CHAPTER FOUR

SYNTHESIS OF CURRENT BUSINESS CASES

Based on the findings of the web-based survey and the literature review, a diverse set of TMCs, partnerships, law enforcement, and transit providers were interviewed from a cross section of the country. Twenty-six interviews were conducted across the United States and in the Netherlands (Figure 26). The agencies were chosen based on their responses to the screening survey, desire to be interviewed, and input from topic panel subject matter experts. The majority of the interviews were conducted by means of conference calls; however, approximately 20% of the interviews were in person. A list of agencies and individuals interviewed can be found in Appendix B.

Table 1 outlines the more frequently cited benefits from information sharing along with at least one example from this report of where that benefit can be found.

Additional key findings of these telephone and face-to-face interviews are summarized here and include both the business cases and benefits of operational data sharing. Issues that hinder sharing are discussed in chapter five.

INTERVIEW FINDINGS

Multi-State, Multi-Agency Data Sharing in the National Capital Region

The MATOC program is a partnership between transportation agencies in the District of Columbia, Maryland, and Virginia with the intention of improving safety and mobility in the region through information sharing, planning, and coordination. Clearing a road quickly requires responders to work together efficiently to accomplish the many tasks involved in TIM. The MATOC program's central mission is to share information between the DOTs, transit, media, and the public to ensure that each agency is aware of what is transpiring across borders so that appropriate actions can be taken to alert travelers in neighboring jurisdictions and help resolve an incident in a timely manner.

The primary way in which MATOC accomplishes its data sharing mission is through the Regional Integrated Transportation Information System (RITIS)—an automated operations data sharing platform. RITIS software collects, standardizes, and disseminates data to thousands of operations personnel throughout the region. It even includes "regional flags" on data elements that are deemed significant for regional coordination to ensure that operators do not miss important events.

A study of the MATOC program (*10*) quantified the benefits of information sharing and coordination for three sample incidents: high severity, medium severity, and low severity. Using RITIS and MATOC for a high-severity, major incident (e.g., a bus crash on I-66) resulted in a savings of more than $340,000 for area commuters, the breakdown of which can be seen in Figure 27.

This savings was the result of a decrease in emissions, fuel consumption, and lost time. This was a conservative analysis in that it did not account for savings resulting from secondary queues, secondary incidents, delay reduction from rubbernecking in the opposite direction, and the benefits of aggregate impacts of multiple, simultaneous incidents. Additional details on this methodology can be found in the full MATOC/RITIS case study in Appendix A.

Similar analysis also revealed substantial savings for medium- and low-severity events. This quantitative analysis is thought to be the first of its kind—calculating the actual benefits of four agencies sharing information to realize benefits that were not possible when acting independently.

In addition to the financial benefits, agencies are simply more capable than they used to be with respect to coordination, speed of notification, and overall situational awareness. Where agency maps previously essentially "stopped" at the state or jurisdiction borders, those same agencies can now see across these boundaries and be informed as to what is happening next door. No longer must operators wait for notification phone calls.

The visibility of multiple agency data in RITIS has led to improvements within each DOT. Now that one's data are widely accessible by many instead of just a few, the agencies are able to improve their data collection both in terms of quality and quantity as they now understand that others are observing and becoming increasingly reliant on their data. Similarly, the increased visibility of each agency's data has led to the additional support of transportation operations programs. The emergency management and first responder communities in the region are taking notice of what ITS are bringing to the table and are both enthusiastic and offering additional support of these transportation programs. These and other unanticipated results are a direct consequence of operations data sharing and an enhanced focus on access to information.

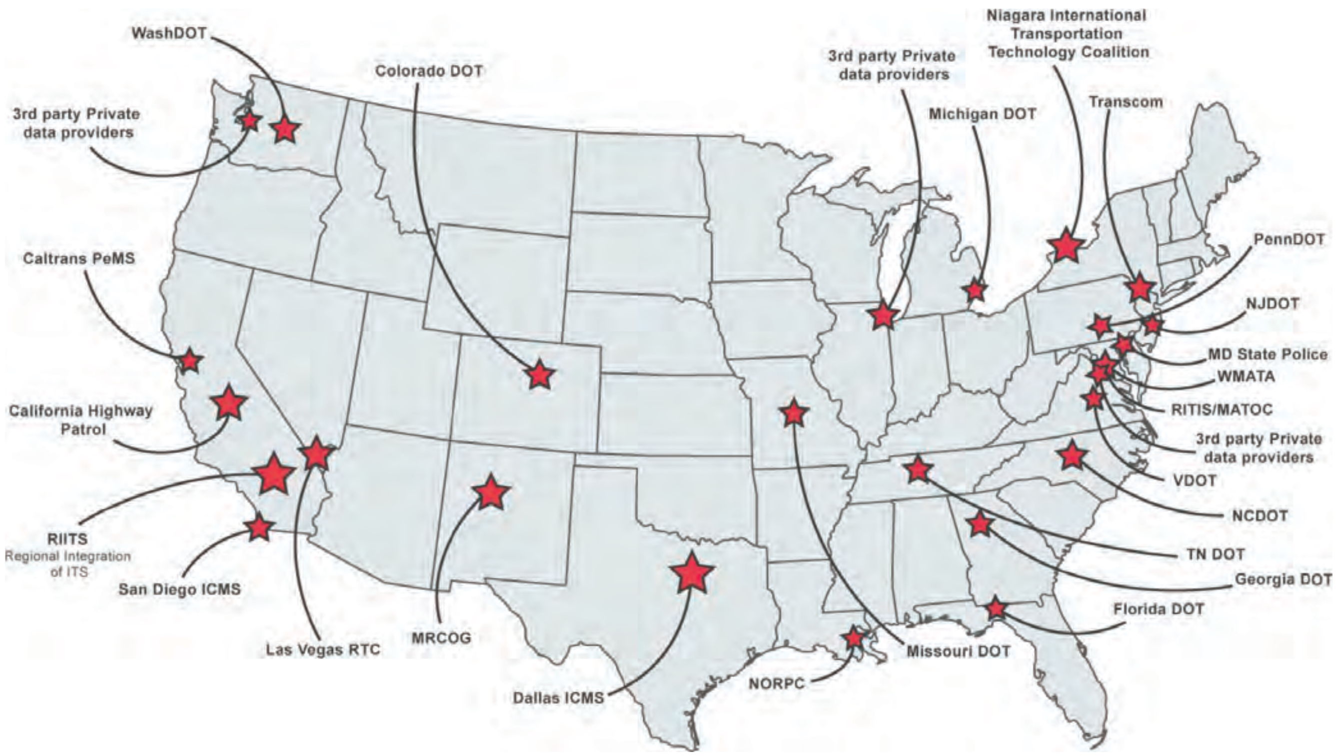

FIGURE 26 Map of agencies sought for in-depth interviews regarding operations data sharing.

TABLE 1
CITED BENEFITS OF INFORMATION SHARING

Cited Benefit	Case Study/Example
reduced incident detection, verification, response, and clearance times to quickly re-establish normal capacity and conditions;	MATOC/RITIS, California Highway Patrol, I-95 Corridor Coalition 3rd Party Probe Data, ICM,
enhanced safety for motorists and field/safety personnel;	I-95 Corridor Coalition 3rd Party Probe Data
reductions in the number of secondary crashes that occur as a result of the primary incident;	Not directly measured by any case study, but still referenced in the literature.
reduced motorist costs (fewer delays, decreases in travel times, increase in reliability, etc.);	MATOC/RITIS, ICM
reduced vehicle emissions;	MATOC/RITIS, ICM
reduced losses to business as a result of shipping delays or congestion around businesses that limit customer throughput;	Freight Data Integration
improved traveler information;	MATOC/RITIS, California Highway Patrol, I-95 Corridor Coalition 3rd Party Probe Data,
increased ridership on transit;	Literature Review: Rural Transit Traveler Information Study
increased customer satisfaction;	I-95 Corridor Coalition 3rd Party Probe Data,
reductions in operations, data collection, and staffing costs;	I-95 Corridor Coalition 3rd Party Probe Data,
increase in the perceived value of transportation operations through transparency and open data policies; and	MATOC/RITIS, California Highway Patrol,
allowing personnel to resume normal duties.	California Highway Patrol
Enhanced ability to produce performance reports	MATOC/RITIS, I-95 Corridor Coalition 3rd Party Probe Data,

Emissions: $ 11,910 (HC $920; CO $9,770; NO_x $840; CO_2 $380)
Fuel Consumption $ 4,570 (Car $3,520; Truck $1,050)
Value of Time $323,700 (Car $292,350; Truck $31,350)
Total = $340,180

FIGURE 27 Overview of the cost savings from data sharing and coordinated operations for a single, high-severity incident in the National Capital Region.

Because all of the regionally shared data are archived and made available in performance monitoring tools, the agencies are now able to rapidly report to state legislators, decision makers, and the public on the combined performance of the system in more meaningful ways. These reports are now automated, which significantly lessens the burden of data mining on the DOTs.

With respect to traveler information, new 511 deployments are now capable of providing information to motorists about conditions in neighboring states without having to transfer the caller to a separate 511 system, making for a significantly less frustrating user experience. In addition, social media is being utilized to disseminate traveler information across the region.

California Highway Patrol

Major metropolitan areas in California are no stranger to extremely heavy traffic, police activity, and major incidents that can inhibit travelers' and shippers' ability to move efficiently. With congestion affecting so many, information about traffic conditions is considered highly valuable. Major media outlets compete for the most useful traffic information to provide their customers. To accomplish this, both radio and television outlets invest in traffic helicopters, mobile road patrols, and operations centers that monitor radio scanners and telephone banks.

One of the major players in traffic accident detection and management is the California Highway Patrol (CHP). CHP is responsible for responding to 911 calls on most of California's major freeways. Radio, television, and even the DOTs acknowledge that CHP usually receives the first notice of any roadway incident and is often the first on the scene and the last to leave. Because of their presence, CHP are viewed as the primary information source for incident details. Therefore, all of the major media players, including some of the relevant agencies, call CHP regularly.

To give an example of the scale of traffic operations, on Wednesday, April 23, 2013, CHP responded to 2,939 traffic-related events, including those listed in Table 2. This table represents all CHP traffic-related incidents statewide and is typical of most weekdays.

CHP Public Affairs and other call-center staff were receiving such an overwhelming number of calls requesting additional information and/or data feeds that the organization eventually saw significant internal value in releasing all of its data. CHP wanted its dispatchers to be able to focus on their true job—dispatching—not answering calls from reporters and the public.

CHP decided to post an unfiltered XML feed of its transportation-related CAD data. These data include detailed text about each and every incident. It can be difficult to parse in an automated way; however, a reader who understands California's 10 codes can quickly understand how severe an incident is and keep up with the details throughout the cleanup process with relative ease.

With details of every incident now posted directly to the Internet, media and other public safety agencies no longer have a reason to directly contact CHP—tying up lines and personnel. Although there are no exact numbers available for the cost savings to CHP, it is clear that significant agency resources are now free to better handle their daily job duties. Similarly, the media and DOTs access to the real-time CAD data means that information is being disseminated to the public much more quickly than before, which ultimately helps to make better-informed travel, mode, and route-choice decisions and aids in DOT response.

Figure 28 is a screenshot from the public CHP Traffic Incident Information Page. The top portion shows all open

TABLE 2
TYPICAL WEEKDAY LOG OF INCIDENTS AS RECORDED BY CHP COMPUTER-AIDED DISPATCH SYSTEMS.

Incident Type	Number of Incidents on April 23rd, 2013
Obstructions/Debris/Other Hazards	1,336
Collisions	1,101
Hit and Runs	153
Animals on Road (both alive and dead)	84
Construction	83
Fires	62
Other	42
Car Fires	34
Signal Issues	28
Wrong Way Drivers	10
Fatalities	3
Jumpers	2
HazMat Spills	1
Total =	**2,939**

Source: RITIS data archive.

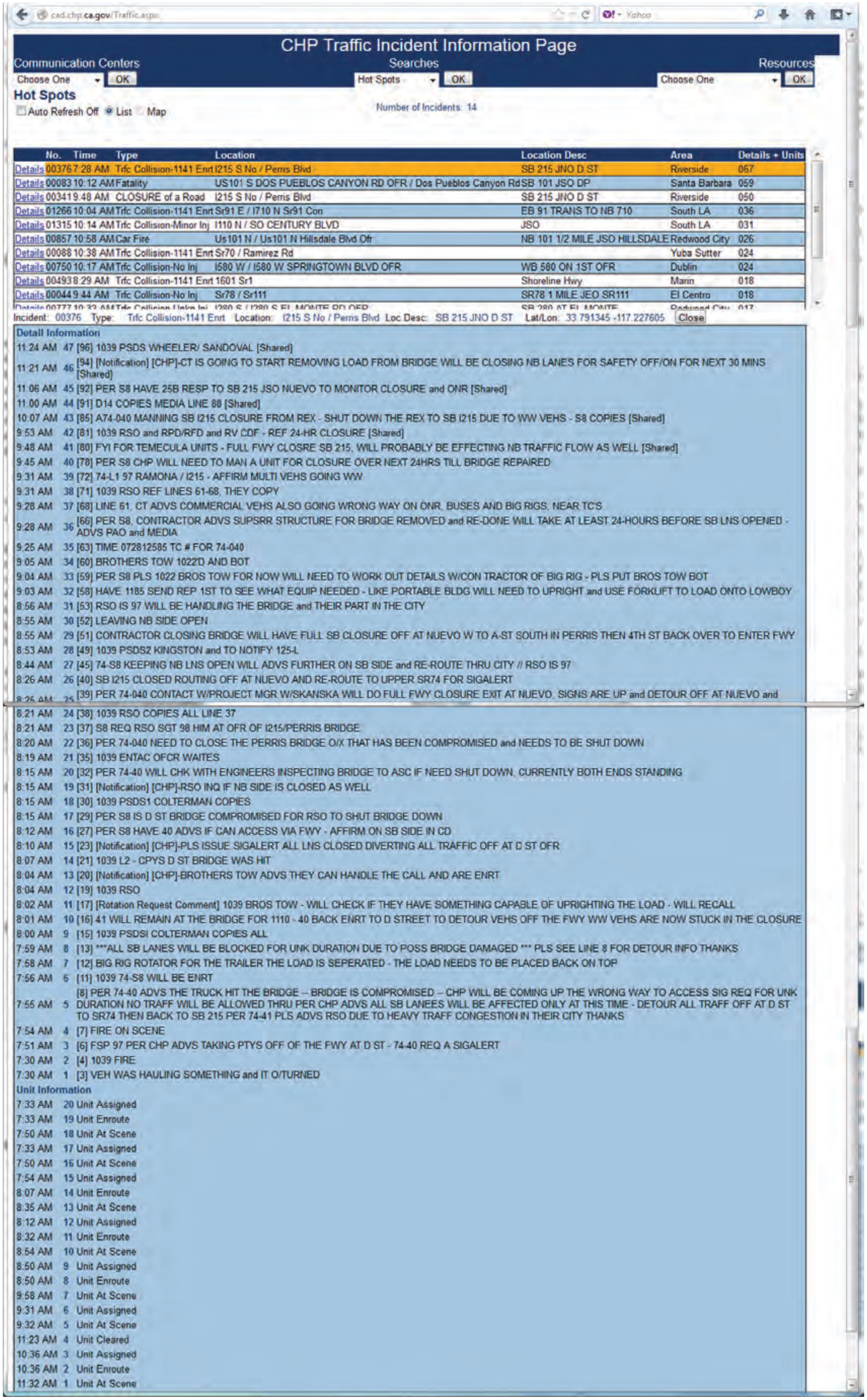

FIGURE 28 Screenshot from the California Highway Patrol's public CAD log available at http://cad.chp.ca.gov/Traffic.aspx.

incidents for the geography specified, and the lower section is the detailed log for the incident that has been selected from the upper list.

Virginia State Police and Montgomery County, Pennsylvania, CAD

CHP is not the only police department that has recognized the benefits of sharing data directly with the public. Figure 29 is a screenshot of the Montgomery County, Pennsylvania, WebCAD website, which shows all active CAD events—not only traffic events, but medical calls and other dispatches.

The Virginia State Police have taken a slightly more restrictive approach to releasing its CAD data. They have allowed third-party integrators to access select incident types—usually those related to transportation events, and then disseminate only those events to VDOT and a few other agencies. VDOT directs the data feeds directly into its TMC software—making access to the CAD data virtually seamless to the operators.

Multi-State Third-Party Probe Data Sharing

The I-95 Corridor Coalition's procurement of data for multiple states is one of the first of its kind in the United States. Operating under a multi-state agreement, the Coalition collects and disseminates probe-based speed and travel time data from a third party to hundreds of operational entities and MPOs across the eastern United States. The Coalition's competitive procurement process (*41*) allows agencies to purchase probe data from

FIGURE 29 Screenshot of the Montgomery County, Pennsylvania, WebCAD system available at http://www.montcopa.org/index.aspx?NID=834.

the selected third-party provider without the need for each agency to issue their own Request for Proposal (RFP)—saving the states and the private sector significant time and energy that would otherwise be spent writing, evaluating, and responding to many individual RFPs. The procurement process also helped to encourage agencies to consider this nontraditional data source as an alternative to point-based sensor technologies.

As part of the procurement, every agency received the same rights to the data through a uniform data use agreement (*42*). Because the Coalition members jointly negotiated the terms of acceptable use, the agencies received uniform access to the speed and travel time data. These data now provide ubiquitous travel time data throughout most of the 15 Coalition states on the East Coast.

According to the I-95 Corridor Coalition's Vehicle Probe Project Website (*43*), the following key results have been documented:

- In addition to providing states with a more complete view of traffic conditions on their major roads, INRIX's real-time traffic information has helped states more effectively allocate limited traffic operations resources. According to North Carolina DOT, where previous approaches to gathering traffic data had a life-cycle cost of nearly $50,000 per mile, INRIX vehicle probe data have been proven to deliver more coverage at about 25% of the per-mile life-cycle cost. Similarly, South Carolina DOT claimed that maintaining coverage to gain speed data for more than 300 miles of South Carolina roads using traditional methods is equal to the total cost of the INRIX speed and travel time data for 1,200 miles of roads.
- **Faster Emergency Response.** In addition to seeing real-time traffic conditions for more roadways and across state lines, member states have been able to more quickly identify and respond to traffic issues. In New Jersey, traffic operations staff identified a serious accident on a stretch of I-80 during a surprise October 2008 snowstorm that they previously wouldn't have been able to see using their CCTV system. Without the Vehicle Probe Project traffic monitoring site, response to the [second] incident would have been delayed by as much as an hour. NJDOT estimated that the expedited response to the second incident translated into $100,000 in savings in user delay costs.
- **New and Improved Traveler Information Services.** In a region of 100 million people, where more than 100,000 cars and trucks travel the I-95 corridor every day, the Project has delivered new and improved traveler information services that help residents and businesses better plan their trips including:
  – <u>On the road:</u> Travel Times on Dynamic Message Signs are driven by [Vehicle Probe Project] VPP data in Maryland, Virginia, and South Carolina.
  – <u>On the phone and online:</u> 511 phone and web services in New Jersey, Pennsylvania, Maryland, North Carolina, South Carolina and Florida utilize VPP data to provide services.

In addition, during the 2009 Thanksgiving evening and the following Friday, a New York State Police Sergeant utilized the shared probe data to make better decisions about if and when to implement changes to traffic management at locations where parking lots were becoming full, closing ramps to prevent back-ups on freeways, and activating DMS to alert motorists. When compared with prior year traffic congestion statistics, it is estimated that the use of these shared data resources largely contributed to a 50% reduction in traffic queues (*44*). In addition to the reduced congestion, the State Police were able to conserve resources by identifying issues through remote analysis of the data feed without having to deploy troopers to the scene.

Not only are the probe data considered a shared data source, but the quality metrics and payment terms are also shared between all of the agencies. For example:

- Payment for the third-party data is based on data quality and availability standards that are universally accepted among all of the agencies (*45*).
- Data quality is measured on a routine basis by a single third party that coordinates all data quality studies throughout the Coalition's members. There are two data quality validation methodologies, one for freeways (*46*) and one for arterials (*47*).

The pooling of resources for monitoring data quality helps to minimize costs and ensure that all agencies are receiving the same quality of data.

Lastly, the data that have been collected since the inception of these data sharing initiatives in 2008 is being stored in a single, shared data repository that is freely accessible by all Coalition member agencies. The repository has a number of web tools for both planning and real-time monitoring that have been built around it and paid for by the Coalition. These tools are being used by thousands of Coalition planners and operations individuals for:

- System performance reporting
- Problem identification
- Project prioritization
- After-action incident review
- Before and after studies
- Operations
- Travel time analysis
- Work zone monitoring.

Because all of the tools are accessible by all Coalition members, every performance measure and query result is calculated the same way, and basic protocols for how to present the results have been agreed upon. This shared data and analysis resource helps each agency reduce IT costs and analysis time while ensuring that states and MPOs are reporting their performances in a uniform manner. A screencast describing the use of some of these tools can be found at www.vpp.ritis.org/suite/screencast.

Private Sector Traveler Information Providers

Three major private sector data and traveler information providers were interviewed as a follow-up to their survey responses. Each of these media and navigational support representatives preferred to remain anonymous; however, they gave strikingly similar responses. Each interviewee was involved in radio and television broadcasts, mobile app development for public consumption, and the provision of information to fleets.

All three providers collect their incident and lane closure data by means of a "journalistic approach"—meaning they access as much information as possible from all available sources including:

- Internet-based sites (511, DOT, etc.)
- Feeds directly from agencies (this is rare)
- Twitter messages (noting that crowdsourcing often leads to better data)
- E-mail alerts
- CAD (where available)
- Their own mobile units both on the ground and in the air
- Collocated staff within DOT operations centers
- Listening to scanner audio
- Phone calls directly to agencies including police, fire, or DOT
- Monitoring CCTV feeds—their own and others
- In some cases—through their own sensor or probe deployments.

All providers admitted that data directly from DOTs varies widely in availability and quality. When quality operations data from DOTs and law enforcement is provided regarding accident locations, construction events, and associated details it has significant value to the private sector because it adds values to its own products being sold or traded.

Data quality is important because many private sector providers are actual news agencies in addition to providing traffic reporting. They believe that just because the news happens to be traffic data does not imply that it is any less important than a story about a shooting, an election, weather reports, etc. Therefore, they believe they must verify every piece of information, otherwise they are not doing their job.

The private sector desires an on-line source, such as a direct electronic data feed or XML interface, that it can subscribe to and trust as accurate 99% of the time. If such a feed existed, it could be ingested, made part of existing products, and would save significant funds usually spent on other things such as:

- Aircraft (traffic copters and airplanes),
- Their own CCTV infrastructure,
- Labor associated with detecting and verifying incidents, or
- Private sector road patrol vehicles.

The private sector understands that data are sometimes going to be wrong; however, they still value the data feeds, as it at least helps the private sector to know where to focus its attention and investigate further.

Each private sector provider noted that it could attribute the loss or gain of several lucrative contracts as a result of CCTV sharing from public agencies. These contracts, varying in size and value depending on the market served, can be as small as $15,000/year up to millions of dollars. The CCTV is particularly valuable because it works for many communication mediums: web, mobile, and broadcast, and it helps the private sector internally to verify information. Two of the private sector interviewees also noted that direct incident and event data feeds from agencies have been the deciding factor in their being able to service particular metro areas and win contracts.

Ultimately, the private sector would like to be viewed more as a true stakeholder and part of the operations team—after all, a major benefit of effective TIM comes from providing quality and timely information to travelers so that they can make better-informed travel decisions. In most markets, the media is better equipped to do this than any of the DOTs or law enforcement agencies—especially through radio broadcasts. As such, the private sector believes that it is in the best interest of both the agency and public to allow operations data to be shared freely and openly.

San Diego and Dallas Integrated Corridor Management Demonstrations

The Dallas ICM deployment is concentrated around the US-75 corridor, which includes freeways with continuous frontage roads, managed HOV lanes, a tollway, 167 miles of arterials, the Dallas Area Rapid Transit (DART) bus and rail network, approximately 900 signals, multiple TMCs, and a regional traveler information system. The partners include the DART Authority as the lead agency, accompanied by the city of Dallas, the city of Richardson, the city of Plano, the city of University Park, the town of Highland Park, the North Central Texas Council of Governments, the North Texas Tollway Authority, and the Texas DOT Dallas District.

The San Diego I-15 ICM transportation corridor is being managed collaboratively and cooperatively through on-going partnerships among the San Diego Association of Governments (SANDAG), the California Department of Transportation, the Metropolitan Transit System, the North County Transit District, CHP, and the cities of San Diego, Poway, and Escondido.

Because of the sharing of information between freeway and arterial TMCs and transit systems it is envisioned that both resulting ICM demonstrations will be able to analyze conditions on all roads and modes, and then provide operators with plans that suggest changes to signal timing plans, fares, managed lane restrictions and tolls (which can have significant

TABLE 3
SIMULATED BENEFITS OF ICM STRATEGIES IN THREE METROPOLITAN AREAS

	San Diego	Dallas	Minneapolis
Annual Travel Time Savings (Person-Hours)	246,000	740,000	132,000
Improvement in Travel Time Reliability (Reduction in Travel Time Variance)	10.6%	3%	4.4%
Gallons of Fuel Saved Annually	323,000	981,000	17,600
Tons of Mobile Emissions Saved Annually	3,100	9,400	175
10-Year Net Benefit	$104M	$264M	$82M
10-Year Cost	$12M	$14M	$4M
Benefit-Cost Ratio	10:1	20:1	22:1

Source: Olyai 2013 (*25*).

economic impacts to the agency and to the public), and many other operational decisions.

At the time of this synthesis report, both the San Diego and Dallas sites were still under development and evaluation by FHWA. Early results from the analysis, modeling, and simulation of ICM strategies under various operational conditions on major corridors produced promising results, as seen in Table 3. Note that the overall benefit-cost ratio of these efforts ranges from 10:1 to 22:1. Although not chosen as a final deployment site, the simulation results of the proposed Minneapolis ICM can also be seen in Table 3.

These benefits are based on modeling and simulation analysis. The formal evaluation of the two deployment sites will be completed within the next year and should be referenced for further information on the realized benefits of the sharing of operations data between multi-modal agencies operating in common geographies. It will be a true before and after study of the impacts of information sharing and enhanced decision-support capabilities made possible because of information sharing.

At the time of this Synthesis report, the Dallas and San Diego ICM sites were just being launched in an official capacity. FHWA is in the process of evaluating the effectiveness of ICM at these two locations and plans on releasing a report quantifying the benefits of various aspects of ICM within the next year and a half.

SUMMARY OF BUSINESS CASES

All agencies interviewed were capable of noting, at least anecdotally, the benefits of sharing operations data; however, when pressed to quantify the benefits in financial or engineering terms most agencies had difficulties. The following were consistently cited as important benefits from information sharing:

- Reduced incident detection, verification, response, and clearance times to quickly re-establish normal capacity and conditions;
- Enhanced safety for motorists and field and safety personnel;
- Reductions in the number of secondary crashes that occur as a result of the primary incident;
- Reduced motorist costs (fewer delays, decreases in travel times, increase in reliability, etc.);
- Reduced vehicle emissions;
- Reduced losses to business as a result of shipping delays or congestion around businesses that limit customer throughput;
- Improved traveler information;
- Increased ridership on transit;
- Increased customer satisfaction;
- Reductions in operations, data collection, and staffing costs;
- Allowing resources to resume nonincident activities; and
- Enabling interagency performance measures generation and comparison.

CHAPTER FIVE

SYNTHESIS OF ISSUES AFFECTING OPERATIONS DATA SHARING

Not all data sharing initiatives are implemented in the same manner. Governance structures, personalities, implementation details, and other factors can heavily influence whether operations data sharing ever takes place, and if it does take place, how successful might it be in producing meaningful, quantifiable benefits.

INSTITUTIONAL CULTURE

In the past, strong personal relationships among handfuls of key staff were crucial to the success of any information sharing initiatives. As such, changes in leadership often have the capacity to affect the relationships (in both positive and negative ways) between organizations. At one agency, there were long-term strong working relationships; therefore, when a change in leadership occurred, it only served to help reinvigorate the partnership. However, at another agency, when champions retired or changed careers, an operational data sharing initiative lost crucial support—allowing previously minor problems to escalate, ultimately ending the project and the years of work that led up to it.

For those agencies that do wish to share their data with other agencies or the public, many operators and/or management are mindful of releasing data that are not guaranteed to be 100% accurate. The concern is that the agency will be criticized for the 1% of the time it makes a mistake rather than commended for the 99% of the time that it provides solid, actionable information. To avoid the negative repercussions resulting from small and infrequent mistakes, some agencies choose not to share any information.

Additional “big brother” concerns can exist in some agencies. Employees are mindful of being overly scrutinized by other organizations or compared with their neighbors. To combat this concern, one operator at a traffic management center was quoted as saying:

> Our job as [a] traffic management agency is to be as visible as possible. Everything that we do impacts the public and other responders. When I post a message to a DMS, I *want* everyone to see it. When there is an accident on the roadway, I want other agencies to know about it and help me clean it up. I need the media to know there is an accident so they can tell the public to take an alternate route. If we aren’t visible to others, we aren’t an effective organization. Transparency is the only way we are successful.

An operator at a different operations center noted that sharing operations data is, and should always be, a core value of public safety and transportation management. The operator stated that shared information ultimately leads to better decisions and performance for our agency.

DATA OWNERSHIP, ACCESS, AND FUNDING

In certain instances, agencies do not own all of their data. Many transit agencies, for example, utilize private sector vendors to supply AVL, scheduling, and other data management systems. If agencies do not stipulate data sharing rights in the terms of their contracts with vendors, they will often not be given the rights to share the data generated by these systems with third parties, even when said third parties are other government entities.

In early 2008, the I-95 Corridor Coalition contracted with INRIX to obtain probe vehicle data for all member agencies in 13 states. Although the procured data has been innovative and transformative in many ways, a notable achievement of the Coalition in this procurement was the thought that went into the acceptable data use agreement that is shared among all Coalition members for the life of the contract. The DUA (*42*) allows for any and all Coalition members (or third parties working on behalf of Coalition members) to gain access to the data with very few restrictions. This DUA was successful because many agencies collaborated and provided input into their shared data needs, and the terms of use were specified as requirements within the RFP for the data procurement.

All-inclusive DUAs are not the norm. In freeway TMC systems and arterial traffic signal systems, vendors will often use proprietary data formats and application programming interfaces that are not publicly available, making it difficult for agencies to share the data. Similarly, if the agency attempting to purchase data does not request specific rights to said data, then the data provider is likely to offer their standard, and usually more restrictive, terms. The buyer, in this case the agency, always has the power to specify the terms of acceptable use for the data, but if the terms are not negotiated from the beginning of the procurement, it becomes more difficult and more costly to negotiate later. Standard data use terms that agencies need to request in their RFPs include:

- Rights to use the data for any and all internal purposes in perpetuity.

- Rights to share the data with operational partners including:
  - Other government agencies that help the procuring agency in its mission,
  - Consultants working on behalf of the procuring agency,
  - University researchers working on studies on behalf of the procuring agency, and
  - To do all of the above even for partner agencies outside of the geography of the procuring agency.
- Rights to summarize the data for use in:
  - Variable message signs,
  - Websites that are sponsored by the procuring agency,
  - Social media postings (such as Facebook, Twitter, etc.),
  - Reports that summarize performance, and
  - Research reports.

Rights that agencies should not expect to get from data procurements (without significantly increasing cost) include:

- The right to provide the raw data to third-party developers or traveler information providers that are not developing websites as "work for hire" for the procuring agency.
- The right to resell the raw data.

Over the last few years, agencies have been more proactive in crafting better systems requirements, RFP language, and DUAs that require vendors to provide data sharing mechanisms. Agencies that are less proactive often have found themselves with expensive bills for change requests to their existing systems.

In rare cases, agencies have played favorites to third parties and even other agencies—severely limiting access to data streams or even refusing to take telephone calls from certain agencies. Other agencies will hold access to operations data until they are given some sort of reciprocity, whether it be access to the other agency's data, financial incentives, or other favors. These seemingly hostile environments persist in a few of the agencies interviewed and/or surveyed.

With constrained fiscal environments, some agencies have felt pressured to attempt to monetize their operations data or recoup their own costs of providing data to others. Viewing their data as an asset, some agencies have attempted to recoup their investments by charging for data access or placing overly burdensome legal requirements on access rights. Although the funding usually does not restrict the larger corporations from gaining access to CCTV and other data feeds, smaller start-ups and even other public safety agencies often are not able to afford access. Because operations data are only valuable and beneficial when they are openly shared with all "need to know" agencies, these types of restrictions on access are generally viewed as detrimental to the health, safety, and efficiency of the transportation system and counterproductive when attempting to realize the significant benefits that have been documented to this point.

In less frequent instances, an agency may be limited in its ability to provide an asset owned by the state for free. Because data are considered a valuable asset, the agency may be compelled to charge for data access or trade the data for in-kind services. For example, the Texas DOT provides some of its data to local television stations in return for access to certain local radar and/or weather services.

LEGAL AGREEMENTS

The level of legal involvement from state to state and agency to agency is significantly different. Agencies with exactly the same operations data elements will argue that the data are sensitive and require tightly controlled data use agreements, while others will distribute their data without any issues or restrictions. This issue has so consumed some modes that entire reports have been dedicated to the subject (*48*). CHP was one of the least restrictive of all agencies interviewed. The level of detail found within its transportation CAD feeds is greater than many other agencies and includes data that some agencies might otherwise classify as sensitive; however, CHP has recognized that these data are a public asset, public knowledge, discoverable, and have value in dissemination—not just to the department, but to many others.

Based on the interview findings and survey results seen in Figure 21, agencies generally implement one of four basic types of agreements when providing data to others:

- No agreements/Open Access
  - Although not technically an agreement, this is where agencies have internal policies that state that their operations data are going to be "open access." This implies that all operations data (or a subset of the operations data) is made freely available on the Internet with little or no stipulations for use. CHP is an example of an Open Access policy for its operations data feeds.
- Handshake agreements
  - This is where agencies agree to the terms of data sharing and data use; however, those terms are not documented. Both agencies agree to provide their data in good faith. Handshake agreements can also lead to reciprocity.
- MOUs
  - MOUs are nonbinding, written agreements between two or more parties that express some overarching goal or policy related to the operational data share.
- Interagency/intergovernmental/DUAs
  - These agreements are legally binding, signed documents between two or more parties. Such agreements typically are more restrictive than MOUs, include terms of use and liability, and can sometimes require financial obligations from one or more parties.

With the exception of the Open Access type of agreement, the other agreement types include reciprocal agreements—

one agency provides data in return for in-kind services that can often include another agency's data.

Currently there are two prevailing strategies in the United States regarding agencies and operations data access. The first is to move toward Open Access (*49*)—providing the data as-is with no expressed warranty or obligation of either party. Many agencies see the value in providing their data to any and all who wish to add value to it, and want to avoid the headaches and overhead associated with managing legal agreements and access control.

Another strategy is to move toward tighter control over data and access. The Virginia DOT (VDOT) has proceeded in this direction—moving all of the CCTV feeds and other operational data to a third party for dissemination. Any third party in the public or private sector can get access to data through this third party vendor; however, access is contingent on the signing of one or more data sharing agreements. Proponents of this method report that DUAs help VDOT maintain stricter control over agency data assets, receive due credit for VDOTs information, and recoup the costs of the data feeds. Opponents of the agreement claim that they are overly restrictive, cause financial hardship to the public (but particularly the private) sector, and cannot be signed by some governmental agencies as a result of liability, indemnification, and other state-based laws. Certain clauses are deemed too risky or contrary to local laws to allow an agency to be able to sign the agreement and acquire access.

TECHNICAL ISSUES

There are several challenges that can present themselves as barriers to successfully implementing regional operations data sharing programs. These technical challenges have been synthesized from interviews and survey responses and include:

Data Availability

Although most large state DOTs have electronic systems to collect and manage transportation operations data, many local jurisdictions rely on paper, phone calls, and e-mails to conduct normal operations and communicate and collaborate with other agencies. Although this approach may be sufficient for internal operations, it limits their ability to share information in an automated and consistent way with neighboring jurisdictions and partners. If an agency does not have data to share, it is limited in its ability to participate in meaningful ways with other agencies. Many agencies are now looking for low-cost alternatives to the traditional TMC operations center software platform.

Data Reliability

Lower quality data can be an issue for all agencies and all data types—speed/volume sensors, incident/event data, CCTV, etc. Maintenance of sensor systems can be problematic because of funding or other issues. Significant effort has gone into various strategies for the analysis of data quality, including imputation algorithms for accounting for poor quality data or missing data (*50*–*53*).

Similarly, instilling values in operations personnel that lead to consistent, clear incident data entry is another challenge. When agencies are aware of these issues, they are often hesitant to share their data owing to potential negative perceptions from external agencies.

Several agencies that were interviewed noted that they *only* share incident data with other agencies *after* they have "verified" that the incident is legitimate, a decision made to prevent false notifications and minimize negative feedback; however, in its caution, the agency is significantly delaying notification to the public and other agencies, which leads to other potential safety concerns, delayed response, secondary incidents, increased clearance time, and ultimately additional congestion.

Many agencies are concerned with liability issues related to the quality and accuracy of shared data, especially in cases where that data may be used to inform the public. However, it can be argued that some information, even if not 100% accurate, is better than no information at all. In the development of the AZTech regional traffic management partnership, Maricopa County DOT and Arizona DOT addressed the liability issues by developing policies in advance and ensuring that concerns over liability do not impede appropriate actions. As stated in its lessons learned, "an agency should not be as concerned with being sued if it were able to put forth a credible defense based on the underlying merits of having and following standard formal and written policies and procedures" (*54*).

Bandwidth Limitations

DOTs and other government agencies often invest heavily in individual, internal, high-speed networks. These networks allow agency-owned equipment and resources to communicate with one another at relatively high data transfer rates; however, agencies often have low-bandwidth pipes to the broader Internet. To complicate matters, these low-bandwidth pipes are shared among tens, hundreds, and sometimes thousands of users—all competing for extremely limited resources. This limited external bandwidth can often be a barrier to operations data sharing on a larger scale, as CCTV and high-frequency detector polling intervals can tax or even cripple already overloaded networks.

To remedy this, agencies will sometimes need to invest in point-to-point networks to ensure sufficient bandwidth is available to get data from point A to point B. As shown in Figure 30, several agencies noted that it can often be more expensive to invest in multiple, point-to-point network pipes for

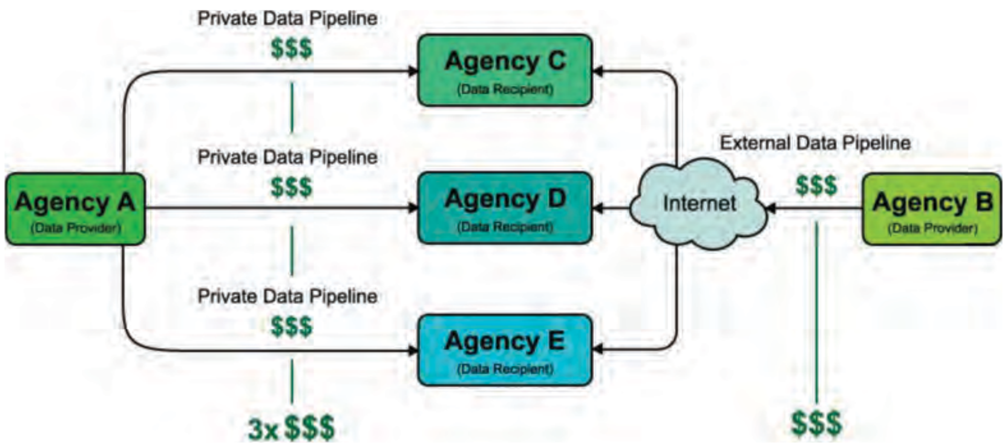

FIGURE 30 Illustration of an agency-provided example of cost comparison of multiple private data pipelines compared to a single, robust pipeline to the Internet.

multiple output streams rather than investing in the agency's overall pipe to the Internet. As noted by several agencies, one workaround solution to bandwidth limitations is to push data from the agency out to a redistributor who has greater bandwidth resources.

Networks

Many agencies spend significant time and resources in an effort to "connect networks" as the only secure/viable way to share information. These agencies often cite security and reliability as primary reasons to create point-to-point connections between the networks used to share data. Interviewees have noted that connecting networks through dedicated physical lines is expensive, time-consuming, not scalable, and often not any more secure or reliable than more conventional paths through the Internet.

The cost of building a direct connection between two networks is significant, as it requires the agencies to agree on the architecture and build the necessary infrastructure to be able to communicate. The cost and complexity multiplies as the number of agencies connecting to the network grows, since each agency requires additional infrastructure and administration to make the connection.

The perceived benefit of a secure and reliable connection through the direct point-to-point connection often does not exist because "private lines" are frequently just leased lines, subject to security breaches and failures owing to the elements being similar to any other connection. Network managers at some agencies noted that private lines often provide less reliability as they are a single point of failure, whereas an Internet connection can be rerouted depending on the availability of individual nodes.

Agencies interviewed have noted that making a connection between two networks does not guarantee that data will be shared between agencies. Additional work is always necessary to enable a mechanism for data sharing regardless of what type of connection is made between the agencies. Managers and network engineers frequently note that connecting networks is not equivalent to actual data sharing.

Human Factors

TMCs frequently tout the benefits of sharing operations data between one another and with first responders; however, simply sharing information in data feeds is not sufficient to claim a true win in terms of increasing one's situational awareness. The manner in which the information is reintegrated into one's existing system and then presented to the operator is often the most critical element in the success of a data sharing initiative.

Human factors researchers at the University of Maryland, working with the I-95 Corridor Coalition, are investigating the major TMCs that have worked to reintegrate other agency operations data into their own systems. While still underway, its study is investigating both TMC software vendors and DOT TMC personnel, and is taking an in-depth human factors look at the effectiveness of various data representation strategies and visualization techniques. The result will be an "effective practices" document that can be used by other TMCs when procuring new TMC software, developing RFPs, and investigating strategies to increase operations efficiencies. It is hoped that the results of this human factors research will foster meaningful change and increased productivity in all TMCs, along with an increased return on investment when sharing information between agencies.

Security Concerns

Security is often quoted as a major obstacle in data sharing efforts. Agencies that characterize their data as secure are concerned that transferring that data across networks exposes it to unsanctioned access, and that control over that "secure" data is lost once it arrives at its destination. Many of the agencies interviewed complained that security appears to be more of an excuse than a true reason for avoiding the sharing of operations data. One agency representative was quoted as saying "security is the reason we give to others to avoid the hassle of exposing ourselves to criticism while simultaneously making us appear more relevant to the national security scene than we really are."

The vast majority of data collected by the transportation, transit, and even law enforcement agencies is in the public domain. Data elements that are truly sensitive can always be filtered out or simply secured in the feed using authentication, authorization, and encryption. Despite remaining security concerns, some agencies have moved toward the open data concept, where virtually all transportation incident management data are available for sharing without significant issues or backlash—for example, CHP.

Reintegration Challenges

If an agency is able to overcome the challenges of data sharing and is successfully ingesting data from another agency, it may still face issues of reintegrating that data into its native system. Some of the primary challenges include dealing with disparate data types, incompatible time scales, and even information overload.

To successfully reintegrate transportation operations data, some agencies generate rules that fuse incoming data fields to the appropriate internal system fields. When implemented well, this fusion allows the agency to filter out information that is not of interest and focus only on relevant incoming data. This is often done through the marking of the incoming incidents as interesting (based on some rule that may include severity, lane closures, geographic extent, etc.) and then importing those incidents into the native system or even creating associated incidents in their own ATMS.

Costs

The cost of sharing data is largely dependent on the stage at which data sharing is introduced in the system. Adding data sharing interfaces to legacy systems can be expensive and time-consuming, especially if the system was designed to be closed. ATMS have traditionally focused on real-time traffic monitoring, device management, and incident response management. As most of these tasks were originally oriented toward internal management and operations, many of these systems were not capable of communicating with each other or sharing the collected data. Sharing data from legacy production systems requires additional investments, including costly change requests. As described in previous sections of this report, many vendor-provided ATMS have historically utilized proprietary protocols or data formats that limited the amount of data that could be shared.

As transportation operations data sharing becomes more common, agencies have revised their requirements generation process to include data feeds to third parties. Vendors are slowly adapting to the new data sharing requirements and are able to provide lower cost solutions, assuming that they are able to overcome other legal issues and institutional challenges. Still, defining interfaces during the design phase drastically reduces the cost of maintaining the schedule.

Other factors affecting the cost of maintaining data feeds are related to the management of changes within various systems and interfaces. Changes to one system or data feed can have ripple effects that can adversely affect the budgets of all other agencies receiving data. To minimize risk and delays, many agencies have identified several strategies, some of which include:

- Creation of Interface Control Documents (ICDs) that clearly define the interface, including data format, connection protocols, and security. These ICDs can be sent to the data consumers giving them clear indications of where the feed is changing. Often, creation and circulation of the ICD can be added to the project schedule during the design phase to ensure that there is ample of time for consumers to develop and test their applications relying on the data feed.
- Providing data in standard format and performing data translation internally. For example, the agency may be providing data in a Traffic Management Data Dictionary standard format, and as the incident responder category changes it is mapped to the appropriate standard format, making the change transparent for the data consumers.
- Creation of redundant test systems that implement the change ahead of deployment and allow consumers to test against and verify that they can consume and process the changed feed data.
- Creation of Configuration Control Boards (CCB) to manage systems and data feed changes that include external entities that are likely to be affected by the internal changes. These CCBs can be separate from internal CCBs and can be concerned only with changes that will affect external agencies.

SUMMARY OF ISSUES

The major issues noted by interviewees, from comments from survey respondents, and the literature review findings included:

- Agency concern over releasing inaccurate data and the possible repercussions.
- Overly restrictive data use agreements from systems vendors and third-party data providers.

- Legal challenges resulting from in-house council insistence on overly protective, complicated agreements that are difficult for certain government agencies to agree to.
- Technical issues such as:
  - Not having any data to share;
  - The data that are available is not reliable;
  - Agency does not have the necessary bandwidth to be able to provide or receive data;
  - Agencies focus too heavily on physical, point-to-point network connections creating expensive silos;
  - Agencies do not spend enough effort ensuring that data are available to users in an interface that is easily understandable, readily accessible, and integrated with day-to-day operations;
  - Agencies will use security concerns as an excuse to avoid sharing data;
  - Reintegrating data into native systems that are not standards compliant can be cumbersome; and
  - Costs associated with creating data feeds or ingesting data feeds.

Any one of these issues, if not properly dealt with, can be enough to slow or halt a data sharing initiative; however, all agencies interviewed commented that none of the issues *should* be a reason to avoid data sharing. All stated that the potential benefits of providing the information to others and/or receiving information from partners nearly always outweighs the risks and concerns. Understanding what these challenges are before beginning a data sharing initiative often helped to allow the agency to plan for acceptable workarounds and gain agency trust ahead of time to help ensure success.

CHAPTER SIX

CONCLUSIONS

The literature review process revealed that there is surprisingly little documentation that explicitly quantifies the direct value of interagency transportation operations data sharing. The documentation that does exist, coupled with the survey responses and follow-on interviews, showed that the majority of state departments of transportation (DOTs) and other respondents is sharing some form of operations data with other agencies. Although encouraging, other survey findings, along with follow-on interviews, suggest that the bulk of the data being shared is basic—vehicle speed, accident type and location, and closed circuit television images. A number of challenges remain that can impede an agency's willingness and ability to share data—the primary one of being apprehensive of being judged, perceived legal concerns, and to a lesser extent funding and technical challenges, especially with respect to more detailed operations data (such as responder locations, notifications, arrivals, computer-aided dispatch, etc.).

Highly detailed operations data that has the potential to have even greater operational benefits, such as responder locations, notifications, arrivals, computer-aided dispatch from law enforcement, and even real-time signal timing plans, is less likely to be shared with other agencies.

Many agencies continue to struggle with quantifying the benefits of operations data sharing; however, several recent studies related to multi-state operations in the Washington, D.C., metropolitan region and the two Integrated Corridor Management demonstration sites have attempted direct benefit-cost studies showing the performance, safety, environmental, and financial benefits of their programs that are direct results of information sharing. Many other agencies have identified significant internal cost savings with respect to receiving data from others, but surprisingly have seen similar or even greater cost savings through their efforts to provide automated data feeds to others.

This report, along with the referenced literature, has noted that the coordination and sharing of operations data may:

- Improve information flow and coordination between all jurisdictions and agencies involved in the incident.
- Enhance the understanding of joint priorities and restrictions by all agencies with responsibility for the incident.
- Provide a single set of objectives for those working to resolve the incident—a collective approach to develop strategies to achieve traffic incident management objectives.
- Optimize the combined efforts of all agencies as they perform their respective assignments to mitigate the impacts of the incident—all of which leads to significant benefits in terms of
  - Safety,
  - Congestion reduction,
  - Environmental benefits, and
  - Cost savings to the agencies and the public.

The findings of this synthesis also suggest that there are additional factors that can significantly impact the value of operations data including:

- Human factors associated with how operations data from other agencies is presented to the user to strike a healthy balance between information overload and hiding information from users deep within complicated systems.
- The level of detail that is presented to the user. Simply stating that an incident has occurred has inherent value; however, informing a user that an incident "has occurred, police, are on the scene, fire and rescue are 2 minutes from arriving, chlorine gas is leaking at the scene, and queues are backing up 5 miles and growing" is significantly more useful in coordinating response.
- The speed at which information is provided to other agencies and third parties is critical. Agencies that wait an excessive amount of time to "confirm an incident" usually reap fewer benefits than those that share openly even "suspected" incidents prior to verification.
- The bureaucracy and legal headaches associated with providing data to third parties or acquiring information from third parties can have significant impacts on an agency's willingness and ability to enter into agreements that can diminish opportunities for collaboration.

The content of this synthesis further supports agencies in making the business case for sharing agency operational data and encourage greater interagency cooperation. The characteristics of the local environment and organizations are key factors affecting the success of a method. There is no guarantee that implementing any of these methods under different institutional, operational, or technical situations will achieve the same results as reported in the case examples. However, the successful programs identified in the case examples are viable candidates for emulation elsewhere.

Further research is needed to help identify the benefits of individual data elements so that data sharing initiatives can be prioritized effectively. Standardization in how agencies share their information (e.g., data formats, transmission methods, and frequency) along with standardization in how the benefits of sharing these data are calculated (e.g., reduction in delays, increase in safety, customer satisfaction, and reduced emissions) would help strengthen the business case.

Additional research is needed to identify a “formula” or “prescription” that will quantify the benefit-cost ratio of specific operations data sharing efforts. This would allow agencies to calculate a benefit-cost ratio before implementation, or use benefit-cost ratios generated by comparable organizations under comparable circumstances to determine which data elements, agreement types, and data sharing frequencies to focus on to obtain the largest benefit.

Agency and private sector interviews and literature findings revealed that there are still significant concerns related to liability with respect to sharing information and open data initiatives. Further research into understanding where that concern emanates and why it affects some agencies more than others would be beneficial. Several agencies have been successful in overcoming these obstacles through transparency and the open data approach. Similarly, further research is needed to determine the value of sharing data elements that are perceived as sensitive by certain agencies to formally recognize both the risks and potential benefits.

GLOSSARY

ATM	Active Traffic Management
ATMS	Advanced Traffic Management System
AVL	Automated vehicle location
BC	Benefit-cost
C2C	Center to Center
CAD	Computer-aided dispatch
CCB	Configuration Control Board
CCTV	Closed circuit television
CHP	California Highway Patrol
ConOps	Concept of Operations
CTA	Chicago Transit Authority
DART	Dallas Area Rapid Transit
DDOT	District of Columbia Department of Transportation
DMS	Dynamic message sign
DOT	Department of transportation
DUA	Data use agreement
EMA	Emergency management agency
EMS	Emergency medical service
FIH	Freight Information Highway
Hazmat	Hazardous material
HOT	High-occupancy toll
HOV	High-occupancy vehicle
ICD	Interface Control Document
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
ITS	Intelligent Transportation System
MATOC	Metropolitan Area Transportation Operations Coordination
MBTA	Massachusetts Bay Transportation Authority
MDOT	Maryland Department of Transportation
MOU	Memorandum of understanding
MTA	Metropolitan Transportation Authority
MTS	Metropolitan Transit System
NITTEC	Niagara International Transportation Technology Coalition
NWS	National Weather Service
OD	Origin–destination
RFP	Request for Proposal
RITIS	Regional Integrated Transportation Information System
RTSOP	Regional Traffic Signal Operations Program
SANDAG	San Diego Association of Governments
TIM	Traffic Incident Management
TMC	Traffic management center
TriMet	Tri-County Metropolitan Transportation District of Oregon
VDOT	Virginia Department of Transportation
VPP	Vehicle Probe Project
WMATA	Washington Metropolitan Area Transit Authority
XML	Extensible Markup Language

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APPENDIX A

MATOC Case Study

BACKGROUND

The Metropolitan Area Transportation Operations Coordination (MATOC) program is a partnership between the Virginia Department of Transportation (VDOT), the Maryland Department of Transportation, the District Department of Transportation (MDOT), the Washington Metropolitan Area Transportation Authority (WMATA), and other Washington, D.C., metropolitan area transportation agencies that aims to improve safety and mobility in the region through information sharing and coordination.

In 2001, several of the region's transportation agencies had implemented stand-alone incident and traffic management programs to mitigate the effects of incidents, improve emergency response, and manage congestion. Each agency operated its systems separately, using its own data collection and processing systems. However, conditions in one jurisdiction can greatly affect travel in others and sometimes throughout the entire region. Disruptions on one part of the network often have significant effects on one or more other jurisdictions on another part of the network. It was believed by many that such regional disturbances required a regional solution.

While there was some nationwide interest in regional transit and traffic management at the time, the need for a regional system in the Washington, D.C., metropolitan area was emphasized after several major incidents, including the September 11th, 2001 attacks, which emphasized the need for a regional evacuation plan. There were other events that warranted better regional coordination, such as jurisdictional confusion over stopping a suicidal man from jumping off the Woodrow Wilson Bridge and managing the resulting traffic in the area of the incident.

At the time, each Washington, D.C., metropolitan area transportation agency maintained its own independent equipment and software for monitoring traffic and travel conditions and for making operational adjustments. Information sharing between transportation agencies was ad hoc and relied on personal relationships between staff from the various transportation operations centers. While this information-sharing technique resulted in cross-jurisdictional and cross-modal coordination during large-scale events such as the annual Fourth of July celebration, it was not a timely, reliable, consistent mechanism for sharing operational data.

This need for regional management of Washington, D.C.'s transportation system was the main impetus for the MATOC and the Regional Integrated Transportation Information System (RITIS). RITIS is a data fusion and dissemination system that collects and fuses transportation data from each participating agency, standardizes it, and makes it available to other participating agencies through each agency's existing transportation management systems. RITIS was not intended to collect data directly from field devices; rather, participating agencies were to collect data from their field devices or enter information into their incident management system and make it available to RITIS. RITIS would then be the "one-stop-shop" for every agency that wanted to tap into external data sources for reintegration into their existing systems. RITIS would also archive data for use in planning, after action reviews, and performance evaluations.

RITIS planning began in 2002 with a grant from the federal government issued to the Metropolitan Washington Council of Governments (MWCOG). The Center for Advanced Transportation Technology (CATT) Laboratory of the University of Maryland, College Park, officially received this funding and began work on RITIS in 2006, and is the RITIS system developer. The following agencies were to be the initial participants in RITIS, with others to join later:

- MDOT
- VDOT
- DDOT
- WMATA

In addition to the four participating agencies, it was anticipated that other transportation agencies in the region could benefit from RITIS

It was determined early on that RITIS should not belong to any single agency. Rather, it will be managed and funded collaboratively by the participating agencies similar to how Transcom and NITEC operate. Concurrent with RITIS development, the DOTs of Virginia, Maryland, and the District of Columbia, along with WMATA and the MWCOG, worked to establish a configuration advisory board and an executive MATOC steering committee to help provide coordination and institutional management.

Vision and Objectives

Through early stakeholder meetings it was determined that the focus of RITIS would be on emphasizing data fusion, sharing, and its relationship to data collection, regional transportation systems management, regional traveler information dissemination, and systems evaluation. It would attempt to enhance ongoing activities performed by individual agencies, companies, and the public by providing each with real-time, regional information in an electronic, standardized format.

By consolidating, disseminating, and archiving transportation-related data from various agencies in the Washington, D.C., area, RITIS would:

- provide improved information for a variety of purposes, including regional transportation management, traveler information, and emergency response
- provide regional data fusion to allow an overall view of the region's transportation network
- support and complement activities of participating agencies in data collection related to regional transportation systems
- support and complement transportation systems management efforts of the member jurisdictions for regional transportation operations
- support and complement traveler information and 511 activities related to regional traveler information
- support and complement the region's emergency preparedness activities
- provide the means to produce regional performance measures and access regional transportation data from a single location

Operational Policies

The sponsoring agencies agreed that RITIS should be used as a tool to help agencies perform their functions through data sharing, but it should not alter the lines of legal or operational responsibility for incident management, traffic management, or other aspects of transportation. Data collection from and maintenance of field devices was to remain the responsibility of the participating agencies. RITIS would compile and distribute traffic and transit information, but it would not actively manage traffic, be directly responsible for transportation operations, or incident management independent of existing lines of authority.

Because RITIS was to provide data to and extract data from multiple systems at multiple agencies, agency firewalls needed to allow RITIS information to flow in and out while preventing system incursions. Policies on data privacy and security were established including the need to restrict safety-sensitive data such as that from CAD systems.

All agencies agreed to an acceptable use policy between one another, and set restrictions on what data could be shared with each other vs. the media vs. the public directly.

Anticipated Users

RITIS's primary users were anticipated to be **staff in the traffic and transit operations centers** of the participating agencies. The goal was to provide TMC personnel with situational awareness of traffic conditions and incidents in other jurisdictions and modes. Operations staff could then adjust their ITS devices—for example, DMS and signal systems—to account for conditions in neighboring jurisdictions that affect their traffic operations.

Table A1 provides a list of these and other expected RITIS users in each established category. Use cases for each of these user groups were created to help justify account requests and stakeholder needs.

Architectural Considerations

Three possible architectures were considered for the RITIS system: centralized, decentralized, and hybrid (more commonly referred to as cloud-based).

In a **centralized architecture**, one central database would be used to collect, store, and distribute all data in RITIS. This single database would have one or more backup databases at distinct physical locations, but these backup databases would not be leveraged to support performance improvements resulting from load and work distribution. They would be used only for system reliability in case of a failure of the main database.

In a **decentralized architecture**, each data provider (or agency) would be responsible for maintaining its own database in its own data format. While this eliminates the problem of a single point of failure, each data provider would be responsible for maintaining and administering its database for both real-time and archived applications and for translating its data to a format usable by all other data consumers. This architecture put the burden of operations, maintenance, backup, and recovery on each agency. Additionally, the number of translation mechanisms increased exponentially as data providers join the network, since every data provider must generate a unique data translator for every other data provider to enable seamless communications to every other agency's database. Operations and maintenance overhead for this architecture would be significantly higher than for the centralized architecture.

TABLE A1
RITIS USERS

Operations Center Staff	**Field Personnel**
Traffic management centers	Freeway service patrols
Transit management centers	Transit operators
Commercial freight dispatch centers	Transit supervisors
Public Safety Staff	Construction crews
Emergency management agencies	Maintenance crews
Public safety operators and dispatchers	**Emergency Responders**
Traveler Information Providers	Law enforcement agencies
Agency traveler information personnel	Fire departments
Agency public affairs staff	Emergency medical services
Proprietary traveler information service providers	Hazardous materials management
Media	Tow truck companies
Archived Data Users	**Information Technology Staff**
Agency operations personnel	System developers
Researchers	System/database administrators
Planners	Agency information technology staff
Senior Managers and Policy Makers	**Travelers**
Agency operations managers	Private vehicle drivers and passengers
Agency senior managers	Transit riders
Elected and appointed officials	Commercial vehicle drivers

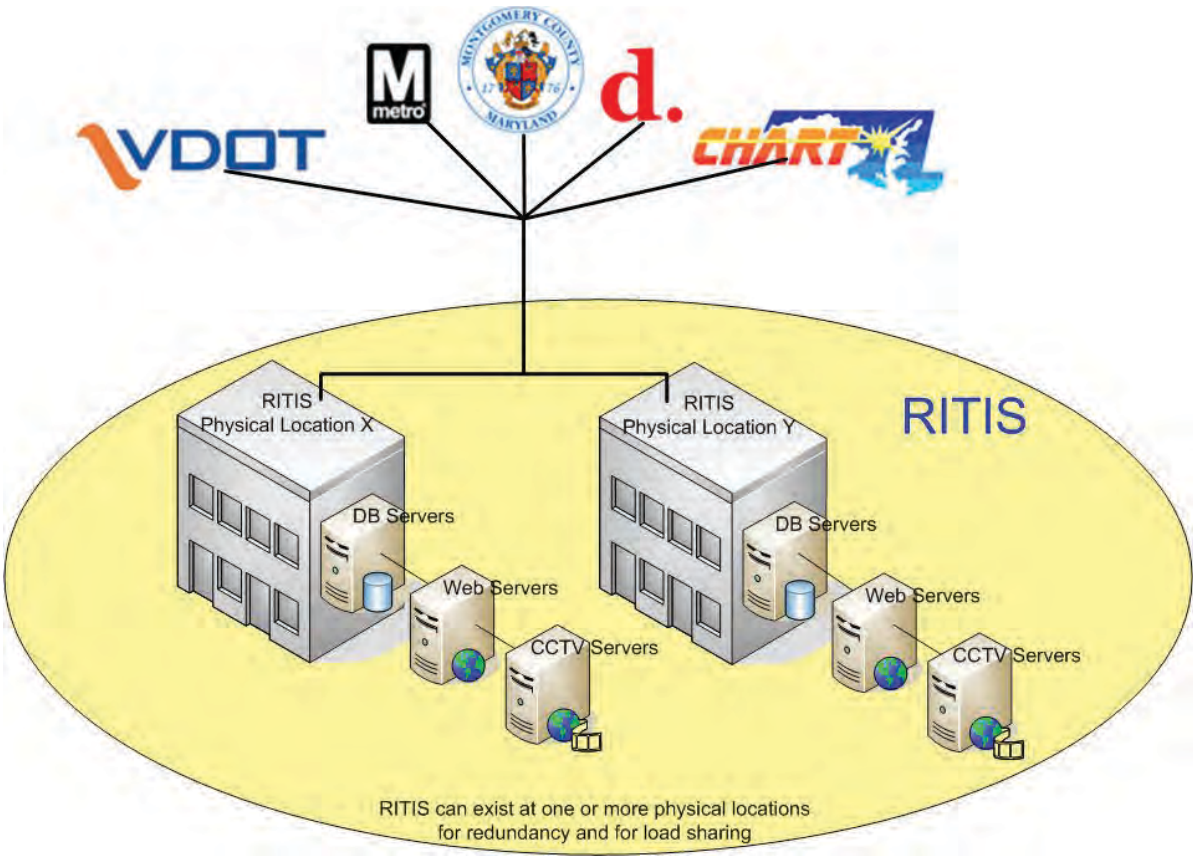


FIGURE A1 RITIS centralized distributed architecture.

Ultimately, a **hybrid architecture (now referred to as "cloud computing")** was chosen for RITIS. Duplicate databases would be deployed at two or more physical locations and load balanced. A single translation layer was used to load the data into each of these databases. Consumer transactions can then be processed in parallel using all of the available databases. When a user requests a set of data, one piece of data can come from a single database, or the transaction can be sped up by distributing the workload over several of the servers residing in one or more locations. This procedure is transparent to the consumer. Most importantly, however, is that failure of one of the databases does not affect the operation of RITIS in any way since all the other databases are redundant and used for load sharing.

The hybrid architecture has several advantages over the centralized and decentralized architectures:

- Distributed transactions run in parallel, increasing processing speed.
- Failure of one of the databases does not affect the rest of the system in any way.
- A single mechanism handles data translation and standardization for all providers and consumers, eliminating the need for a unique translation mechanism for each producer/consumer pair.
- Data redundancy improves system reliability.

Figure A1 shows a high-level representation of the RITIS architecture. The RITIS architecture is consistent with the Washington, D.C. area's regional ITS architecture, as required by U.S. Department of Transportation regulations.

Early Data Provider Analysis

Within RITIS, all participating systems can exist as providers and/or users of particular classes of information. Any single system can be a data provider, a data consumer, or both. Table A2 shows the available data sources from each original RITIS agency.

Tables A3 and A4 show more detail about the data sources and which agencies are providers and consumers of each type of data. The tables demonstrate the breadth of available information and agencies that will benefit from accessing both static and real-time information.

TABLE A2
DATA SOURCES

	MDOT	VDOT	DDOT	WMATA
TMC	✓	✓	✓	✓
VMS	✓	✓		
Systemized traffic signals	✓	✓	✓	
CCTV	✓	✓	✓	✓
Full motion video from aircraft				
HAR	✓	✓		
RWIS	✓	✓		
Ramp meters		✓		
Traffic sensors	✓	✓	✓	
HOV gates		✓		
AVL-equipped buses				✓

TABLE A3
DATA PRODUCTION

⊙ Agency produces this data for its own jurisdiction and would like to receive it from other agencies, where available
● Agency does not produce this data for its own jurisdiction but would like to receive it from other jurisdictions, where available
◇ Agency already receives this data from another source, and may or may not decide to switch to RITIS for this information

Category	Data Item	DDOT	MDOT	VDOT	Montgomery County	WMATA Bus	WMATA Rail	911 Center	Local Police	State Police	Fire	Emergency Management	Media	Private ISP	Public
Video and Images	CCTV	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	⊙	●	●
	First-responder on-scene still images	●	●	●	●	●	●		●	●	●	●	●	●	●
	Aerial video from aircraft	●	●	●	⊙	●	●		⊙	⊙	●	⊙	⊙	●	●
Construction and Maintenance	Planned lane or road closures	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	●	●	●
	Emergency road or lane closures	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	●	●	●
	Construction detour plans	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	●	●	●
	Planned maintenance	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	●	●	●
	Emergency maintenance	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	●	●	●
Traffic Control	VMS status and message	⊙	⊙	⊙	⊙	⊙			●	●		●	●	●	●
	HAR status and message	⊙	⊙	⊙	⊙	⊙			●	●		●	●	●	●
	Signal status	⊙	⊙	⊙	⊙	⊙			●	●		●	●	●	●
	Traffic signal timing plans	⊙	⊙	⊙	⊙	⊙									
Traffic Flow Data	Volume	⊙	⊙	⊙	⊙	⊙									
	Speed	⊙	⊙	⊙	⊙	⊙			●	●	●	●	●	●	●
	Lane occupancy	⊙	⊙	⊙	⊙	⊙									
	Vehicle classification	⊙	⊙	⊙	⊙	⊙			●	●		●		●	
	Travel time	⊙	⊙	⊙	⊙	⊙			●	●	●	●	●	●	●
	AVL	⊙	⊙	⊙	⊙	⊙	⊙					●			
	HOV/toll/drawbridge status	⊙	⊙	⊙	●	●			●	●		●	●	●	●
Incident Management	Incident information	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	●	●	●
	CAD incident information	●	●	●	●	●	●		⊙	⊙	⊙	⊙			
	Alternate routing	●	●	●	●	●			●	●	●	●	●	●	●
Events	Special event schedule	●	●	●	●	●	●		●	●	●	●	●	●	●
	Traffic control plans	●	●	●	●	●	●		●	●	●	●	●	●	●
Road Weather Conditions	Pavement condition (wet, icy, snow-covered, etc.)	⊙	⊙	⊙	⊙	⊙			●	●	●	●	●	●	●
	Roadside weather	⊙	⊙	⊙	⊙	⊙			●	●	●	●	●	●	●
Weather	Live radar	●	●	●	●	●	●		●	●	●	●	◇	◇	◇
	NWS alerts	◇	◇	◇	◇	◇	◇		◇	◇	◇	◇	◇	◇	◇
Transit	AVL/probe data	⊙	⊙	⊙	⊙	⊙	⊙					●			
	Service disruption data	⊙	⊙	⊙	⊙	⊙	⊙					●	●	●	●
	Line or station closure data	⊙	⊙	⊙	⊙	⊙	⊙		●			●	●	●	●
	Transit incident	⊙	⊙	⊙	⊙	⊙	⊙		●	●	●	●	●	●	●
Emergency Alerts	Department of Homeland Security alert	◇	◇	◇	◇	◇	◇		◇	◇	◇	◇	◇	◇	◇
	Emergency Alert Broadcasting System	◇	◇	◇	◇	◇	◇		◇	◇	◇	◇	◇	◇	◇
	Amber alerts	◇	◇	◇	◇	◇	◇		◇	◇	◇	◇	◇	◇	◇
	Emergency management agency data	●	●	●	●	●	●		⊙	⊙	●	⊙	●	●	
Documents	Evacuation plans	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇	◇
System Static Data/GIS	Location of roadway cameras, detectors, VMS, etc.	⊙	⊙	⊙	⊙	⊙	⊙					●	●	●	●
Archived Data		●	●	●	●	●	●		●	●	●	●	●	●	●

TABLE A4
DATA CONSUMPTION

● Agency will provide this data to RITIS
⊙ To be determined

Category	Data Item	DDOT	MDOT	VDOT	Montgomery County	WMATA Bus	WMATA Rail	911 Center	Local Police	State Police	Fire	Emergency Management	Media	Private ISP	Public
Video and Images	CCTV	●	●	●	●	●	●								
	First-responder on-scene still images	●	●	●	●				●	●	●	●			
	Aerial video from aircraft				●				●	●	●	●	●		
Construction and Maintenance	Planned lane and road closures	●	●	●	●										
	Emergency road and lane closures	●	●	●	●				●	●	●	●			
	Construction detour plans	●	●	●	●	●			●	●	●	●			
	Planned maintenance	●	●	●	●	●	●								
	Emergency maintenance	●	●	●	●	●	●								
Traffic Control	VMS status and message	●	●	●	●										
	HAR status and message		●	●	●										
	Signal status	●	●	●	●										
	Traffic signal timing plans	●	●	●	●										
Traffic Flow Data	Volume	●	●	●	●										
	Speed	●	●	●	●										
	Lane occupancy	●	●	●	●										
	Vehicle classification	●	●	●	●										
	Travel time		⊙	⊙			●							⊙	
	AVL	●	●	●	●										
	HOV/toll/drawbridge status	●	●	●											
Incident Management	Incident information	●	●	●	⊙							⊙	⊙		⊙
	CAD incident information							⊙	⊙	⊙	⊙	⊙		⊙	
	Alternate routing	●	●	●	●	●			●	●					
Events	Special event schedule	●	●	●	●	●	●		●	●		●	●		
	Event traffic control plans	●	●	●	●				●	●		●			
Road Weather Conditions	Pavement condition (wet, icy, snow-covered, etc.)	●	●	●	●	●									
	Roadside weather	●	●	●	●	●									
Weather	Live radar														
	NWS alerts														
Transit	AVL/probe data		●	●	●	●	●								
	Service disruption data		●		●	●	●								
	Line or station closure data		●		●	●	●								
	Transit incident		●		●	●	●								
Emergency Alerts	Department of Homeland Security alert														
	Emergency Alert Broadcasting System														
	Amber alerts								●	●		●			
	Emergency management agency data											●			
Documents	Evacuation plans	●	●	●	●	●	●		●	●		●			
System Static Data/GIS	Location of roadway cameras, detectors, VMS, etc.	●	●	●	●	●	●								
Archived Data															

Data Fusion and Processing

During the design phase, an inventory of all available data sources was made to determine the desired data precision and reliability and the best data adjustment methods to minimize distortion and maximize the usefulness of the substituted data. The selected methods are internally consistent, efficient, traceable, and objective. To ensure data quality, RITIS performs data quality assessments and abnormality checks on much of the data it receives. Every data element has a time and date stamp. Data are also stored two separate ways: in its native format as provided by the agency, and also in the fused "RITIS" format. This ensures traceability of all data and enables the RITIS system to act as a backup data repository for all agencies that provide data. Figure A2 shows the high-level approach to processing data sources automatically.

RITIS will pull data from agency systems in a variety of ways, depending on the design of each agency's systems. The preferred method, however, is an asynchronous web-service that is persistent—guaranteeing delivery of information. After collecting the data, RITIS prepares it to be distributed in both standard and custom formats.

RITIS performs regimented data quality checks on select data to detect and attempt to repair data losses. Where checks are not or cannot be made, RITIS documents the handling of the data so that users are fully aware of the nature of the data.

Data quality performance measures that have been established include:

Completeness: Reported as percent complete, this measure compares the amount of data actually available for analysis with the amount that should be available based on data sampling rates and active sensor configurations.

Validity: Reported as percent valid data, this measure reports the percent of data that passes acceptance criteria such as valid value checks based on traffic flow properties.

RITIS Capabilities

RITIS was designed for two primary capabilities: the exchange of real-time transportation-related information, and the archiving of regional transportation-related data.

Real-time Information Exchange

RITIS information is available to participating agencies through electronic data feeds and a web interface. The electronic data feeds to other systems ultimately make data available to thousands of users beyond those who use the website alone.

The RITIS website allows users with appropriate credentials to monitor real-time performance and situational awareness in a browser. The website provides users with a dynamic set of visualizations and tools that afford efficient situational awareness. Authorized users can interact with live events, incidents, weather, sensors, radio scanners, CCTV, weigh stations, evacuation information, and other data sources and devices in maps, lists, and other graphics as is shown in Figures A3–A8. Users can apply a rich set of filters, access contact information, and even set up alerts. The RITIS website is freely available to any public transportation agency employee or public safety employee. These individuals can request credentials to the site through https://www.ritis.org/register/ by filling out their contact information.

Archived Data Analysis

All data within RITIS (except for CCTV video and law enforcement scanner audio) is archived indefinitely—meaning that no data are ever deemed "too old" to be removed from user access. A number of online tools have been developed to allow users to query, analyze, and derive performance measures from the RITIS archive. Many of these tools are highly interactive and dynamic. They have been developed with the user in mind and afford a high degree of freedom to explore the data with minimal training needed. Data within the archive can also be downloaded and/or exported so that users can perform their own, independent

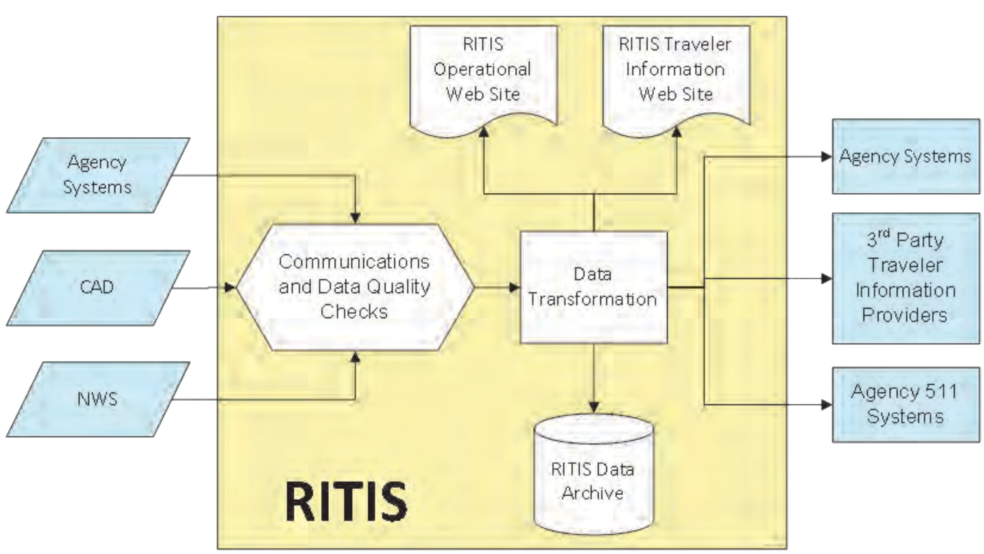


FIGURE A2 RITIS automated data processing.

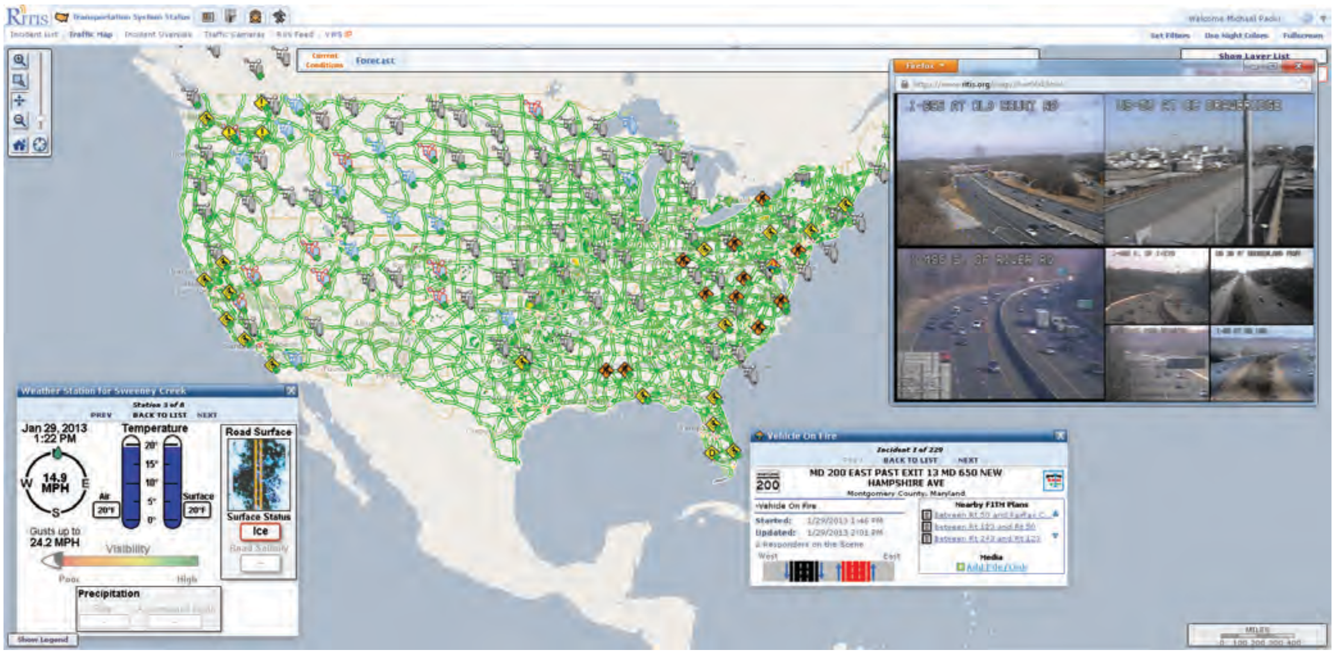


FIGURE A3 A high level screenshot of the real-time RITIS user interface showing several layers of data visualization from comparative traffic flow, to weather, incidents, and even CCTV.

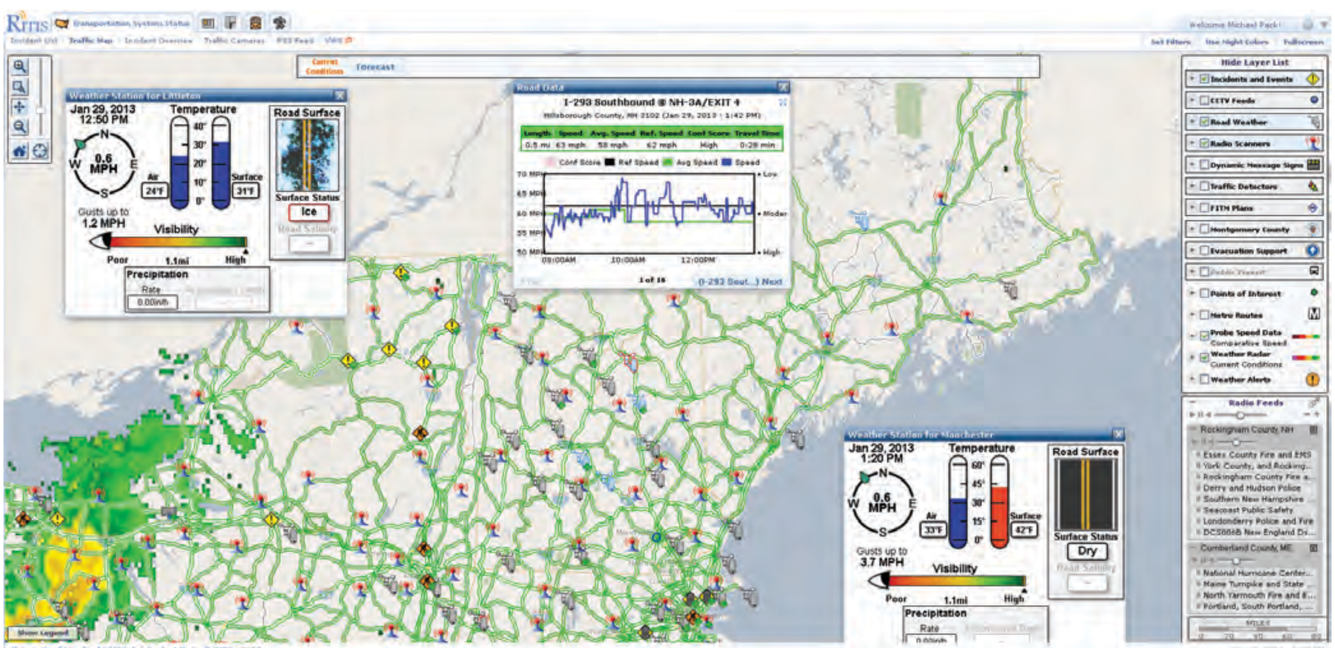


FIGURE A4 Road weather stations (RWIS), National Weather Service radar, speed and volume data, and region-wide scanner audio feeds are just several of the many data layers that are shared between agencies within RITIS.

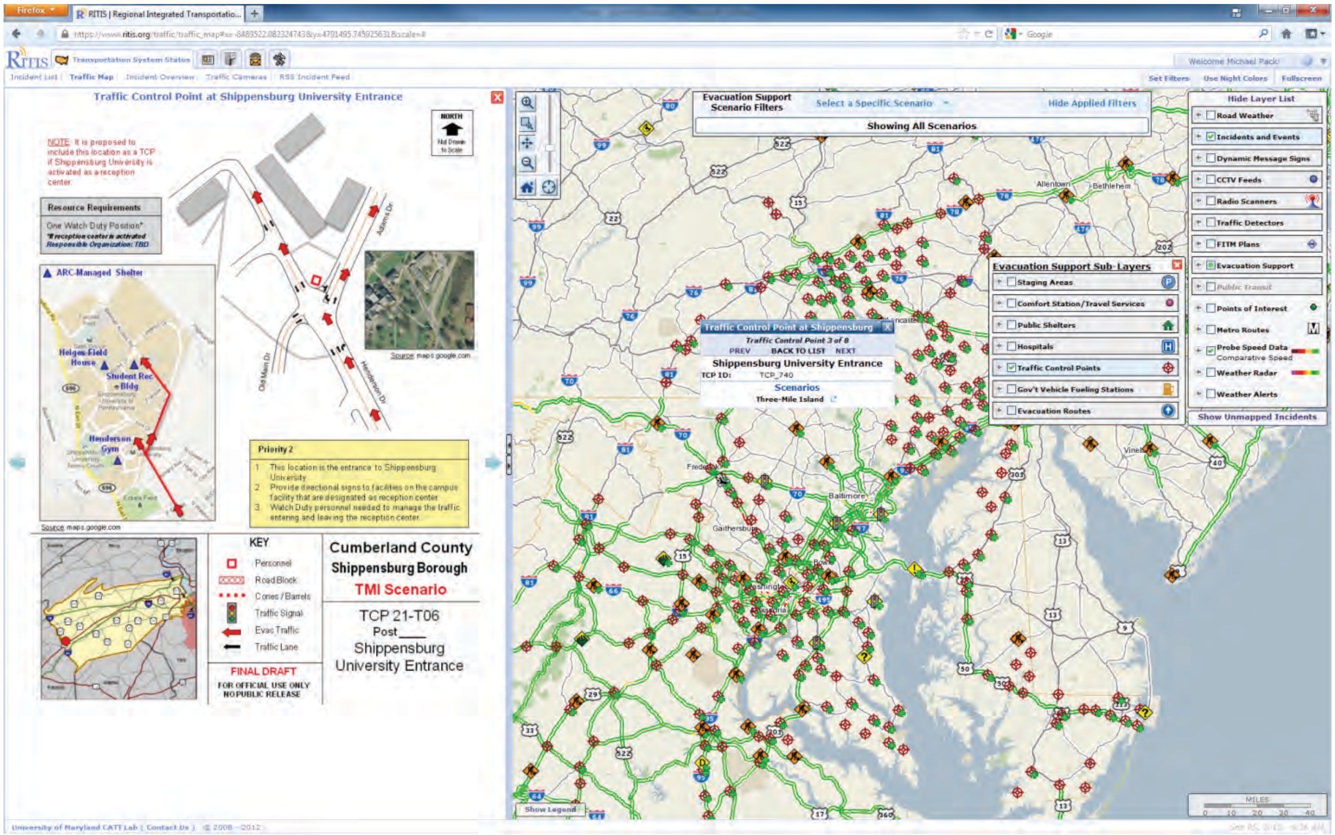


FIGURE A5 Evacuation data within RITIS is shared between agencies to help understand how to manage traffic control points, visualize hospital beds, routes, and even equipment staging areas.

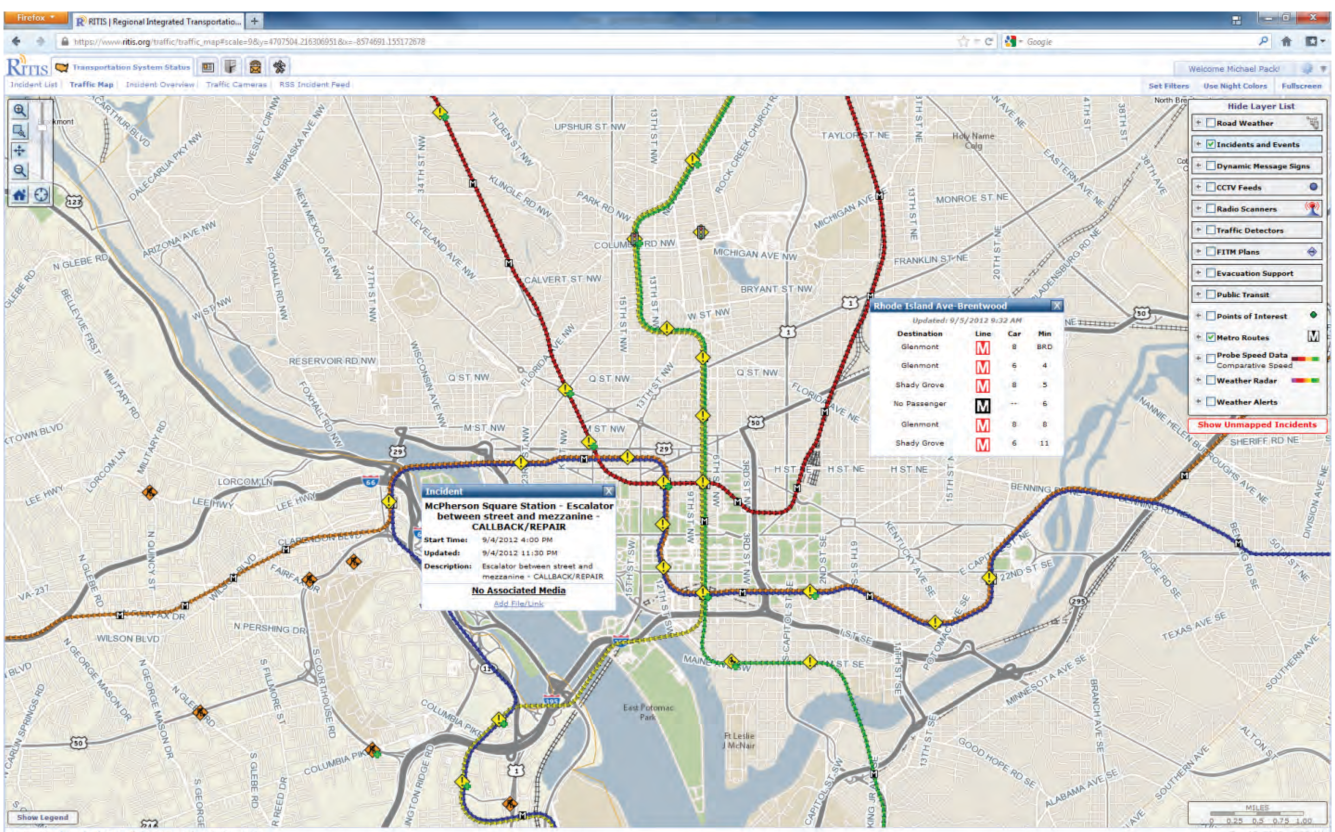


FIGURE A6 Information on real-time train, subway, and bus AVL and schedule data are visualized.

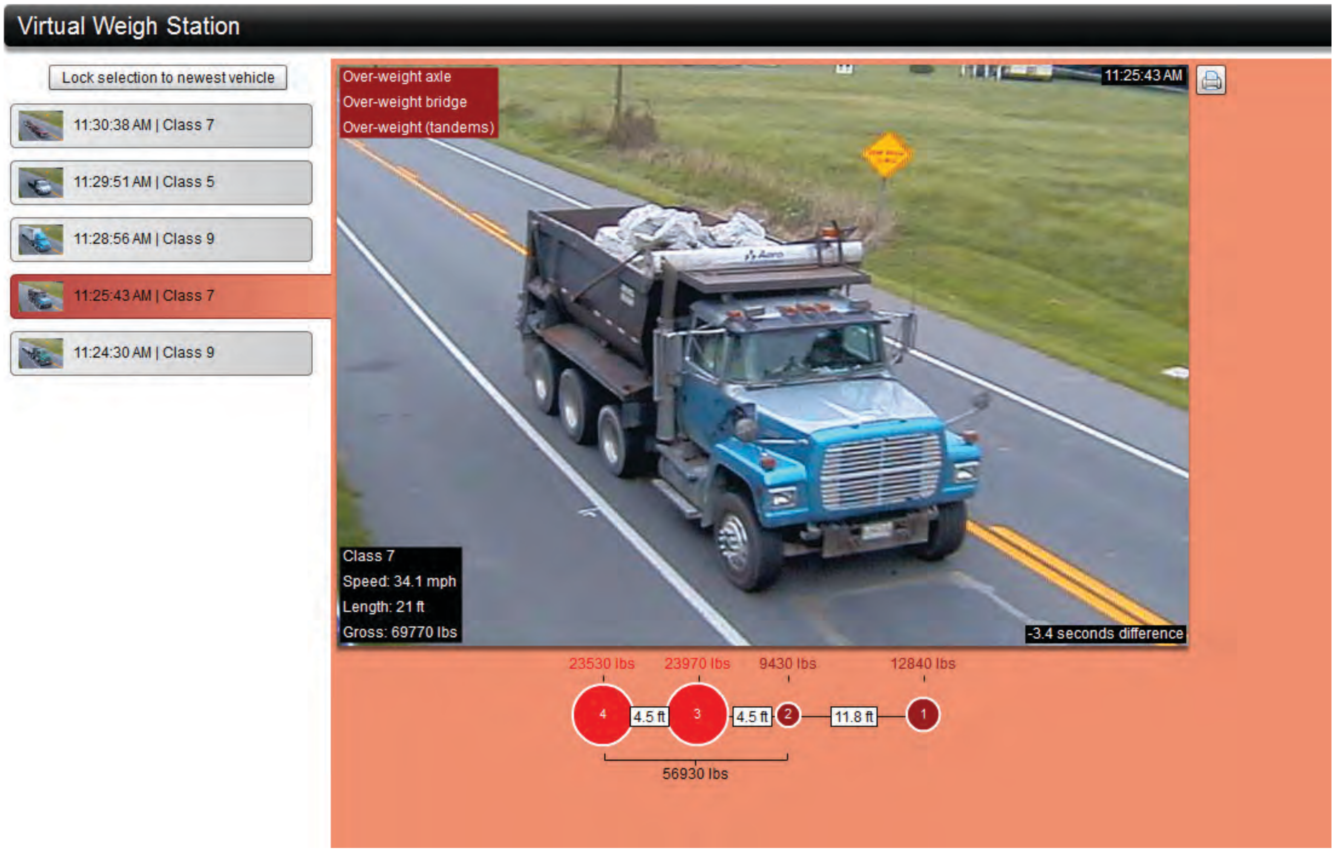


FIGURE A7 Virtual weigh station sensors are visualized within RITIS—axle spacing, axle weights, and other measurements help to target enforcement activities.

analysis. These tools can allow users to identify accident hotspots, analyze queue lengths and traffic congestion/bottlenecks at specific areas, perform after action reviews, understand unit response times, clearance times, weather impacts, and evaluate the effectiveness of transportation operations strategies (Figure A9).

Through the data sharing and archiving efforts of RITIS, agencies have access to tools that allow them to support operations, planning, analysis, research, and performance measures generation using multi-source fused transportation data. These tools include:

- Dashboard displays
- Easy probe data downloads
- Real-time bottleneck views
- Historic bottleneck views
- Statewide bottleneck ranking
- Travel Time Index
- User-delay and user-delay costs
- Queue measurements
- Corridor congestion charts
- Real-time speed data
- Travel time reliability metrics
- Animated maps, congestion scan graphics, charts, graphs, and other interactive graphics

RITIS is constantly under development through grant funding from state DOT contributions, FHWA, and DHS, so users can expect to see frequent updates to functionality and usability. For example, the Maryland State Highway Administration recently funded the development of a series of new features that allow users to derive vehicle hours of delay, user costs, and fuel consumption based on the coupling of probe data readings with volume measurements. When this new functionality was completed, these features were shared with other RITIS participating agencies that are providing probe data.

A number of other visual analytics have been developed that allow agencies to analyze incident data, weather data, and derive other performance measures based off of available data sets. Examples of these and other historical data analysis applications can be seen in the screenshots shown in Figures A10–A15.

Systems Support

It was originally envisioned that RITIS functions would be largely invisible to operations centers in participating agencies since they will see RITIS data through their native system. Because of this, most users were expected to require very little training on RITIS.

RITIS is unusual because no single agency can claim ownership of the project and, by extension, pay all of the recurring costs. Participating agencies must commit to working collaboratively through MATOC to ensure that RITIS is properly operated and maintained. The establishment of a configuration advisory board and executive steering committee were beneficial in ensuring continued support.

The value to participating agencies depended largely on changes made to each agency's existing transportation manage-

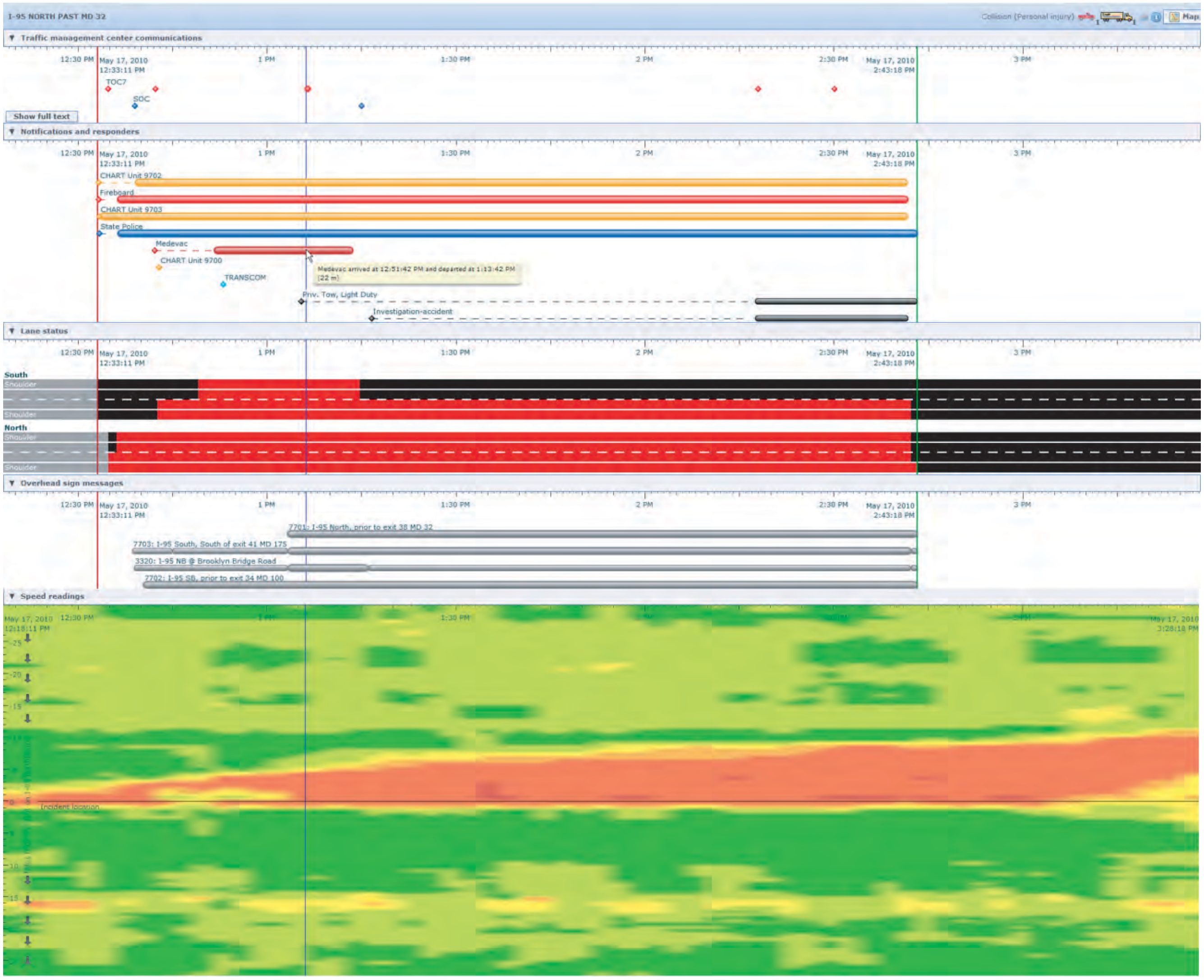


FIGURE A8 Incident timelines show the relationship between agency notification data, arrival times, lane closures, and traffic queues.

FIGURE A9 Most RITIS visualization tools provide an overview of the data; allowing the user to zoom to selected performance measures, and then bringing up specific details upon demand.

ment system to accommodate RITIS data feeds. RITIS provides a structure for the exchange of event information but does not itself provide integration between systems. Subscribing agencies are still responsible for changing or upgrading its system complying with RITIS requirements and standards before publishing or receiving information through RITIS.

As systems evolve, participating agencies will need IT personnel to manage changes in translation and interface software at the point of connection to their operating systems. Because of the complex nature of translating information tailored to each individual participating system, RITIS and participating agencies must ensure that configuration changes are carefully managed. This requires, at a minimum, documentation of each system's configuration at the time of its initial interface with RITIS. It also requires clearly defined policies and procedures for consulting with RITIS developers and maintainers to ensure that subsequent changes to an agency's native system(s) will not preclude RITIS participation.

This requirement is one of the driving forces behind the success of the RITIS website. The RITIS website, as described

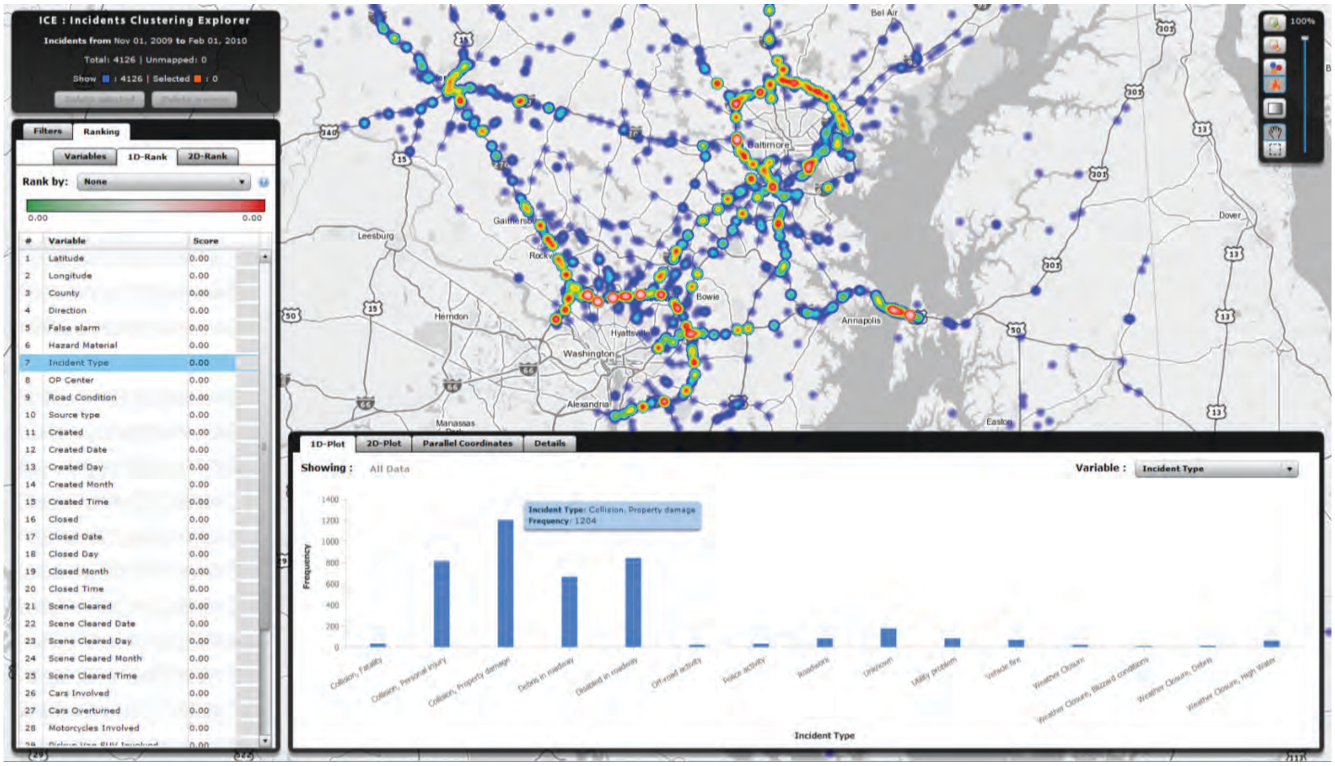


FIGURE A10 The RITIS Incident Cluster Explorer allows agencies to analyze trends in accident data, generate histograms and other charts, graphs, and statistical functions.

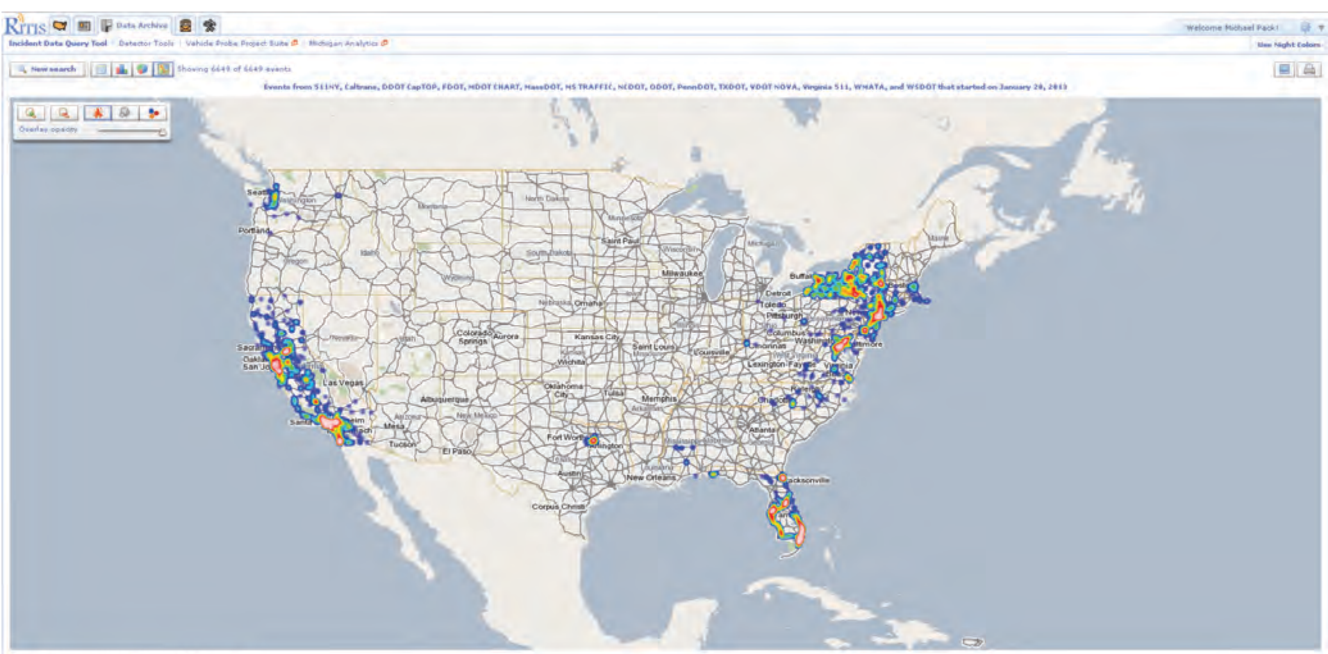


FIGURE A11 Local and regional incident, construction, or special event heatmaps for user-specified date ranges.

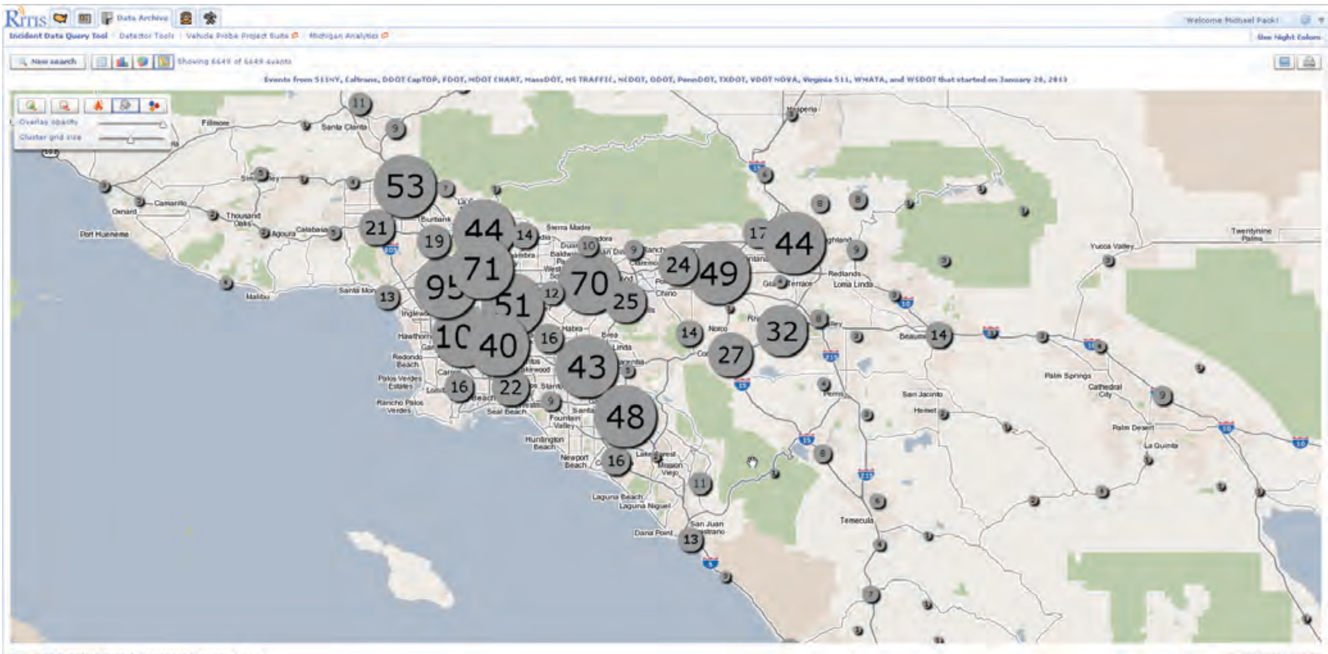


FIGURE A12 Incident cluster diagrams give users a better idea of exactly how many events are occurring in specific regions.

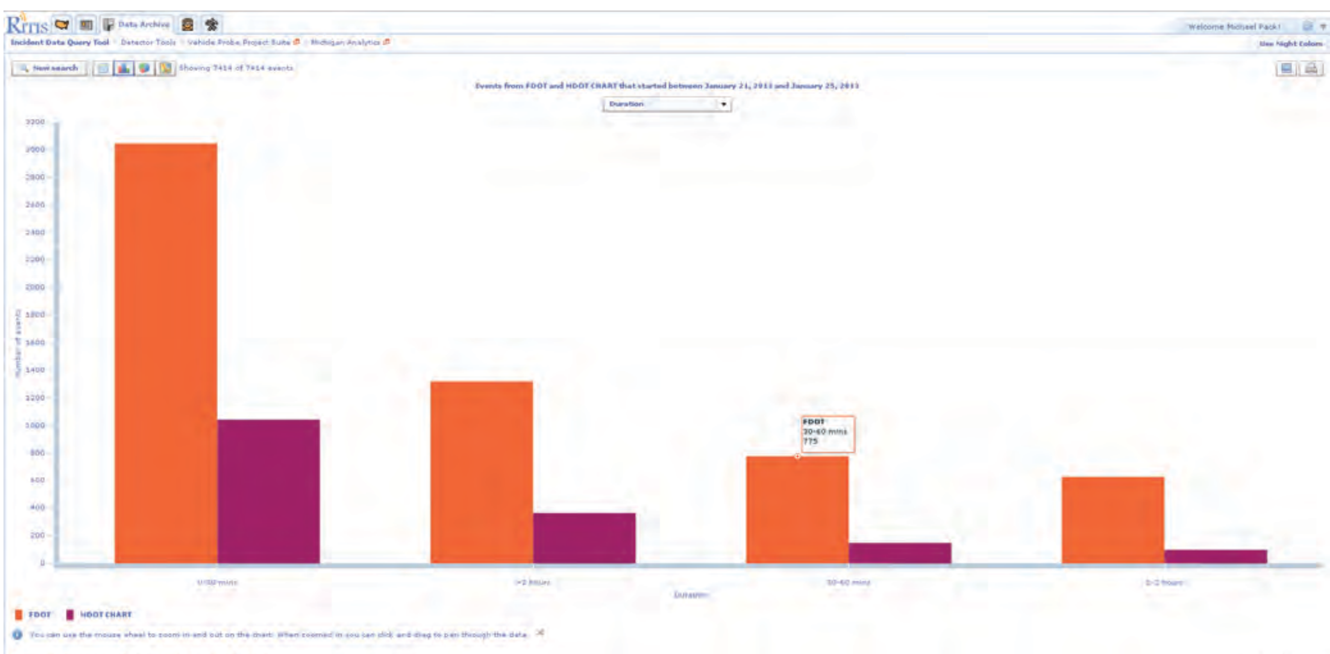
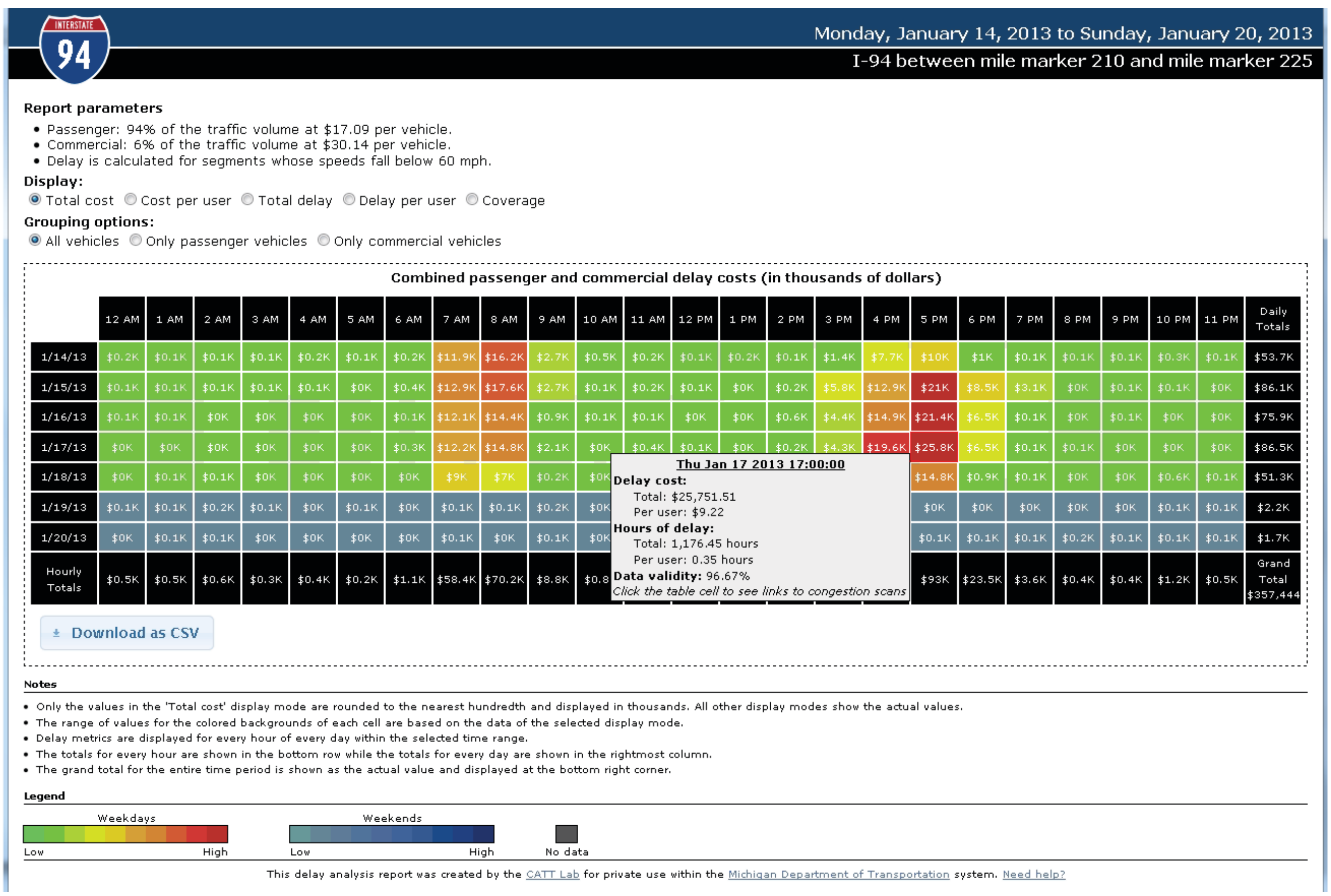


FIGURE A13 Charts and graphs allow users to analyze incident response times, clearance times, or event types by roadways.

FIGURE A14 An RWIS data explorer allows an agency to see how localized weather, visibility, surface temps, etc., can affect traffic speeds, volumes, and accidents near RWIS stations.



Monday, January 14, 2013 to Sunday, January 20, 2013

I-94 between mile marker 210 and mile marker 225

Report parameters

- Passenger: 94% of the traffic volume at $17.09 per vehicle.
- Commercial: 6% of the traffic volume at $30.14 per vehicle.
- Delay is calculated for segments whose speeds fall below 60 mph.

Display:
Total cost · Cost per user · Total delay · Delay per user · Coverage

Grouping options:
All vehicles · Only passenger vehicles · Only commercial vehicles

Combined passenger and commercial delay costs (in thousands of dollars)

	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	Daily Totals
1/14/13	$0.2K	$0.1K	$0.1K	$0.1K	$0.2K	$0.1K	$0.2K	$11.9K	$16.2K	$2.7K	$0.5K	$0.2K	$0.1K	$0.2K	$0.1K	$1.4K	$7.7K	$10K	$1K	$0.1K	$0.1K	$0.1K	$0.3K	$0.1K	$53.7K
1/15/13	$0.1K	$0.1K	$0.1K	$0.1K	$0.1K	$0K	$0.4K	$12.9K	$17.6K	$2.7K	$0.1K	$0.2K	$0.1K	$0K	$0.2K	$5.8K	$12.9K	$21K	$8.5K	$3.1K	$0K	$0.1K	$0.1K	$0K	$86.1K
1/16/13	$0.1K	$0.1K	$0K	$0K	$0K	$0K	$0.1K	$12.1K	$14.4K	$0.9K	$0.1K	$0.1K	$0K	$0K	$0.6K	$4.4K	$14.9K	$21.4K	$6.5K	$0.1K	$0K	$0.1K	$0K	$0K	$75.9K
1/17/13	$0K	$0K	$0K	$0K	$0K	$0K	$0.3K	$12.2K	$14.8K	$2.1K	$0K	$0.4K	$0.1K	$0K	$0.2K	$4.3K	$19.6K	$25.8K	$6.5K	$0.1K	$0.1K	$0K	$0K	$0K	$86.5K
1/18/13	$0K	$0.1K	$0.1K	$0K	$0K	$0K	$0K	$9K	$7K	$0.2K	$0K							$14.8K	$0.9K	$0.1K	$0K	$0K	$0.6K	$0.1K	$51.3K
1/19/13	$0.1K	$0.1K	$0.2K	$0.1K	$0K	$0.1K	$0K	$0.1K	$0.1K	$0.2K	$0K							$0K	$0K	$0K	$0K	$0K	$0.1K	$0.1K	$2.2K
1/20/13	$0K	$0.1K	$0.1K	$0K	$0K	$0K	$0K	$0.1K	$0K	$0.1K	$0K							$0.1K	$0.1K	$0.1K	$0.2K	$0.1K	$0.1K	$0.1K	$1.7K
Hourly Totals	$0.5K	$0.5K	$0.6K	$0.3K	$0.4K	$0.2K	$1.1K	$58.4K	$70.2K	$8.8K	$0.8							$93K	$23.5K	$3.6K	$0.4K	$0.4K	$1.2K	$0.5K	Grand Total $357,444

Thu Jan 17 2013 17:00:00
Delay cost:
Total: $25,751.51
Per user: $9.22
Hours of delay:
Total: 1,176.45 hours
Per user: 0.35 hours
Data validity: 96.67%
Click the table cell to see links to congestion scans

Download as CSV

Notes

- Only the values in the 'Total cost' display mode are rounded to the nearest hundredth and displayed in thousands. All other display modes show the actual values.
- The range of values for the colored backgrounds of each cell are based on the data of the selected display mode.
- Delay metrics are displayed for every hour of every day within the selected time range.
- The totals for every hour are shown in the bottom row while the totals for every day are shown in the rightmost column.
- The grand total for the entire time period is shown as the actual value and displayed at the bottom right corner.

Legend

Weekdays: Low – High · Weekends: Low – High · No data

This delay analysis report was created by the CATT Lab for private use within the Michigan Department of Transportation system. Need help?

FIGURE A15 User Delay Cost analytics in RITIS help agencies understand the financial and environmental impact of congestion. The graphic shows user delay costs in thousands of dollars for each.

previously, is a common operating platform that shows fused data in a central viewer. Because some agencies have not been successful in fully integrating data feeds in a meaningful way into their own systems, many operators rely heavily on the RITIS website for viewing real-time data more so than they rely on their own native systems.

False Assumptions

MATOC Steering Committee Members and RITIS developers made many assumptions, as described previously, during the conception and build-out of the original RITIS system. However, many of these assumptions were incorrect or have evolved over time. These include things such as:

- **Users:** While it was always envisioned that third parties and travelers may want access to RITIS, the extent to which it would be adopted by non-transportation agencies has been astonishing. Less than 50% of current RITIS users are transportation agencies. The bulk of RITIS users are governmental agencies that want to maintain situational awareness, need help with decision support, or have logistical concerns that can be addressed by the data found within RITIS. Examples of non-transportation agencies that use RITIS include:
  - Emergency management agencies
  - FEMA
  - U.S. Army, Air Force, Navy, Coast Guard
  - NorthCom
  - U.S. Secret Service
  - U.S. Capitol and Park Police
  - Fire and rescue
  - Law enforcement (state and local)
  - U.S. Joint Forces Headquarters
  - NSA
  - U.S. Office of Personnel Management
  - Third party travelers information providers
  - University researchers
  - Social Security
  - Pentagon Force Protection
- **Growth Potential:** The number of agencies and users signing up for access to RITIS is growing well beyond what was originally imagined. The number of RITIS website users has tripled in the last year and a half. The number of agencies that want to provide their data to RITIS so that they can better meet their data sharing objectives continues to grow with dozens of agencies now providing their real-time data to the program.
- **Reliance:** RITIS is now viewed as the primary source for transportation data on the Eastern Seaboard. As such, many agencies are beginning to rely on RITIS significantly more than was ever expected. Critical data sources for regional evacuation plans and emergency management information are now stored within RITIS and agencies now know that in an emergency RITIS is where they need to look. This has increased the perceived worth of the system; however, it places a significant operational burden on the support staff.
- **Performance Measures and Planning Applications:** While real-time operations remains the primary focus of RITIS, the number of users who request access solely for the purpose of historical data retrieval and analysis is beginning to advance. Hundreds of individuals access RITIS daily for the sake of studying traffic patterns, identifying congested corridors, developing performance measures, developing reports for the media and decision makers, prioritizing projects, etc. While the data archive was always at the front of developers minds, the success of the RITIS data visualization and performance measurement tools has been a true driving force in continued funding and development.

APPENDIX B

Contacts for Interviewed Agencies

3rd Party Private Sector Data Provider
Anonymous

3rd Party Private Sector Data Provider
Anonymous

3rd Party Private Sector Data Provider
Anonymous

California Highway Patrol
Fran Clader,
Media Relations
fclader@chp.ca.gov

Caltrans PeMS
Karl Petty,
Chief Technologist, Iteris, Inc

Colorado DOT
Jeannie Burkhardt,
ITS Planner
Jeannie.burkhardt@state.co.us

Dallas ICMS
Koorosh Olyai,
Assistant VP of DART
olyai@dart.org

FHWA
Robert Sheehan,
Robert.sheehan@dot.gov

Florida DOT
Arun Krishnamurthy,
ITS Software and Architecture Coordinator
Arun.krishnamurthy@dot.state.fl.us

Georgia DOT
Hugh Colton,
TMC Operations Manager
hcolton@dot.ga.gov

MATOC/RITIS
Taran Hutchinson,
MATOC Facilitator
Taran.hutchinson@matoc.org
&
Andrew Meese,
Systems Management & Planning Director
ameese@mwcog.org

MD State Police
Marier Upshur,
Statewide CAD/RMS/AVL/AFR Program Manager
mupshur@mdsp.org

Michigan DOT
Jason Firman,
Congestion & Mobility
firmanj@michigan.gov

Missouri DOT
Jon Nelson,
Traffic Management & Operations Engineer
Jonathan.nelson@modot.mo.gov

MRCOG
Nathan Masek,
Transportation Planner
nmasek@mrcog-nm.gov

NC DOT
Jennifer Portanova,
NCDOT Traffic Operations Engineer
jportanova@ncdot.gov
&
Kelly Wells,
kwells@ncdot.gov

Niagara International Transportation Technology Coalition
Athena M. Hutchins,
Executive Director
ahutchins@nittec.org

NJDOT
Dhanesh Motiani,
Assistant Commissioner, Transportation Systems Management
Dhanesh.motiani@dot.state.nj.us

NORPC
Clare Brown,
Data Manager
cbrown@norpc.org

PennDOT
Doug Tomlinson,
Chief, Traffic Operations
dtomlinson@pa.gov
&
Robert J. Pento,
Manager, Traveler Information and Special Projects
rpento@pa.gov

San Diego ICMS
Peter Thompson,
Peter.thompson@sandag.org

TN DOT
Frank Horne,
Director, Office of Incident Management
Frank.c.horne@tn.gov

Transcom
Matt Edelman,
Executive Director
Edelman@xcm.org

VDOT
Scott Cowherd,
Transportation, Video and Data Distribution Services Contract Program Manager
Scott.cowherd@vdot.virginia.gov

WashDOT
Daniela Bremmer,
Director of Strategic Assessment
brimmed@wsdot.wa.gov

WMATA
Mark Miller,
Emergency Management Coordinator
Mmiller1@wmata.com

APPENDIX C

Survey Questionnaire

Please enter the date (MM/DD/YYYY).

____

Please enter your contact information.

First Name*: ______________________________
Last Name*: ______________________________
Title: ______________________________
Agency/Organization*: ______________________________
Street Address*: ______________________________
Suite: ______________________________
City*: ______________________________
State*: ______________________________
Zip Code*: ______________________________
Country: ______________________________
E-mail Address*: ______________________________
Phone Number*: ______________________________
Fax Number: ______________________________
Mobile Phone: ______________________________
URL: ______________________________

1) **Is your organization a: (check all that apply)***
[ ] US DOT
[ ] Federal Highway Administration (FHWA)
[ ] State DOT
[ ] County DOT
[ ] City/Local DOT
[ ] Transportation/Transit/Port Authority
[ ] Emergency Management Agency
[ ] Transportation Association
[ ] State Police
[ ] County Police
[ ] City Police
[ ] Park Police
[ ] Other Law Enforcement Agency (Please Specify):
[ ] Fire Department
[ ] Emergency Medical Services
[ ] Metropolitan Planning Organization
[ ] Transit Provider: Rail
[ ] Transit Provider: Bus
[ ] University
[ ] Private Sector Entity Responding on Behalf of an Agency
[ ] Private Sector Entity Responding on Own Behalf
[ ] Other (Please Specify):

2) **What is your role at the organization? (check all that apply)***
[ ] Operations Manager
[ ] Traffic Management Operator
[ ] Field Operator
[ ] Traffic Planner
[ ] Traffic Engineer
[ ] Law Enforcement
[ ] Emergency Manager
[ ] Program/Project Manager
[ ] Public Information Officer
[ ] IT Specialist
[ ] GIS Specialist
[ ] Researcher
[ ] Policy
[ ] Legal
[ ] Other (Please Specify):

SURVEY QUALIFICATION

3) **Does your organization provide operations data to other organizations?***
( ) Yes
( ) No
( ) I don’t know

INFORMATION ABOUT DATA YOUR ORGANIZATION PROVIDES TO OTHERS

4) What types of operations data does your organization provide to other organizations? (check all that apply)*

[ ] Incident/Event/Construction Type
[ ] Location
[ ] Lane Closures
[ ] Injuries/Fatalities
[ ] Property Damage
[ ] Hazmat Information
[ ] Vehicles Involved
[ ] Notifications
[ ] Responder Status
[ ] Operator Logs
[ ] Queue Length
[ ] Clearance Time
[ ] Detour Information
[ ] Construction/Special Event Schedule
[ ] Expected Duration
[ ] Speed
[ ] Volume
[ ] Lane Occupancy
[ ] Vehicle Occupancy
[ ] Vehicle Classification
[ ] Speed
[ ] Travel Time
[ ] Sample Size of Probes to General Traffic Flow
[ ] Other (Please Specify):
[ ] Dynamic Messaging Signs
[ ] Highway Advisory Radio
[ ] Gate Status
[ ] CCTV/Video
[ ] Road Weather Information System (RWIS)
[ ] Maintenance
[ ] Snow Plow
[ ] Transit
[ ] Responder Locations
[ ] Road Weather Conditions
[ ] Radar
[ ] Road Weather Information System (RWIS)
[ ] Law Enforcement
[ ] Fire/Rescue
[ ] Emergency Medical Services (EMS)
[ ] Timing Plans
[ ] Status
[ ] Text/Paging Alerts
[ ] Geographic Information System (GIS)/Map Information (Road Network)
[ ] Radio Communications
[ ] Transit Schedules
[ ] Emergency/Evacuation Plans
[ ] I don't know
[ ] Other (Please Specify):

INFORMATION ABOUT DATA YOUR ORGANIZATION PROVIDES TO OTHERS

5) How does your organization provide its operations data? (check all that apply)*

[ ] I don't know
[ ] Center-to-Center (C2C) Feeds or Other Webservices
[ ] Publicly Available Internet Feeds
[ ] File Transfer Protocol (FTP)
[ ] 511 Websites and Phone Systems
[ ] Third Party Hosted Sharing/Integration Systems
[ ] Paper Forms Faxed or Other Media (e.g., CDROM, Flashdrive) Sent via Currier/Mail
[ ] E-mail
[ ] Phone Calls
[ ] Radio
[ ] Other (Please Specify):

6) Does your organization require data recipients to execute any of the following? (check all that apply)*

[ ] I don't know
[ ] Formal Data Use Agreements and/or Contracts
[ ] Memorandums of Understanding (MOUs)
[ ] Implied Good Faith/Hand-Shake Agreements
[ ] No Specific Agreement Needed
[ ] Electronic Signatures/Checkboxes on Web Sites (e.g., "I agree to the terms and conditions")
[ ] Reciprocal Agreement (e.g., "I will share with you, if you share with me.")
[ ] Other (Please Specify):

7) How often does your organization provide operations data? (check all that apply)*

[ ] I don't know
[ ] Continuously in Real Time
[ ] Near-Real Time
[ ] Hourly
[ ] Daily/Nightly
[ ] Weekly
[ ] Monthly
[ ] Quarterly
[ ] Yearly
[ ] Other (Please Specify):

8) Who are the consumers of your organization's operations data? (check all that apply)*

[ ] I don't know
[ ] US DOT
[ ] Federal Highway Administration (FHWA)
[ ] State DOT
[ ] County DOT
[ ] City/Local DOT
[ ] Transportation/Transit/Port Authority
[ ] Emergency Management Agency
[ ] Transportation Association
[ ] Media
[ ] State Police
[ ] County Police
[ ] City Police
[ ] Park Police
[ ] Other Law Enforcement Agency (Please Specify):
[ ] Fire Department
[ ] Emergency Medical Services
[ ] Metropolitan Planning Organization
[ ] Transit Provider: Rail
[ ] Transit Provider: Bus
[ ] University
[ ] Private Sector Entity Acting on Behalf of an Agency
[ ] Third Party For Profit Company
[ ] Third Party Non Profit
[ ] Other (Please Specify):

9) Why does your organization provide its operations data to others? (check all that apply)*

[ ] **I don't know**
[ ] **Safety Benefits such as:**
- *Faster Incident Response
- *Faster Incident Clearance
- *Reduction in Number of Incidents
- *Reduction in Number of Secondary Incidents
- *Increased Responder Safety

[ ] **Resource Sharing Benefits such as:**
- *Shared ITS Device Deployment
- *Shared Safety/Service Patrol Deployment
- *Shared Operations Personnel
- *Shared IT Personnel
- *Shared IT Equipment

[ ] **Traveler Information Benefits such as:**
- *Providing better traveler information through additional channels/media

[ ] **Economic Benefits for the Traveler such as:**
- *Reduction in User Delays
- *Reduction of Travel Time
- *Reduction of Fuel Consumption

[ ] **Enhancing the Visibility of Your Program that can lead to:**
- *Better Public Perception
- *Additional Funding Opportunities
- *Increased Transparency

[ ] **Legal Requirement such as:**
- *Local, State, or Federal Laws that Mandate We Share Information with Third Parties
- *Freedom of Information Act (FOIA) Request

[ ] **Transportation Planning benefits such as:**
- *Validation of model conditions
- *Validation of other collected and/or gathered data

[ ] **Performance Measurement and/or Performance Management Information for:**
- *System Performance Summaries
- *Investment Decision Making

[ ] **Reciprocal Agreement such as:**
- *"I will share with you, if you share with me."

[ ] **Other (Please Specify):**

INFORMATION ABOUT AGENCY THAT DOES NOT PROVIDE DATA

10) If your organization does not share its operations data with others, or if there are certain data elements that your organization is not sharing yet, what are the reasons your organization does not share all or portions of operations data with others? (check all that apply):*

[ ] I don't know
[ ] Not Applicable (e.g., Organization already shares all of its data.)
[ ] Technical Challenges (Please Explain):
[ ] Lack of Funding
[ ] Lack of Expertise
[ ] Sensitivity of Operations Data (e.g., There is just too much sensitive information, like victim's phone numbers, names, etc.)
[ ] Exposure of Proprietary Process or Technologies
[ ] Private Data Provide Constraints (e.g., We don't own the data, and are not allowed to share it with others.)
[ ] No person in or out of the organization has been pushing to have our data shared with others

[ ] Lack of Clear Quantifiable Benefits, so I'm not inclined to make the investment needed to share my data
[ ] Poor Quality of Data
[ ] No One Has Requested the Data
[ ] Concerns about my own operations being overly scrutinized
[ ] Liability and indemnification concerns (e.g., I don't want to be sued for sharing inaccurate information)
[ ] Other (Please Specify):

11) If your organization could overcome those challenges, would it provide its operations data to other organizations?*
( ) Yes
( ) No
( ) I don't know
( ) Other (Please Specify): _________________
( ) Not Applicable

SURVEY QUALIFICATION

12) Does your agency gather operations data from other organizations?*
( ) Yes
( ) No
( ) I don't know

INFORMATION ABOUT DATA YOUR ORGANIZATION GATHERS FROM OTHER ORGANIZATIONS

Information about Operations Data your Organization Gathers from Other Organizations

13) What types of operations data does your organization gather from other organizations? (check all that apply)*
[ ] Incident/Event/Construction Type
[ ] Location
[ ] Lane Closures
[ ] Injuries/Fatalities
[ ] Property Damage
[ ] Hazmat Information
[ ] Vehicles Involved
[ ] Notifications
[ ] Responder Status
[ ] Operator Logs
[ ] Queue Length
[ ] Clearance Time
[ ] Detour Information
[ ] Construction/Special Event Schedule
[ ] Expected Duration
[ ] Speed
[ ] Volume
[ ] Lane Occupancy
[ ] Vehicle Occupancy
[ ] Vehicle Classification
[ ] Speed
[ ] Travel Time
[ ] Sample Size of Probes to General Traffic Flow
[ ] Other (Please Specify):
[ ] Dynamic Messaging Signs
[ ] Highway Advisory Radio
[ ] Gate Status
[ ] CCTV/Video
[ ] Road Weather Information System (RWIS)
[ ] Maintenance
[ ] Snow Plow
[ ] Transit
[ ] Responder Locations
[ ] Road Weather Conditions
[ ] Radar
[ ] Road Weather Information System (RWIS)
[ ] Law Enforcement
[ ] Fire/Rescue
[ ] Emergency Medical Services (EMS)
[ ] Timing Plans
[ ] Status
[ ] Text/Paging Alerts
[ ] Geographic Information System (GIS)/Map Information (Road Network)
[ ] Radio Communications
[ ] Transit Schedules
[ ] Emergency/Evacuation Plans
[ ] I don't know
[ ] Other (Please Specify):

INFORMATION ABOUT DATA YOUR ORGANIZATION GATHERS FROM OTHER ORGANIZATIONS

14) How does your organization gather data from other organizations? (check all that apply)*
[ ] I don't know
[ ] Center-to-Center (C2C) Feeds or Other Webservices
[ ] Publicly Available Internet Feeds
[ ] File Transfer Protocol (FTP)
[ ] 511 Websites and Phone Systems
[ ] Third Party Hosted Sharing/Integration Systems
[ ] Paper Forms Faxed or Other Media (e.g., CDROM, Flashdrive) Sent via Currier/Mail
[ ] Phone Calls
[ ] Radio
[ ] Other (Please Specify):

15) Is your organization required to execute any of the following in order to gather data from other organizations? (check all that apply)*

[ ] I don't know
[ ] Formal Data Use Agreements and/or Contracts
[ ] Memorandums of Understanding (MOUs)
[ ] Implied Good Faith/Hand-Shake Agreements
[ ] No Specific Agreement Needed
[ ] Electronic Signatures/Checkboxes on Web Sites (e.g., "I agree to the terms and conditions")
[ ] Reciprocal Agreement (e.g., "I will share with you, if you share with me.")
[ ] Other (Please Specify):

16) How often does your organization gather data from other organizations? (check all that apply)*

[ ] I don't know
[ ] Continuously in Real Time
[ ] Near-Real Time
[ ] Hourly
[ ] Daily/Nightly
[ ] Weekly
[ ] Monthly
[ ] Quarterly
[ ] Yearly
[ ] Other (Please Specify):

17) What are the organizations that provide data to your organization? (check all that apply)*

[ ] I don't know
[ ] State DOT
[ ] County DOT
[ ] City/Local DOT
[ ] Transportation/Transit/Port Authority
[ ] Emergency Management Agency
[ ] Transportation Association
[ ] Media
[ ] State Police
[ ] County Police
[ ] City Police
[ ] Park Police
[ ] Other Law Enforcement Agency (Please Specify):
[ ] Fire Department
[ ] Emergency Medical Services
[ ] Metropolitan Planning Organization
[ ] Transit Provider: Rail
[ ] Transit Provider: Bus
[ ] University
[ ] Private Sector Entity Acting on Behalf of an Agency
[ ] Third Party For Profit Company
[ ] Third Party Non Profit
[ ] Other (Please Specify):

18) Why does your organization gather data from other organizations? (check all that apply)*

[ ] **I don't know**
[ ] **Safety Benefits such as:**
- *Faster Incident Response
- *Faster Incident Clearance
- *Reduction in Number of Incidents
- *Reduction in Number of Secondary Incidents
- *Increased Responder Safety

[ ] **Resource Sharing Benefits such as:**
- *Shared ITS Device Deployment
- *Shared Safety/Service Patrol Deployment
- *Shared Operations Personnel
- *Shared IT Personnel
- *Shared IT Equipment

[ ] **Traveler Information Benefits such as:**
- *Providing better traveler information through additional channels/media

[ ] **Economic Benefits for the Traveler such as:**
- *Reduction in User Delays
- *Reduction of Travel Time
- *Reduction of Fuel Consumption

[ ] **Enhancing the Visibility of Your Program that can lead to:**
- *Better Public Perception
- *Additional Funding Opportunities
- *Increased Transparency

[ ] **Legal Requirement such as:**
- *Local, State, or Federal Laws that Mandate We Share Information with Third Parties
- *Freedom of Information Act (FOIA) Request

[ ] **Transportation Planning Benefits such as:**
- *Validation of model conditions
- *Validation of other collected and/or gathered data

[ ] **Performance Measurement and/or Performance Management Information for:**
- *System Performance Summaries
- *Investment Decision Making

[ ] **Reciprocal Agreement such as:**
- *"I will share with you, if you share with me."

[ ] Other (Please Specify):

DESIRED ELEMENTS

19) What types of data would your organization be interested in gathering if it was available and accessible (and is not currently being gathered)? (check all that apply)*

[ ] Incident/Event/Construction Type
[ ] Location
[ ] Lane Closures
[ ] Injuries/Fatalities
[ ] Property Damage
[ ] Hazmat Information
[ ] Vehicles Involved
[ ] Notifications
[ ] Responder Status
[ ] Operator Logs
[ ] Queue Length
[ ] Clearance Time
[ ] Detour Information
[ ] Construction/Special Event Schedule
[ ] Expected Duration
[ ] Speed
[ ] Volume
[ ] Lane Occupancy
[ ] Vehicle Occupancy
[ ] Vehicle Classification
[ ] Speed
[ ] Travel Time
[ ] Sample Size of Probes to General Traffic Flow
[ ] Other (Please Specify):
[ ] Dynamic Messaging Signs
[ ] Highway Advisory Radio
[ ] Gate Status
[ ] CCTV/Video
[ ] Road Weather Information System (RWIS)
[ ] Maintenance
[ ] Snow Plow
[ ] Transit
[ ] Responder Locations
[ ] Road Weather Conditions
[ ] Radar
[ ] Road Weather Information System (RWIS)
[ ] Law Enforcement
[ ] Fire/Rescue
[ ] Emergency Medical Services (EMS)
[ ] Timing Plans
[ ] Status
[ ] Text/Paging Alerts
[ ] Geographic Information System (GIS)/Map Information (Road Network)
[ ] Radio Communications
[ ] Transit Schedules
[ ] Emergency/Evacuation Plans
[ ] I don’t know
[ ] Other (Please Specify):

APPENDIX D

Detailed Survey Results

(D1–D3)

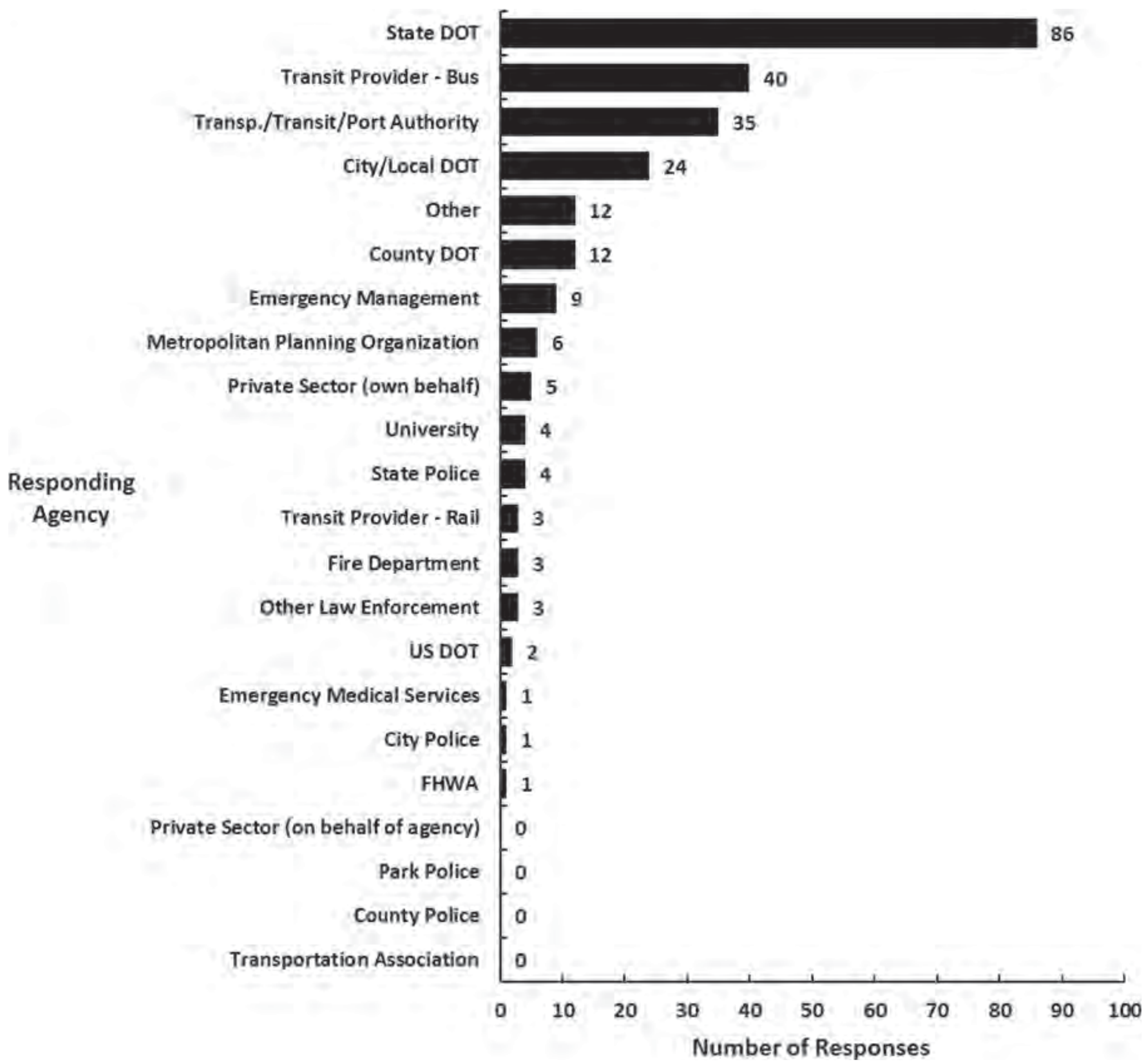


FIGURE D1 Agencies participating in the survey—198 responses (Question 1).

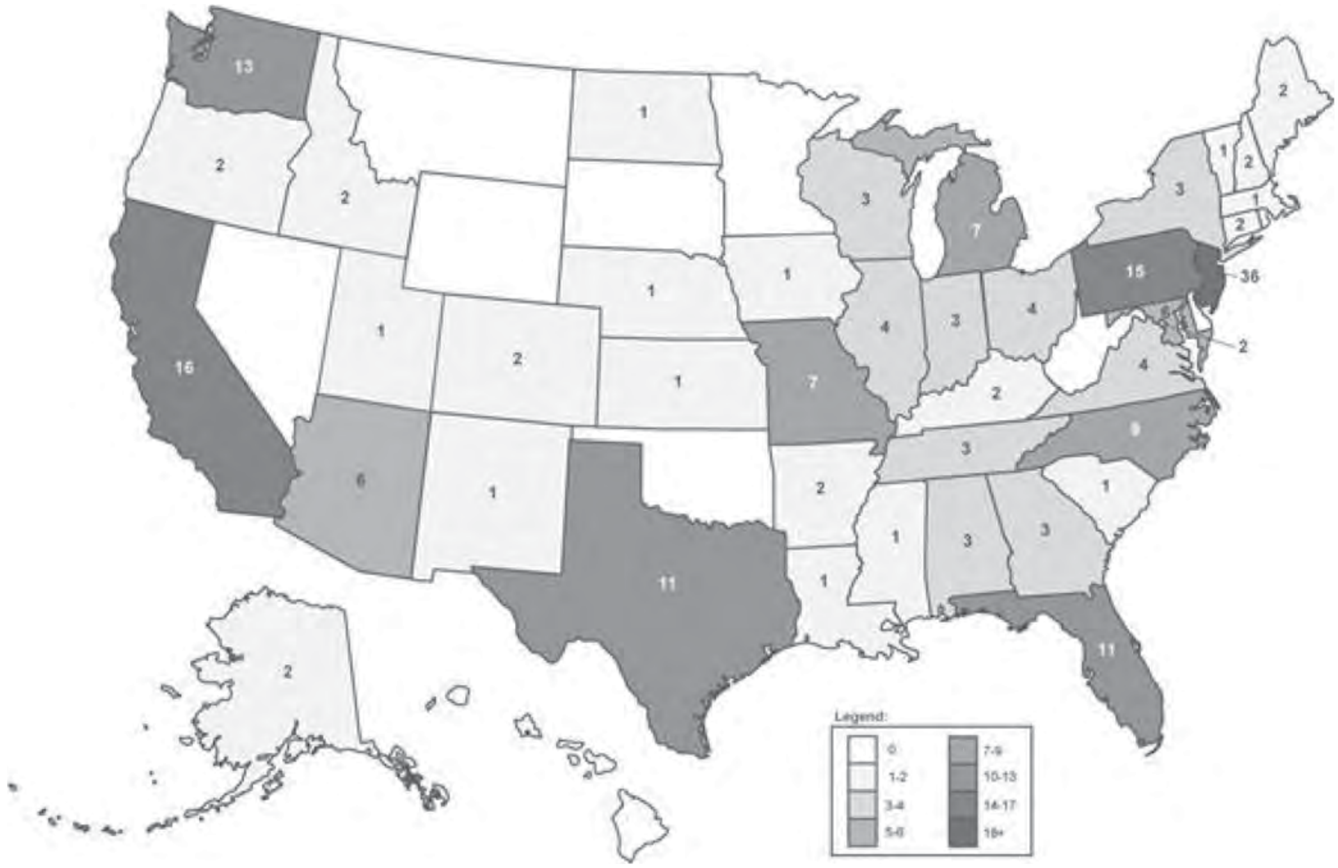


FIGURE D2 Number of respondents by state.

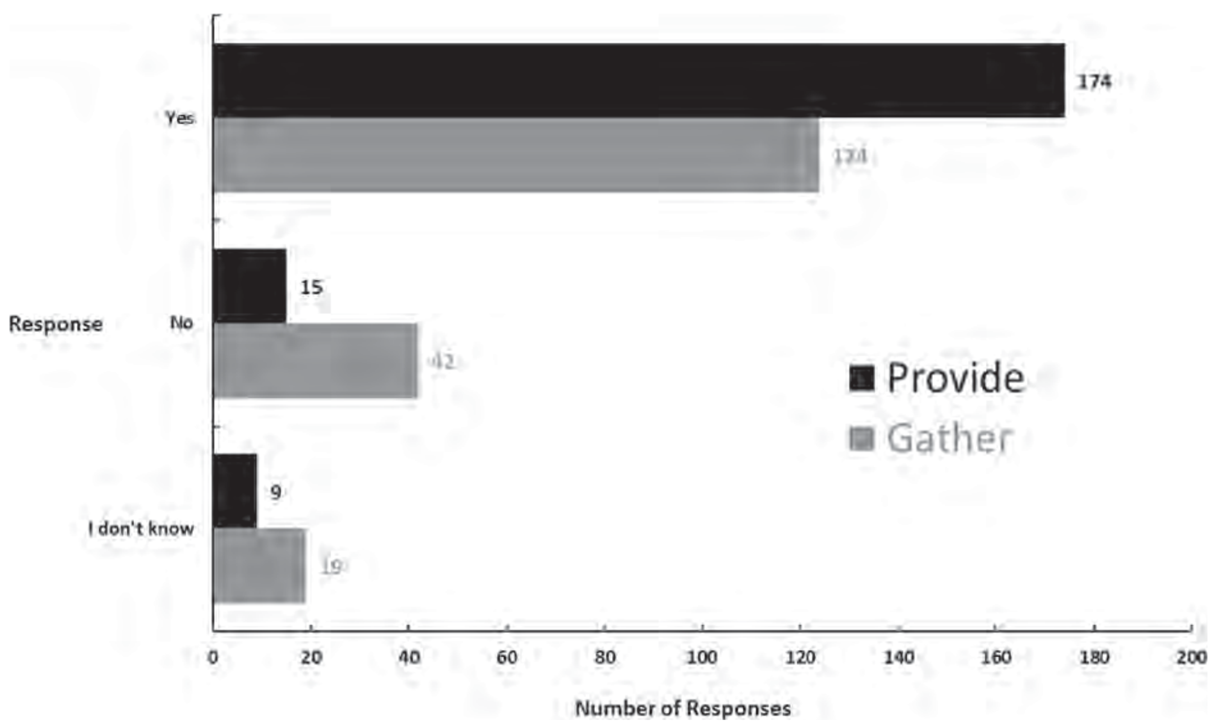


FIGURE D3 Agencies providing and gathering operations data—198 responses (Questions 3, 12).

AGENCIES SHARING INCIDENT DATA (D4–D18)

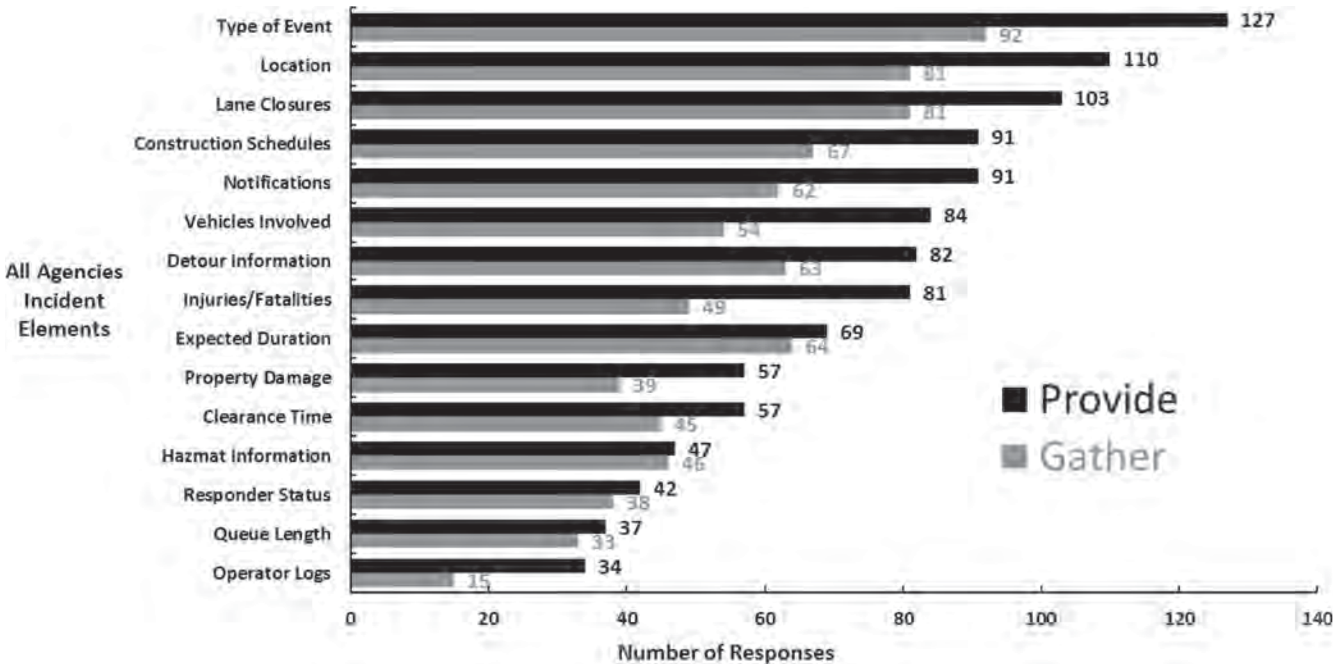


FIGURE D4 Incident elements shared by agencies in general—198 responses (Questions 4, 13).

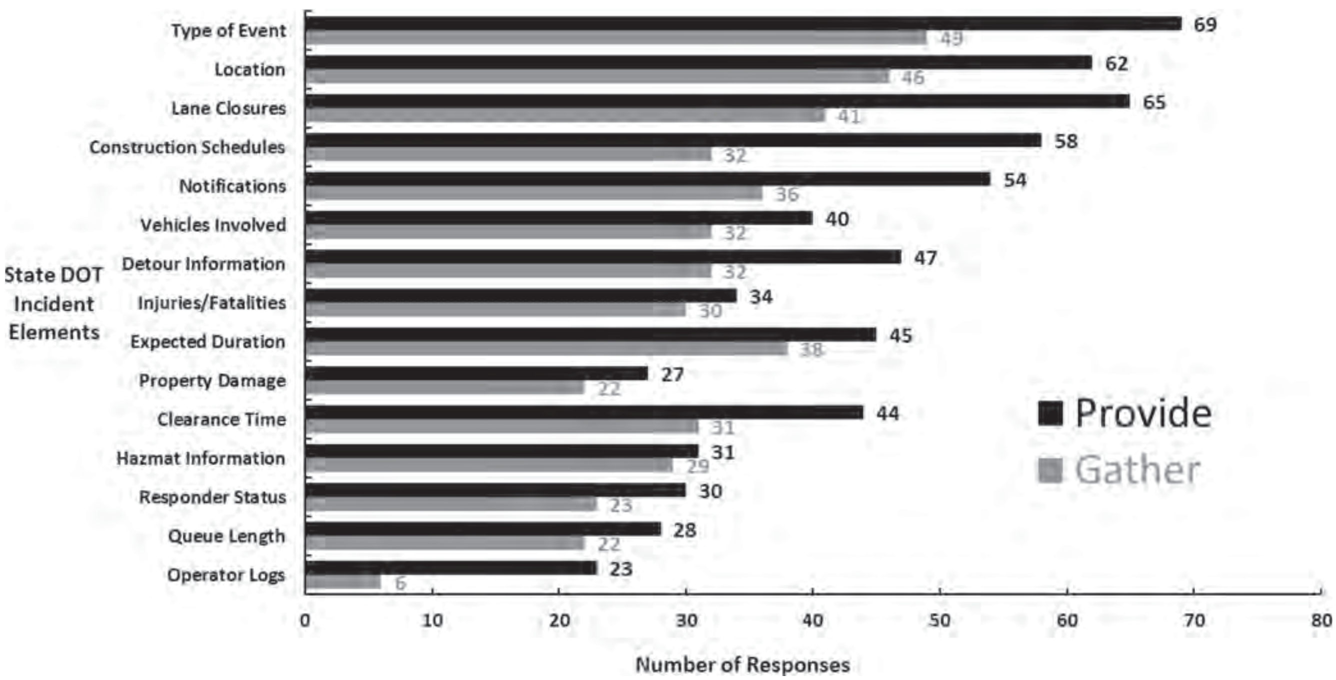


FIGURE D5 Incident elements shared by state DOTs—86 responses (Questions 4, 13).

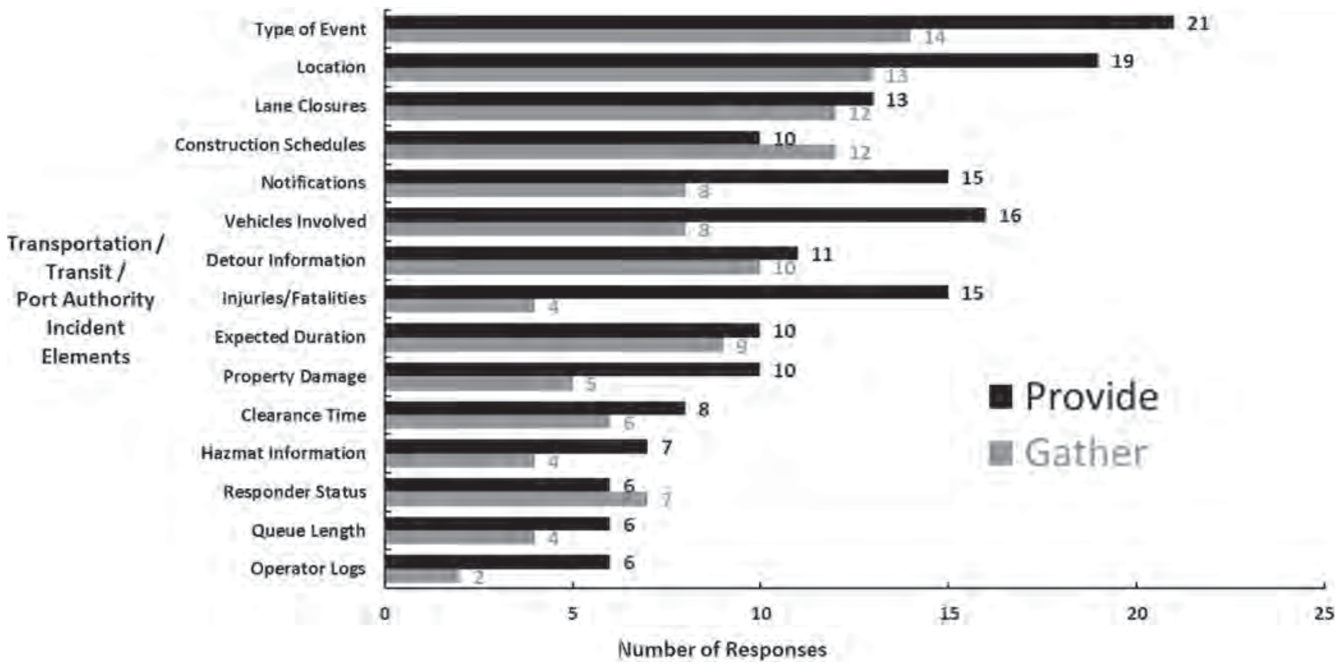


FIGURE D6 Incident elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

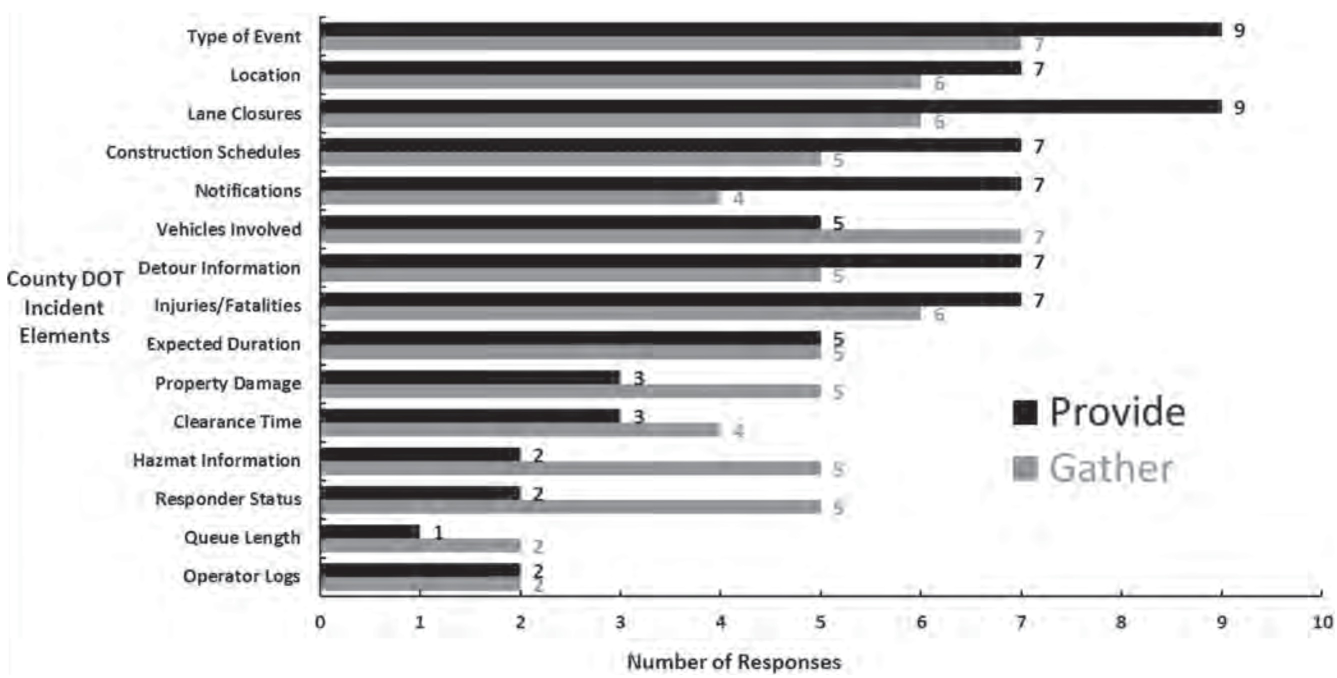


FIGURE D7 Incident elements shared by county DOTs—12 responses (Questions 4, 13).

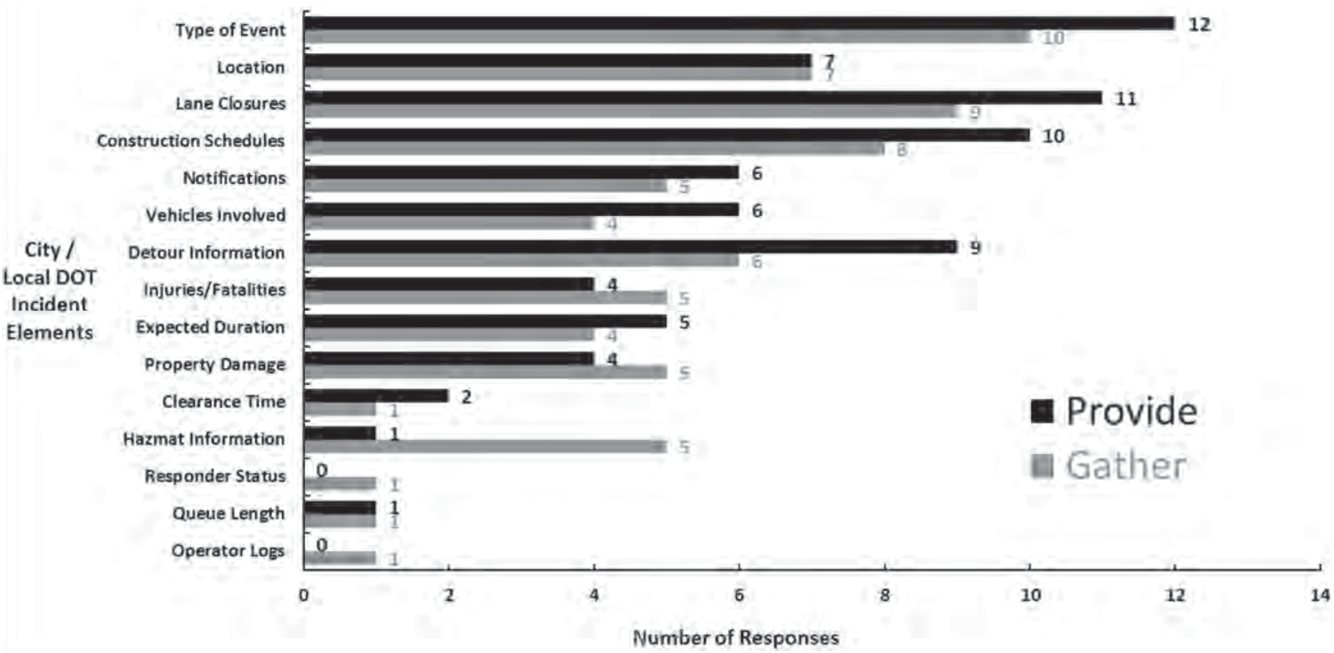


FIGURE D8 Incident elements shared by city and local DOTs—24 responses (Questions 4, 13).

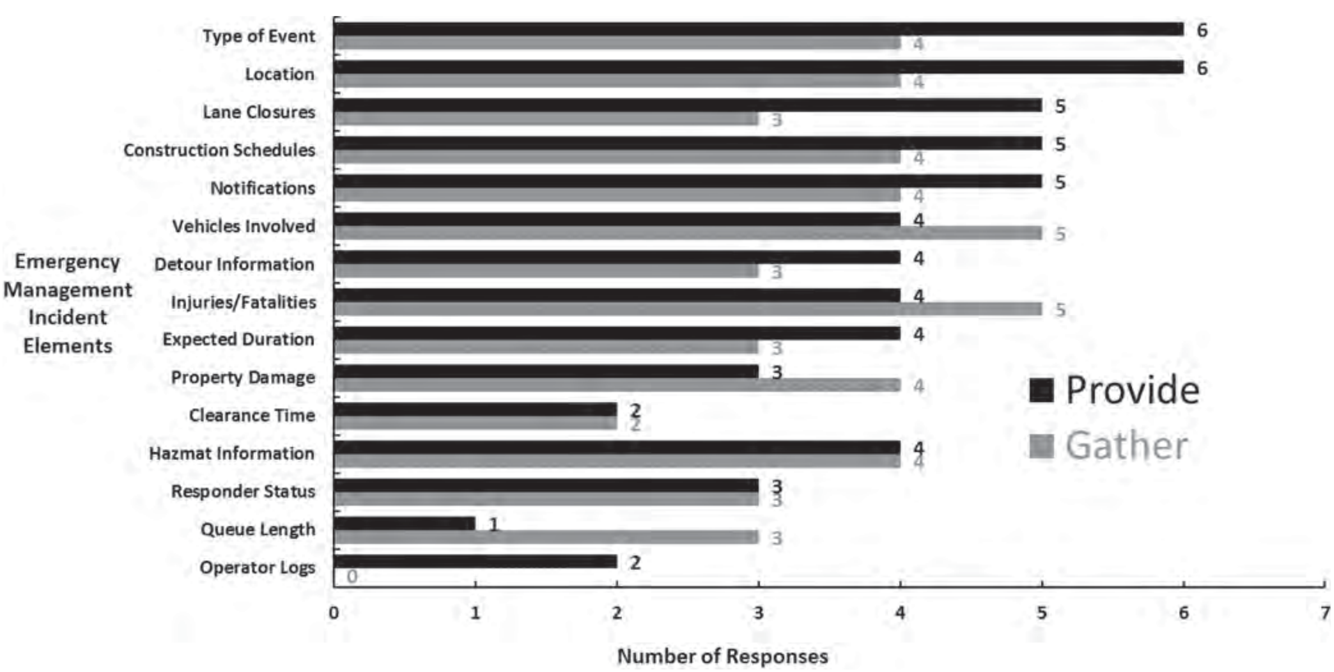


FIGURE D9 Incident elements shared by emergency management agencies—9 responses (Questions 4, 13).

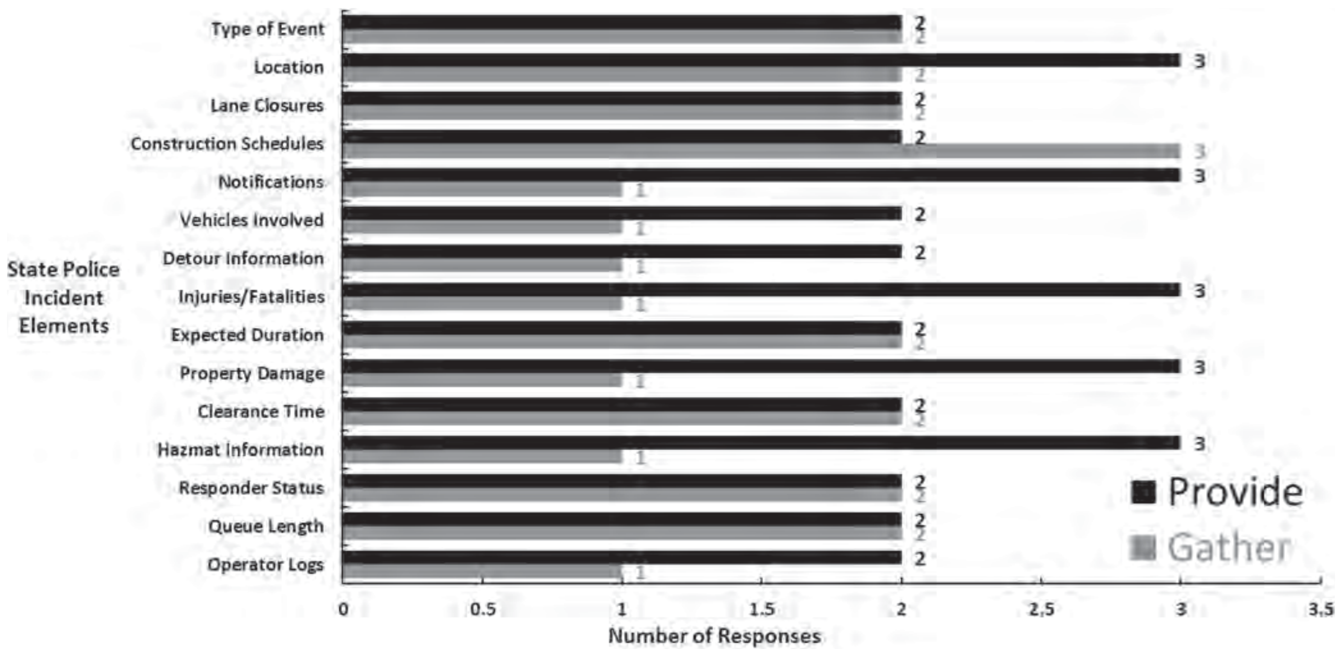


FIGURE D10 Incident elements shared by state police—4 responses (Questions 4, 13).

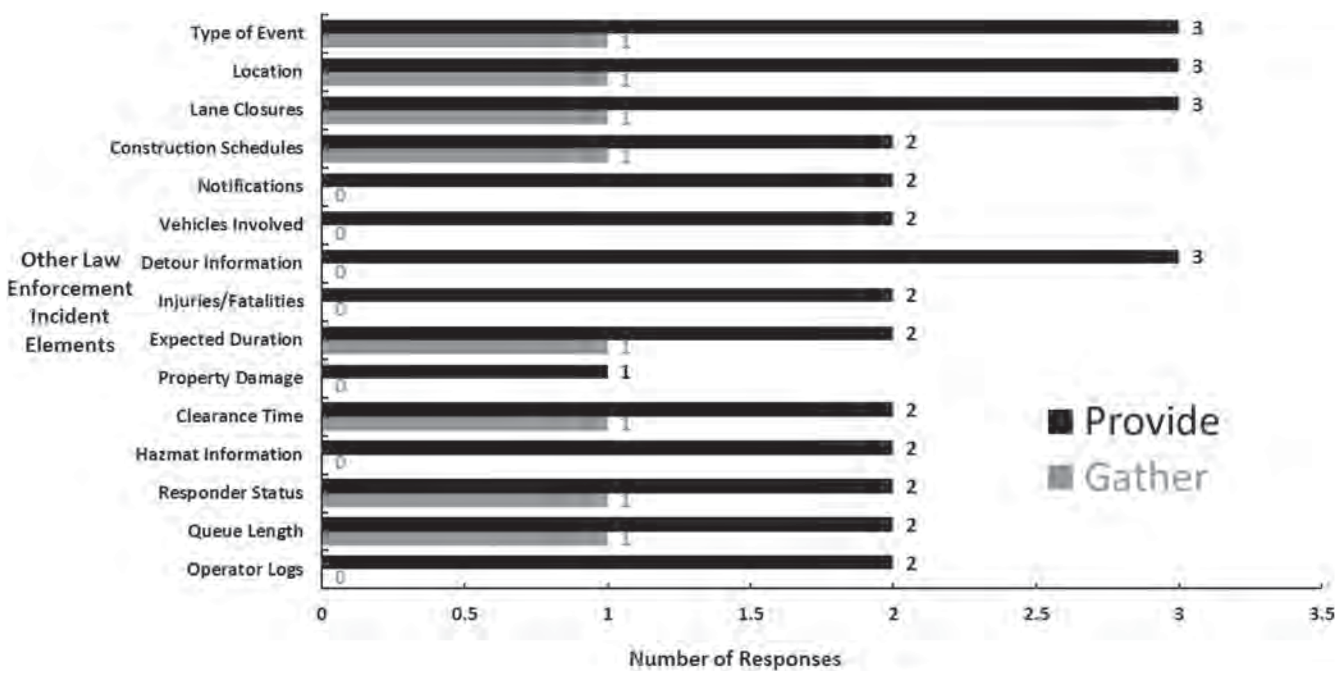


FIGURE D11 Incident elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

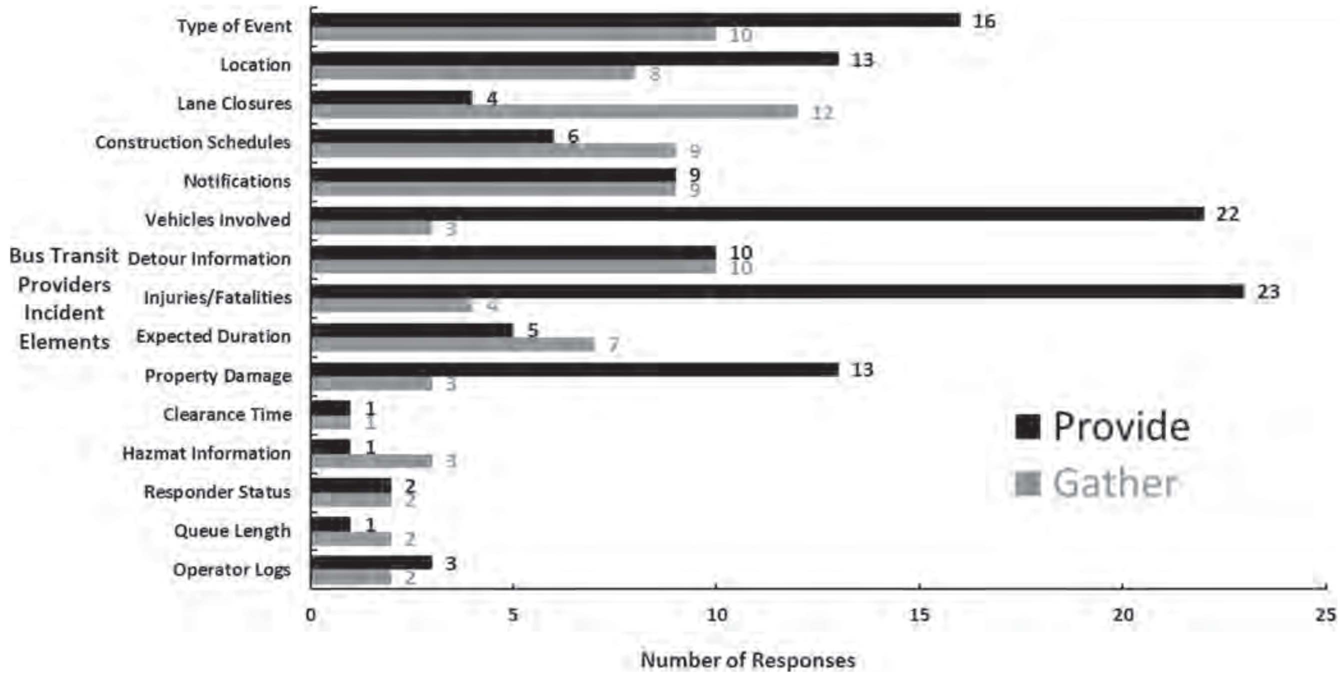


FIGURE D12 Incident elements shared by bus transit providers—40 responses (Questions 4, 13).

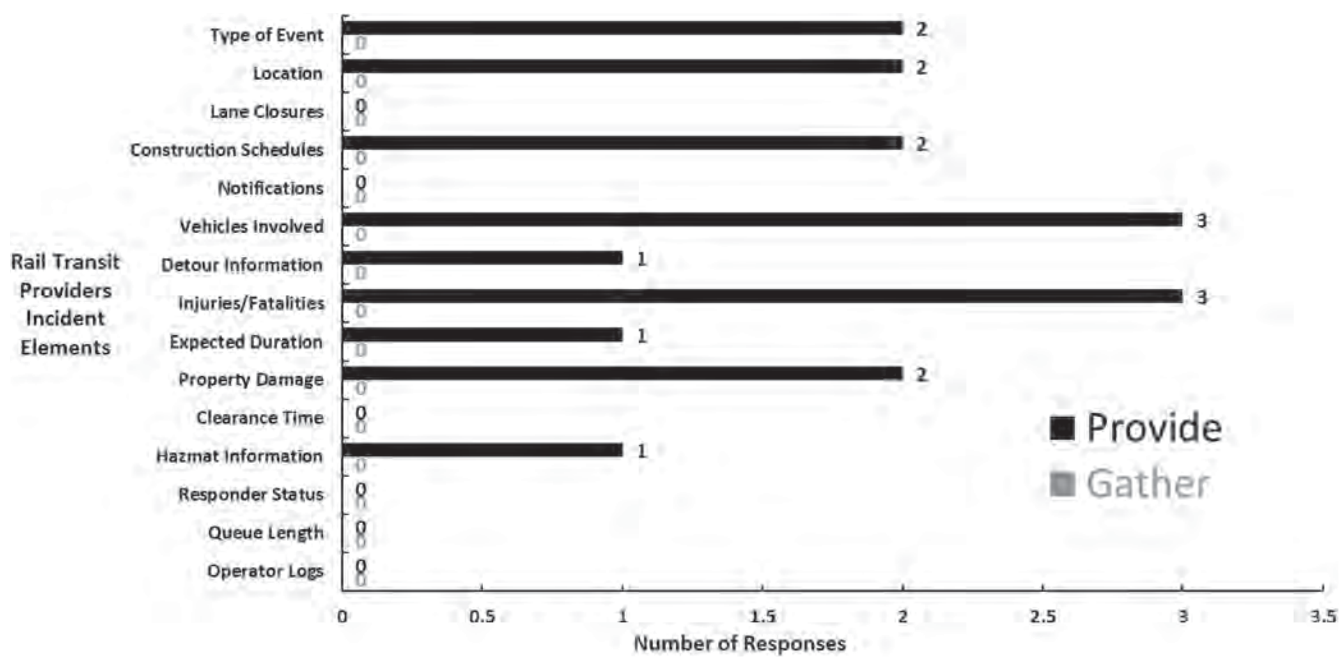


FIGURE D13 Incident elements shared by rail transit providers—3 responses (Questions 4, 13).

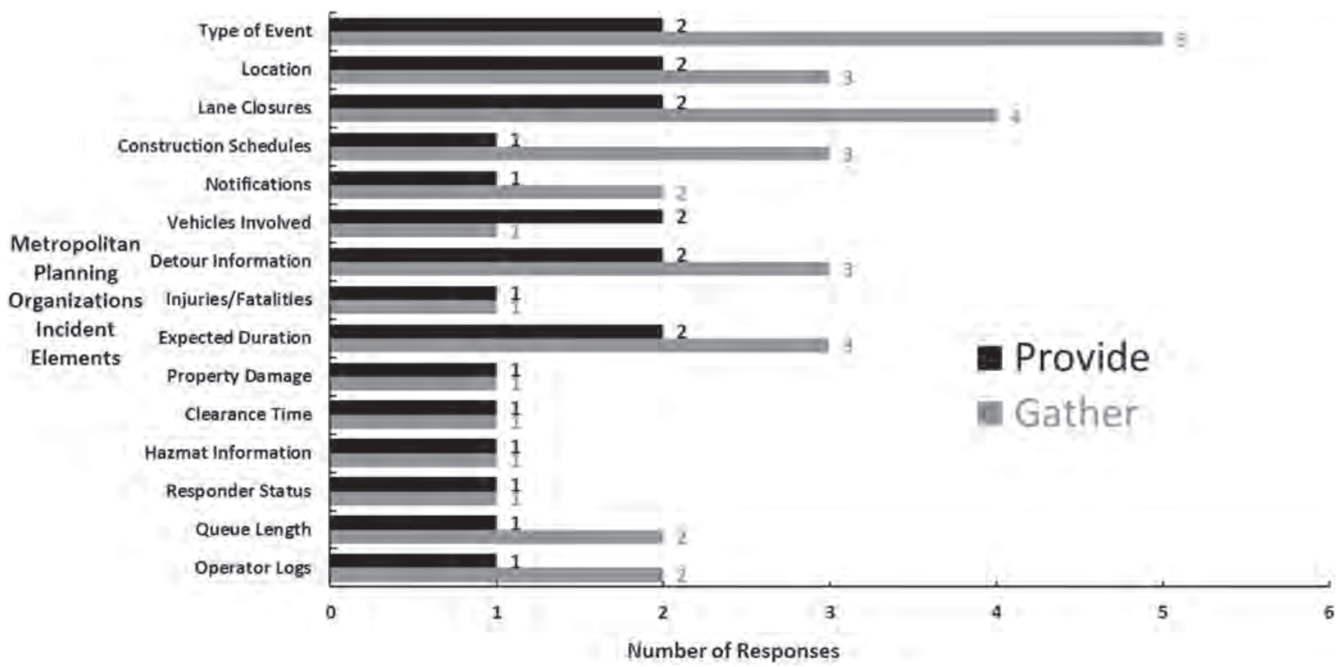


FIGURE D14 Incident elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

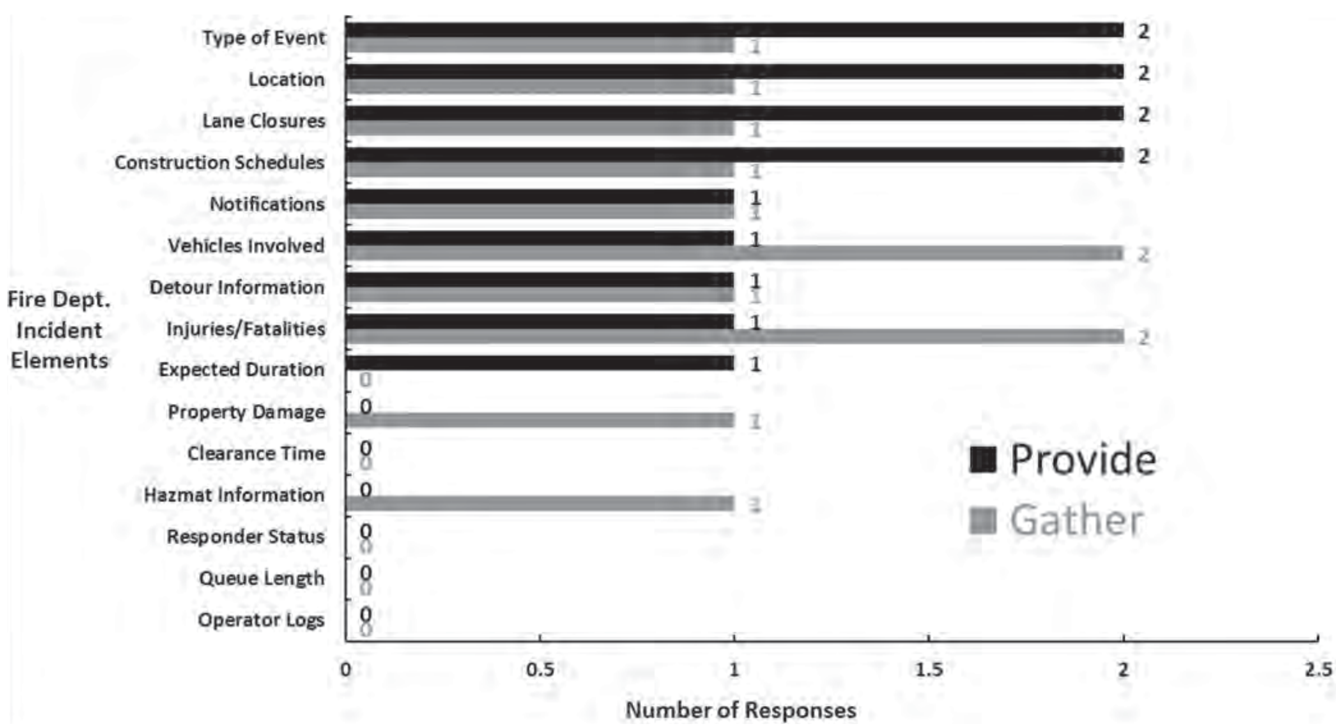


FIGURE D15 Incident elements shared by fire departments—3 responses (Questions 4, 13).

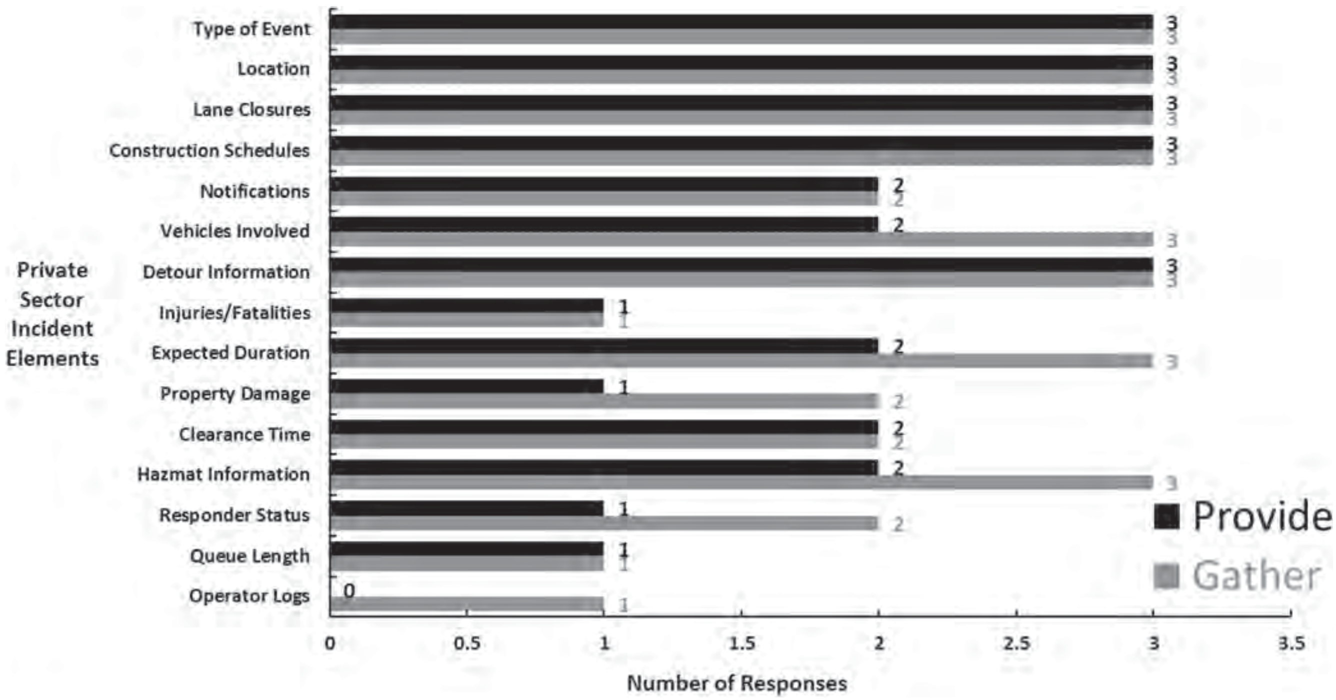


FIGURE D16 Incident elements shared by private sector entities—5 responses (Questions 4, 13).

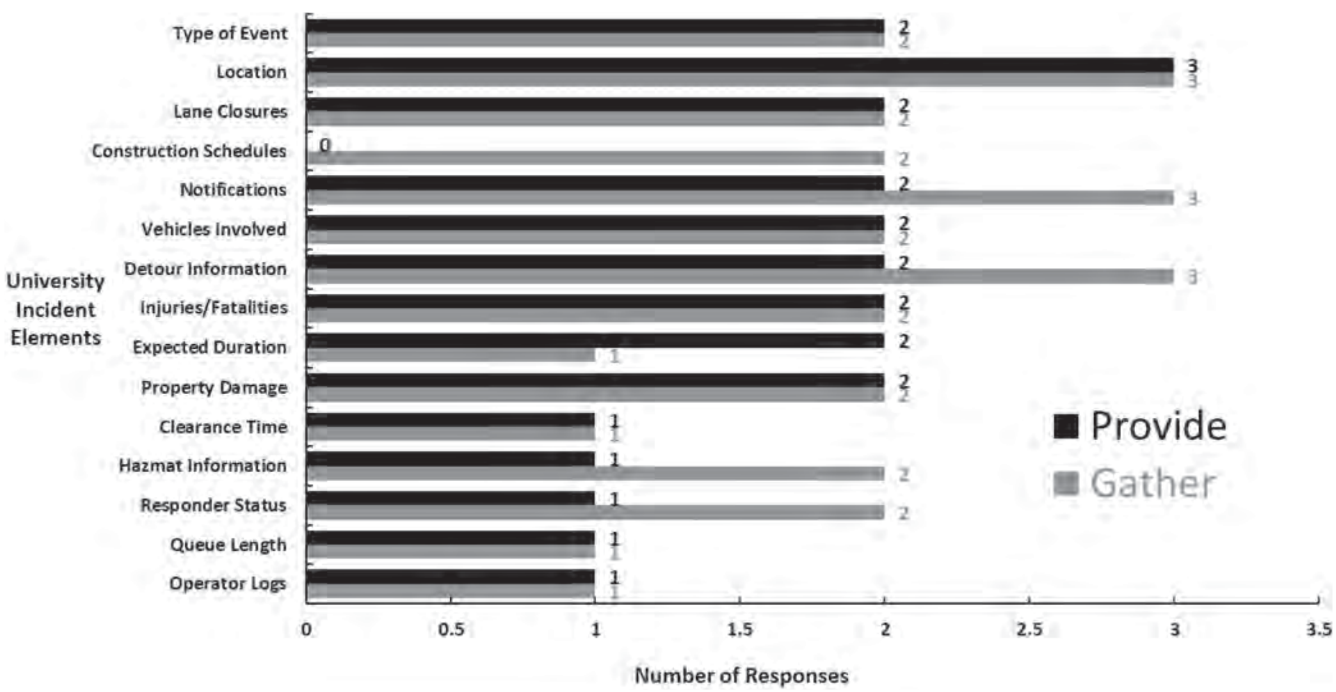


FIGURE D17 Incident elements shared by universities—4 responses (Questions 4, 13).

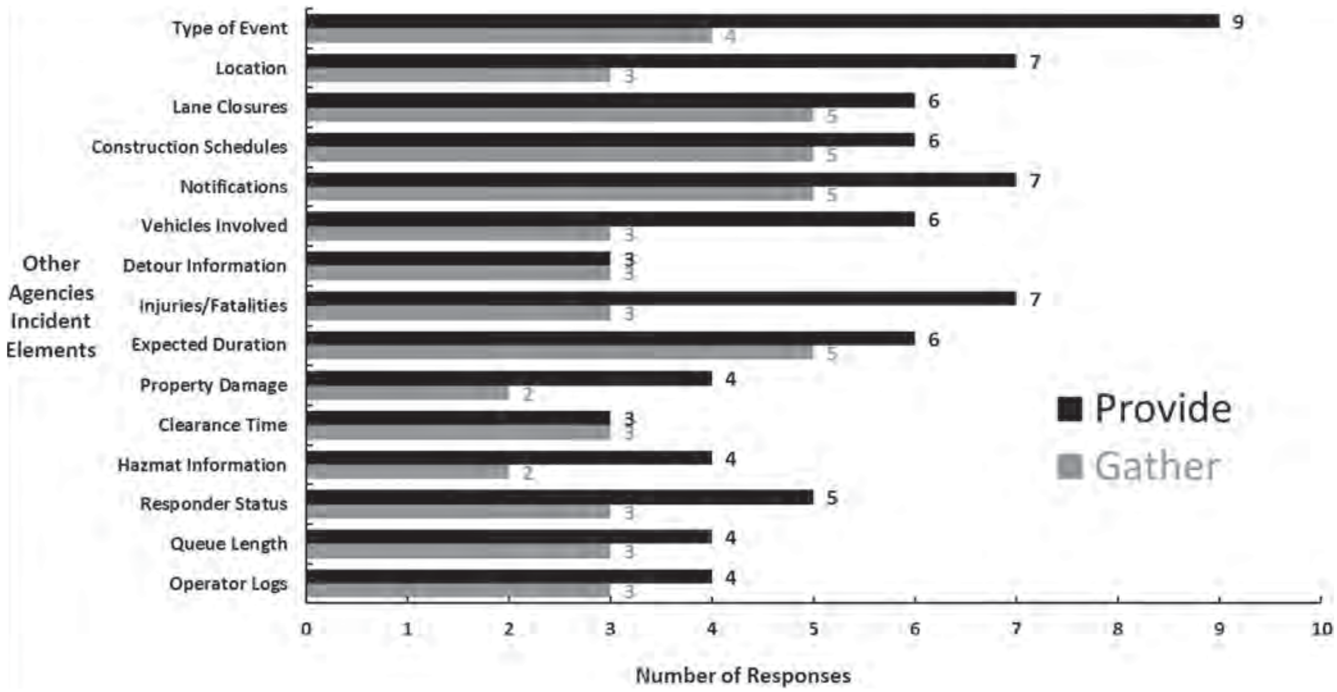


FIGURE D18 Incident elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING DETECTOR DATA (D19–D33)

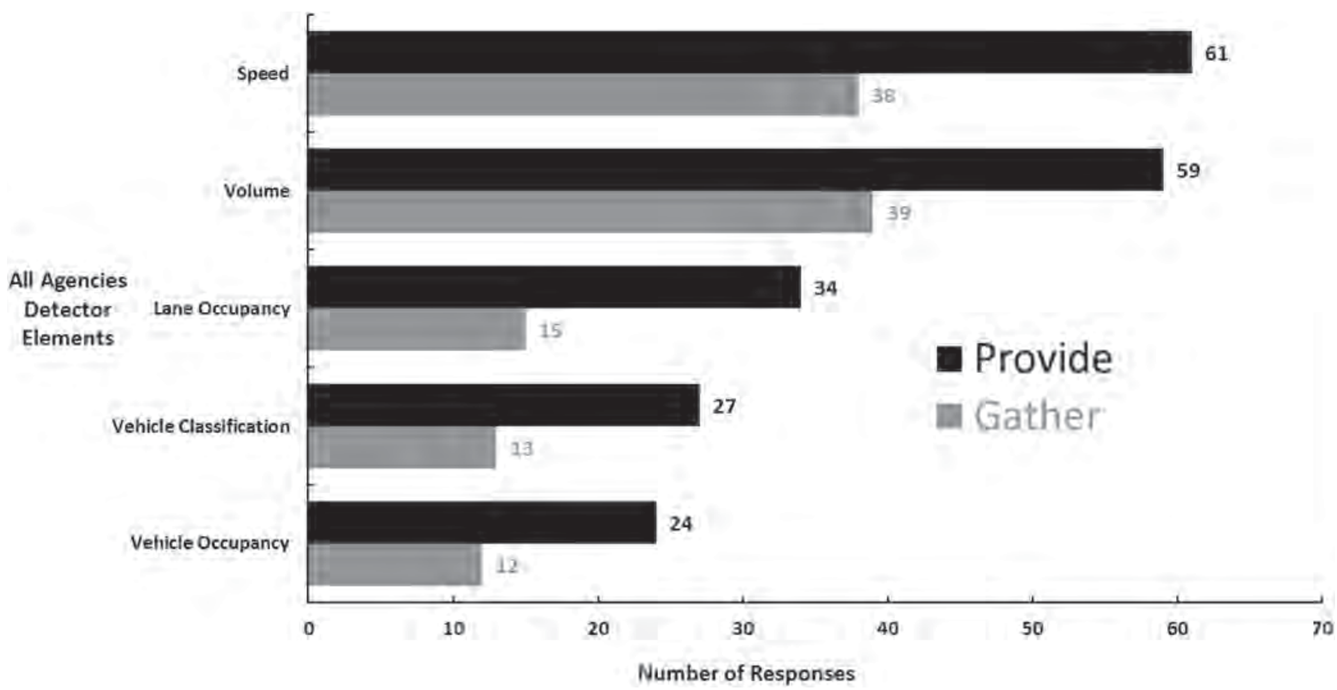


FIGURE D19 Detector elements shared by agencies in general—198 responses (Questions 4, 13).

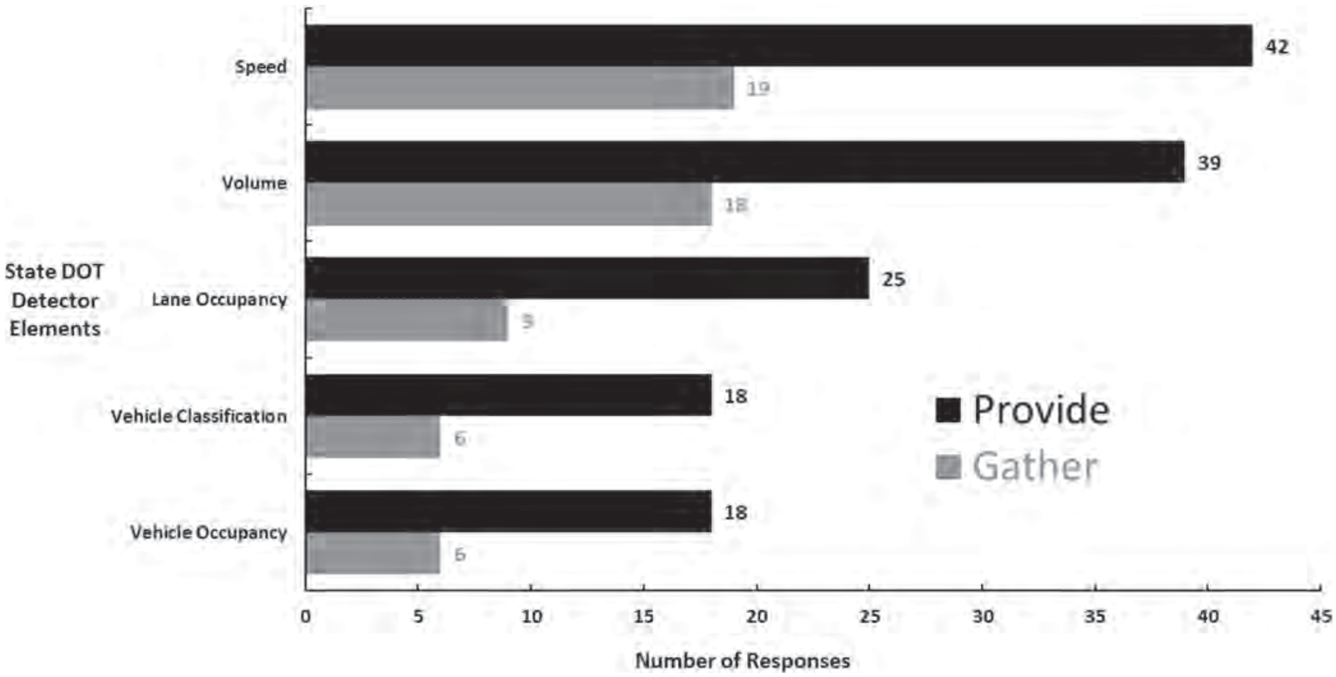


FIGURE D20 Detector elements shared by state DOTs—86 responses (Questions 4, 13).

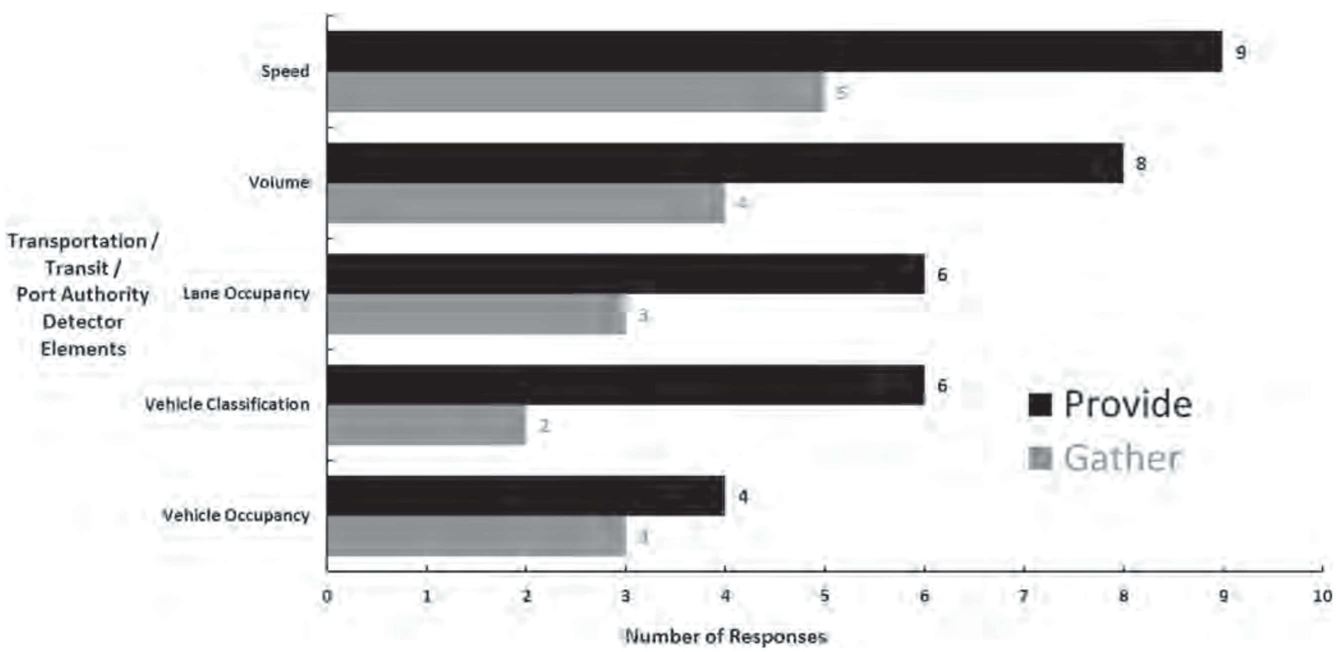


FIGURE D21 Detector elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

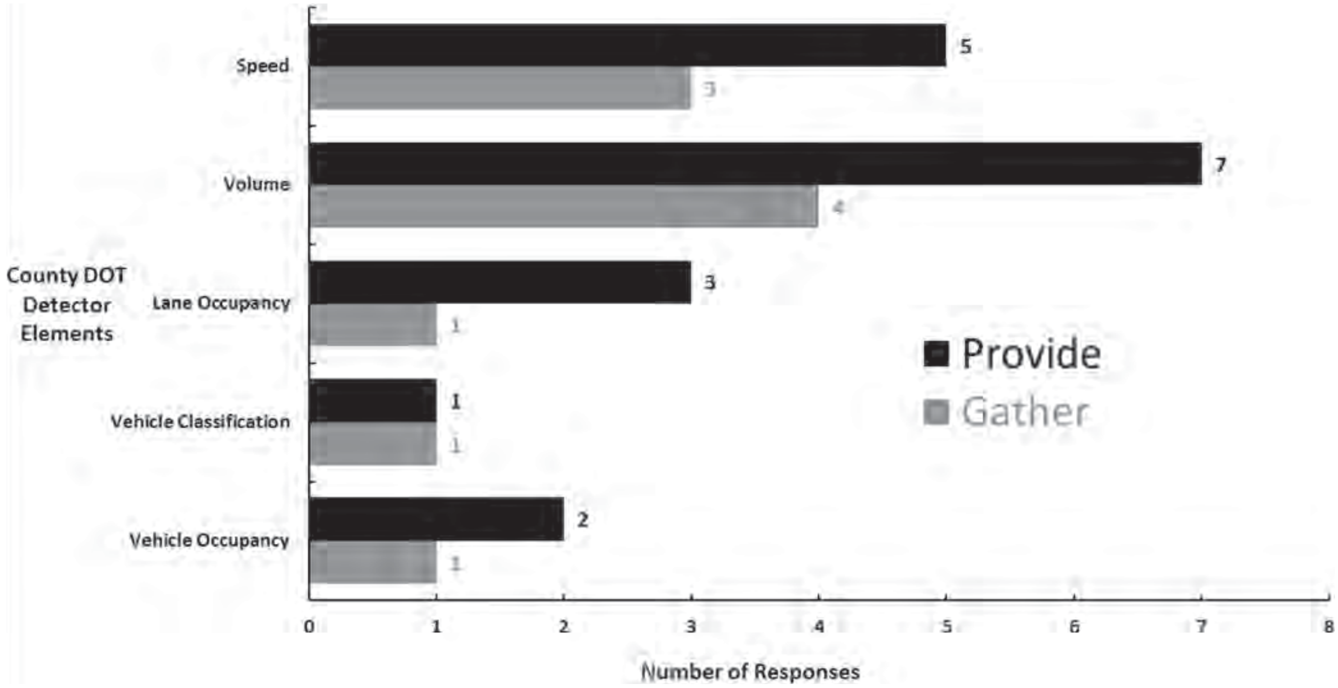


FIGURE D22 Detector elements shared by county DOTs—12 responses (Questions 4, 13).

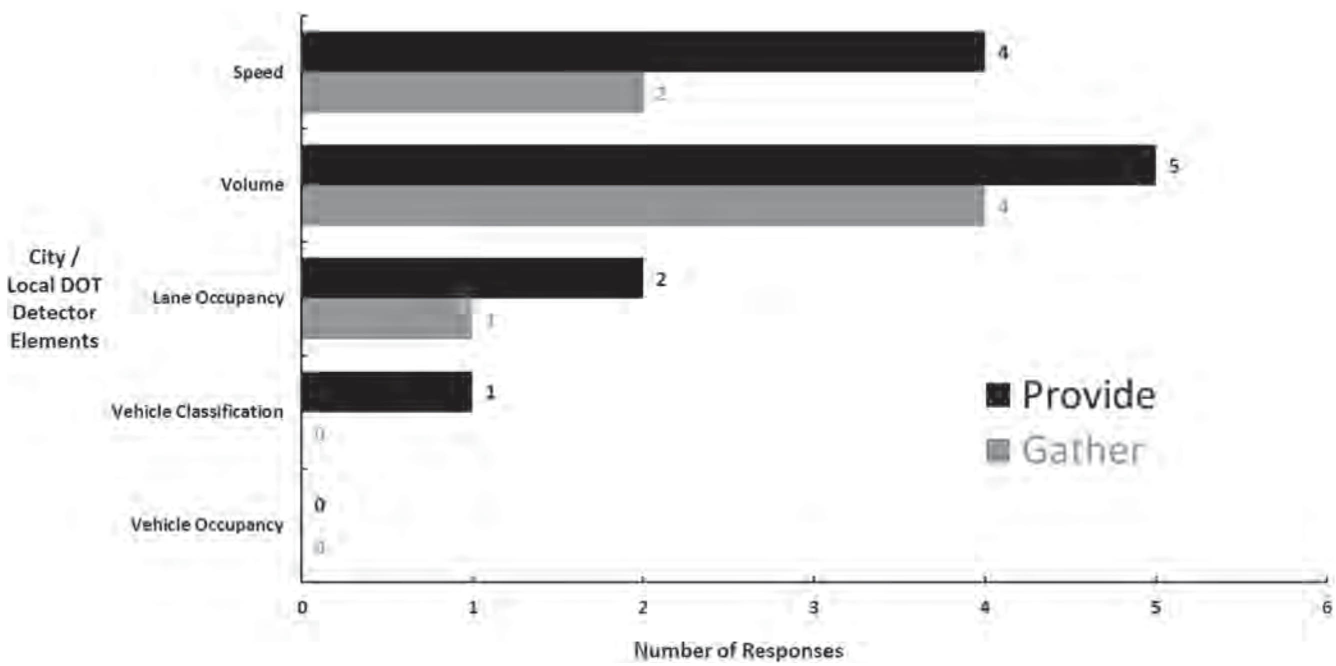


FIGURE D23 Detector elements shared by city and local DOTs—24 responses (Questions 4, 13).

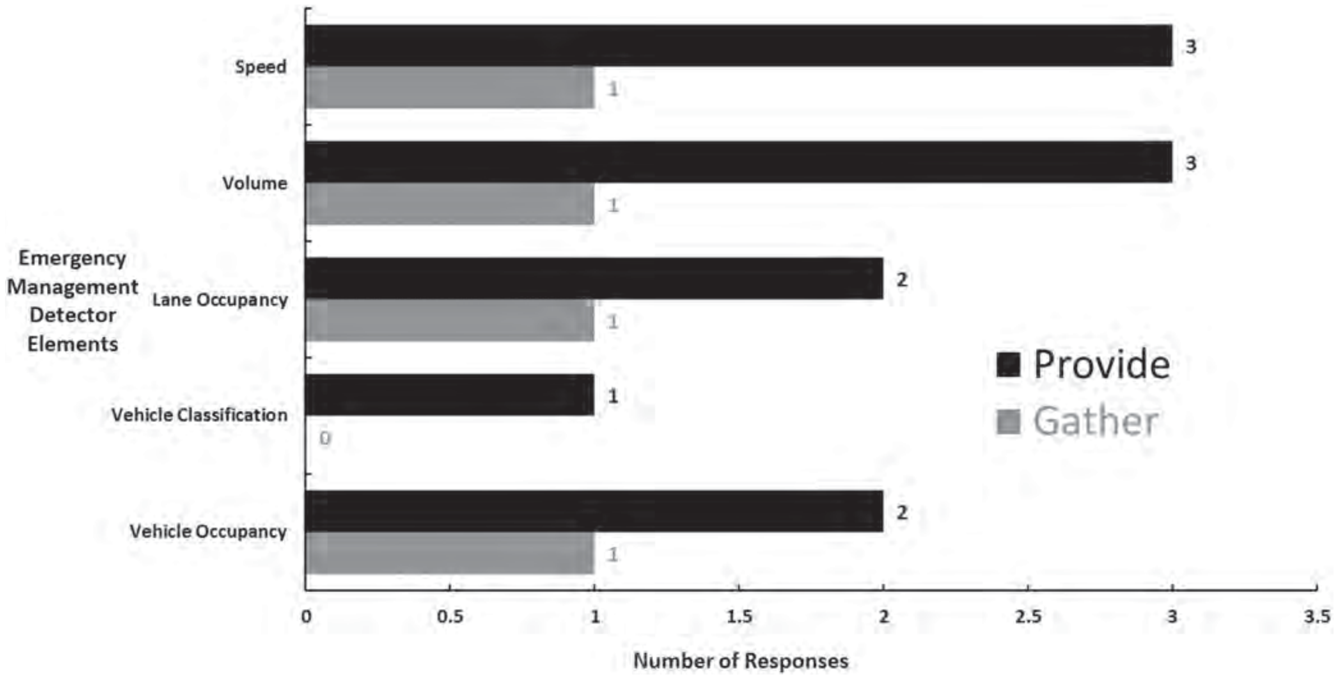


FIGURE D24 Detector elements shared by emergency management agencies—9 responses (Questions 4, 13).

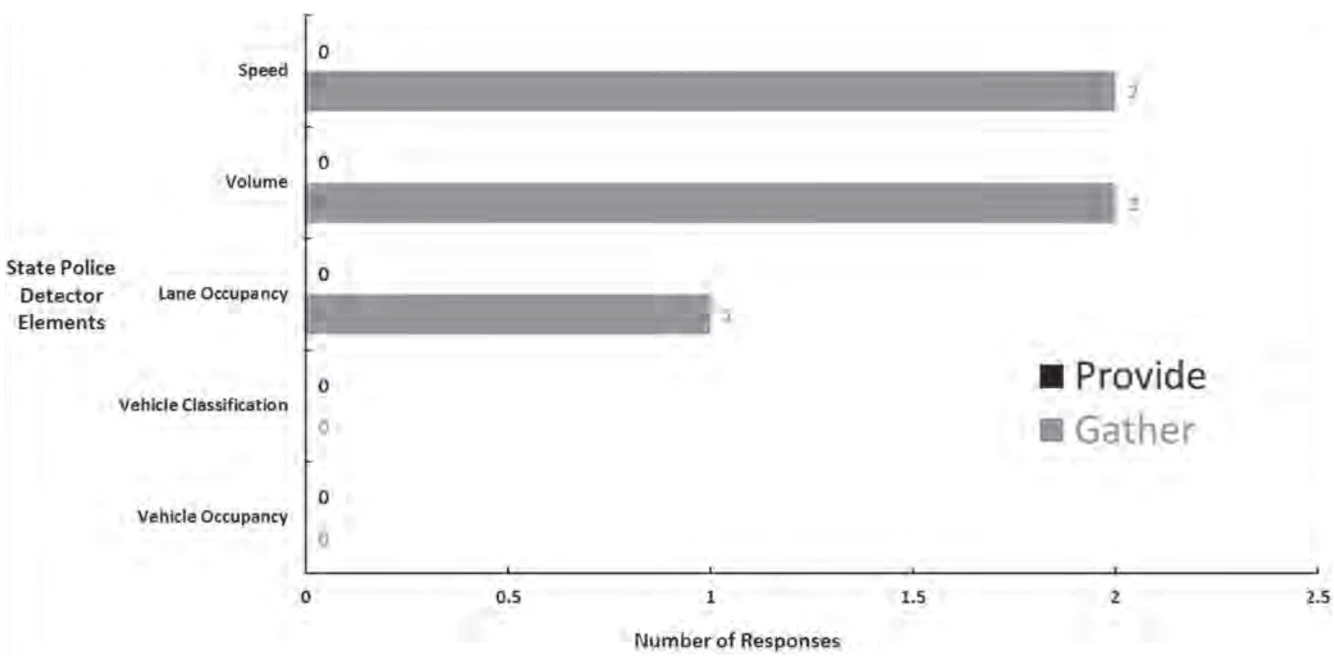


FIGURE D25 Detector elements shared by state police—4 responses (Questions 4, 13).

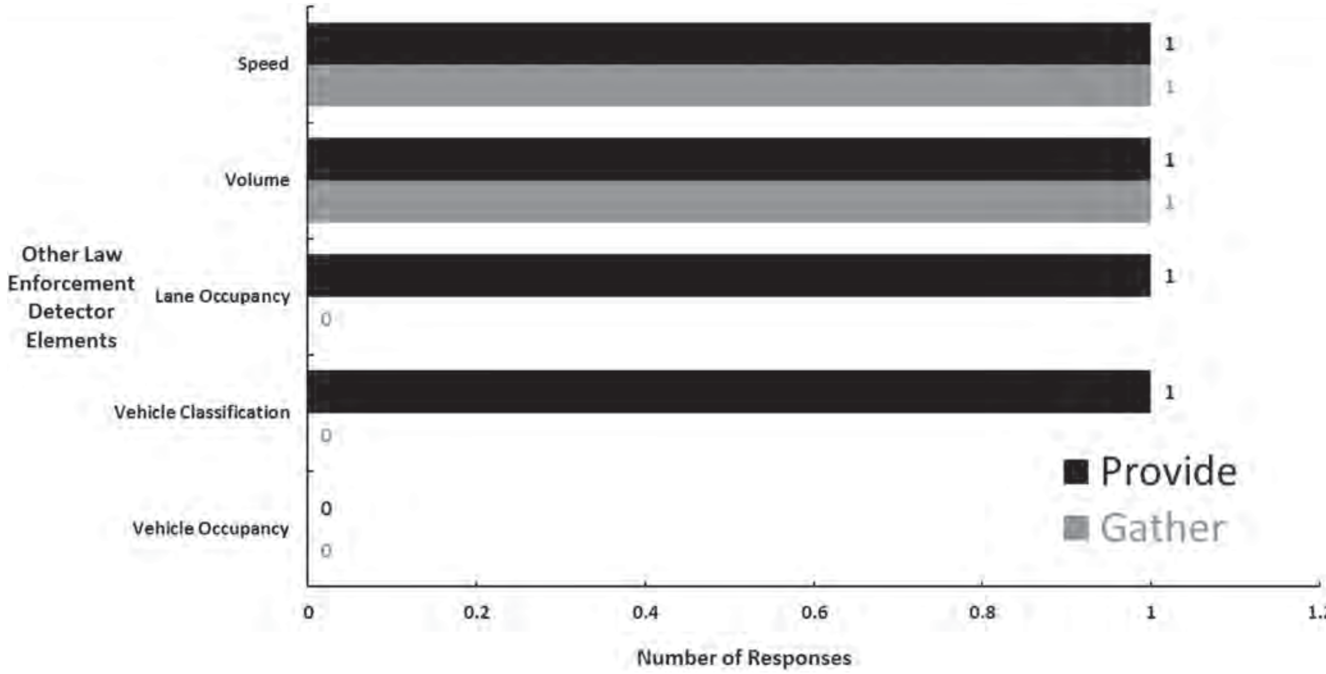


FIGURE D26 Detector elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

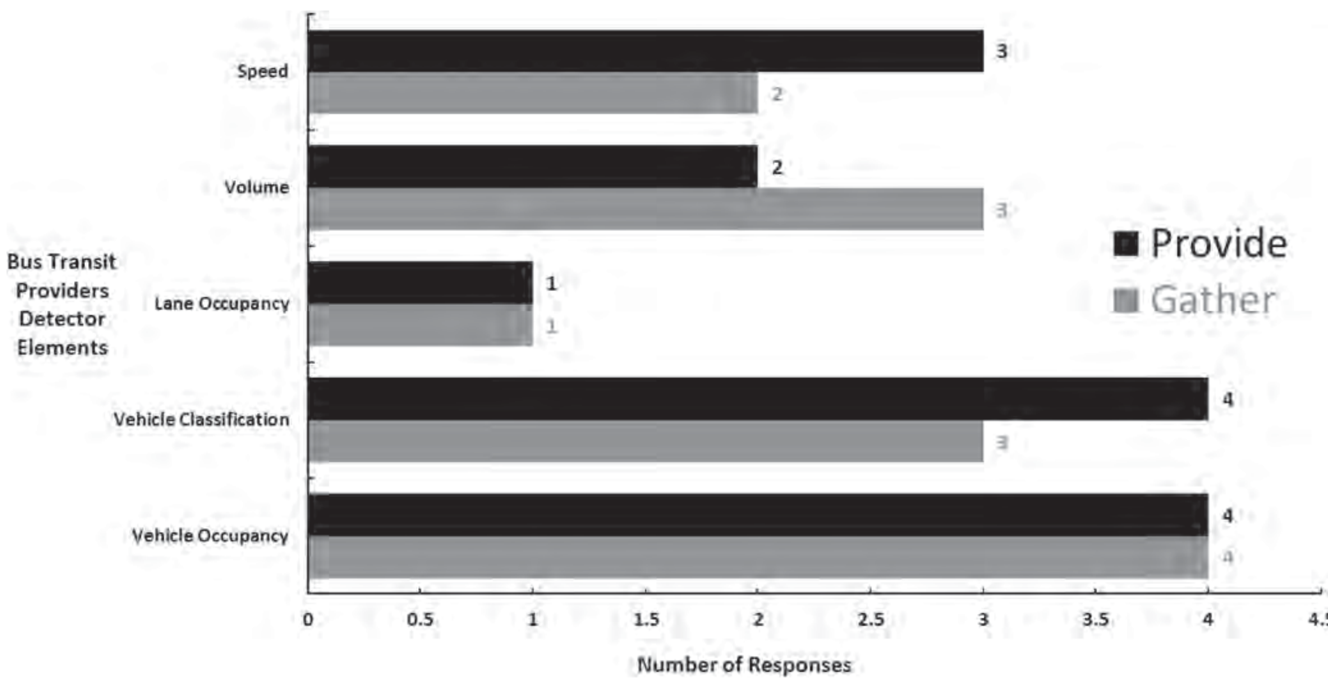


FIGURE D27 Detector elements shared by bus transit providers—40 responses (Questions 4, 13).

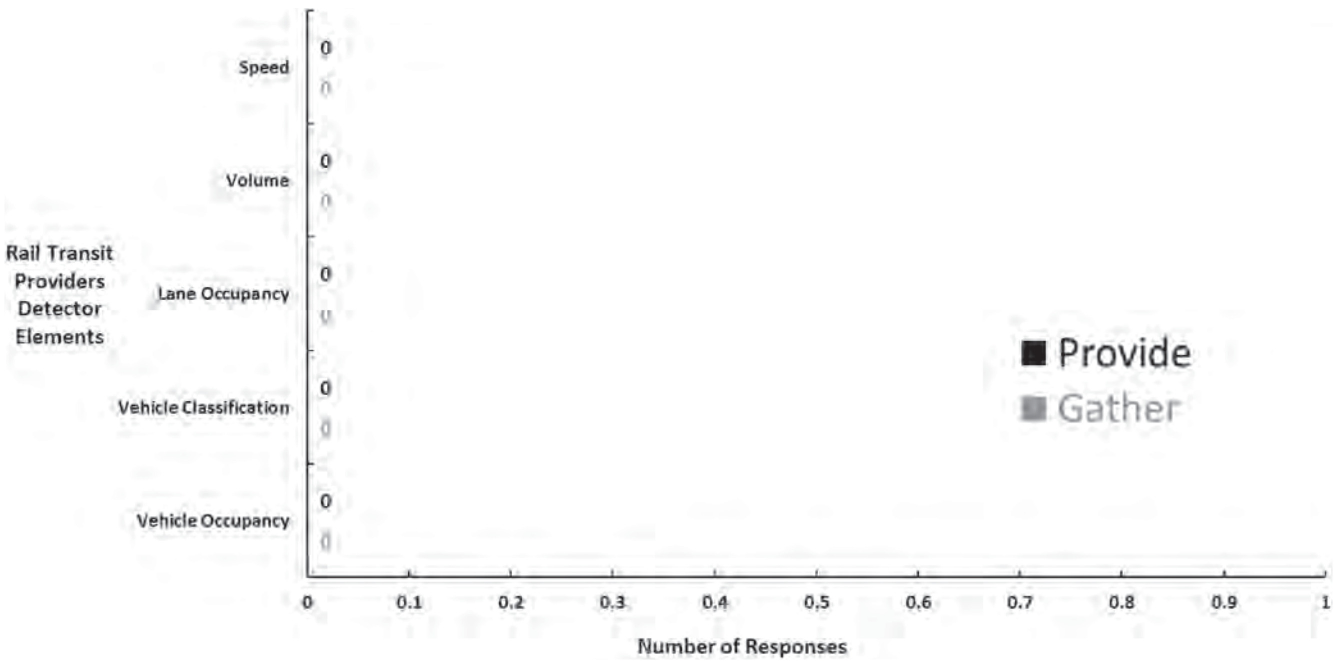


FIGURE D28 Detector elements shared by rail transit providers—3 responses (Questions 4, 13).

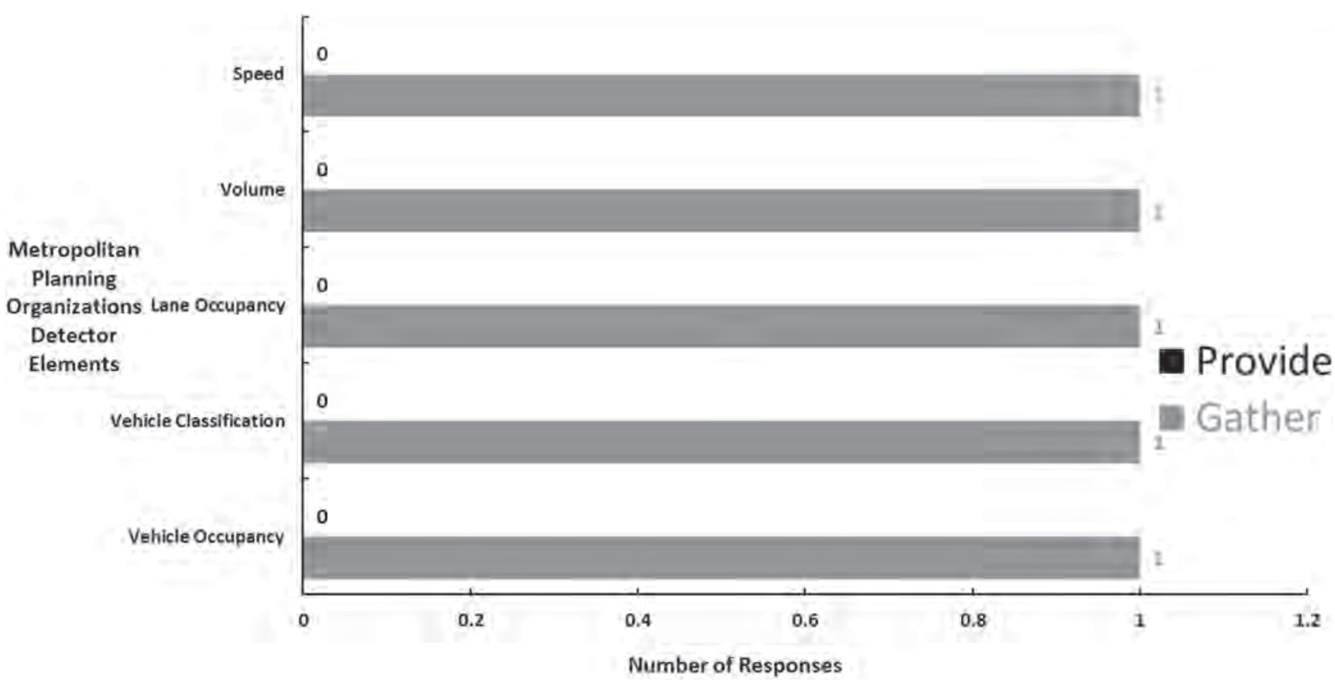


FIGURE D29 Detector elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

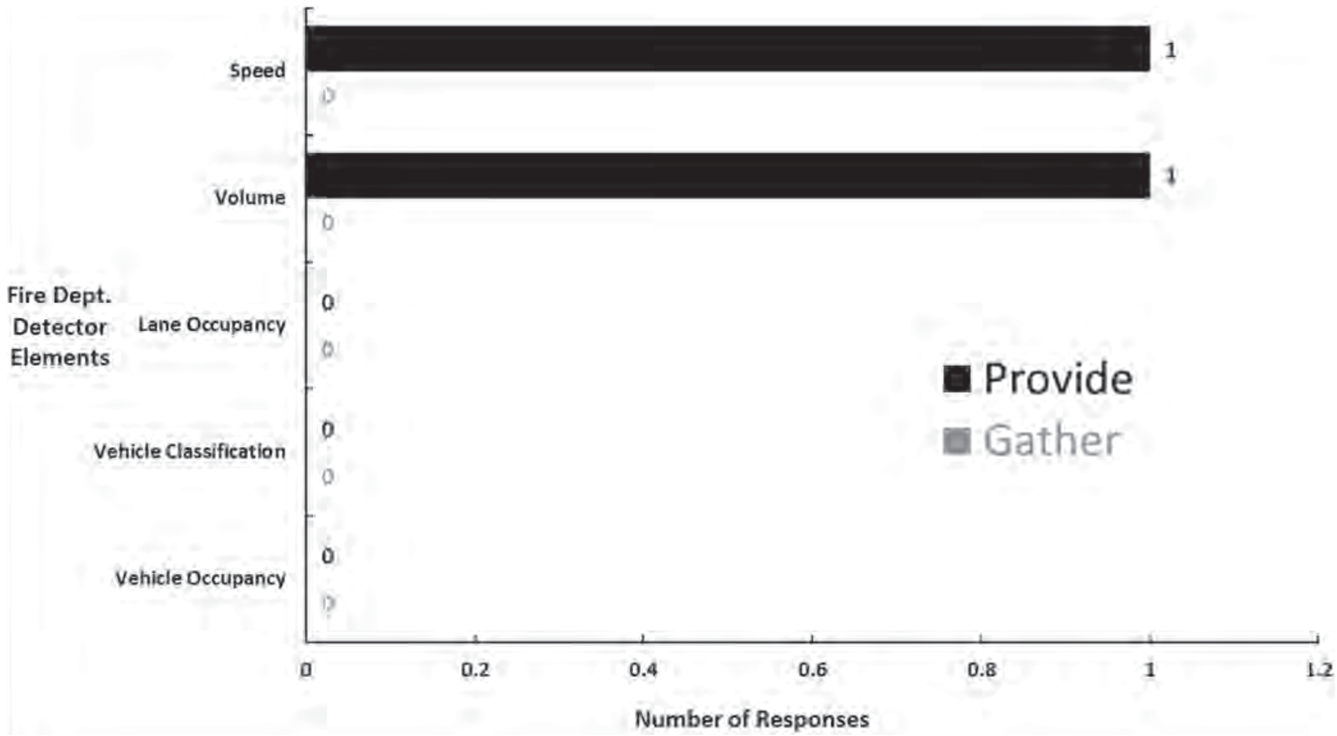


FIGURE D30 Detector elements shared by fire departments—3 responses (Questions 4, 13).

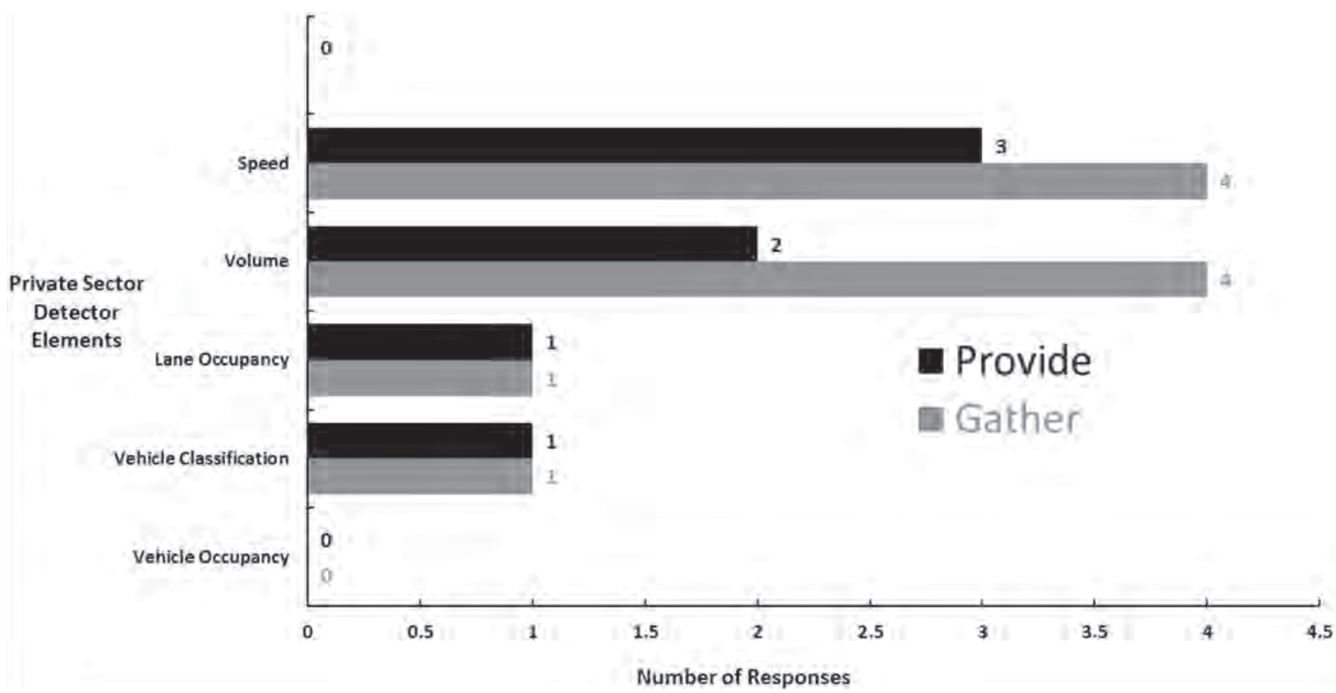


FIGURE D31 Detector elements shared by private sector entities—5 responses (Questions 4, 13).

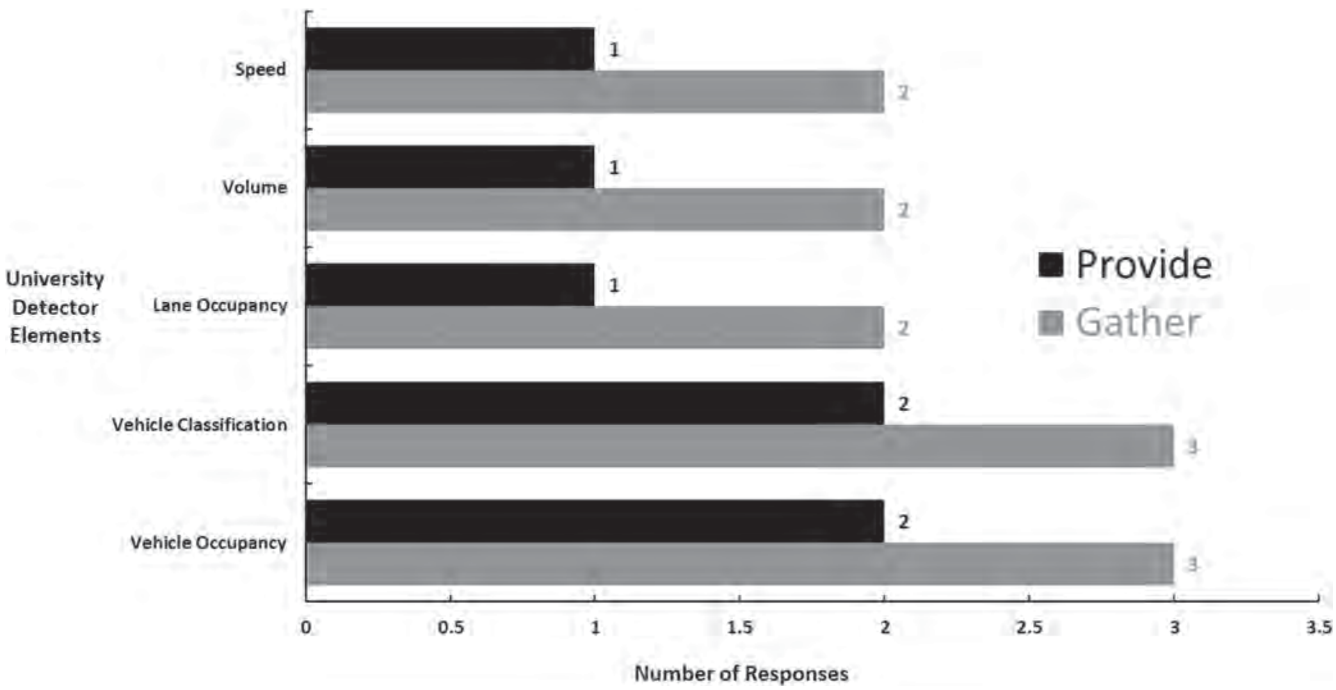


FIGURE D32 Detector elements shared by universities—4 responses (Questions 4, 13).

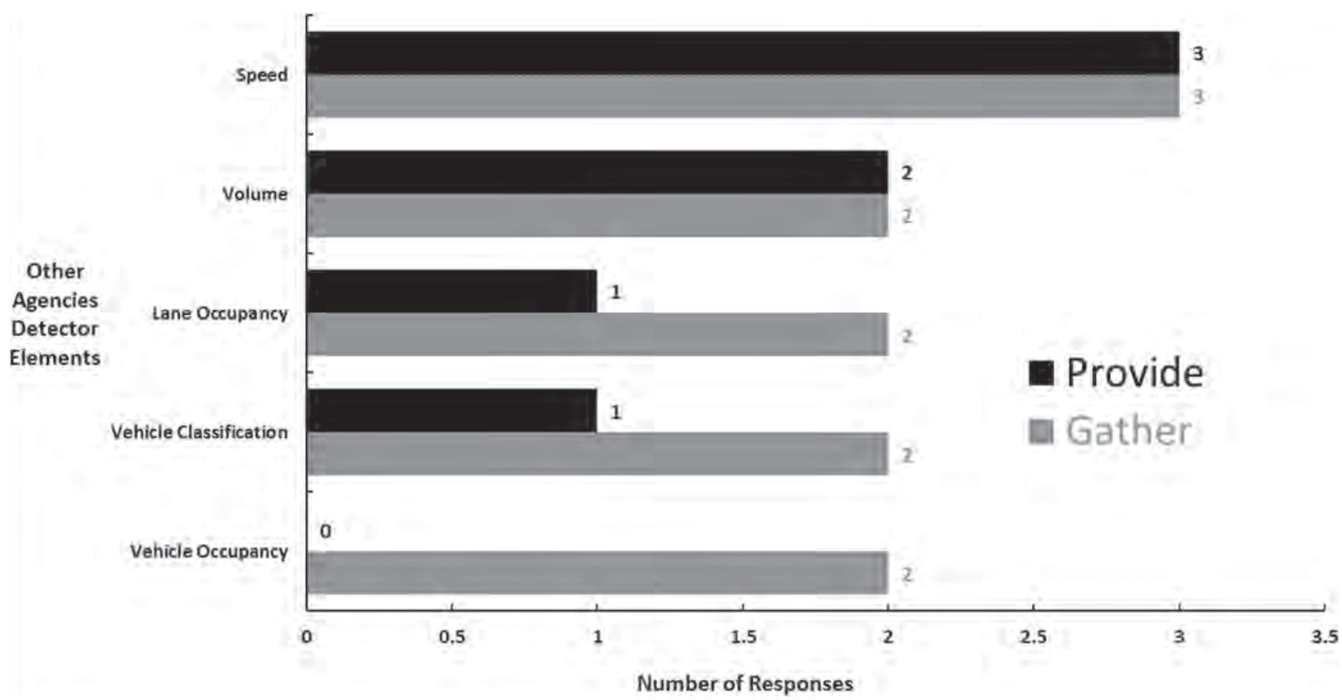


FIGURE D33 Detector elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING PROBE VEHICLE DATA (D34–D48)

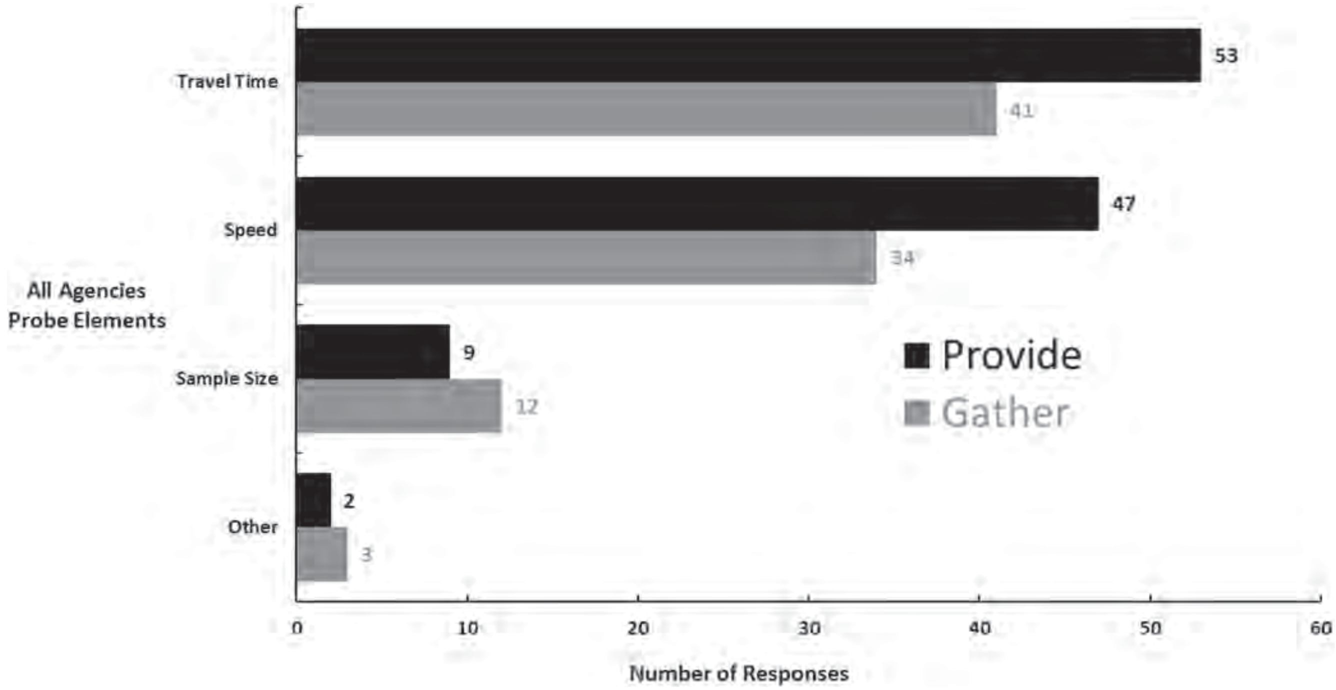


FIGURE D34 Probe vehicle elements shared by agencies in general—198 responses (Questions 4, 13).

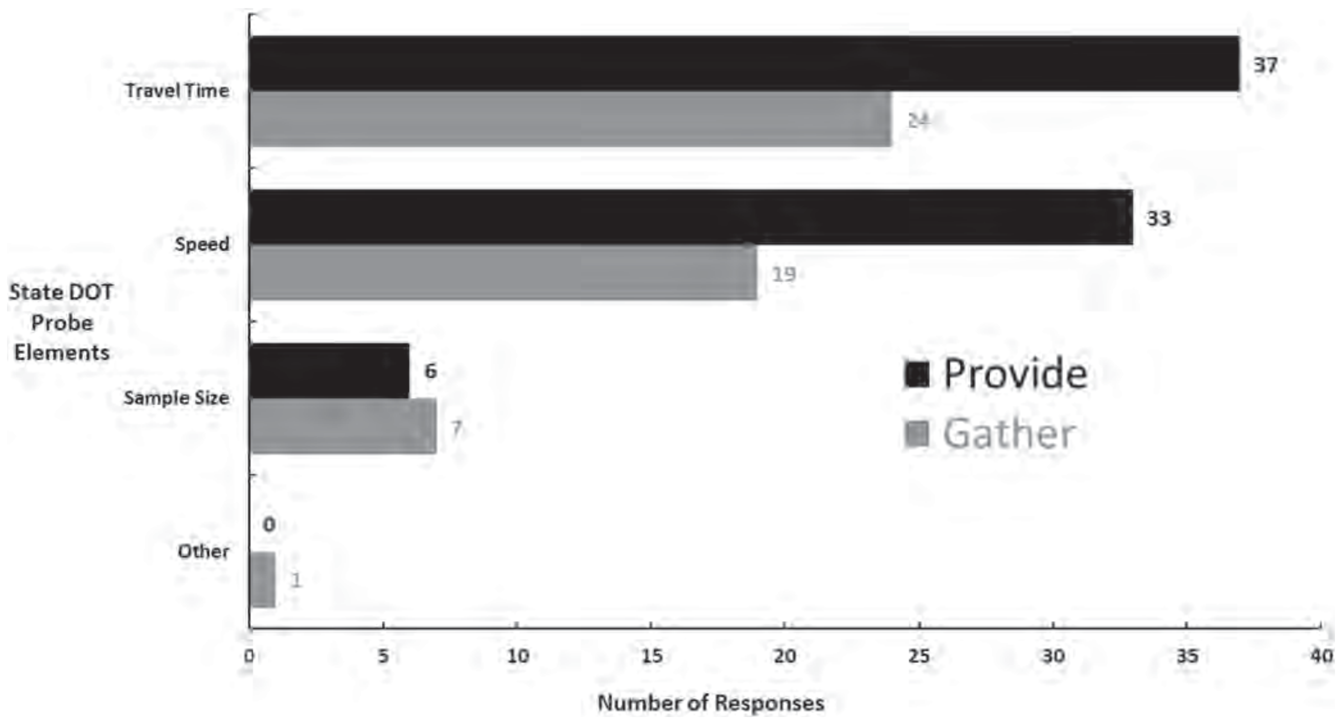


FIGURE D35 Probe vehicle elements shared by state DOTs—86 responses (Questions 4, 13).

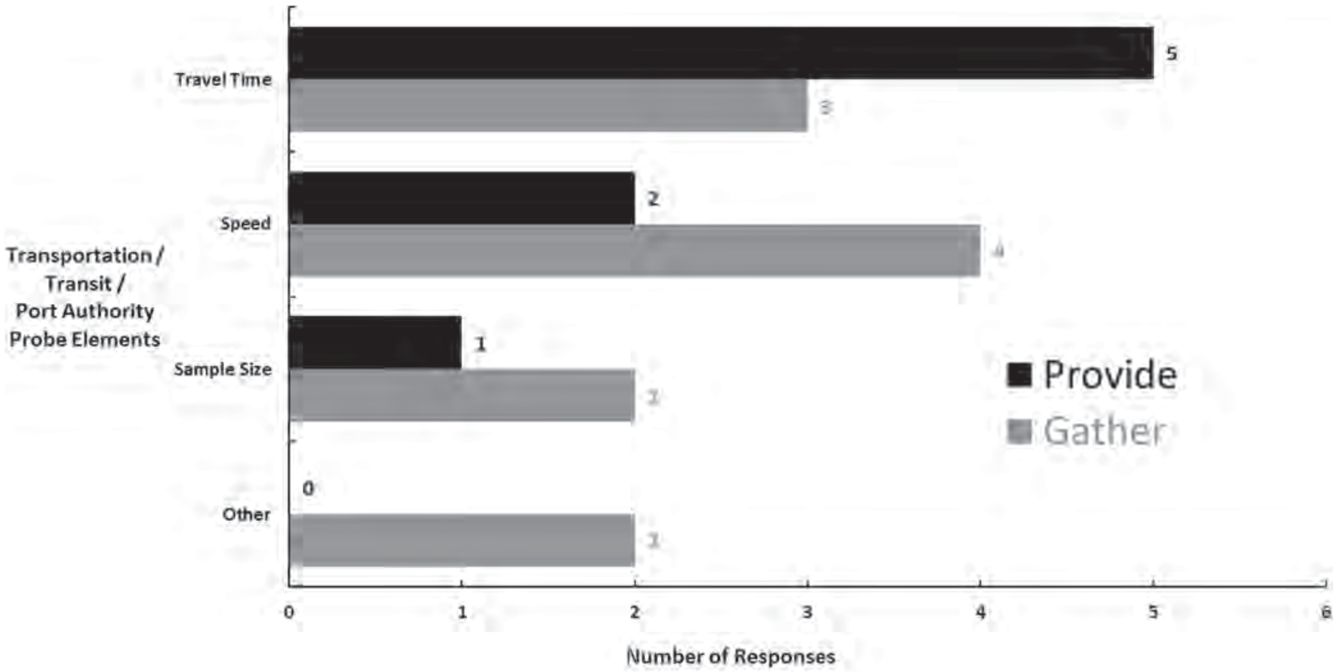


FIGURE D36 Probe vehicle elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

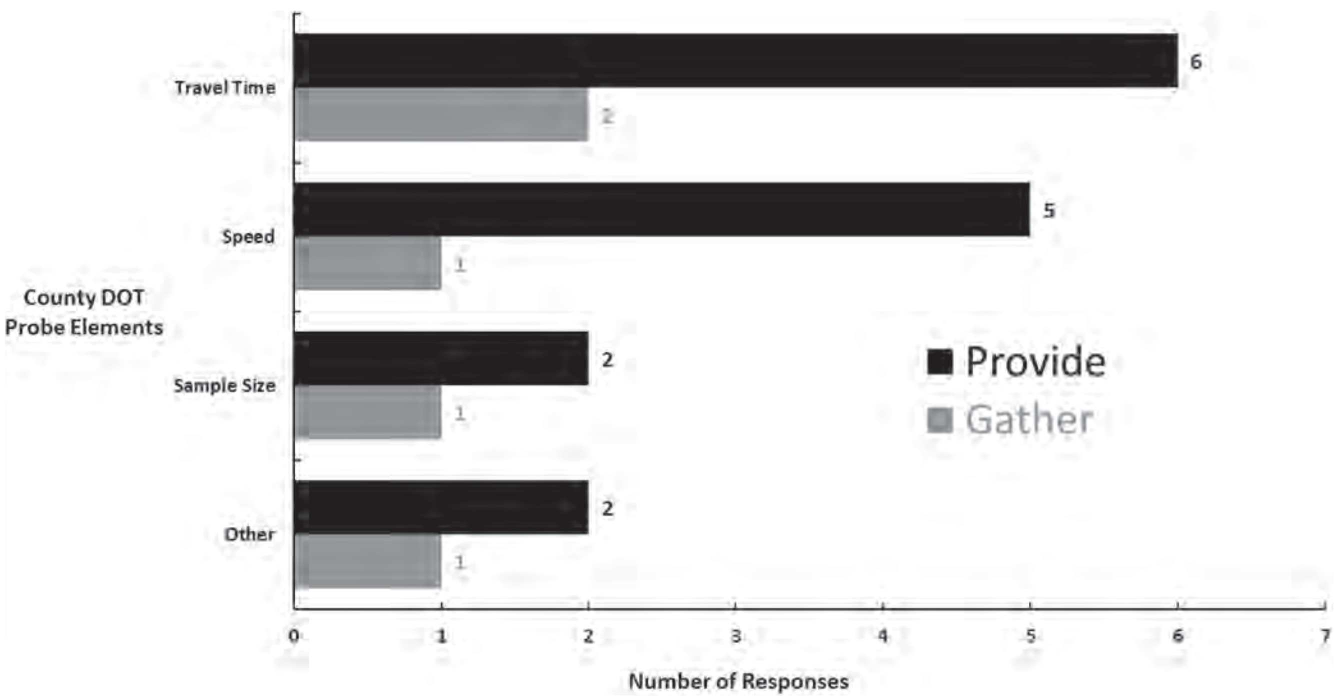


FIGURE D37 Probe vehicle elements shared by county DOTs—12 responses (Questions 4, 13).

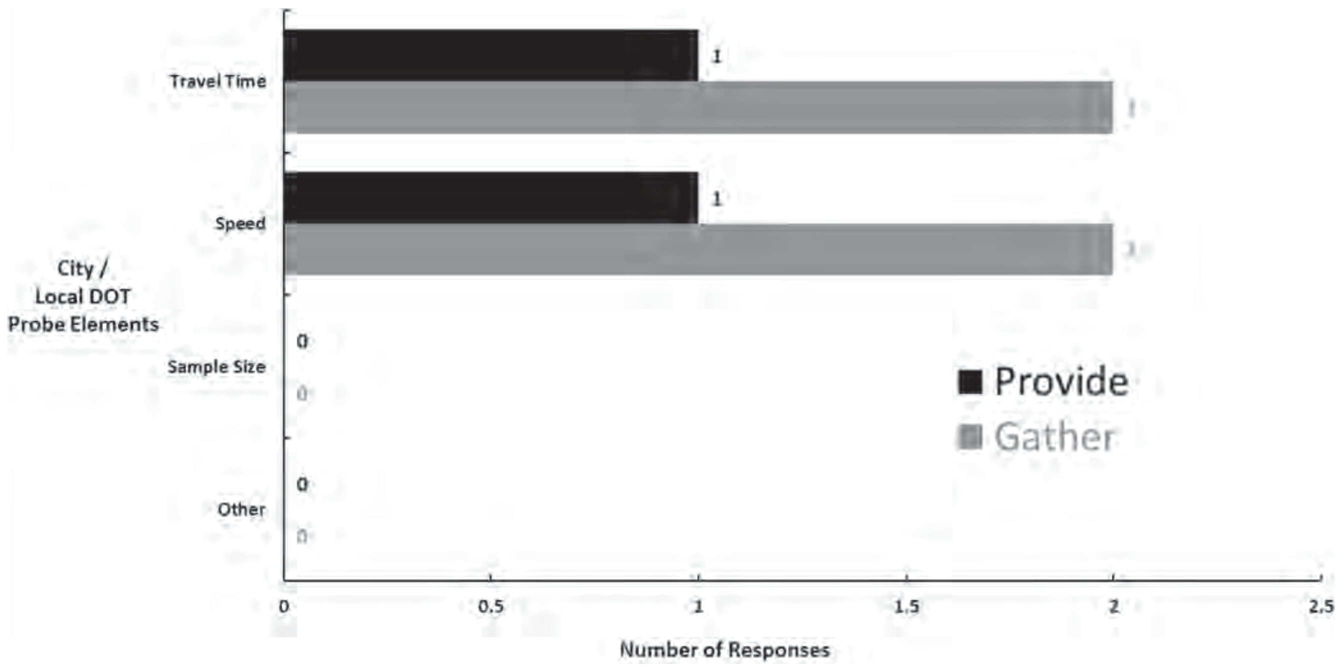


FIGURE D38 Probe vehicle elements shared by city and local DOTs—24 responses (Questions 4, 13).

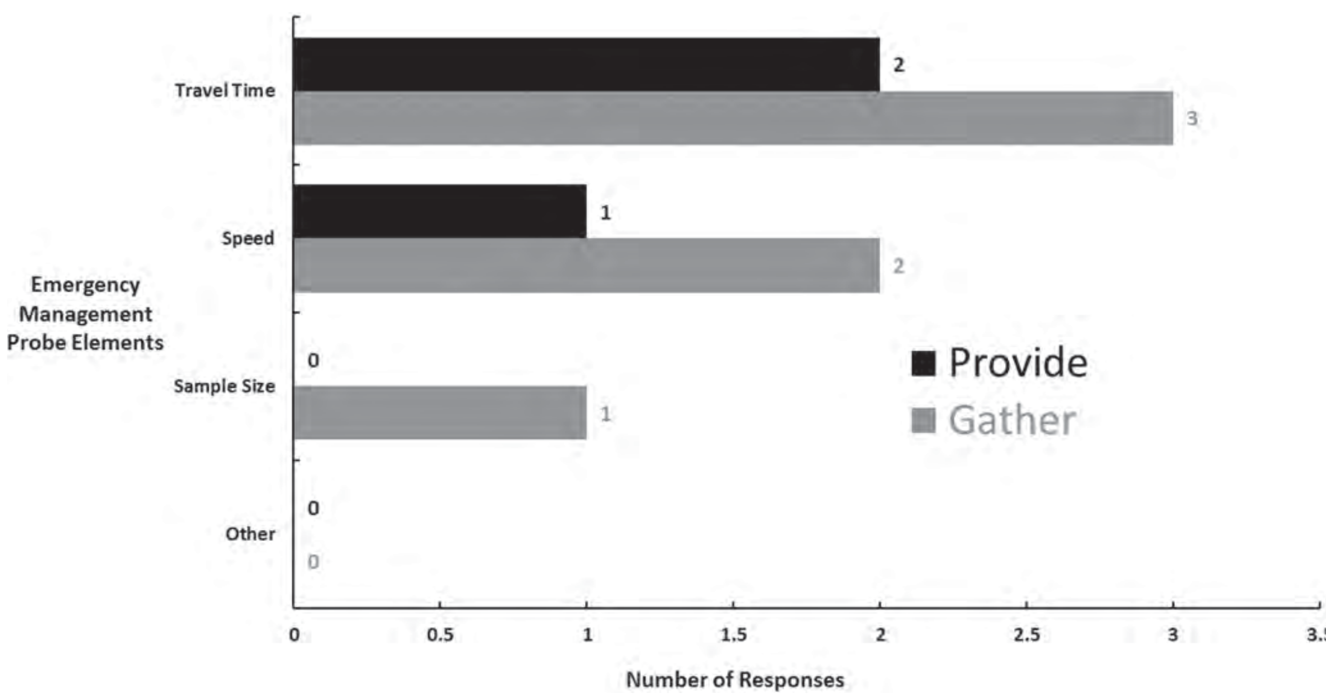


FIGURE D39 Probe vehicle elements shared by emergency management agencies—9 responses (Questions 4, 13).

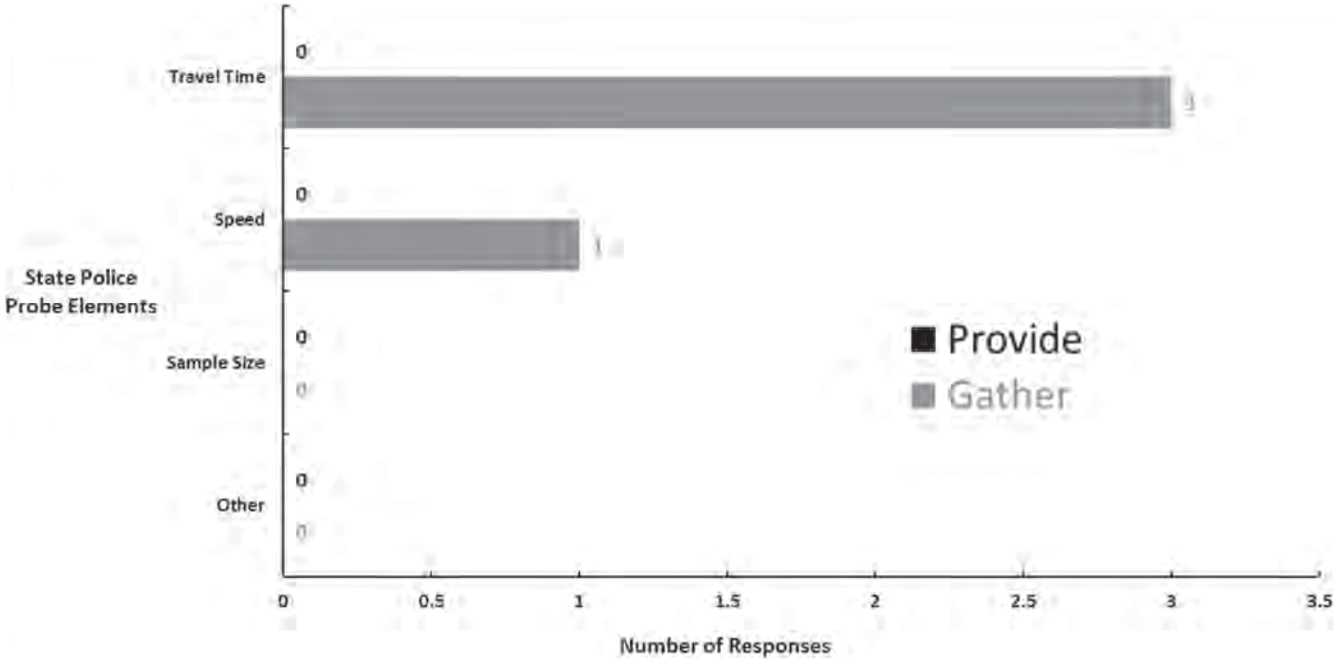


FIGURE D40 Probe vehicle elements shared by state police—4 responses (Questions 4, 13).

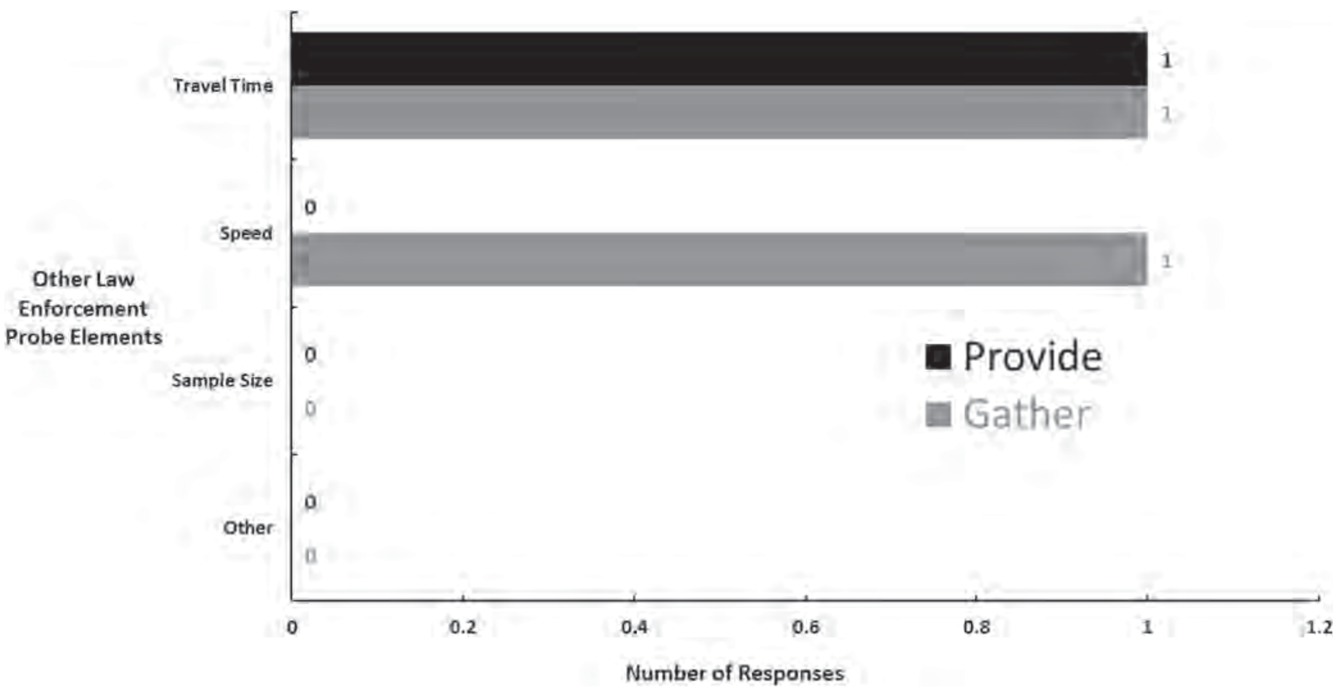


FIGURE D41 Probe vehicle elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

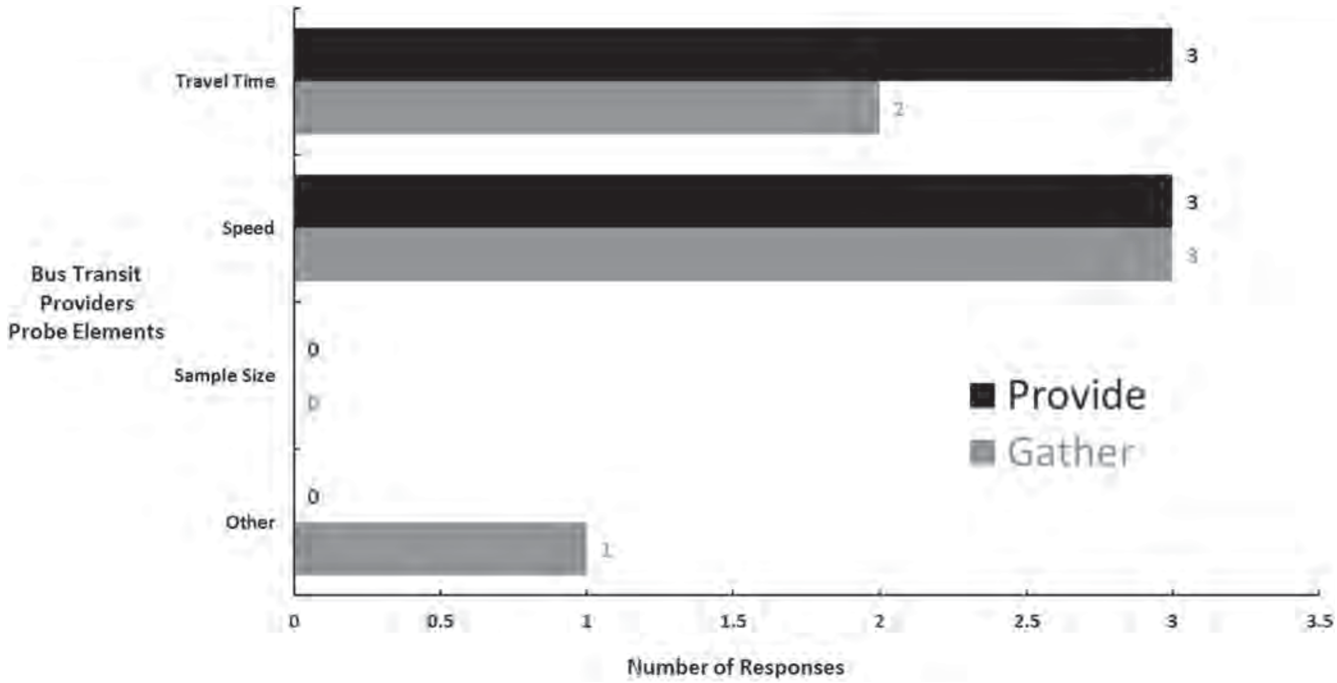


FIGURE D42 Probe vehicle elements shared by bus transit providers—40 responses (Questions 4, 13).

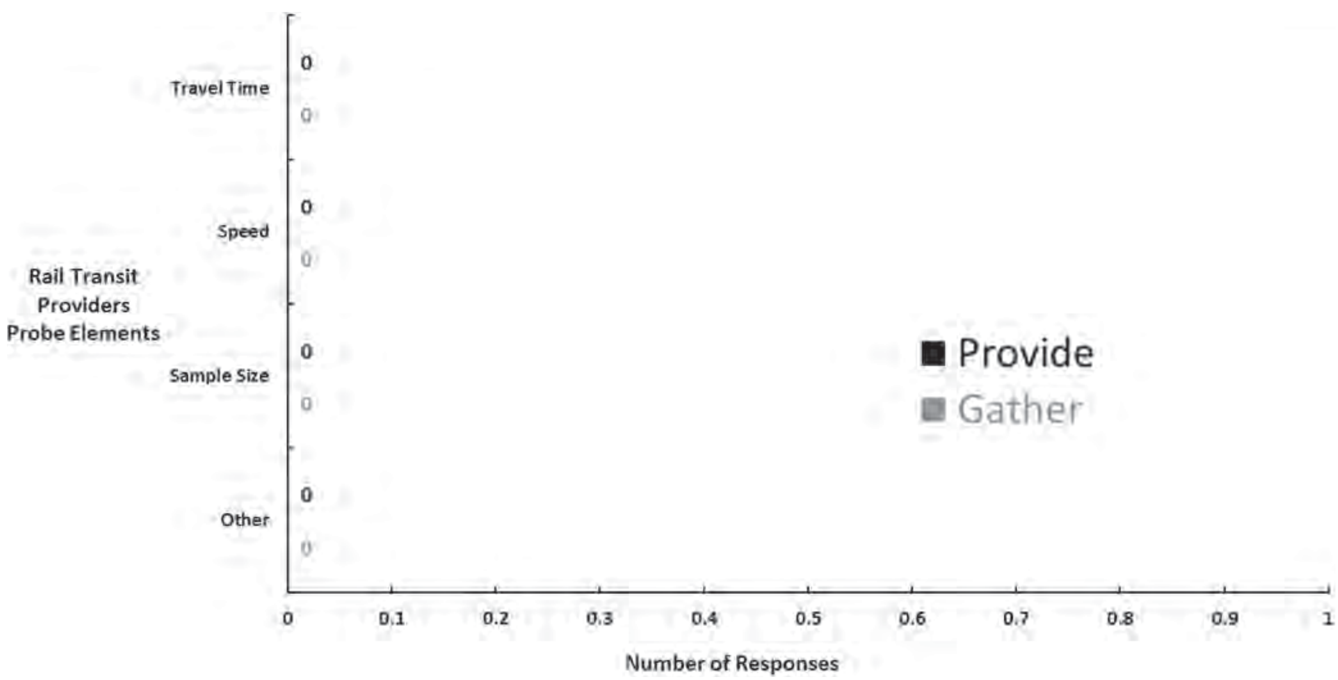


FIGURE D43 Probe vehicle elements shared by rail transit providers—3 responses (Questions 4, 13).

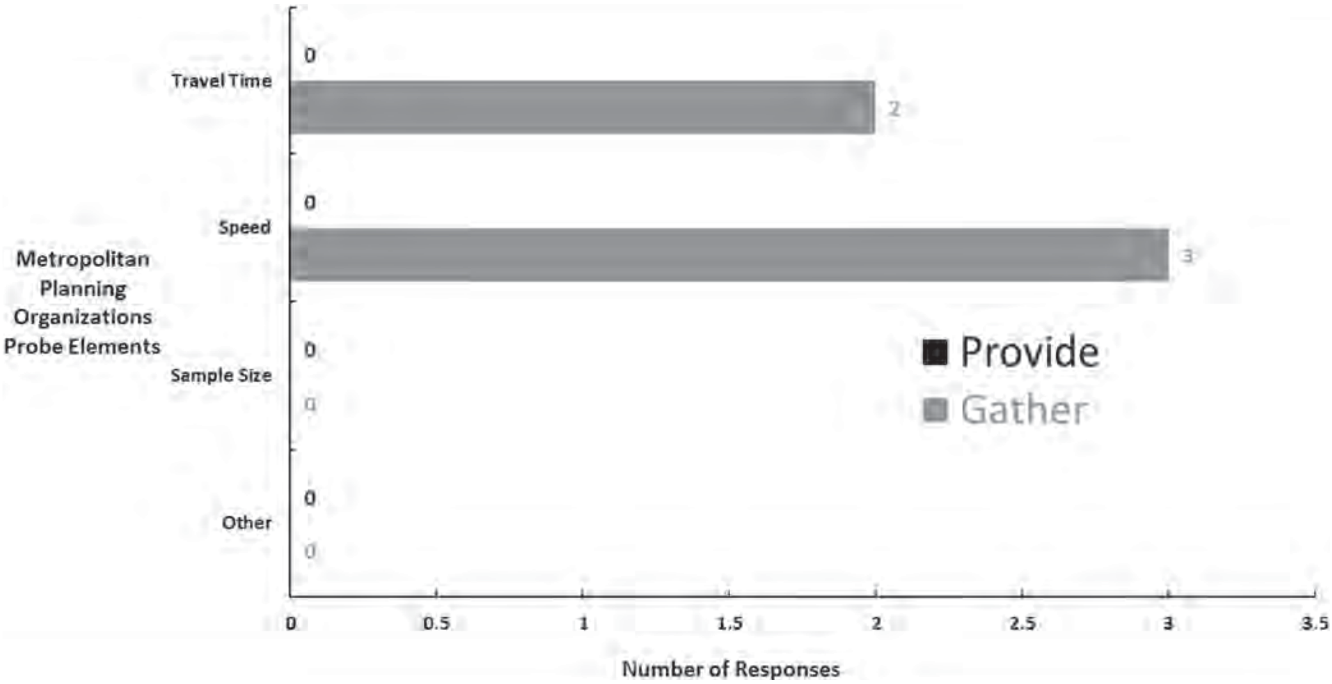


FIGURE D44 Probe vehicle elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

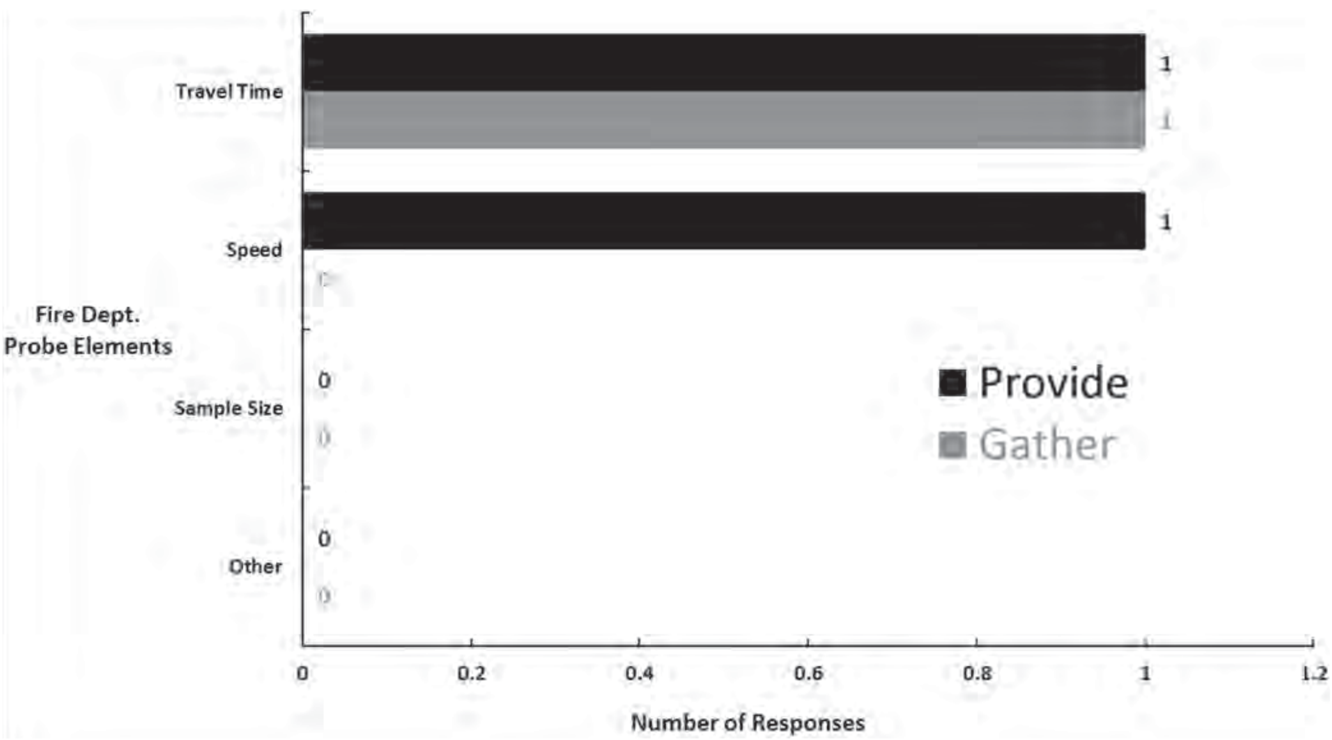


FIGURE D45 Probe vehicle elements shared by fire departments—3 responses (Questions 4, 13).

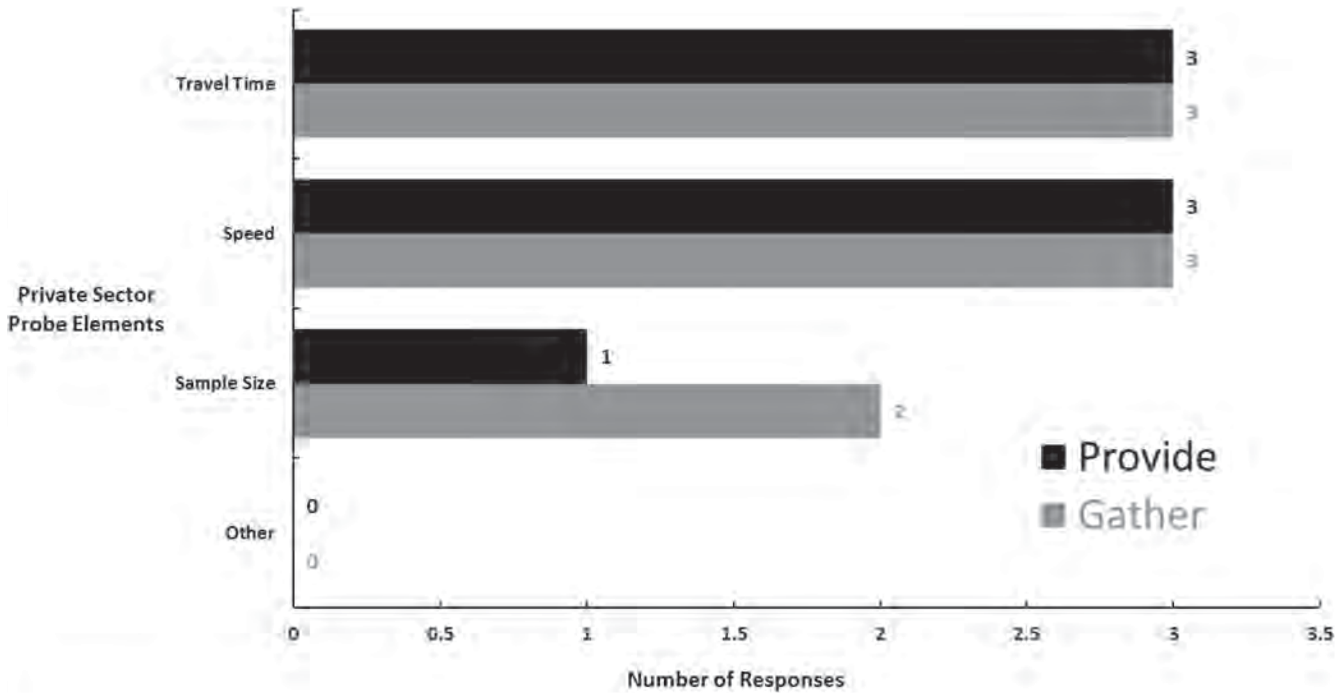


FIGURE D46 Probe vehicle elements shared by private sector entities—5 responses (Questions 4, 13).

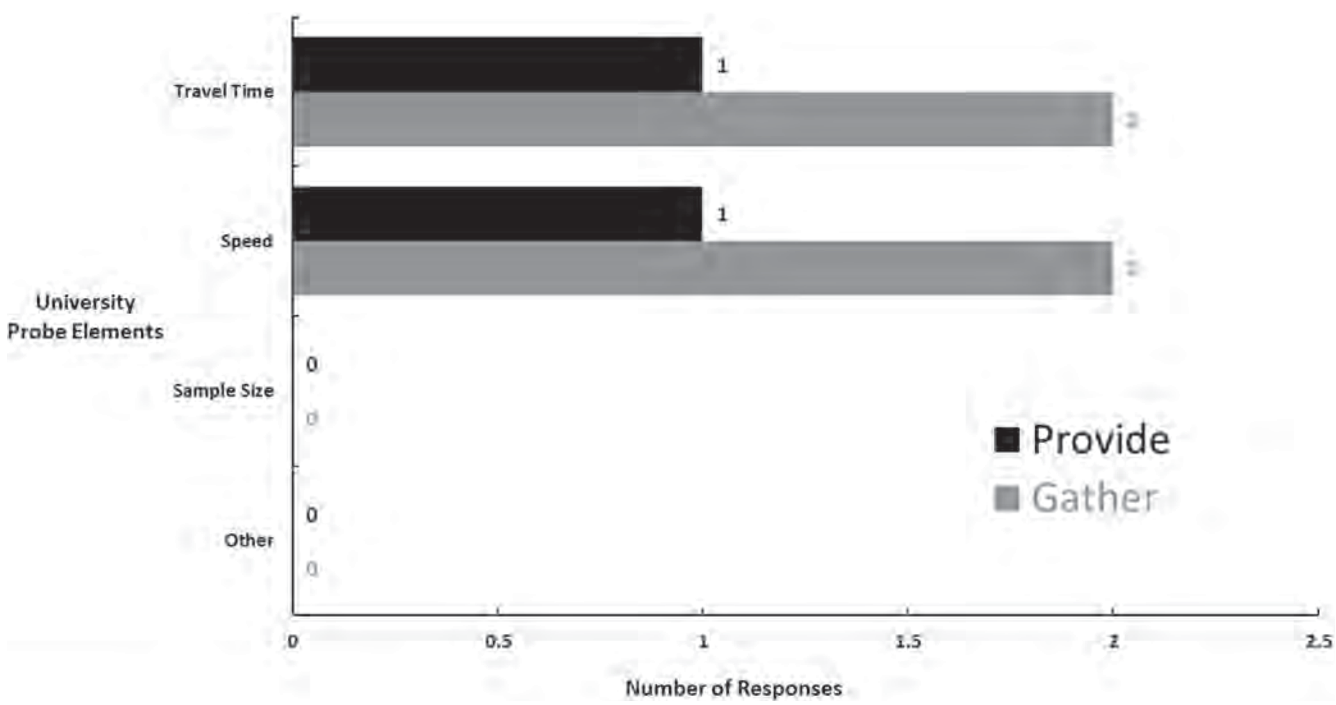


FIGURE D47 Probe vehicle elements shared by universities—4 responses (Questions 4, 13).

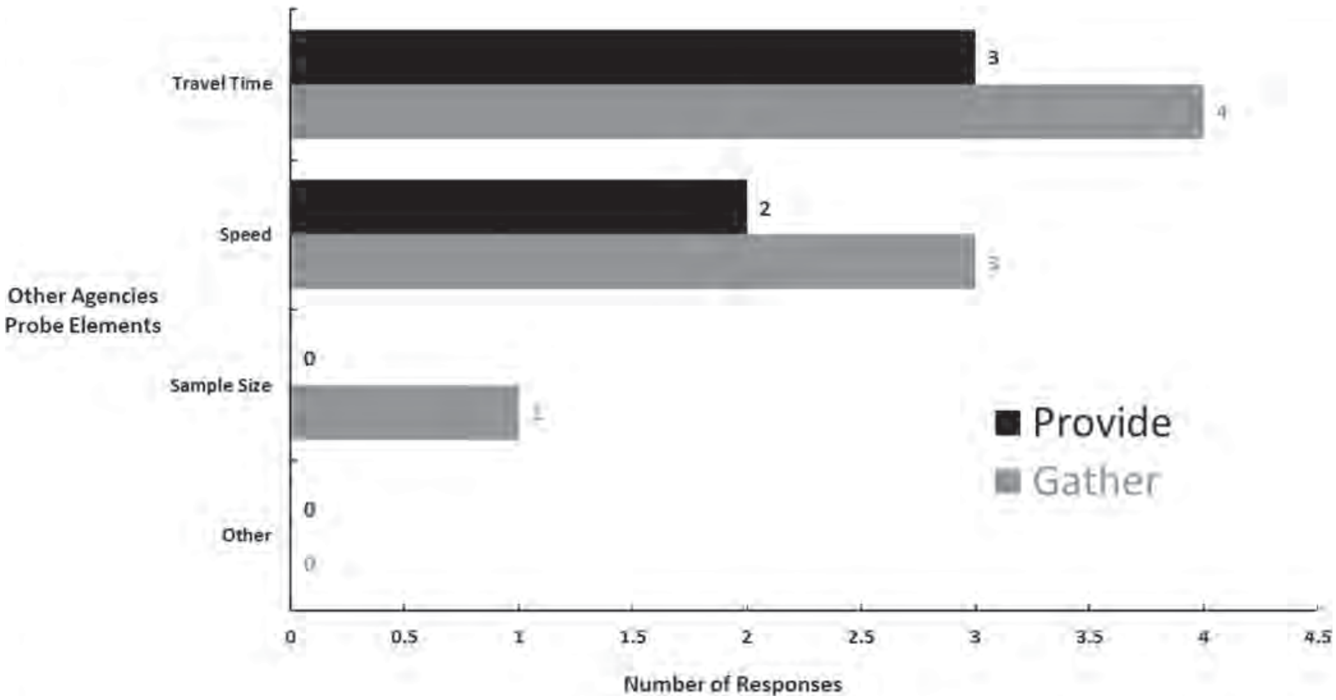


FIGURE D48 Probe vehicle elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING OTHER ITS DATA (D49–D63)

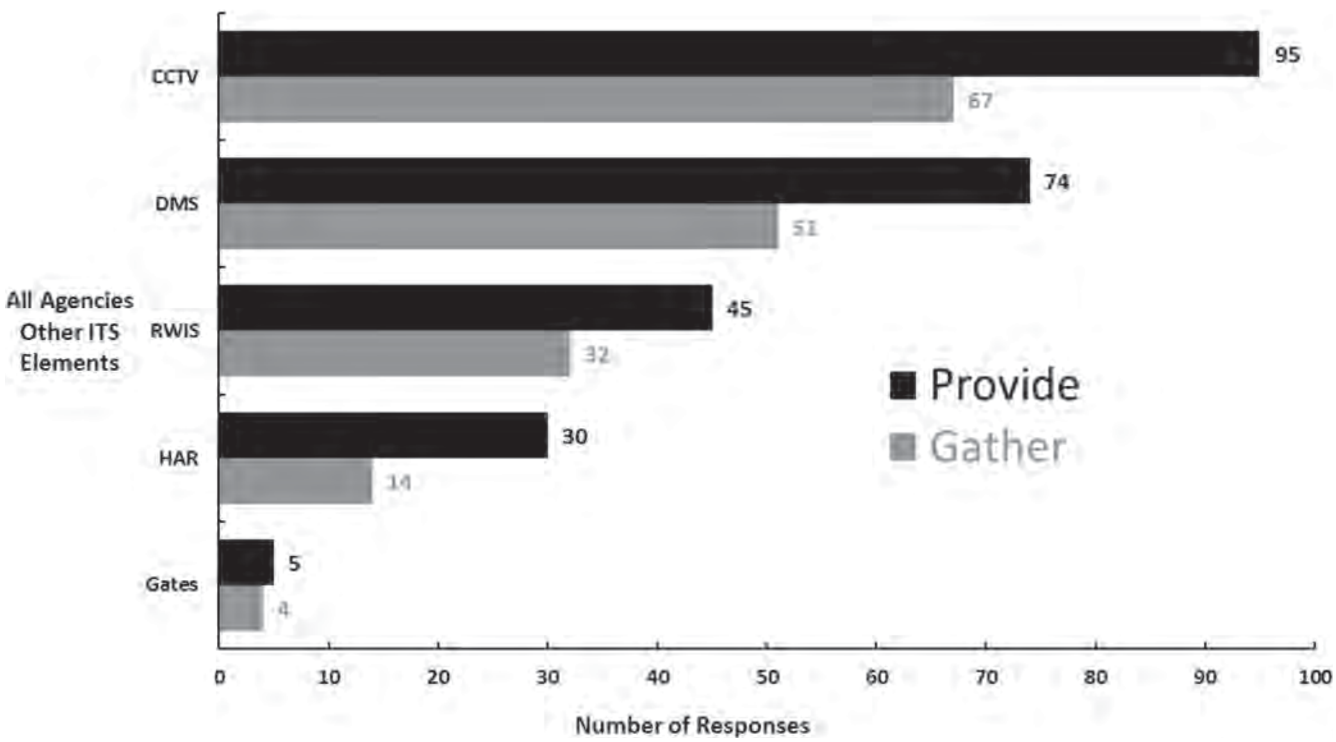


FIGURE D49 Other ITS elements shared by agencies in general—198 responses (Questions 4, 13).

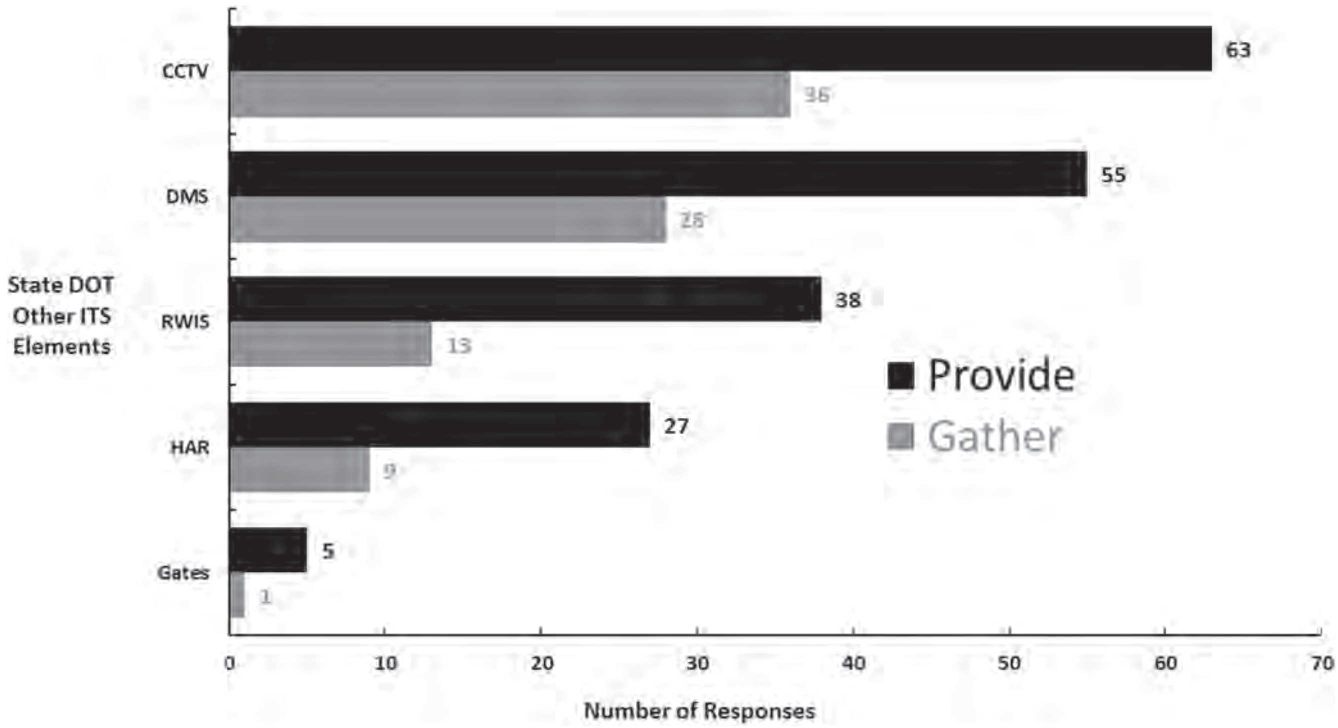


FIGURE D50 Other ITS elements shared by state DOTs—86 responses (Questions 4, 13).

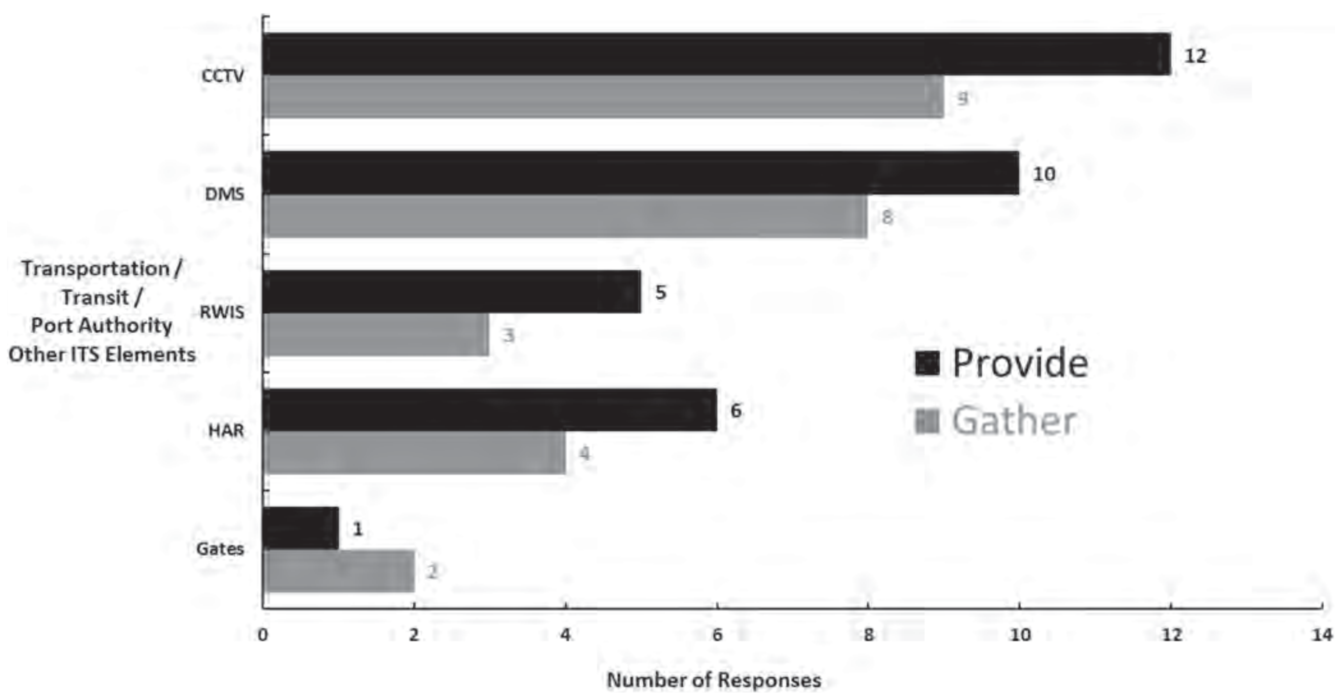


FIGURE D51 Other ITS elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

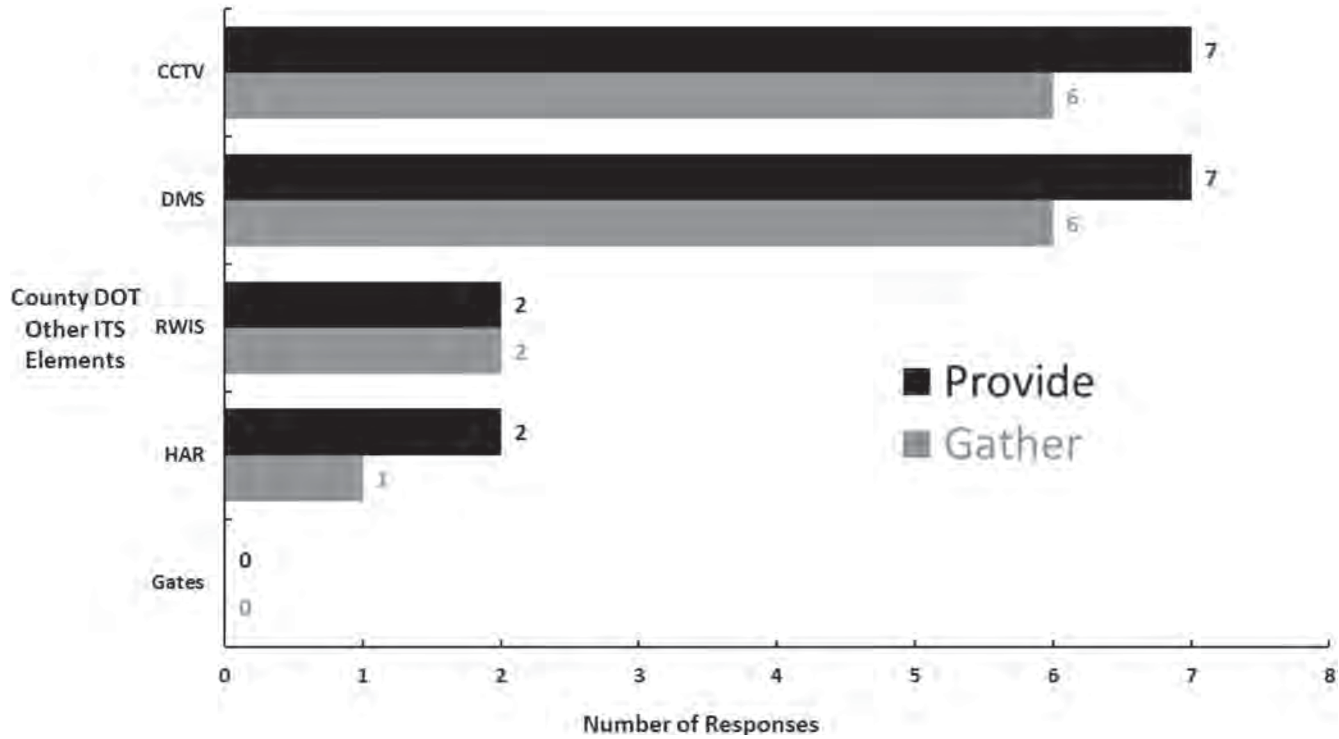


FIGURE D52 Other ITS elements shared by county DOTs—12 responses (Questions 4, 13).

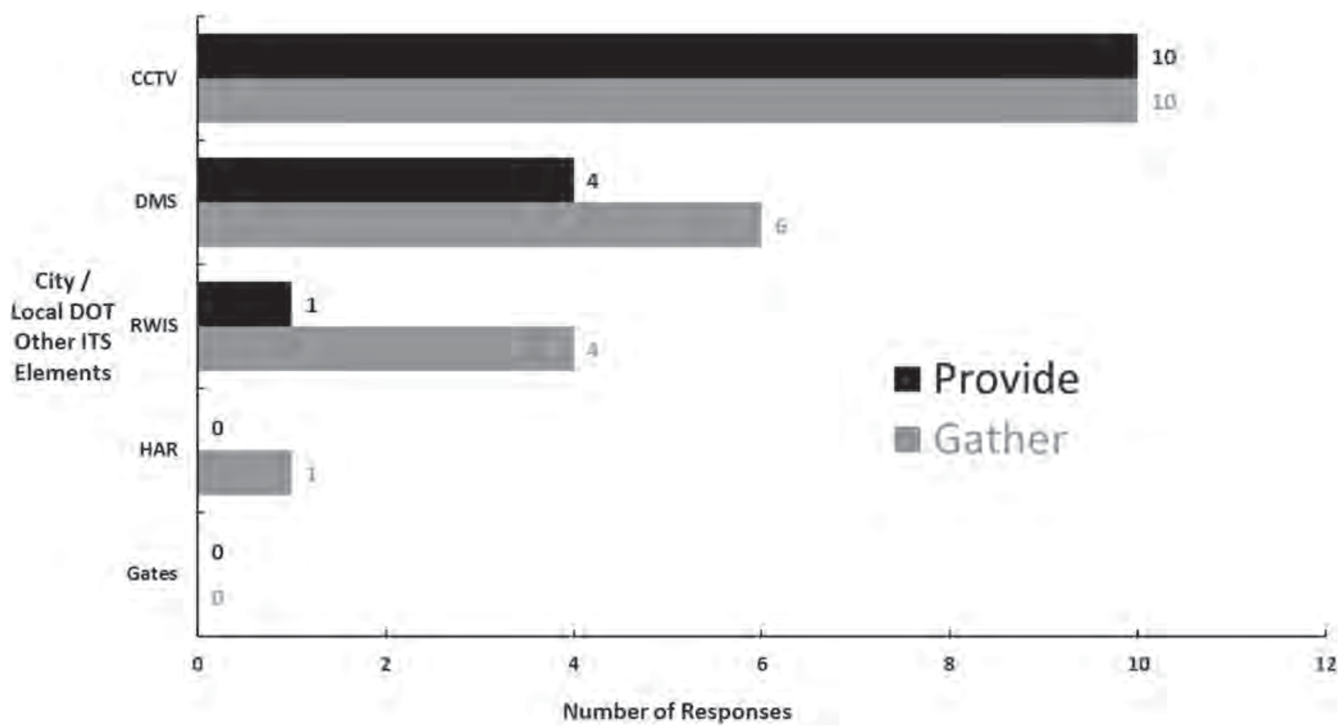


FIGURE D53 Other ITS elements shared by city and local DOTs—24 responses (Questions 4, 13).

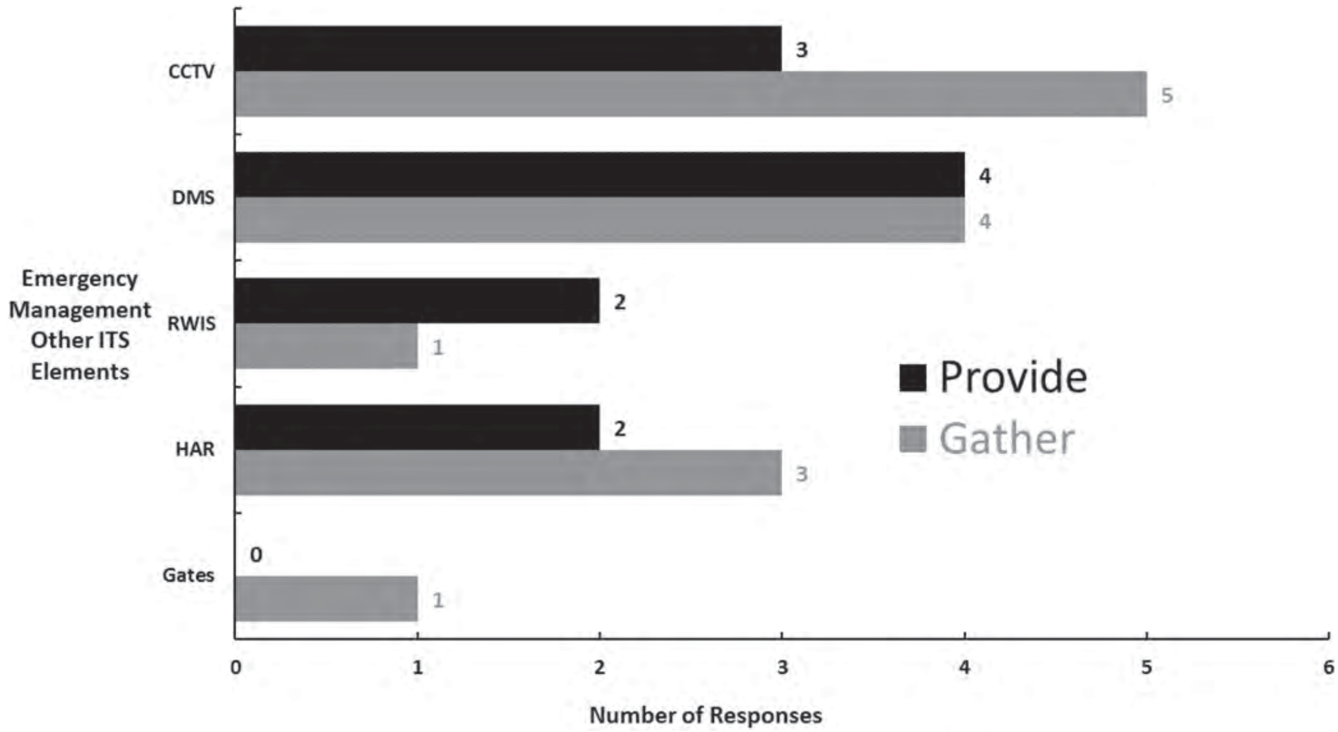


FIGURE D54 Other ITS elements shared by emergency management agencies—9 responses (Questions 4, 13).

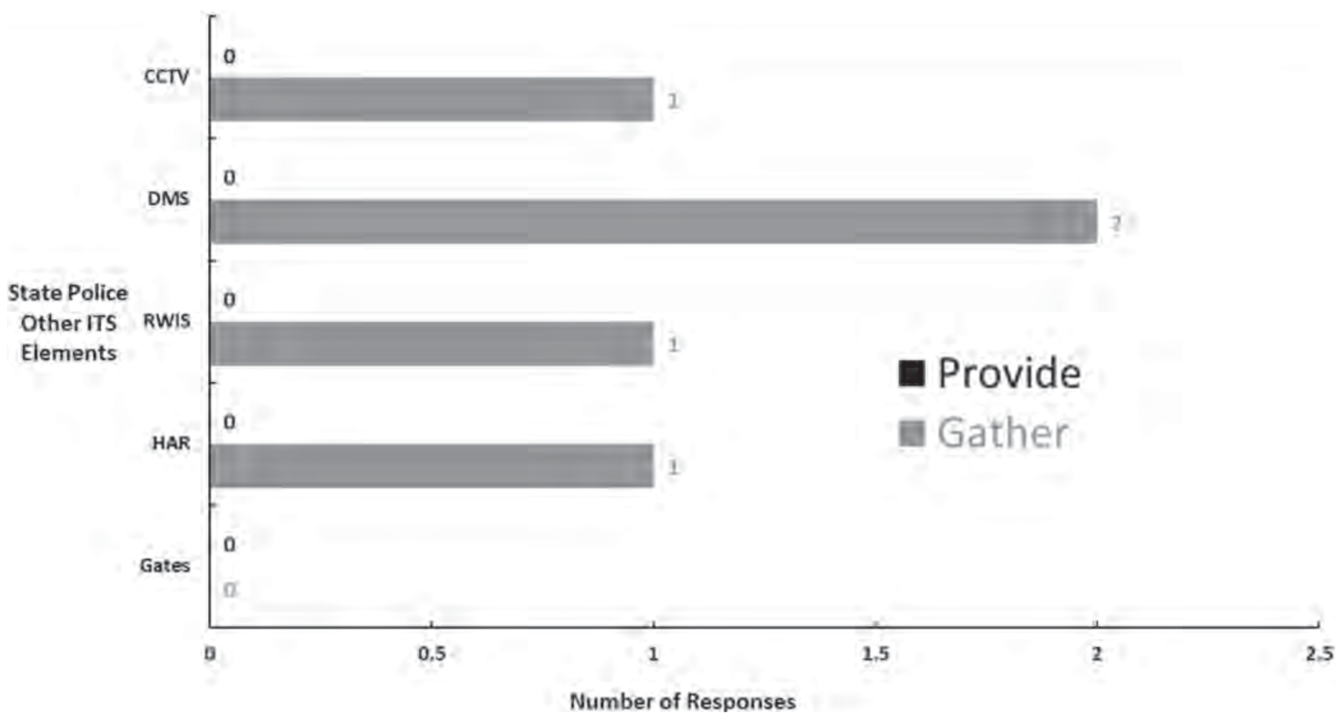


FIGURE D55 Other ITS elements shared by state police—4 responses (Questions 4, 13).

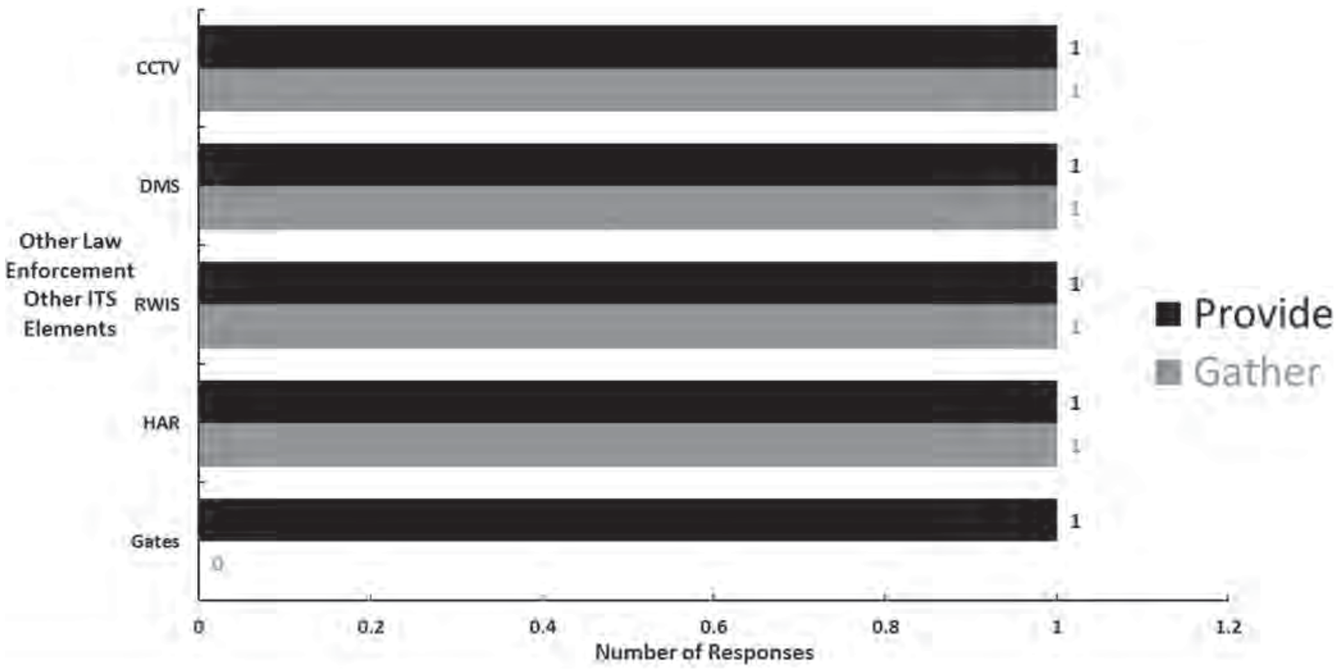


FIGURE D56 Other ITS elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

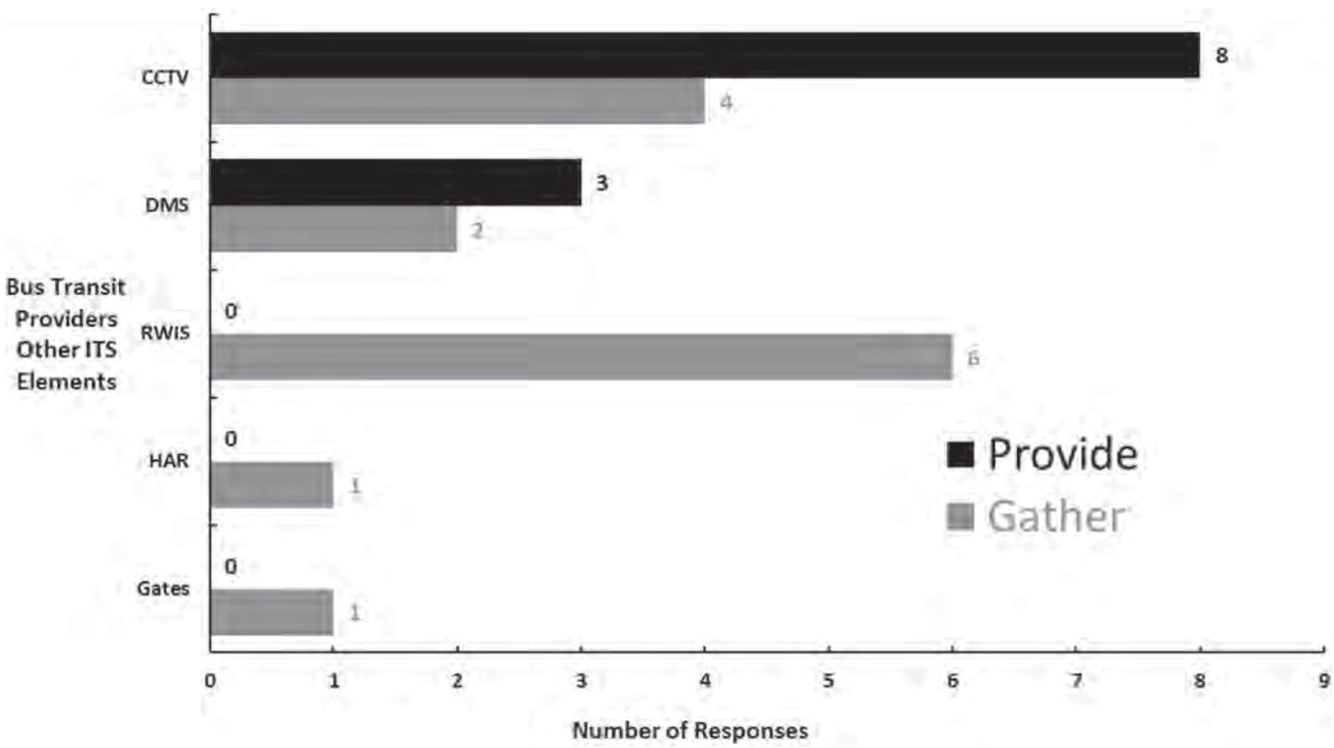


FIGURE D57 Other ITS elements shared by bus transit providers—40 responses (Questions 4, 13).

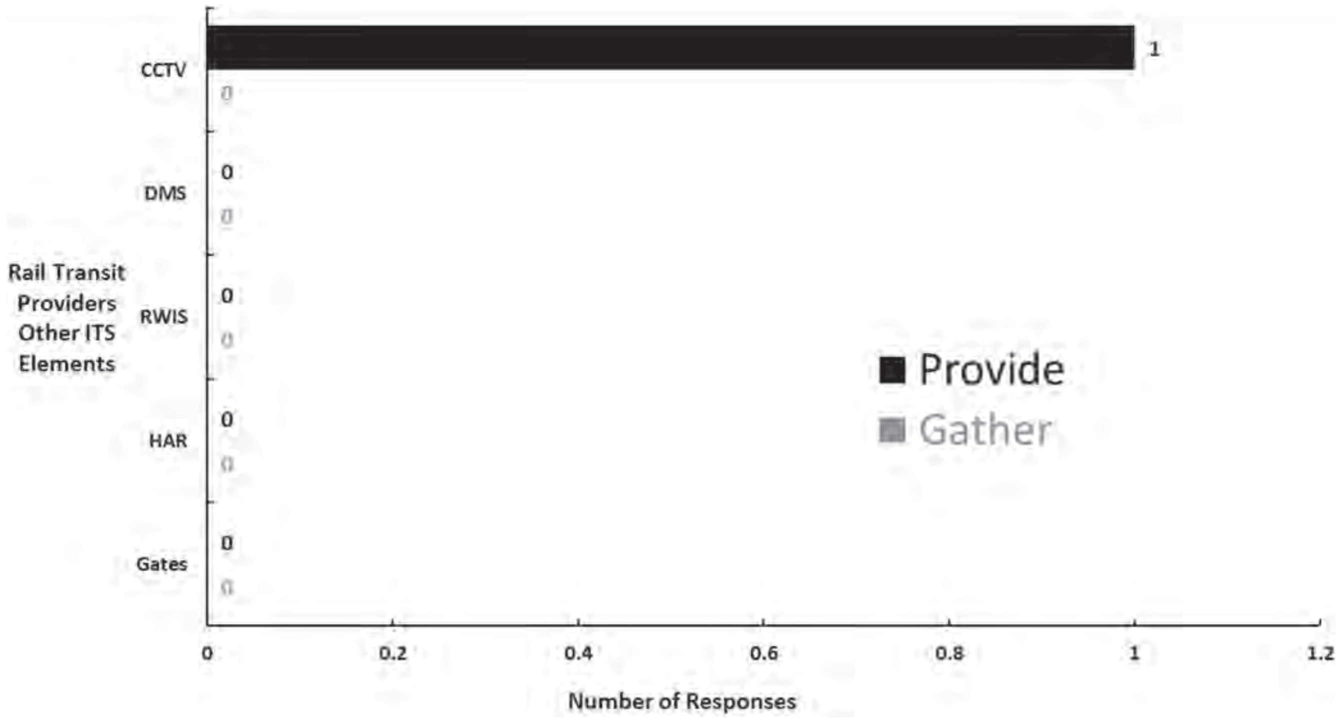


FIGURE D58 Other ITS elements shared by rail transit providers—3 responses (Questions 4, 13).

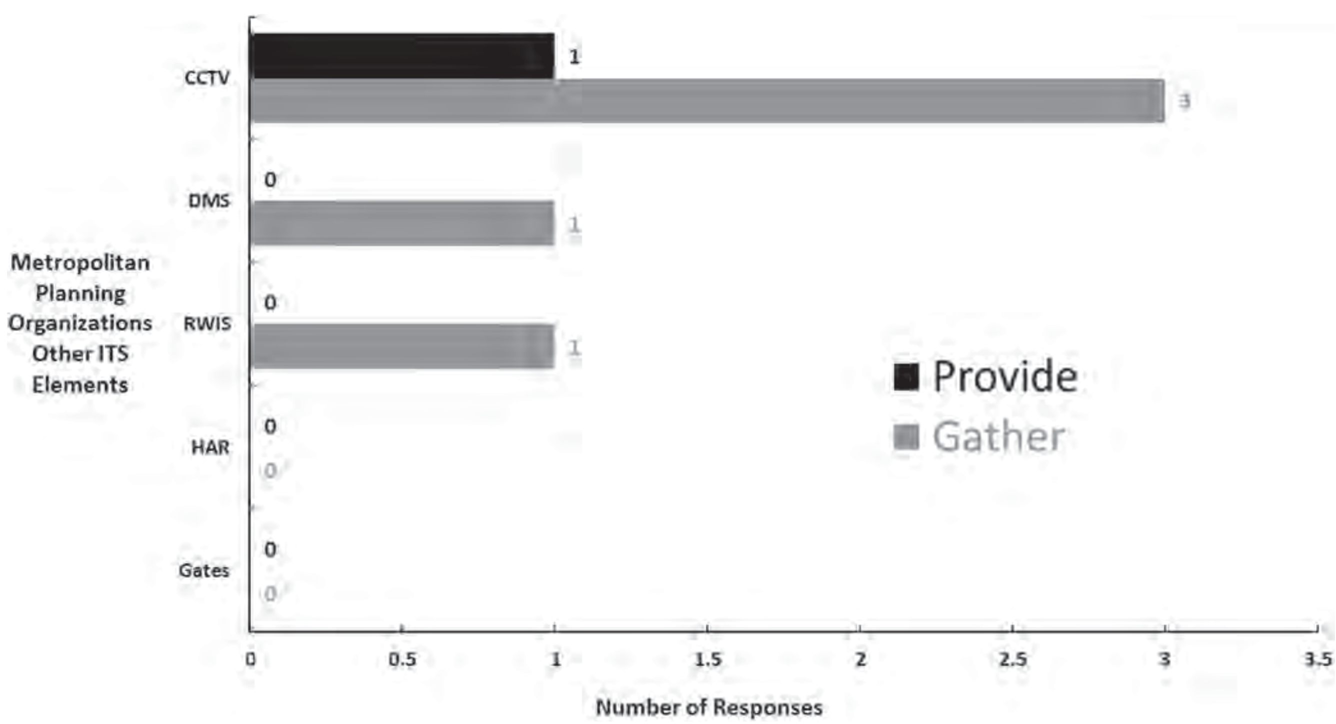


FIGURE D59 Other ITS elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

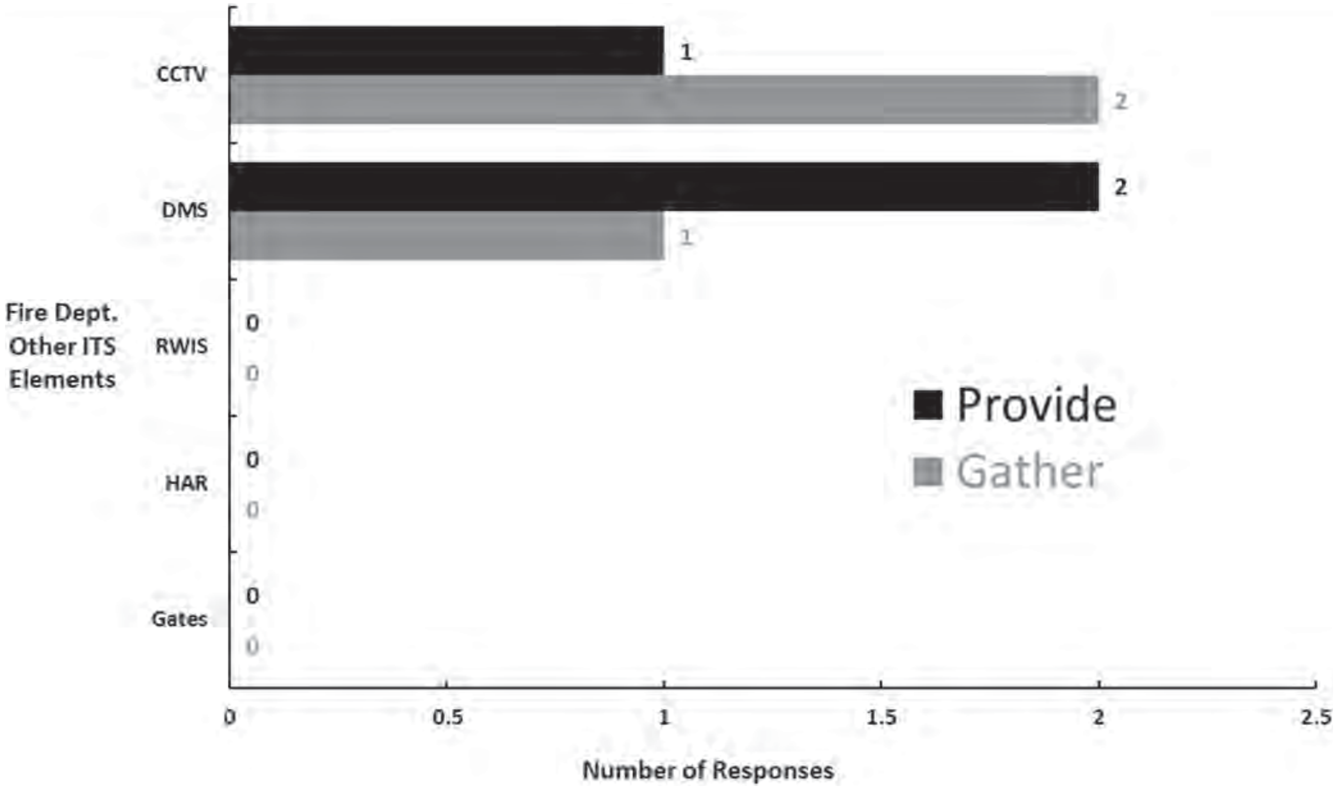


FIGURE D60 Other ITS elements shared by fire departments—3 responses (Questions 4, 13).

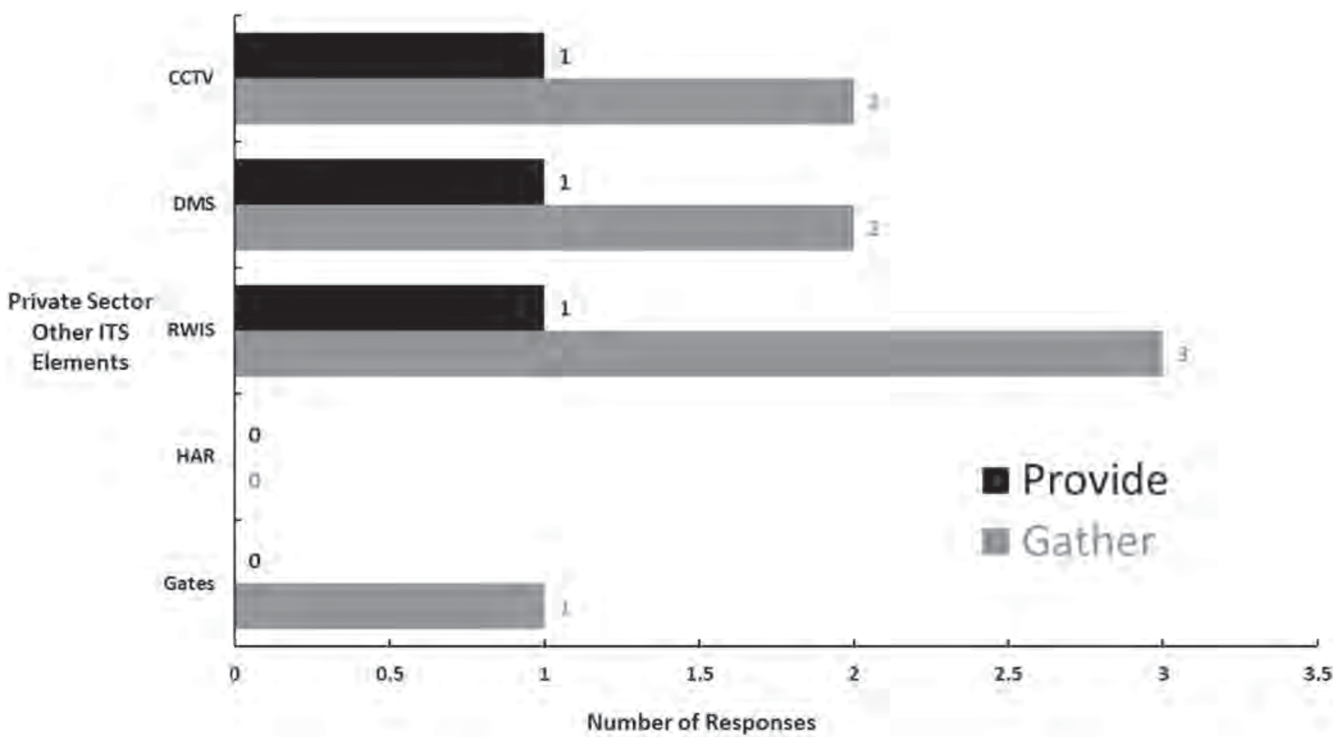


FIGURE D61 Other ITS elements shared by private sector entities—5 responses (Questions 4, 13).

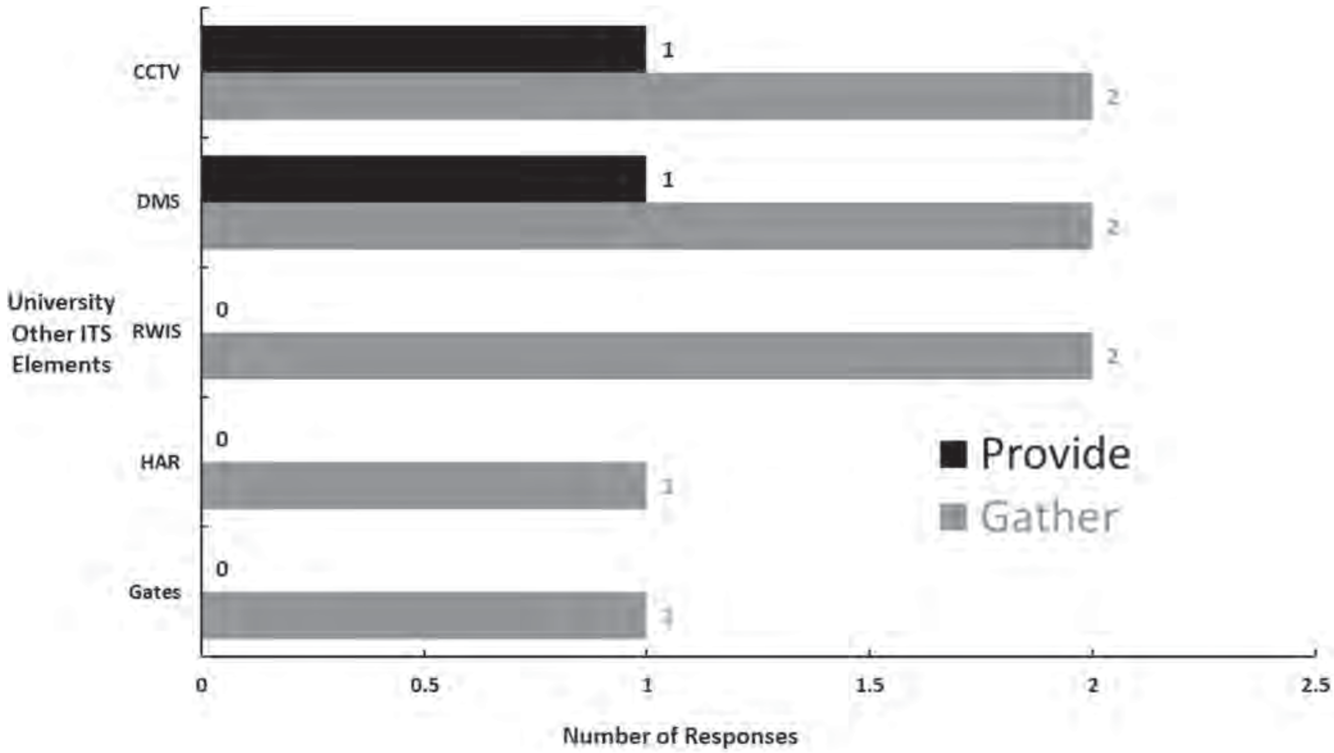


FIGURE D62 Other ITS elements shared by universities—4 responses (Questions 4, 13).

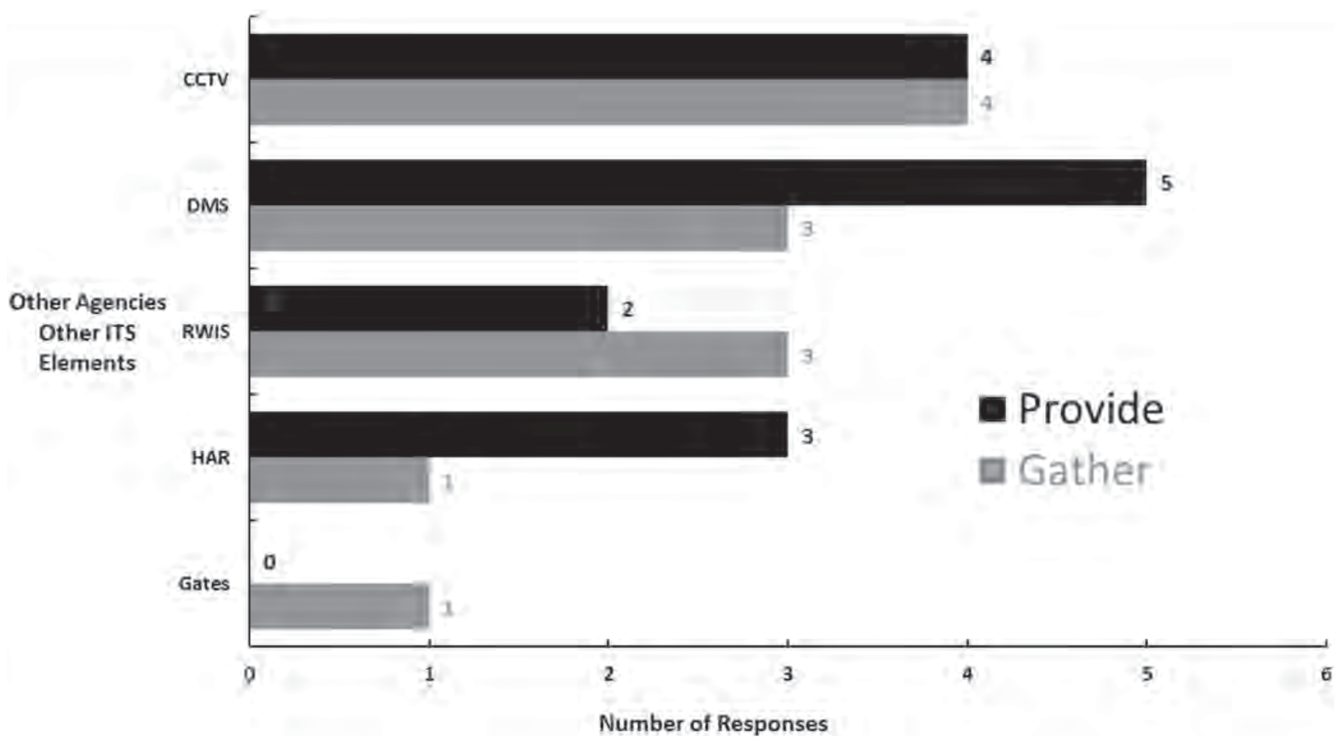


FIGURE D63 Other ITS elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING AUTOMATED VEHICLE LOCATION DATA (D64–D78)

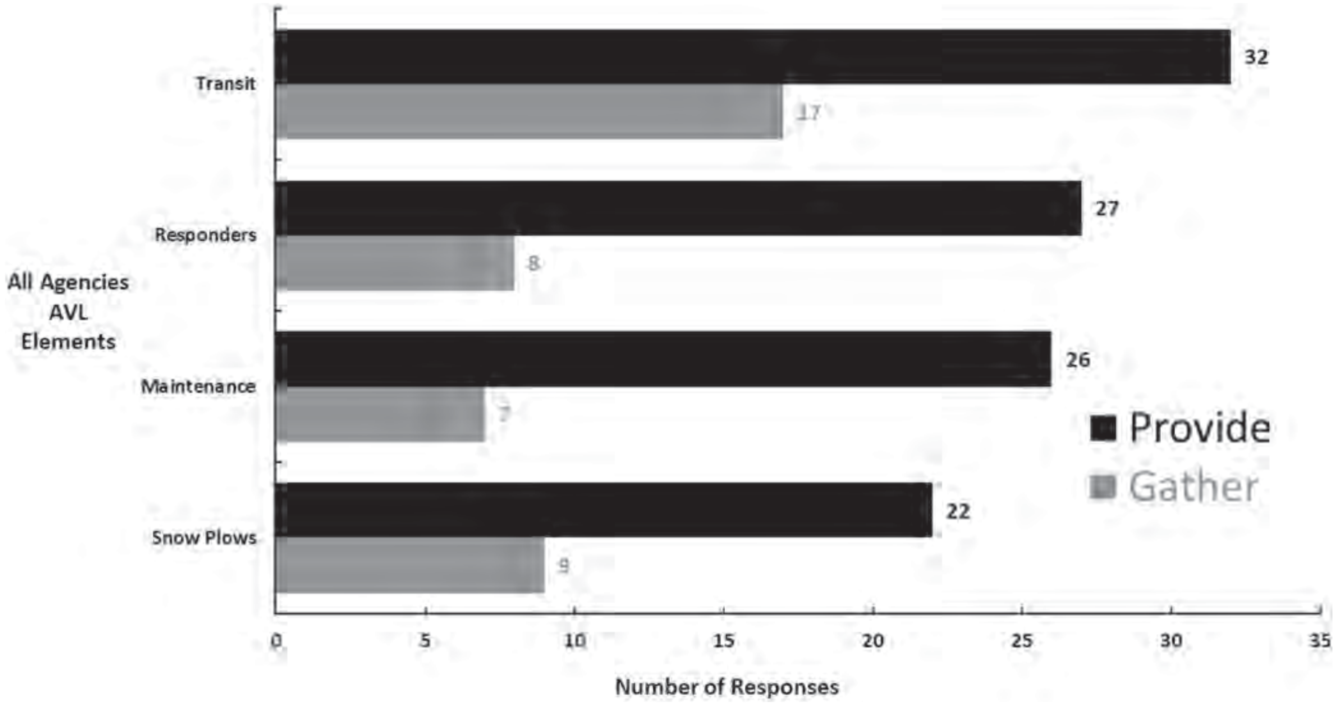


FIGURE D64 AVL elements shared by agencies in general—198 responses (Questions 4, 13).

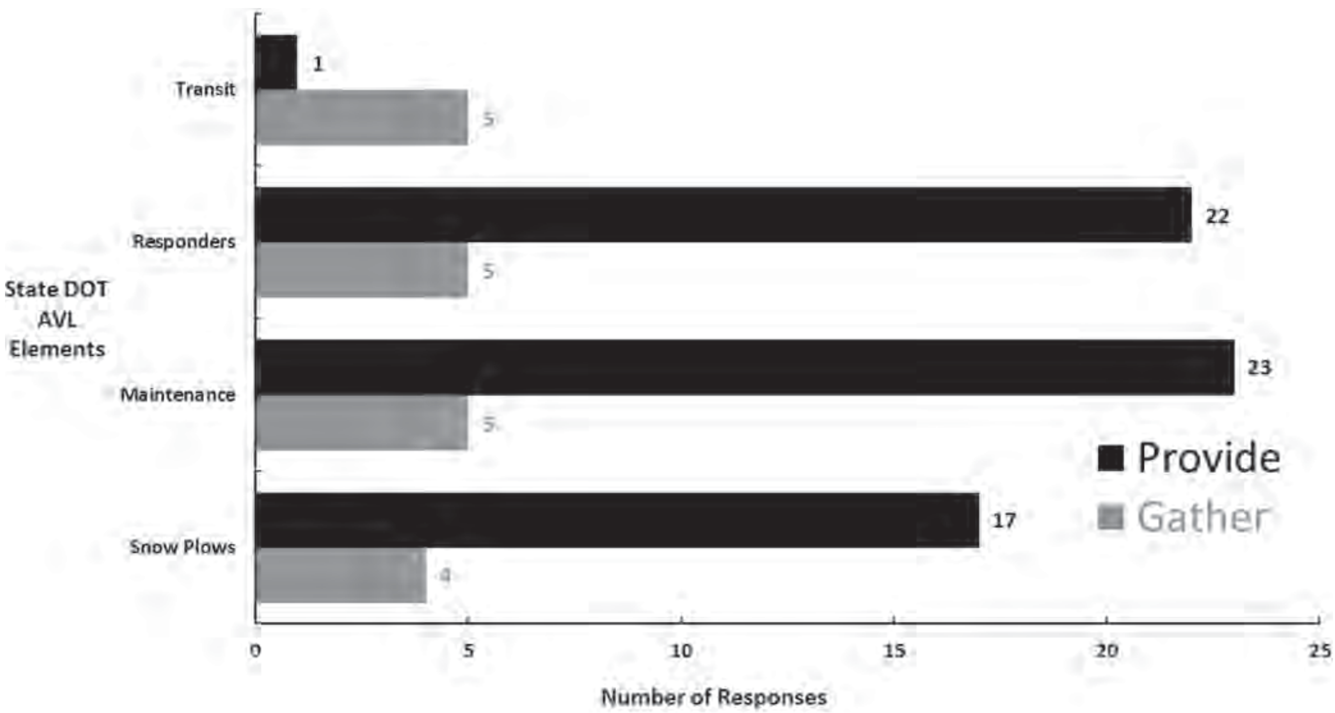


FIGURE D65 AVL elements shared by state DOTs—86 responses (Questions 4, 13).

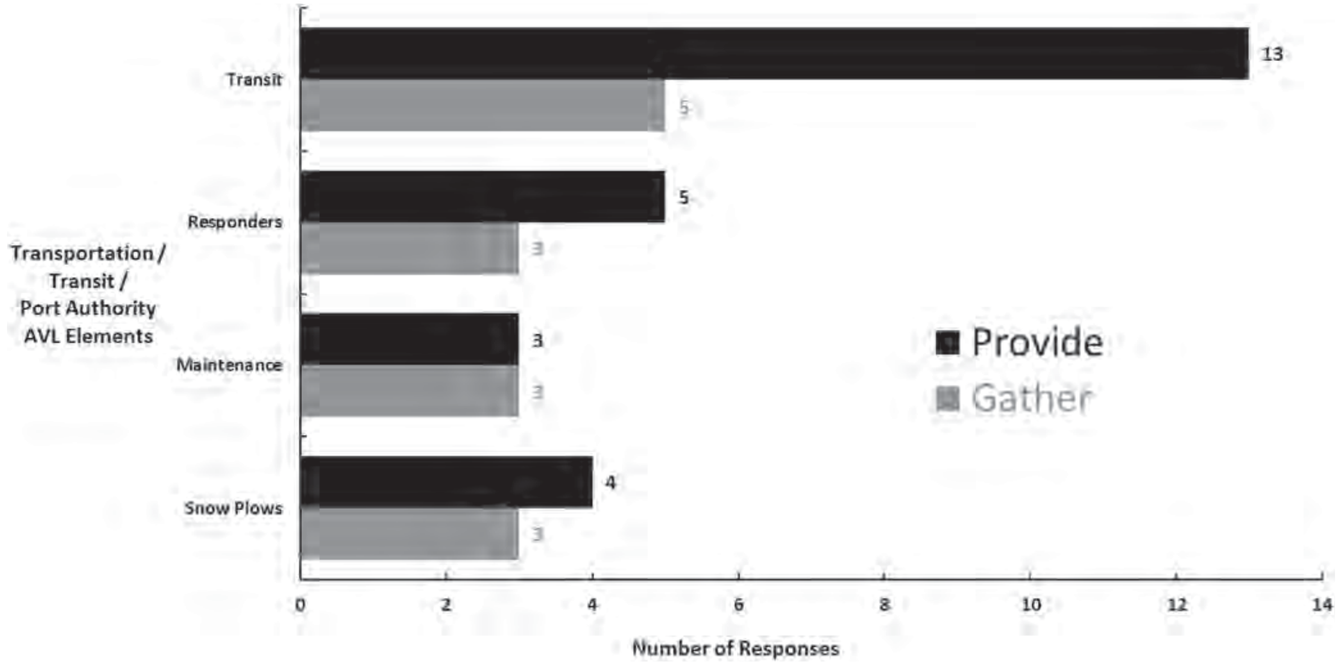


FIGURE D66 AVL elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

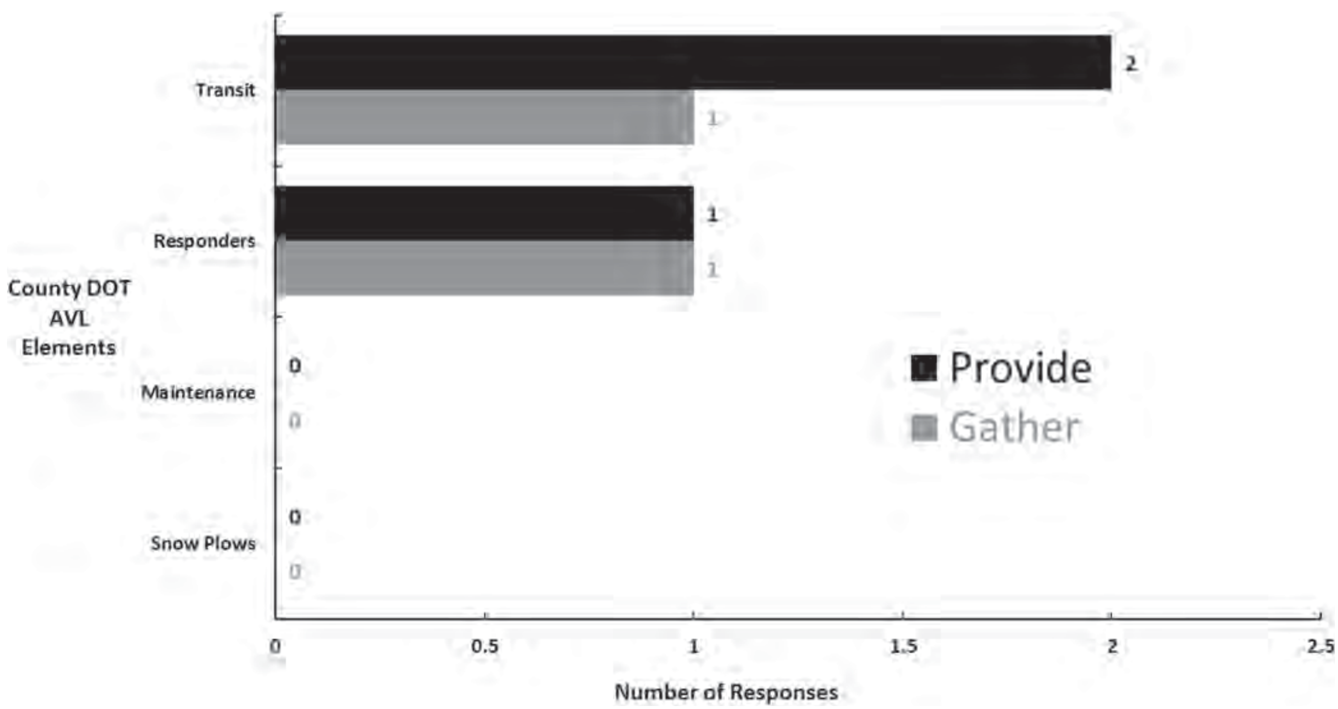


FIGURE D67 AVL elements shared by county DOTs—12 responses (Questions 4, 13).

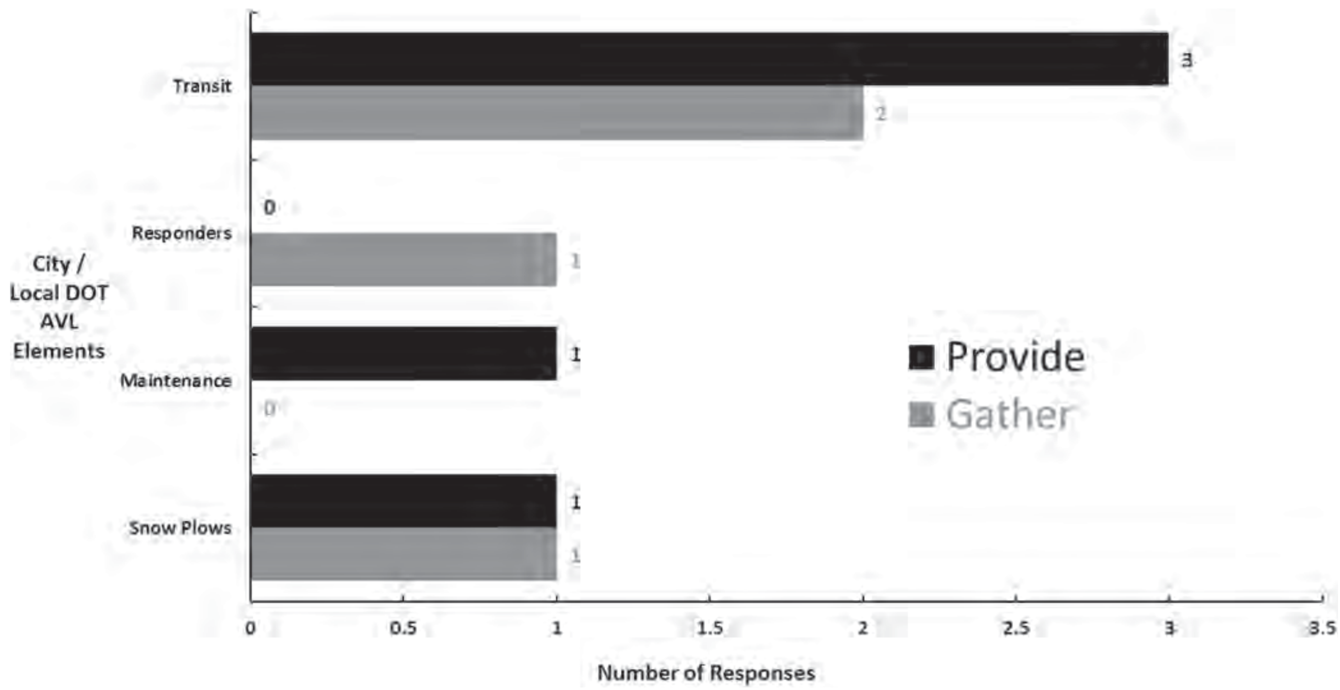


FIGURE D68 AVL elements shared by city and local DOTs—24 responses (Questions 4, 13).

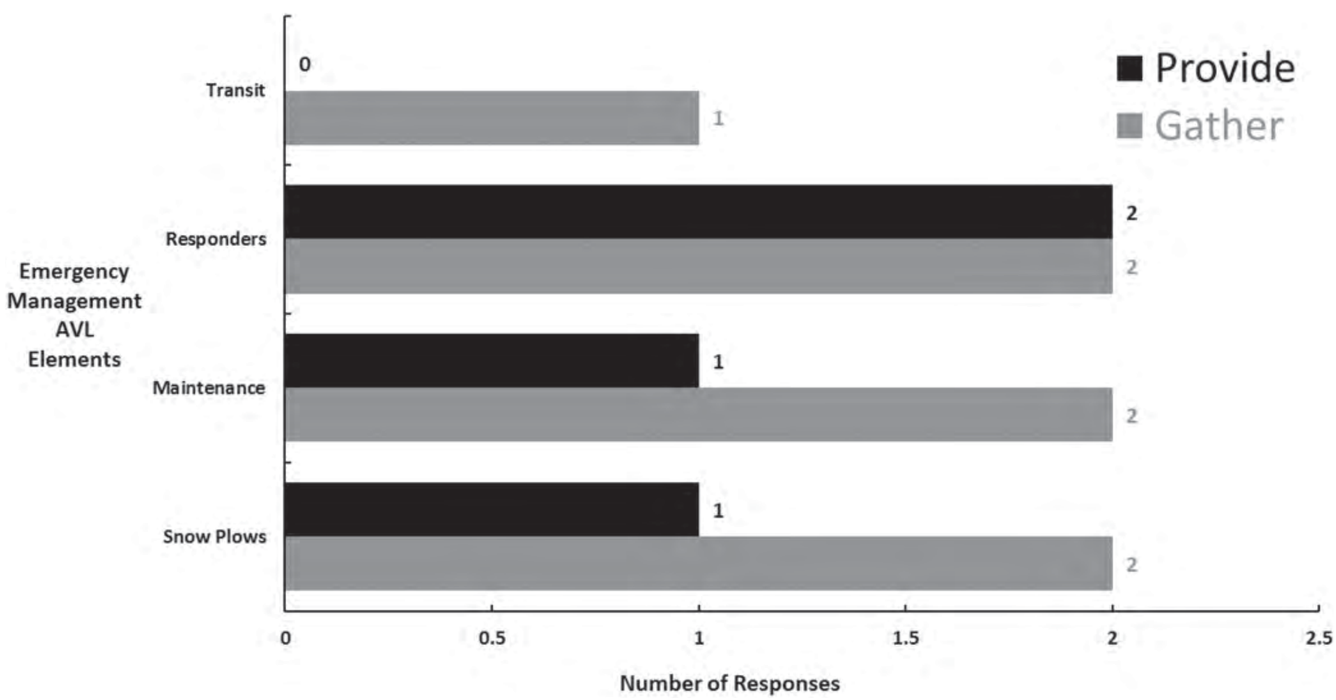


FIGURE D69 AVL elements shared by emergency management agencies—9 responses (Questions 4, 13).

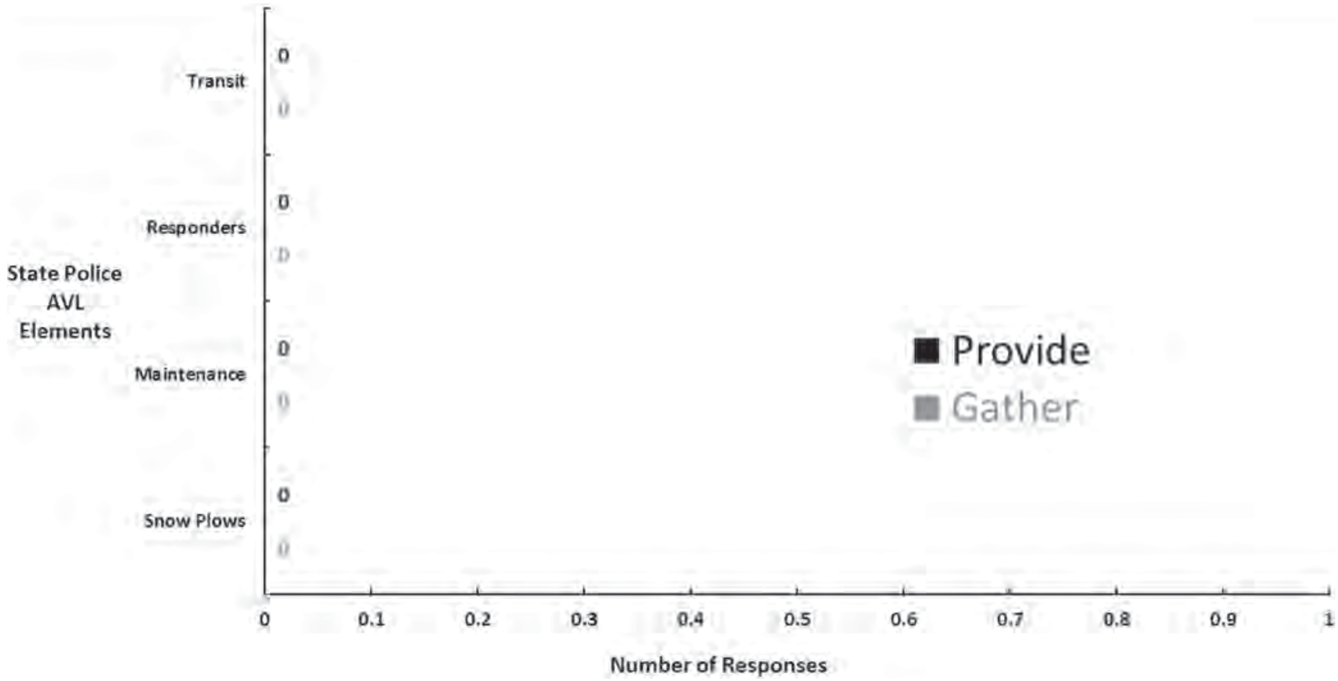


FIGURE D70 AVL elements shared by state police—4 responses (Questions 4, 13).

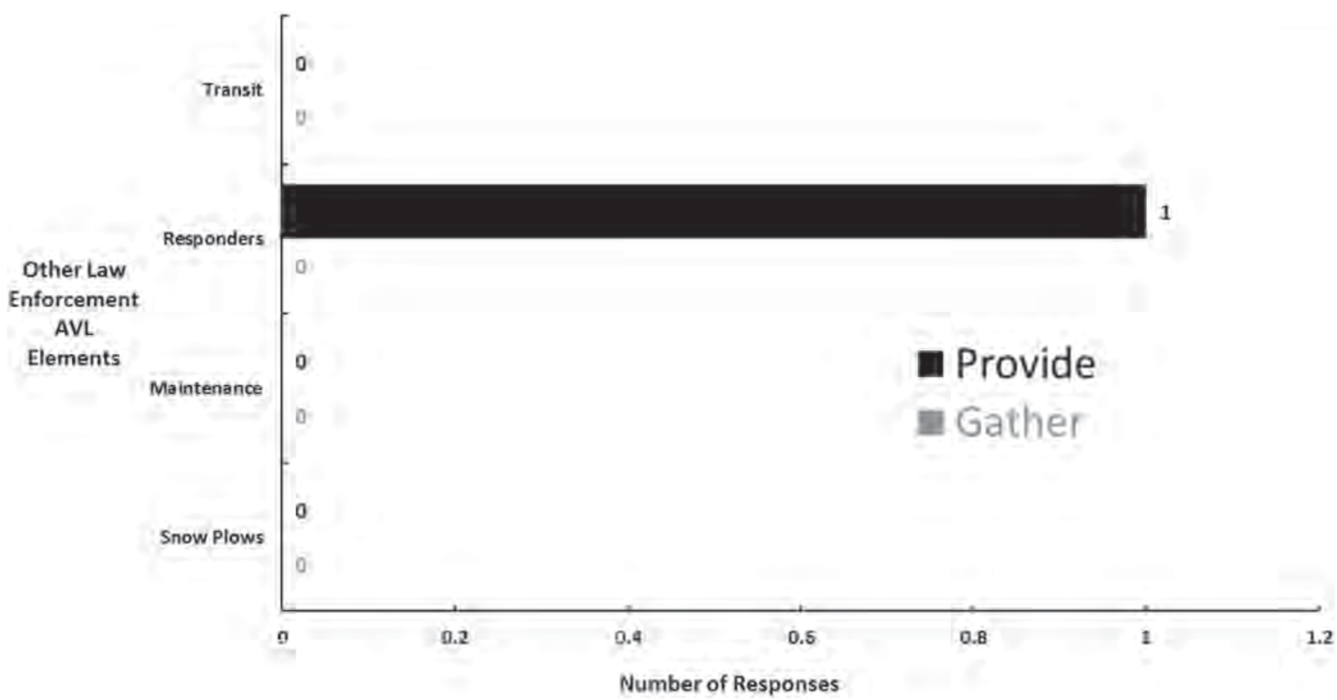


FIGURE D71 AVL elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

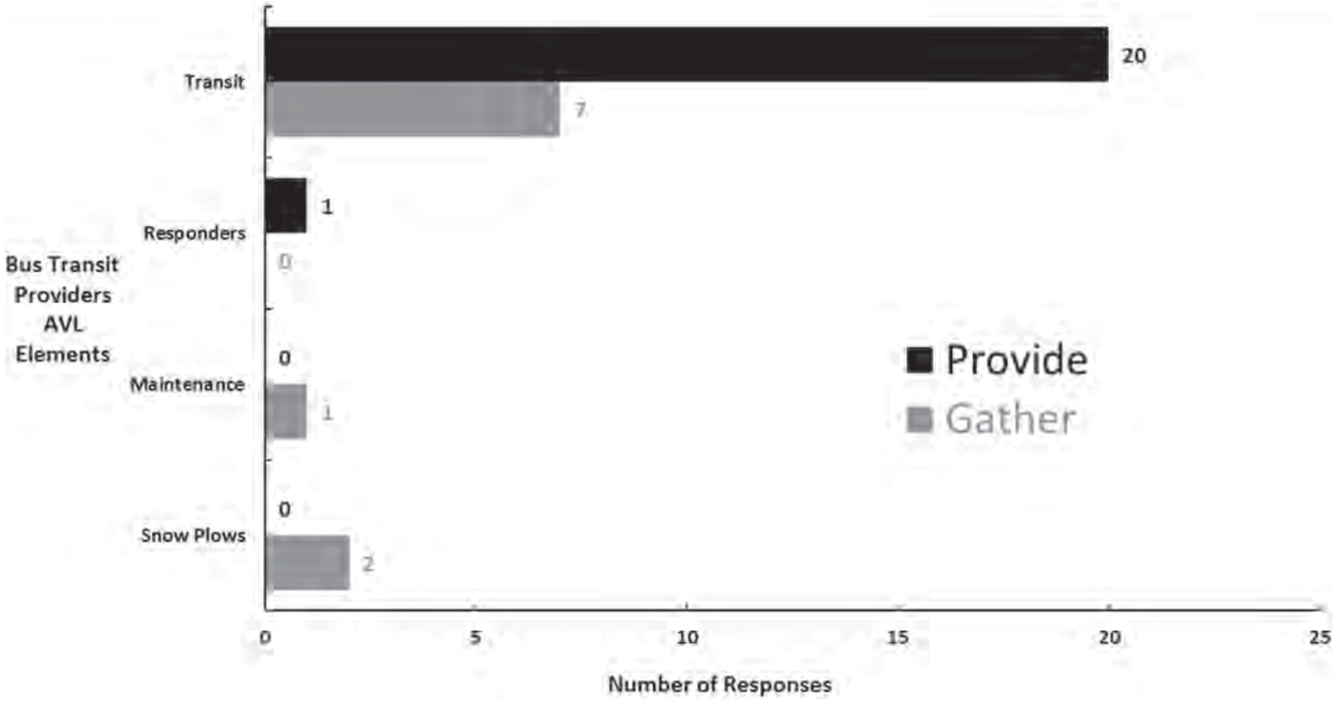


FIGURE D72 AVL elements shared by bus transit providers—40 responses (Questions 4, 13).

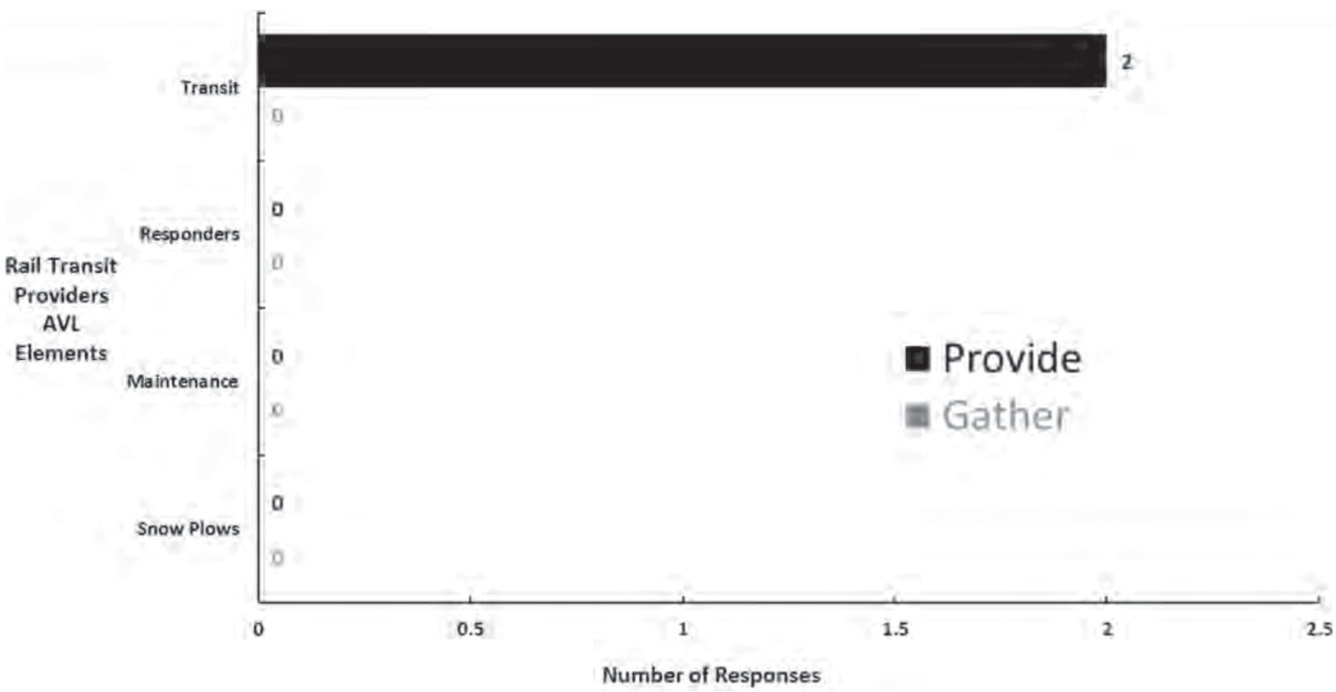


FIGURE D73 AVL elements shared by rail transit providers—3 responses (Questions 4, 13).

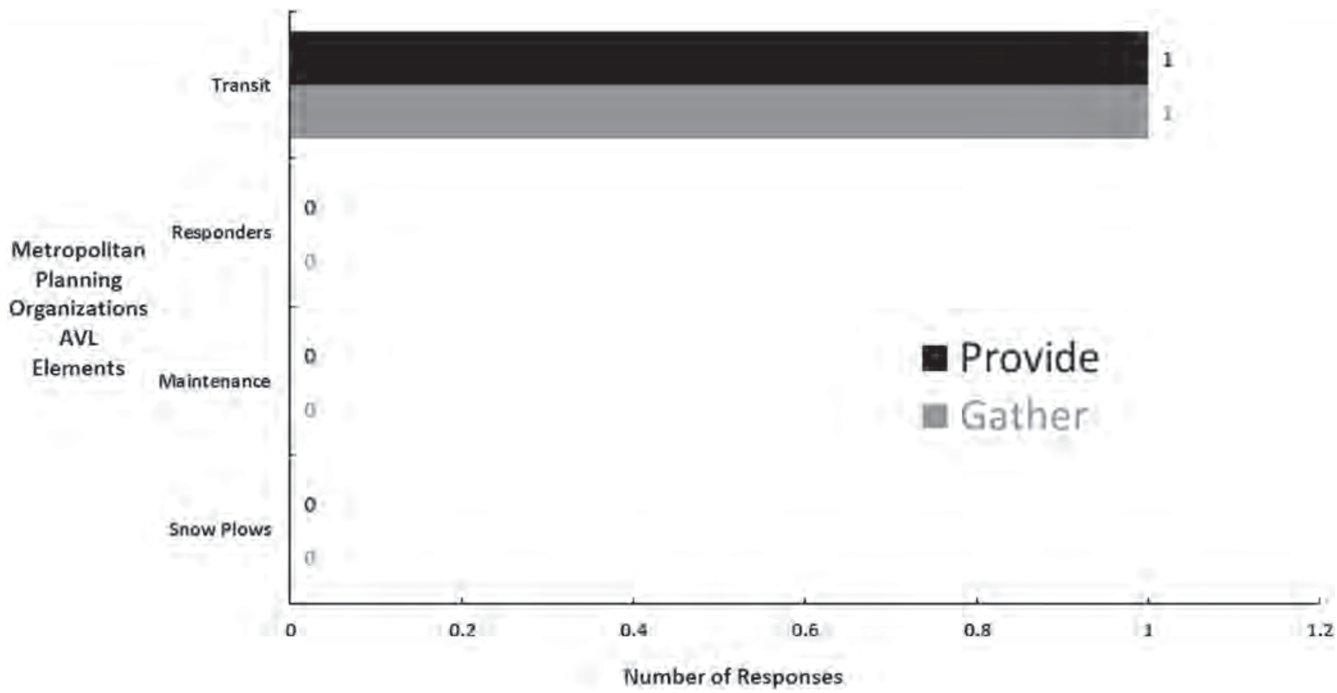


FIGURE D74 AVL elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

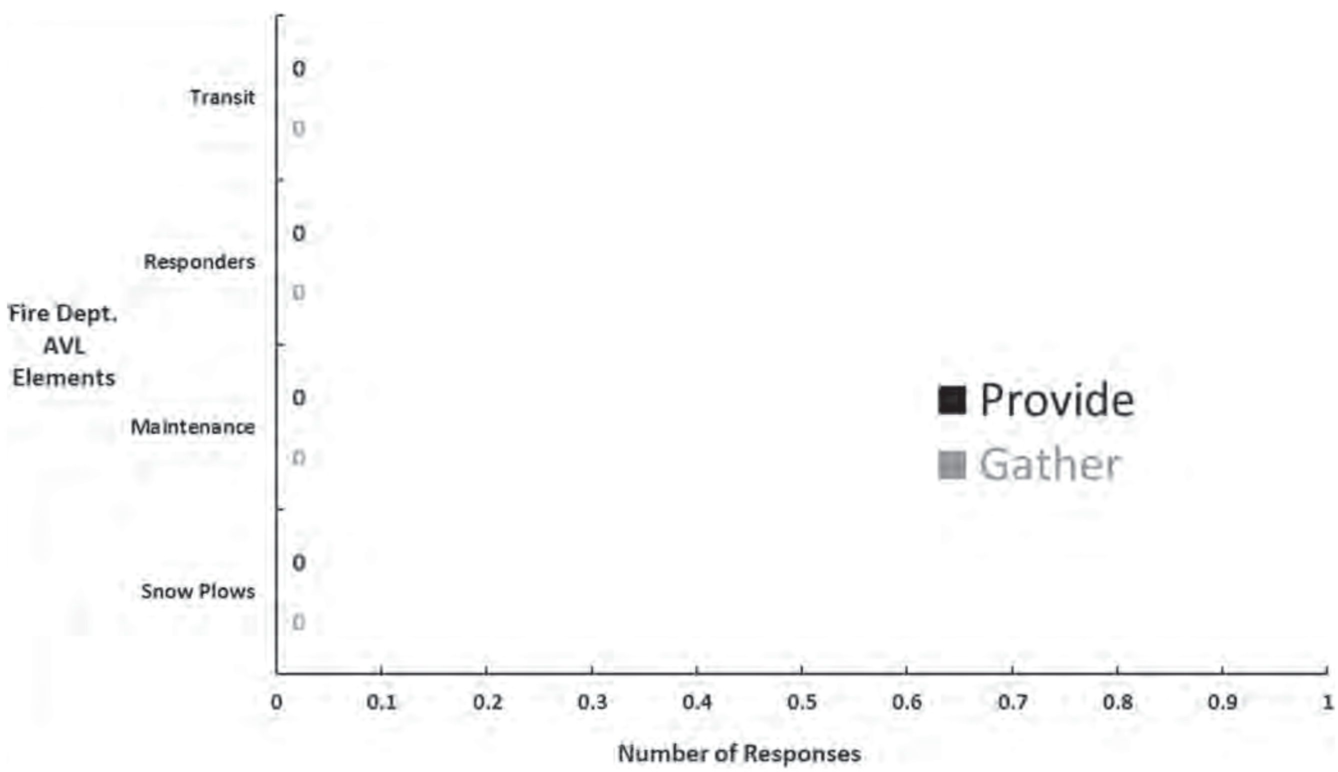


FIGURE D75 AVL elements shared by fire departments—3 responses (Questions 4, 13).

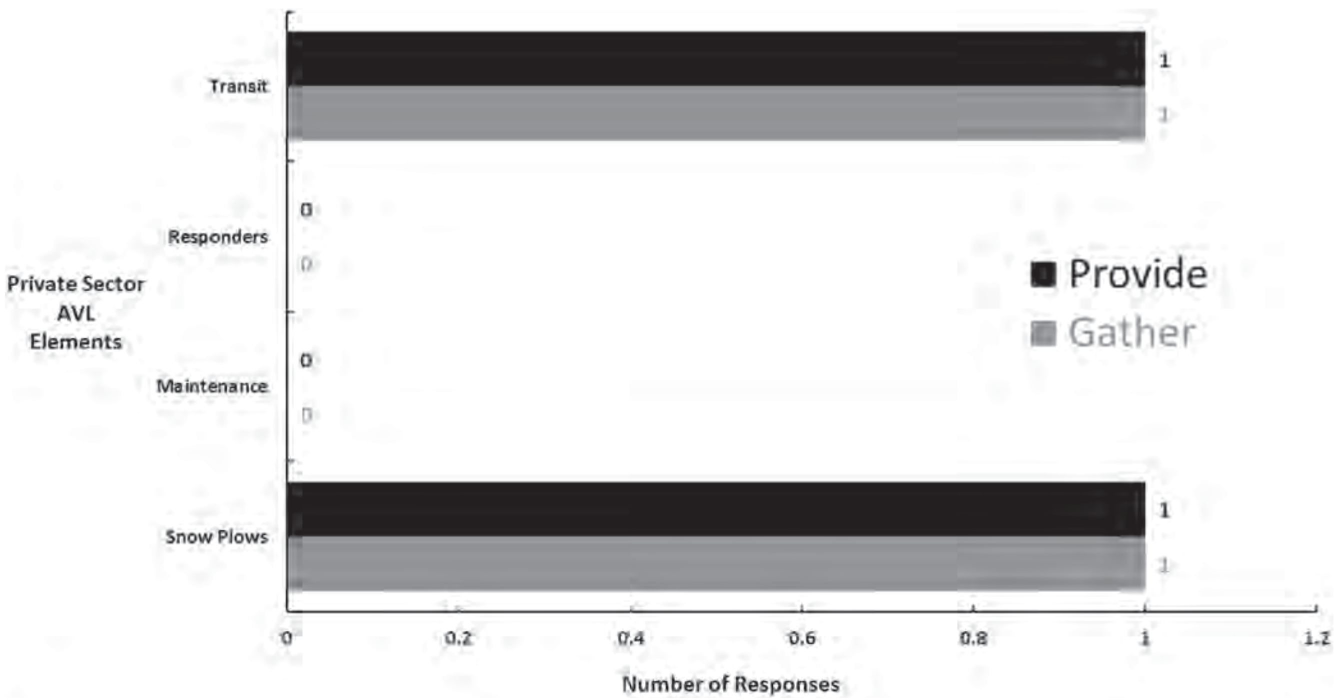


FIGURE D76 AVL elements shared by private sector entities—5 responses (Questions 4, 13).

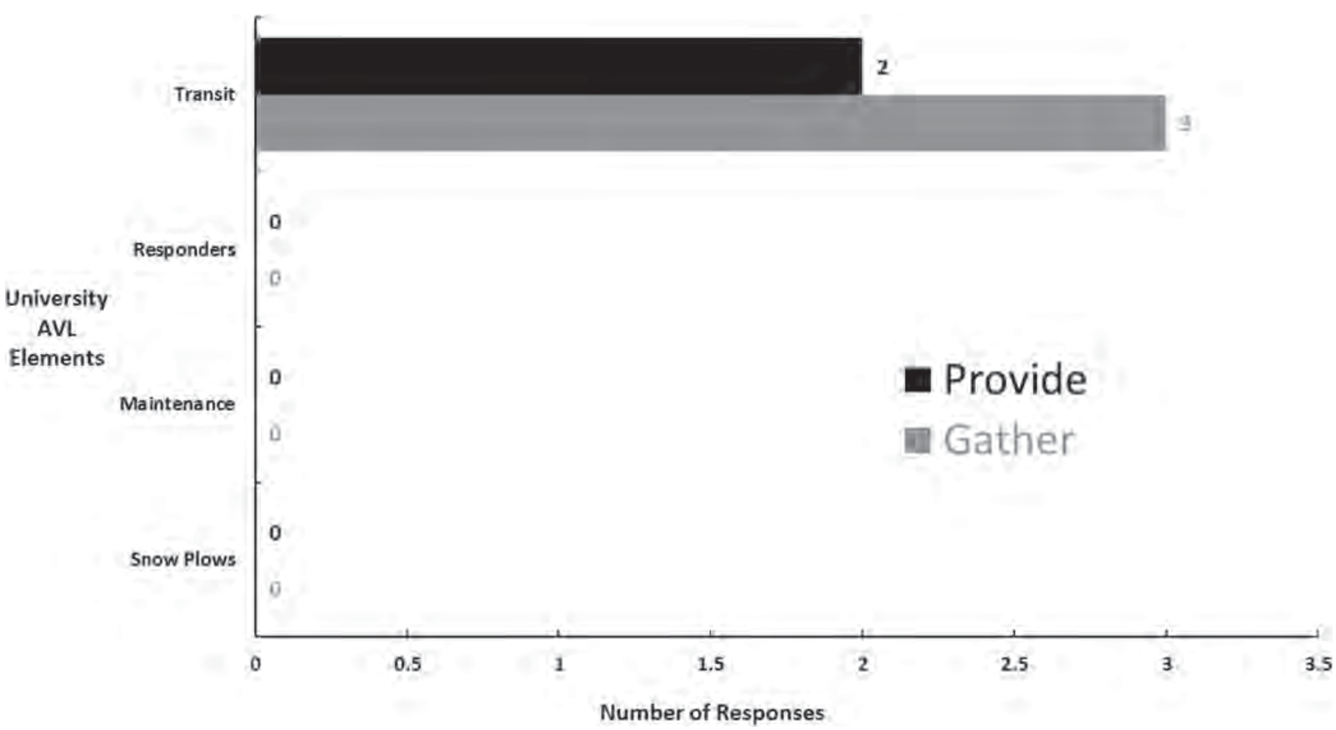


FIGURE D77 AVL elements shared by universities—4 responses (Questions 4, 13).

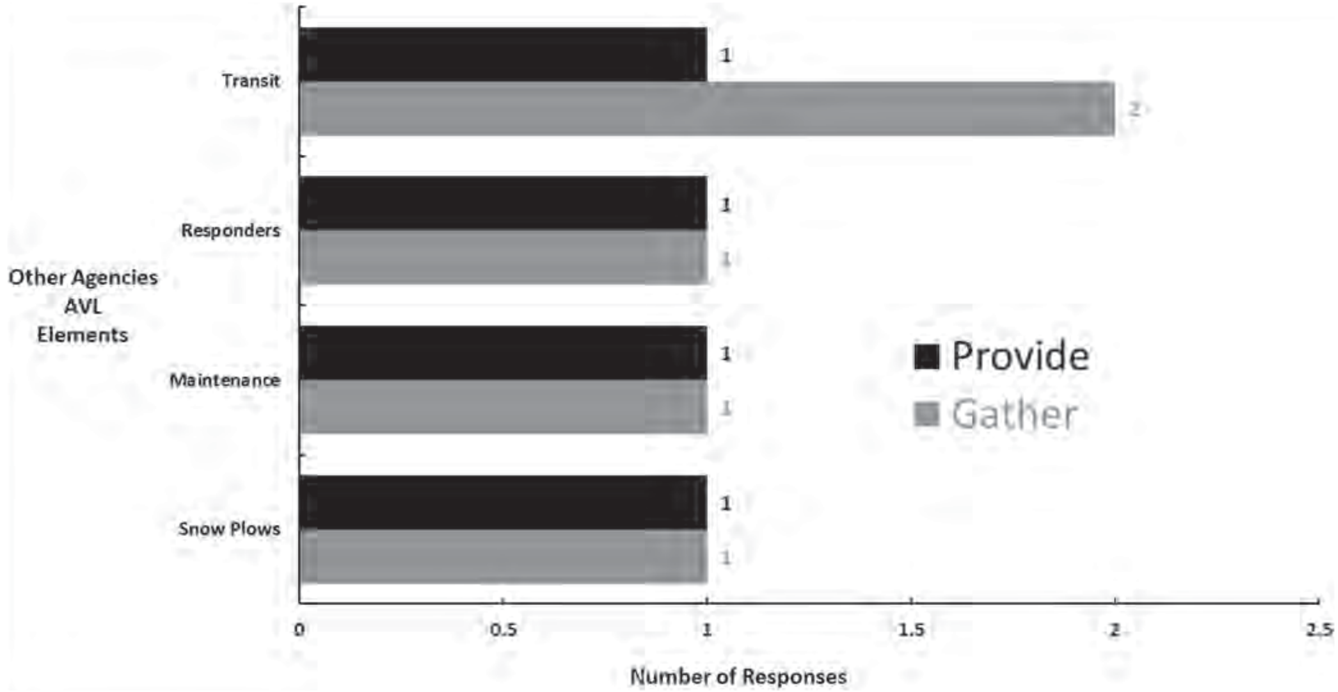


FIGURE D78 AVL elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING WEATHER DATA (D79–D93)

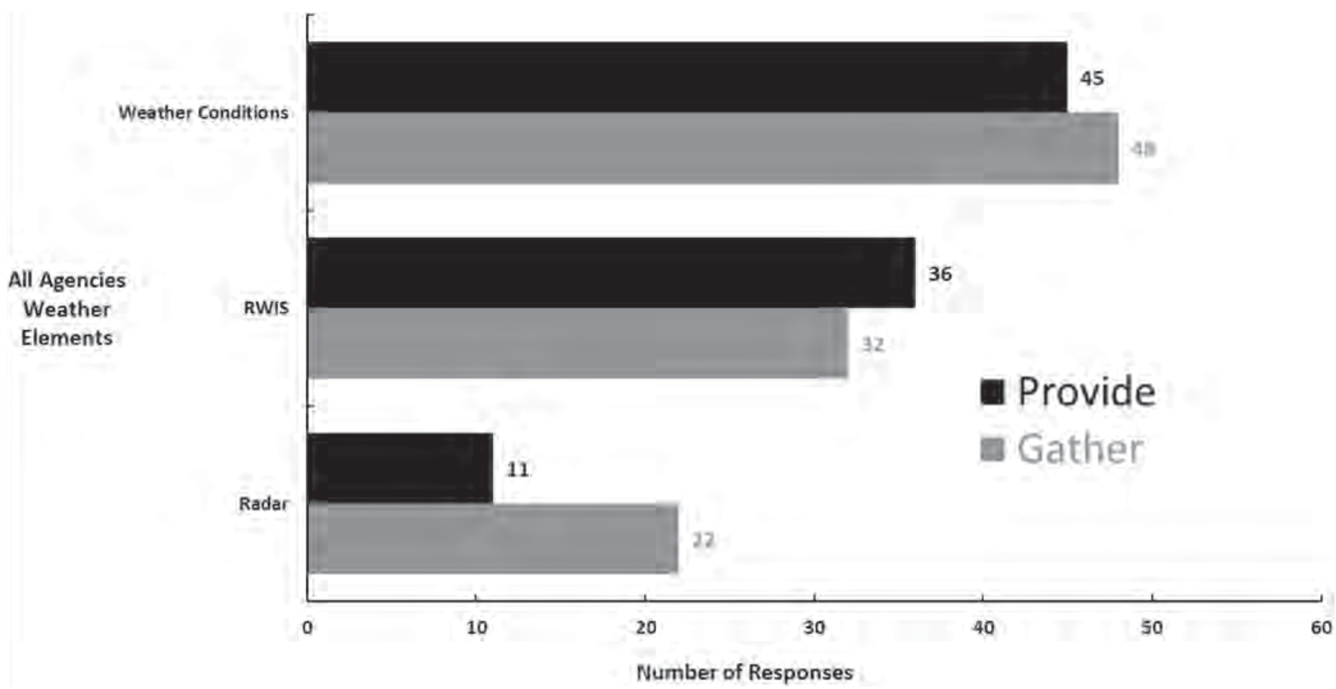


FIGURE D79 Weather elements shared by agencies in general—198 responses (Questions 4, 13).

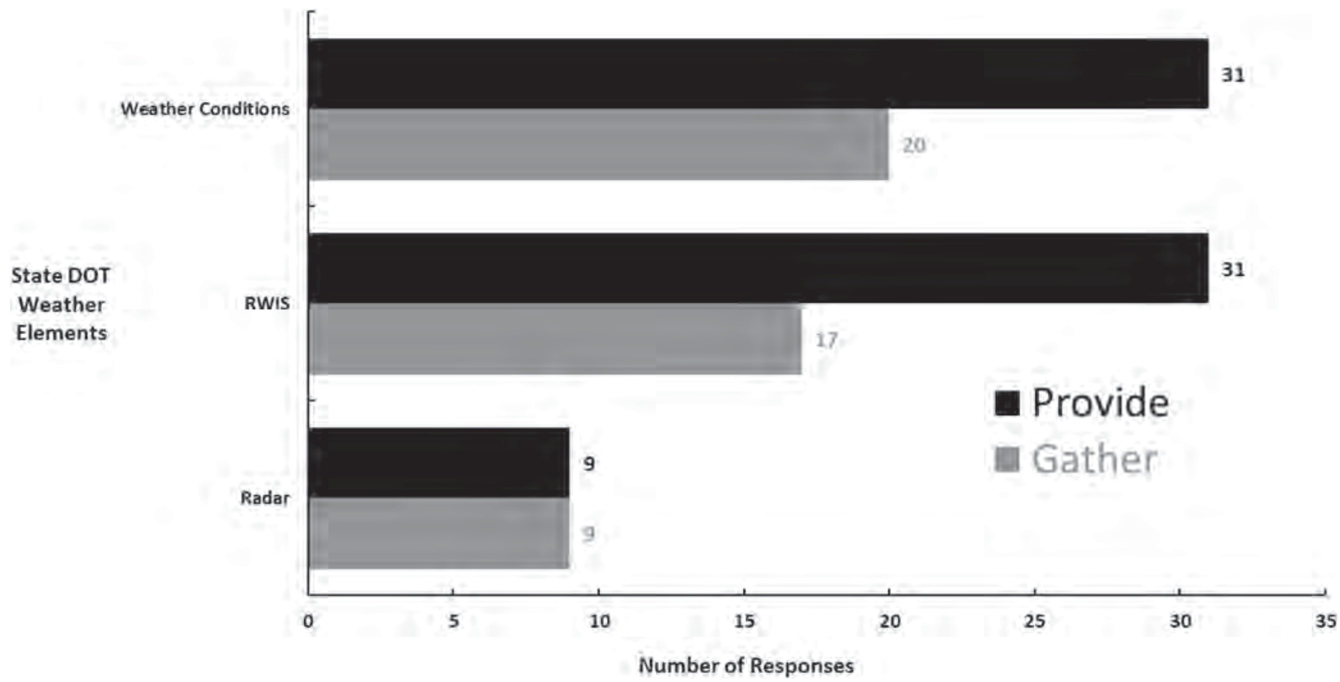


FIGURE D80 Weather elements shared by state DOTs—86 responses (Questions 4, 13).

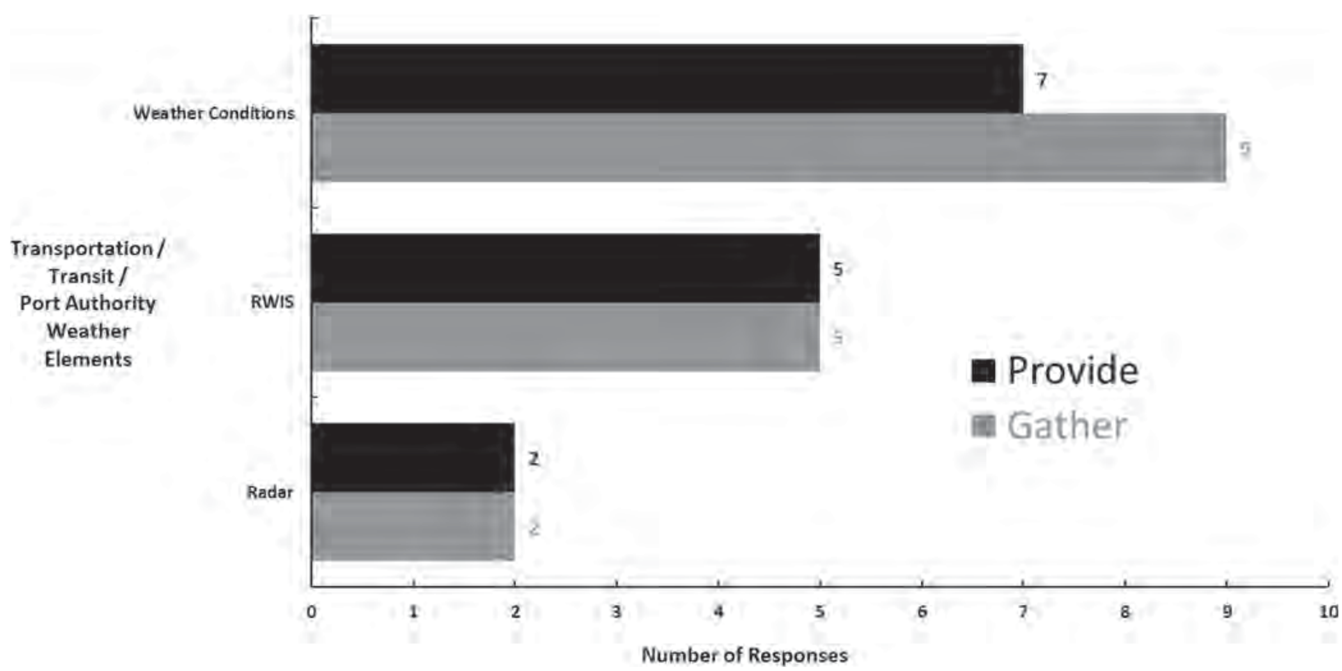


FIGURE D81 Weather elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

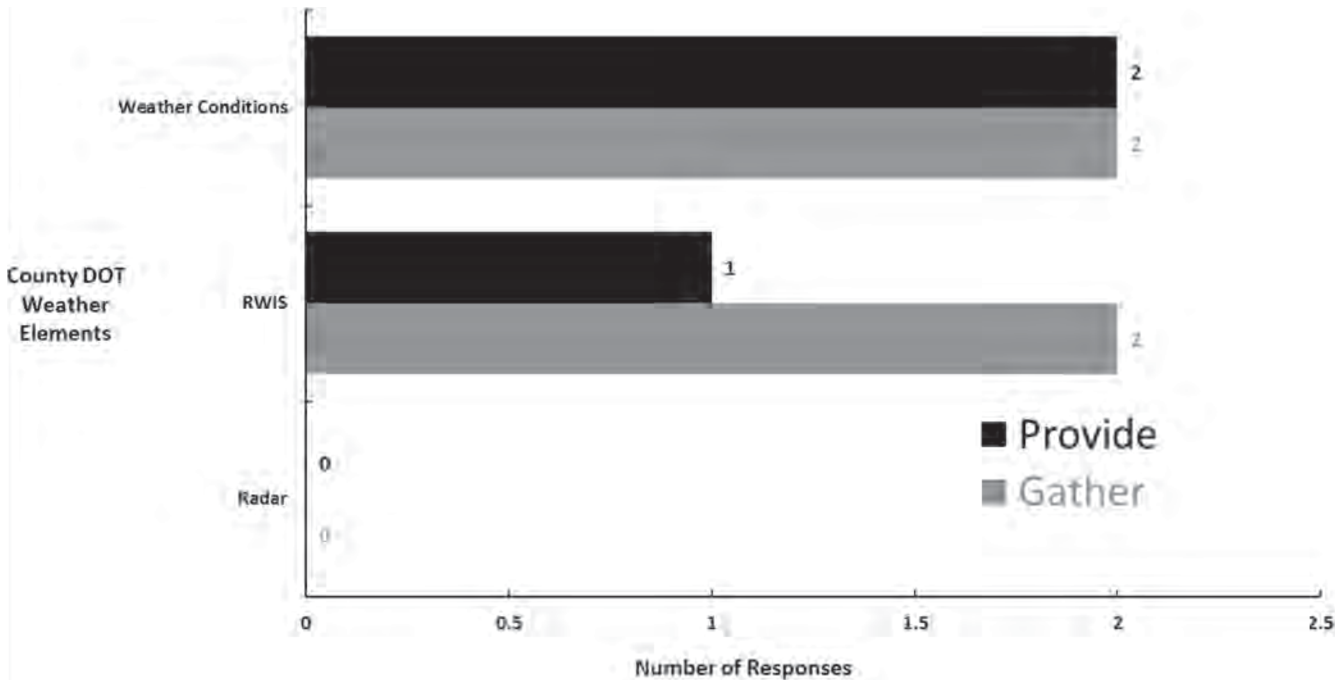


FIGURE D82 Weather elements shared by county DOTs—12 responses (Questions 4, 13).

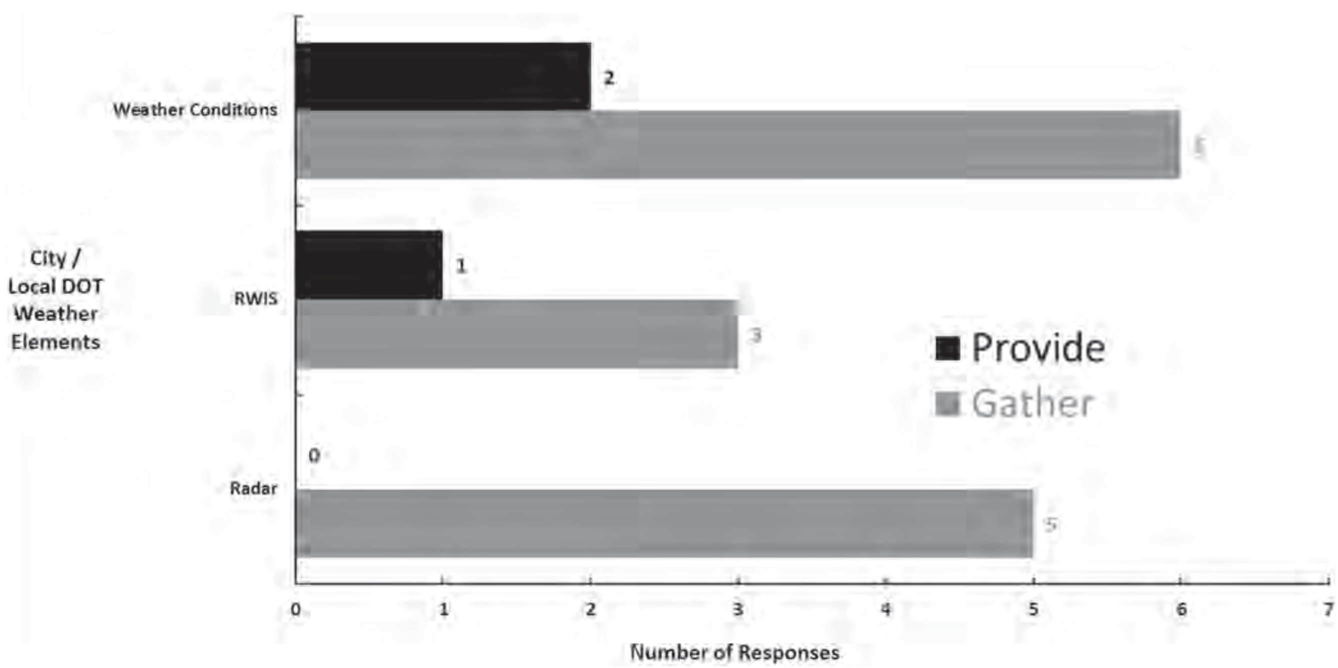


FIGURE D83 Weather elements shared by city and local DOTs—24 responses (Questions 4, 13).

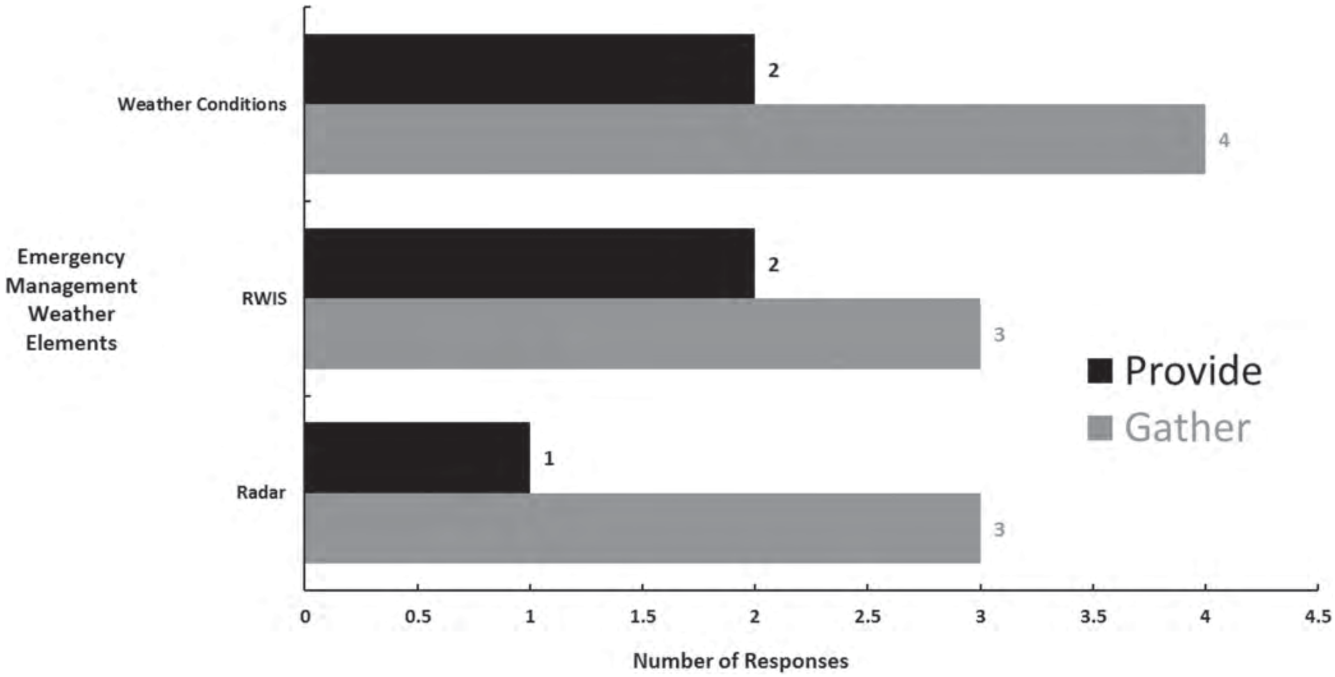


FIGURE D84 Weather elements shared by emergency management agencies—9 responses (Questions 4, 13).

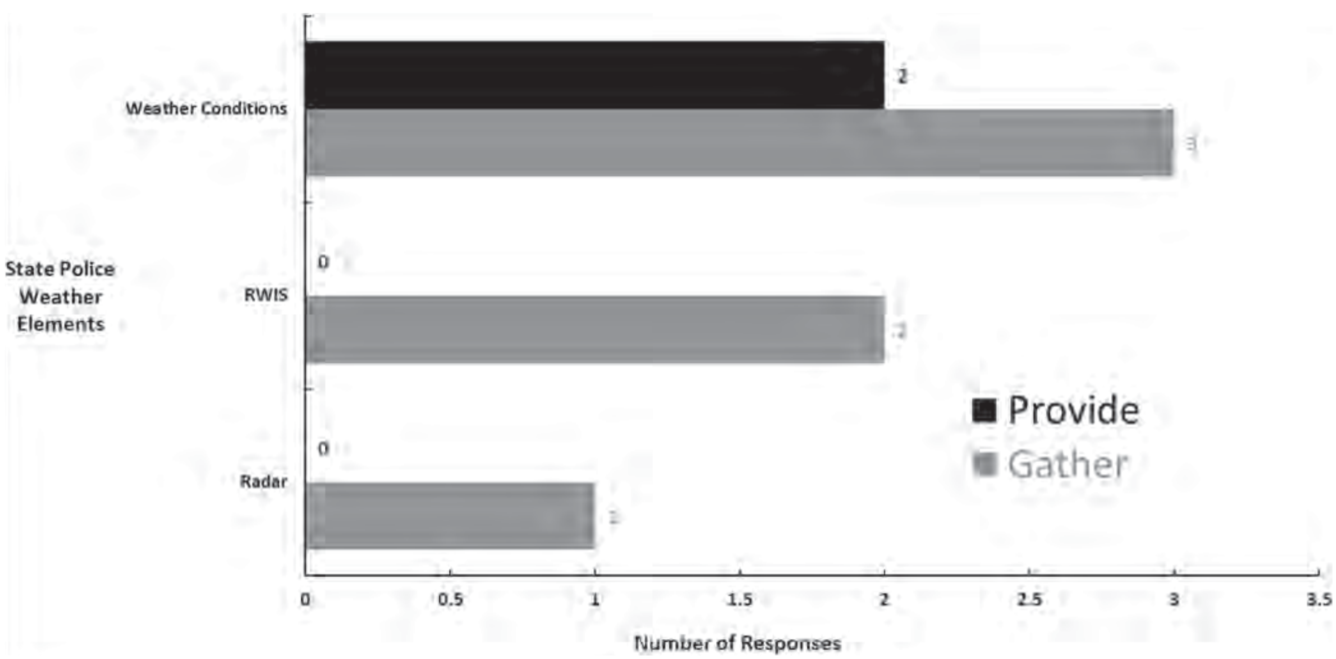


FIGURE D85 Weather elements shared by state police—4 responses (Questions 4, 13).

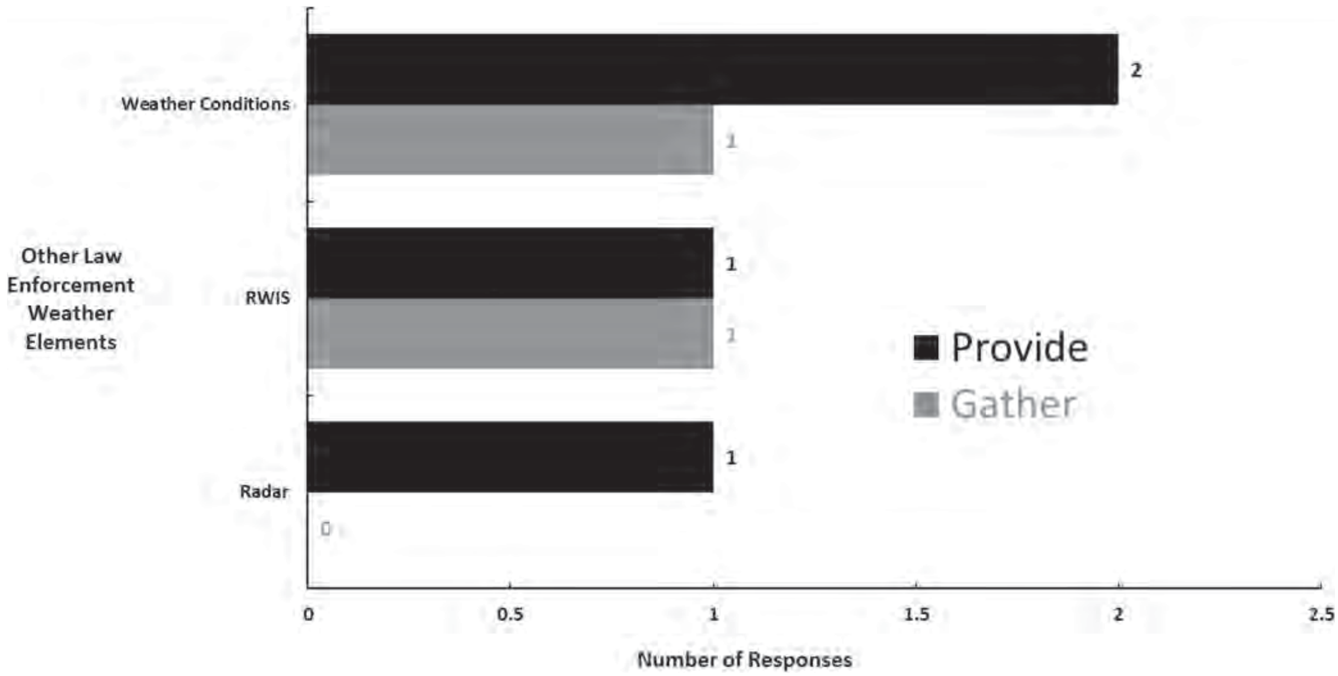


FIGURE D86 Weather elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

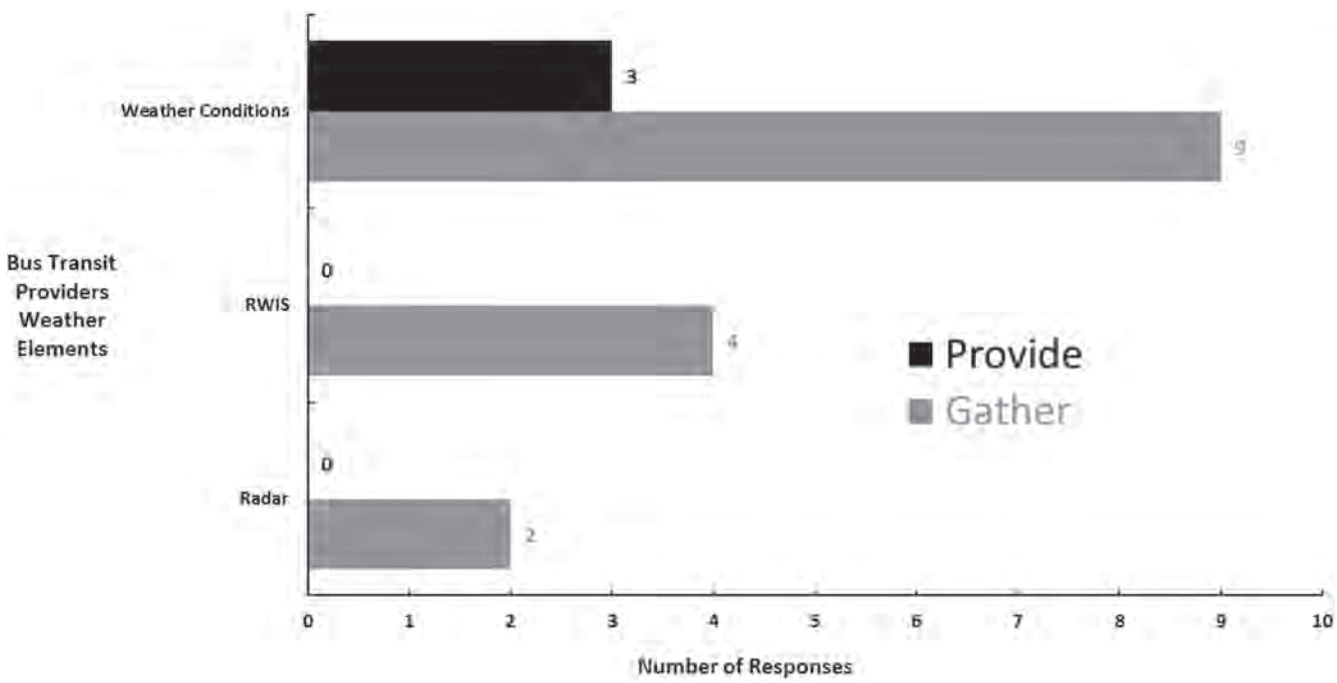


FIGURE D87 Weather elements shared by bus transit providers—40 responses (Questions 4, 13).

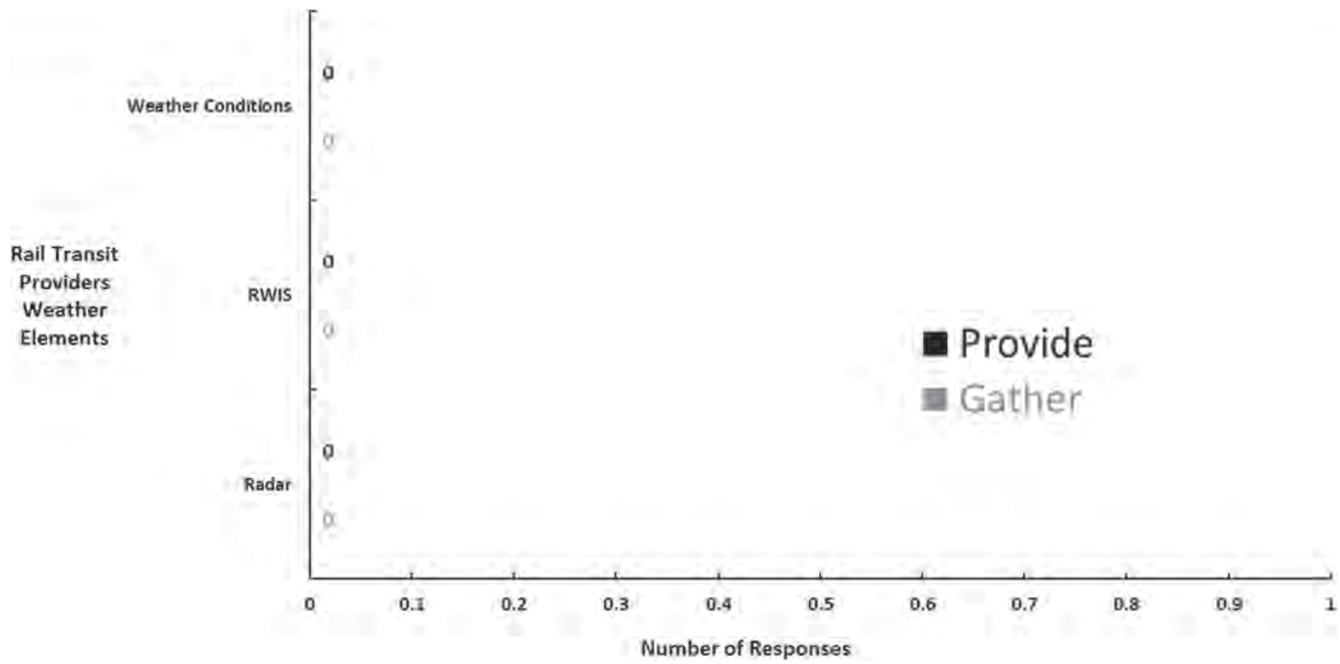


FIGURE D88 Weather elements shared by rail transit providers—3 responses (Questions 4, 13).

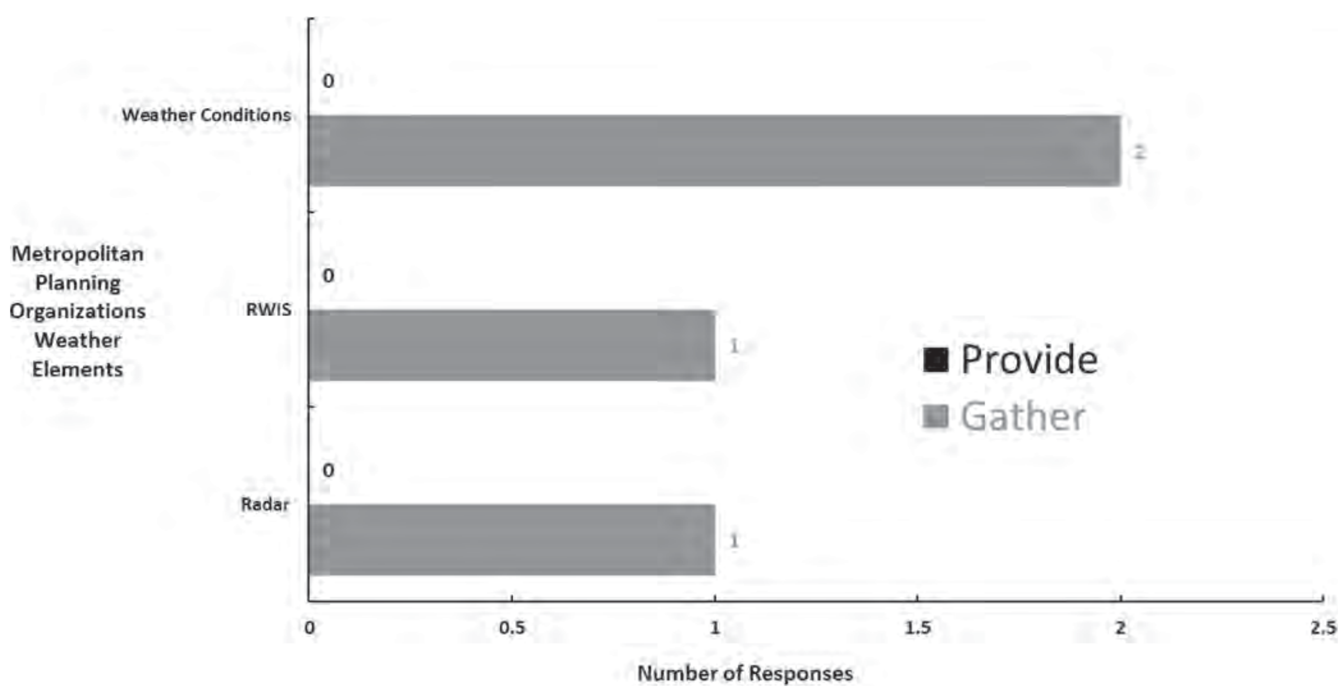


FIGURE D89 Weather elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

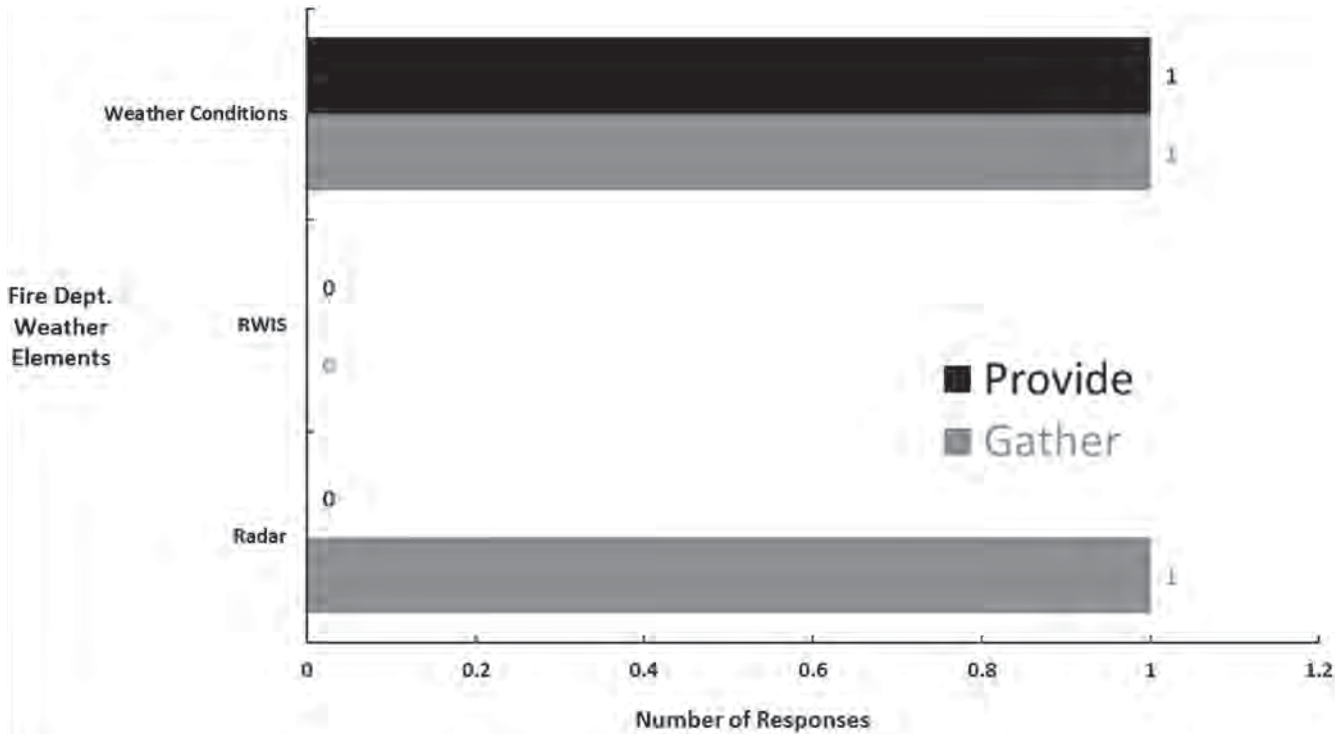


FIGURE D90 Weather elements shared by fire departments—3 responses (Questions 4, 13).

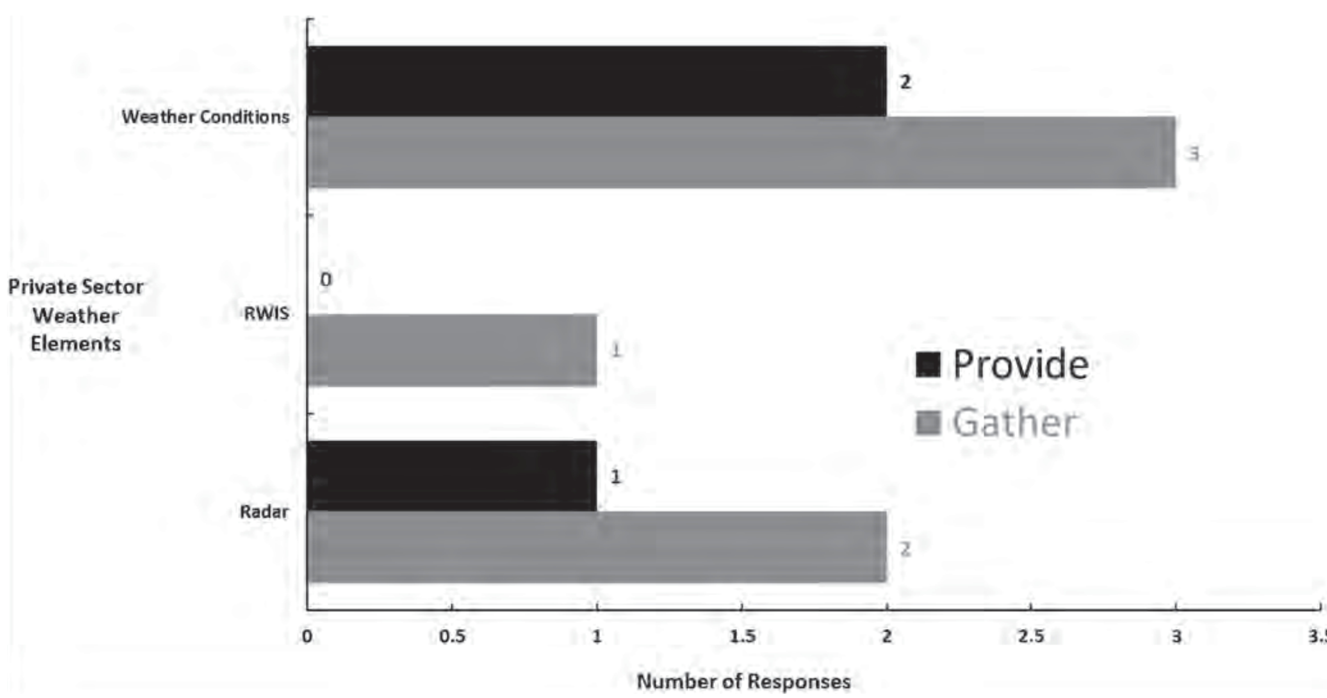


FIGURE D91 Weather elements shared by private sector entities—5 responses (Questions 4, 13).

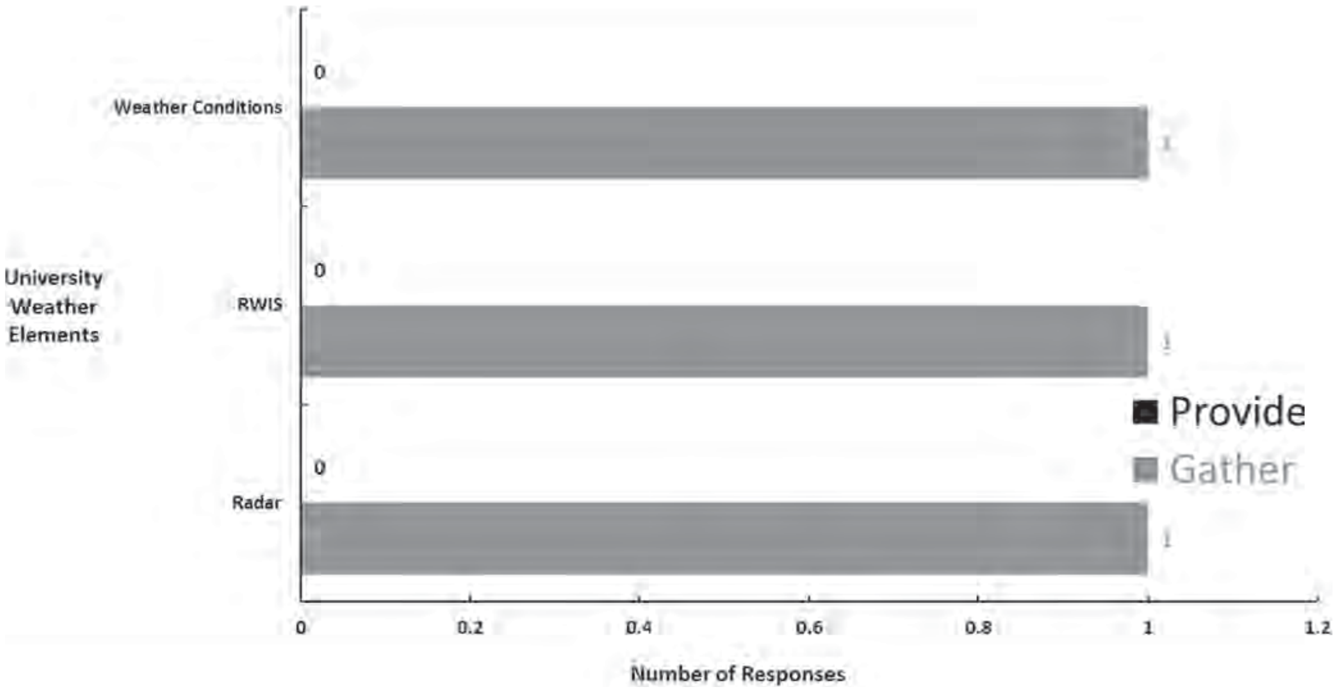


FIGURE D92 Weather elements shared by universities—4 responses (Questions 4, 13).

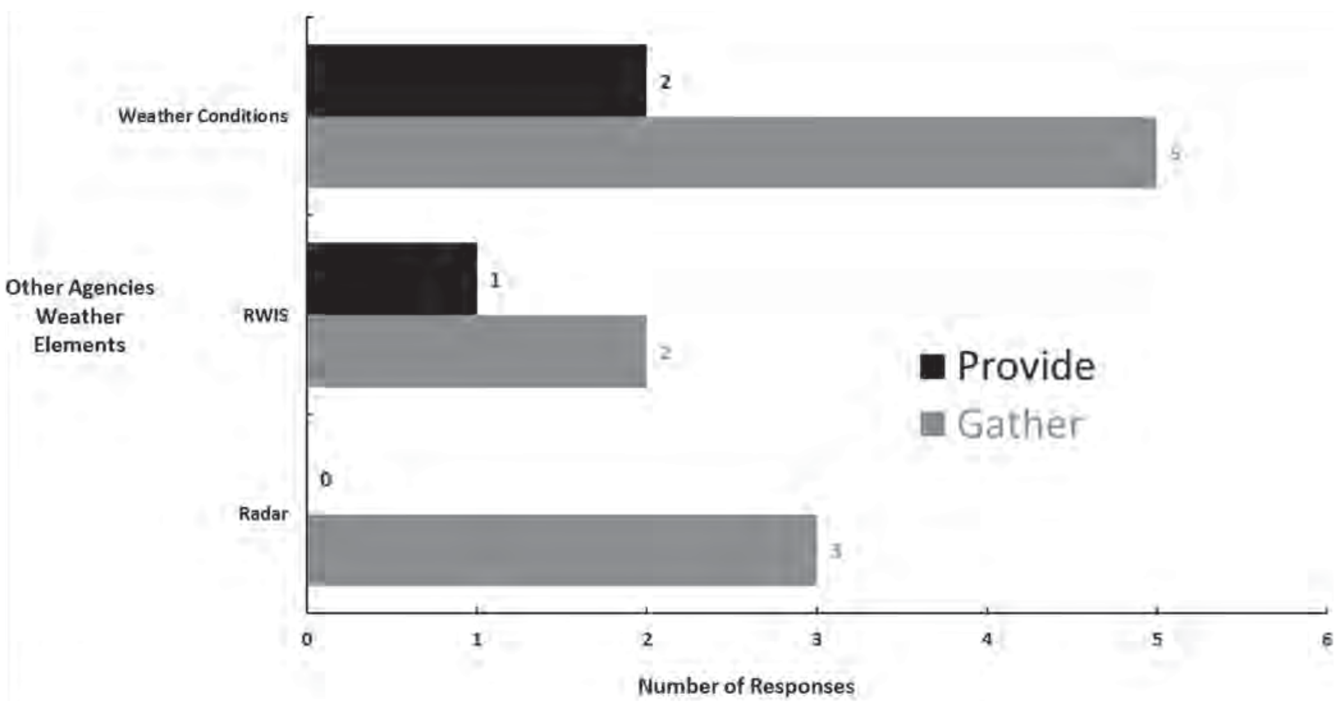


FIGURE D93 Weather elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING COMPUTER-AIDED DISPATCH DATA (D94–D108)

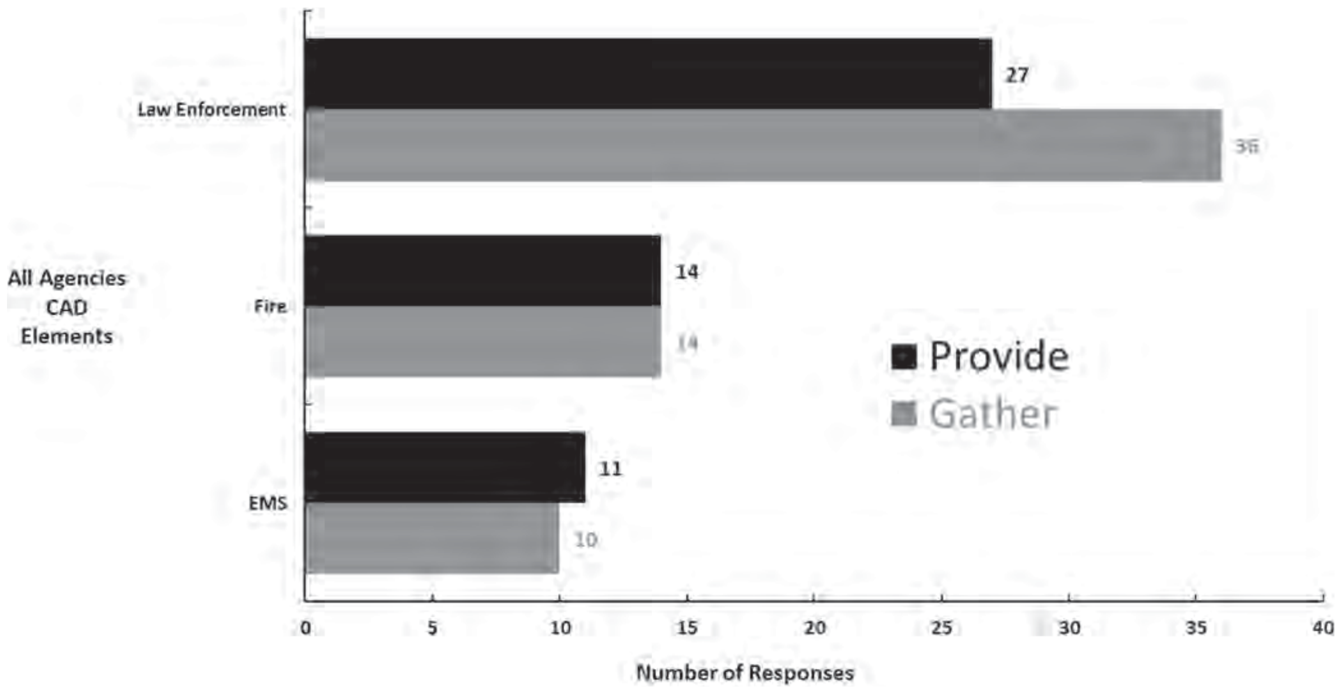


FIGURE D94 CAD elements shared by agencies in general—198 responses (Questions 4, 13).

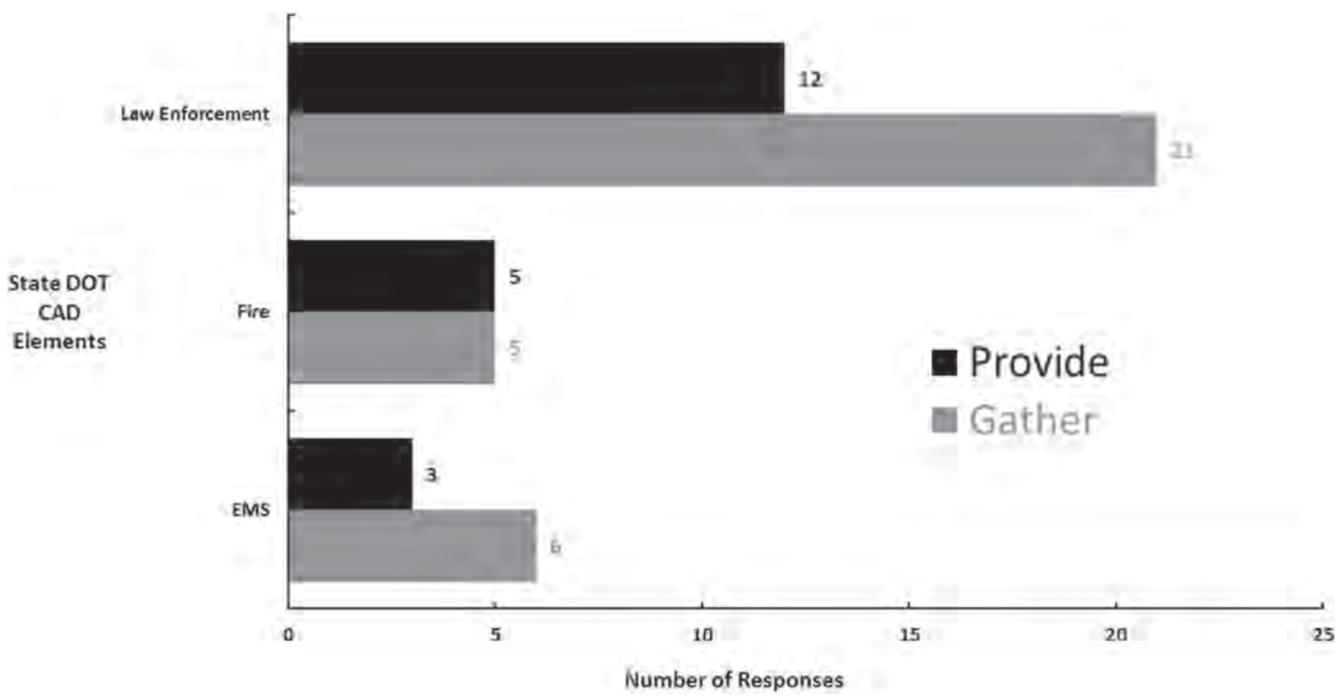


FIGURE D95 CAD elements shared by state DOTs—86 responses (Questions 4, 13).

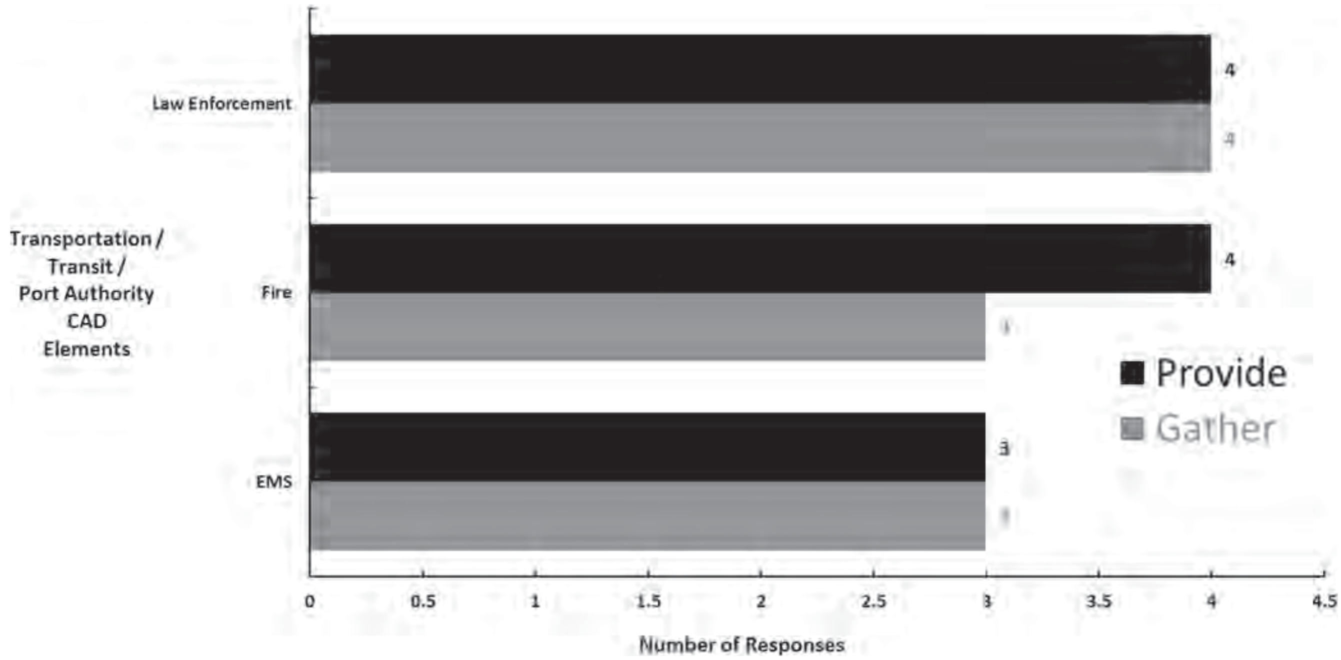


FIGURE D96 CAD elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

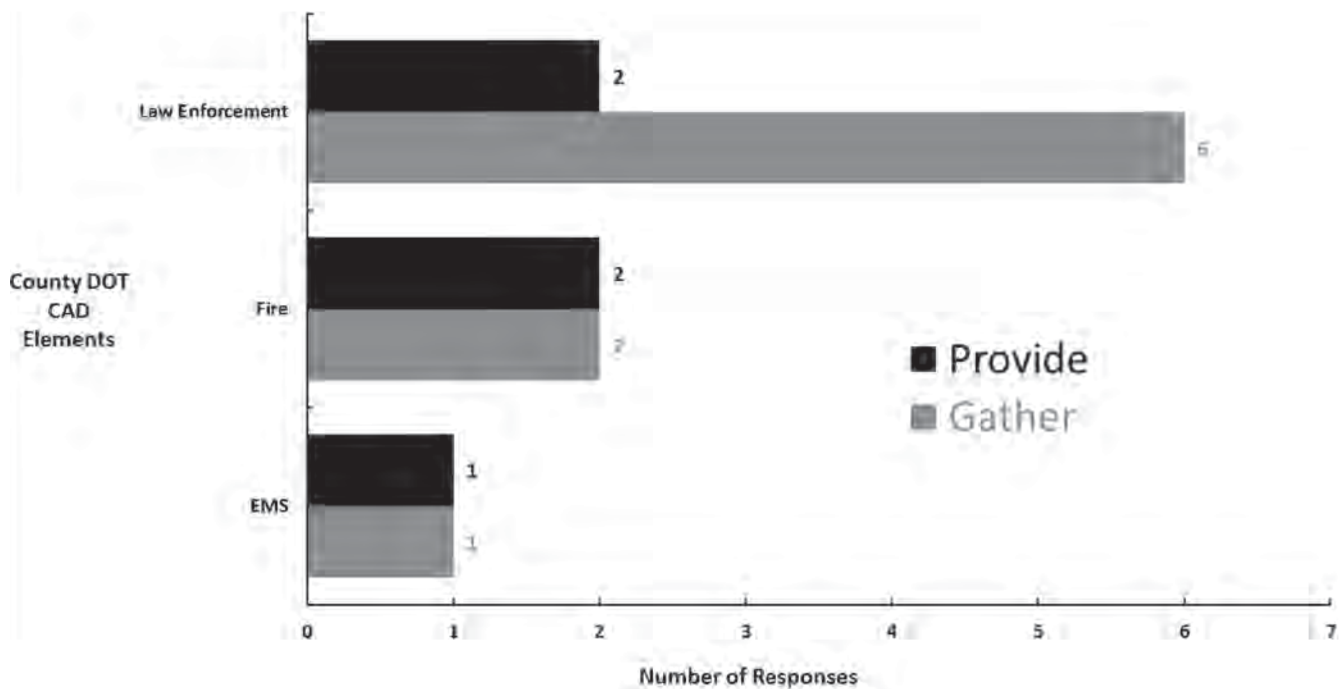


FIGURE D97 CAD elements shared by county DOTs—12 responses (Questions 4, 13).

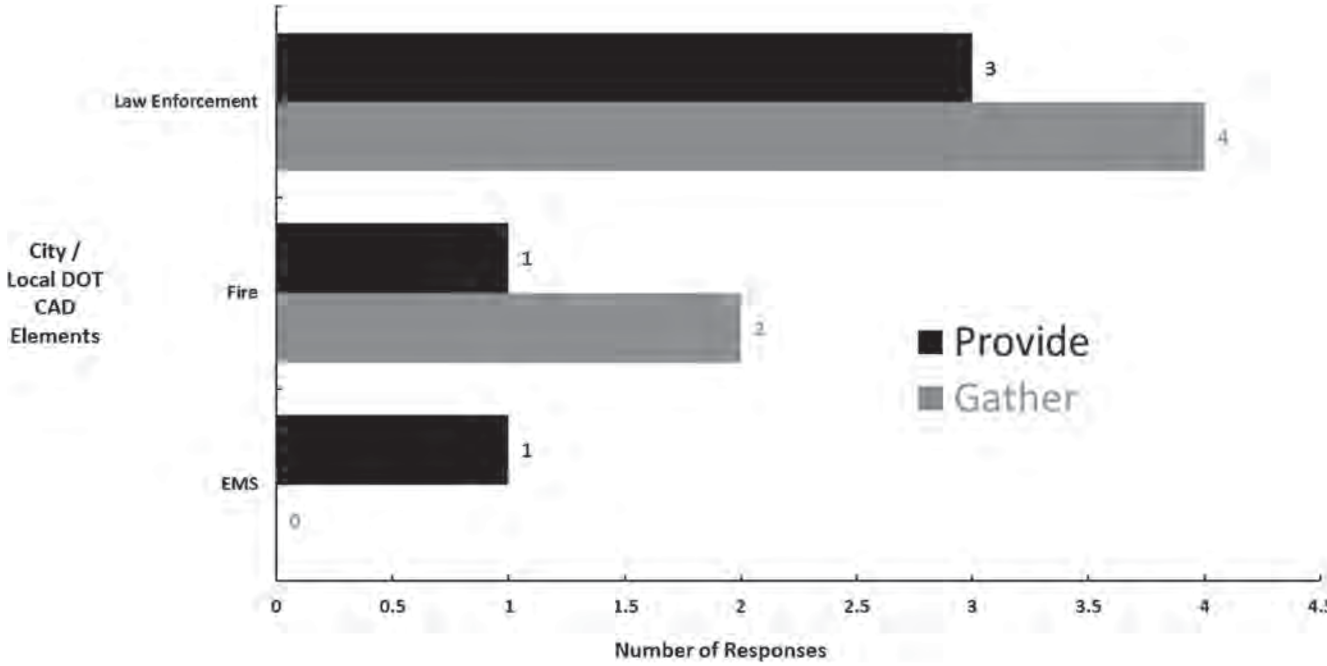


FIGURE D98 CAD elements shared by city and local DOTs—24 responses (Questions 4, 13).

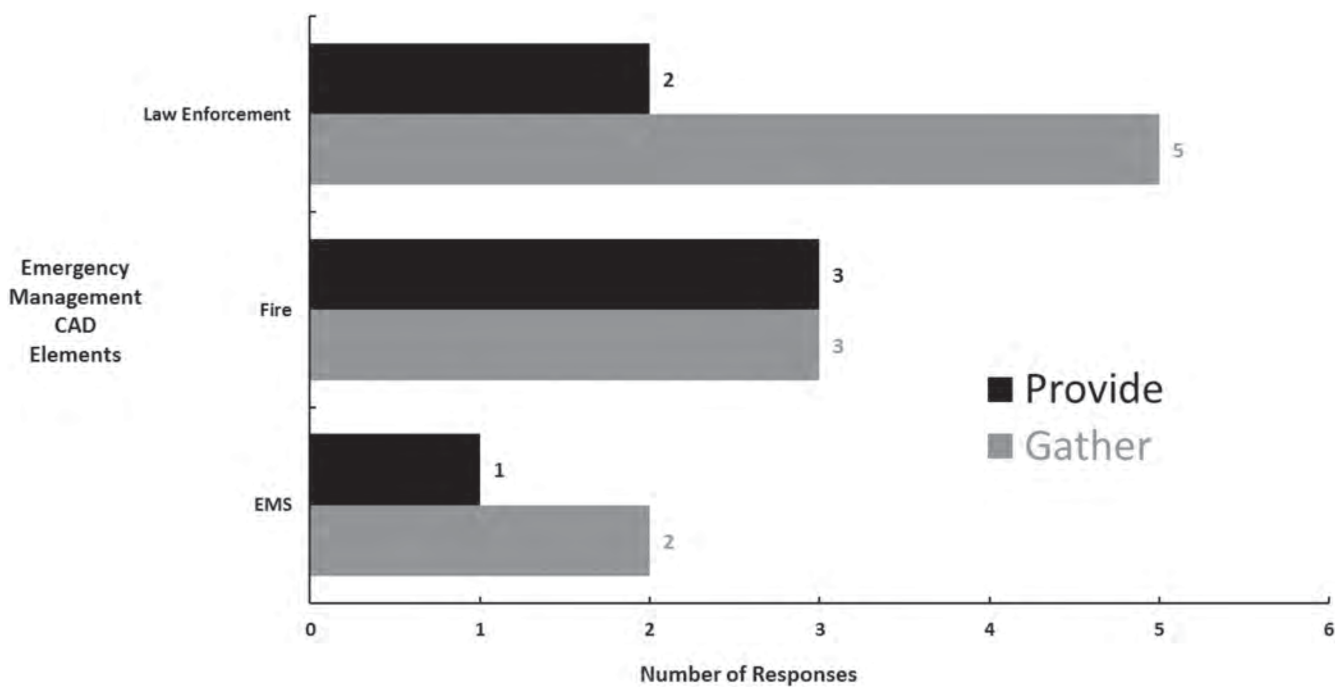


FIGURE D99 CAD elements shared by emergency management agencies—9 responses (Questions 4, 13).

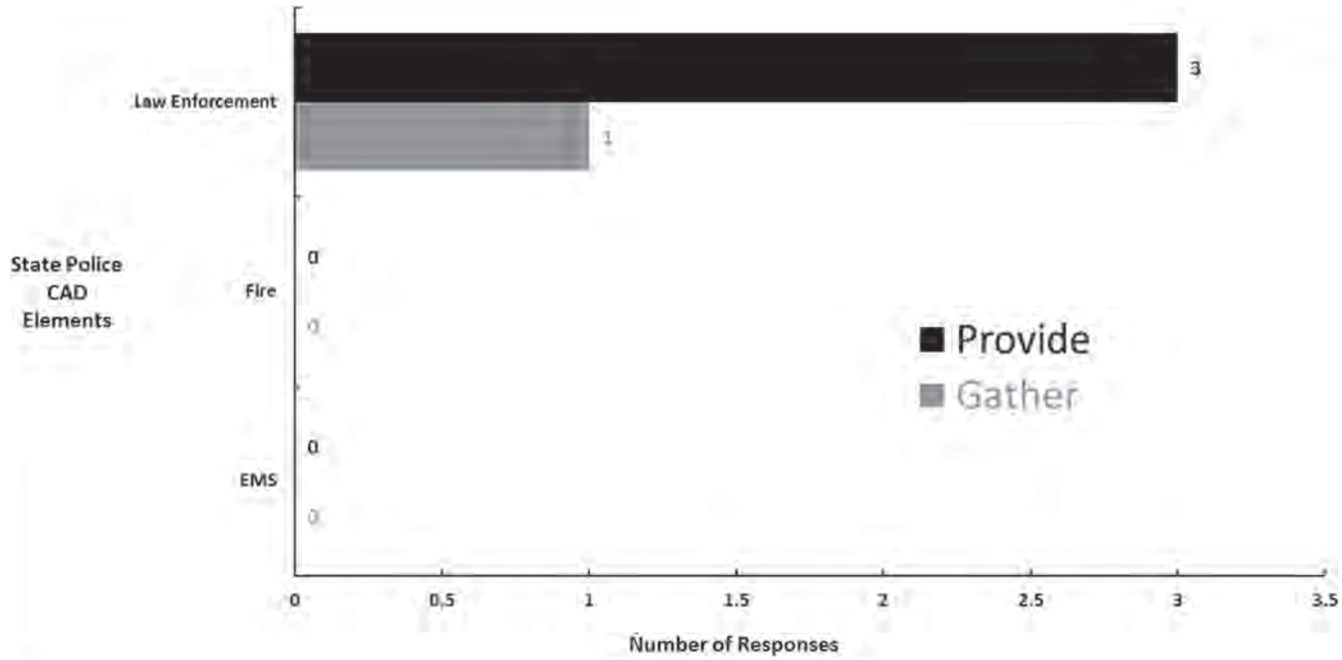


FIGURE D100 CAD elements shared by state police—4 responses (Questions 4, 13).

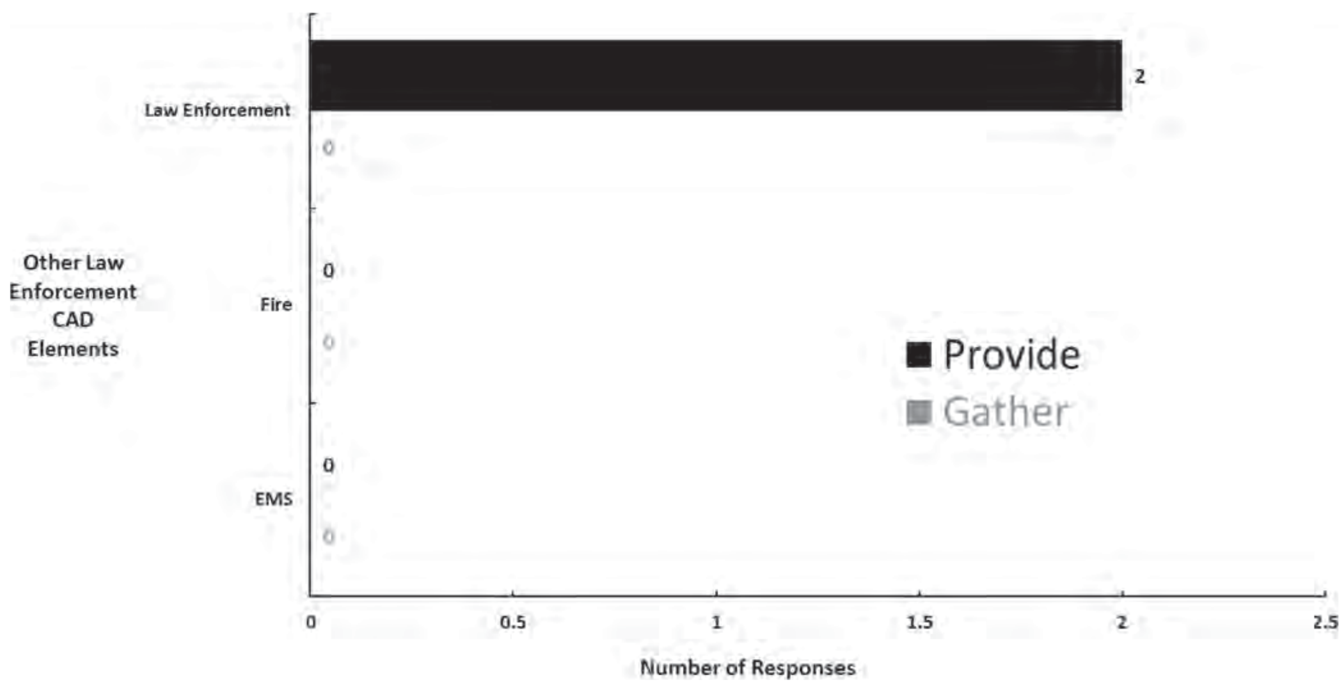


FIGURE D101 CAD elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

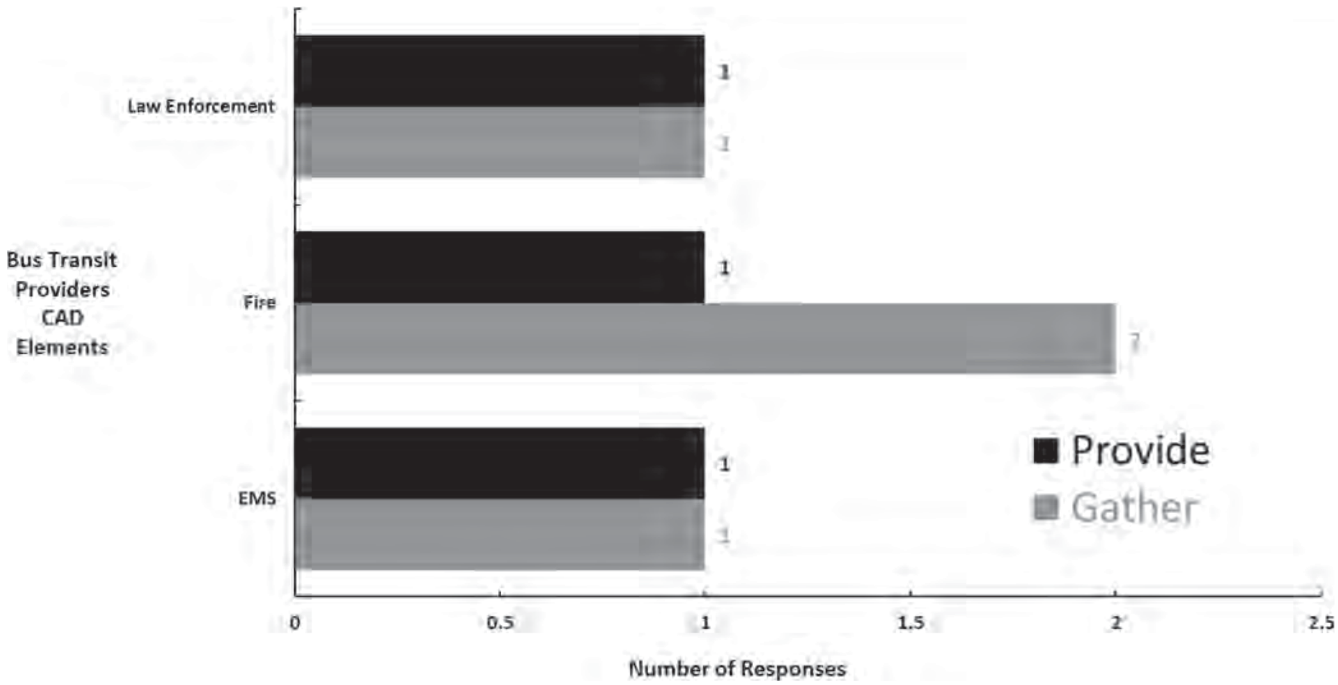


FIGURE D102 CAD elements shared by bus transit providers—40 responses (Questions 4, 13).

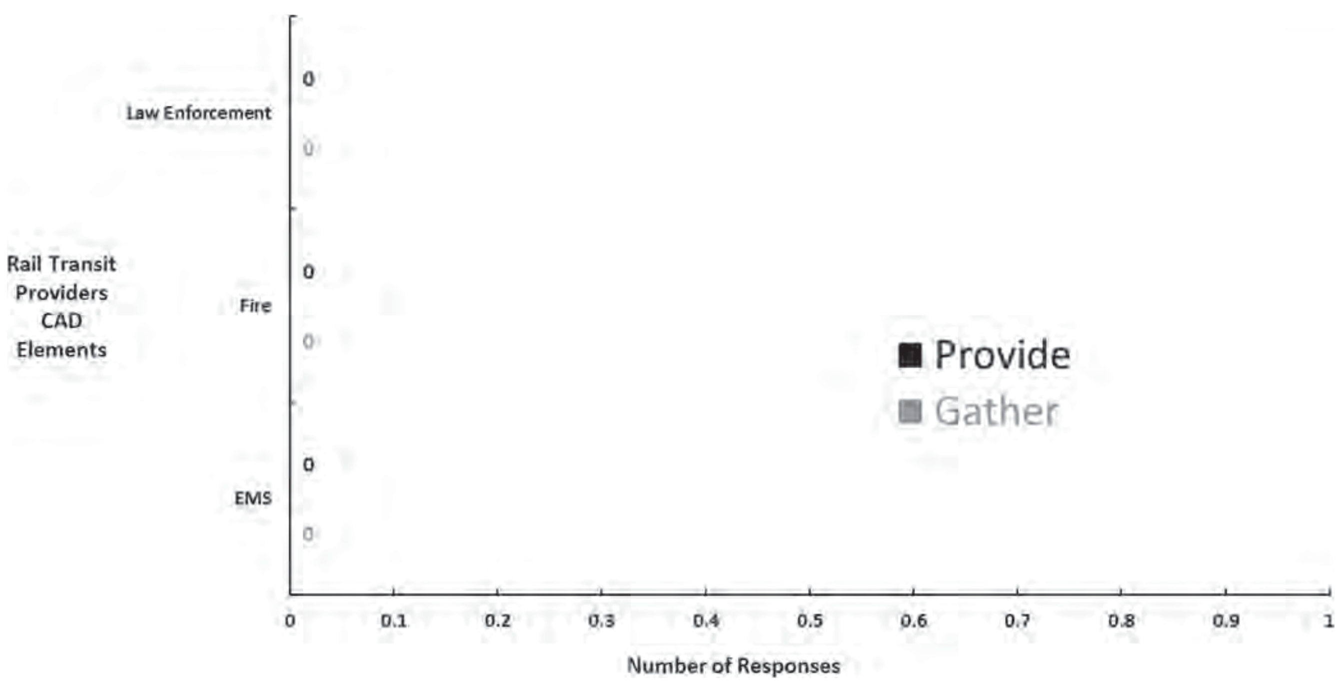


FIGURE D103 CAD elements shared by rail transit providers—3 responses (Questions 4, 13).

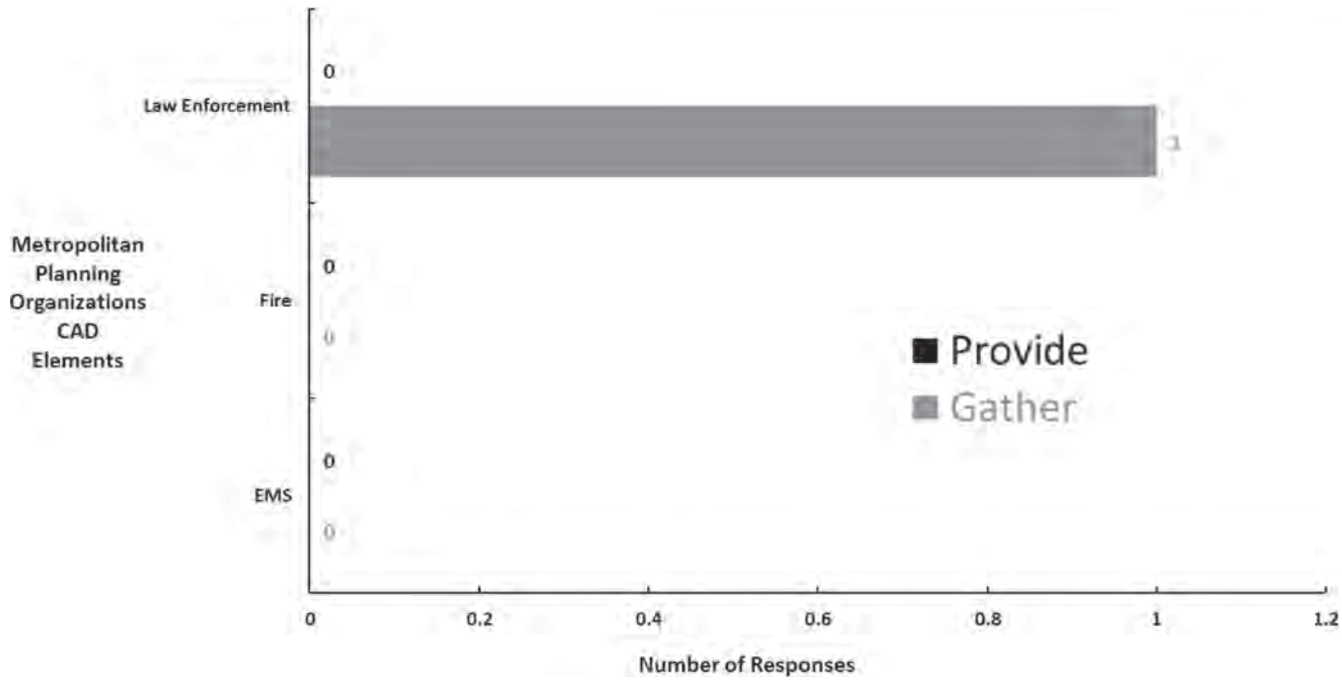


FIGURE D104 CAD elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

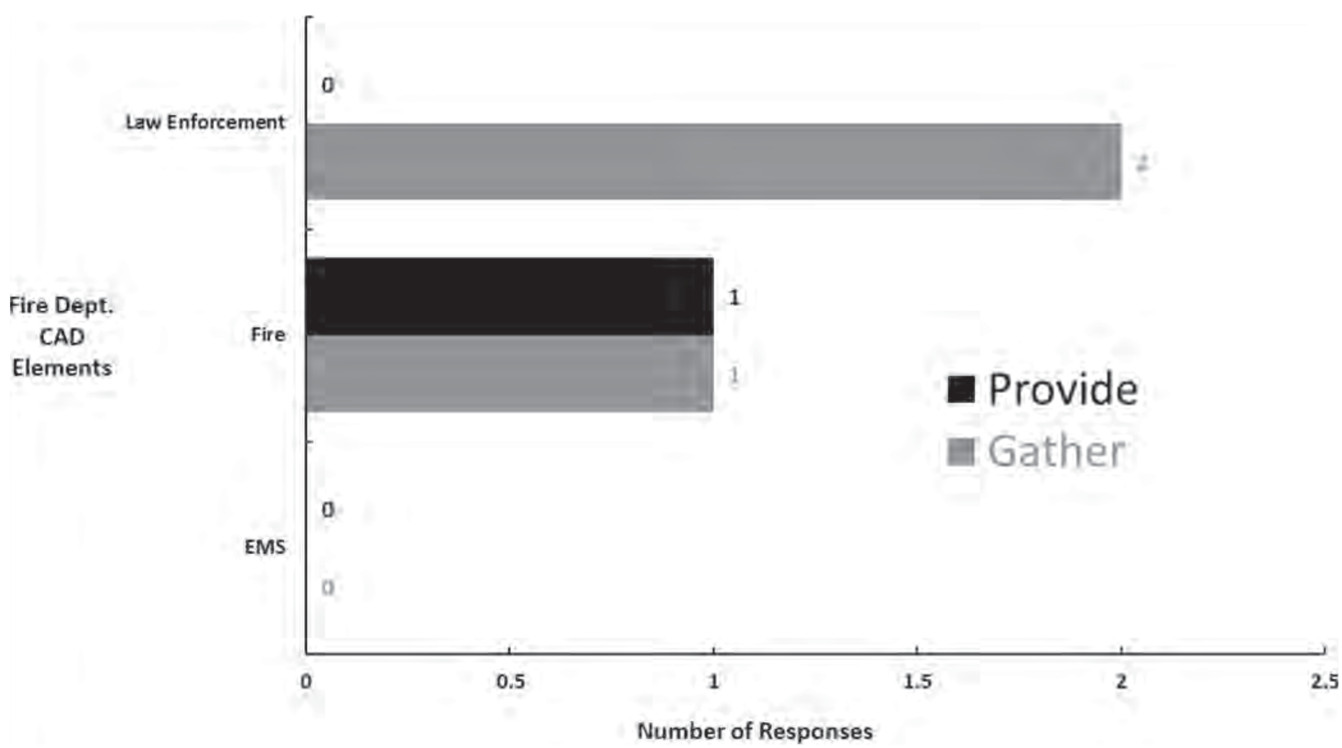


FIGURE D105 CAD elements shared by fire departments—3 responses (Questions 4, 13).

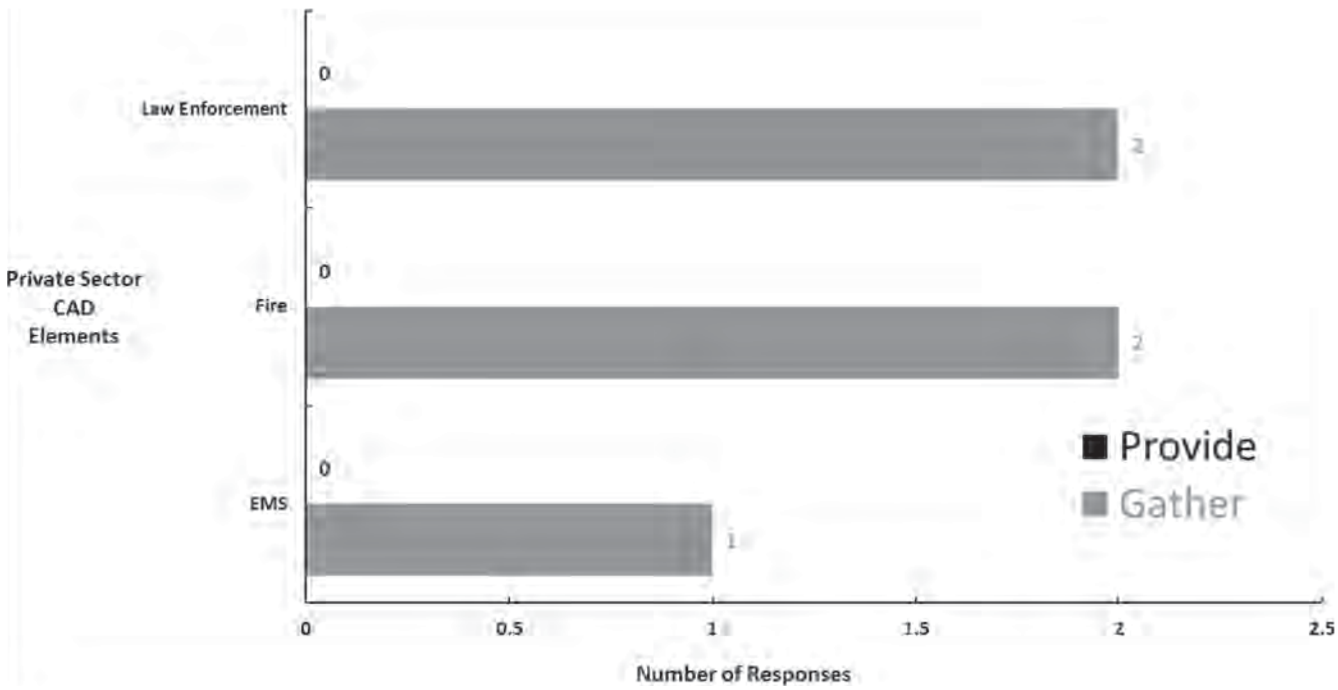


FIGURE D106 CAD elements shared by private sector entities—5 responses (Questions 4, 13).

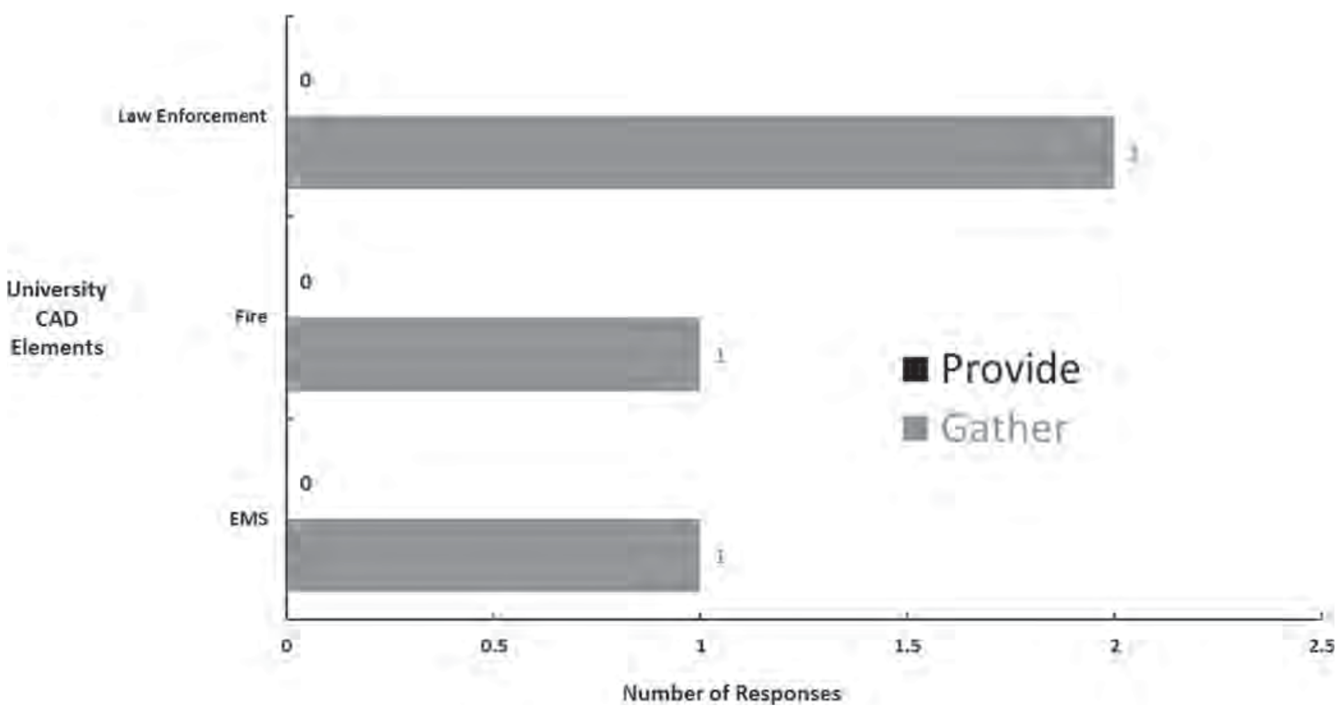


FIGURE D107 CAD elements shared by universities—4 responses (Questions 4, 13).

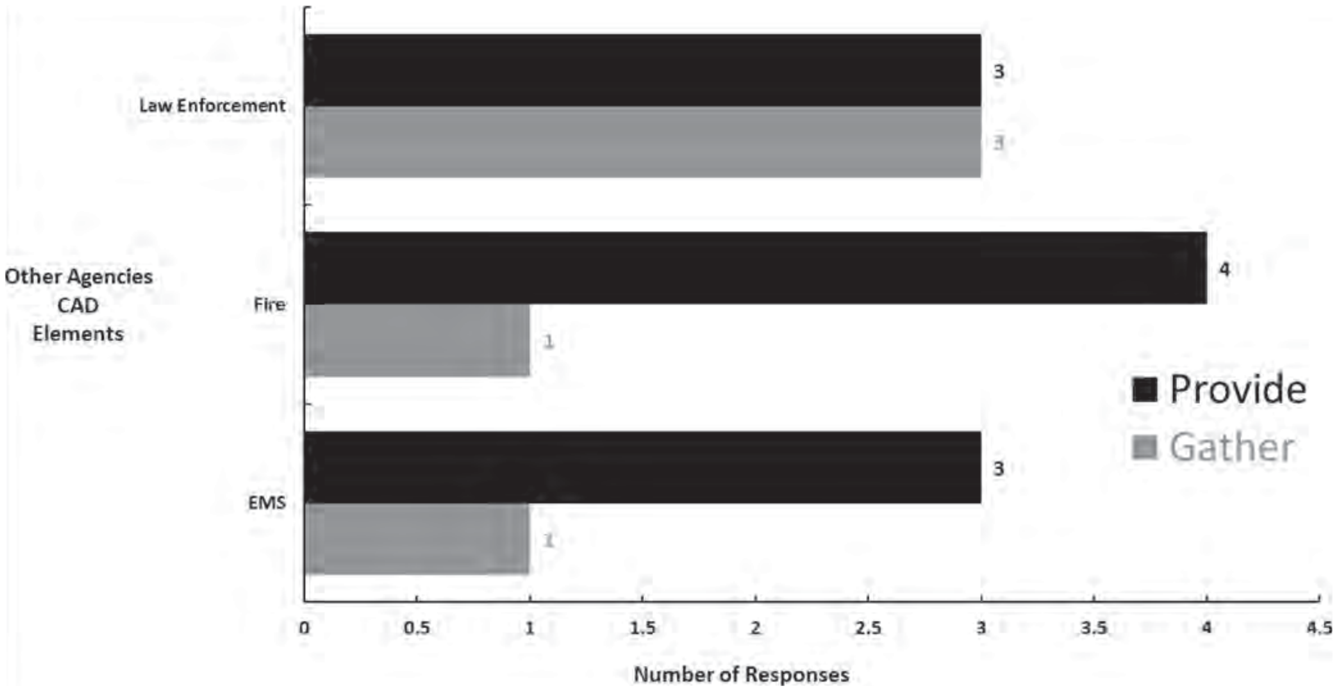


FIGURE D108 CAD elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING SIGNAL SYSTEM DATA (D109–D123)

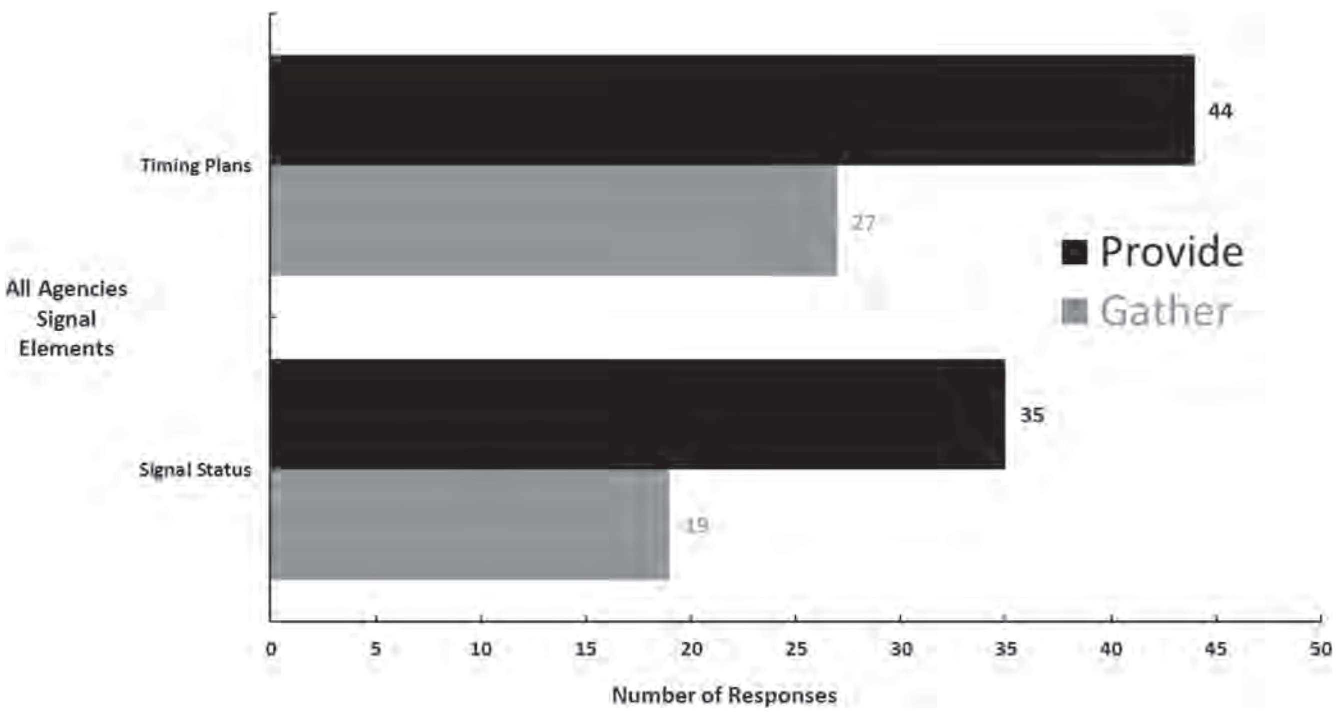


FIGURE D109 Signal elements shared by agencies in general—198 responses (Questions 4, 13).

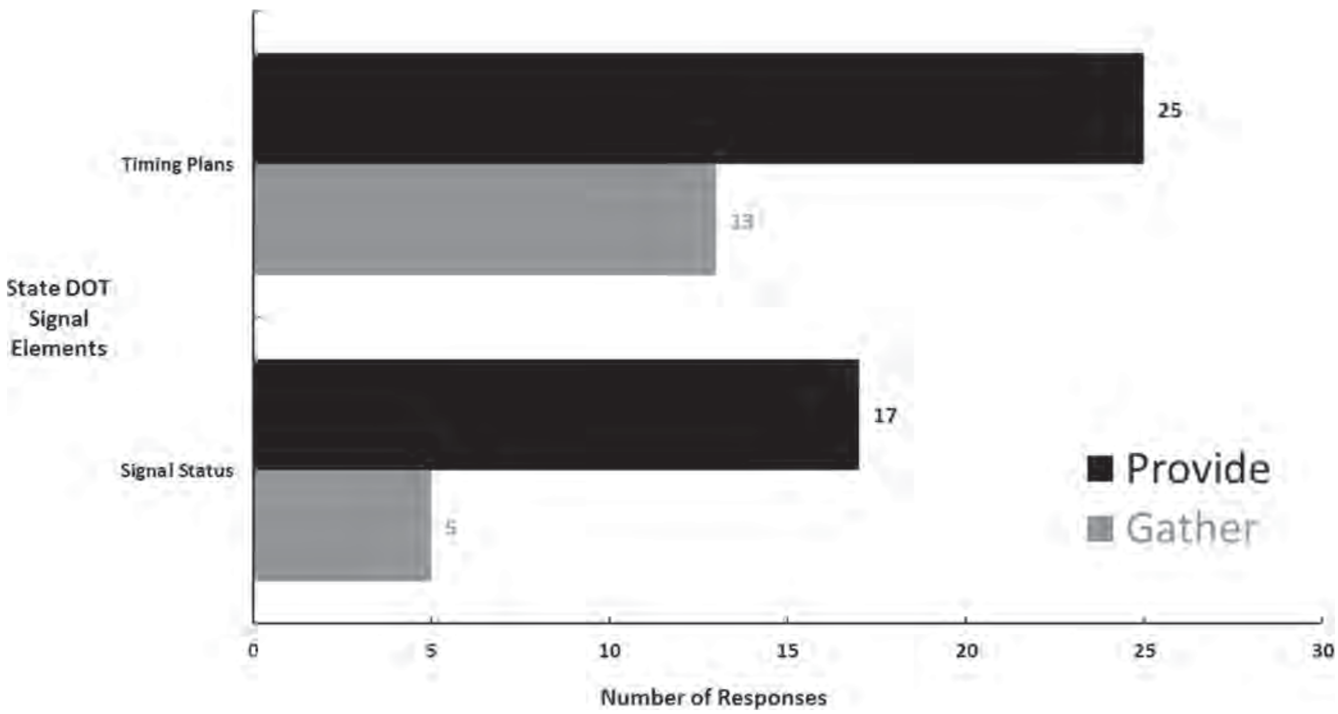


FIGURE D110 Signal elements shared by state DOTs—86 responses (Questions 4, 13).

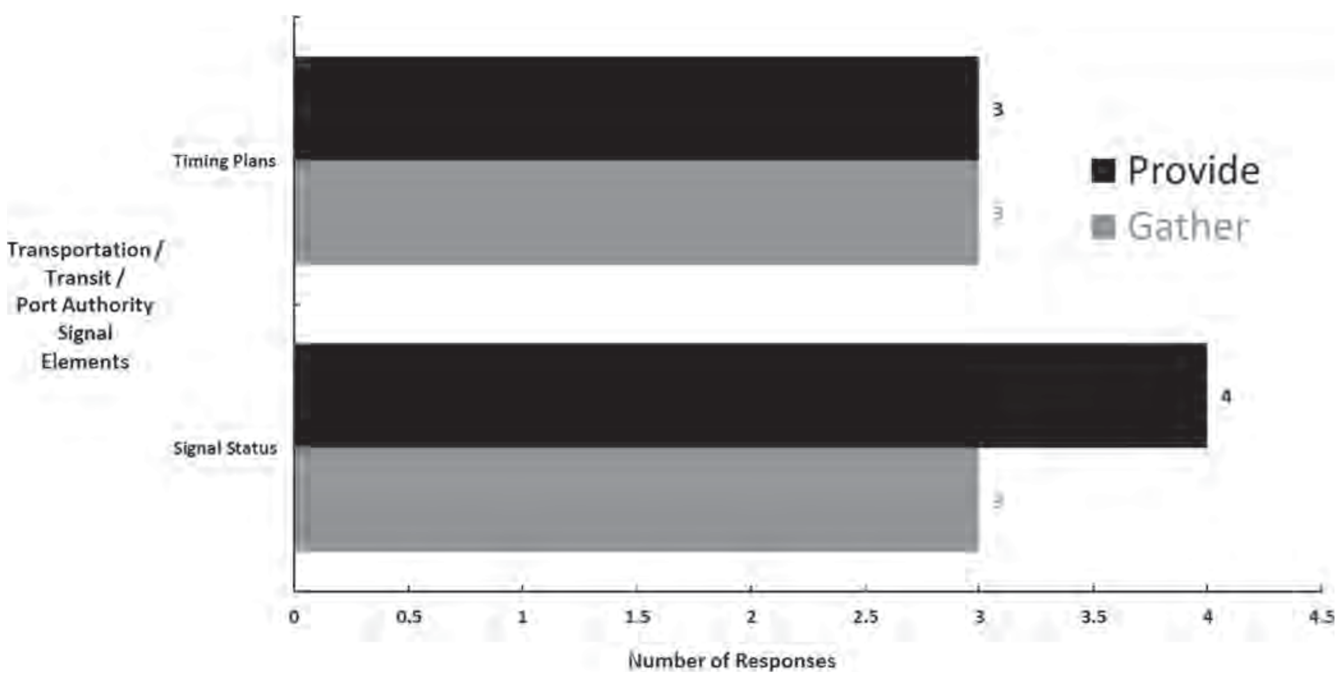


FIGURE D111 Signal elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

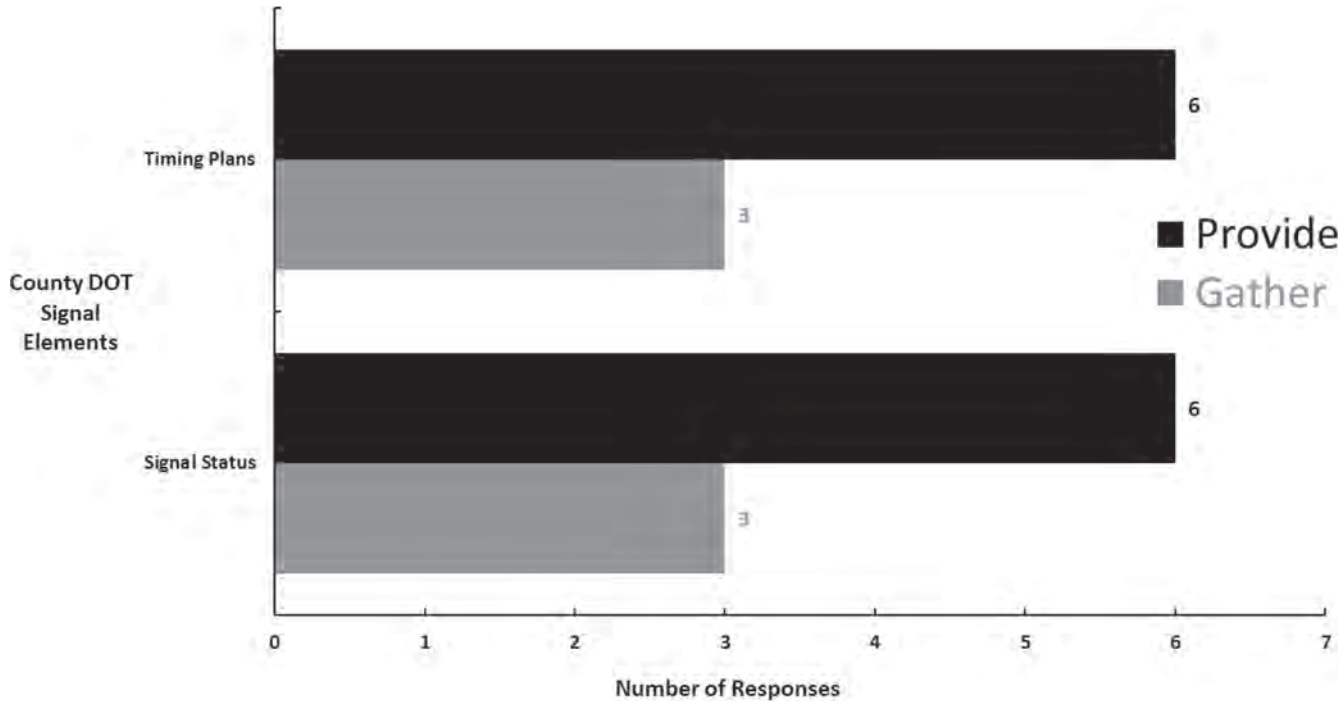


FIGURE D112 Signal elements shared by county DOTs—12 responses (Questions 4, 13).

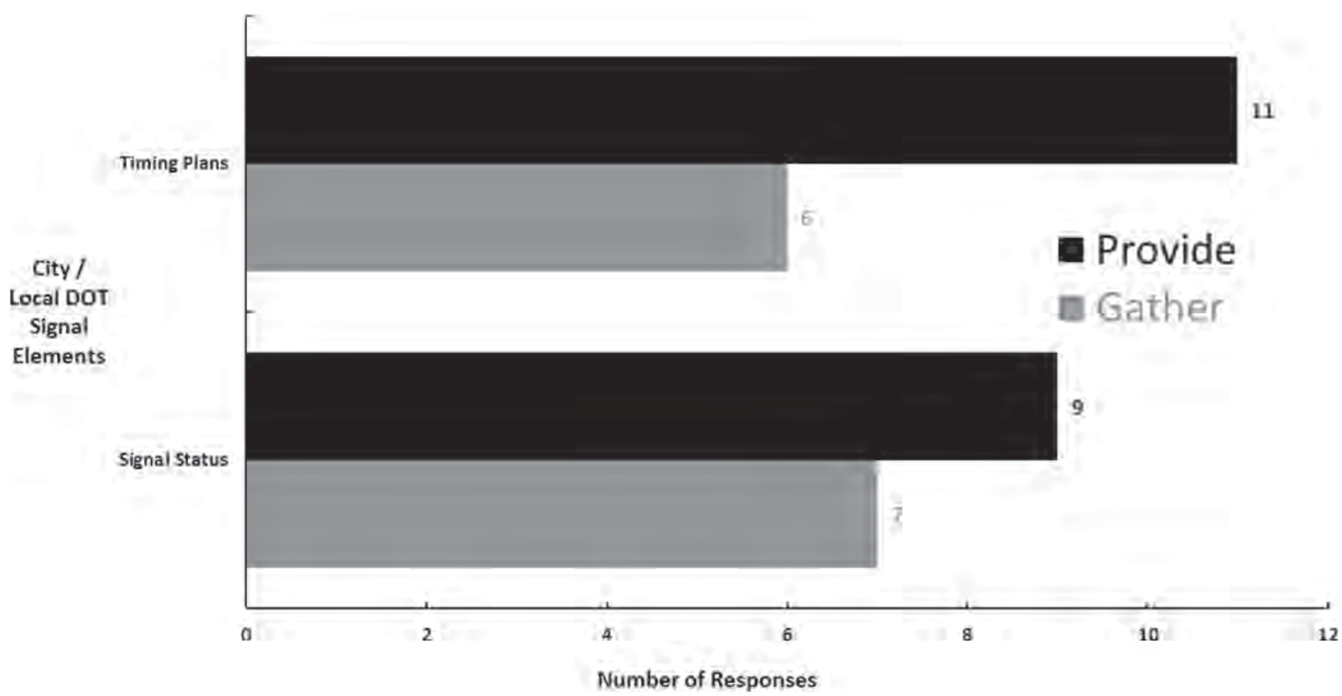


FIGURE D113 Signal elements shared by city and local DOTs—24 responses (Questions 4, 13).

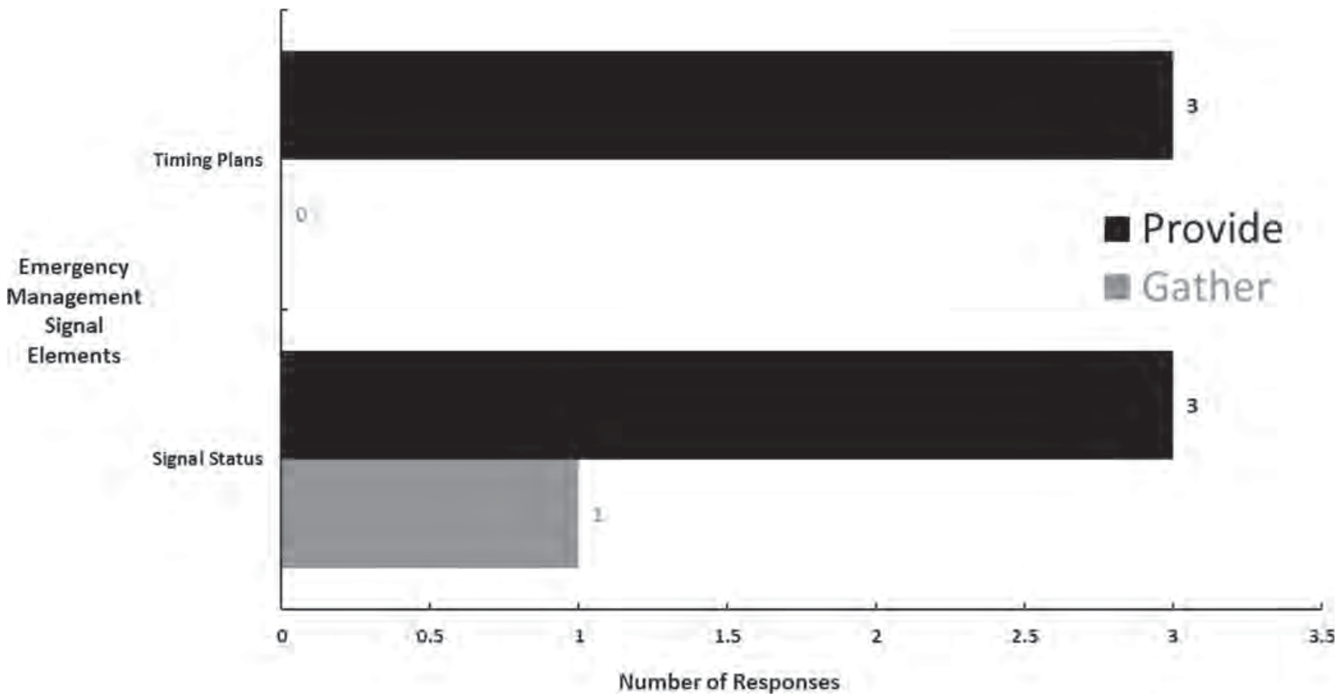


FIGURE D114 Signal elements shared by emergency management agencies—9 responses (Questions 4, 13).

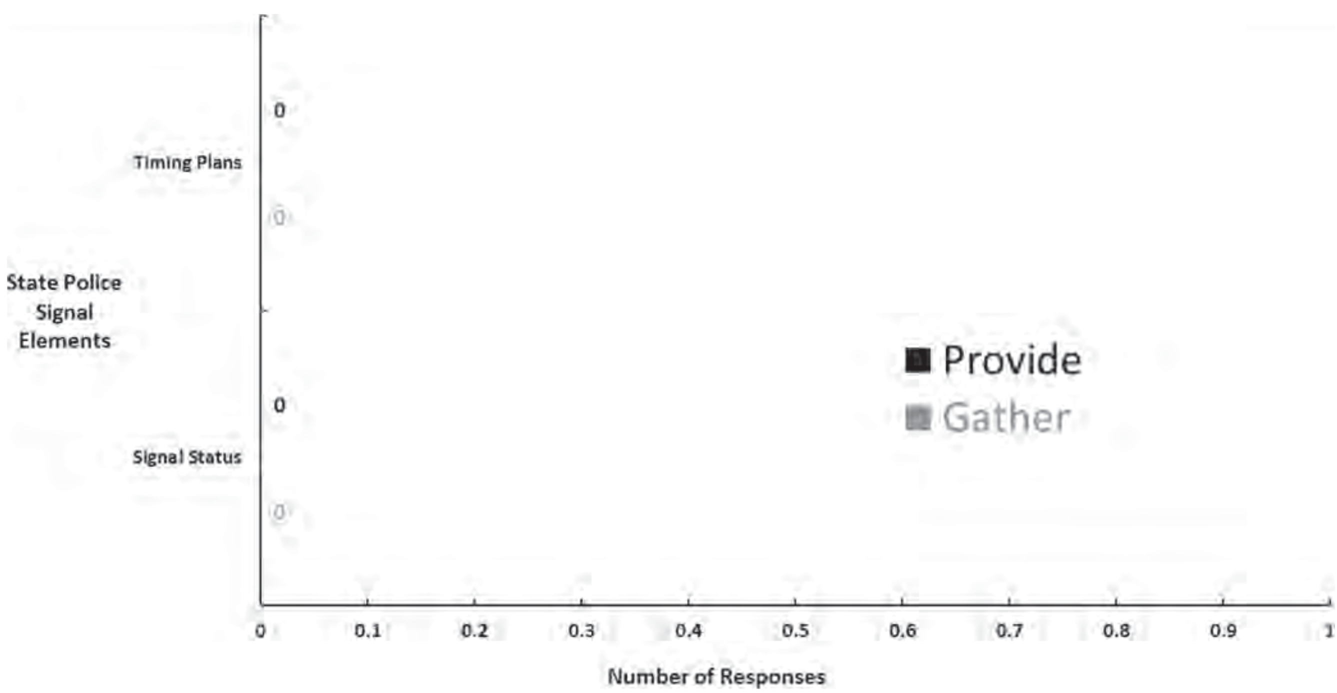


FIGURE D115 Signal elements shared by state police—4 responses (Questions 4, 13).

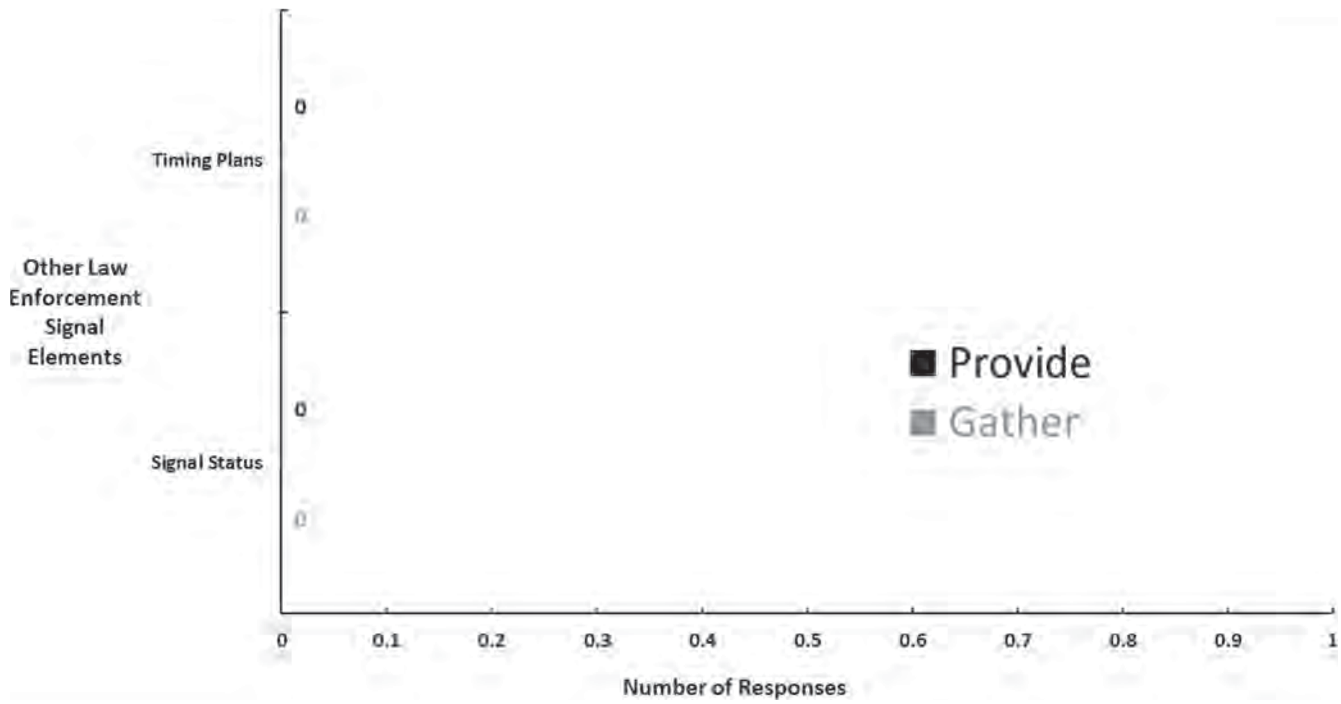


FIGURE D116 Signal elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

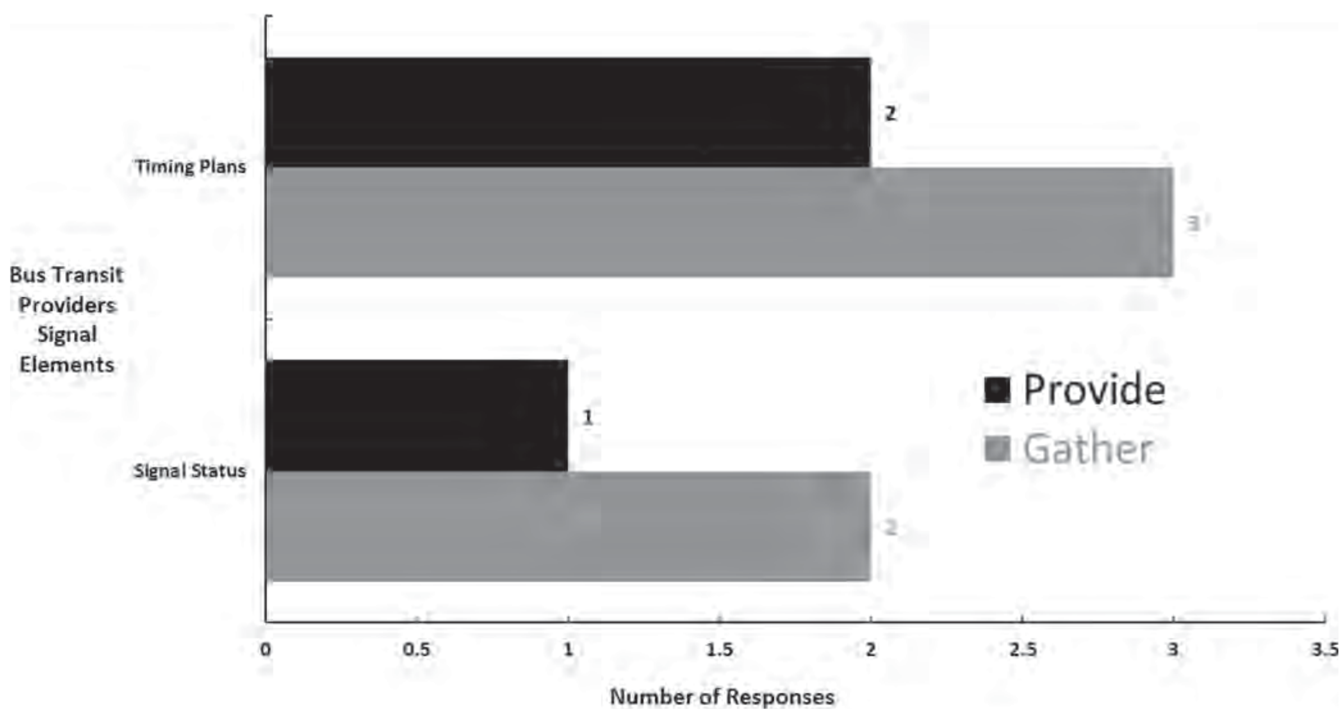


FIGURE D117 Signal elements shared by bus transit providers—40 responses (Questions 4, 13).

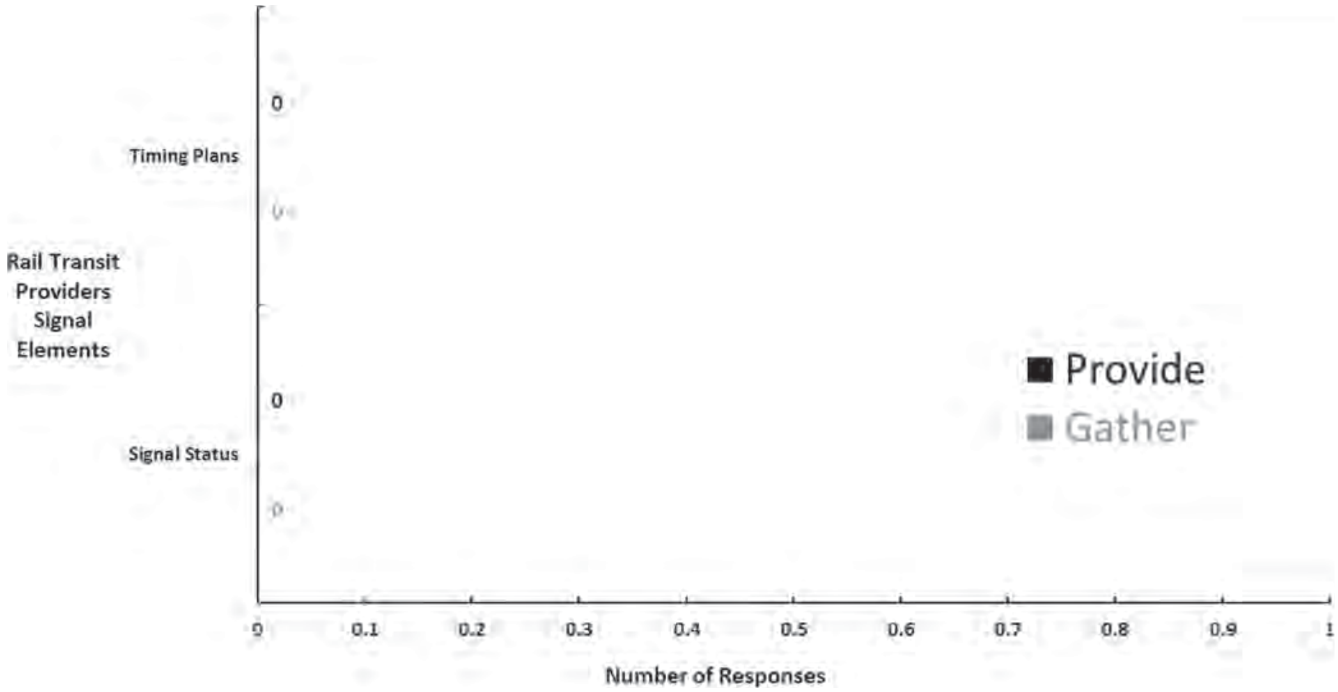


FIGURE D118 Signal elements shared by rail transit providers—3 responses (Questions 4, 13).

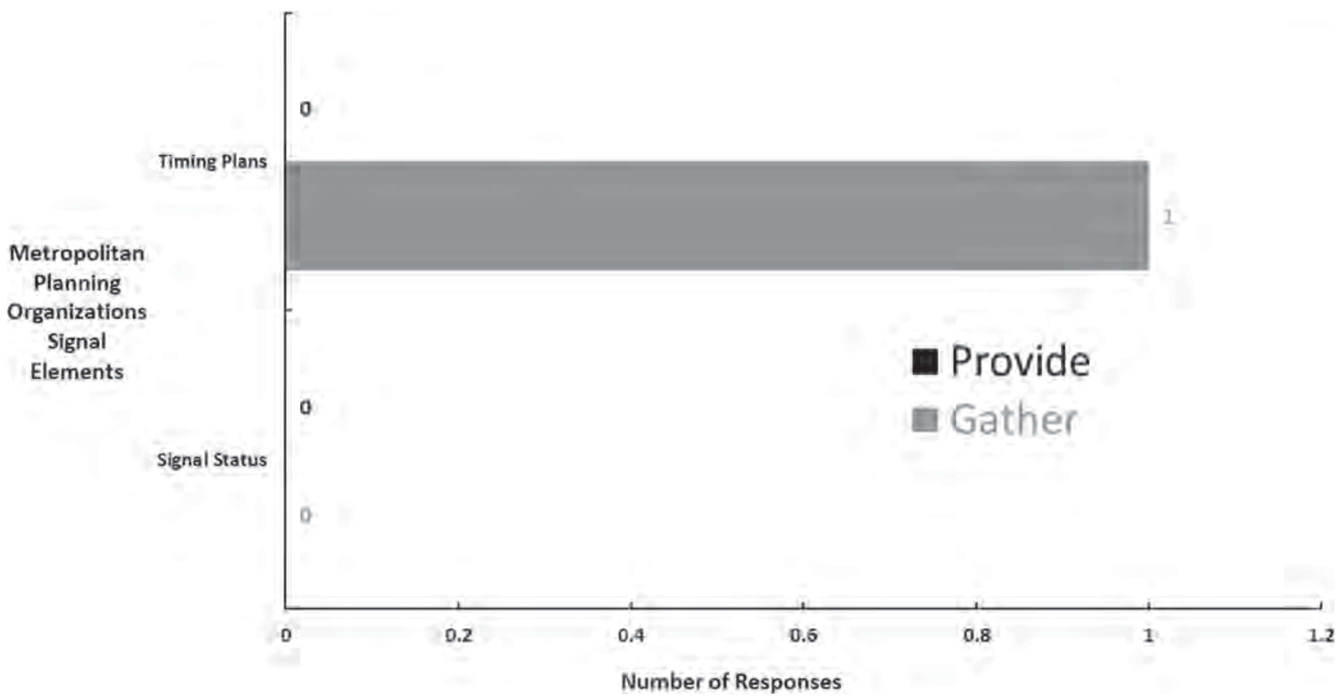


FIGURE D119 Signal elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

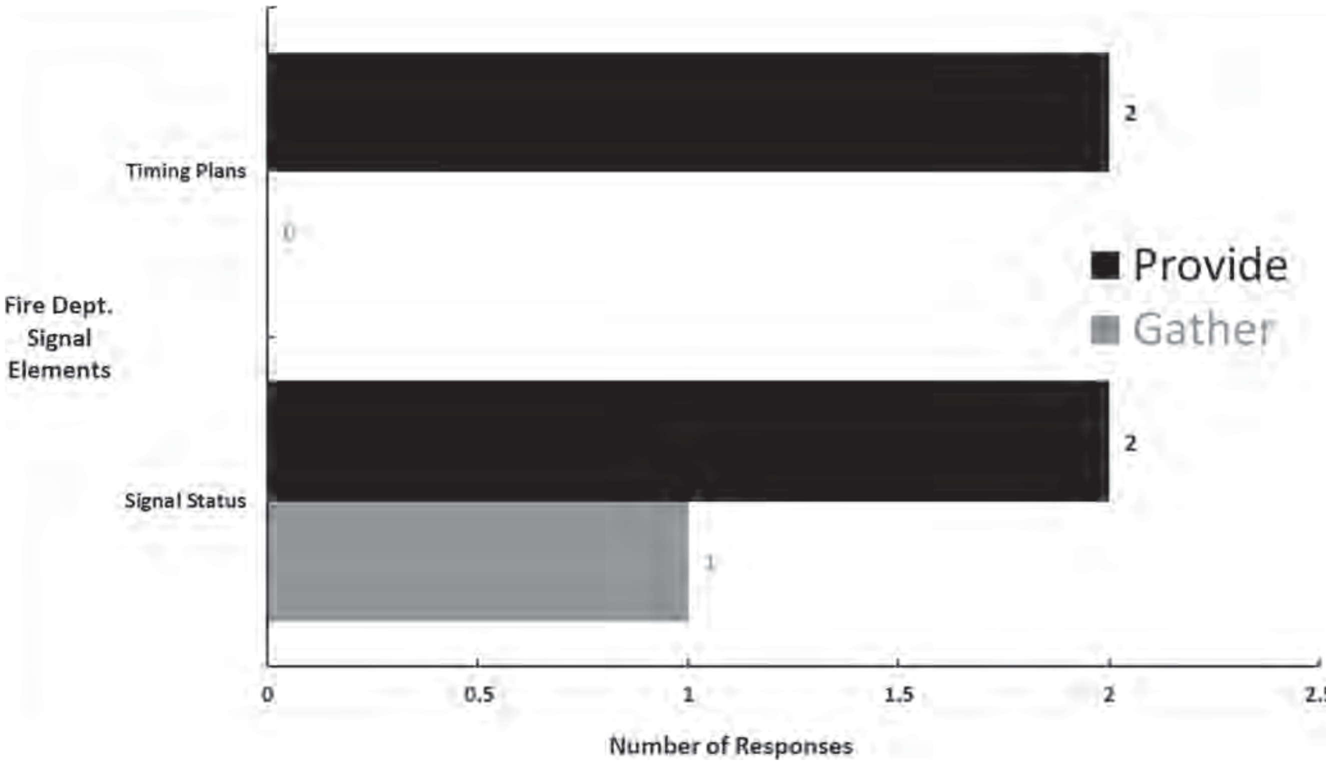


FIGURE D120 Signal elements shared by fire departments—3 responses (Questions 4, 13).

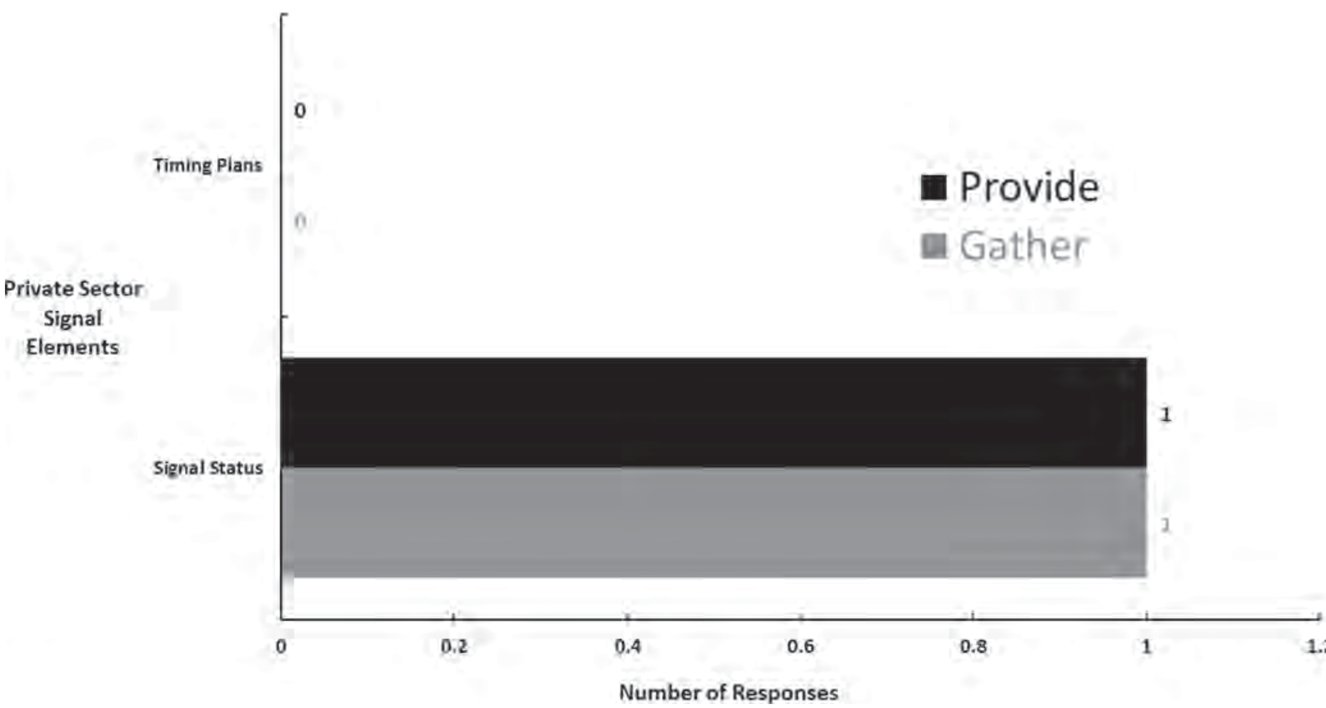


FIGURE D121 Signal elements shared by private sector entities—5 responses (Questions 4, 13).

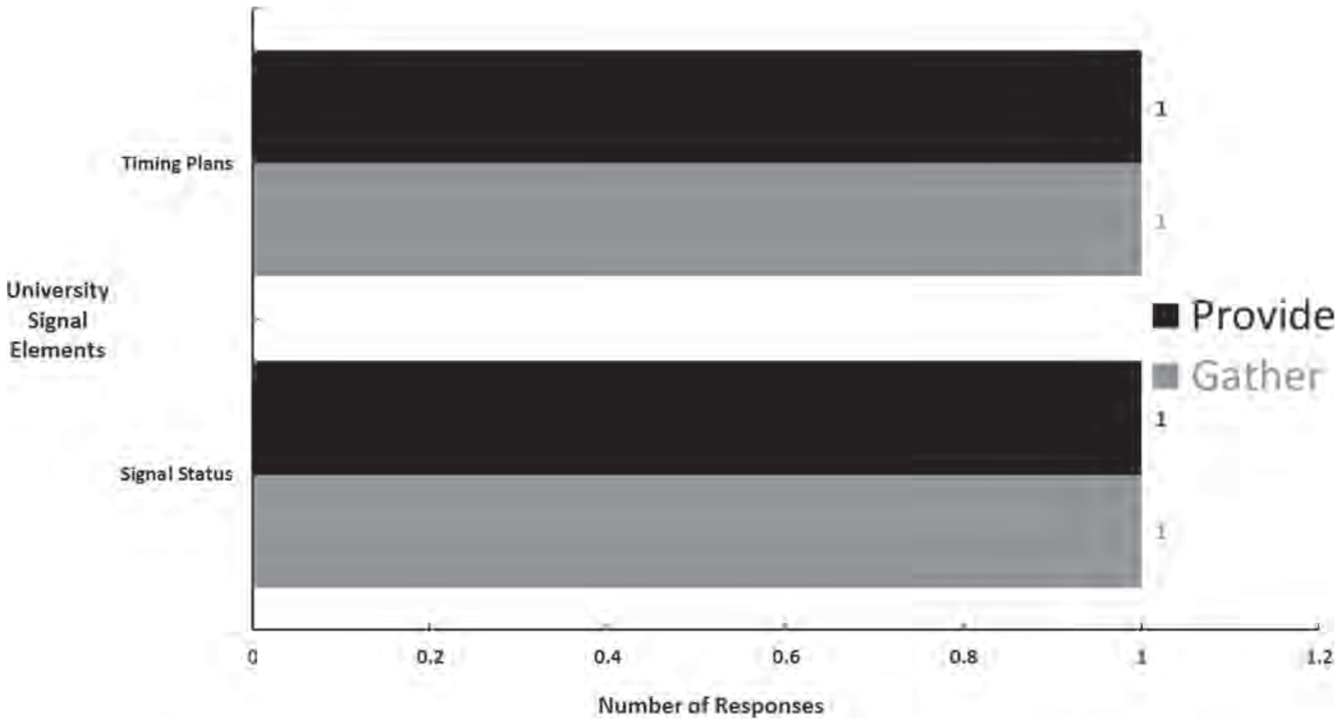


FIGURE D122 Signal elements shared by universities—4 responses (Questions 4, 13).

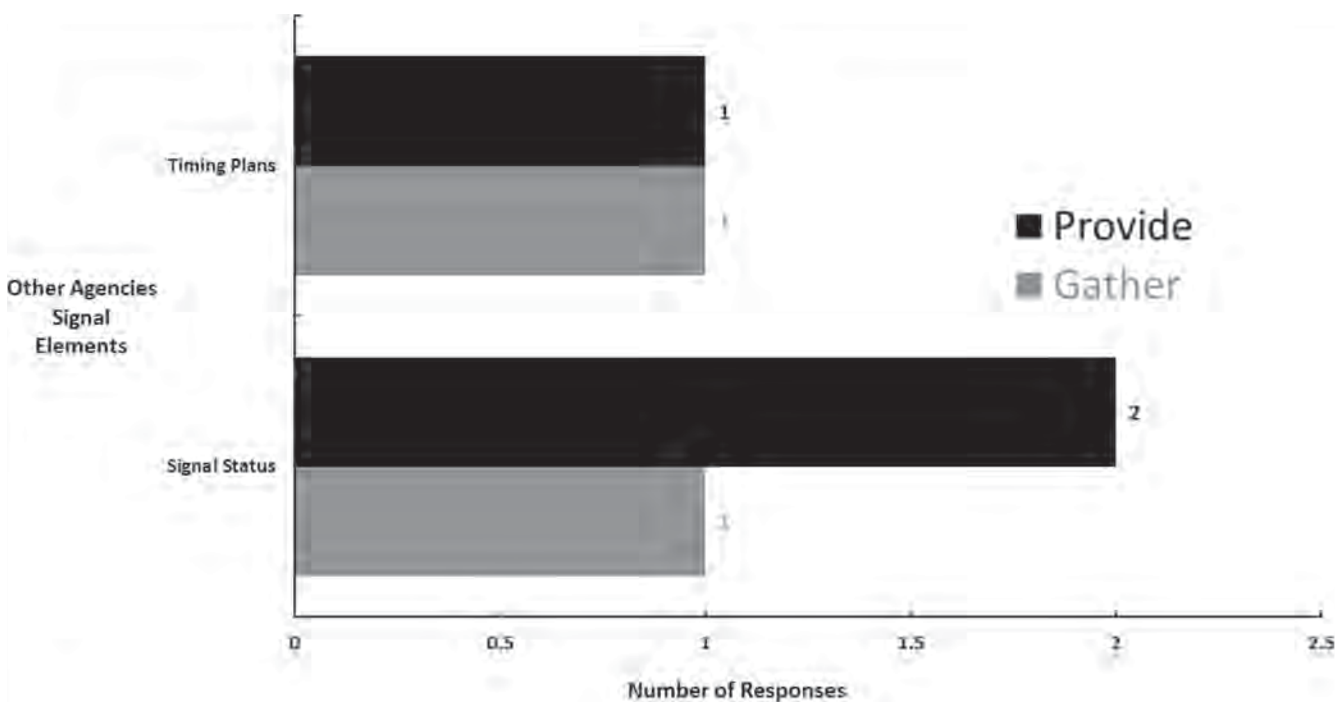


FIGURE D123 Signal elements shared by other agencies—12 responses (Questions 4, 13).

AGENCIES SHARING OTHER DATA (D124–D138)

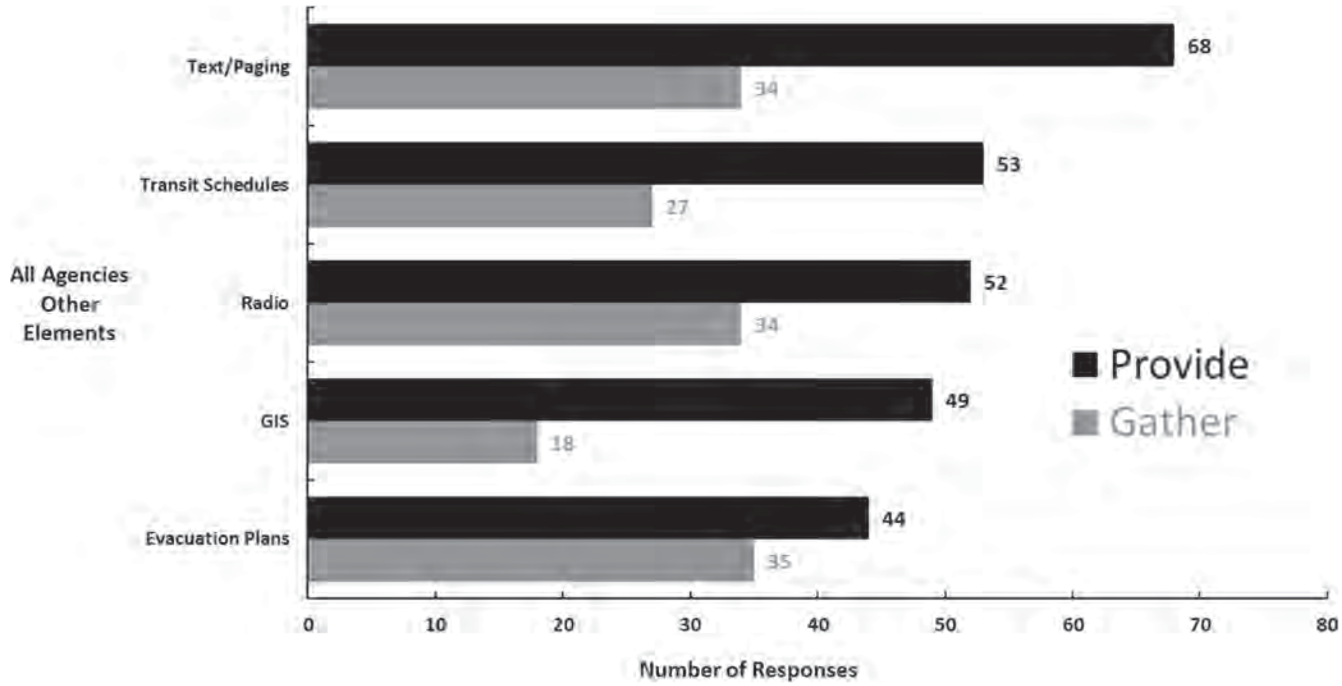


FIGURE D124 Other data elements shared by agencies in general—198 responses (Questions 4, 13).

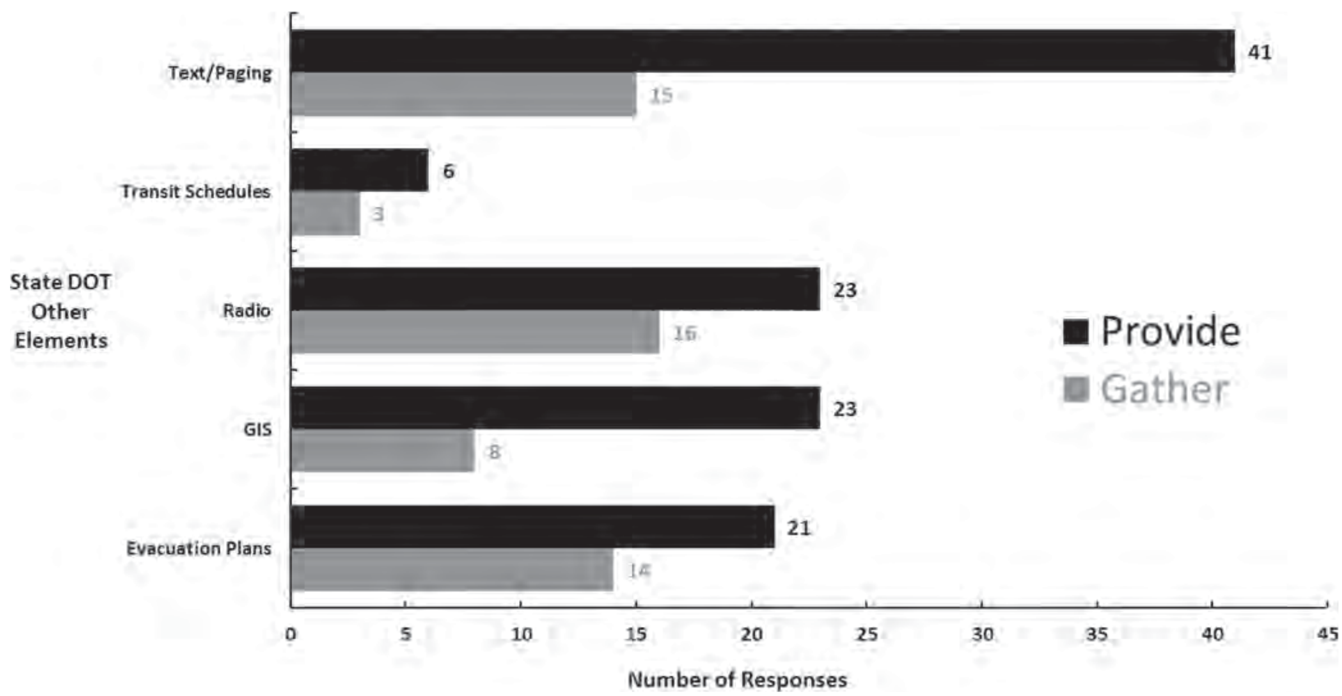


FIGURE D125 Other data elements shared by state DOTs—86 responses (Questions 4, 13).

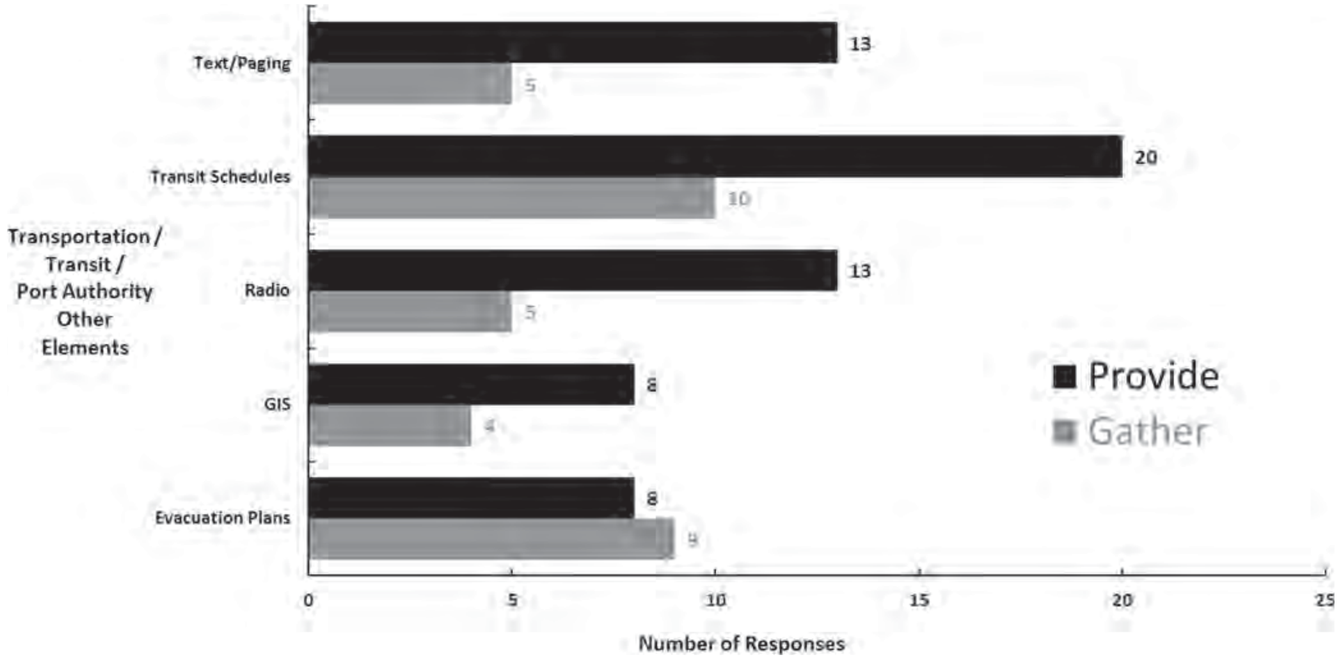


FIGURE D126 Other data elements shared by transportation/transit/port authorities—35 responses (Questions 4, 13).

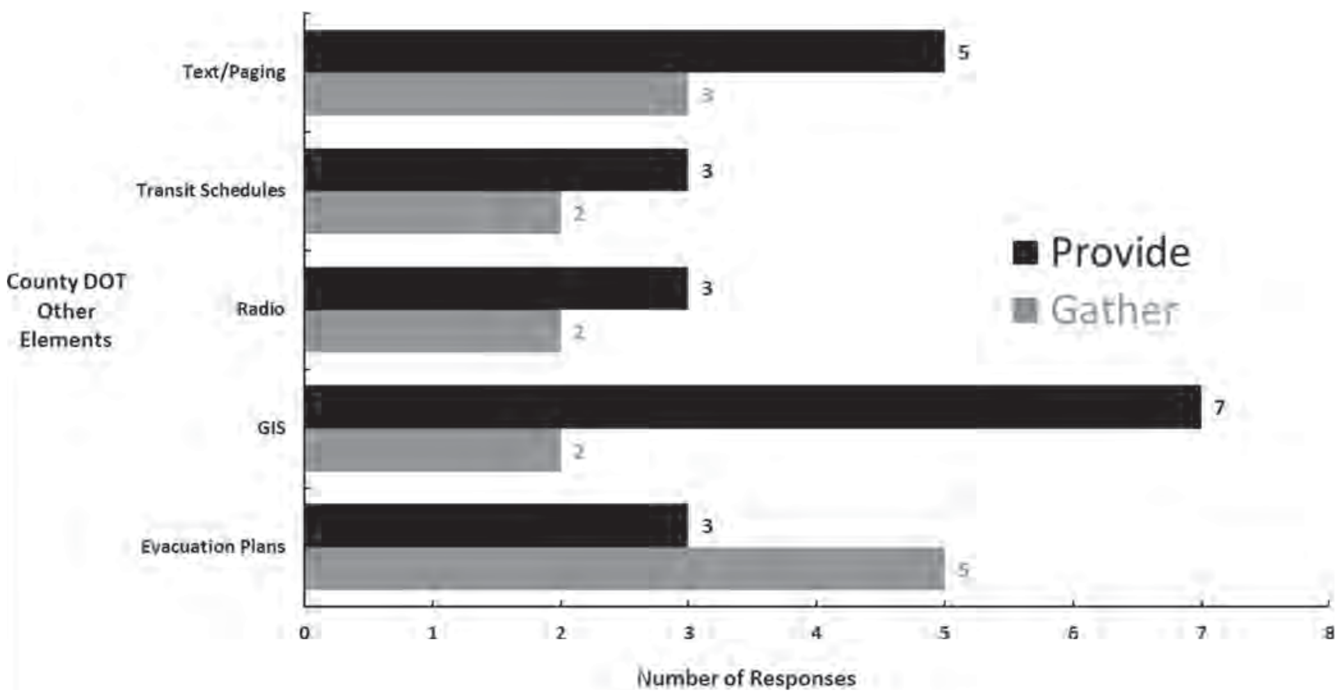


FIGURE D127 Other data elements shared by county DOTs—12 responses (Questions 4, 13).

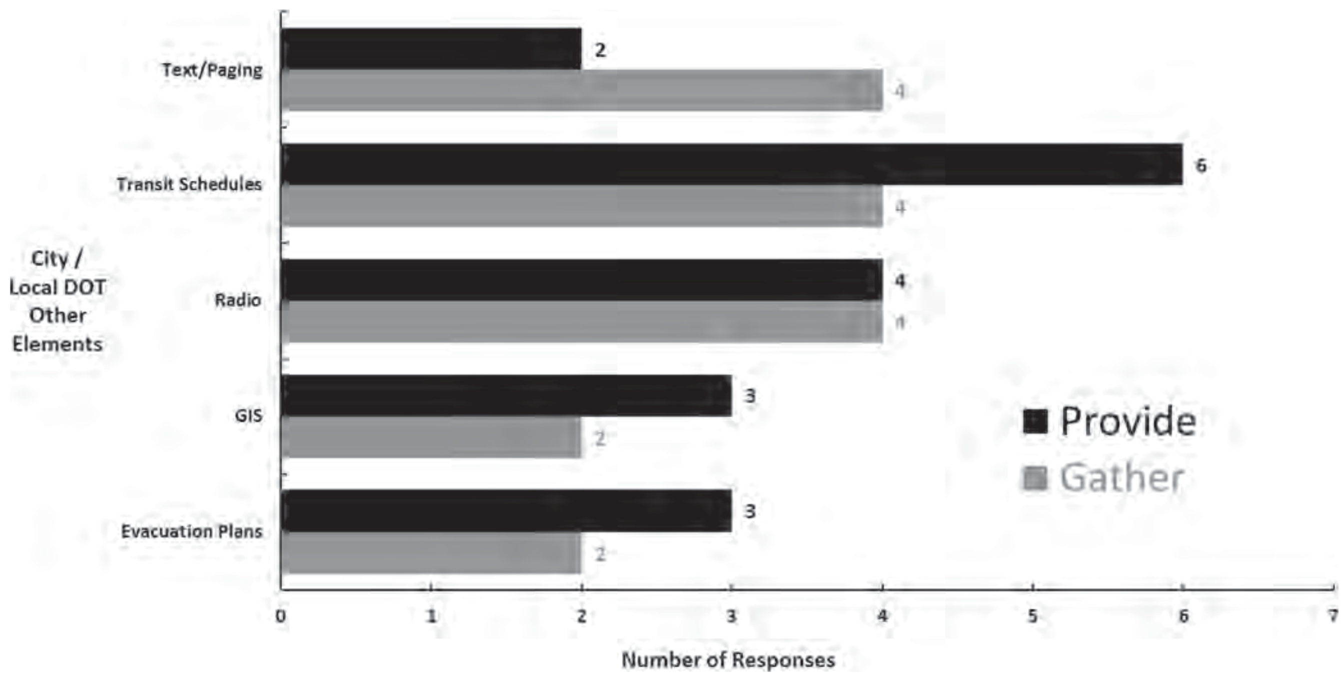


FIGURE D128 Other data elements shared by city and local DOTs—24 responses (Questions 4, 13).

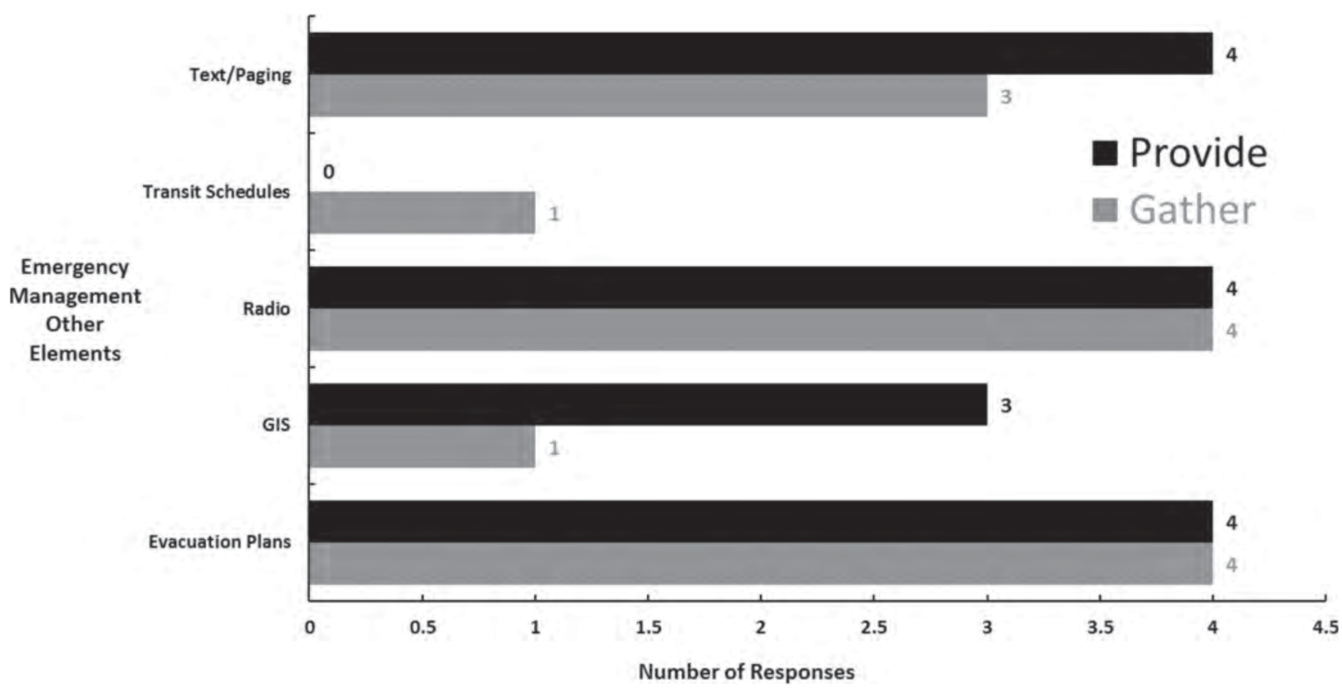


FIGURE D129 Other data elements shared by emergency management agencies—9 responses (Questions 4, 13).

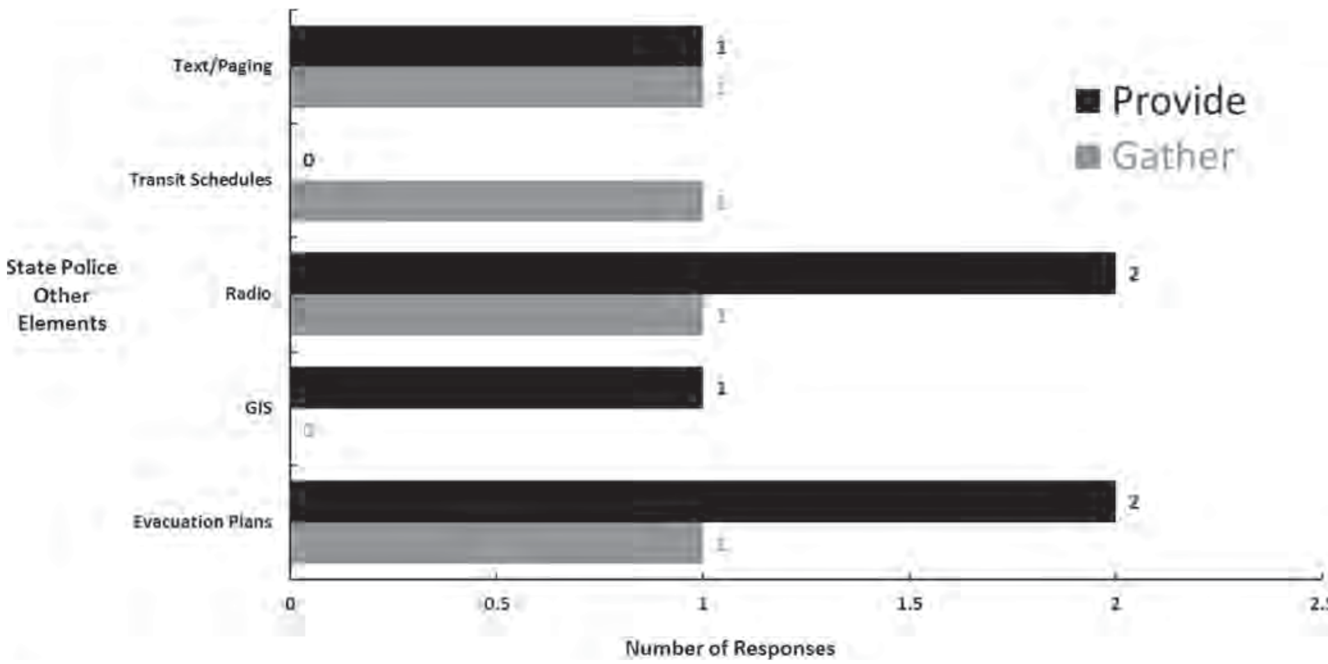


FIGURE D130 Other data elements shared by state police—4 responses (Questions 4, 13).

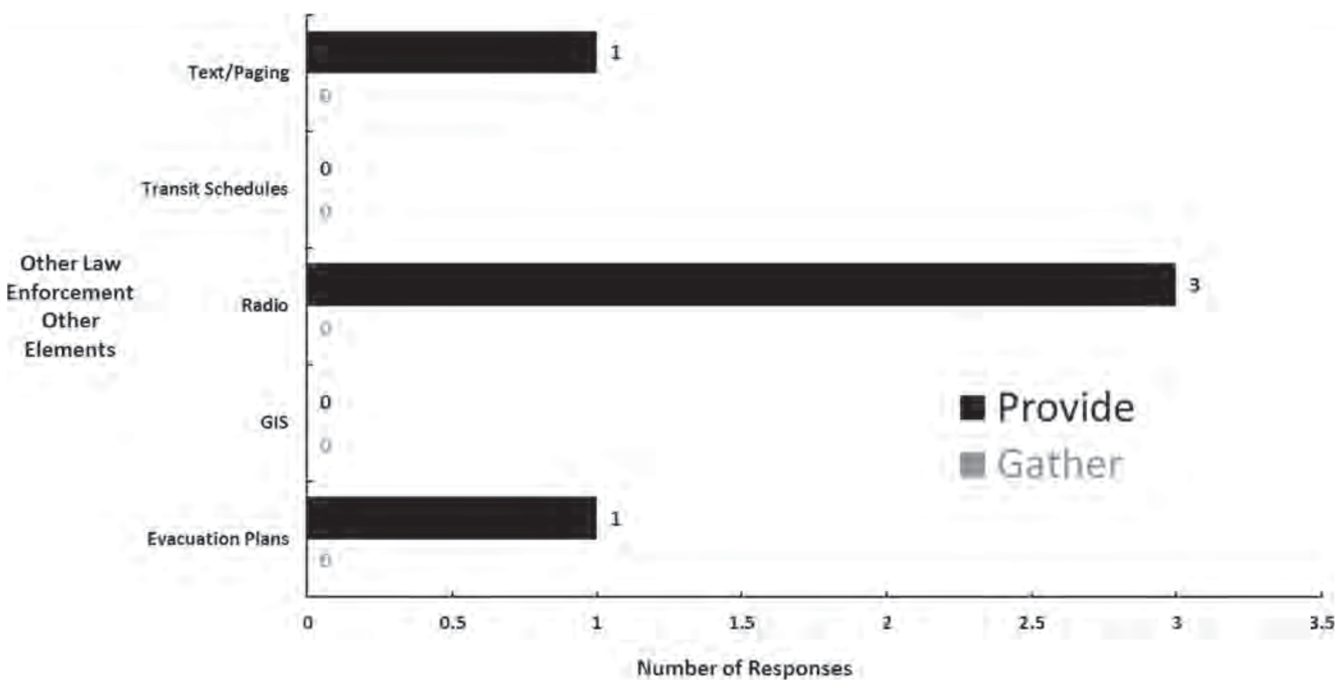


FIGURE D131 Other data elements shared by other law enforcement agencies—3 responses (Questions 4, 13).

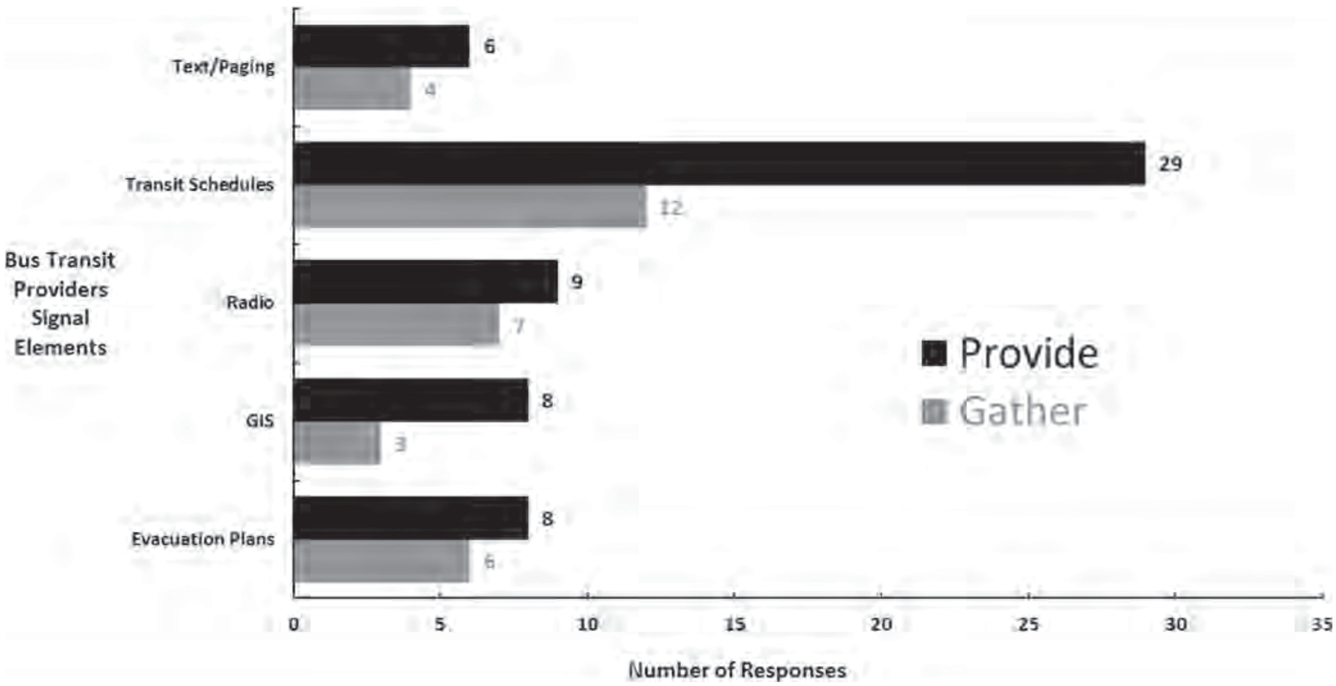


FIGURE D132 Other data elements shared by bus transit providers—40 responses (Questions 4, 13).

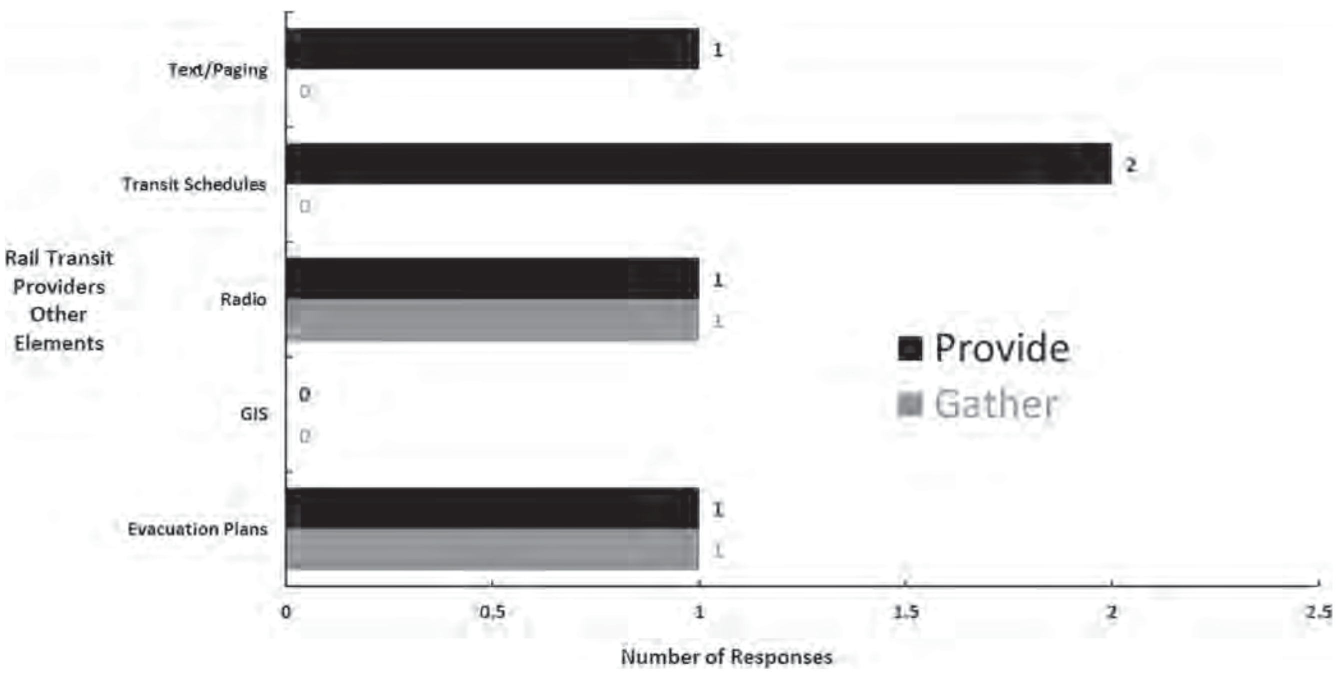


FIGURE D133 Other data elements shared by rail transit providers—3 responses (Questions 4, 13).

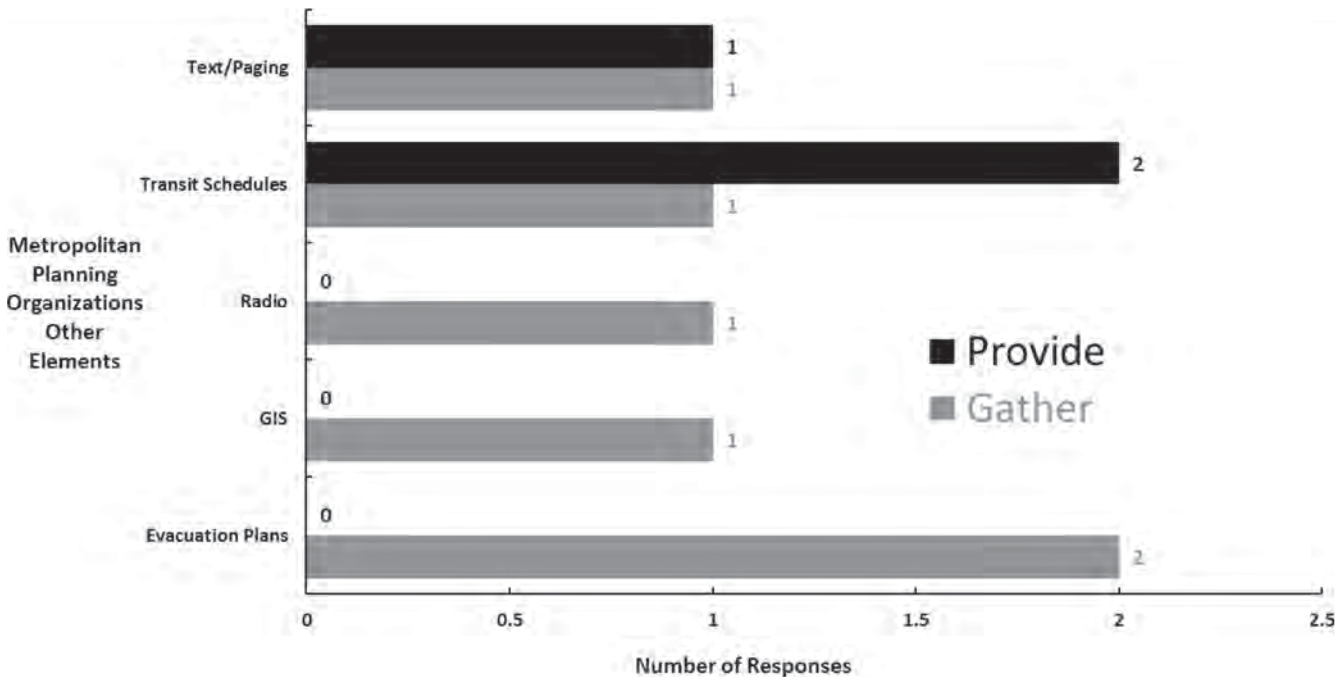


FIGURE D134 Other data elements shared by metropolitan planning organizations—6 responses (Questions 4, 13).

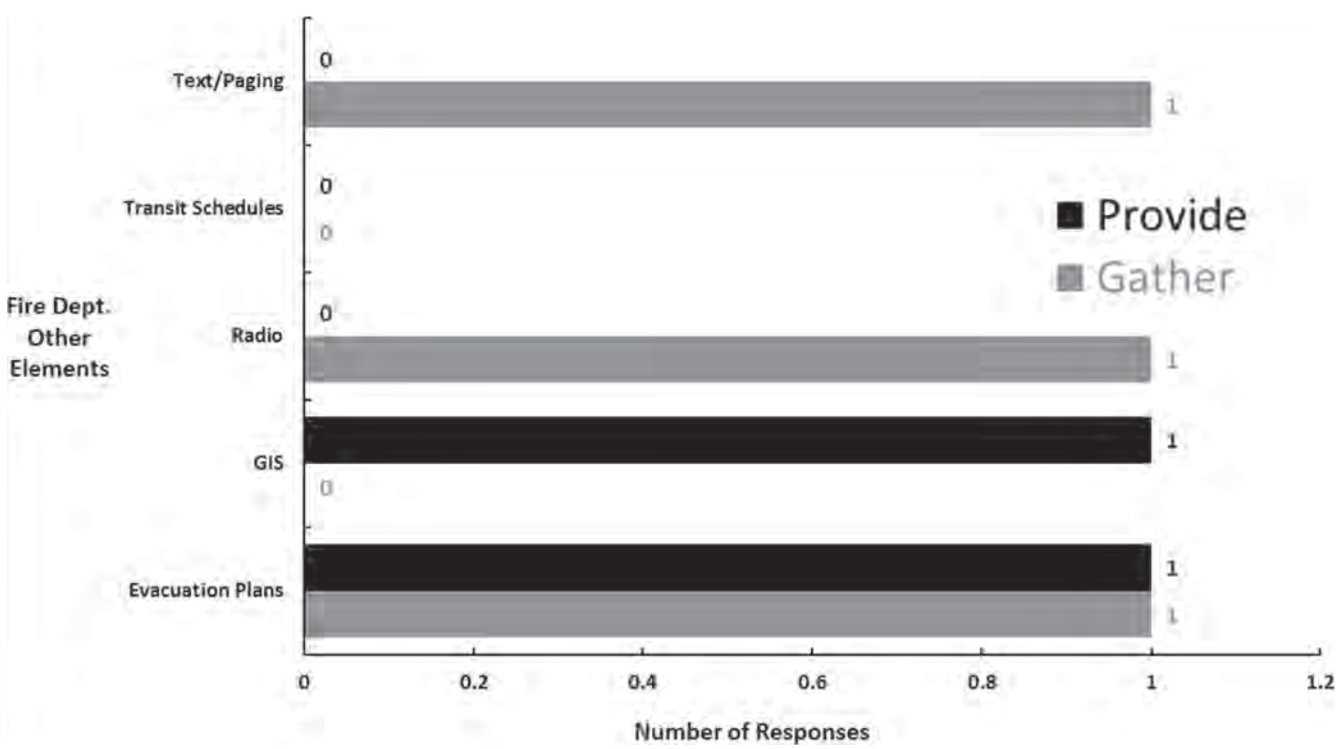


FIGURE D135 Other data elements shared by fire departments—3 responses (Questions 4, 13).

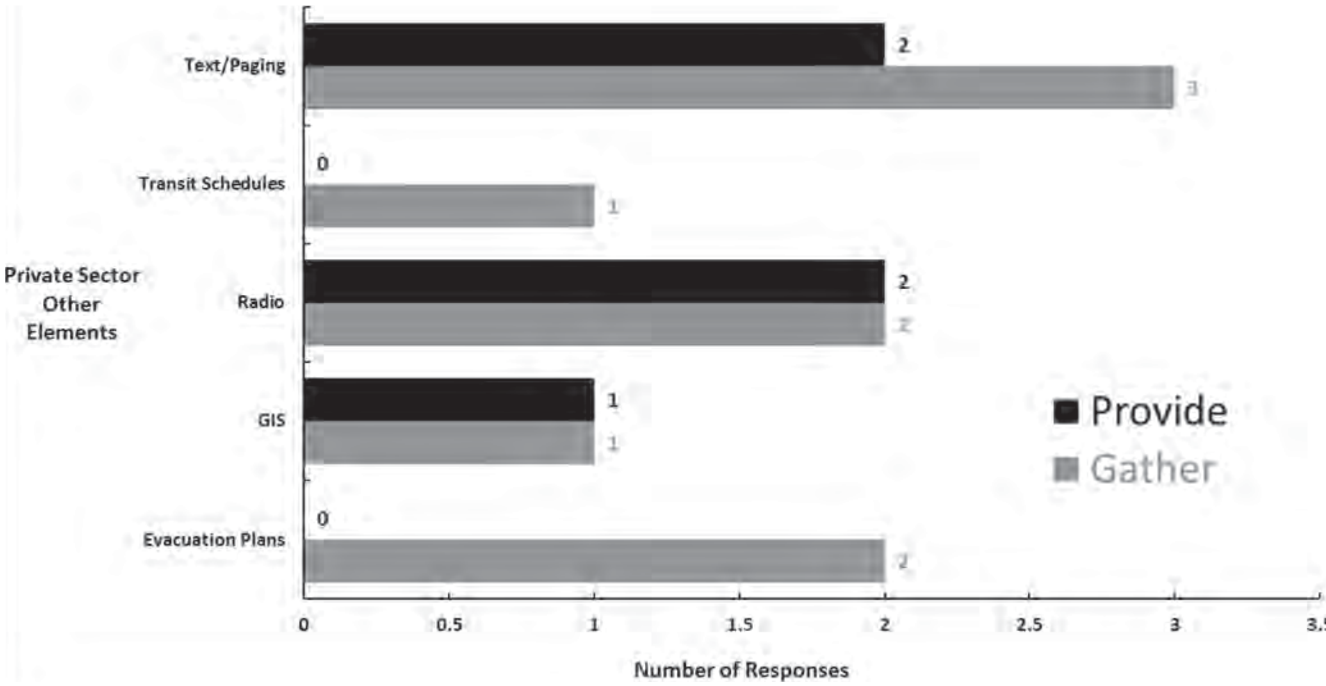


FIGURE D136 Other data elements shared by private sector entities—5 responses (Questions 4, 13).

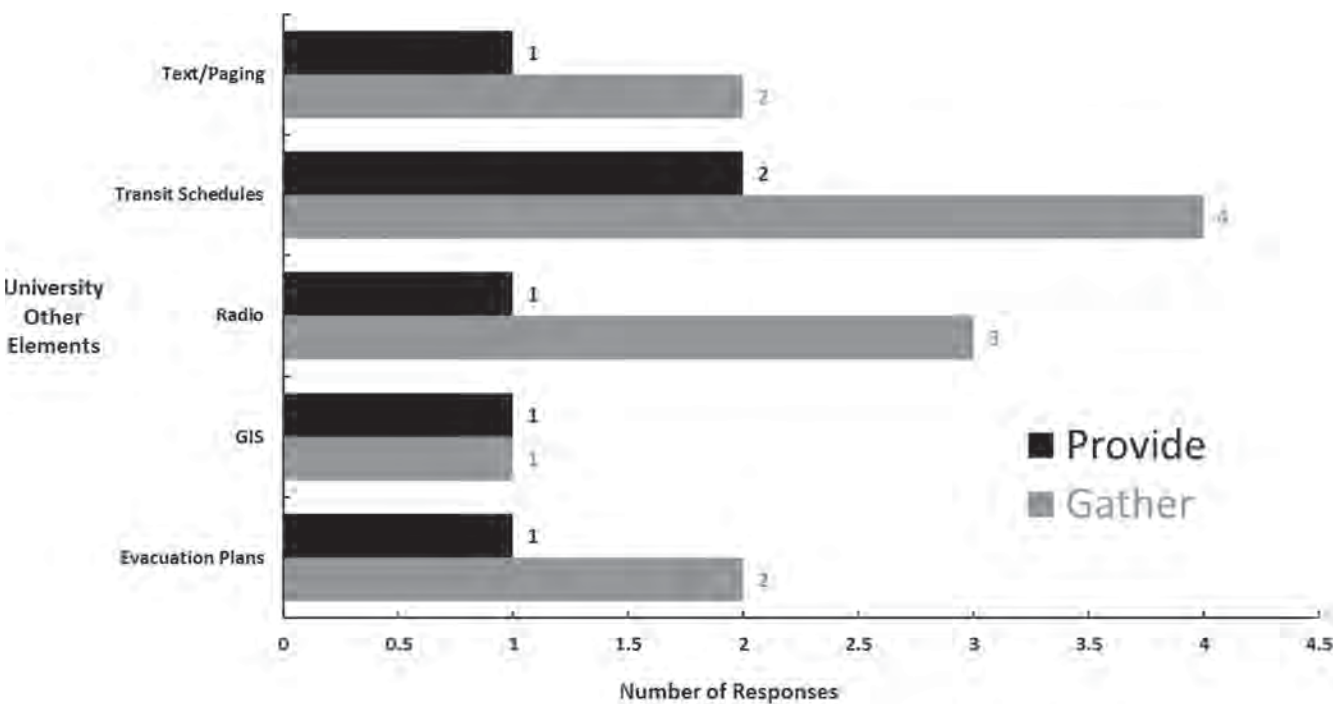


FIGURE D137 Other data elements shared by universities—4 responses (Questions 4, 13).

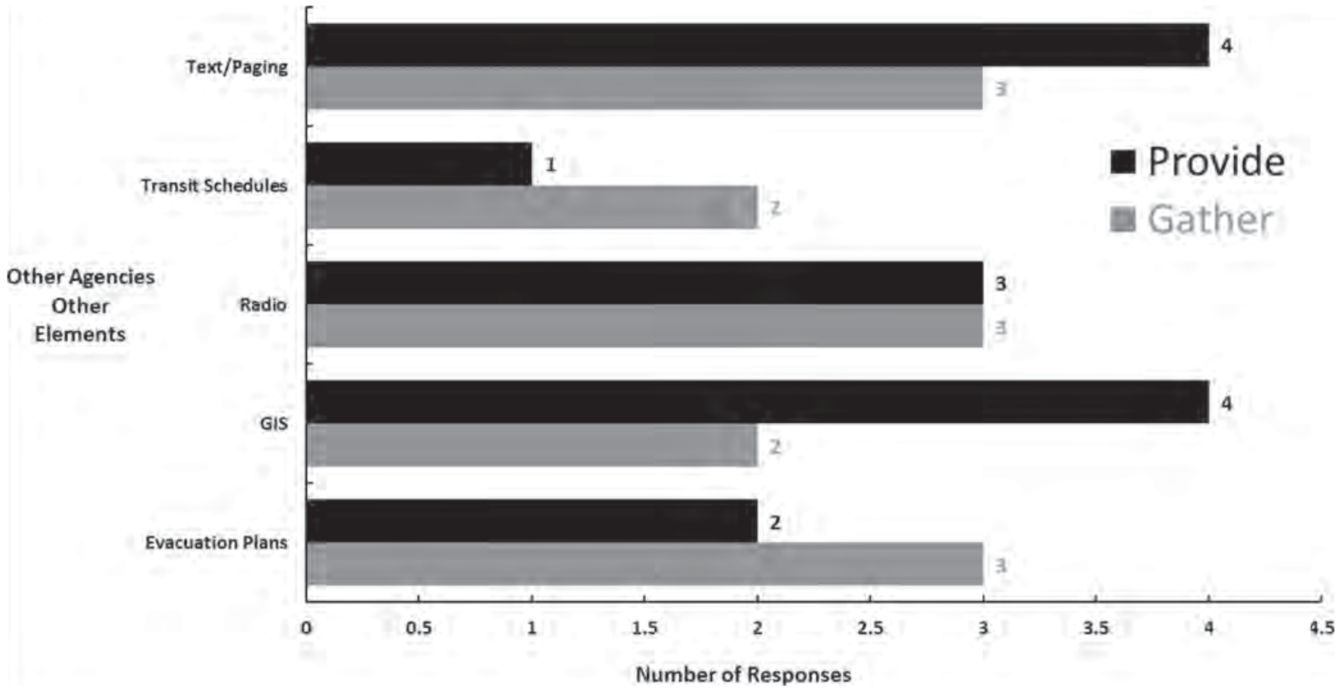


FIGURE D138 Other data elements shared by other agencies—12 responses (Questions 4, 13).

METHODS OF SHARING OPERATIONS DATA AMONG AGENCIES (D139–D153)

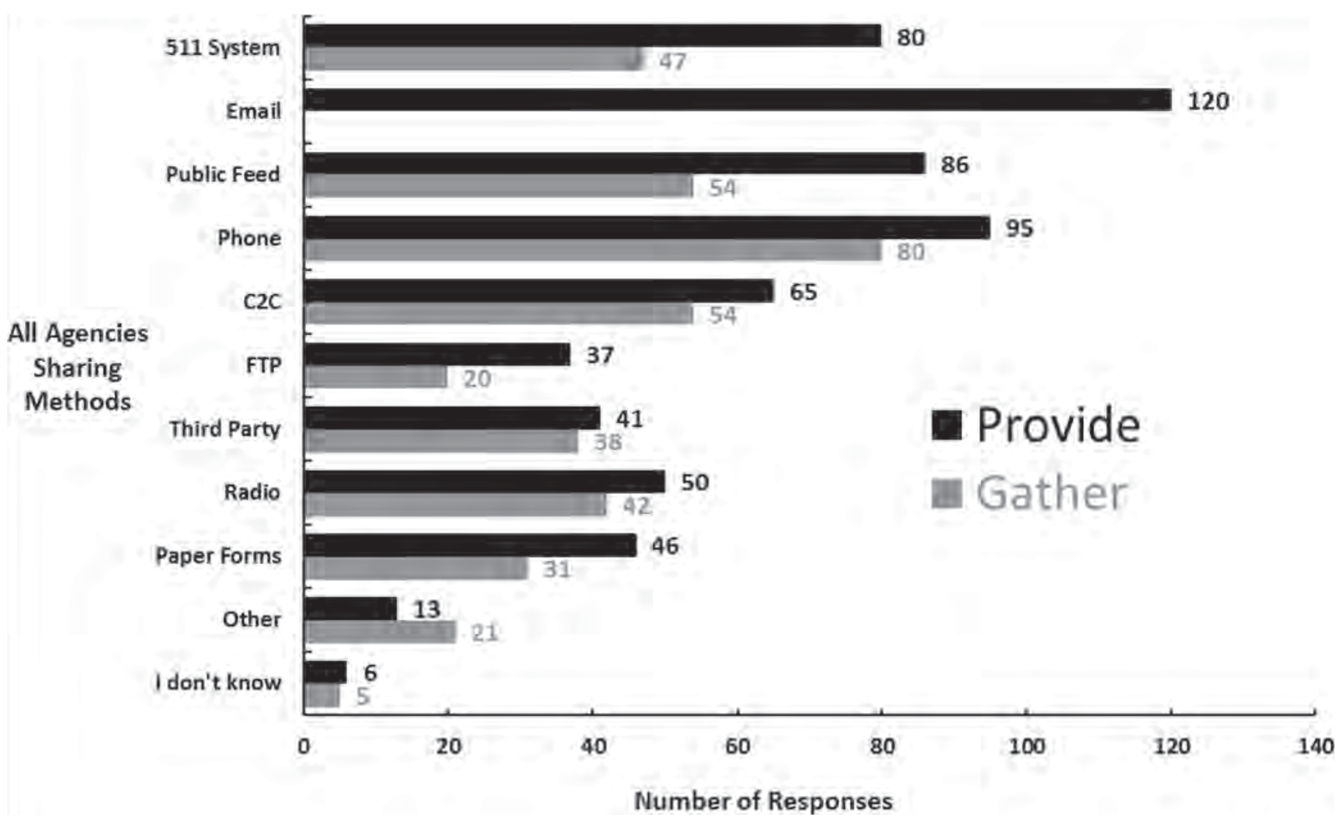


FIGURE D139 Sharing methods utilized by agencies in general—98 responses (Questions 5, 14).

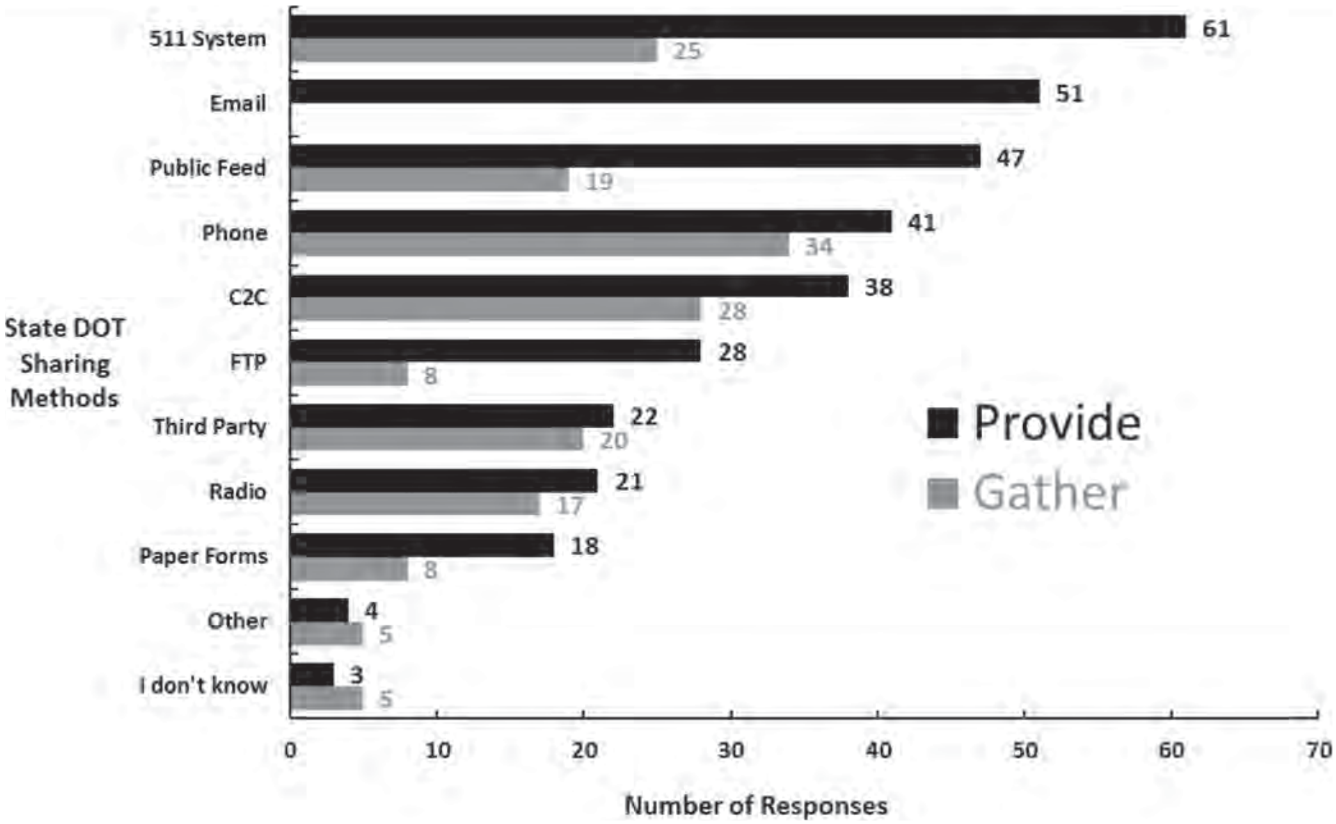


FIGURE D140 Sharing methods utilized by state DOTs—86 responses (Questions 5, 14).

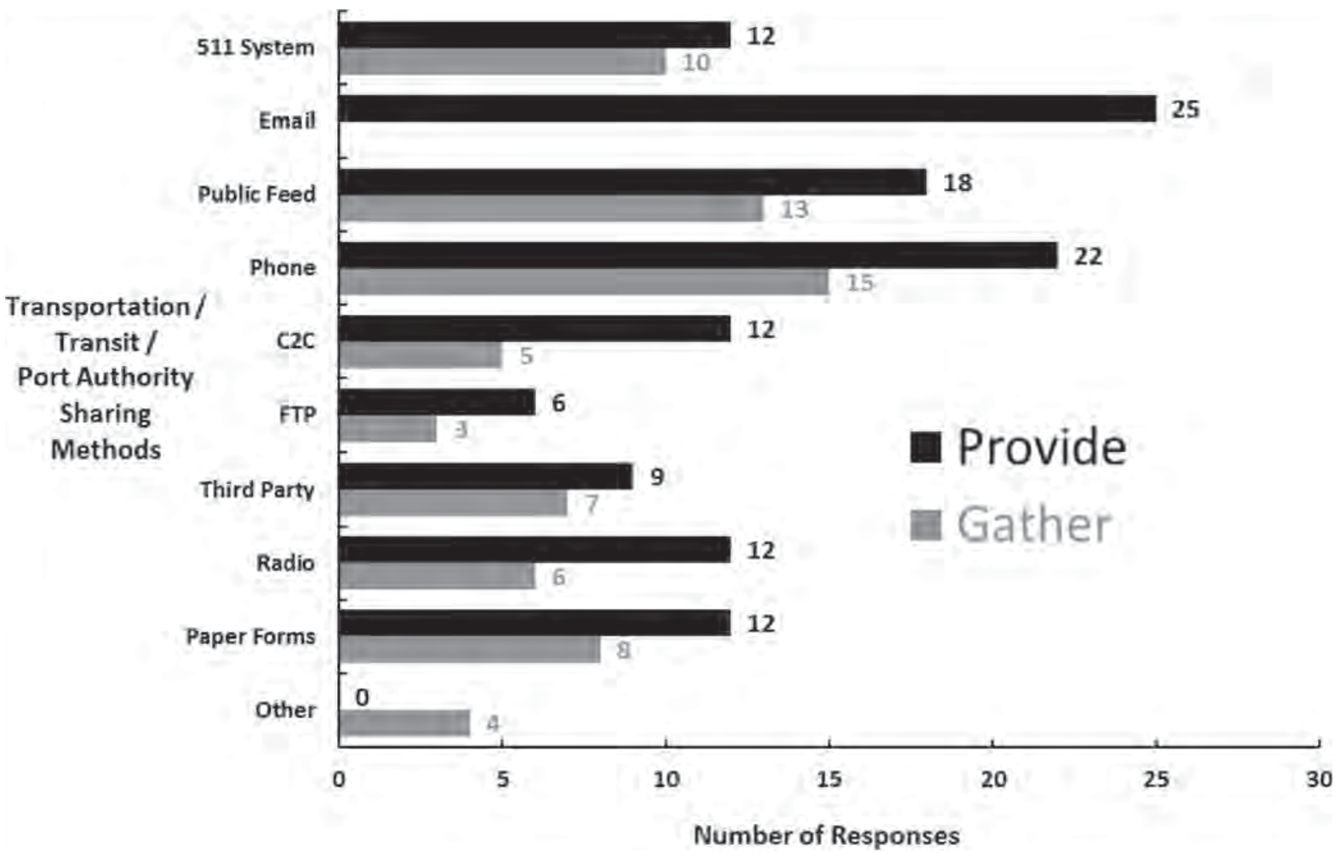


FIGURE D141 Sharing methods utilized by transportation/transit/port authorities—35 responses (Questions 5, 14).

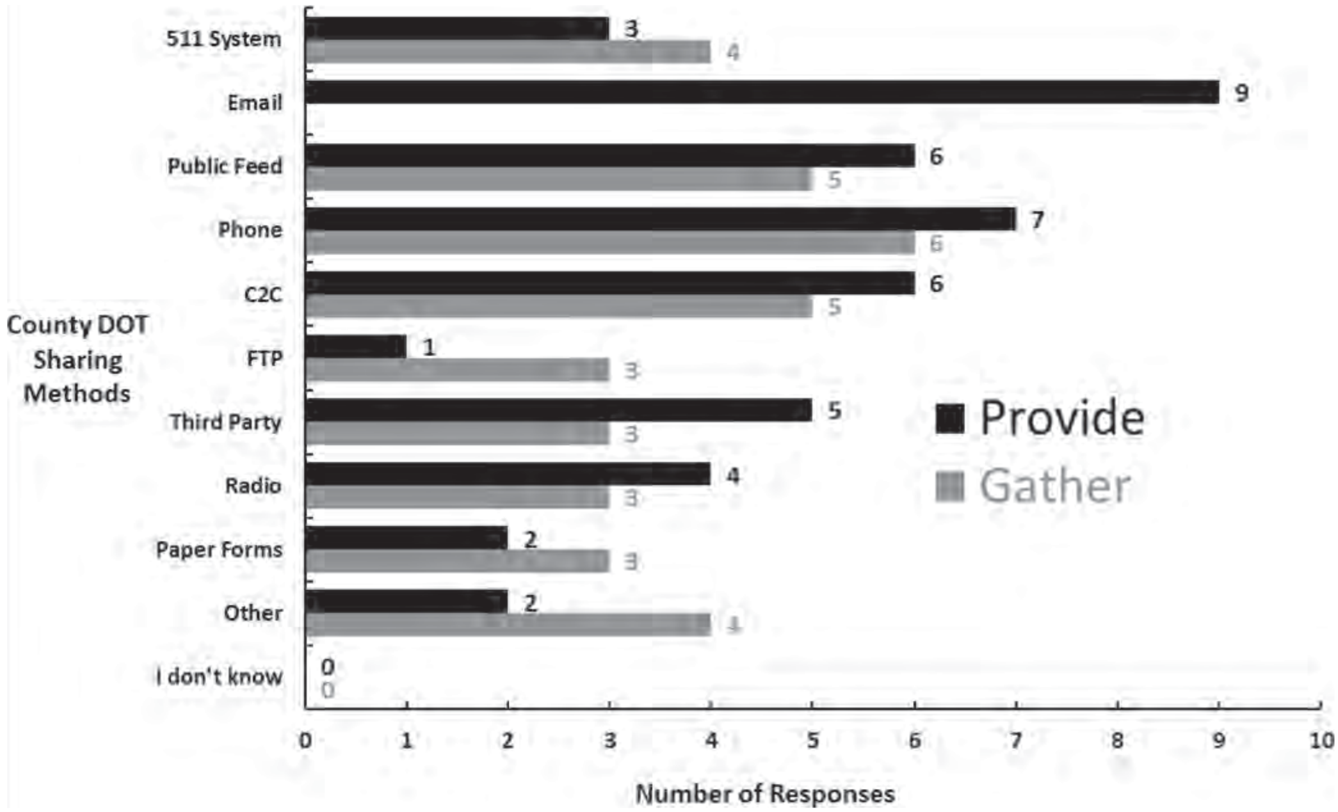


FIGURE D142 Sharing methods utilized by county DOTs—12 responses (Questions 5, 14).

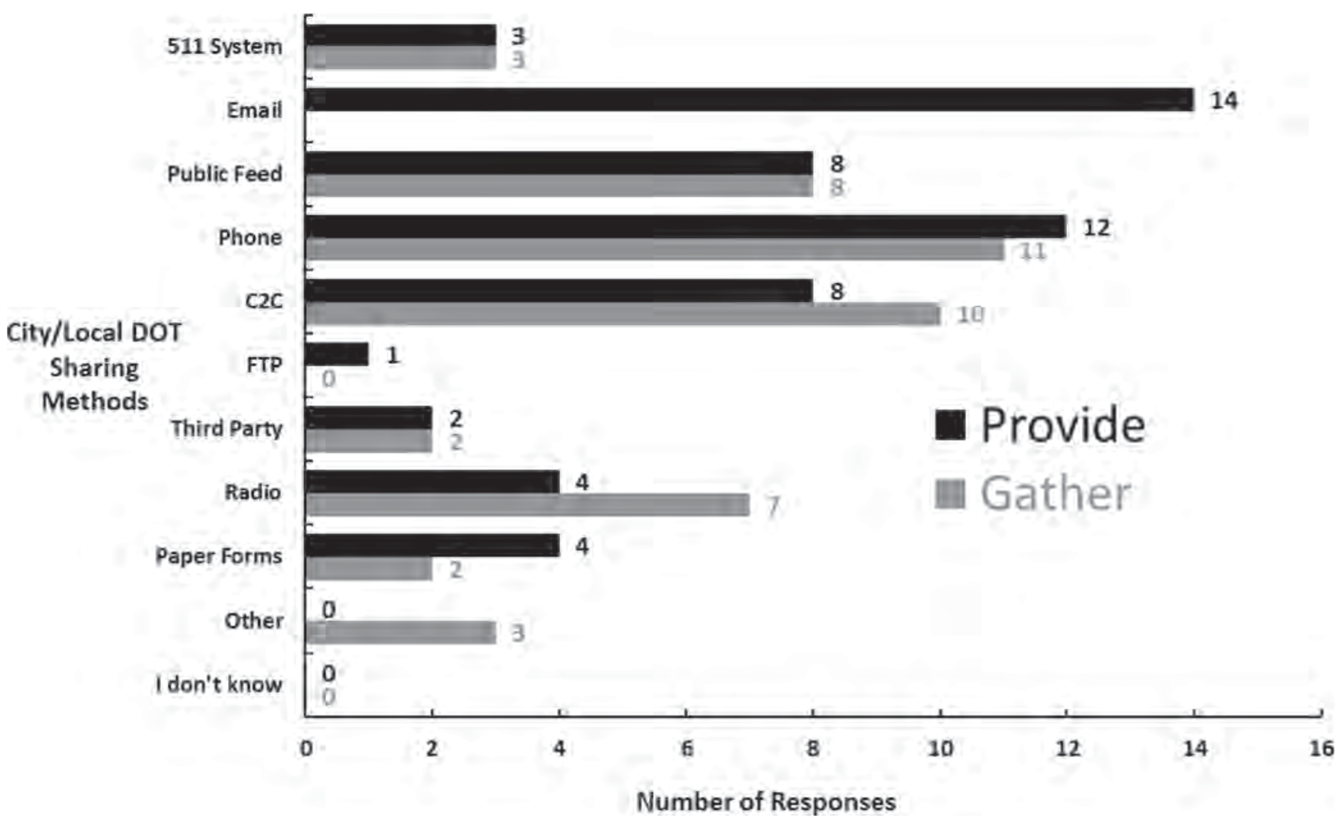


FIGURE D143 Sharing methods utilized by city and local DOTs—24 responses (Questions 5, 14).

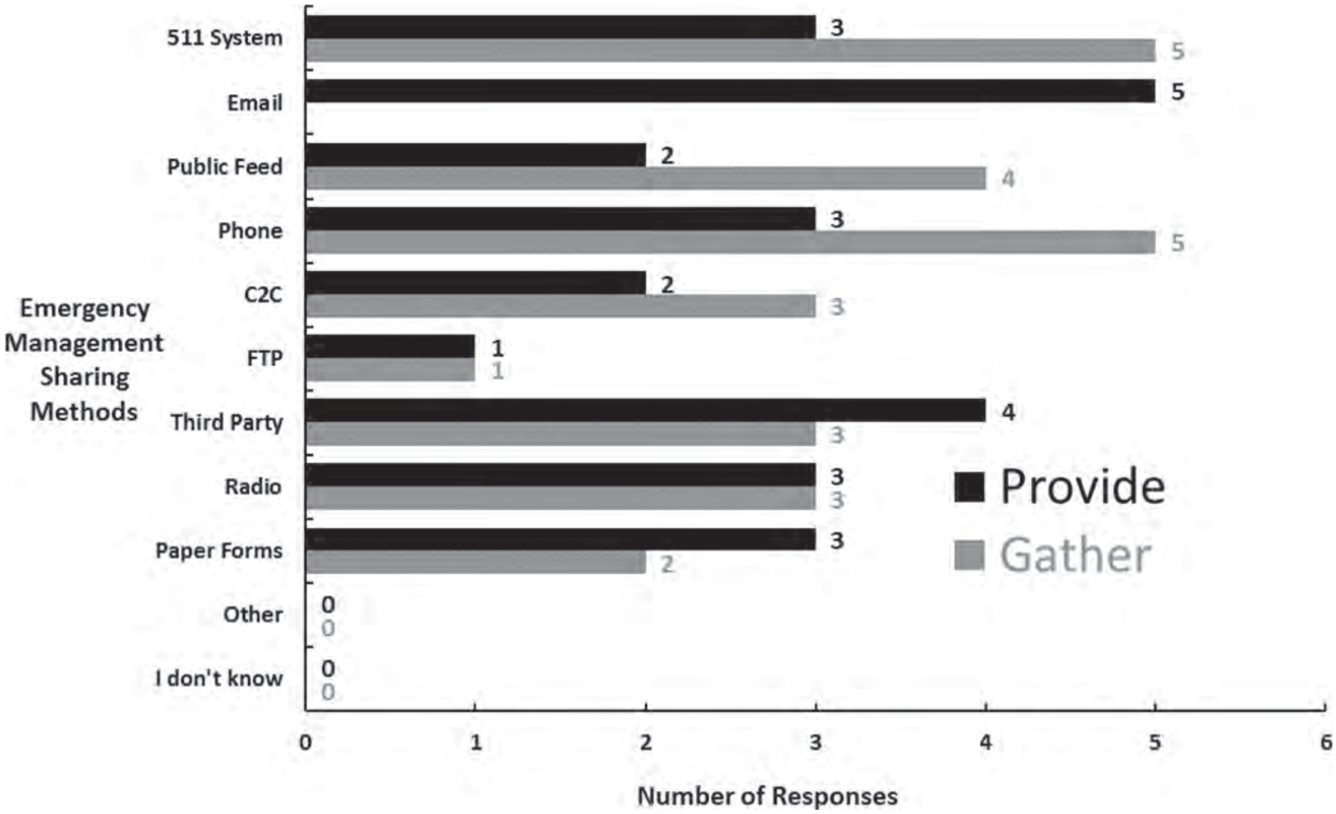


FIGURE D144 Sharing methods utilized by emergency management agencies—9 responses (Questions 5, 14).

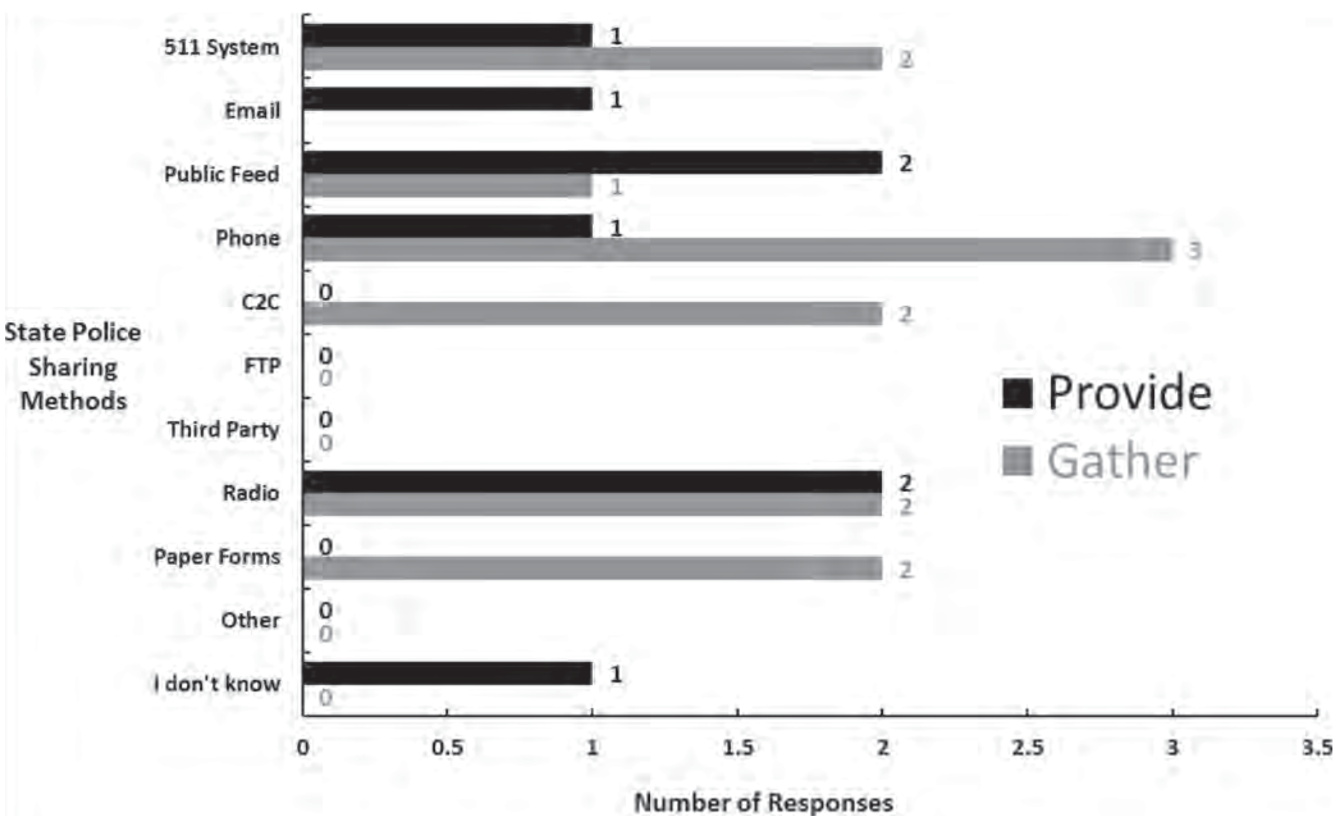


FIGURE D145 Sharing methods utilized by state police—4 responses (Questions 5, 14).

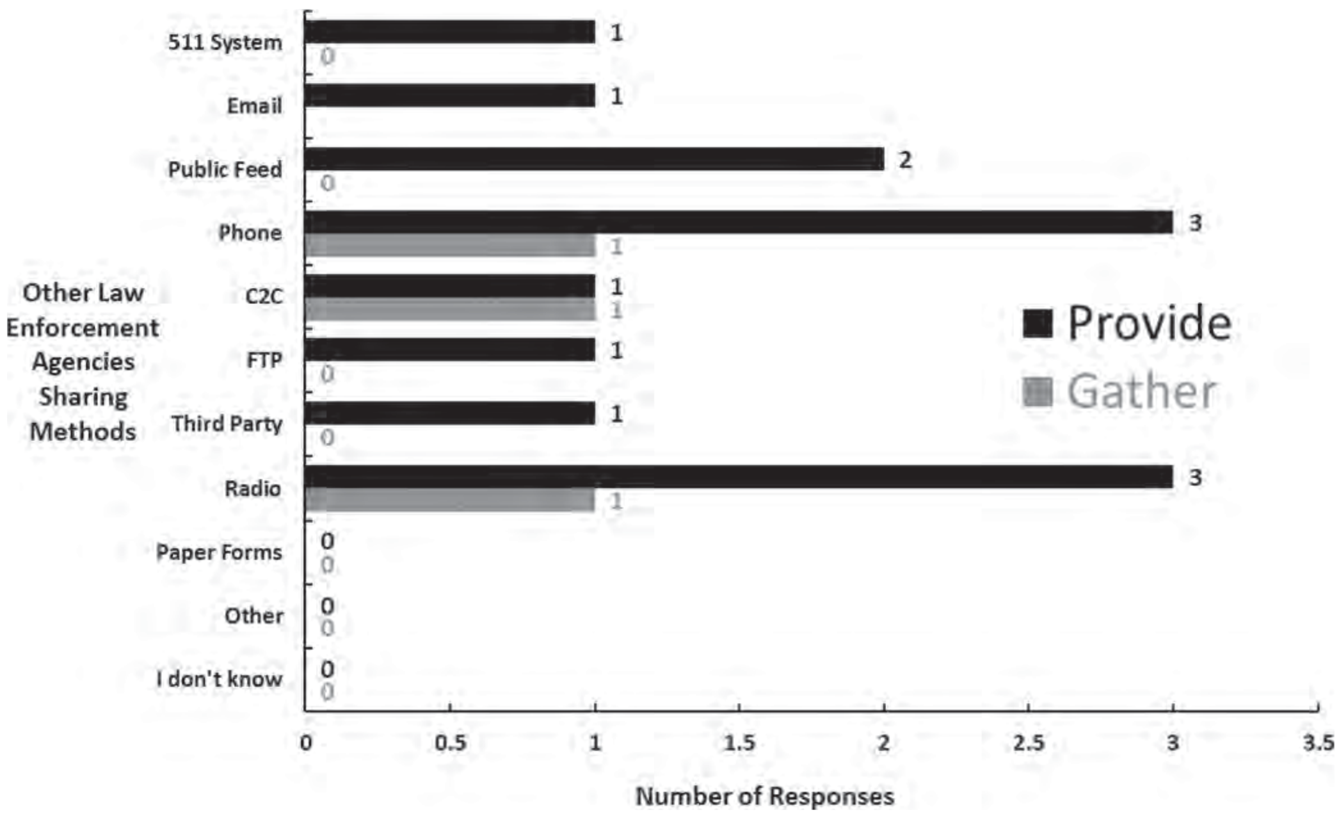


FIGURE D146 Sharing methods utilized by other law enforcement agencies—3 responses (Questions 5, 14).

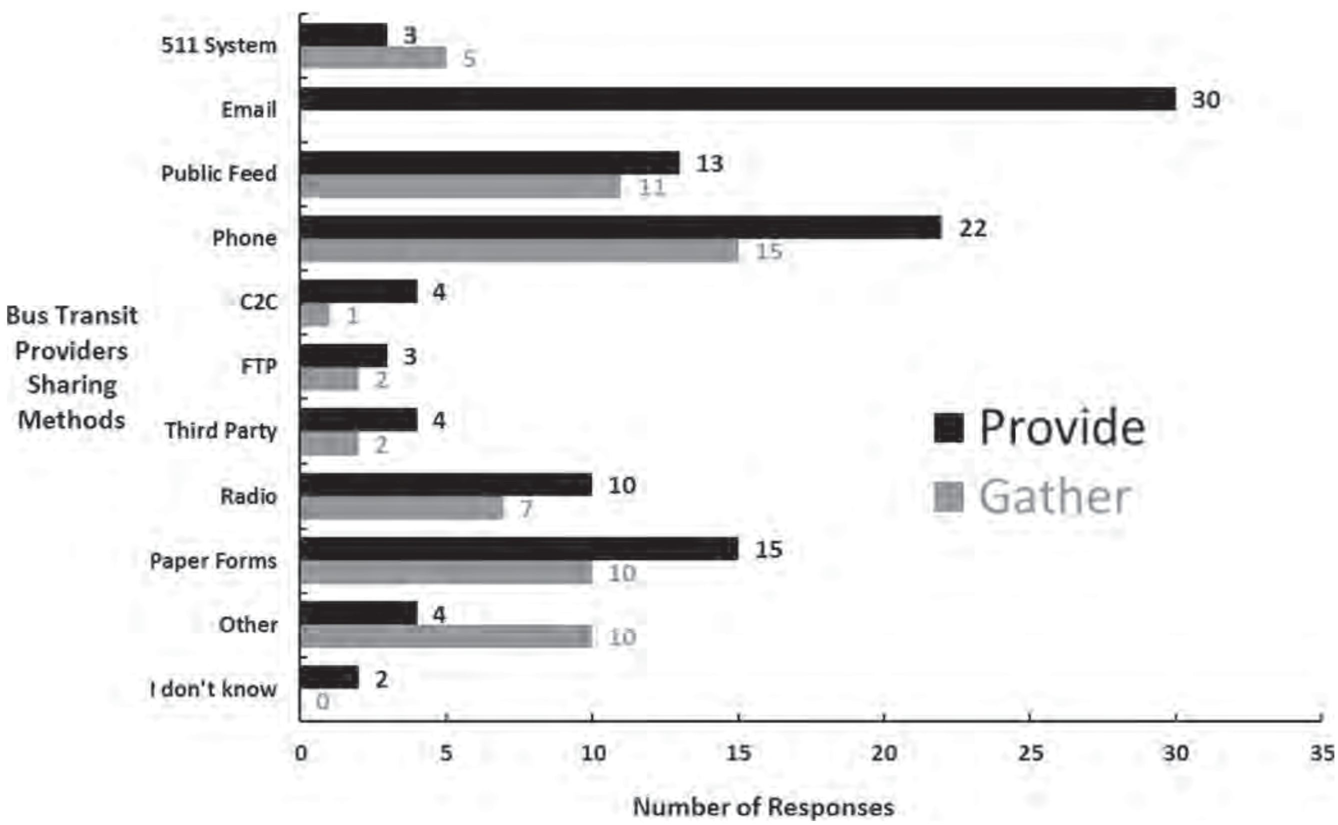


FIGURE D147 Sharing methods utilized by bus transit providers—40 responses (Questions 5, 14).

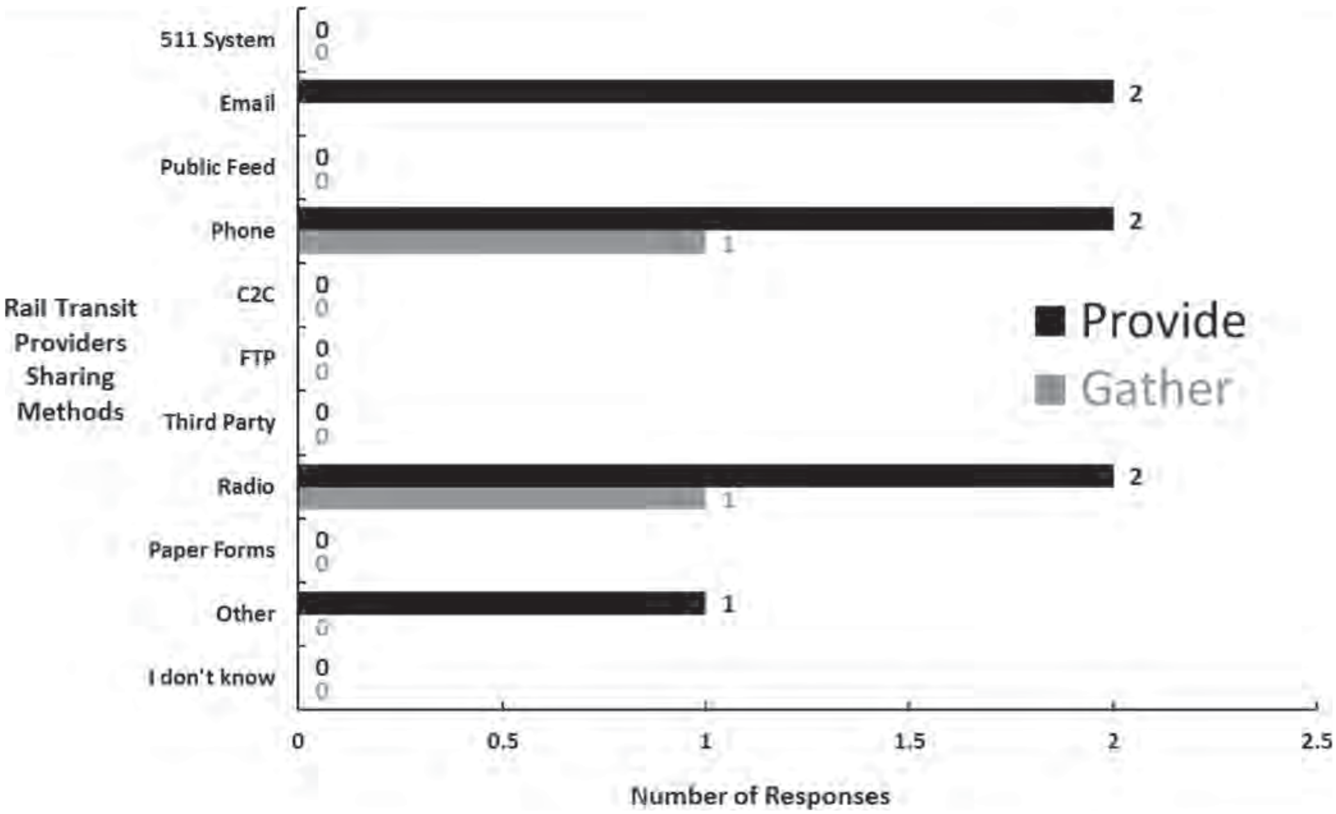


FIGURE D148 Sharing methods utilized by rail transit providers—3 responses (Questions 5, 14).

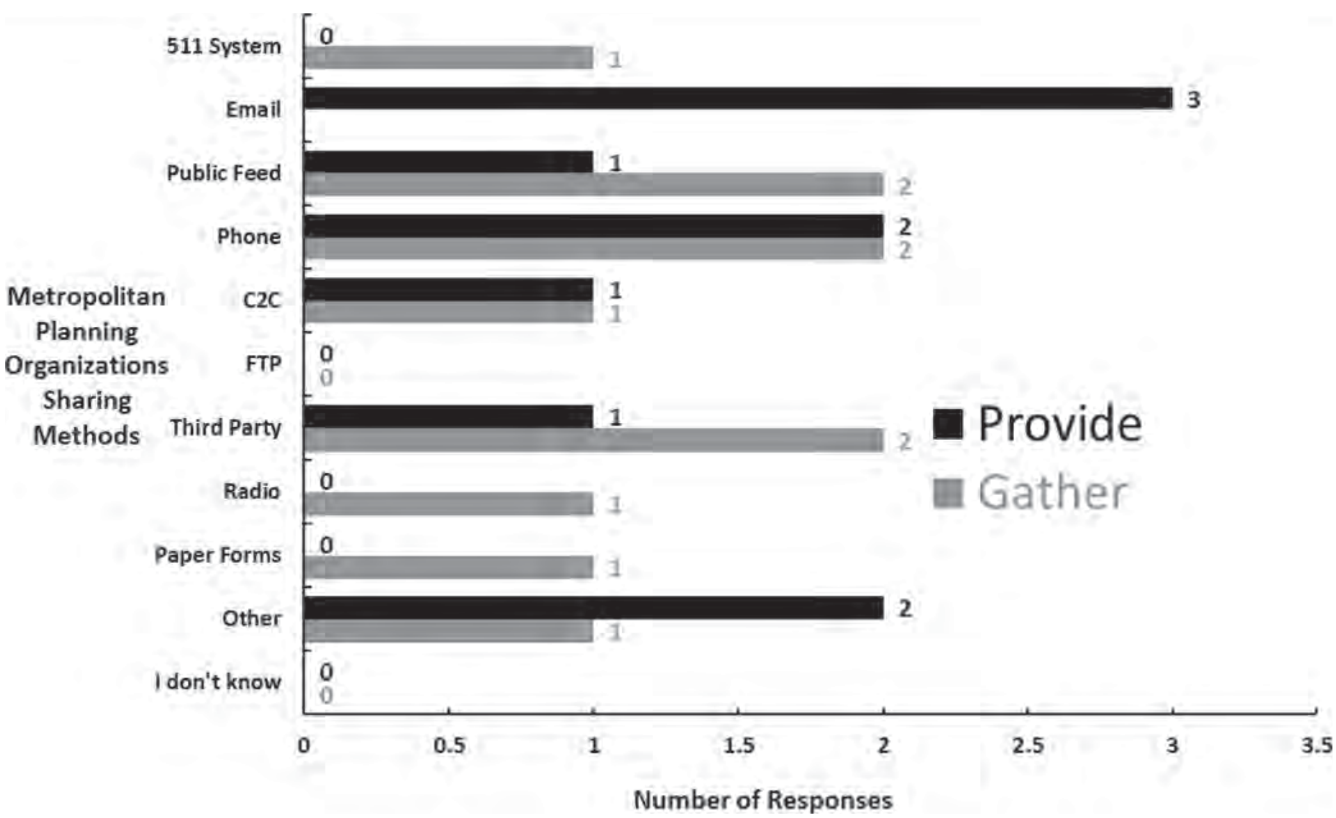


FIGURE D149 Sharing methods utilized by metropolitan planning organizations—6 responses (Questions 5, 14).

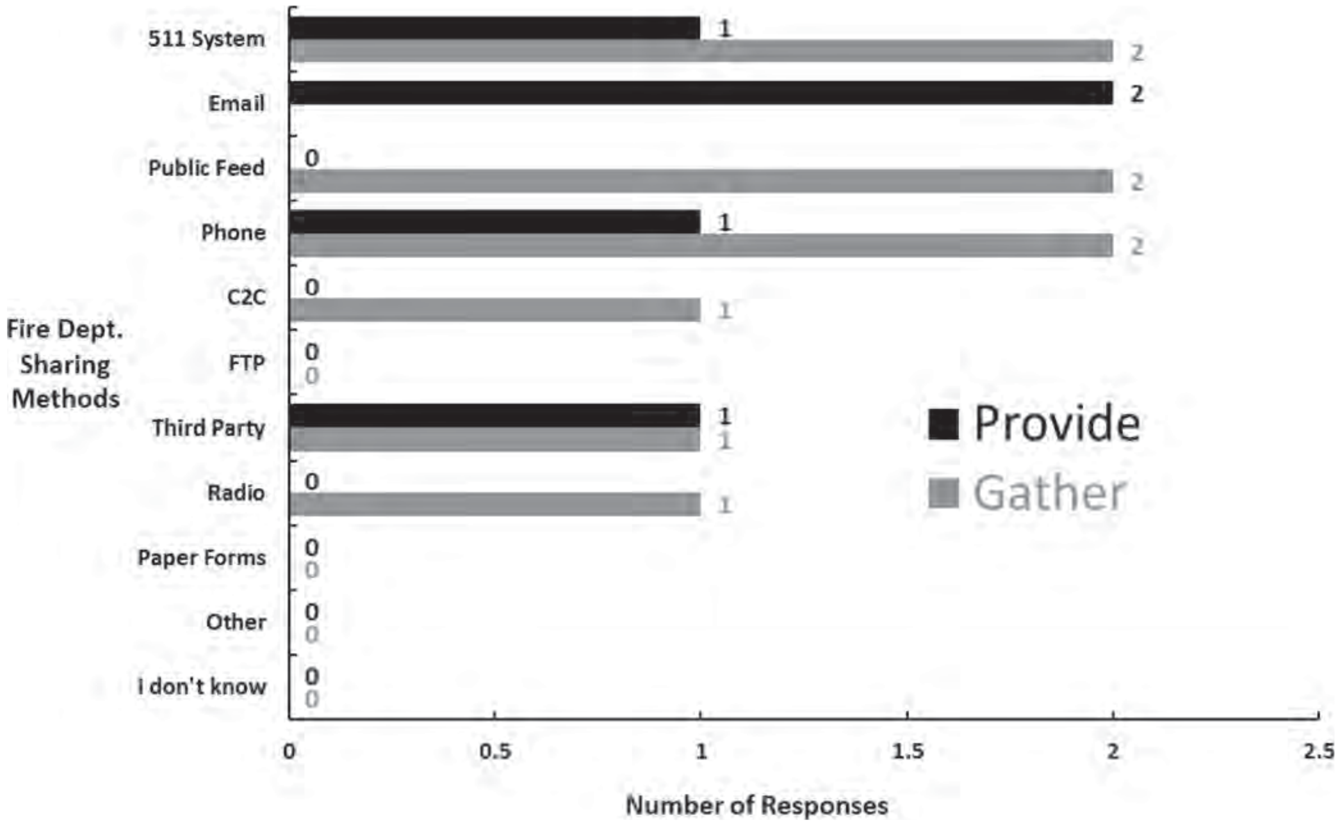


FIGURE D150 Sharing methods utilized by fire departments—3 responses (Questions 5, 14).

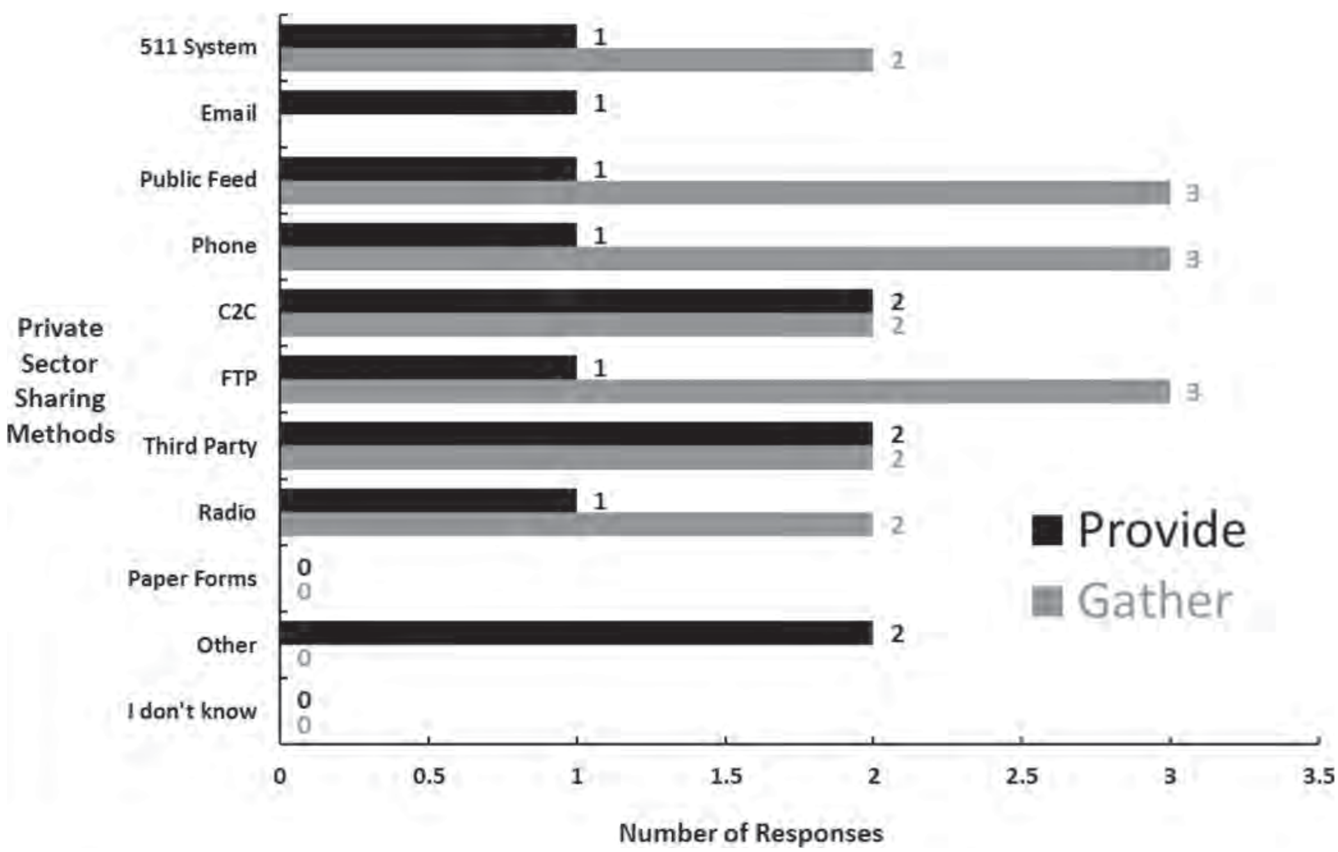


FIGURE D151 Sharing methods utilized by private sector entities—5 responses (Questions 5, 14).

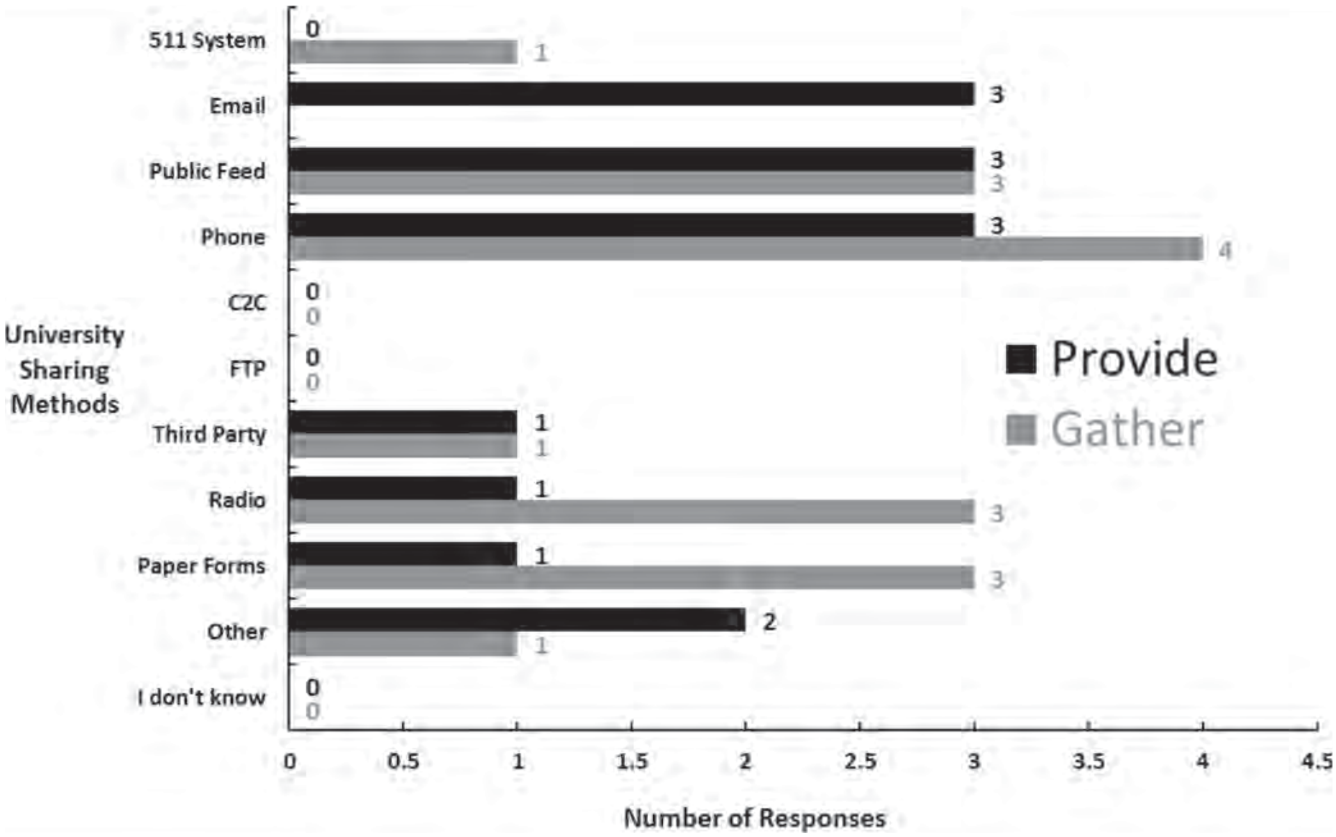


FIGURE D152 Sharing methods utilized by universities—4 responses (Questions 5, 14).

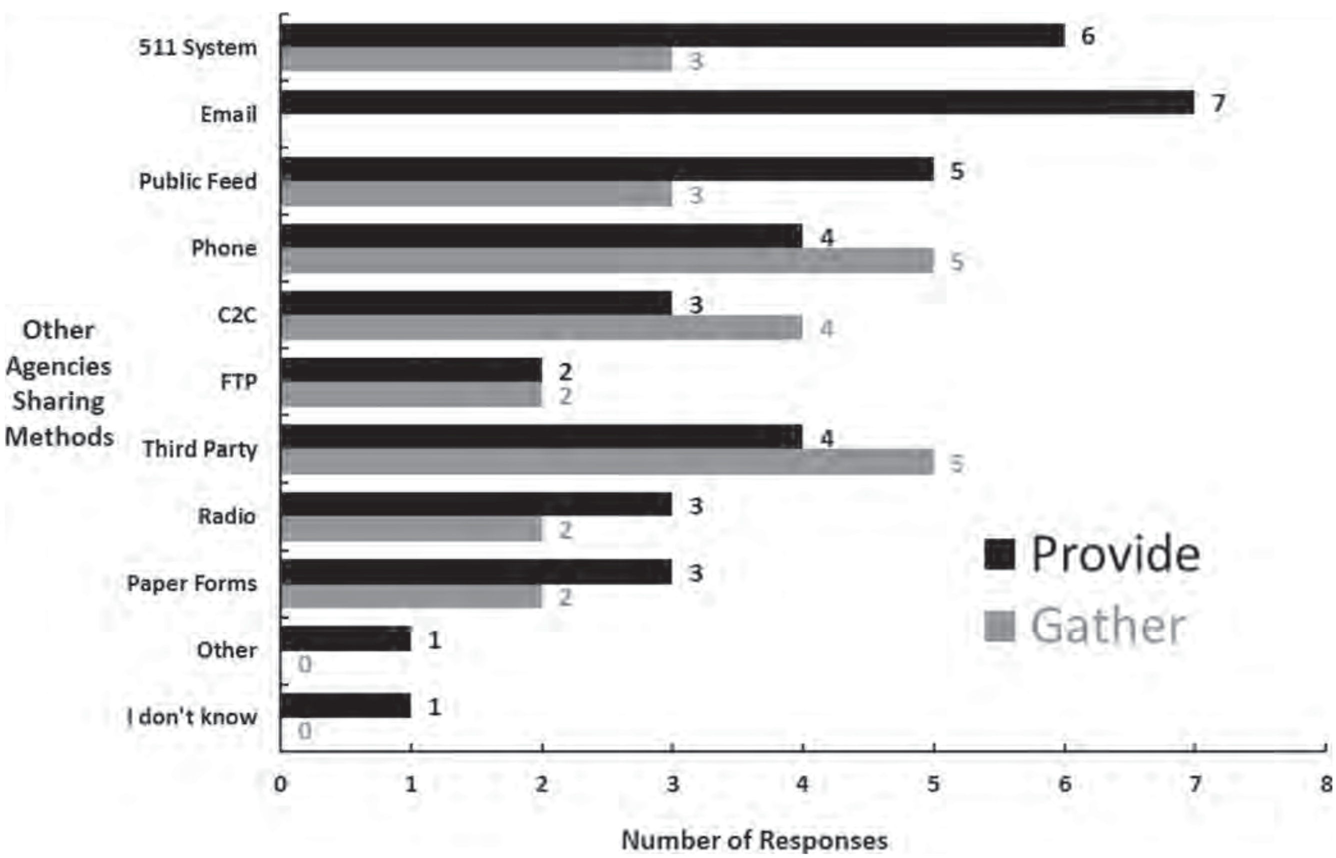


FIGURE D153 Sharing methods utilized by other agencies—12 responses (Questions 5, 14).

LEGAL FRAMEWORKS UNDER WHICH AGENCIES SHARE OPERATIONS DATA (D154–D168)

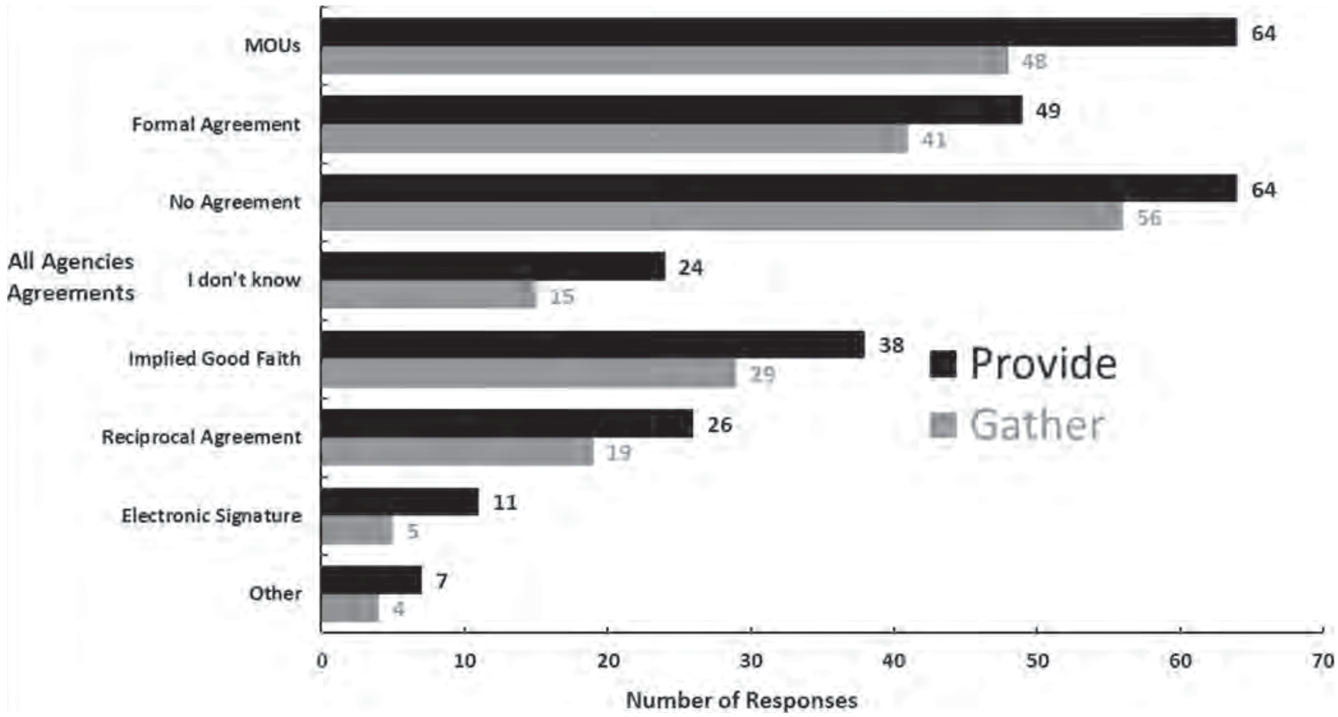


FIGURE D154 Agreements utilized by agencies in general—198 responses (Questions 6, 15).

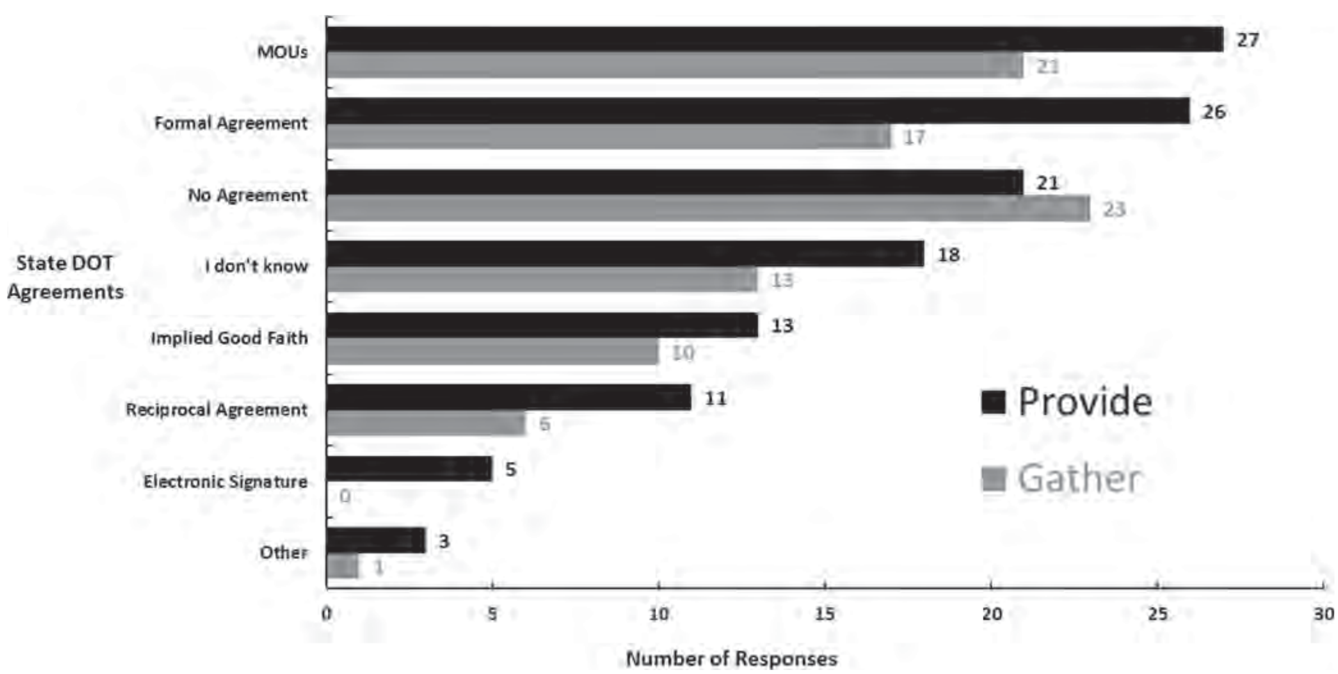


FIGURE D155 Agreements utilized by state DOTs—86 responses (Questions 6, 15).

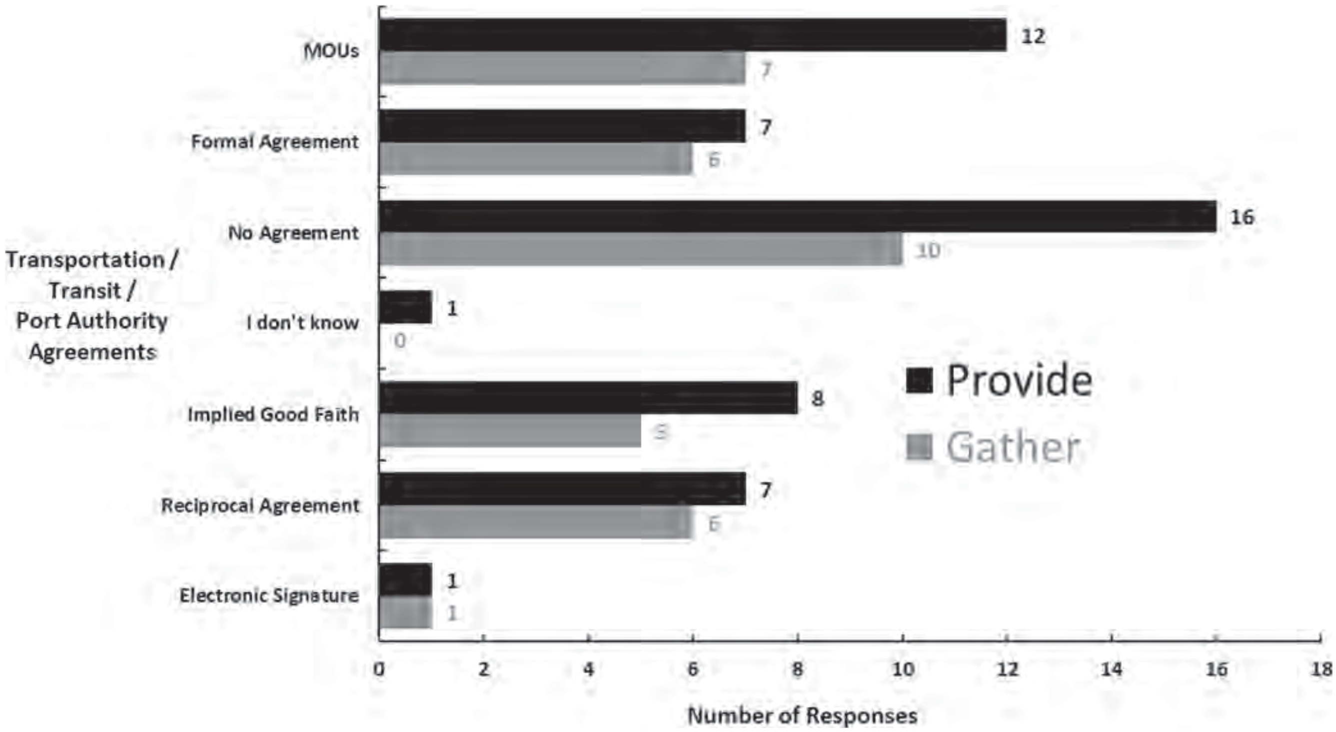


FIGURE D156 Agreements utilized by transportation/transit/port authorities—35 responses (Questions 6, 15).

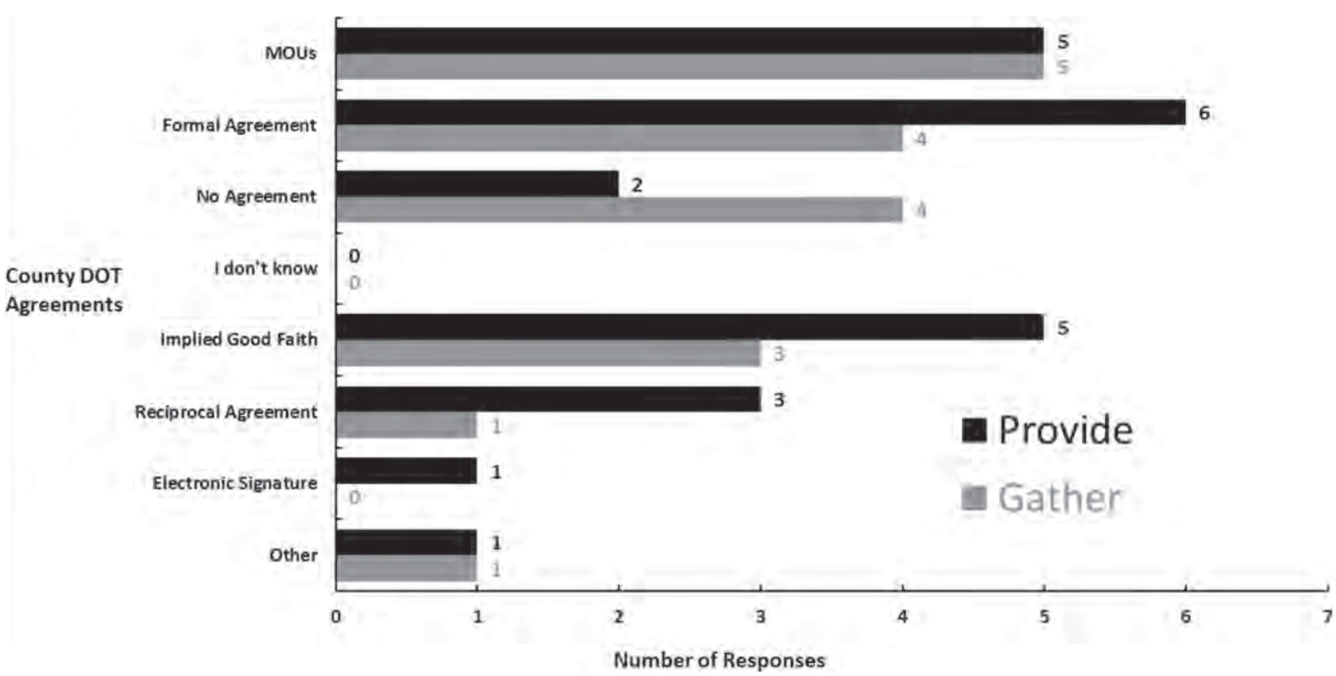


FIGURE D157 Agreements utilized by county DOTs—12 responses (Questions 6, 15).

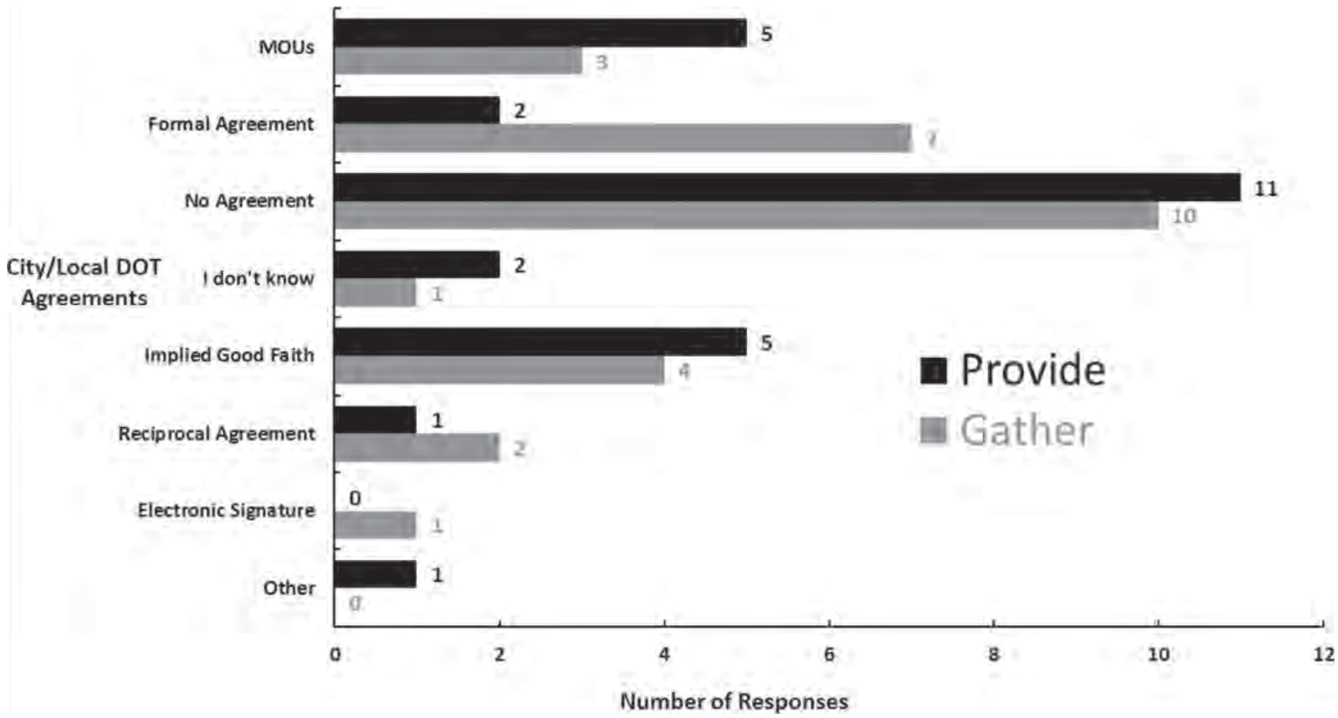


FIGURE D158 Agreements utilized by city and local DOTs—24 responses (Questions 6, 15).

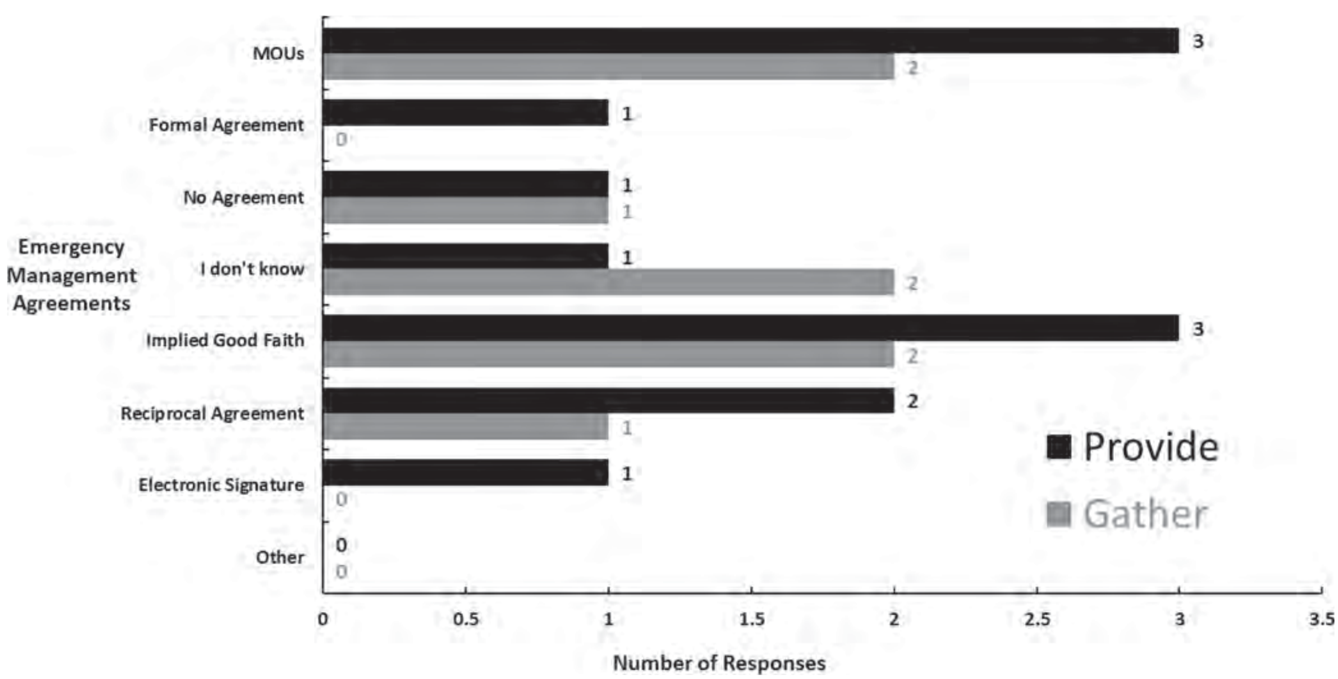


FIGURE D159 Agreements utilized by emergency management agencies—9 responses (Questions 6, 15).

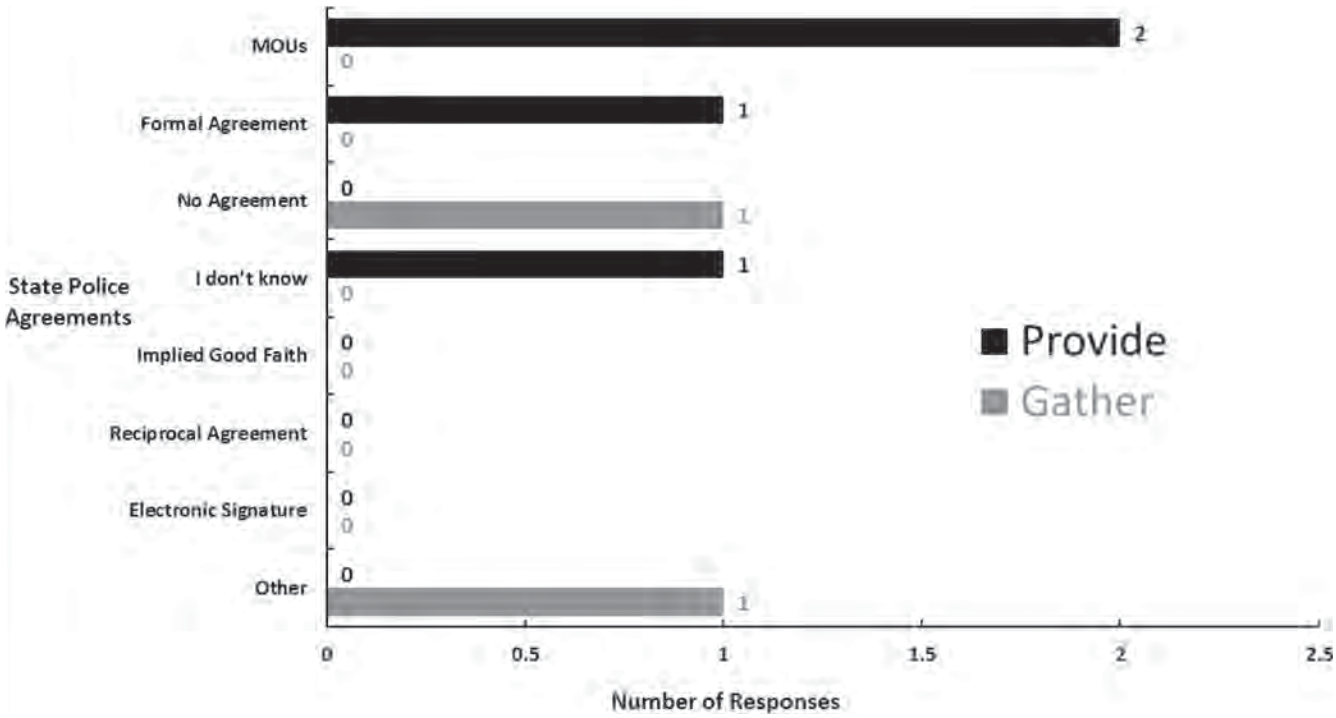


FIGURE D160 Agreements utilized by state police—4 responses (Questions 6, 15).

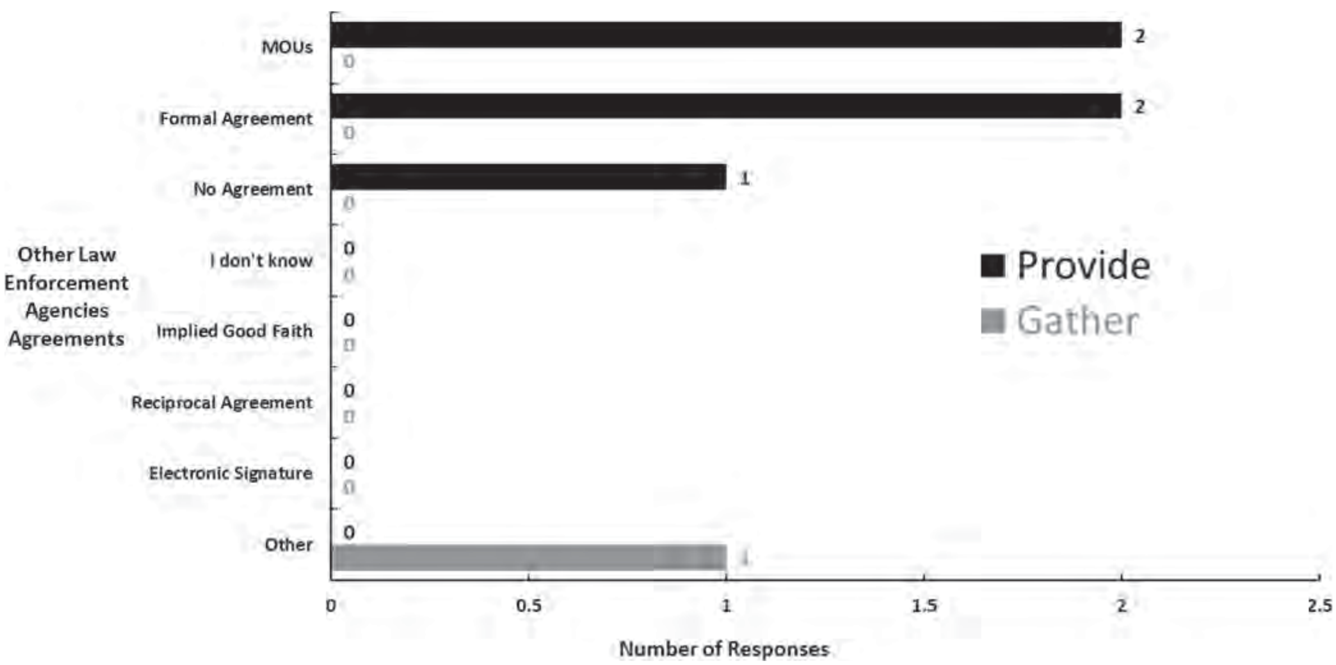


FIGURE D161 Agreements utilized by other law enforcement agencies—3 responses (Questions 6, 15).

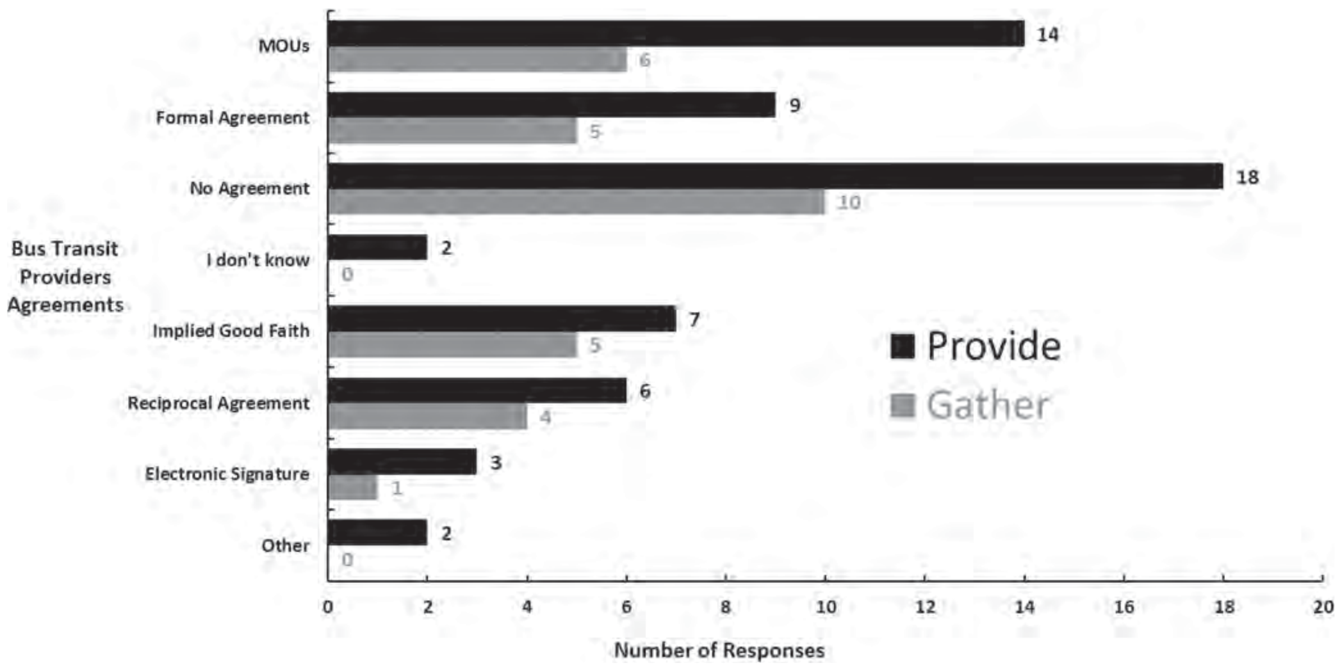


FIGURE D162 Agreements utilized by bus transit providers—40 responses (Questions 6, 15).

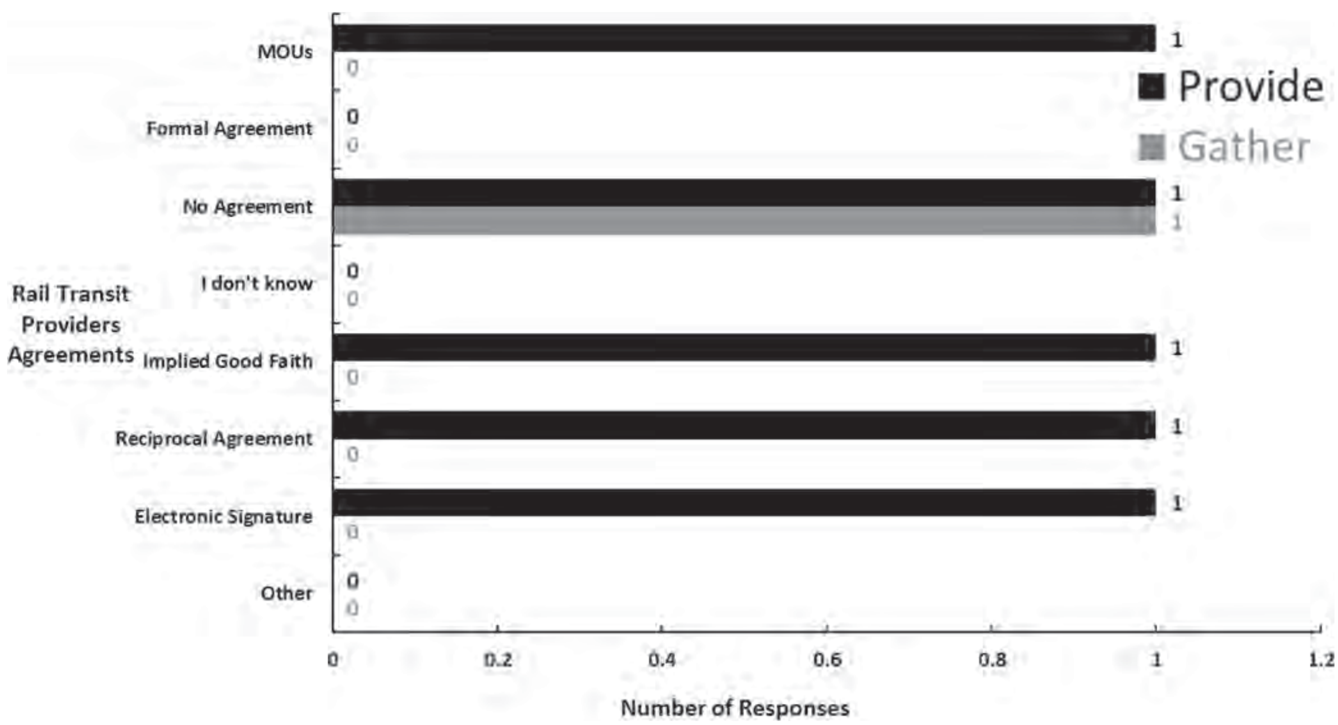


FIGURE D163 Agreements utilized by rail transit providers—3 responses (Questions 6, 15).

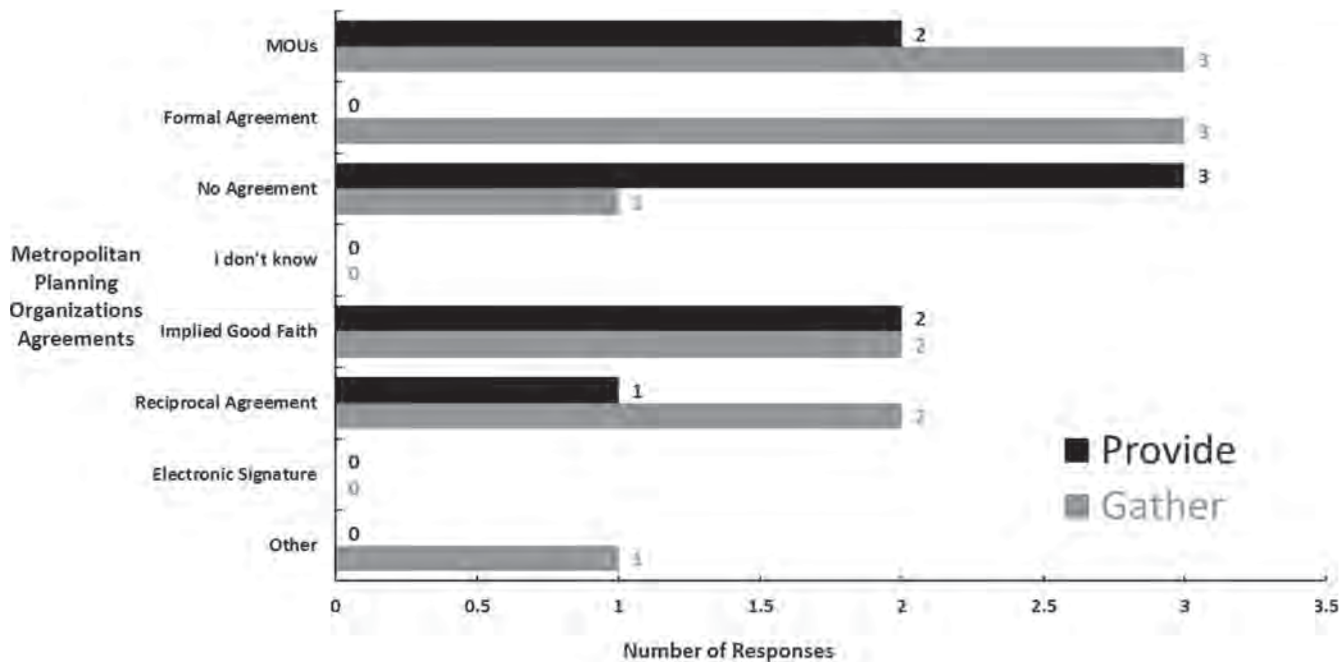


FIGURE D164 Agreements utilized by metropolitan planning organizations—6 responses (Questions 6, 15).

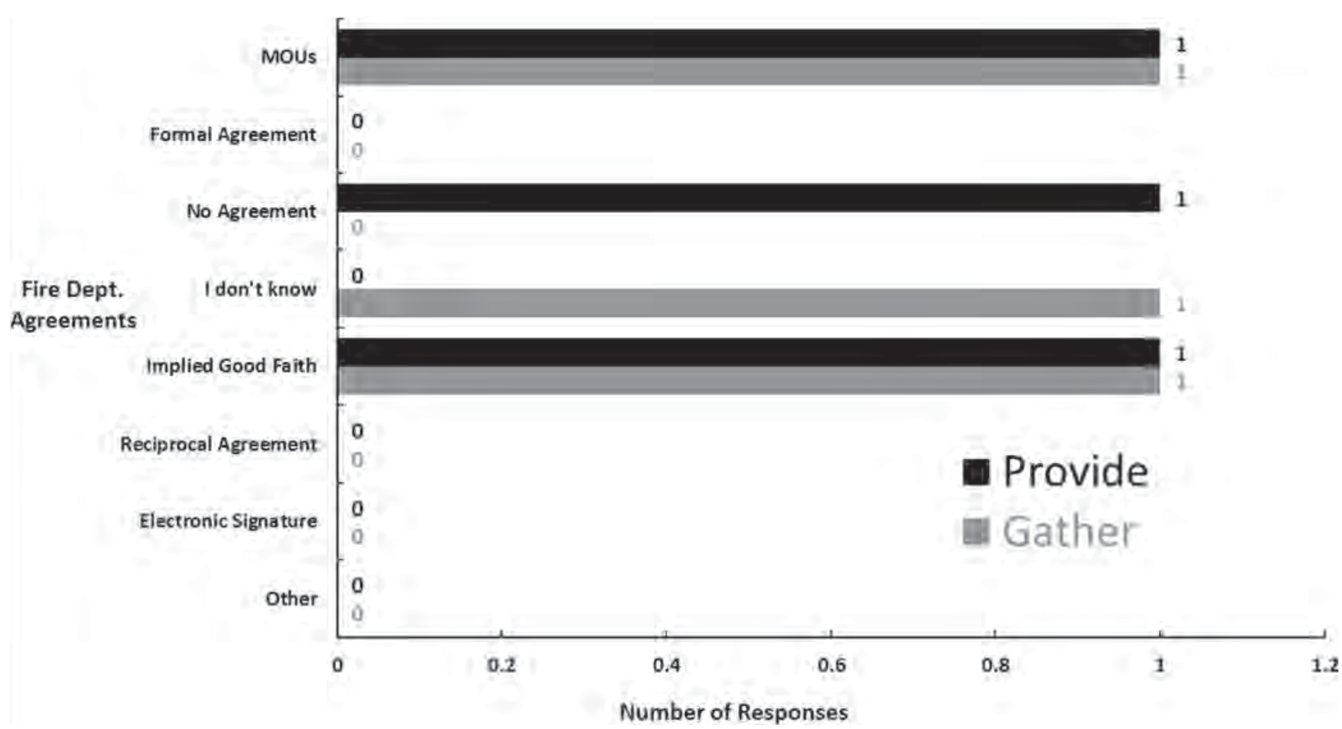


FIGURE D165 Agreements utilized by fire departments—3 responses (Questions 6, 15).

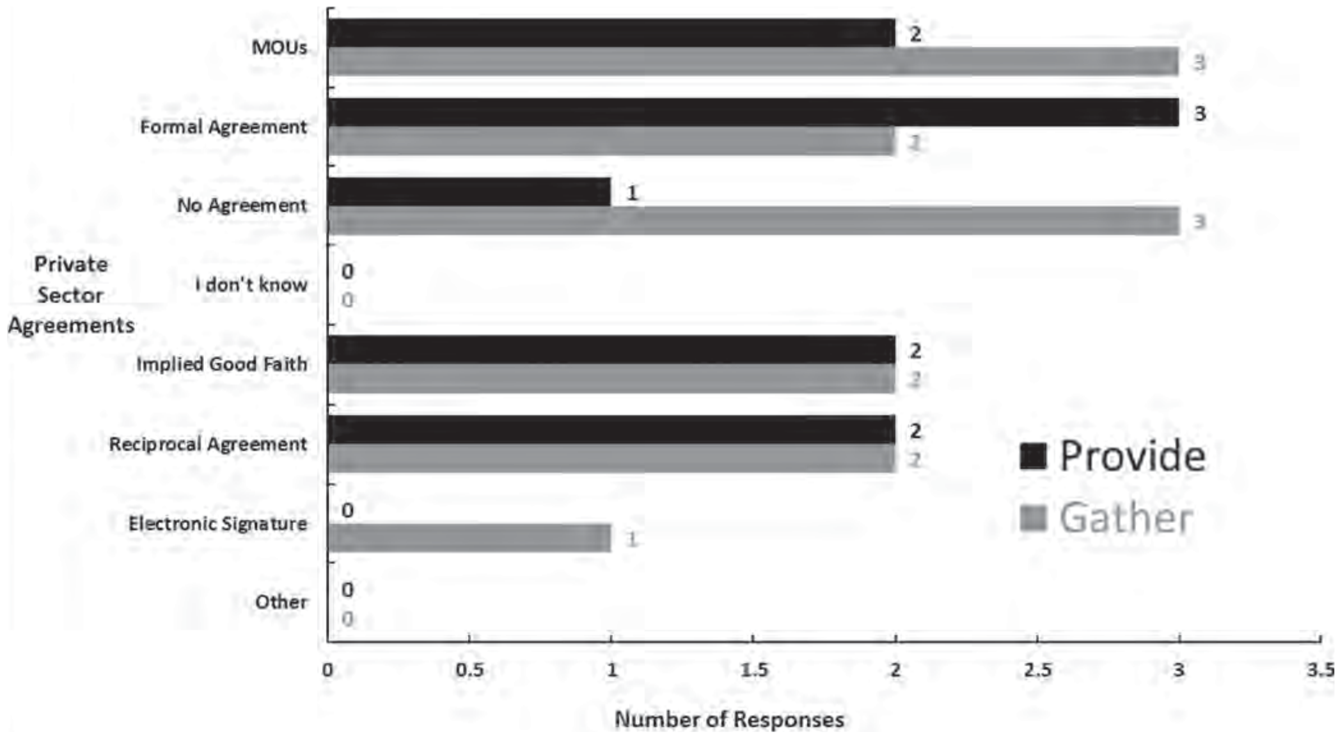


FIGURE D166 Agreements utilized by private sector entities—5 responses (Questions 6, 15).

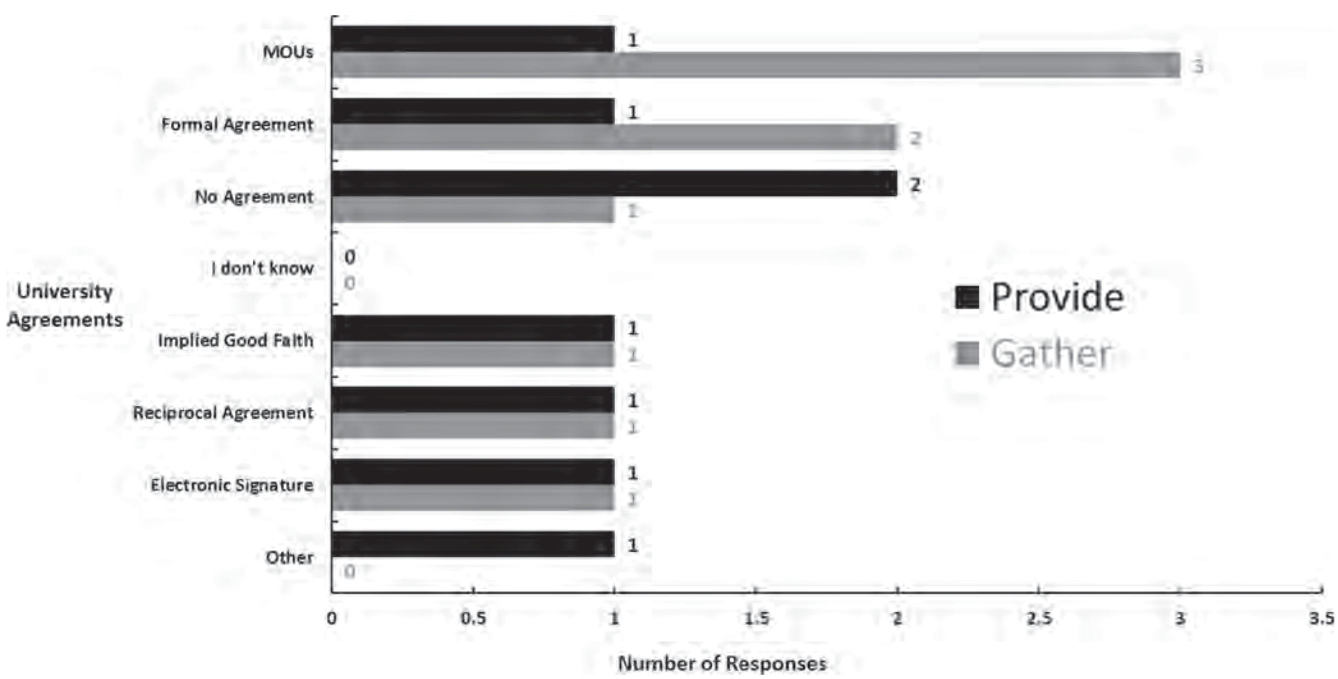


FIGURE D167 Agreements utilized by universities—4 responses (Questions 6, 15).

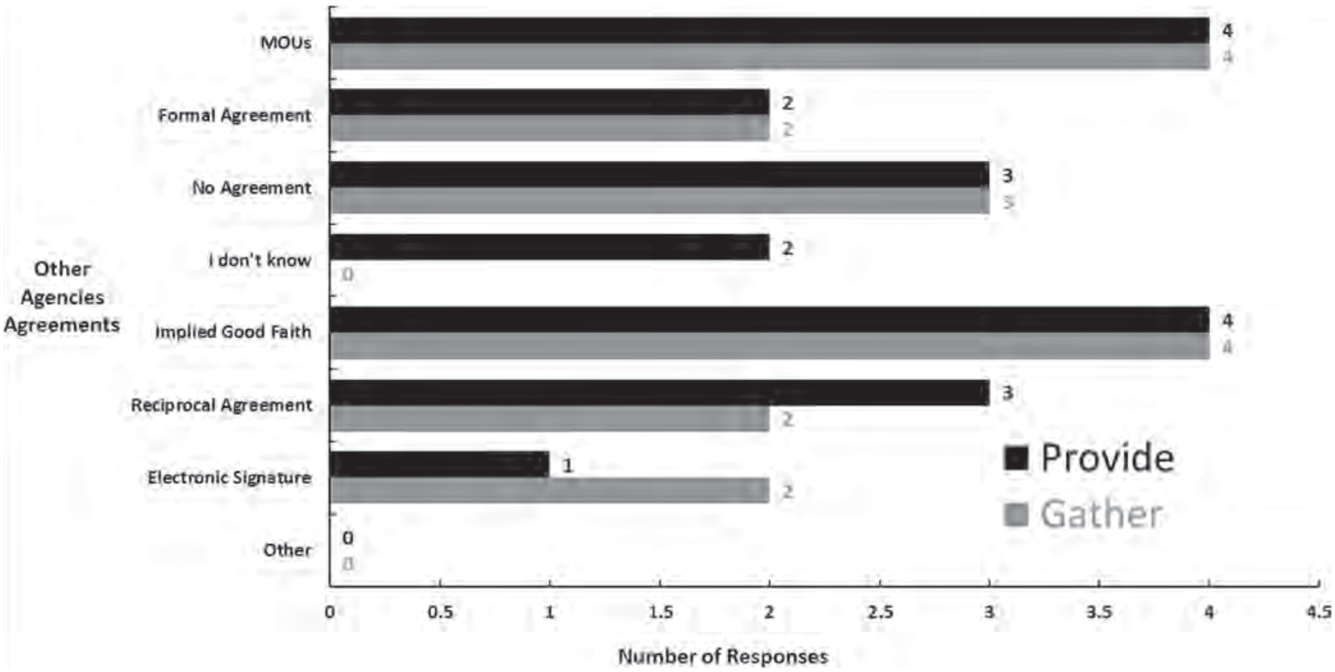


FIGURE D168 Agreements utilized by other agencies—12 responses (Questions 6, 15).

OPERATIONS DATA SHARING FREQUENCIES (D169–D183)

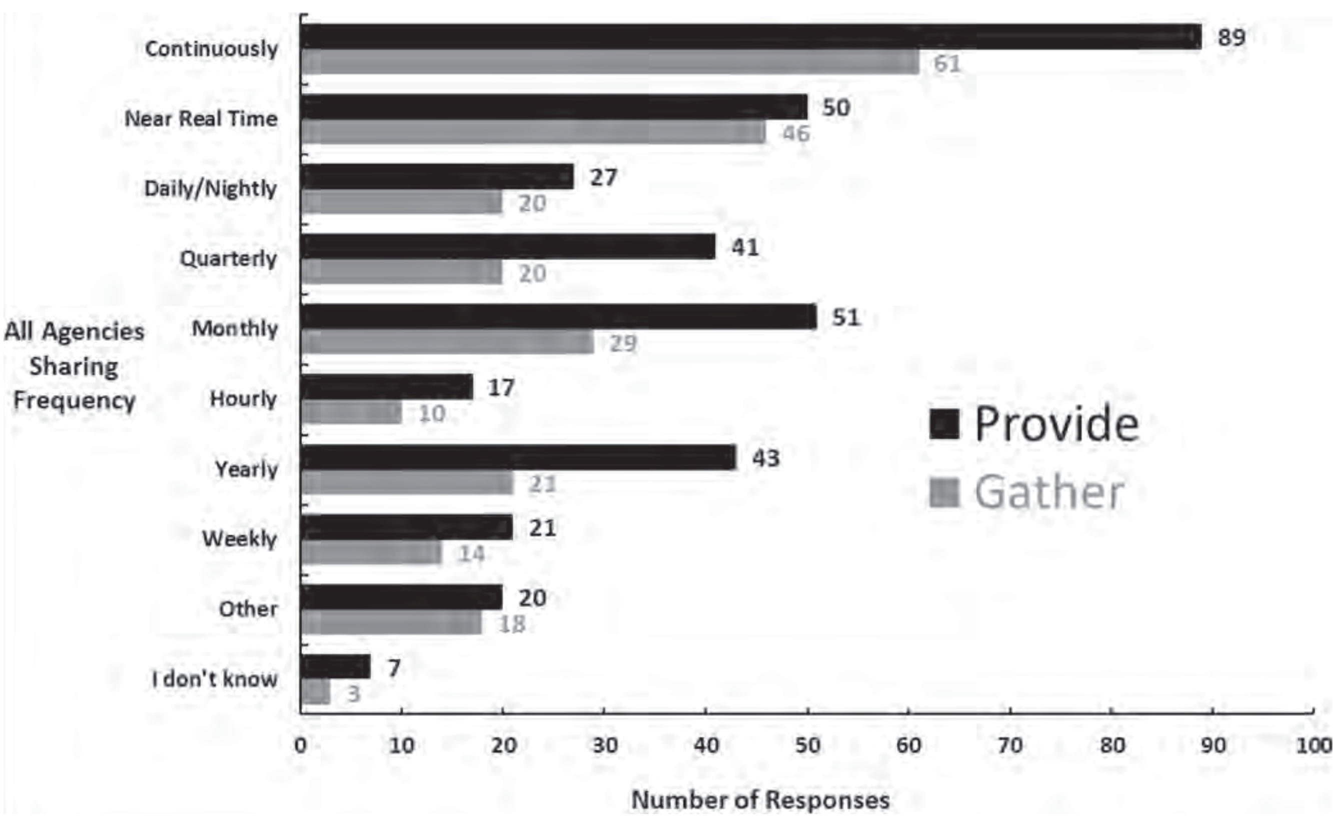


FIGURE D169 Agencies data sharing frequency in general—198 responses (Questions 7, 16).

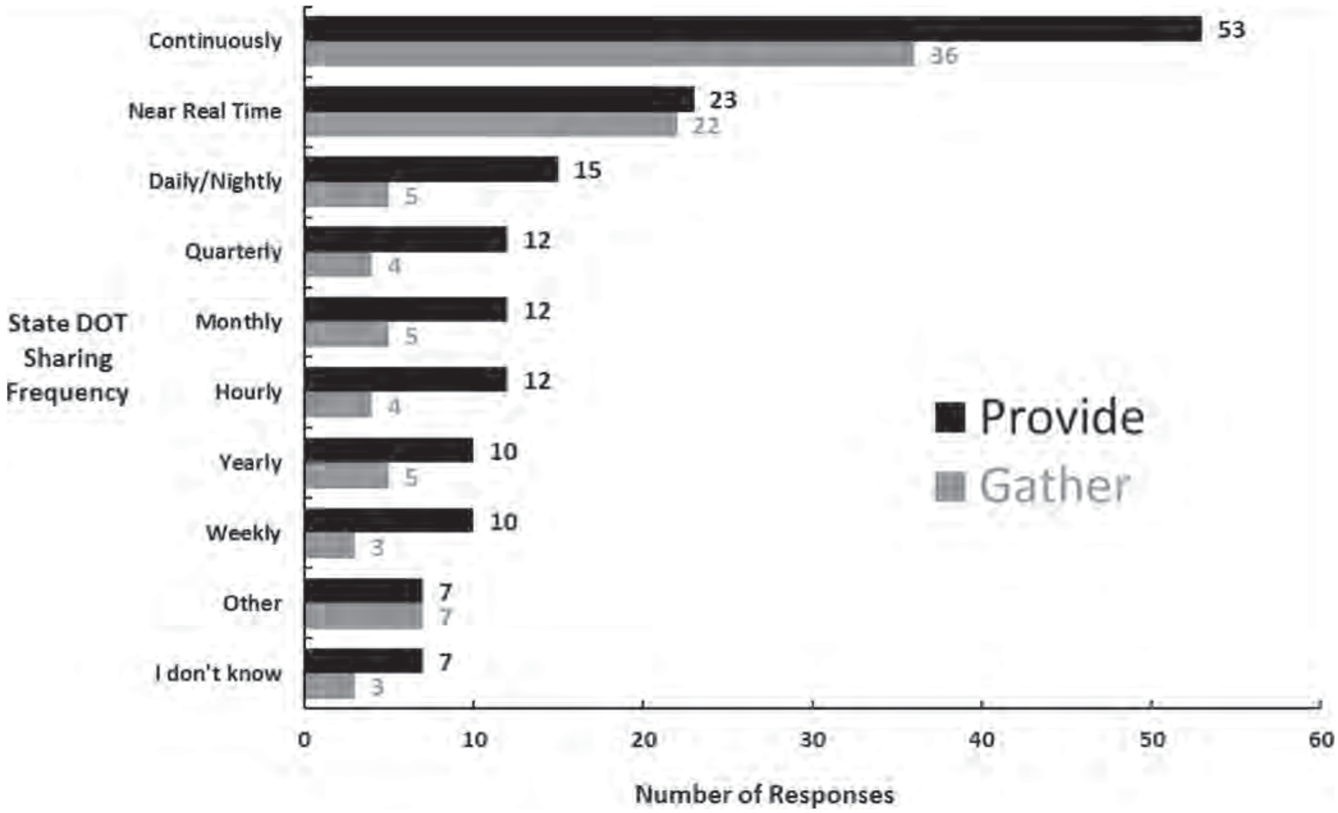


FIGURE D170 State DOTs data sharing frequency—86 responses (Questions 7, 16).

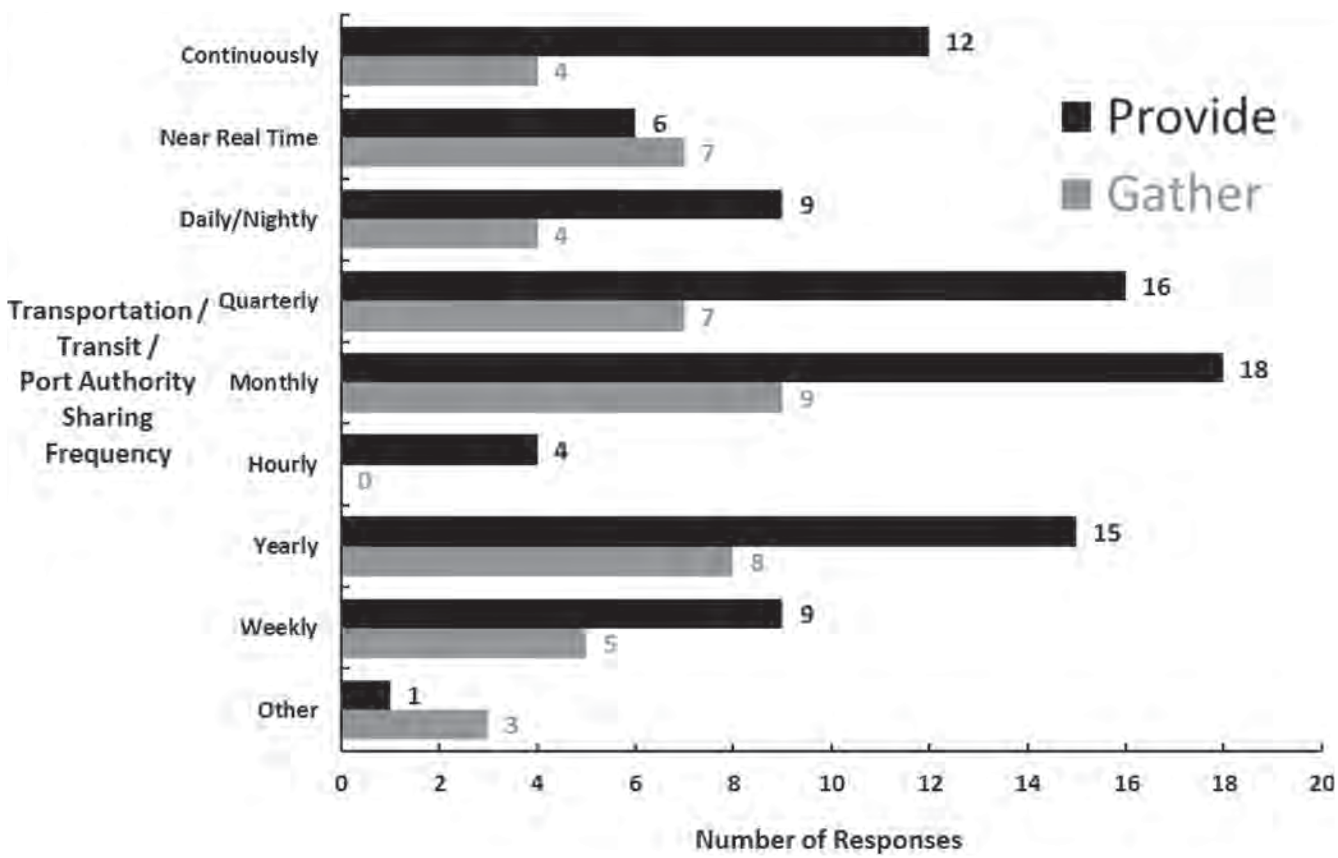


FIGURE D171 Transportation/transit/port authorities data sharing frequency—35 responses (Questions 7, 16).

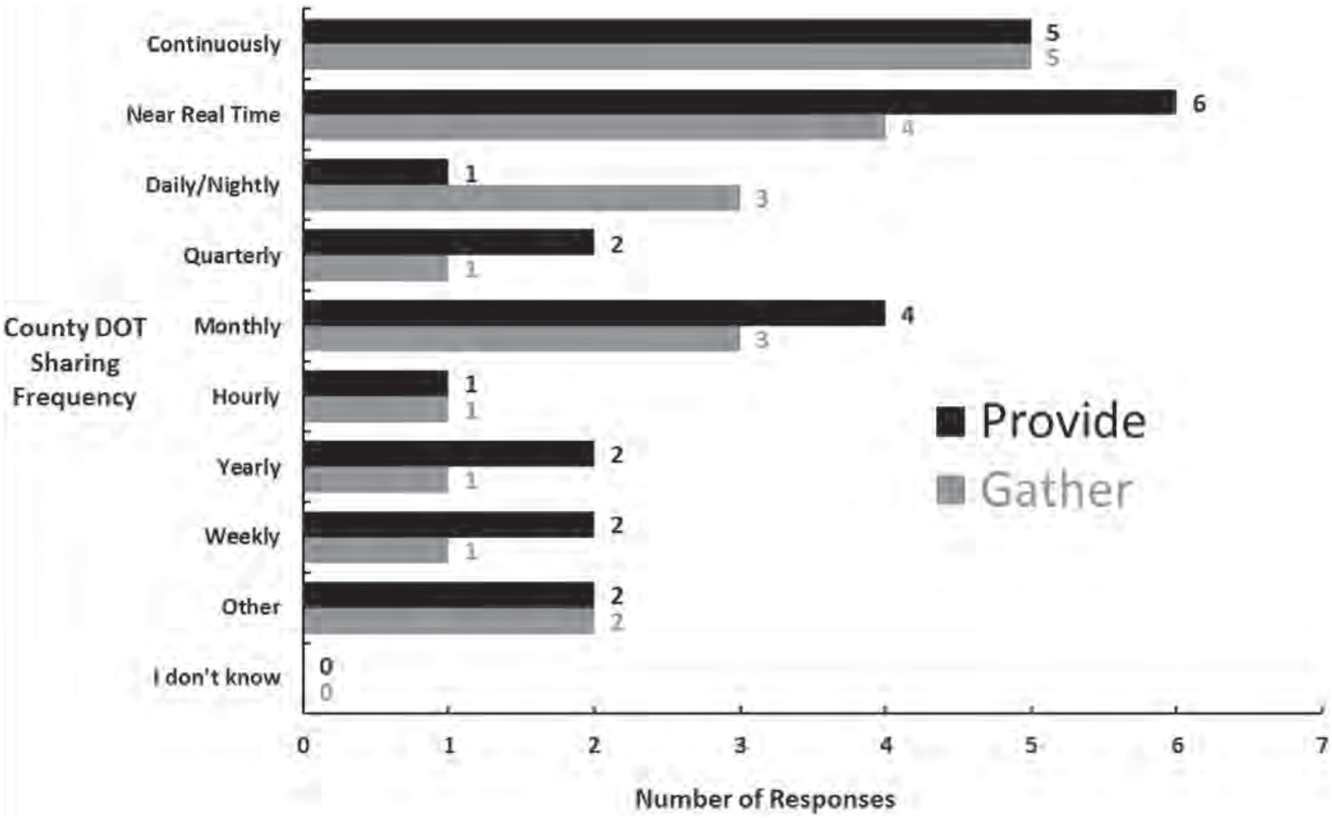


FIGURE D172 County DOTs data sharing frequency—12 responses (Questions 7, 16).

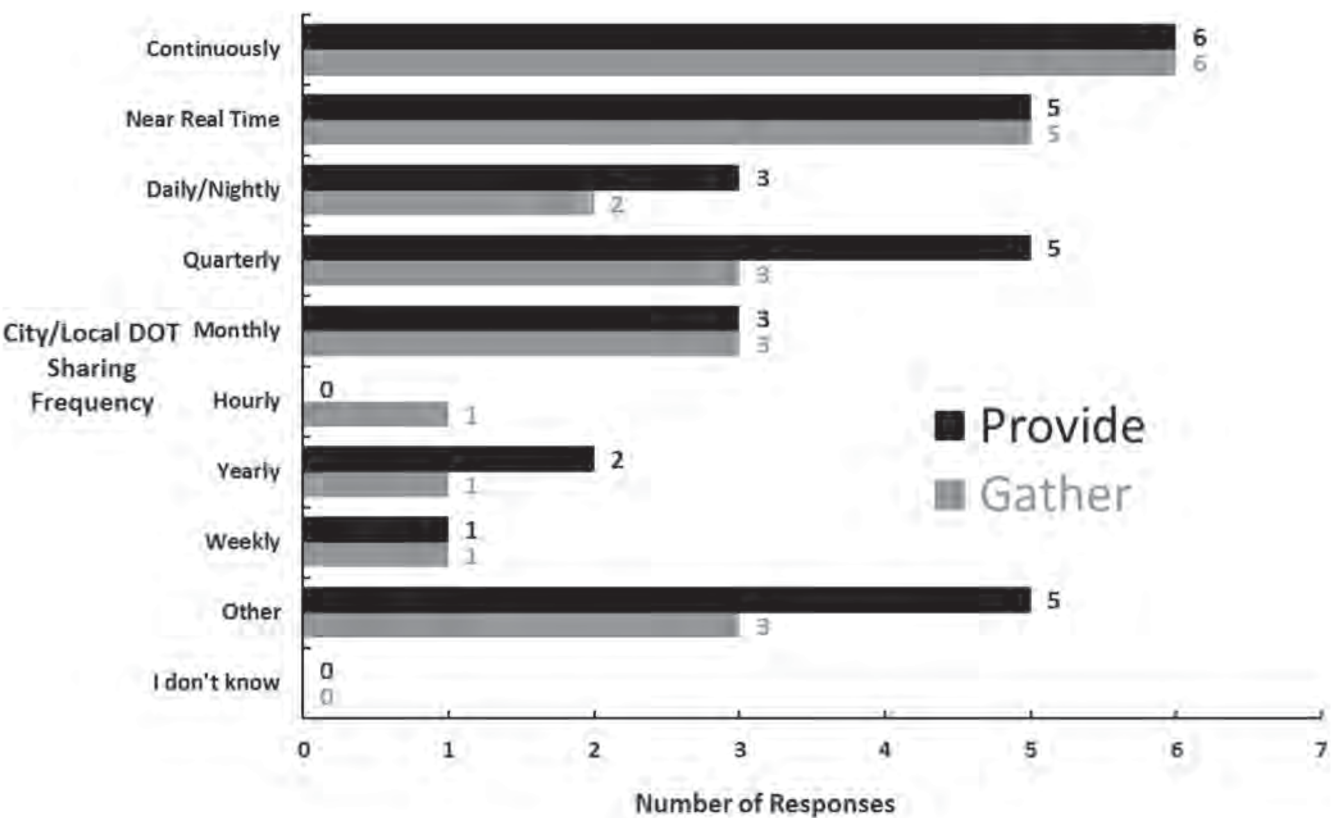


FIGURE D173 City and local DOTs data sharing frequency—24 responses (Questions 7, 16).

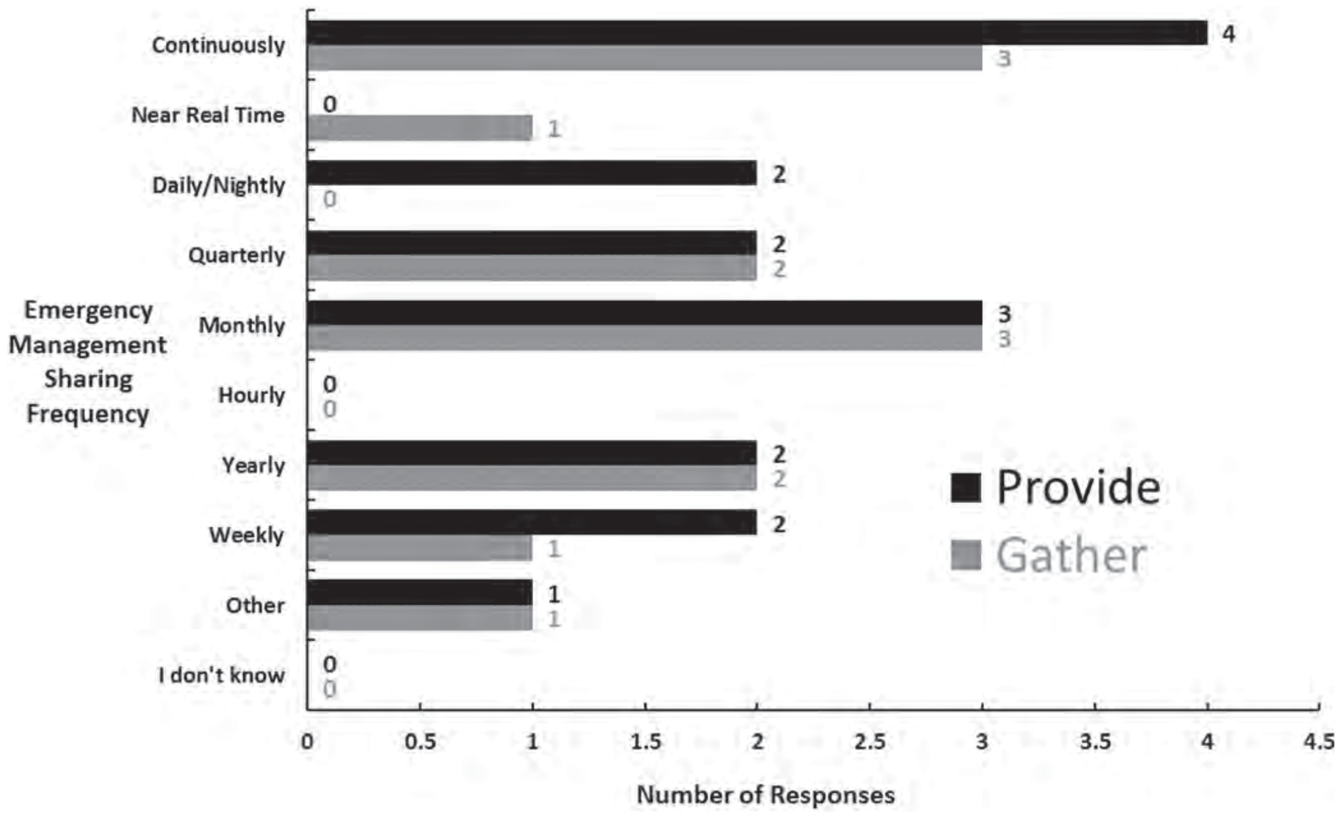


FIGURE D174 Emergency management agencies data sharing frequency—9 responses (Questions 7, 16).

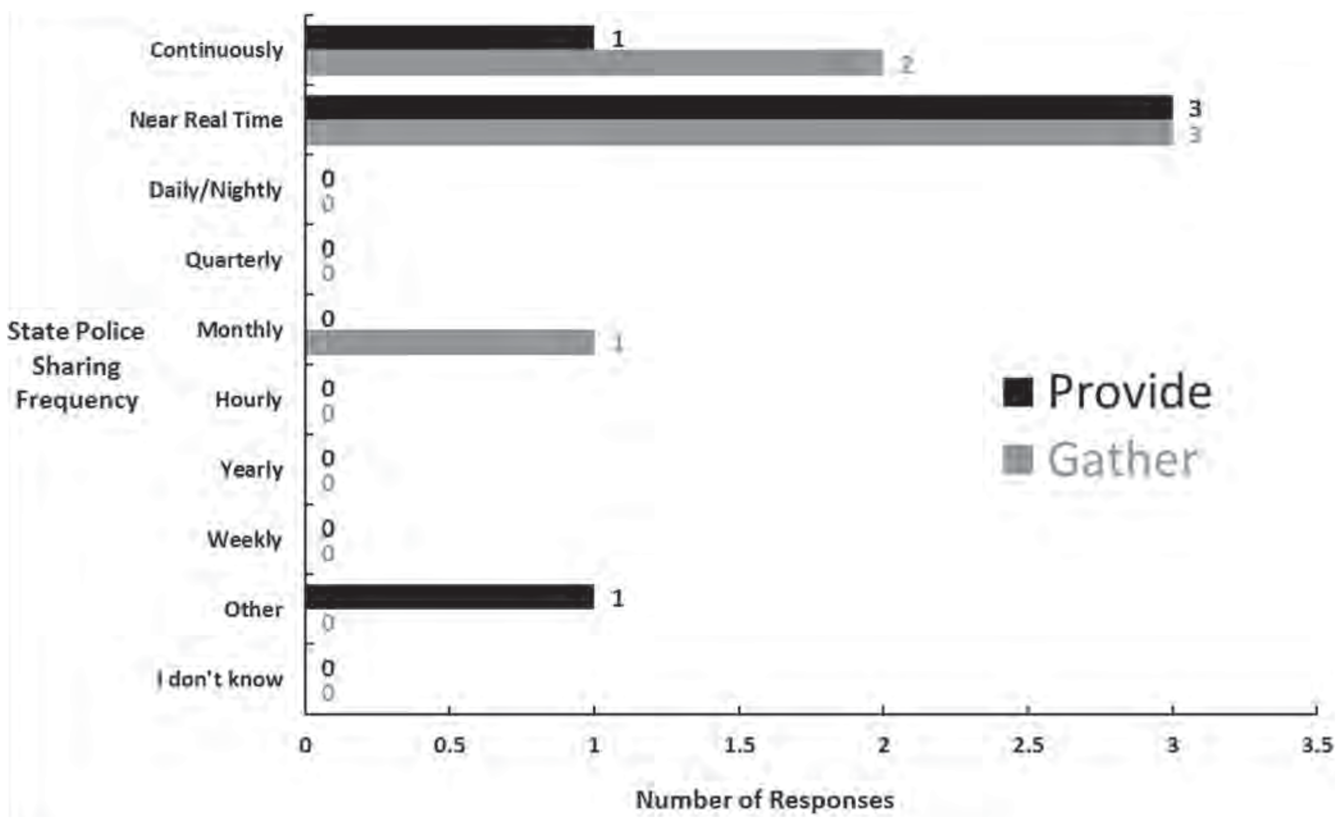


FIGURE D175 State police data sharing frequency—4 responses (Questions 7, 16).

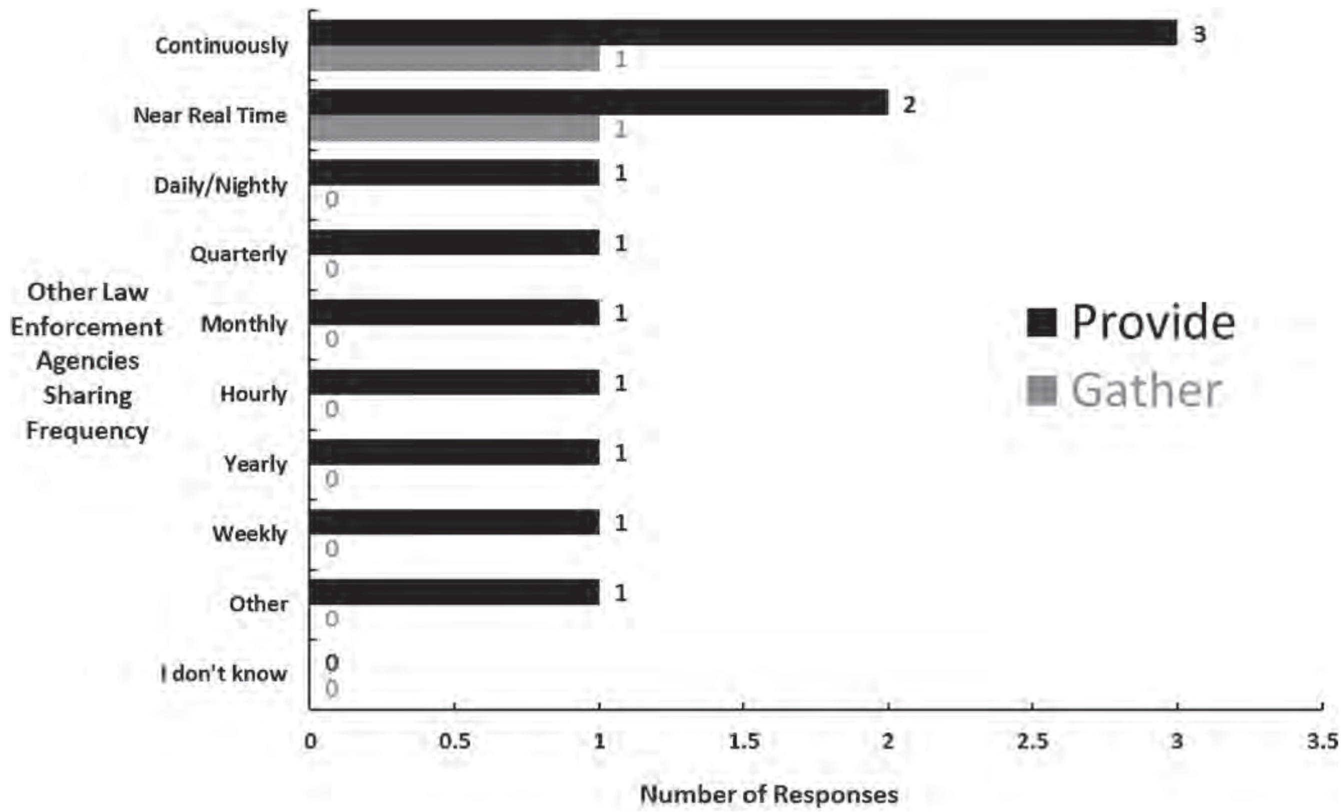


FIGURE D176 Other law enforcement agencies data sharing frequency—3 responses (Questions 7, 16).

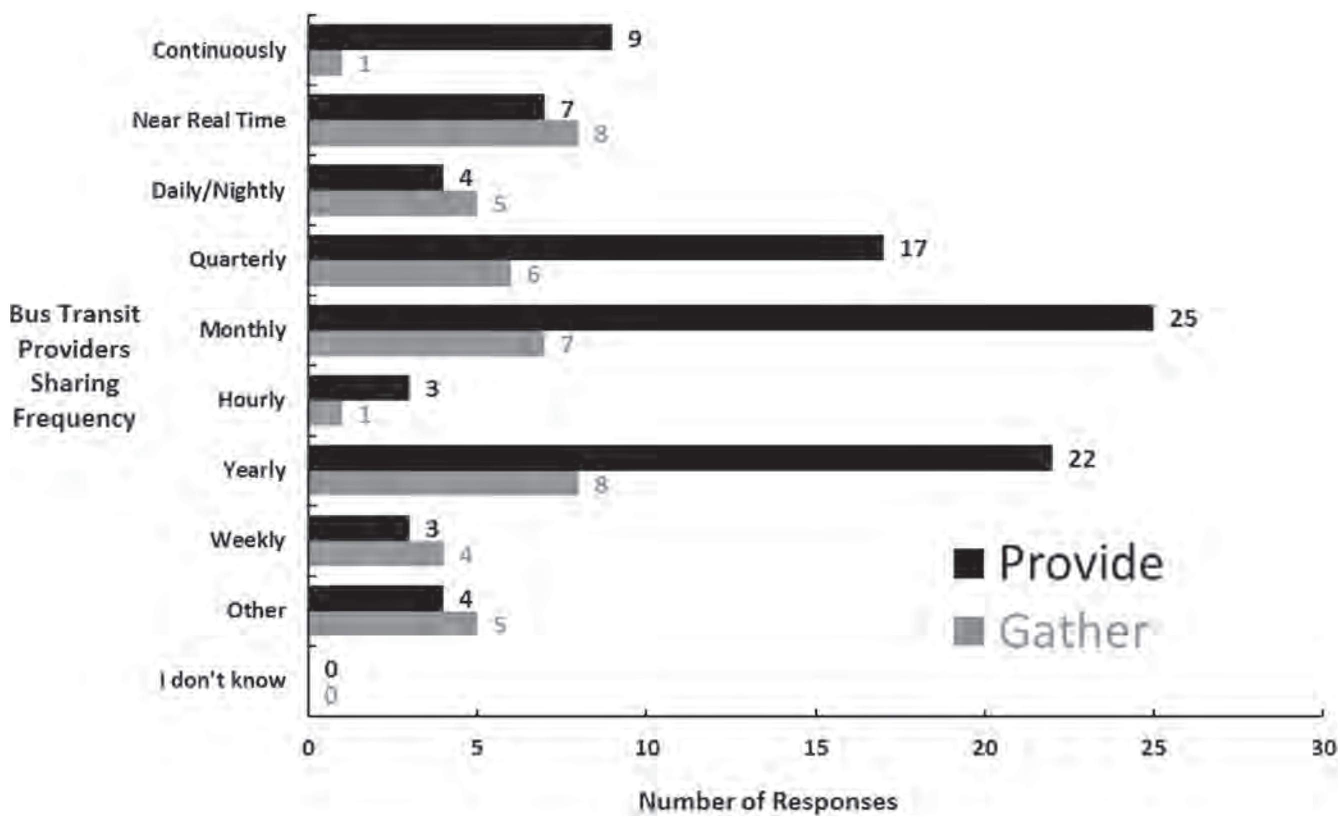


FIGURE D177 Bus transit providers data sharing frequency—40 responses (Questions 7, 16).

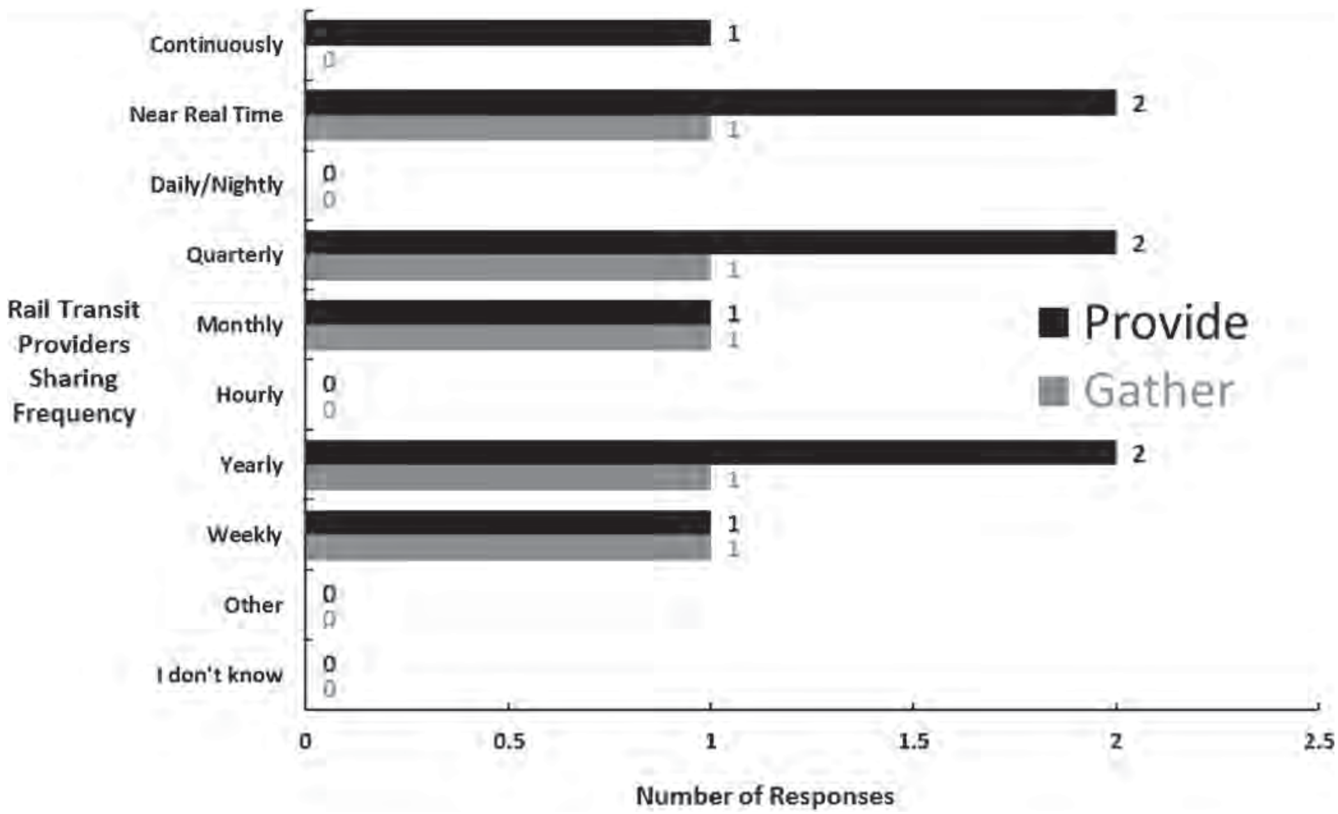


FIGURE D178 Rail transit providers data sharing frequency—3 responses (Questions 7, 16).

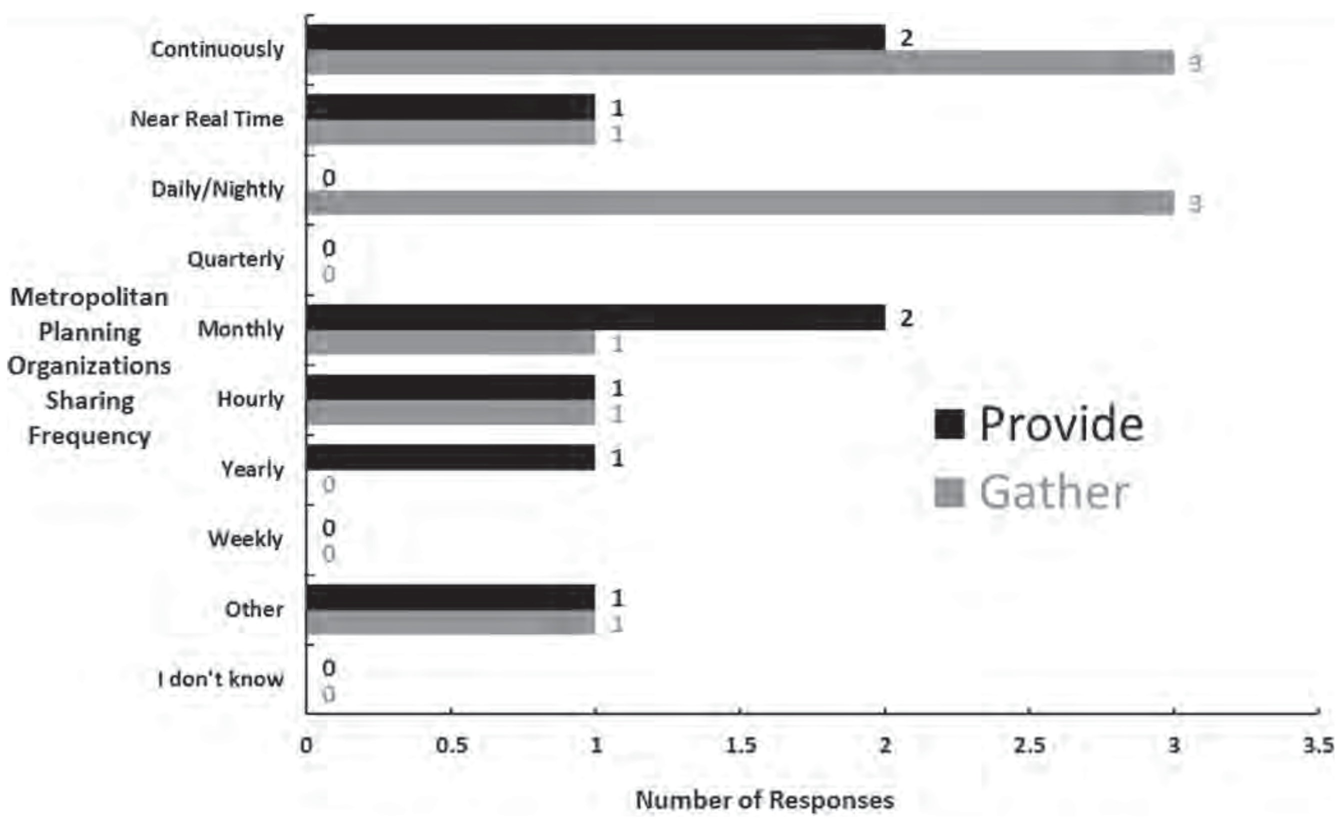


FIGURE D179 Metropolitan planning organizations data sharing frequency—6 responses (Questions 7, 16).

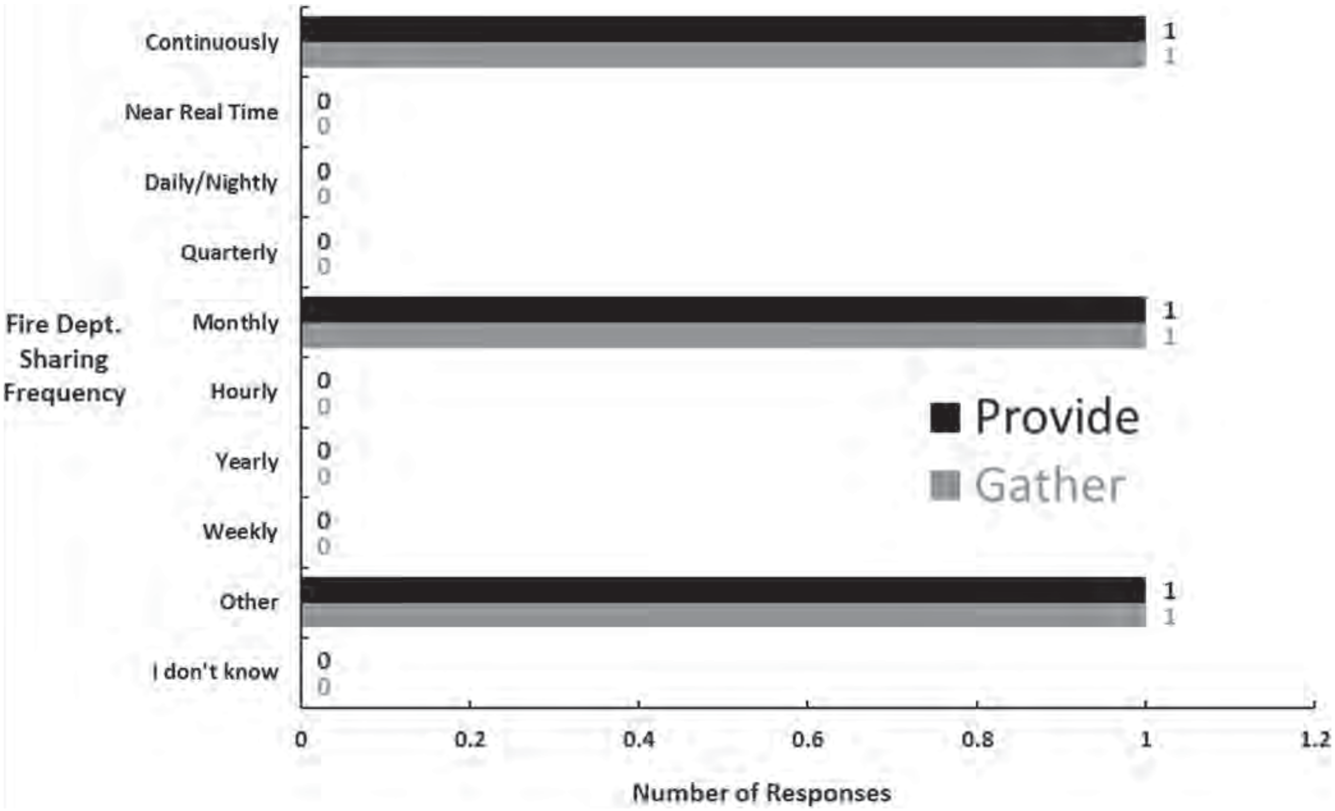


FIGURE D180 Fire departments data sharing frequency—3 responses (Questions 7, 16).

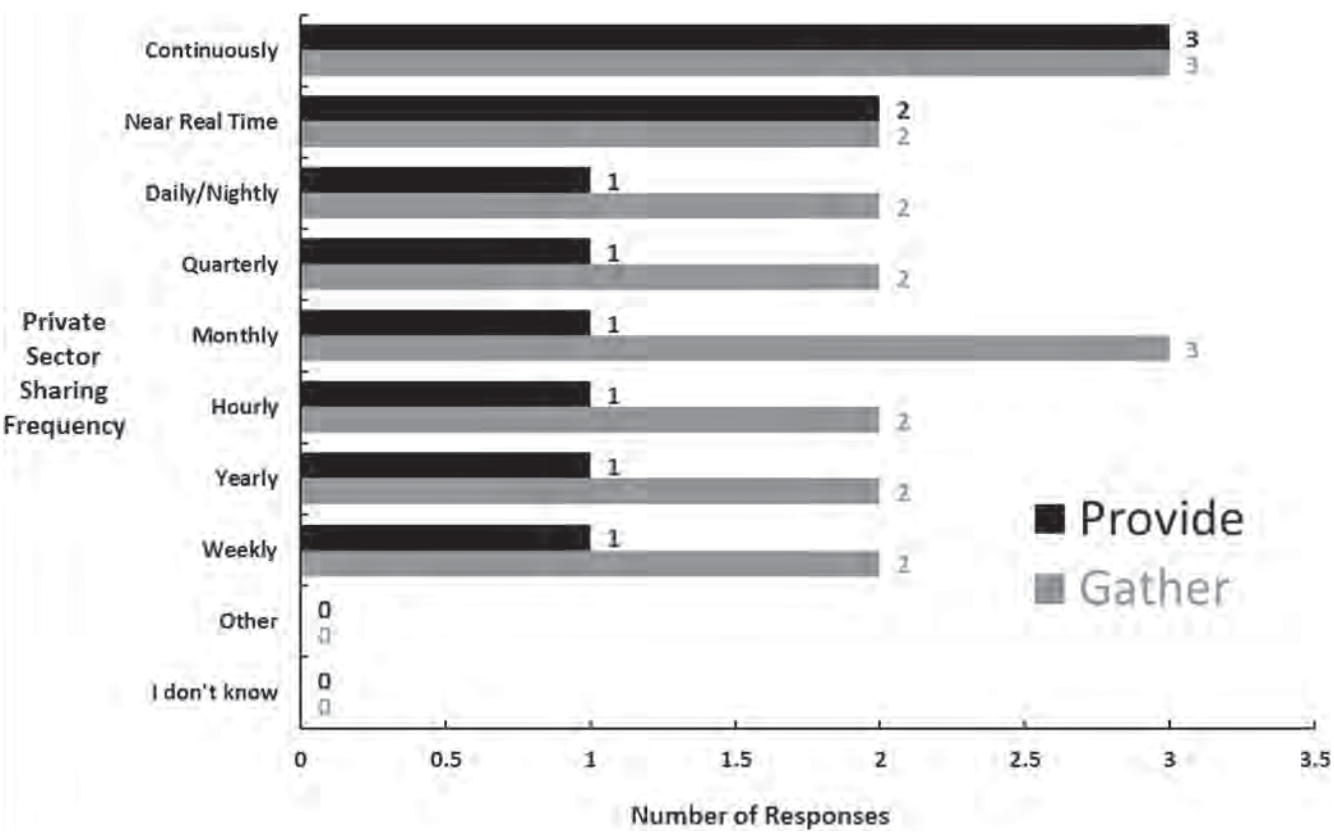


FIGURE D181 Private sector entities data sharing frequency—5 responses (Questions 7, 16).

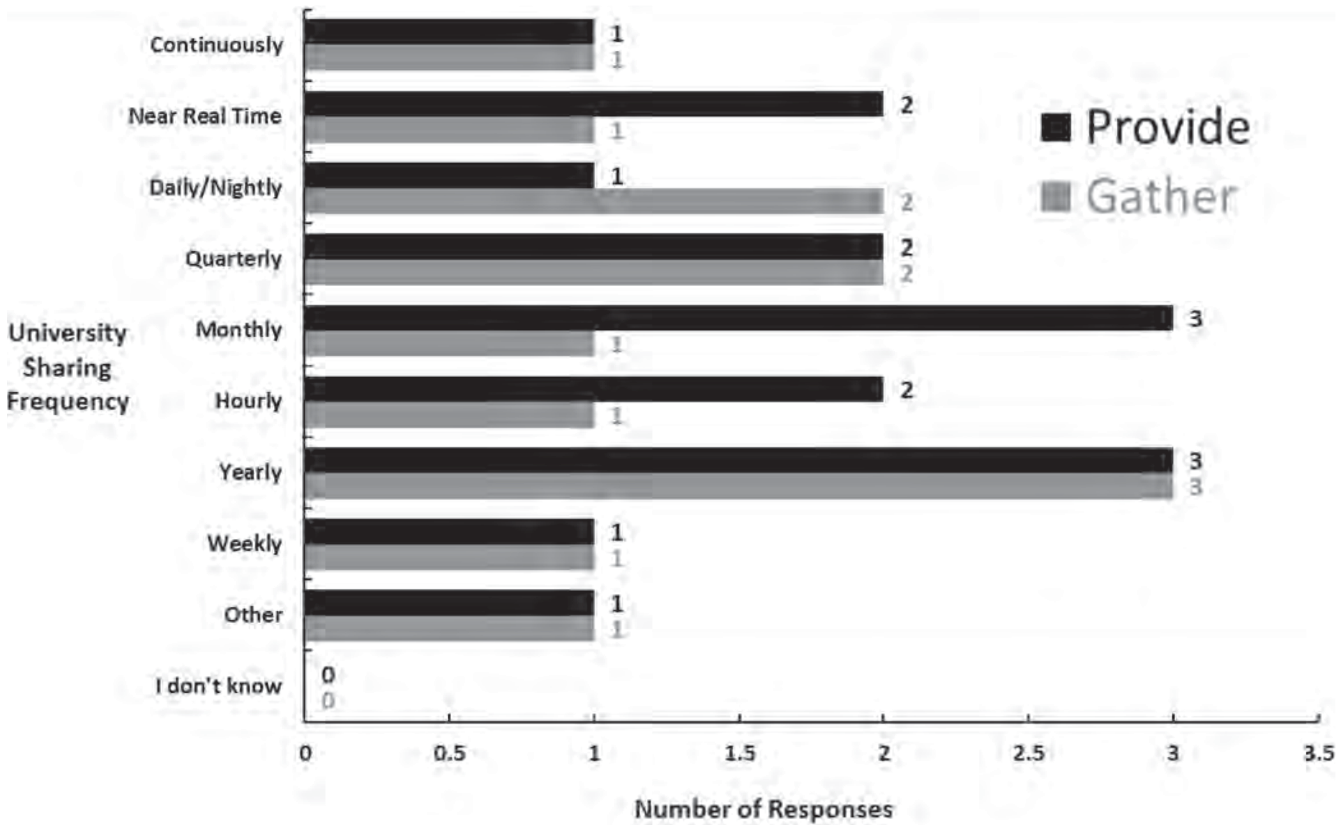


FIGURE D182 Universities data sharing frequency—4 responses (Questions 7, 16).

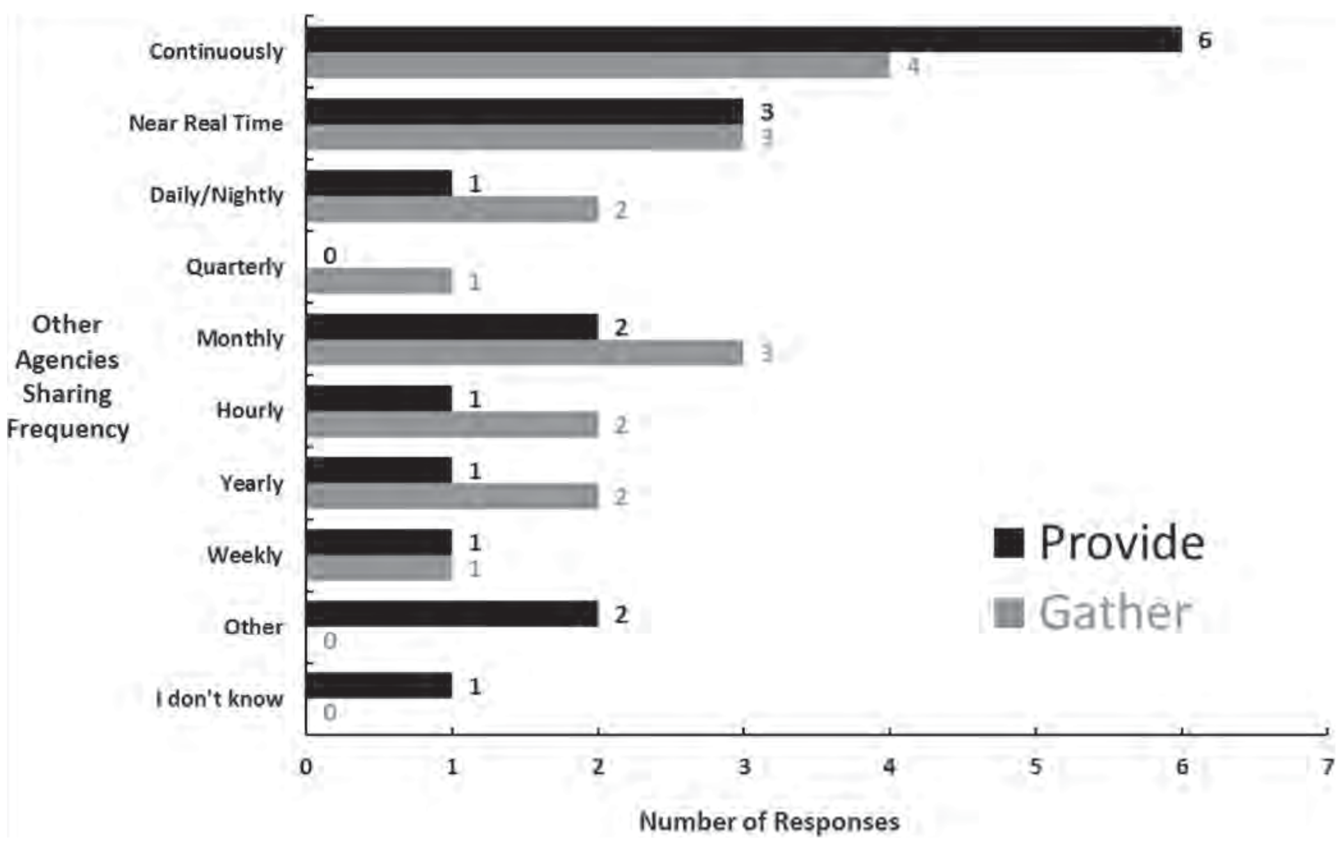


FIGURE D183 Other agencies data sharing frequency—12 responses (Questions 7, 16).

WHY DO AGENCIES SHARE OPERATIONS DATA (D184–D198)

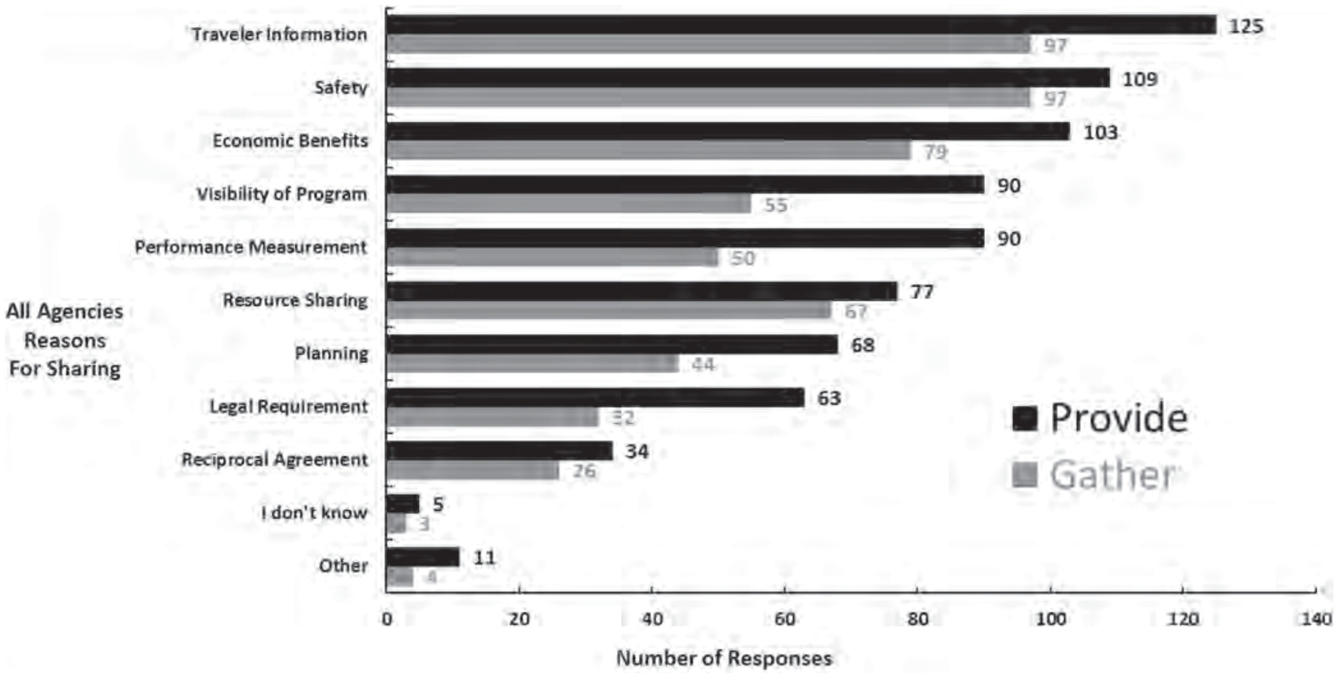


FIGURE D184 Reasons for sharing by agencies in general—198 responses (Questions 9, 18).

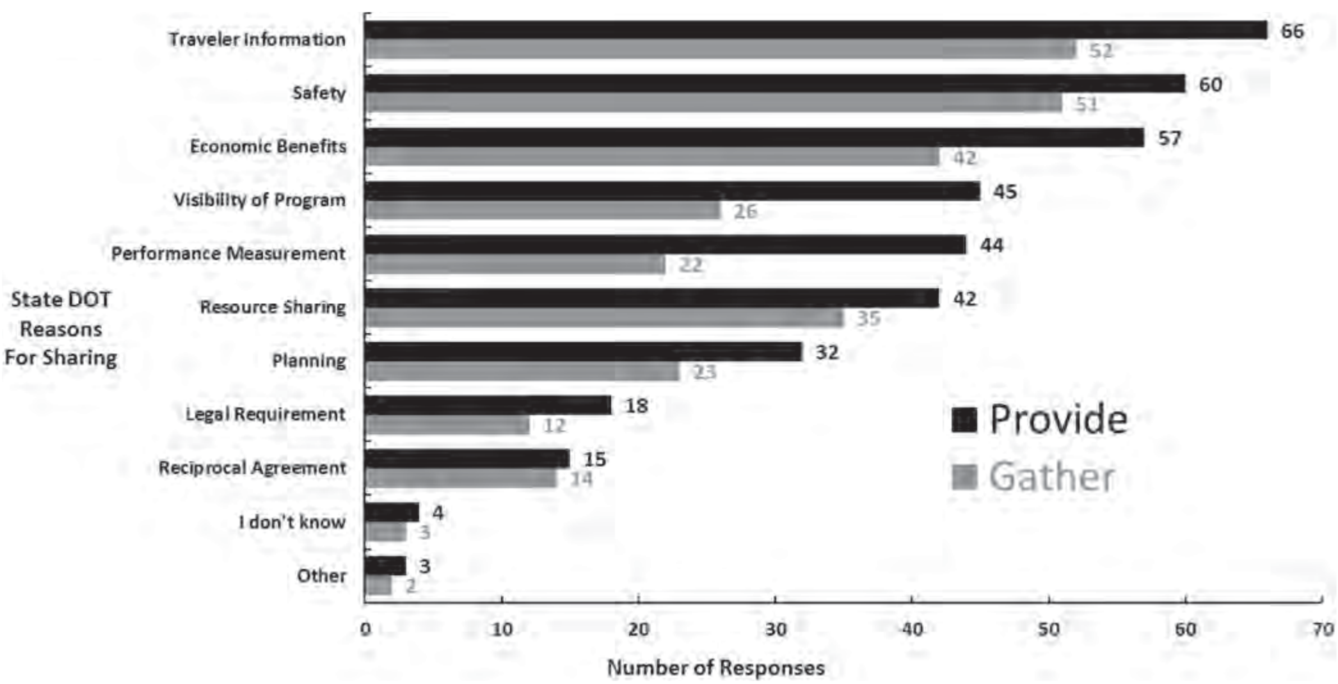


FIGURE D185 State DOTs reasons for sharing—86 responses (Questions 9, 18).

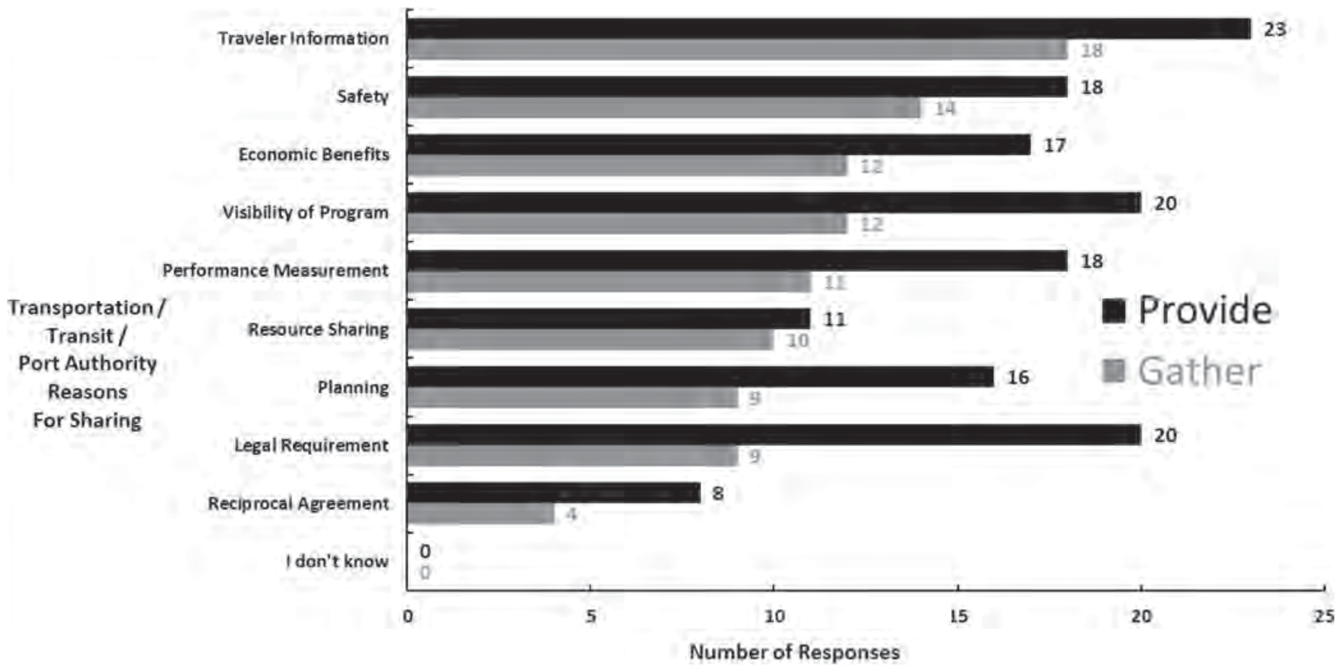


FIGURE D186 Transportation/transit/port authorities reasons for sharing—35 responses (Questions 9, 18).

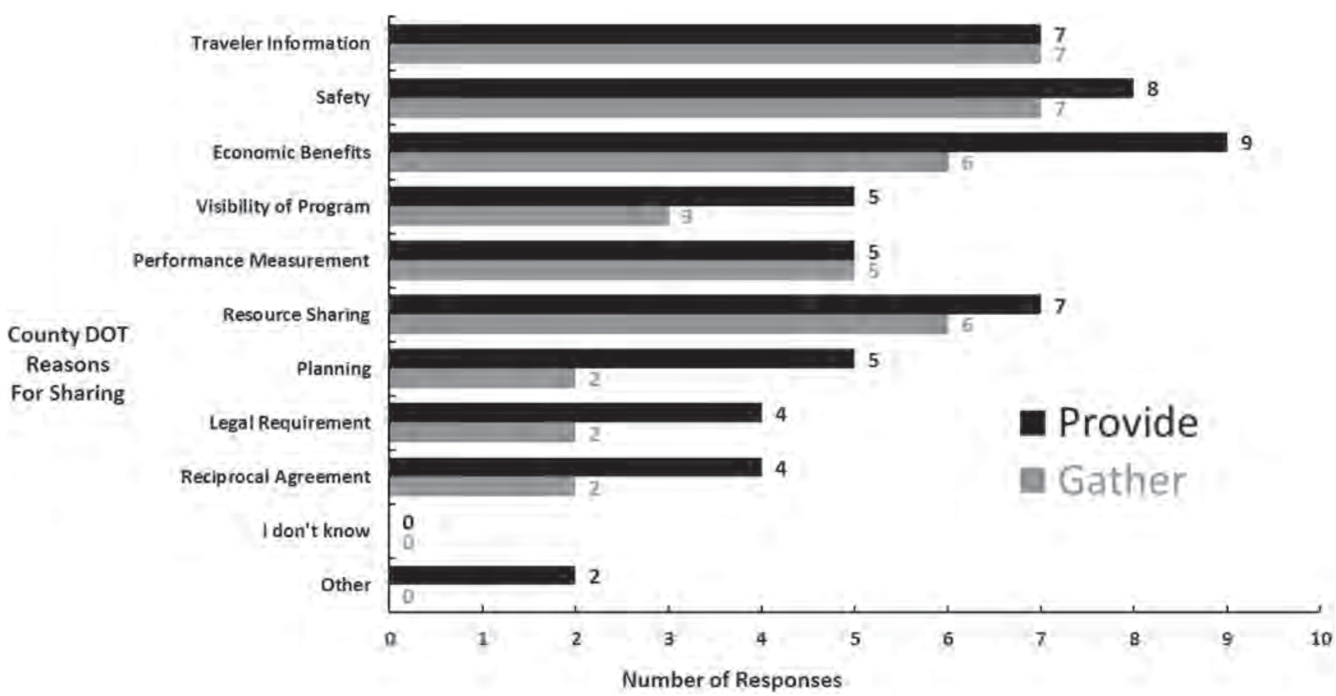


FIGURE D187 County DOTs reasons for sharing—12 responses (Questions 9, 18).

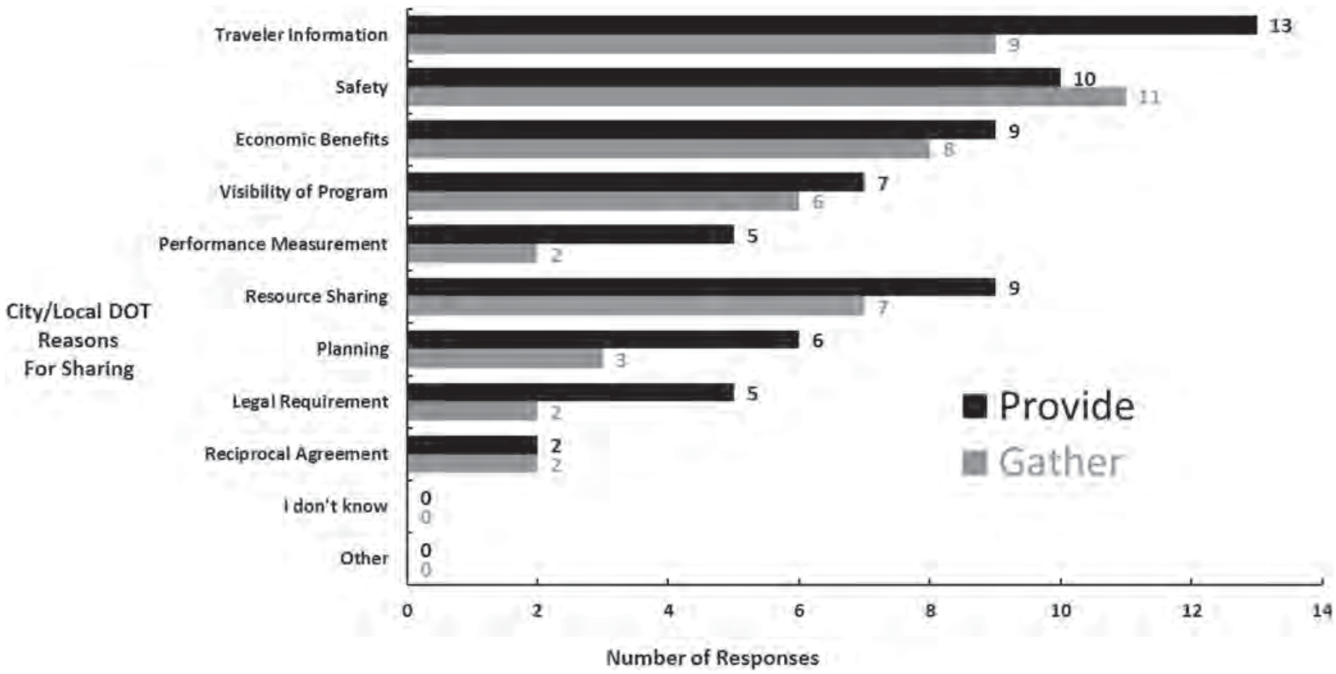


FIGURE D188 City and local DOTs reasons for sharing—24 responses (Questions 9, 18).

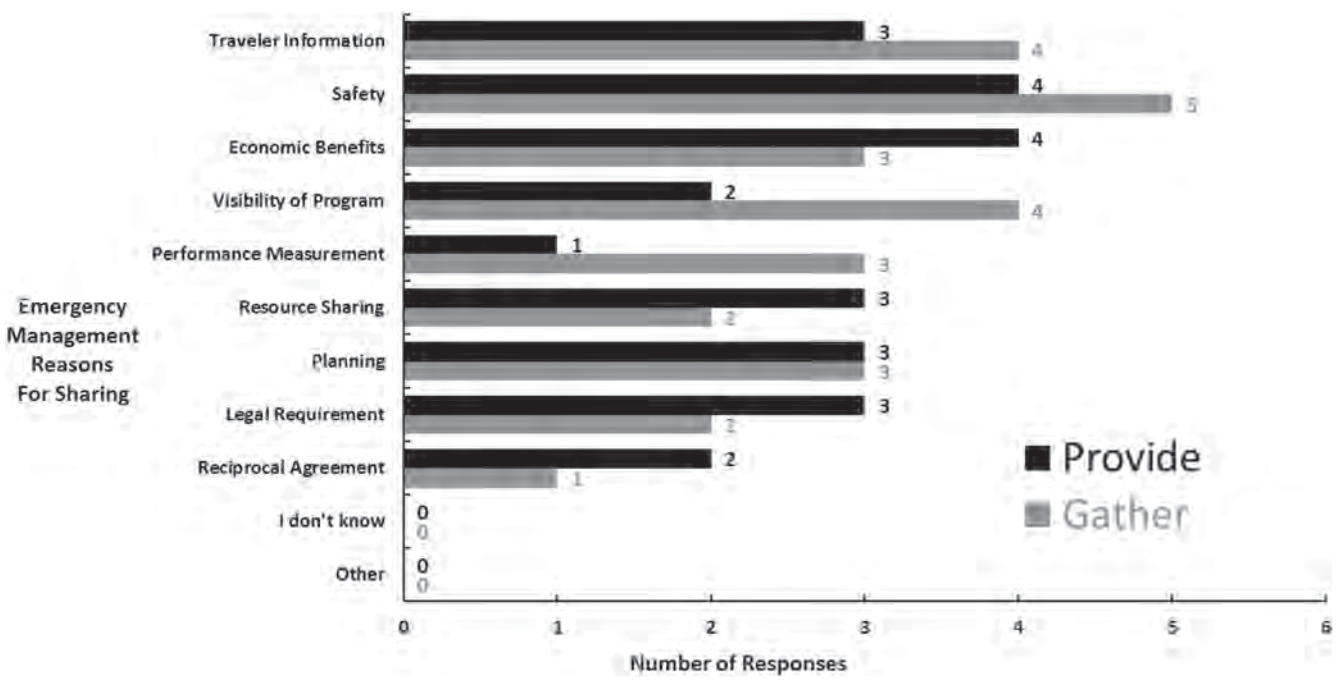


FIGURE D189 Emergency management agencies reasons for sharing—9 responses (Questions 9, 18).

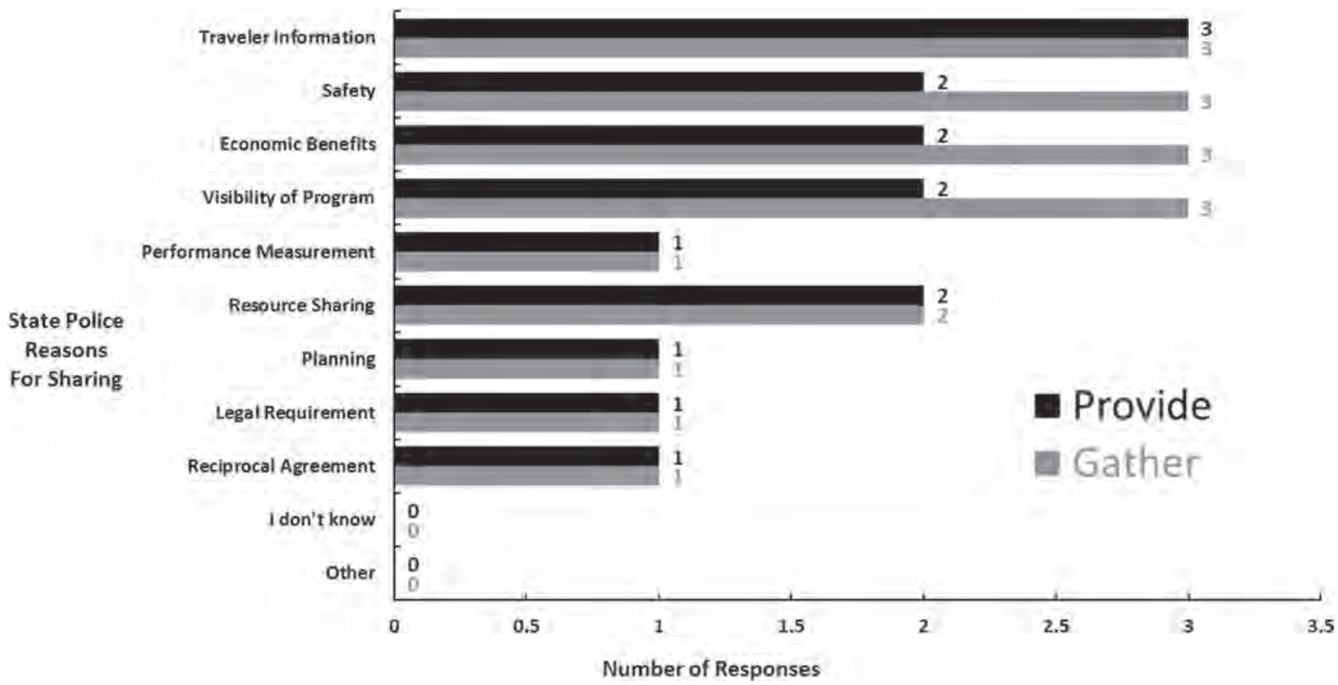


FIGURE D190 State police reasons for sharing—4 responses (Questions 9, 18).

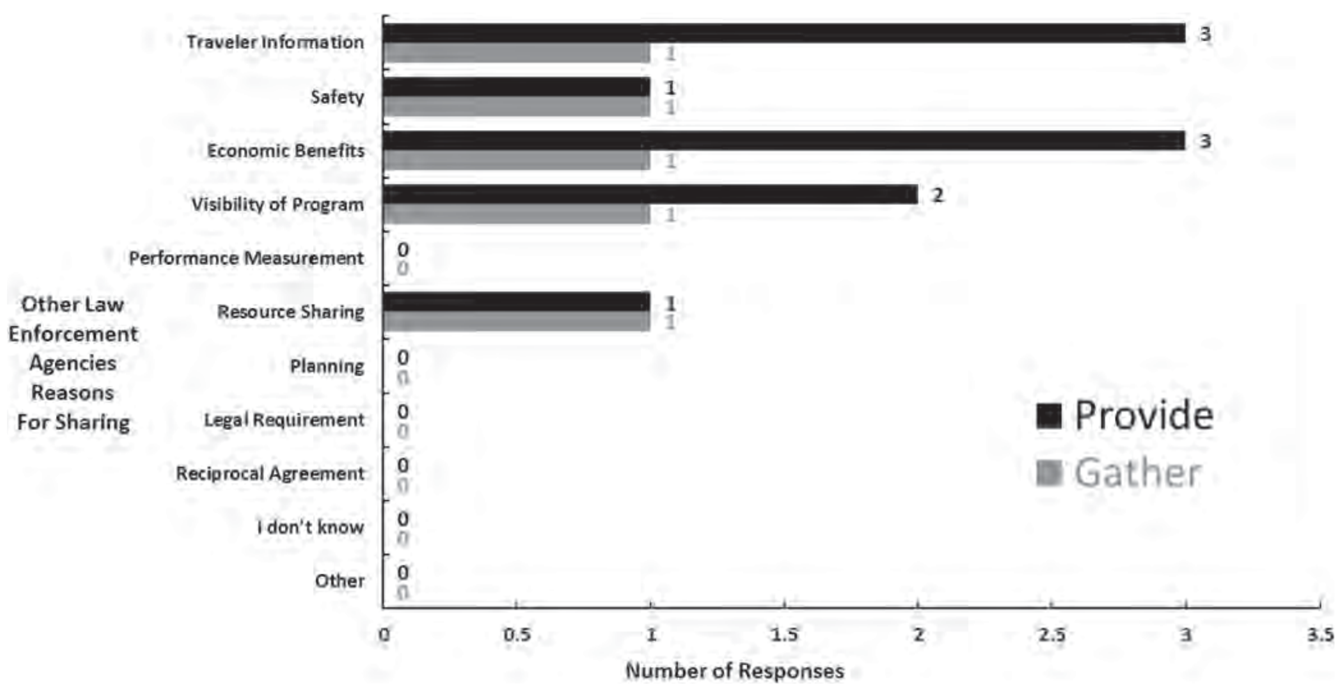


FIGURE D191 Other law enforcement agencies reasons for sharing—12 responses (Questions 9, 18).

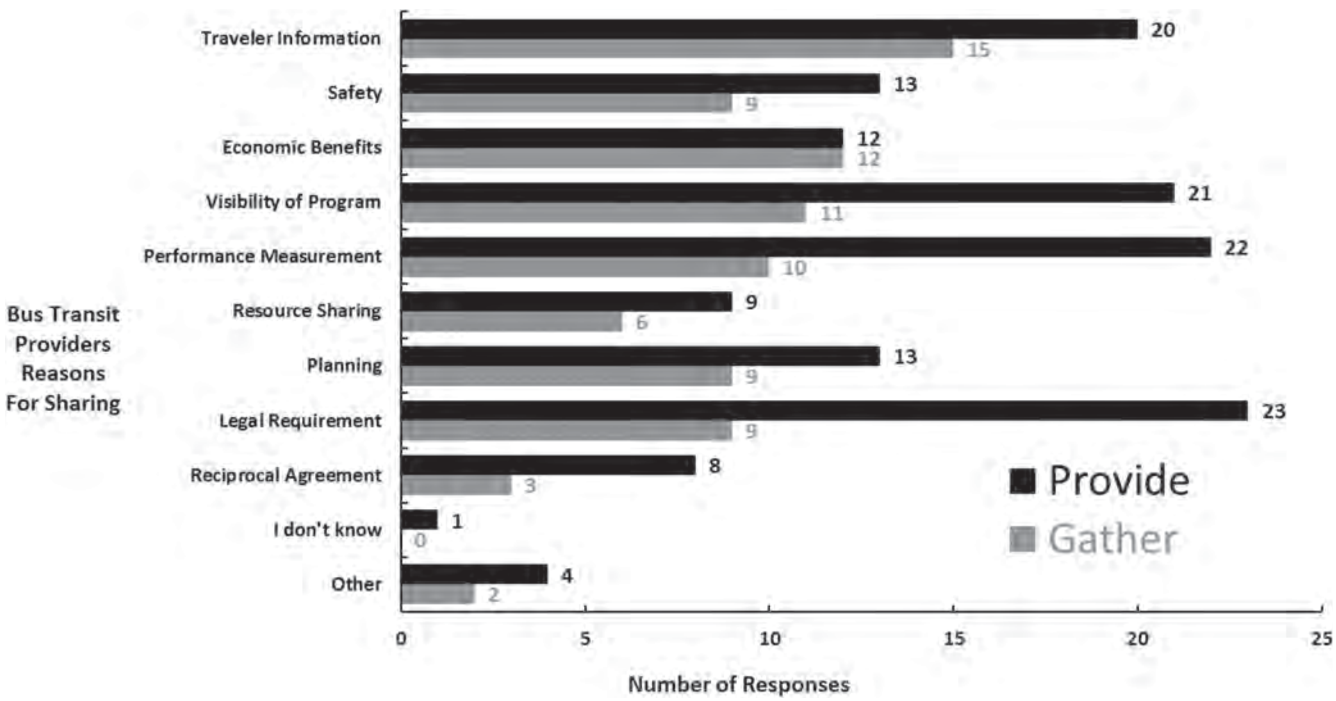


FIGURE D192 Bus transit providers reasons for sharing—40 responses (Questions 9, 18).

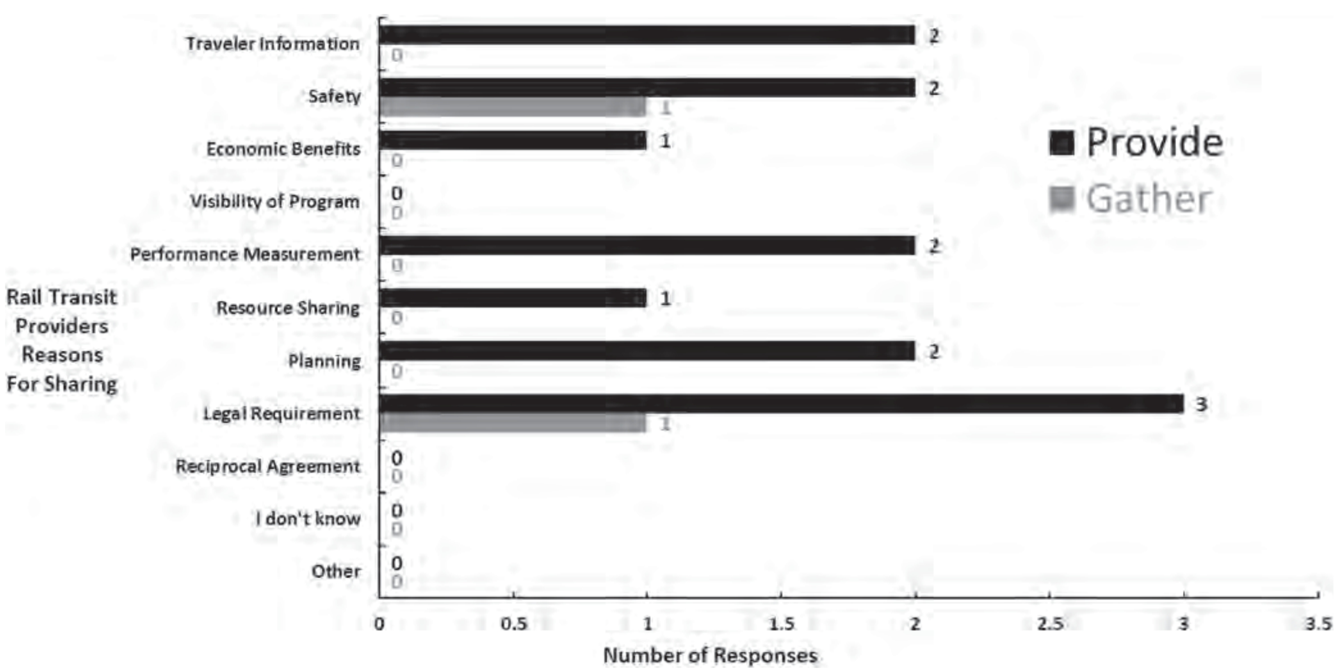


FIGURE D193 Rail transit providers reasons for sharing—3 responses (Questions 9, 18).

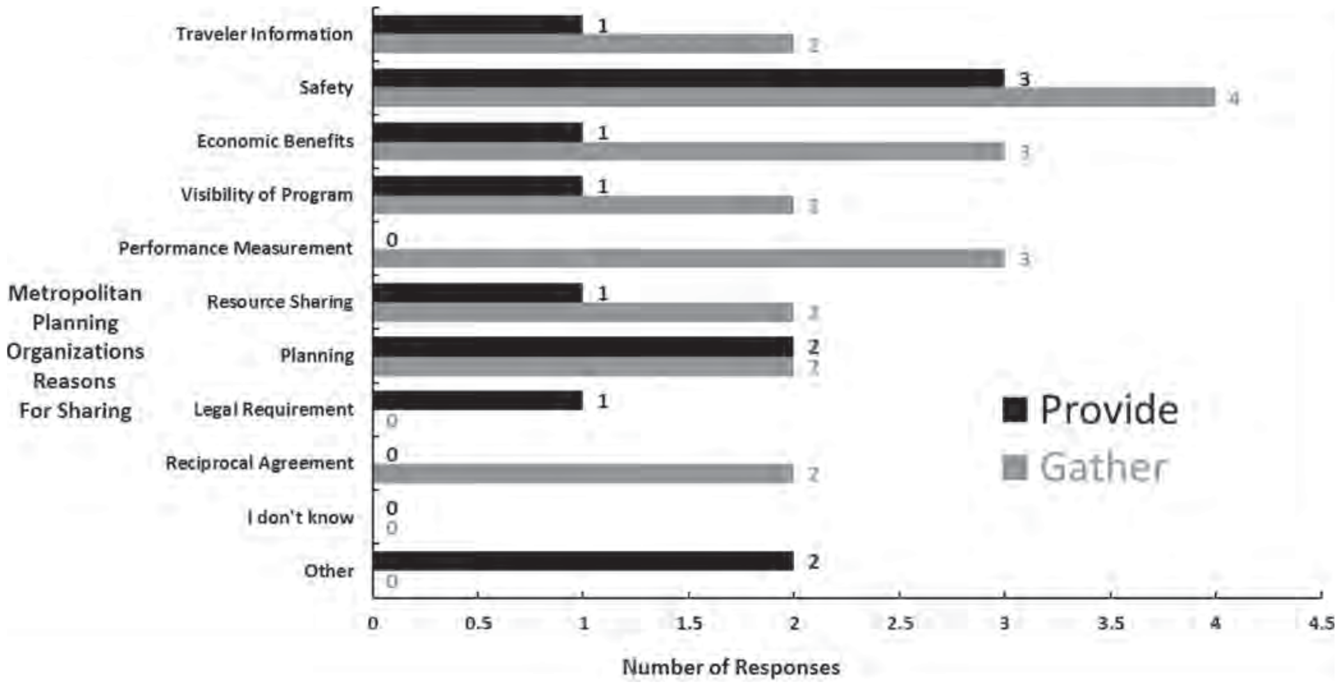


FIGURE D194 Metropolitan planning organizations reasons for sharing—6 responses (Questions 9, 18).

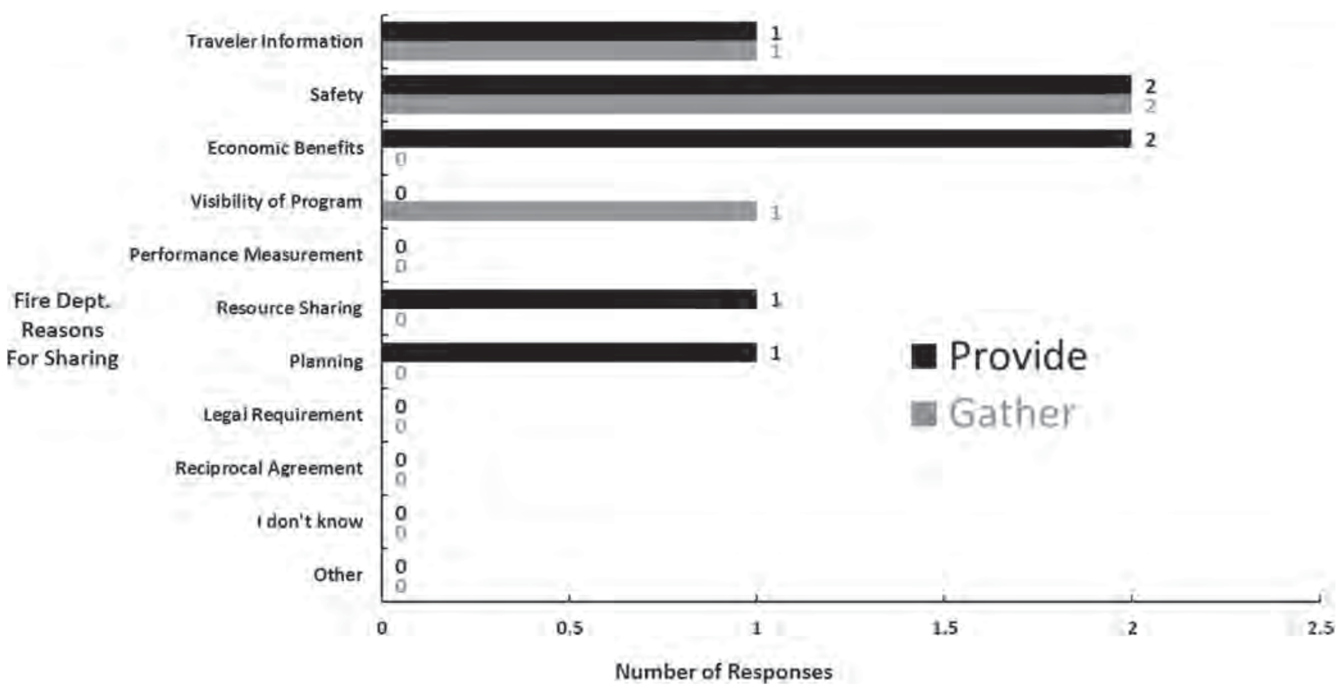


FIGURE D195 Fire departments reasons for sharing—3 responses (Questions 9, 18).

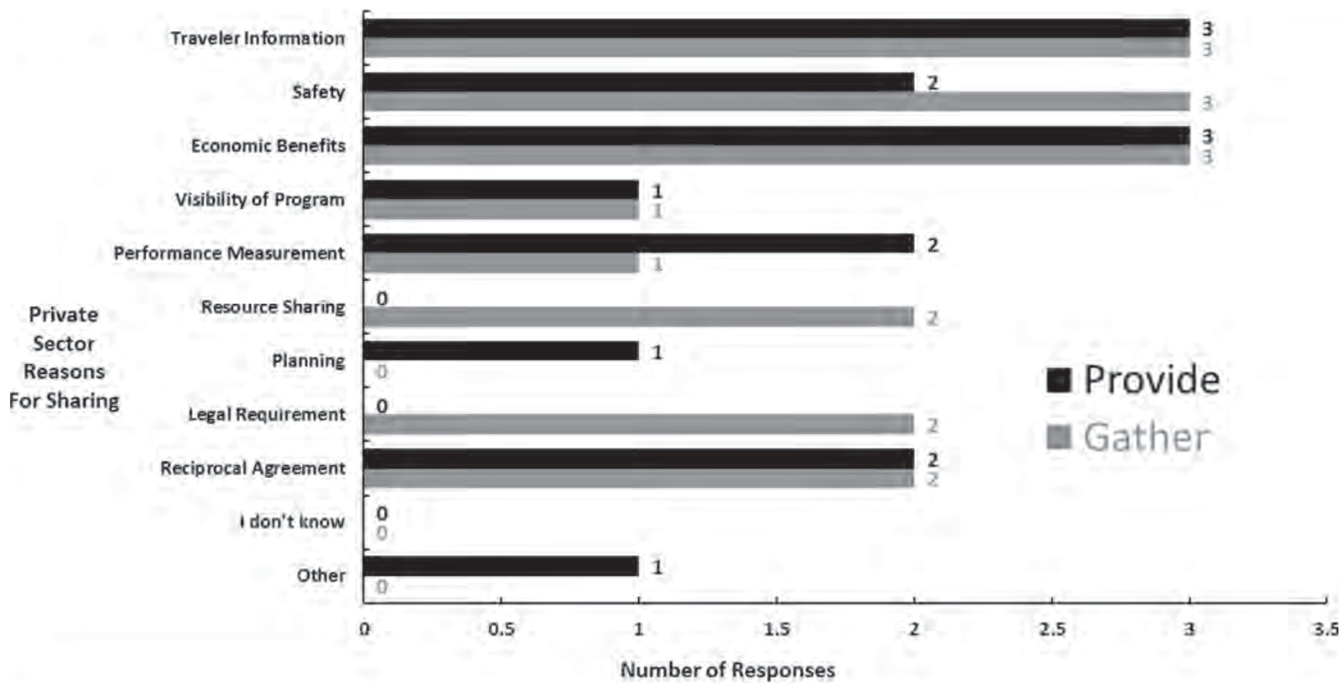


FIGURE D196 Private sector entities reasons for sharing—5 responses (Questions 9, 18).

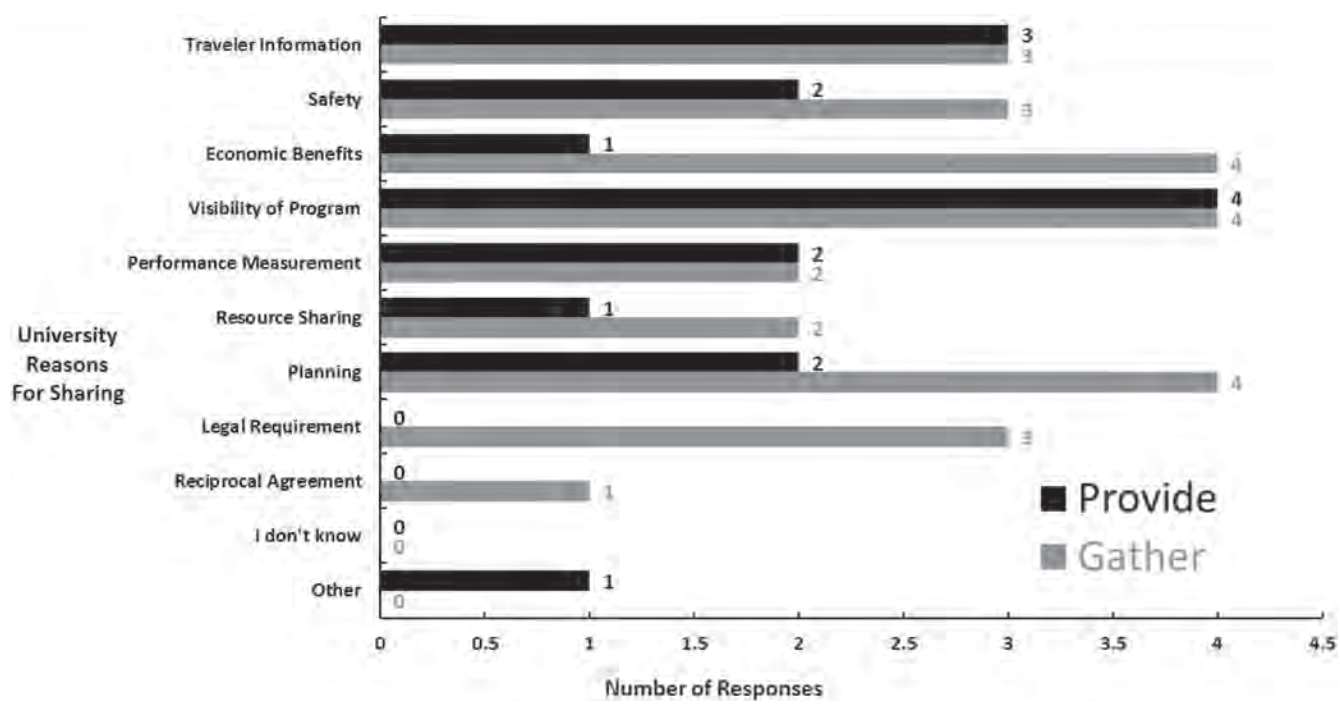


FIGURE D197 Universities reasons for sharing—4 responses (Questions 9, 18).

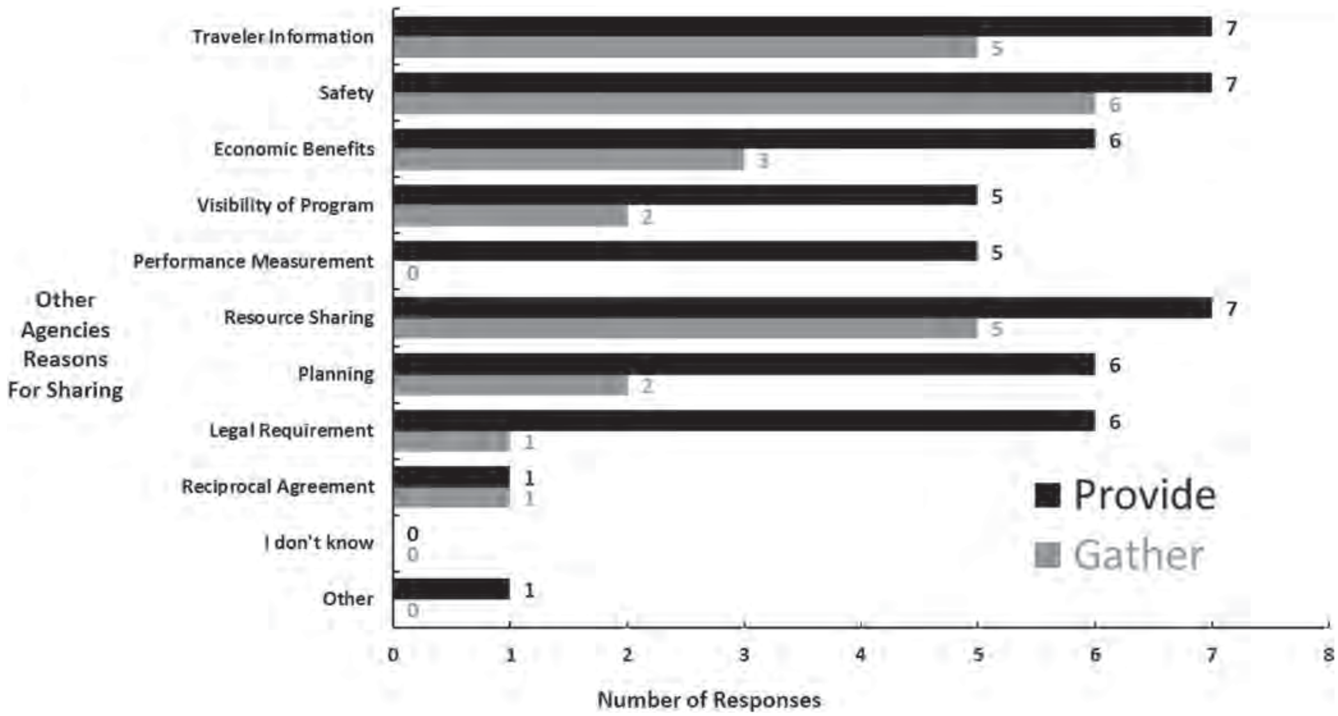


FIGURE D198 Other agencies reasons for sharing—12 responses (Questions 9, 18).

BARRIERS TO OPERATIONS DATA SHARING (D199–D228)

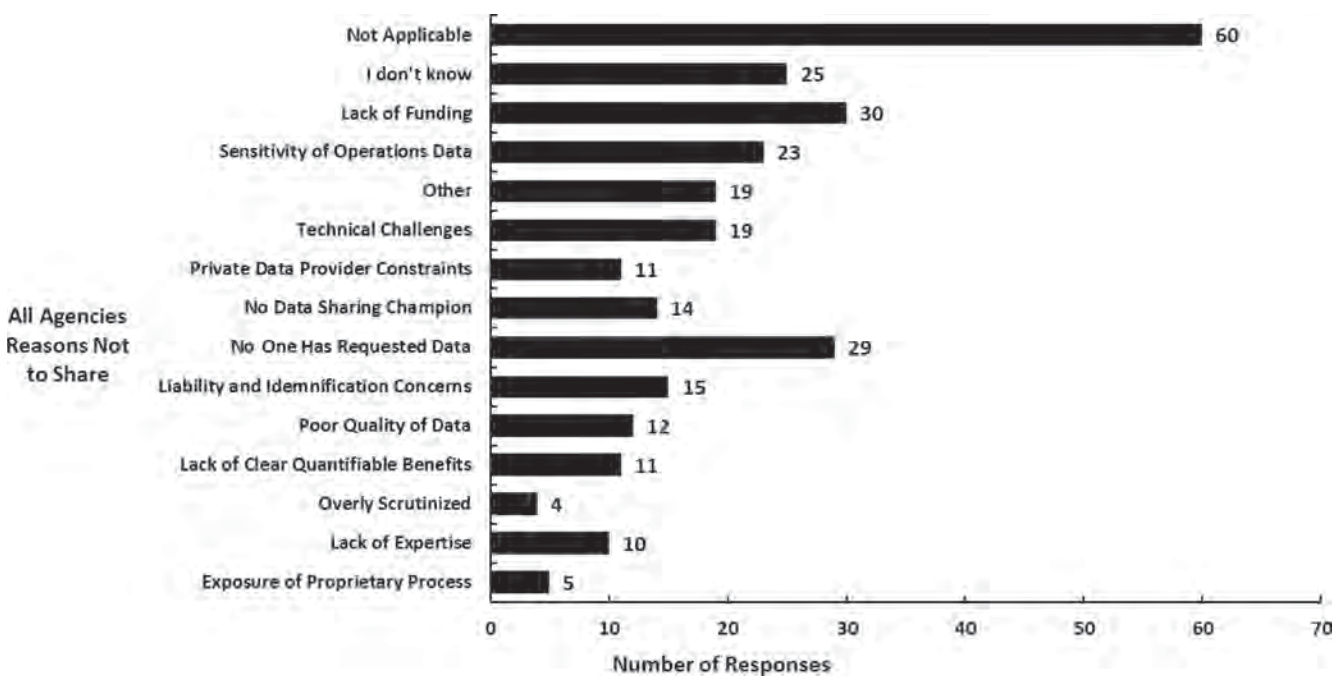


FIGURE D199 Data sharing barriers for agencies in general—198 responses (Question 10).

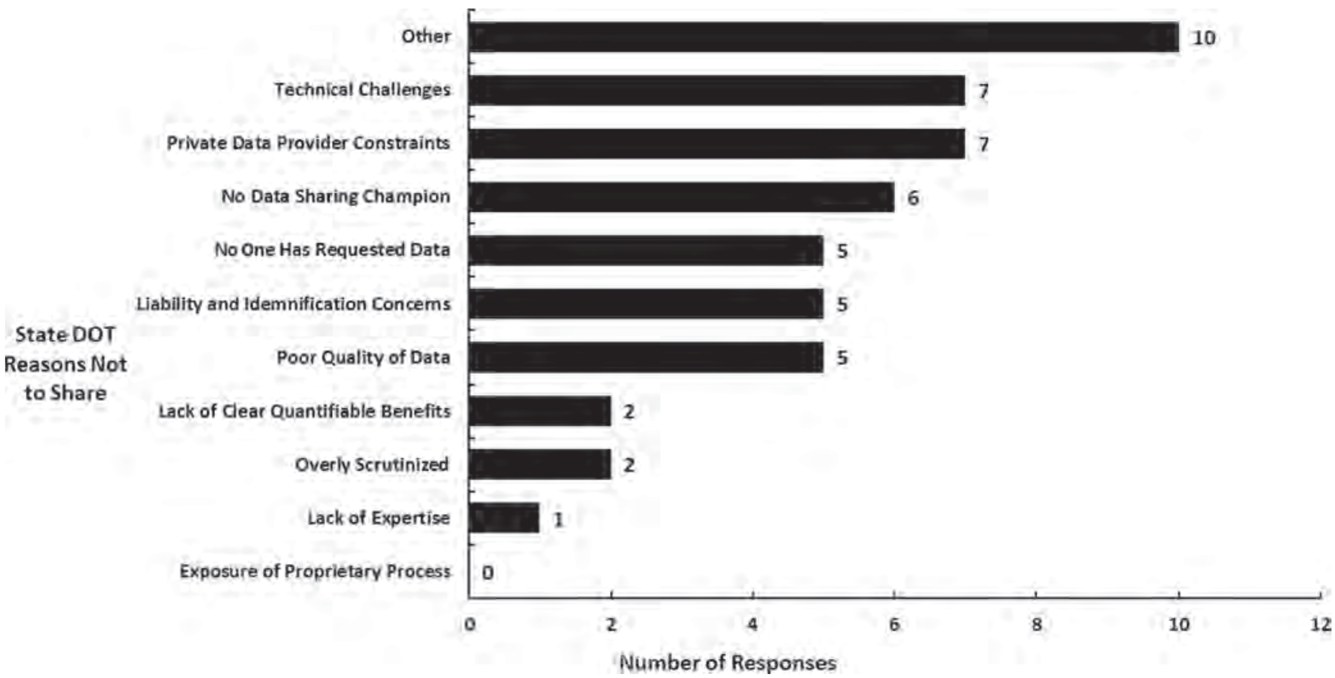


FIGURE D200 State DOTs data sharing barriers—86 responses (Question 10).

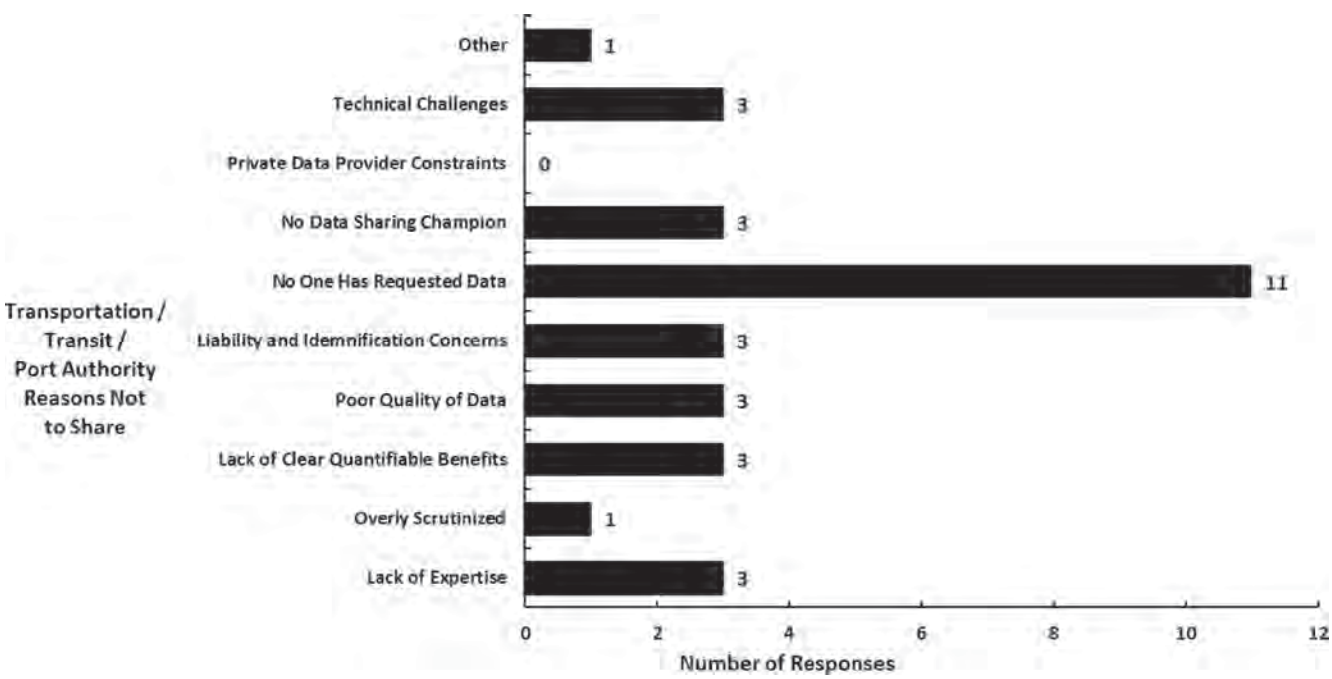


FIGURE D201 Transportation/transit/port authorities data sharing barriers—35 responses (Question 10).

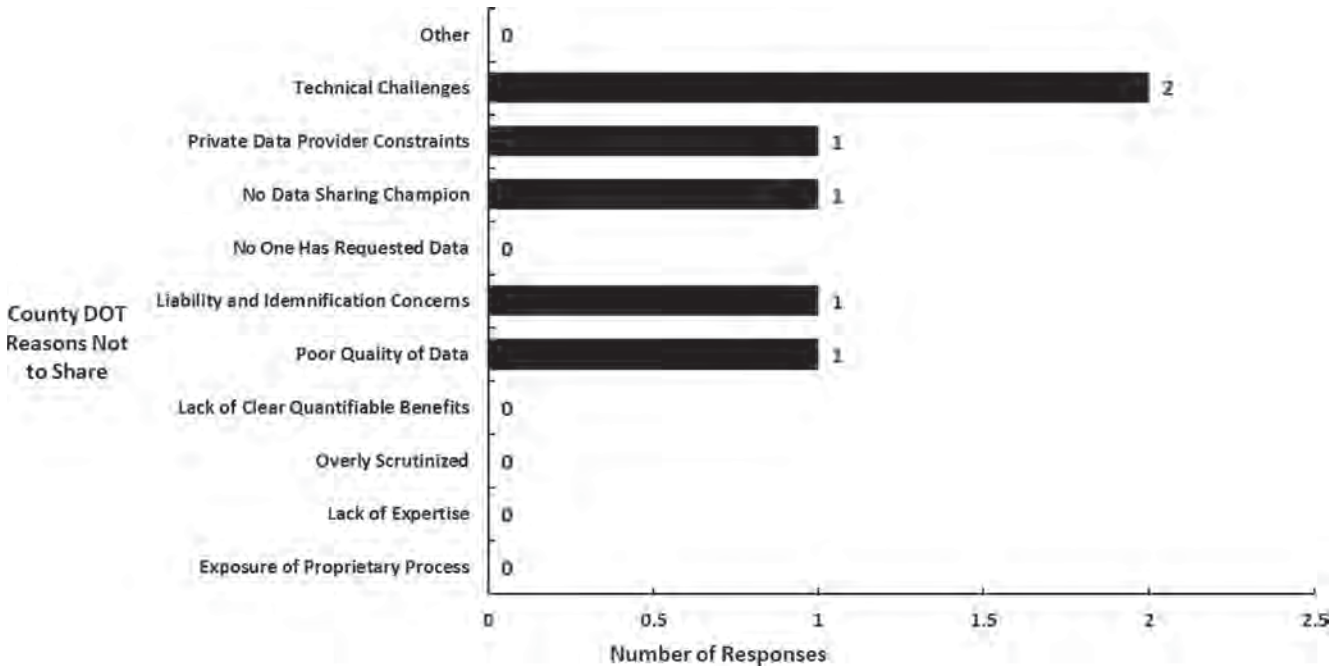


FIGURE D202 County DOTs data sharing barriers—12 responses (Question 10).

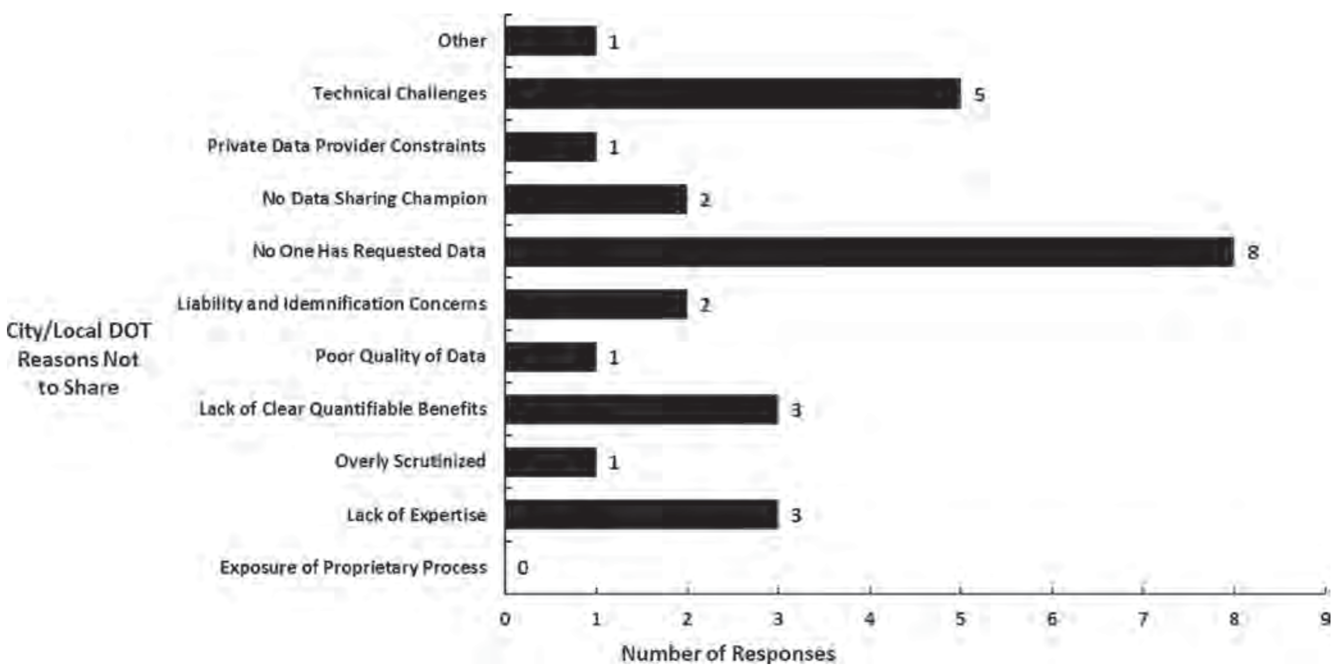


FIGURE D203 City and local DOTs data sharing barriers—24 responses (Question 10).

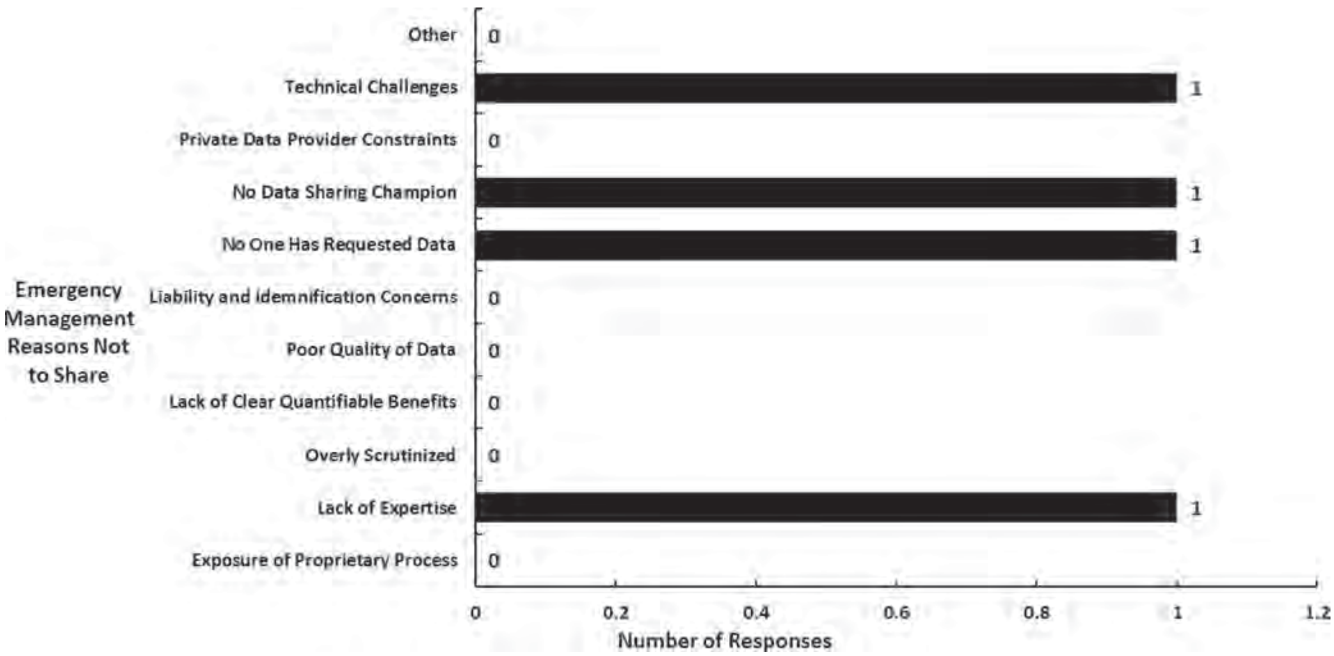


FIGURE D204 Emergency management agencies data sharing barriers—9 responses (Question 10).

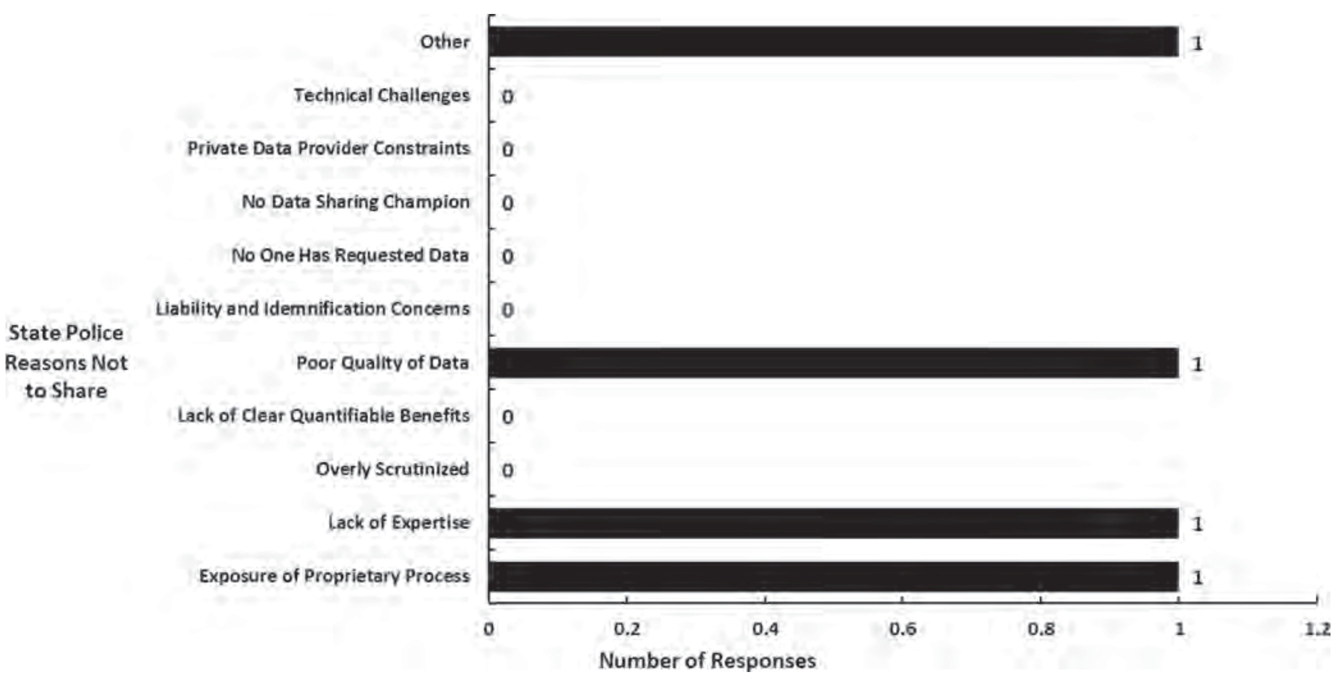


FIGURE D205 State police data sharing barriers—4 responses (Question 10).

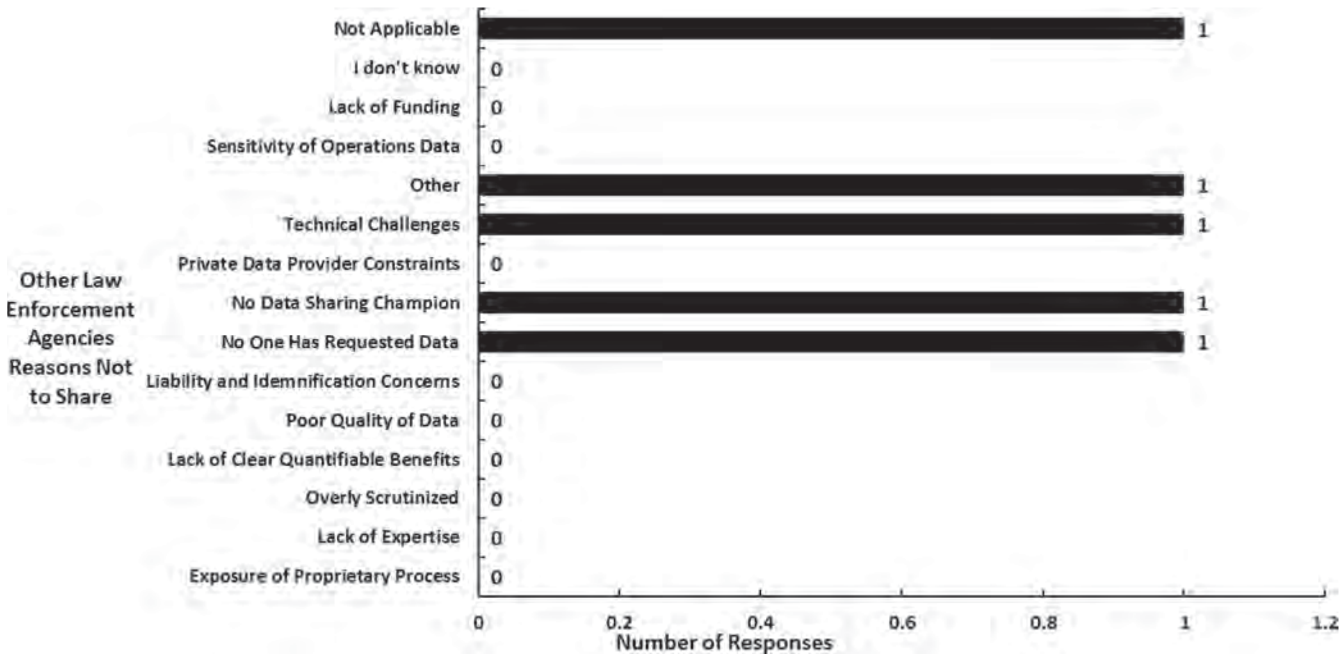


FIGURE D206 Other law enforcement agencies data sharing barriers—3 responses (Question 10).

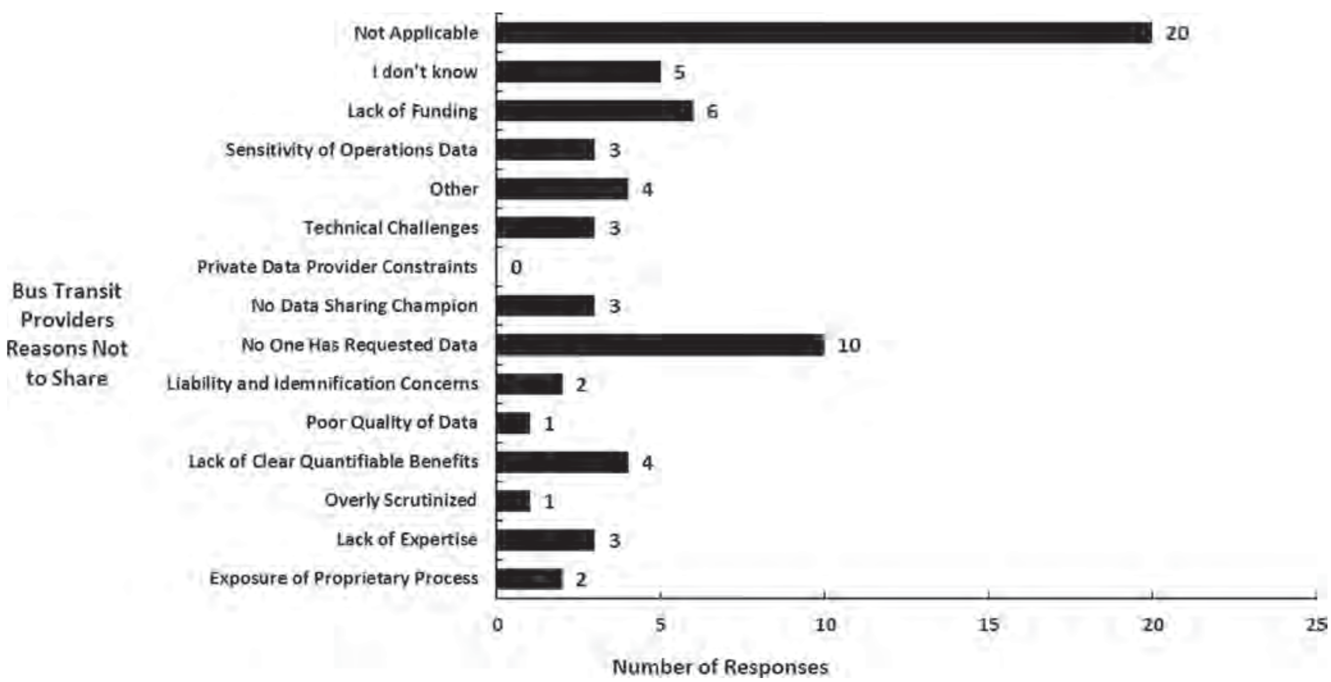


FIGURE D207 Bus transit providers data sharing barriers—40 responses (Question 10).

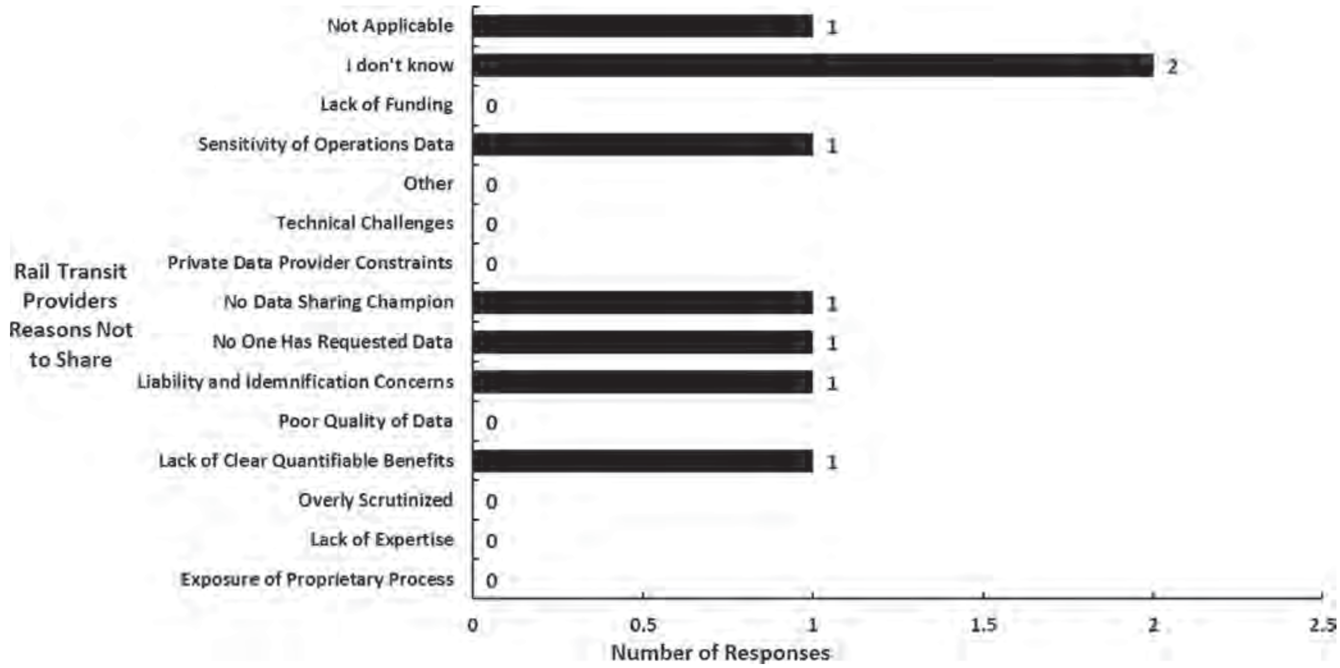


FIGURE D208 Rail transit providers data sharing barriers—3 responses (Question 10).

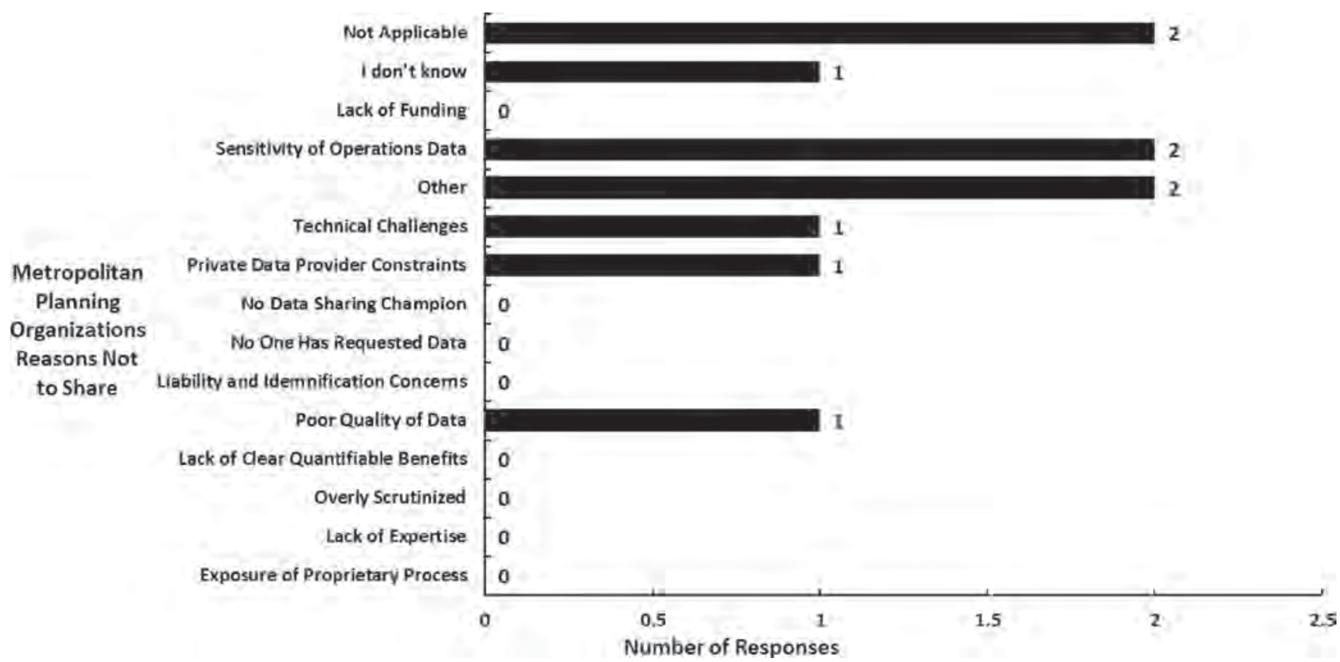


FIGURE D209 Metropolitan planning organizations data sharing barriers—6 responses (Question 10).

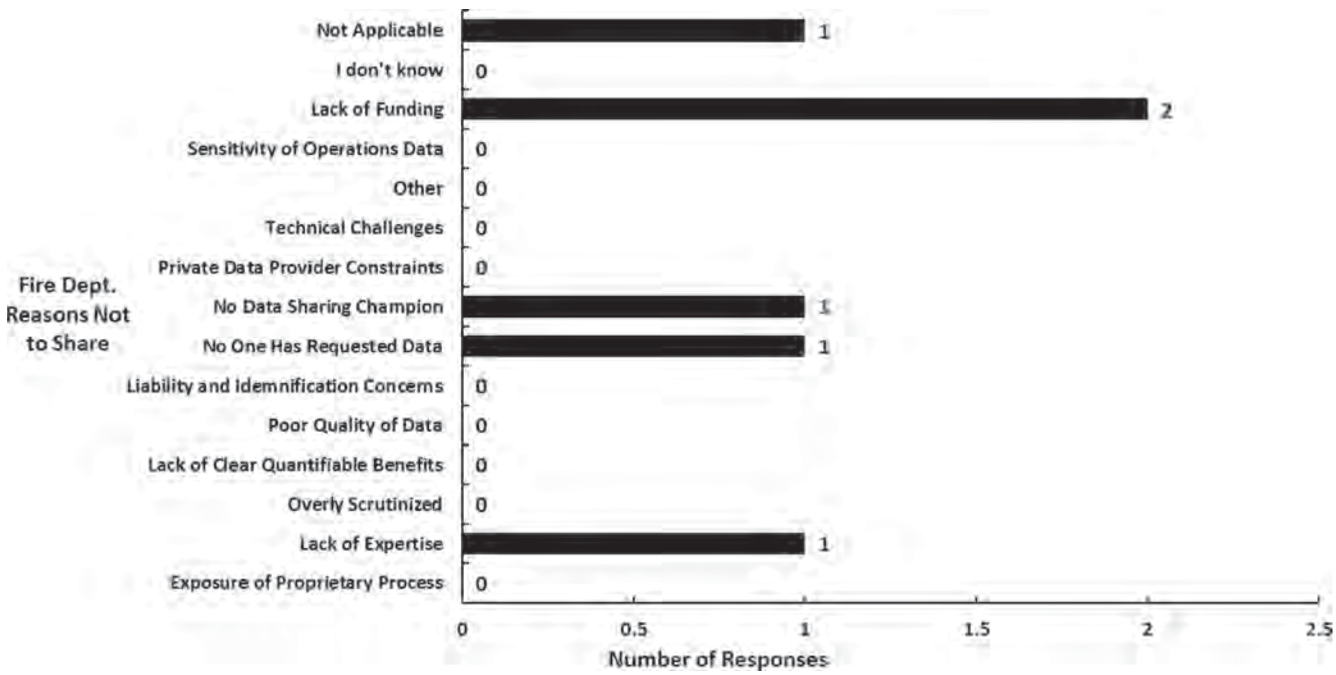


FIGURE D210 Fire departments data sharing barriers—3 responses (Question 10).

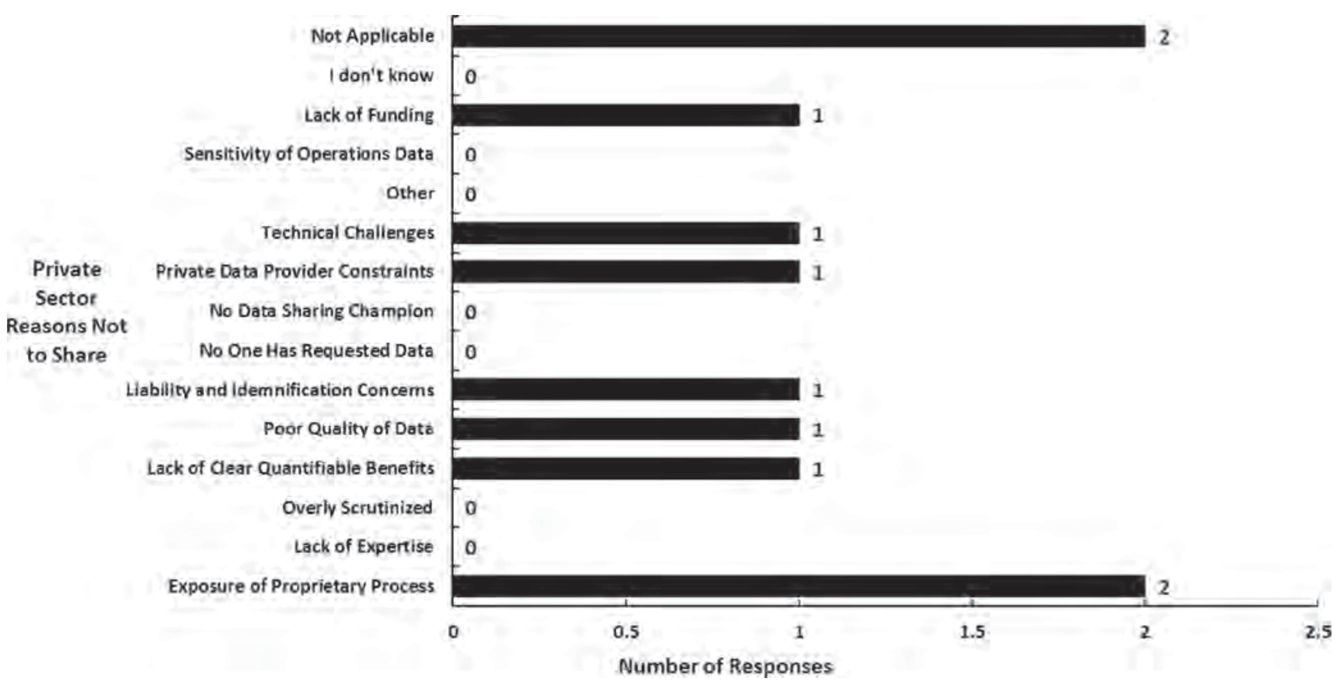


FIGURE D211 Private sector entities data sharing barriers—5 responses (Question 10).

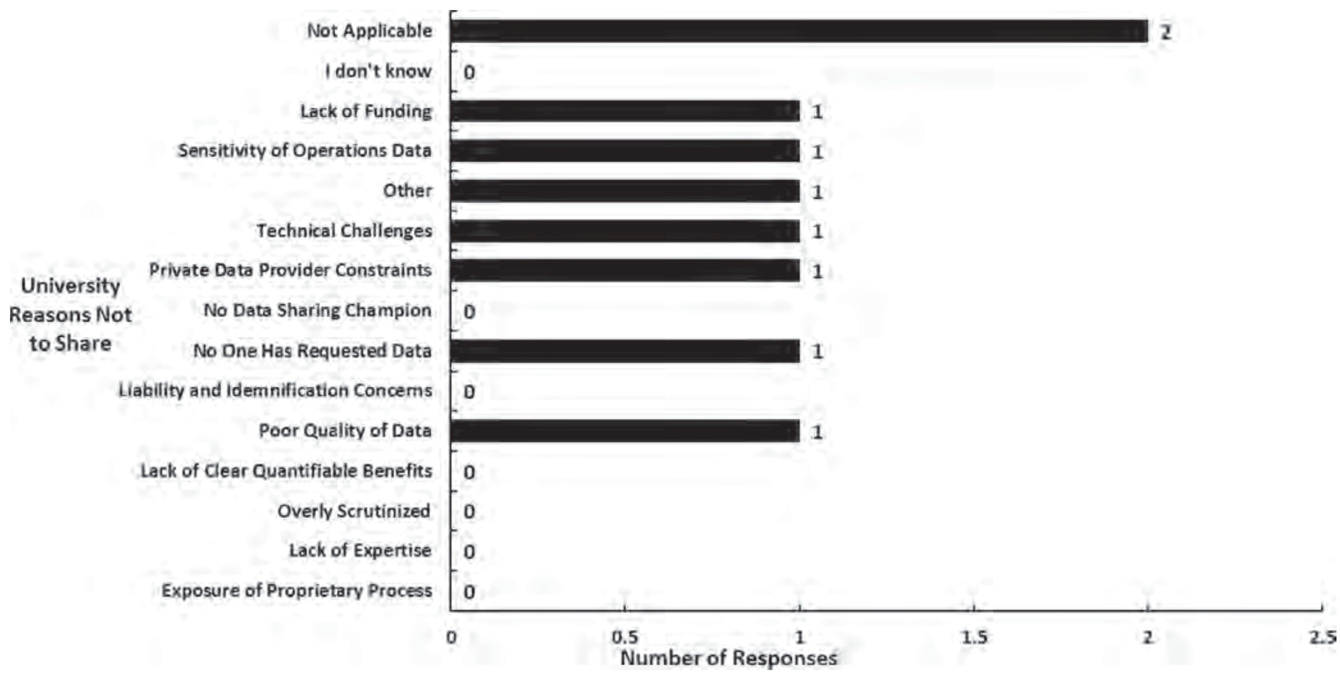


FIGURE D212 Universities data sharing barriers—4 responses (Question 10).

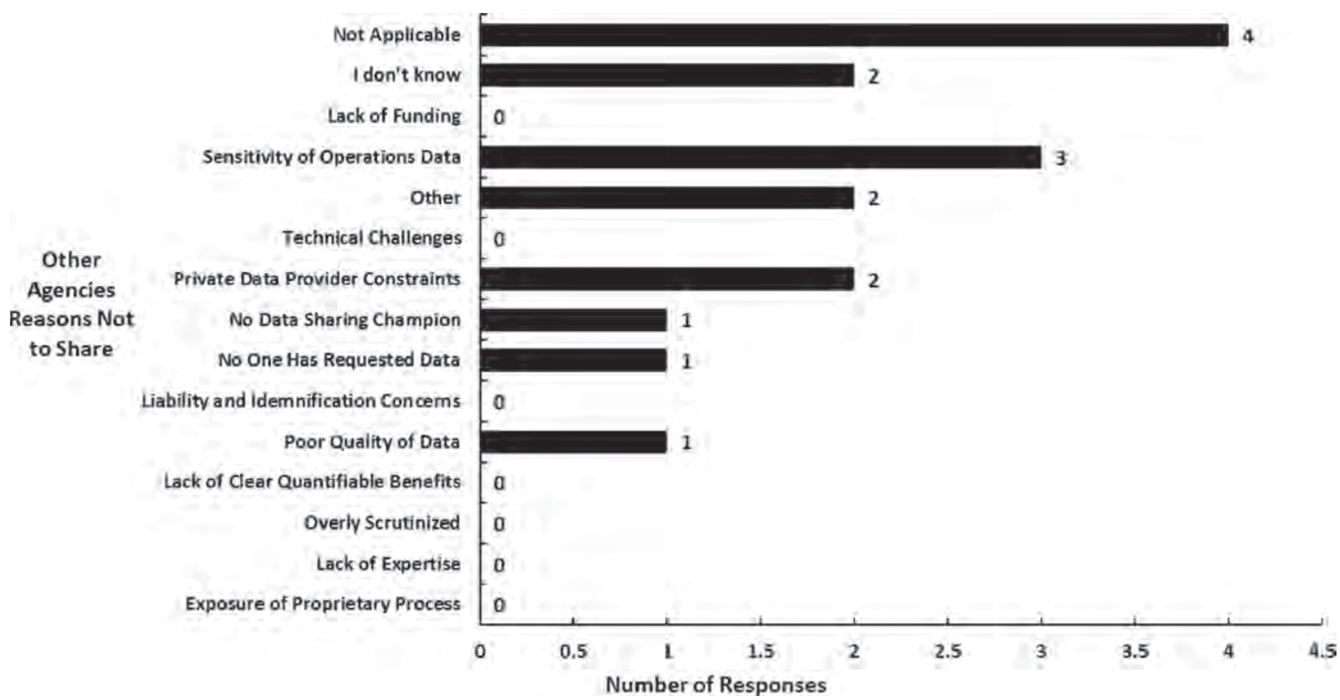


FIGURE D213 Other agencies data sharing barriers—12 responses (Question 10).

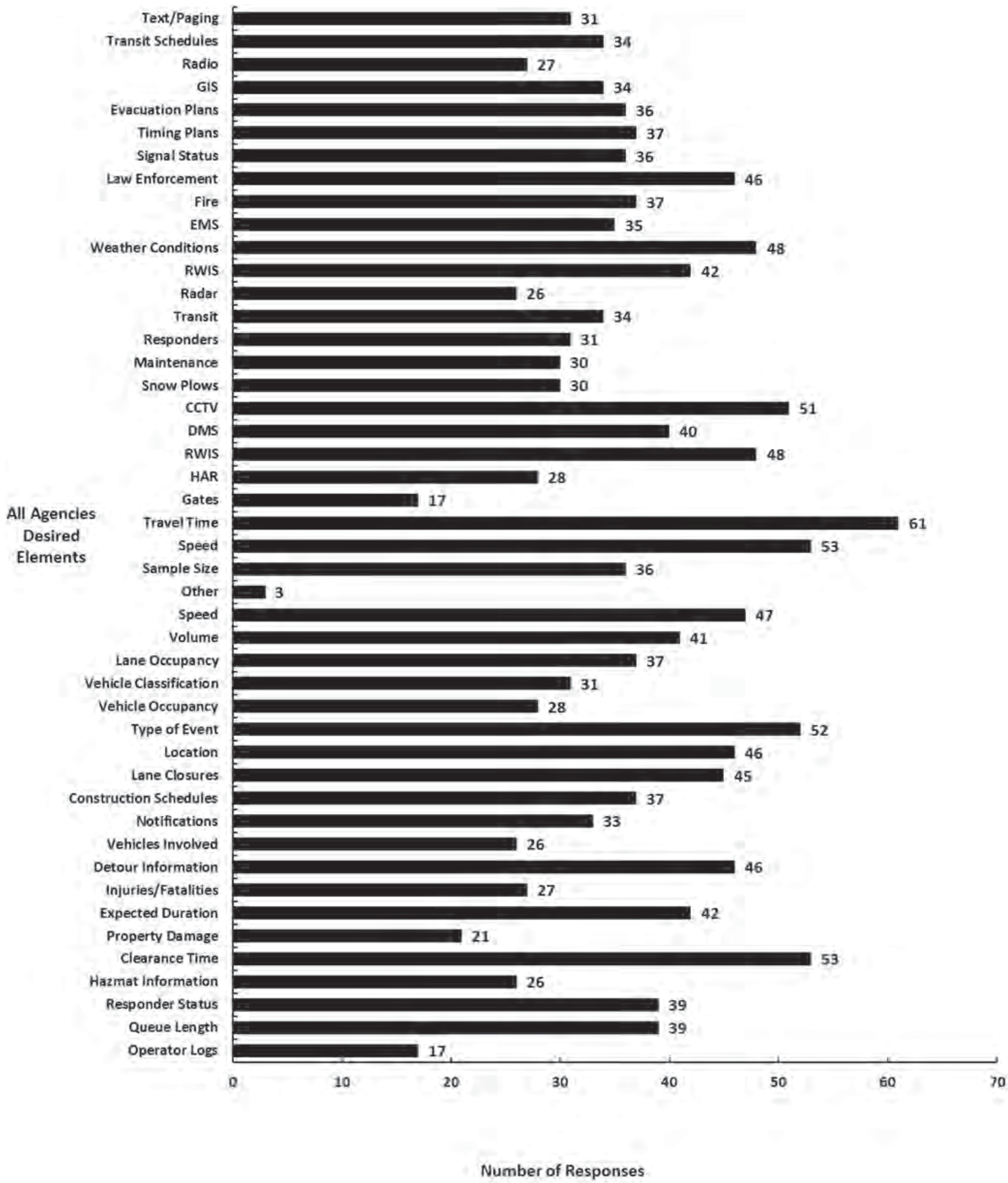


FIGURE D214 Desired elements in general—198 responses (Question 19).

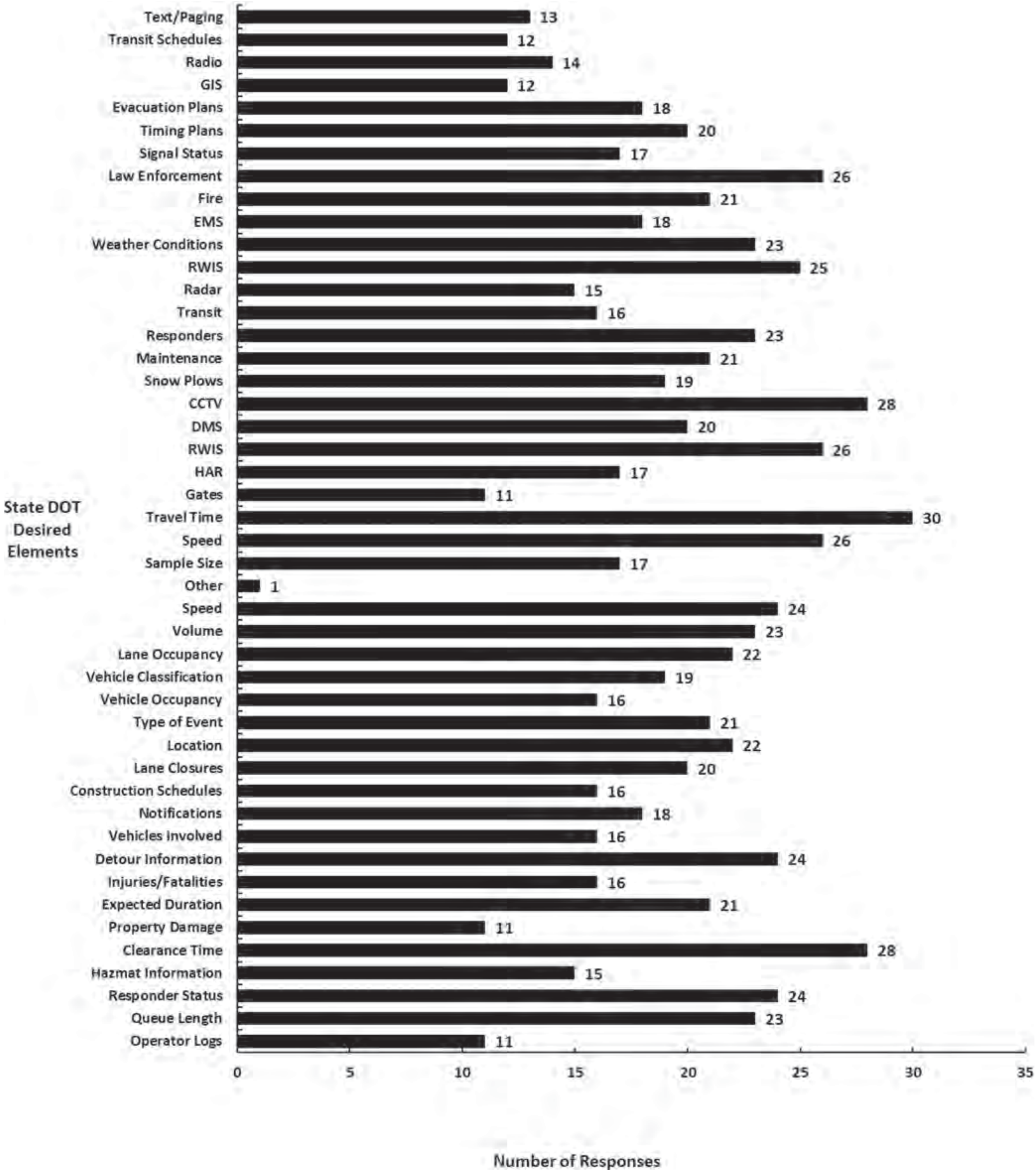


FIGURE D215 State DOTs desired elements—86 responses (Question 19).

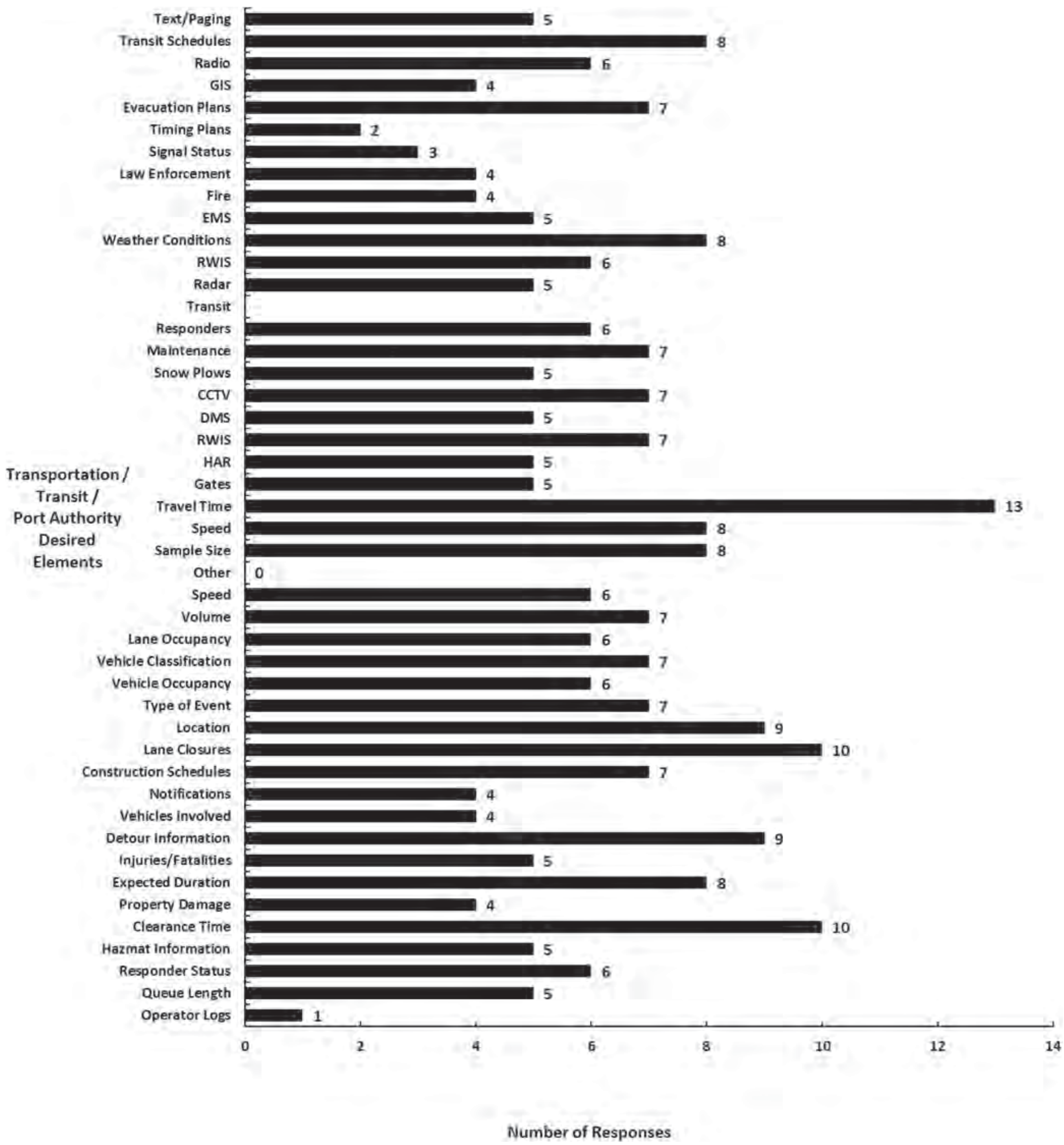


FIGURE D216 Transportation/transit/port authorities desired elements—35 responses (Question 19).

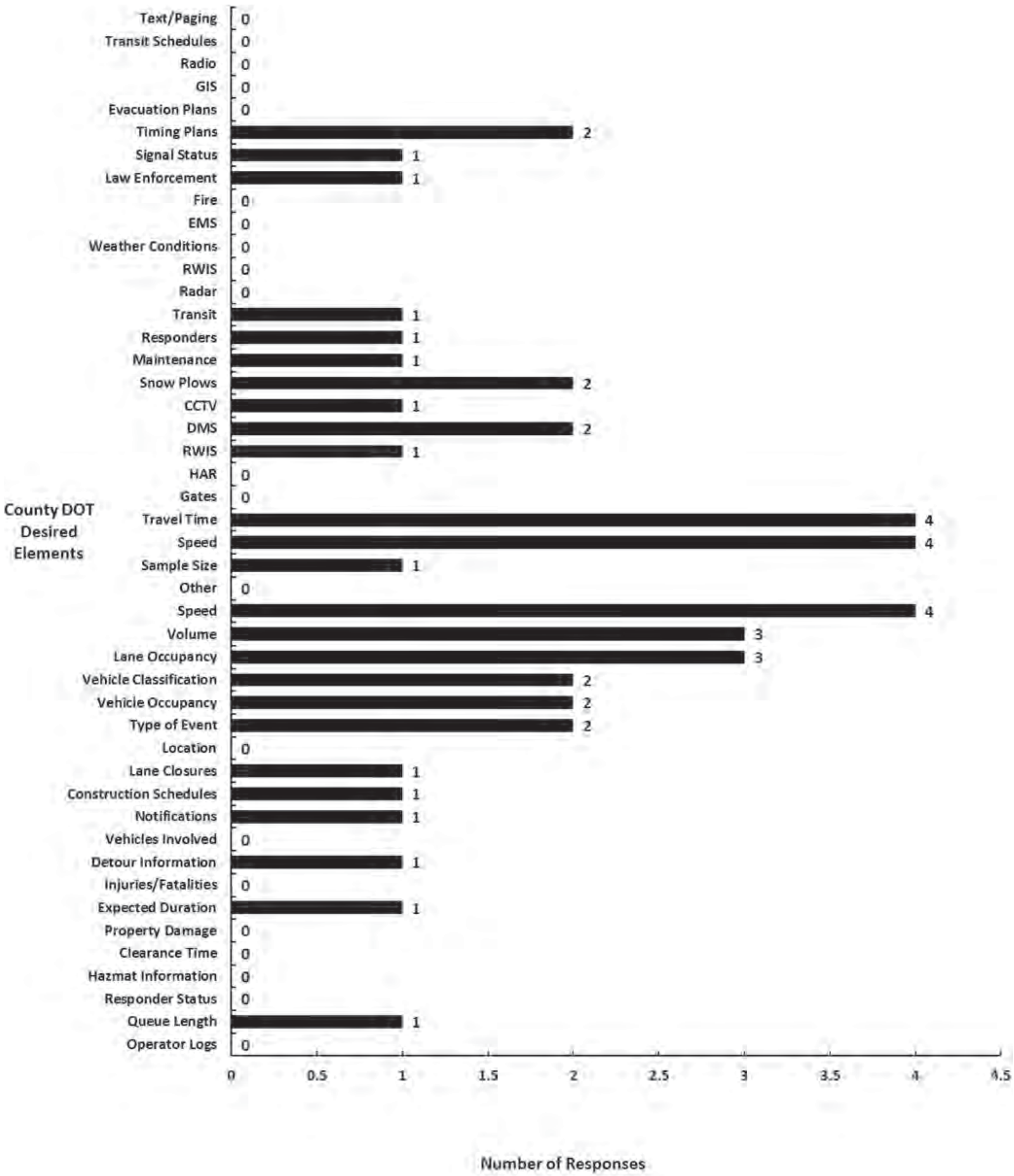


FIGURE D217 County DOTs desired elements—12 responses (Question 19).

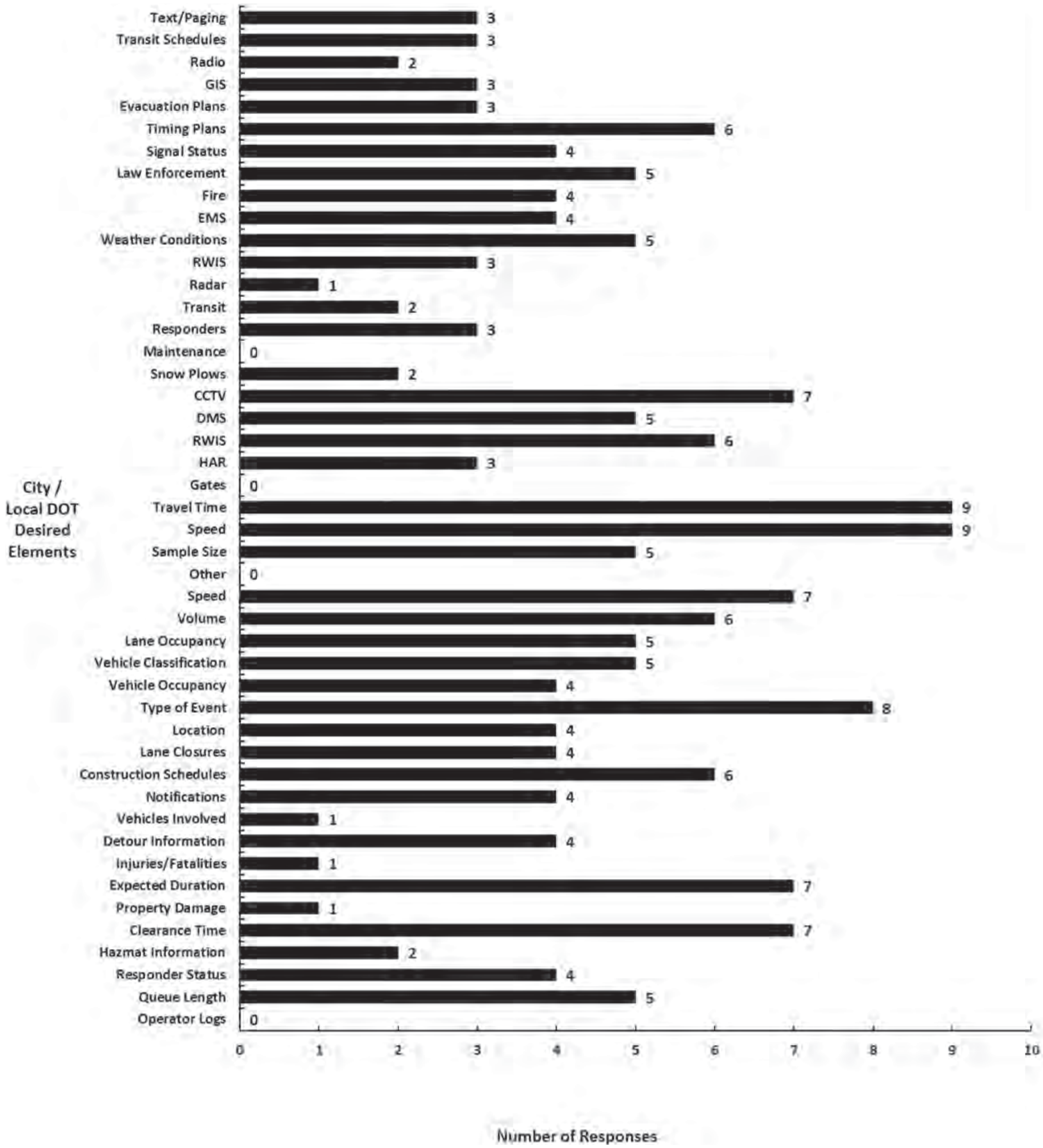


FIGURE D218 City and local DOTs desired elements—24 responses (Question 19).

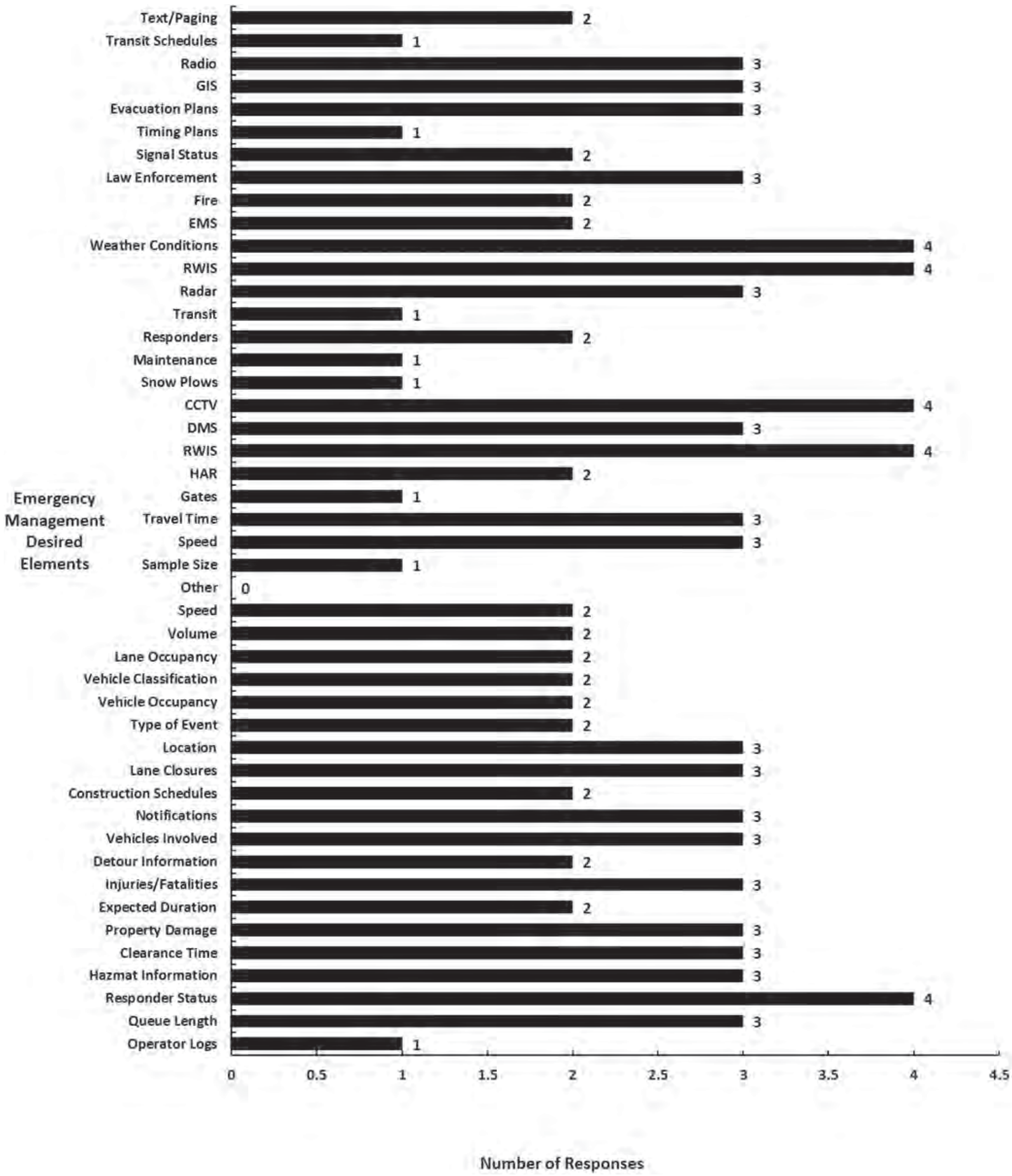


FIGURE D219 Emergency management agencies desired elements—9 responses (Question 19).

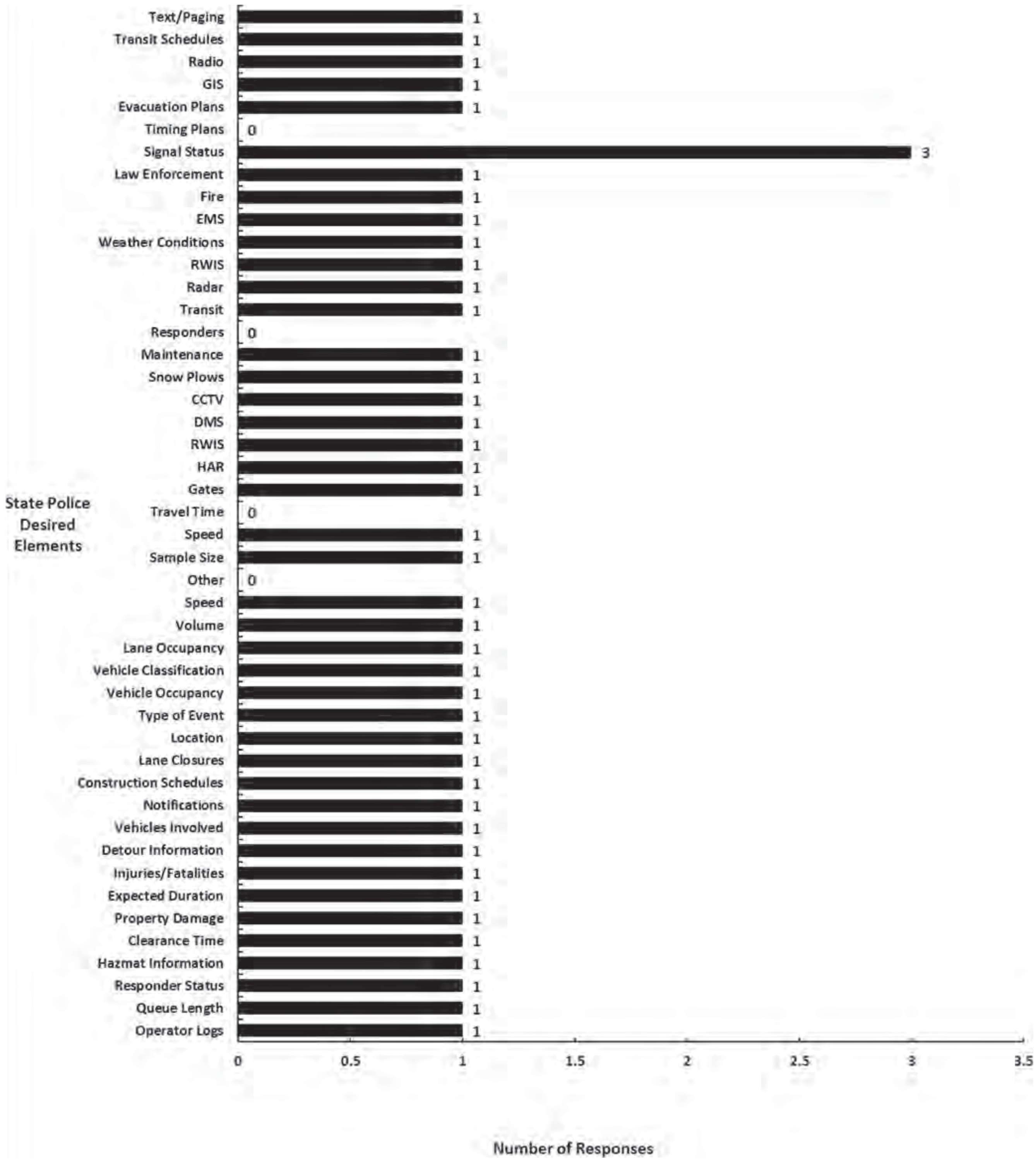


FIGURE D220 State police desired elements—4 responses (Question 19).

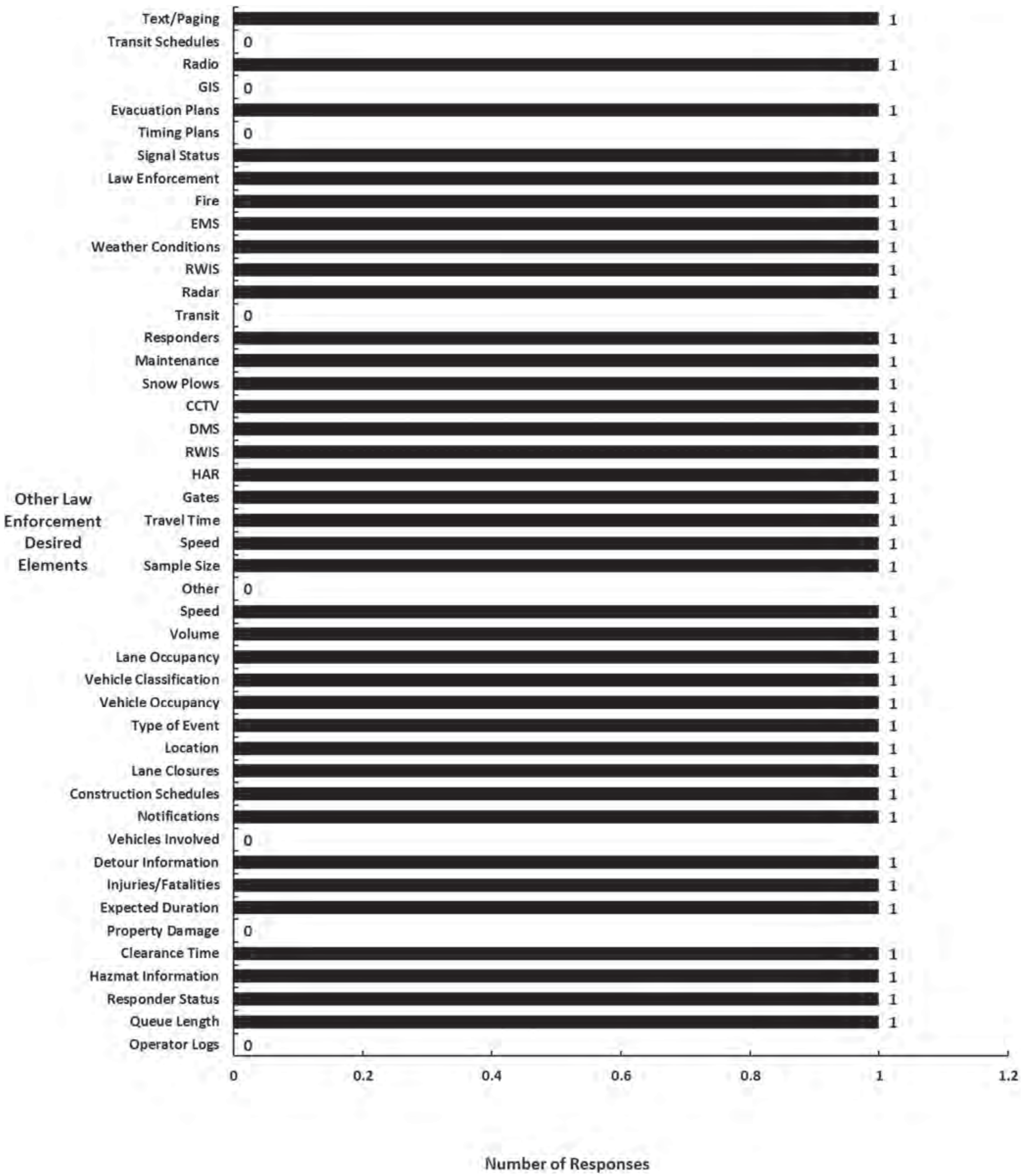


FIGURE D221 Other law enforcement agencies desired elements—3 responses (Question 19).

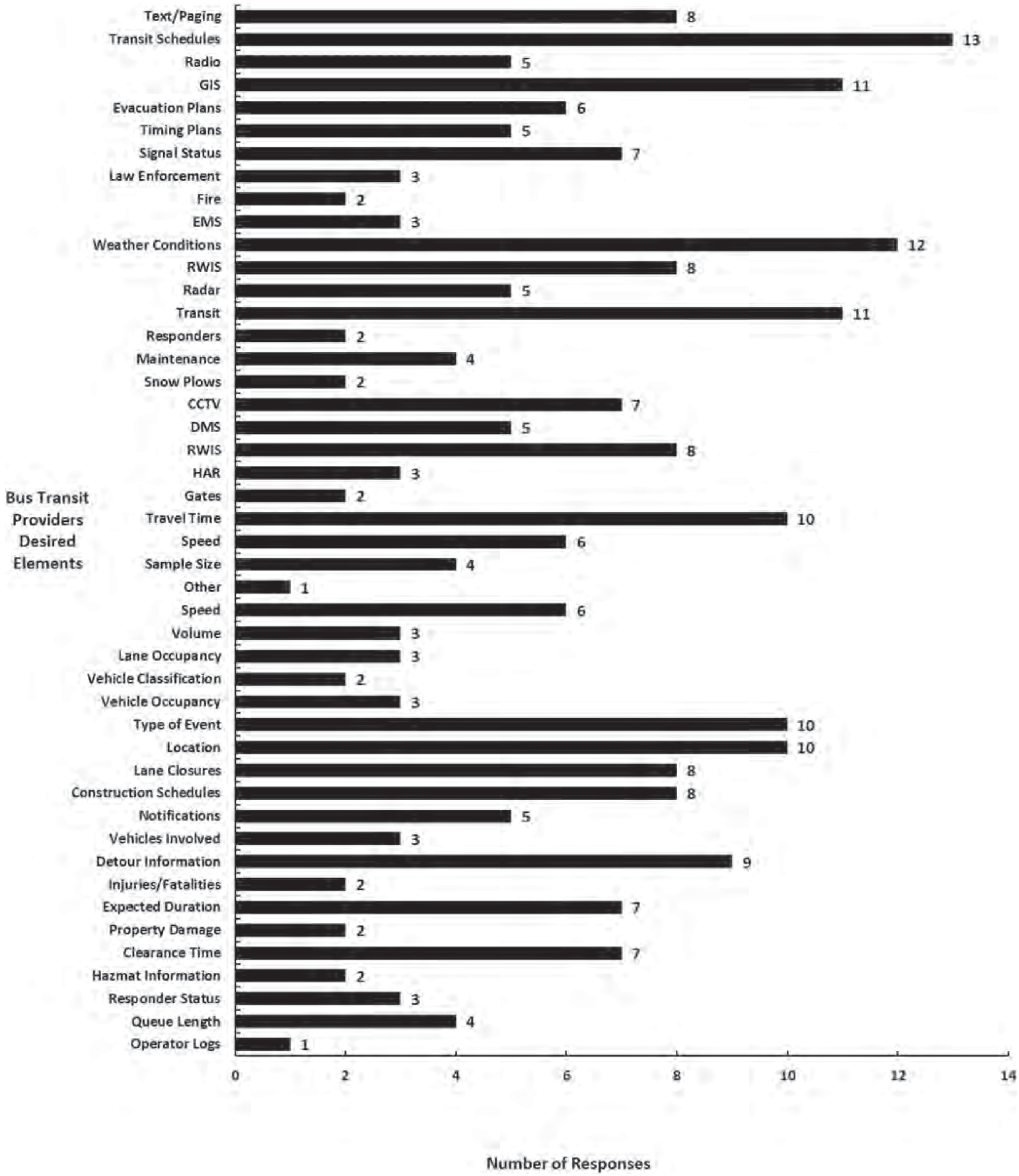


FIGURE D222 Bus transit providers desired elements—40 responses (Question 19).

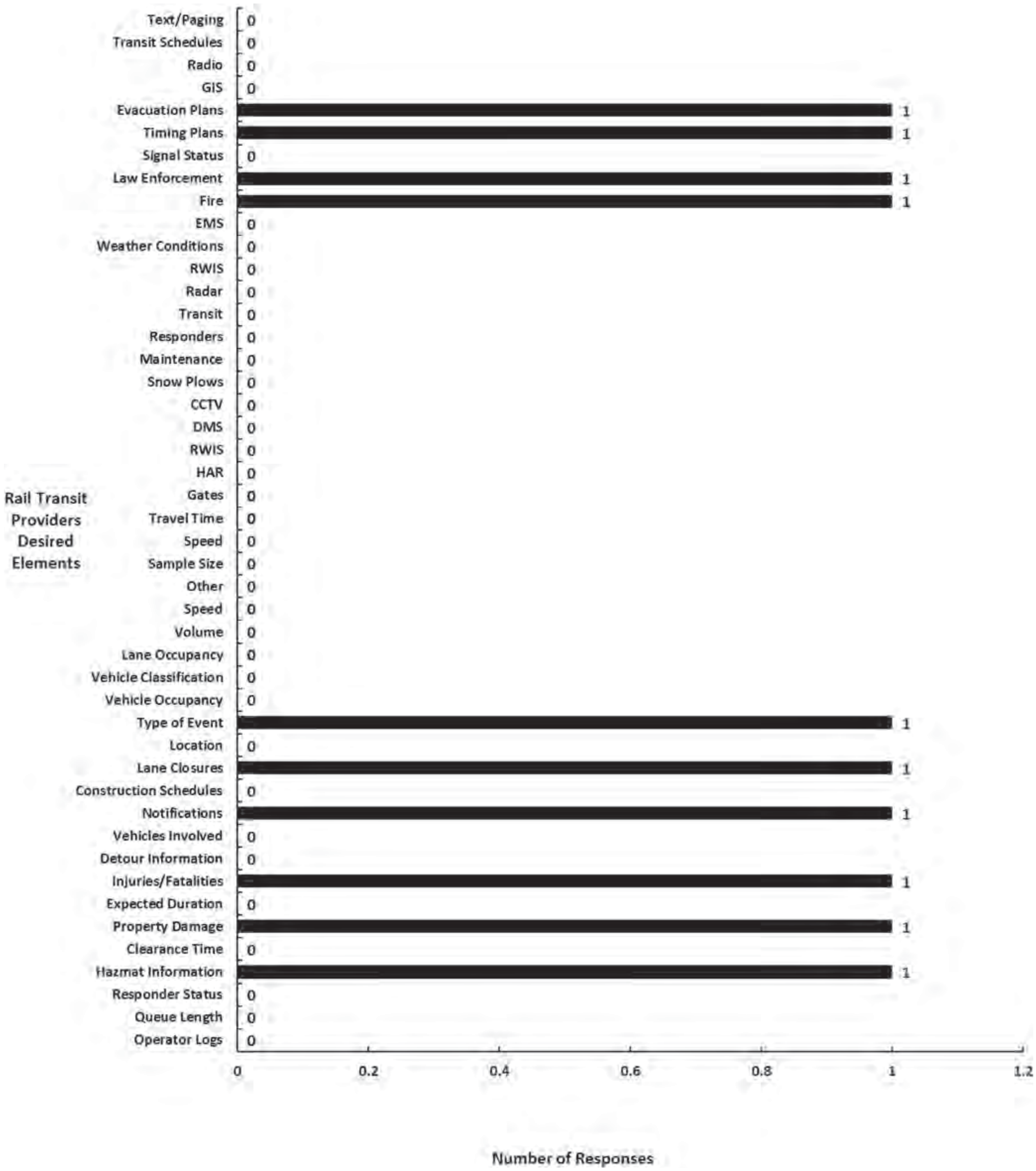


FIGURE D223 Rail transit providers desired elements—3 responses (Question 19).

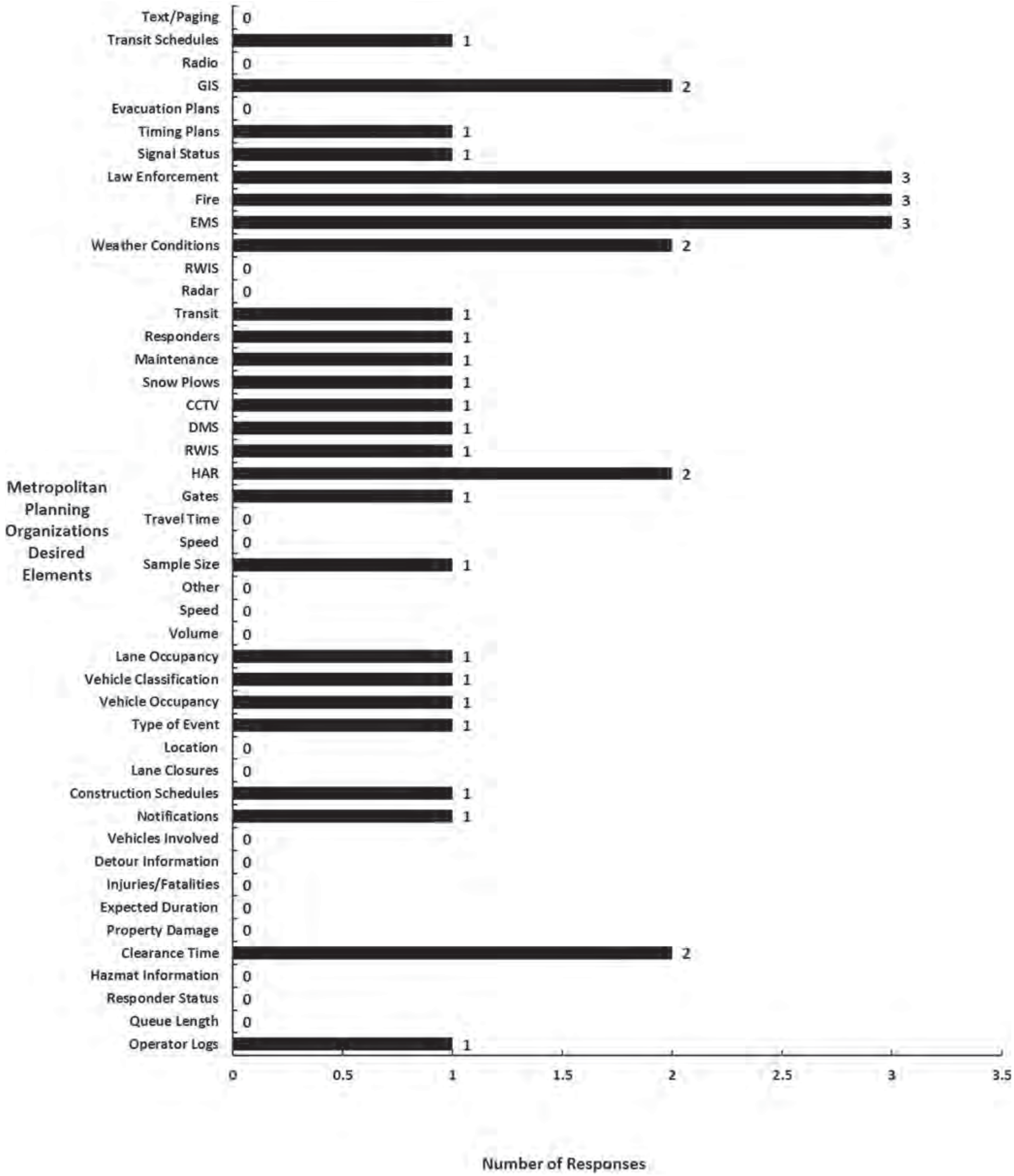


FIGURE D224 Metropolitan planning organizations desired elements—6 elements (Question 19).

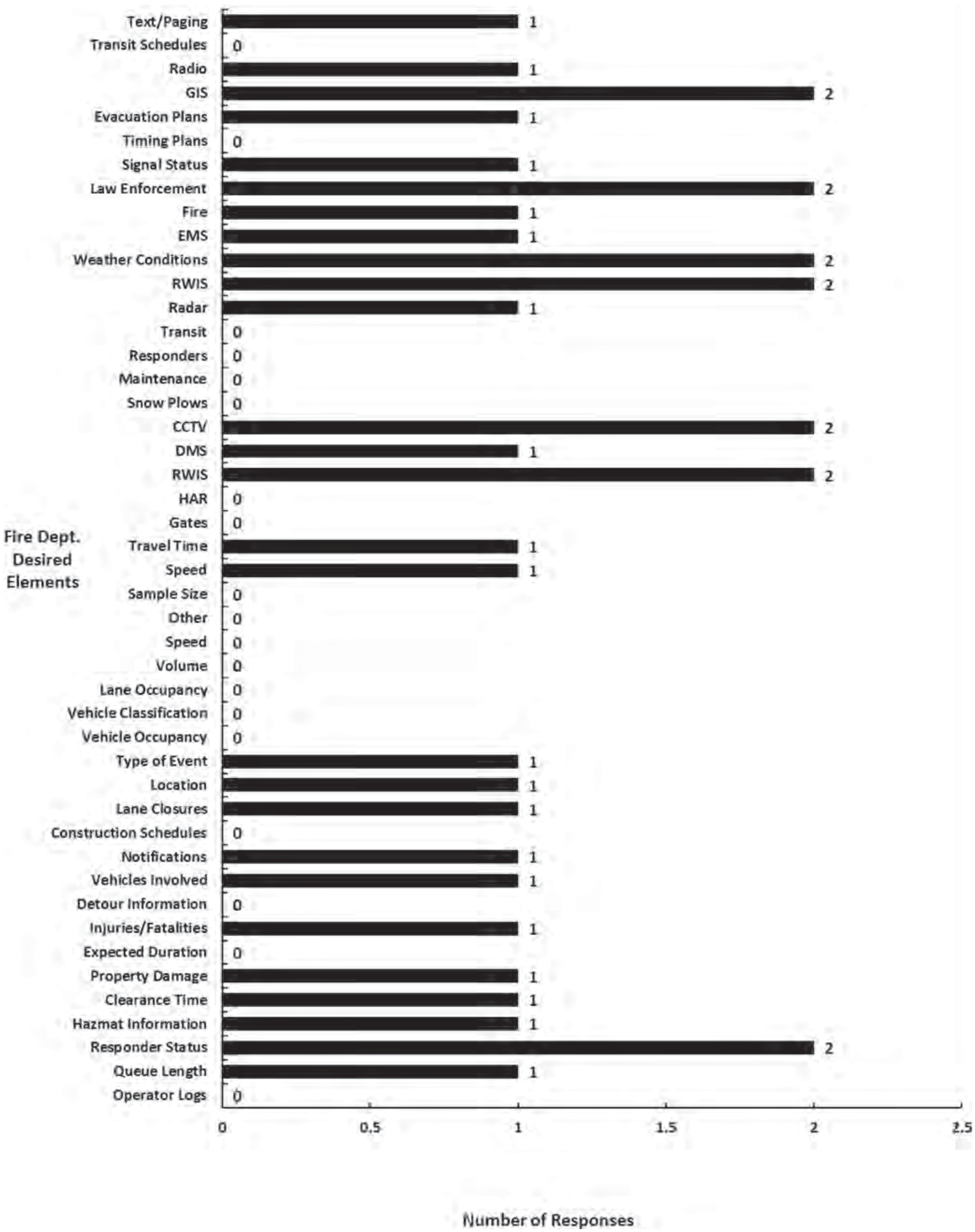


FIGURE D225 Fire departments desired elements—3 responses (Question 19).

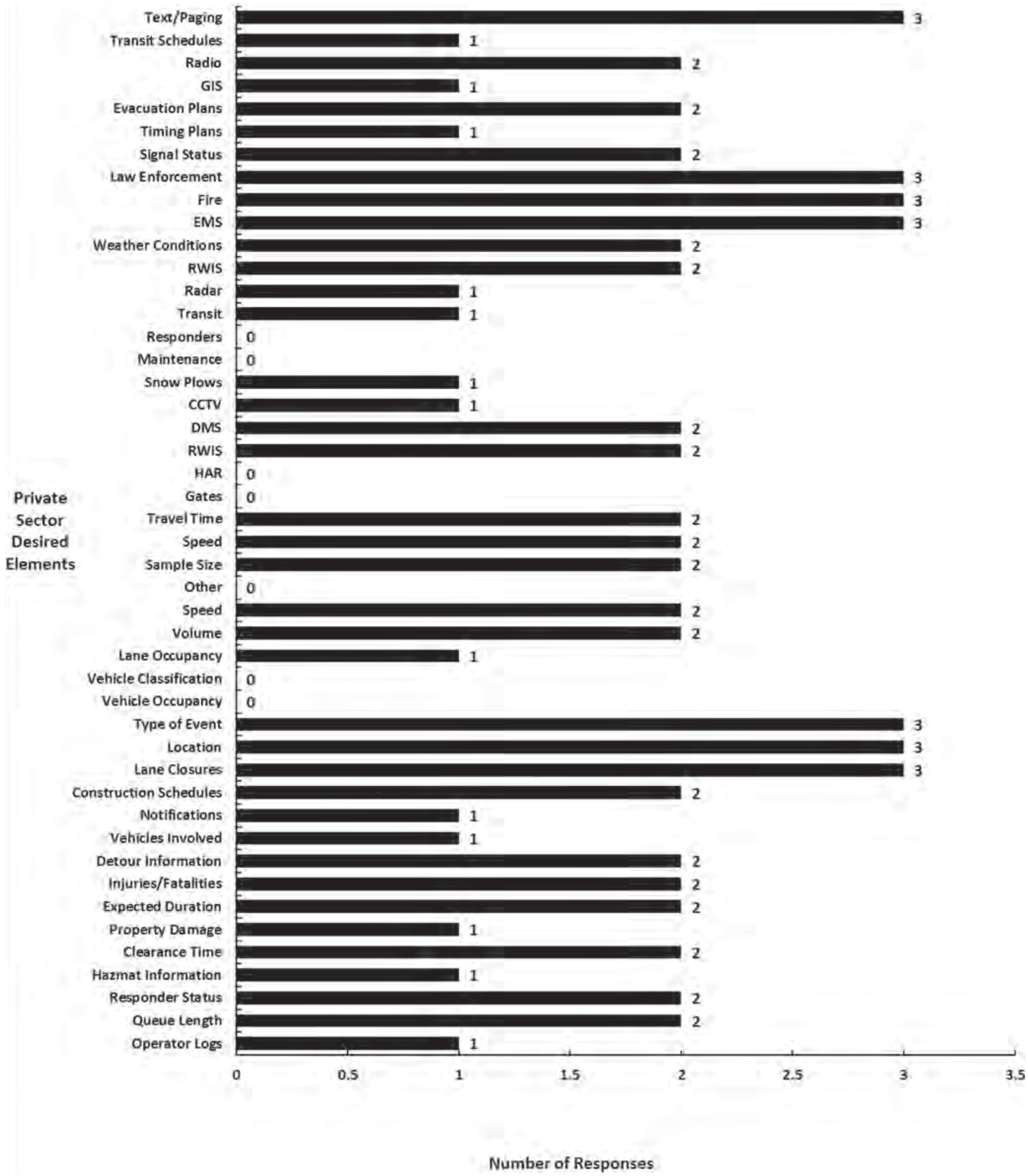


FIGURE D226 Private sector entities desired elements—5 responses (Question 19).

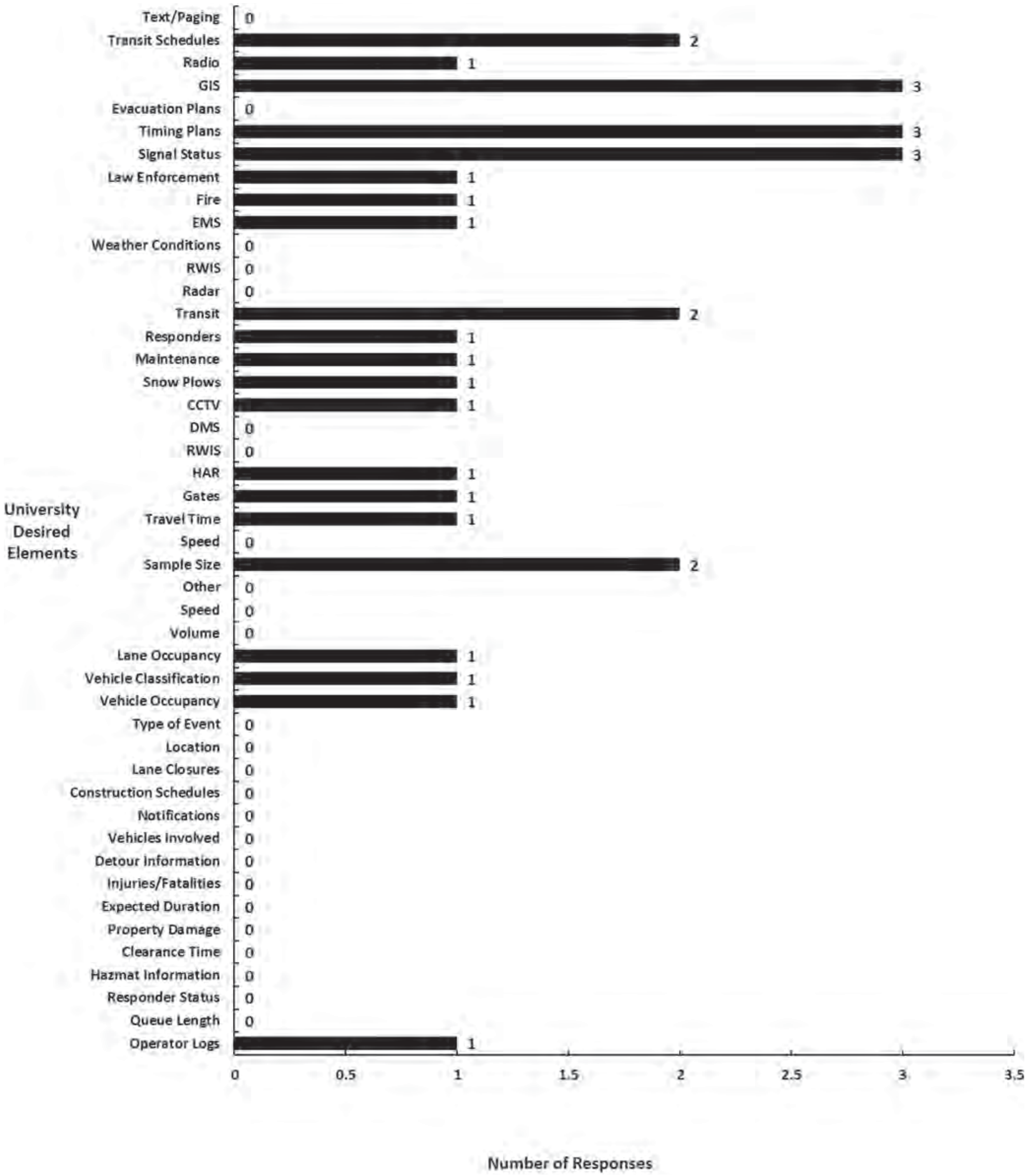


FIGURE D227 Universities desired elements—4 responses (Question 19).

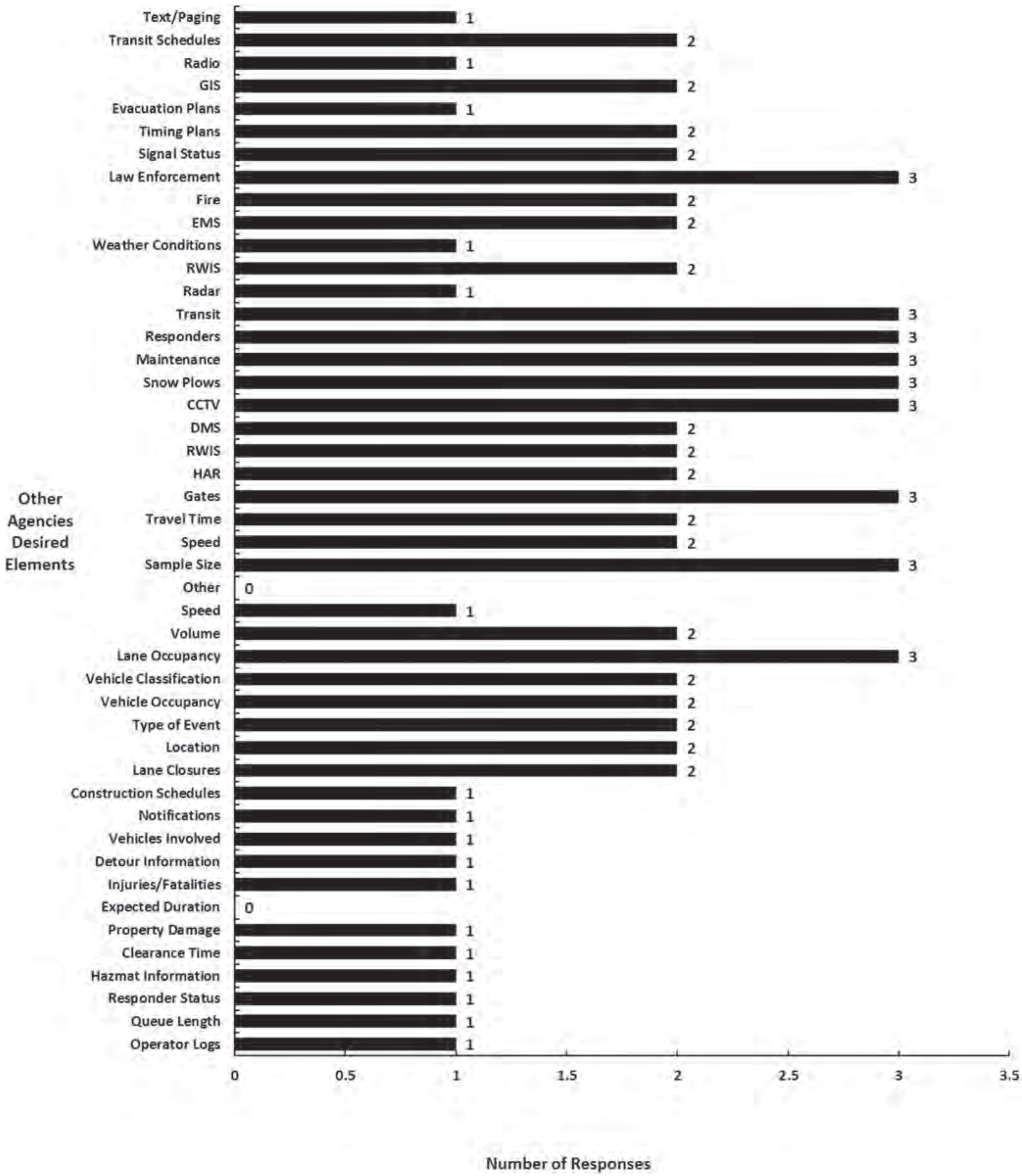


FIGURE D228 Other agencies desired elements—12 responses (Question 19).

Abbreviations used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation