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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP RESEARCH REPORT 210

Development of Transactional Data Specifications for Demand-Responsive Transportation

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TRANSPORTATION RESEARCH BOARD

2020

TRANSIT COOPERATIVE RESEARCH PROGRAM

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FOREWORD

By Dianne S. Schwager
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TCRP Research Report 210: Development of Transactional Data Specifications for Demand-Responsive Transportation presents a transactional data specification for demand-responsive transportation (DRT) to facilitate interactions among the software systems that manage these services. The specification accomplishes two objectives. First, it establishes a common language for software systems to communicate transactional data—all pertinent DRT trip details, such as origin and destination of the traveler and time of the requested pickup or delivery—with each other to accomplish DRT trips from the beginning to the end of the trip lifecycle. Second, it provides a recommended technical approach for how data communication will occur among the interoperating computer systems. Public transportation agencies, DRT service providers, and technology providers can use the products of this report to improve DRT services. Cities, planning agencies, and health-care organizations will benefit from the adoption of transactional data specifications as a means of fostering the cost-effective evolution and growth of DRT services.

Currently in the United States, DRT services almost always operate in isolation from other DRT services in their proximity. This precludes the possibility of cross-system interactions that could reduce cost per passenger served and improve service quality. Being able to interact can produce benefits—fewer empty seats, lower cost per passenger, less delay for customers—to both passengers and transportation service providers, particularly the public and private nonprofit agencies that finance DRT services with public funds.

The research products presented in *TCRP Research Report 210* include

- *A transactional data specification,* which is the set of rules for data interactions among software systems—encompassing both the structure and syntax for such interactions—that span the entire DRT trip lifecycle. Using these specifications will enable multiple organizations to participate in the DRT trip ordering and delivery process with the assurance that their software systems will have access to the complete set of data needed to perform their specific function(s) properly. Every step in the process will be recorded, and the data details will be available in a standardized data format for subsequent reporting and analysis, including for financial transactions.
- A recommended *data communication mechanism* to allow software systems of multiple service providers to exchange transactional data, using a telegram concept that includes a typology of data messages with mandatory and optional data fields.
- A *validator software tool* that verifies that the telegrams—data messages—generated by a software system intending to communicate with another system are specification compliant. The website that hosts the data validation service is http://tcrp.demandtrans.com.

- *Key tools to support a more bottom-up approach* to specification adoption, a strategy that may yield more near-term results, most likely at a regional or local level. For example, the tools can be used in requests for proposal by public agencies procuring technology or transportation services for DRT systems, to require respondents to comply with the proposed transactional data specification.

The report concludes with a discussion of possible ways forward to implement a transactional data specification in the DRT industry in the United States, so that the potential benefits of standardized data exchanges can be realized. The key challenges to moving forward quickly with industry-level adoption of a data specification are identified. The goal is to enable DRT services in the United States to more fully and easily participate in an era of new mobility, a new generation of technology-enabled urban transportation services that include bike sharing, car sharing, electric scooters, and on-demand transportation services operated by both private-sector and public-sector entities.

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SUMMARY

Development of Transactional Data Specifications for Demand-Responsive Transportation

This report documents the development of a transactional data specification for demand-responsive transportation (DRT) (Box S-1). *Transactional data* contains all pertinent DRT trip details in a reservations scheduling and dispatching system, such as origin and destination of the traveler and time of the requested pickup or delivery. The *transactional data specification* is the set of rules that explain what data is needed, and in what format, for these trip requests and responses when the fulfillment of the trip involves at least two systems that must exchange data.

Box S-1. Demand-Responsive Transportation Definition

Demand-responsive transportation (DRT) services, sometimes referred to as on-demand services, are those in which a customer requests a trip from one specific location to another specific location that is then scheduled to a vehicle and dispatched. The vehicle does not travel on a fixed route nor follow a fixed schedule. DRT for public transportation purposes typically requires the vehicles providing the rides to be shared by unrelated parties, but for the purposes of this study DRT is defined more broadly and includes taxi and ride-hailing services.

A primary purpose of a transactional data specification is to enable DRT services in the United States to participate more fully and easily in an era of new mobility by facilitating interactions among the software systems that manage them. New mobility refers to a new generation of technology-enabled urban transportation services that includes bike sharing, car sharing, electric scooters, and on-demand transportation services operated by both private-sector and public-sector entities, including Uber and Lyft as well as public transit agencies.

DRT, whose roots as shared-use public transportation extend back to dial-a-ride services beginning in the 1970s and continue operating in many communities today, encompasses these newer forms of on-demand service as well. DRT today includes comprehensive and fully automated technology platforms that manage service, smartphone apps for customers and drivers, Global Positioning System (GPS) tracking of vehicles, and digital data communications. Customers include the general public, older adults and young people lacking access to a vehicle, and individuals with disabilities.

Why a Transactional Data Specification Is Needed

Under current practice in the United States, each DRT reservations/scheduling software system is designed to meet the needs of the individual transportation service provider using that system. These software systems record trip characteristics in their own specific formats and have proprietary approaches to organizing and managing the trip lifecycle—consisting of trip booking, vehicle scheduling, service execution, and post-trip data reporting. These proprietary approaches prevent the routine exchange of trips among different transportation service providers with different software systems.

The result: DRT services almost always operate in isolation from others in their proximity. This precludes the possibility of cross-system interactions that could reduce cost per passenger served and improve service quality. The ability to interact across the boundaries of services would produce benefits—fewer empty seats, lower cost per passenger, less delay for customers—to both passengers and transportation service providers, particularly the public and private nonprofit agencies that finance DRT services with public funds.

In other transportation industries, the organizations that control the key software systems—or pay to use them—have developed transactional data specifications precisely to avoid the barriers to interoperability among systems. They have important business reasons to ensure that transactions can readily occur across organizational boundaries so the economic value of such transactions can be realized.

For example, in the airline industry it is necessary for airline reservations systems to exchange data so that passengers can seamlessly make trips involving two or more airlines. Millions of airline trips every day make use of transactional data specifications initially developed several decades ago and evolved over time to handle increasingly complex data interchanges among industry participants. The airline industry could not exist in its current form without the data exchanges made possible by these specifications.

In DRT itself, there is a precedent for transactional data specifications. The Swedish government initiated the development of DRT data specifications in the 1990s to enable local governments sponsoring DRT services to change software providers or transportation service providers—often large, regional scale taxi companies—without adverse consequence. As a result, the Standardiserat Utbyte av Trafik Information (SUTI, a Swedish acronym) standards, became mandatory for software and transportation service providers in Sweden and were eventually adopted by public agencies in the other Scandinavian countries. These agencies understood the benefits of imposing specifications that guaranteed the software systems of all DRT technology providers and transportation providers could interoperate. Vendor lock-in is avoided, trips could be allocated to multiple service providers, and service sponsors had more control over outcomes; the SUTI standards set the conditions for how technology worked, not the software vendors. Adherence to SUTI standards became the gateway to doing business in the DRT industry in Scandinavia.

What a DRT Transactional Data Specification Encompasses

A transactional data specification sets forth the vocabulary and syntax for how information about individual DRT trips can be transmitted from one computer system to another. This information includes the essential details about the traveler(s), the logistics of the trip, and any other information required to successfully order, schedule, and execute each trip.

The recommended DRT transactional data specification spans the entire trip lifecycle, from the initial ordering of the trip to its execution and subsequent delivery of data to all relevant parties about how the service was performed (e.g., when the passenger was actually picked up and dropped off), all the way back to the entity that originated the trip order. This means that multiple organizations are able to participate in the trip ordering and delivery process with the assurance that each will have access to the complete set of data it needs to perform its specific function(s) properly. Every step in the process is recorded, and the data details are available—in a standardized data format—for subsequent reporting and analysis, including for financial transactions. In addition, the transactional data specification developed for this study includes a recommended data communication mechanism to allow software systems from various service providers to exchange specification-compliant trip-related data.

What Other Experiences with Data Specifications Teach Us

Core principles for designing the transactional data specification—simplicity, sufficiency, flexibility, adaptability, compatibility, and technical appropriateness—were identified through research on data specifications for software system interactions in transportation and other industries, including directly relevant DRT situations. Five examples of specification-based common data formats in the transportation industry are identified in this report, with a short case study presented for each—the airline industry; the General Transit Feed Specification (GTFS) for fixed-route transit; the GTFS-flex extension for flexible transit service; SUTI in Scandinavia; and a DRT trip exchange in the Denver region.

The case studies of the transportation-related data specifications revealed four key lessons concerning implementation of DRT transactional data specifications.

First, Data Specifications Truly Can Produce Game-Changing Results

Transactional data specifications make possible not just data interoperability, but also business interoperability—organizations can concert their activities in mutually beneficial ways. The airline industry started down this pathway many decades ago with less than elegant technical approaches, but an evolutionary process involving specification-based data exchange for mutual business advantage was set in motion and continues to this day.

Much can be learned from the situation in Scandinavia that is directly relevant to the focus of this study. Not only does the existence of SUTI standards make it clear that data specifications for DRT are both technically and operationally feasible, equally significant is the key role those specifications played in making possible the development of the remarkable FlexDanmark system in Denmark.

FlexDanmark is likely the largest publicly supported DRT system in the world. In a country of 5.5 million people, it operates in each of Denmark's six public transit regions, transporting up to 24,000 passengers per day—the general public, senior citizens, individuals with mobility limitations, people needing transportation for healthcare purposes, schoolchildren with special needs, and others. It uses more than 500 different transportation service providers—taxi companies, medi-van operators, school bus companies, public transport contractors—that collectively operate more than 5,000 vehicles. Passenger trips are sponsored by more than 500 publicly funded agencies, including municipalities paying for trips for the general public, many healthcare organizations (including large hospitals and medical centers), and school districts, some of which enter orders for their clients directly into the FlexDanmark trip-booking system. All data communication between the ordering systems, the FlexDanmark scheduling system, and the transportation providers' computer systems—including the devices used by their drivers in the vehicles—is accomplished with data messages based on the SUTI standards.

Second, and Equally Important, the Ability to Achieve Specification Implementation Is Strongly Related to Key Stakeholders Perceiving Financial Benefits or Other Direct, Concrete Benefits from Specification Adoption

Implementing a specification in organizations' software systems requires the expenditure of resources and ongoing efforts to enhance or simply maintain the specification.

There must be a compelling business reason for organizations to agree voluntarily to make such commitments. "Nice to have" will almost certainly not be adequate motivation.

A business reason is clearly seen in the airline industry example, where the financial benefits of interlined ticketing are clear to all participants and resulted in specifications for data exchange several decades ago that have been maintained and evolved ever since. In the case of the initial development of SUTI standards there was also a strong business reason based on financial considerations. The Swedish national transport ministry wished to ensure that local public-sector organizations to which it distributed transportation funds would be able to procure technology systems that by design worked well together, and would not need expensive custom integrations that would also result in vendor lock-in and lack of future competition.

Third, the Pace of Specification Development and Adoption by an Industry or Sector Is Strongly Influenced by the Resources Under the Control of a Specification's Proponents

GTFS was adopted and disseminated and came into widespread use in several years once Google put its resources behind the specification. Google could devote substantial resources to an ambitious specification development undertaking that in a short period of time fundamentally changed how public transit data was structured and exchanged. In contrast, the developers of GTFS-flex have had limited and only episodic access to financial resources for developing specifications and promoting their adoption; this proposed extension is not yet formally adopted.

Fourth, Authoritative Actors, Whether They Are the Government or Private Companies That Are Major Players in an Industry or Sector, Make All the Difference in Achieving Specification Implementation

While a voluntary, industry-initiated process is the most typical approach to specification development, an alternative pathway is for an organization with authority over industry participants to mandate that specifications be adopted, as occurred with the Swedish government and the SUTI standards. Market leaders do not have the same formal authority as governmental entities, but if an industry leader proposes technical specifications, smaller competitors are likely to feel compelled to fall into line for fear of losing business.

In Denmark, transportation service providers and technology companies were required to adhere to the SUTI standards if they wanted to be included in the FlexDanmark system. As that system became the gateway to most public-sector–funded DRT in Denmark, businesses had no practical alternative to adhering to the specification if they wanted to participate. Google's promulgation of the GTFS specification and the fact that Google Transit would only work with this data meant that transit agencies were essentially forced to publish their data in this format if they wanted information about their services to be widely available.

What We Learned from the Stakeholders in the U.S. DRT Industry

To obtain input directly from individuals knowledgeable about DRT, the research team convened an advisory panel of 22 members representing DRT industry stakeholders: software companies and other technology providers; transportation service providers (public transit and healthcare/human services contractors, TNCs, taxi companies); public transportation agencies; and researchers involved in data-related matters. The advisory panel served as a key resource to the research team, meeting six times via conference calls. Structured interviews with panel members provided additional information on industry perspectives and objectives regarding transactional data specification.

The advisory panel process resulted in several key findings.

1. There is general agreement among DRT industry stakeholders with the objectives of a transactional data specification.
2. There is an awareness among many stakeholders of the challenges that must be overcome if a specification is to achieve an industry scale, most importantly:
   – Lack of incentives to induce technology providers to standardize data formats and adopt a common data vocabulary for transactions;
   – Cost of switching to a data specification from current proprietary data approaches; and
   – Current absence of any governance structure to assume the leadership and direction of a specification development/implementation process.
3. There is a shortage of strong advocates within the DRT industry prepared to assume a leadership role in an adoption process. Advisory panel members liked the concept of transactional data specifications for DRT, but few seemed interested in taking a direct role in undertaking specification implementation.

The advisory panel process, inputs from multiple other DRT industry sources, and the experience with successful specification development in other industries all point to the development of a governance structure led by a neutral, well-respected party that can take ownership of the proposed specification as critically important.

The perspective of a key group of stakeholders, namely the agencies funding a significant amount of DRT service, also bears emphasis. The business reasons for a transactional data specification have not been clear to many in this group, even though they could be major beneficiaries. Moreover, those agencies that may understand the business reasons for adopting a data specification for DRT do not perceive that they have the power to effect change for what is a national issue. They view their agency as one of many buyers of DRT software, and typically do not believe that they have sufficient leverage or technical expertise to propose or impose nationally relevant specifications.

What the Recommended Specification Makes Possible: Data Interoperability

The core purpose of a transactional data specification is simple: to enable different computer software systems to interoperate to achieve some defined business and/or technical purpose. The specification that has been developed in this study accomplishes two objectives.

- First, it establishes common language for entities to communicate transactional data with one another, to accomplish DRT trips from beginning to end of the trip lifecycle.
- Second, it provides a recommended technical approach for how data communication would occur among the interoperating computer systems.

The proposed specification is based on a *telegram* concept—the same used by the SUTI standard in Scandinavia. Telegrams consist of message types with specified data elements. Telegrams are sent from the computer system of one party to the computer system of another party to advance a transaction involving a passenger trip. All valid telegrams are composed of a predefined message type whose message contents must include all the data elements required for that type of message, and can include optional data elements.

The Way Forward: Next Steps to Implement a Specification

This report concludes with a discussion of possible ways forward to implement a data specification in the U.S. DRT industry so the potential benefits of standardized data exchanges can be realized. The key challenges to moving forward quickly with industry-level adoption of a transactional data specification have been identified above. In consideration of those challenges, the study team has provided some key tools to support a more bottom-up approach to specification adoption, a strategy that may yield more near-term results, most likely at a regional or local level.

Toward that end, we have provided documents that (1) make the case for why DRT transactional data specifications are important to improving the benefits from DRT services; and (2) can be used in requests for proposal by public agencies procuring technology or transportation services for DRT systems, to require that respondents be compliant with the proposed data specification.

In addition, a transactional data specification validator software tool has been developed that can be used by software systems that want to implement the specification proposed in this report. The software tool verifies that the telegrams—data messages generated by a software system to communicate with another system—are specification-compliant. The website that hosts the data validation service is http://tcrp.demandtrans.com

Public transportation agencies, DRT service providers, and technology providers can use the products of this report to move forward toward implementation—and operational use—of transactional data specifications in existing and new DRT services. The products are also available to other actors involved in new mobility, such as cities, planning agencies, and healthcare organizations, to support adopting transactional data specifications to foster the cost-effective evolution and growth of DRT services.

CHAPTER 1

Introduction

1.1 About This Research Project

This project focuses on a key building block for enabling demand-responsive transportation services in the United States to participate more fully and easily in the era of new mobility. The primary product of this effort is a comprehensive data specification for ordering and scheduling trips and vehicles in demand-responsive transportation services, the transactions that are at the heart of providing these types of services. Transactional data specifications include the mechanisms for the software systems of various service providers to routinely exchange such information, so that interoperability among services becomes feasible. This report (1) presents new transactional data specifications for demand-responsive transportation; (2) makes a case for why key stakeholders in the public sector—those that fund and provide demand-responsive services—should adopt and build out these specifications; and (3) provides some tools to help them do so.

Once implemented, the proposed transactional data specifications will improve the availability, cost-effectiveness, and quality of demand-responsive transportation services. The primary beneficiaries include:

- *Customers,* who will benefit because transactional data specifications can help increase availability of demand-responsive services.
- *Demand-responsive service providers,* which will benefit because they can better utilize their vehicles, serving more customers at a lower cost per trip, and more seamlessly interoperate with public transportation organizations and others that fund these services.
- *Publicly supported transportation organizations,* which can benefit from improved cost-effectiveness of DRT services as it becomes possible to use multiple transportation providers for a single service program, while also fostering competition among them.
- *Government transportation funding programs,* which will benefit by using public resources more efficiently and effectively to fund transportation services and by improving mobility services to local communities.

Experience in Denmark over the past 10 years demonstrates that improvements can occur when transactional data specifications become integral to demand-responsive transportation. Making this a reality in the United States would represent an important building block for more effective use of demand-responsive transportation for public purposes.

1.2 What Is Demand-Responsive Transportation?

Demand-responsive transportation (DRT) covers a wide range of on-demand services. For this report, DRT refers broadly to transportation services in which vehicles operate only in response to ride requests and are routed to transport passengers from their origin to their destination. In contrast to fixed-route transit, in which the passenger must access the service, in DRT the service is mostly or completely tailored to the passenger's specific trip. Rider trip requests are scheduled through an automated or manual system. Vehicles are scheduled and routed in accordance with the specific elements of the demand for service; the scheduling system considers origin, destination, desired pickup time and/or desired arrival time, vehicle requirements, and other trip requirements.

Applying this broad definition to both public and private transportation services, DRT includes the following:

- *Dial-a-ride services,* the term historically used for public transit shared-ride DRT services for the general public, or similar services geared toward seniors.
- *Americans with Disabilities Act (ADA) complementary paratransit services,* shared-ride DRT required by the ADA and restricted to individuals unable to use fixed-route services because of a disability.
- *On-demand/flex/microtransit services (all referring to essentially the same thing),* contemporary versions of shared-ride DRT service using more advanced technology and potentially using service concepts such as virtual stops or dynamic routes, provided for public transportation purposes for community circulation or first-mile/last-mile access to rail transit and express bus services.
- *Ride-hailing services,* for-hire on-demand transportation services engaged by a smartphone app, such as Uber, Lyft, Via, and other transportation network companies (TNCs), most commonly using vehicles owned by the drivers who connect to the service network via a driver app. These services may be of a shared-ride nature, e.g., Uber Pool, Lyft Shared, Via Van, as well as individually directed, taxi-like trips.
- *Taxi services,* for-hire transportation providing on-demand rides for any paying passenger, using vehicles clearly identified as taxis.

Together, these demand-responsive services provide transportation to a wide variety of passengers, with or without mobility impairments, in both urban and rural communities. Figure 1-1 shows two of the many types of vehicles used for DRT services.

Historically, DRT has referred to public transportation services that are shared-ride in nature and exclude general, for-hire transportation in which the vehicle is under exclusive control of the rider. Taxis or similar services provided by ride-hailing services (i.e., TNCs such as Uber

Figure 1-1. Examples of vehicles used for DRT service.

and Lyft) are typically in the latter category but have been used for public transportation purposes in certain situations. For the purposes of this report, DRT is defined broadly, to include all forms of demand-responsive transportation in the transactional data specification.

As emphasized, DRT services for public transportation purposes typically involve unrelated parties sharing a vehicle which is under the control of the system, not each individual rider. Examples include services for the general public—often referred to as dial-a-ride—that exist in hundreds of communities throughout the United States, as well as services operated by publicly funded human service organizations, ADA paratransit services, and many airport shuttle services. In this report, DRT services that feature mandatory sharing of the vehicle by unrelated parties are referred to as *shared-ride DRT*.

1.3 What Is Transactional Data for DRT?

Transactional data is the data created for each ride occurring in a DRT service spanning a trip lifecycle that begins with a trip-booking request and ends when a customer is delivered and the financial settlement information for the trip has been exchanged among the customer, service provider, and any third-party funding entity. Transactional data contains all pertinent trip details in a reservations and scheduling system, including:

- Origin
- Destination
- Requested time (pickup/arrival)
- Passenger attributes (e.g., wheelchair)
- Actual pickup time
- Actual arrival time
- Trip fare (to passenger)
- Trip cost (to provider)
- Fare, payment, or funding information

1.4 The Technology and Market Context of Transactional Data Specifications

Technology platforms have become the centerpiece of new mobility services. New mobility services include ride hailing, bike sharing, car sharing, electric scooters, and other smartphone-enabled travel modes. These service platforms are also accessible via Mobility as a Service (MaaS) applications, providing an integrated view of all urban transportation options including multimodal trips and certain transactional and payment capabilities. Platforms are now the gateway to most mobility services—of whatever type—that are available on demand.

This essential connection between technology and new mobility services provides the background for the direction of this study. The importance of a transactional data specification is integrally connected to the need for interoperability among multiple technology systems; connected digital platforms promise more effective approaches to providing DRT.

Figure 1-2 shows how DRT transactional data specifications fit into the larger data framework that is developing for public transportation services. This framework began with the development (by Google) of the General Transit Feed Specification (GTFS) and is moving rapidly in the direction of MaaS platforms that encompass all forms of available mobility services, and can include open source trip-planning tools such as Open Trip Planner that promise to make basic MaaS functionality widely available.

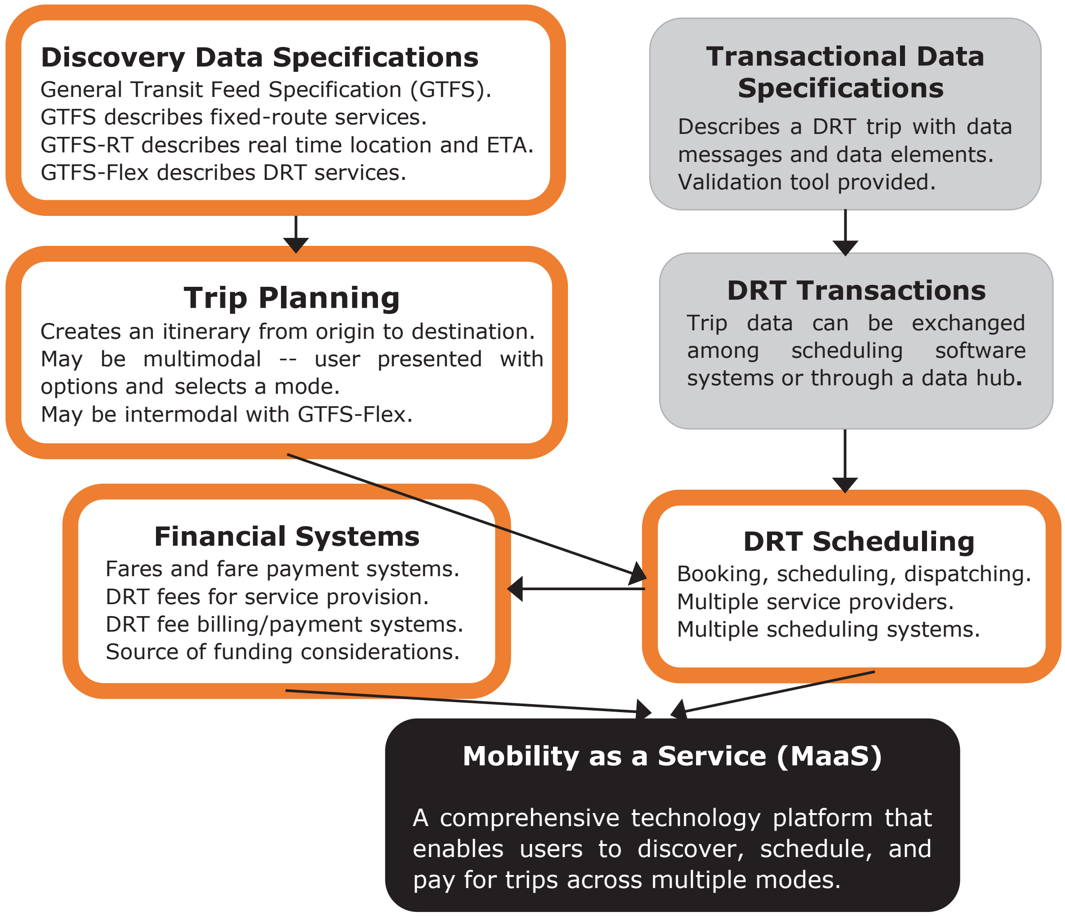


Figure 1-2. DRT transactional specification in transit data context.

As Figure 1-2 illustrates, transactional data specifications are poised to play a key role in a public transportation future in which demand-responsive services are an important element of local mobility. In particular, they make it simple for DRT services to be included in MaaS systems, not merely as an available service but also to book rides on the service and pay for those trips. This is essential if such services are to realize their potential for first-mile/last-mile access to high-capacity rail and bus transit and for community circulation in environments in which fixed-route bus service is ineffective and costly.

Transactional data specifications in conjunction with technology platforms also offer the possibility of more effective resource utilization for DRT services. Traditionally, such services—whether in the public or private sector—have been managed by a single software system in a closed environment that is incompatible with software systems of other transportation service organizers or providers. Service integration either vertically or horizontally could occur only if all participants used the same software or if bespoke data specifications were developed to enable interoperability, which has rarely occurred. As a result, demand-responsive transportation in which coordination across suppliers and service organizers occurs in ways that improve service and efficiency is virtually nonexistent in the United States.

Data interoperability across software systems is essential for technology platforms to make possible more coordinated, integrative approaches to service organization and delivery for demand-responsive transportation services. This research project has considered the methods of achieving interoperability and identified the development of transactional data specifications as the preferred solution to achieving software/data interoperability and facilitating service coordination across demand-responsive transportation systems. Such data specifications are essential to a future in which these services can readily involve multiple service sponsors, funding sources, and transportation providers interoperating via—or across—technology platforms.

1.5 Examples of Transactional Data Specifications in Transportation

Transactional data specifications are used in many market contexts. The combination of data specifications and technology platforms has fundamentally changed other transportation markets; two highly relevant examples are the online travel agencies and demand-responsive transportation for public transportation purposes in Denmark.

Online Travel Agencies

Online travel agencies (OTAs) such as Orbitz and Expedia revolutionized how consumers select a travel itinerary and purchase airline tickets and other travel services. The OTA platforms became feasible because of data technology developments circa 2000 that made it possible to interoperate, using standardized data flows, with the technology systems used by the airlines and the global distribution systems, which manage transactions for many airline ticket bookings. Standardized data made price/service comparisons among airlines seamless. Consumers—platform users—could view and compare information about services and prices on multiple airlines without searching among multiple airline websites and then select and book their preferred flight and pay for their tickets, all using the OTAs. Over time, the scope of what these platforms can accomplish for consumers has expanded (seat assignments, baggage fees, and the like) as all parties (airlines, global distribution systems, OTAs) agreed on additional data specifications, a process that continues to evolve.

The OTAs are examples of consumer-payment–based, platform-enabled transportation services. They represent a specific type of e-commerce service targeted at individual consumers—the entire process is handled through private-sector mechanisms. In contrast, FlexDanmark is an example of platform-enabled transportation services constructed on a public-sector foundation. The FlexDanmark organization, itself a government-chartered enterprise, has developed the world's largest demand-responsive transportation system on a foundation whose essential elements are third-party funding sources from the public sector and a comprehensive technology platform.

FlexDanmark: Denmark's Nationwide DRT

FlexDanmark is the platform for DRT delivery throughout Denmark. Organized into Denmark's six large regional public transportation service districts, DRT services are available to the general public and other target populations, with a large healthcare–related transportation component. Overall ridership is about 18,000 trips per weekday. Funding is provided by more than 500 public-sector (or quasi-public-sector) entities, including municipalities, human service organizations, hospitals and other healthcare organizations, and school districts. Service providers include more than 500 private transportation contractors—taxi companies, school bus contractors, medical van providers, and others, all of which must meet certain performance standards. The FlexDanmark platform includes comprehensive functionality for trip booking—via both agents in call centers and direct online access for many agencies, trip scheduling, assignment of transportation service providers and vehicles, vehicle tracking, and financial transactions for funding sources and service providers.

The FlexDanmark central platform interoperates with the scheduling/dispatching systems of all transportation service providers using standardized data protocols and flows based on a Scandinavian transactional data specification scheme (the SUTI standard), developed specifically for demand-responsive transportation. The SUTI specification—to which adherence is mandatory for all transportation service providers (i.e., their software systems must be able to exchange data messages with the FlexDanmark platform using SUTI language)—is the foundation for the interoperability that enables multiple providers and/or multiple service purchasers (e.g., hospitals, municipalities) to be able to "speak" with the FlexDanmark platform—and hence indirectly with each other. This world-class DRT system depends fundamentally on a comprehensive transactional data specification.

1.6 Who Are the Stakeholders for DRT Data Specifications?

The DRT industry is composed of a variety of organizations with different roles. These include public-sector organizations—whose roles in DRT can include organizing/sponsoring services, funding the service, and/or managing service as well as directly operating the service, and private-sector entities that may operate DRT services or provide technology of various types. Adoption of the recommended transactional data specification will require buy-in and action from stakeholders.

The primary stakeholders for DRT data specifications, and the most important target audience for this report, are the following types of organizations and actors:

- *Public transportation agencies.* In the United States, public transportation agencies (including municipalities and counties when they play this role) typically fund and manage DRT services such as dial-a-ride, ADA paratransit, and the emerging on-demand/flex/microtransit services. A public transit agency may operate the services directly, or it may contract with a private company to operate these services; the latter is more common.
- *Human service agencies.* Human service agencies, typically private, nonprofit organizations, may also directly provide DRT services. Often these services are oriented to the elderly, persons with disabilities and/or mobility limitations, or other human service clients.
- *FTA.* While the FTA provides policy leadership and funding programs for public transportation, it has not to date extended its mandate to providing regulations for data standards for operating transportation programs and services. Policy-makers at FTA clearly understand the desirability of data specifications for all aspects of public transportation where data interchanges can improve outcomes.
- *State DOTs.* As significant funders of public transportation in many states, particularly for small cities and rural/semirural areas where DRT services are more likely to be found, state DOTs have reasons for a policy interest in the adoption of data specifications. But like FTA, this is not an area where virtually any state DOT has been involved to date.
- *Other public funders of transportation service.* A significant amount of DRT service is funded through healthcare or human service transportation programs. This includes Older Americans Act services, Centers for Medicare and Medicaid Services, and a variety of other public-sector–funded programs. The organizations in this category do not directly operate DRT for their clients, but fund the services that are provided by others, typically private transportation contractors, often including taxi companies.
- *Technology providers.* Private companies that provide specific technology (typically software) systems or services in the DRT industry are stakeholders. The technology includes software systems used to schedule and manage DRT trips; larger software platforms that include trip-planning and fare-payment capabilities and integrated mechanisms to engage DRT services

for consumers; and hardware-based technology with embedded software such as mobile data terminals and handheld devices. Some of these companies have hundreds of customers, and others have a handful. With the advent of a new generation of on-demand services, in conjunction with developments in technology, there has been a significant expansion of the number of companies in this category.

- *Private transportation operators.* A variety of private companies provide DRT services to publicly funded agencies or to businesses. Some operate under contracts in which the vehicles, DRT software, and other technology are provided by the service organizer. Others are required to provide vehicles and technology, along with drivers, as part of the contract. Depending on the structure of the contract, these companies may provide their own vehicles, drivers, and operational staff, as well as specialized software for DRT and/or ADA paratransit and other technology (e.g., mobile or tablet computers in the vehicle). Private operators include national companies (e.g., First Transit, TransDev, MV Transportation) as well as regional and local companies. They also include taxi companies in many settings.
- *Taxi operators.* Taxi operators occupy a special position, as they derive the majority of their revenues from private for-hire services—as with TNCs—yet have been used for public-sector–funded demand-responsive transportation services for many decades in many U.S. cities. Now facing an existential threat from the TNCs, the taxi sector has been a partner to the public transportation sector that has certain advantages compared to TNCs and whose preservation is considered important by many involved in DRT.
- *Transportation network companies (TNCs).* Private providers of ride-hailing (or ride-sourcing) services, they typically have a technology platform that manages the entire service, accepting trip requests from customers initiated via a smartphone application, and then assigning rides to specific vehicles. They include companies such as Uber and Lyft for taxi-like service (which includes shared taxi services such as Uber Pool and Lyft Shared) and Via for shared-ride van services. It bears emphasizing that the TNCs are larger economic entities than any of the other organizations in the DRT industry.
- *Researchers and consultants.* Academic researchers and consultants who work on projects in the DRT industry may also find this report relevant to their work, particularly the community of data specialists in the public transportation and on-demand services sectors. The latter recognize the importance of data specifications in all forms of urban mobility.

1.7 Benefits and Challenges of Implementing Specifications

Benefits

The benefits of transactional data specifications vary according to the interest of the stakeholder. For public transportation agencies and publicly funded entities that operate or fund DRT services, the implementation and use of transactional data standards would help them achieve three important policy goals.

1. *Improve coordination.* Data specifications for DRT services can improve productivity and effectiveness by better enabling existing DRT providers to share riders and group passengers traveling along similar paths and reduce the number of empty seats on return trips. For difficult-to-serve, lengthy regional or rural trips, implementation and use will allow providers to schedule vehicle trips that combine a variety of passengers, so the cost per passenger is reduced.
2. *Create opportunities for improved cost-effectiveness of DRT services.* Many DRT services are costly and strain the resources of the organizations that fund them. There are multiple reasons for this, but transactional data specifications that enable multiple DRT service providers

(particularly those not previously involved but able to provide nondedicated vehicles) to be engaged so the supply of service can be more closely tailored to demand patterns, creates opportunities for more cost-effective DRT. FlexDanmark has been particularly effective in taking advantage of these nondedicated vehicle providers. Studies in Denmark indicate it is able to deliver service for significantly less cost per passenger trip than DRT services that existed prior to its introduction.

3. *Strengthen private-sector involvement.* Digital interaction capabilities that encompass both the source of DRT trips (trip-booking systems) and the software systems of DRT providers—which require a data specification that spans these domains—will enable transportation and human service agencies to more easily use a variety of DRT providers, many of which are in the private sector. A few agencies have developed efficient approaches to serve multiple types of trips with diverse purposes and destinations by creating fleets from multiple sources, including contracting some service to taxi companies and other private providers.

A brokerage model is often cited as desirable, with a single agency controlling many providers using a single scheduling system. The ACCESS service in Pittsburgh and throughout Allegheny County is an example of this, serving a population of 1.2 million in an area of 745 square miles. It provides services for more than 140 agencies using six providers and over 300 vehicles, so each provider's fleet is fairly large. Contrast this with FlexDanmark, which serves a population of 6 million in a much larger area (875,500 square miles) and uses 500 providers, many of which are small, "mom-and-pop" providers. Larger forms of the broker model are feasible with the right underpinnings.

A uniform approach for transactional data would make it much easier for a multitude of small providers to participate in the delivery of DRT services. The expected benefits are similar to what FlexDanmark has experienced, namely, lower costs and a more robust network of service providers.

Challenges

There are at least three key challenges that must be overcome for the benefits of transactional data specifications for DRT to be realized.

- *Widespread adoption takes time.* It takes time to develop, implement, and institutionalize the use of specifications. While GTFS is an example of the effective use of a specification, it is important to remember that it took well over a decade for widespread adoption. Early adopters do enjoy some benefits, but it is not until a significant number of entities adopt a standard that the benefits multiply.
- *Change is difficult.* Change itself is often the most formidable challenge. Adopting a new way of doing business requires change among public agencies, DRT service providers, and technology companies. This will require adaptation, learning a new language and establishing new business rules and quality control mechanisms.
- *Lack of leadership or champion.* A fundamental challenge to the adoption of recommended transactional data specifications by the DRT industry is that there is no current group or entity leading this effort. To date, no stakeholder has demonstrated sufficient interest or willingness to take a leadership role in promoting transactional data specifications for DRT. Without a leader, it will be difficult to carry such an initiative far enough to realize the complete benefits. A champion would inform others about the benefits of adopting data specifications, provide technical materials (such as language for procurement documents), and oversee a process to develop and maintain the integrity of the specifications. This latter process is important so developers can depend on the specifications for use in creating a technology platform.

1.8 Strategies for Successful Adoption of Data Specifications

Existing Systems

While establishing a specification-based digital infrastructure for demand-responsive transportation in the United States will be challenging, successful models exist. As explained in Chapter 3, several European countries have adopted transactional data specifications developed initially in Sweden (SUTI standards), and there is now a process that spans multiple countries by which those data standards are governed and can evolve. But while the technical approach to the SUTI data specifications provided an excellent framework for this research project, the way in which those specifications have been adopted and subsequently governed cannot simply be transferred to the U.S. context, in view of the more authoritative role of the central government in Scandinavian countries.

The successful systems from Sweden and Denmark do provide important guidance to the U.S. situation, the key lesson being that it is the governmental (or quasi-governmental) organizations that fund local transportation services that must act decisively to initiate the process of specification adoption. Specification implementation will occur only when such entities insist upon it as a condition for doing business. For transactional data specifications to be widely adopted, it is desirable that one or more organizations that represent public-sector funding sources assume a leadership role. For assuring the specification can continue to be developed while maintaining the integrity necessary for use in technology platforms, such leadership and a process of governance will be necessary.

Support Materials

The research team developed materials to assist public agencies and other funding sources in understanding the transactional data specifications developed in this project so that they can advocate for, and potentially lead, a process that could result in industry-wide adoption of these (or comparable) specifications. The research report includes information that will facilitate the adoption and use of transactional data specifications for DRT, including:

- *Materials to market the specifications,* specifically a document that makes the business case for the proposed specifications;
- *Stand-alone technical materials,* including a software tool that can validate data flows for consistency with the proposed specifications, that can be used to develop specification-compliant data exchanges; and
- *Requirements that can be included in requests for proposal,* useful for organizations to stipulate that services they fund or contract for, and scheduling software they purchase, must comply with the proposed transactional data specifications for DRT.

For the interested few to use these materials could result in a bottom-up approach to specification adoption, one that is relatively novel and could take a few years to make an impact across the entire industry. However, if even a relatively small number of organizations or states adopted this approach to technology procurement, it might lead to a much broader movement within a year or two and stimulate an industry-wide adoption of transactional data specifications.

The experience from Europe with the SUTI standards indicates that DRT transactional data specifications can be developed and adopted by those that fund these services. To support continued development of the specifications, and maintain the integrity necessary to develop the technology platforms that will allow entities to realize the full benefits, a means of governance will be needed.

The purpose of this report is to provide those who wish to engage in this process with the rationale, knowledge, and practical tools to adopt and promote the widespread use of transactional data standards for DRT in the United States.

1.9 How This Report Is Organized

This report consists of five chapters and eight appendices. The first and fifth chapters are oriented to a broad audience, covering all stakeholders who have an interest in developing and adopting transactional data standards for DRT. Chapters 2, 3, and 4 focus on the process of developing specifications that are functional for DRT providers and practical for technology vendors. These three chapters provide information on what was considered in developing the specifications and the result of the research, a proposed specification. Chapter 5 returns to a broader discussion of implementation. The appendices provide technical documentation of the specification and tools for implementation.

Chapter 1—Introduction provides overviews of demand-responsive transportation and transactional data. It identifies the report's target audience and previews the rest of the report.

Chapter 2—Principles and Considerations in Developing the Transactional Data Specification discusses the key factors that were considered to develop the proposed DRT transactional data specification. These factors include core design principles such as simplicity and flexibility, market considerations, and the specific functional requirements for a DRT transactional data specification. Different technical models for implementing a DRT transactional data flow are described and a preferred model is presented.

Chapter 3—Examples of Transportation Industry Data Specifications presents five examples of common data formats in the transportation industry, beginning with an example from the airline industry. The second and third examples pertain to the GTFS, which is commonly used to provide information about fixed-route transit services, and a new extension for flexible transit services. The last two examples—one from the Denver region and another from Scandinavia—are most relevant to this project and present examples specific to DRT transactional data.

Chapter 4—Summary of the Specification presents an overview of the proposed DRT transactional data specification. Important technical elements, such as the data communication approach and types of data elements, are explained. Additional technical details can be found in Appendices D and E, which contain the full documentation for the proposed specification.

Chapter 5—Conclusions and Future Considerations presents a short summary and key conclusions from this research project. Notable future considerations for implementation, such as governance for the specification moving forward, are also discussed.

Appendix A—Industry Advisory Panel Members contains a list of the industry experts on the advisory group that participated in some or all of the industry advisory panel meetings.

Appendix B—Engaging Industry Experts outlines the group of industry experts who were engaged to advise this project's development process. This appendix summarizes the research team's interactions with the industry experts throughout the duration of this project. The industry advisory panel participants took part in regular virtual meetings (calls) to provide input on the specification implementation. In the early stages of the project, team members conducted semi-structured telephone interviews with the members of this group to document their views of the benefits, challenges, and best approaches to developing a DRT transactional data specification. This appendix contains the protocol for those interviews.

Appendix C—Industry Advisory Panel Final Meeting Presentation contains the presentation provided to industry advisory panel members on the final meeting of the project with this group. It summarizes the project and outlines important future considerations, such as governance issues.

Appendix D—Detailed Specification Description provides the full documentation for the proposed DRT transactional data specification. This appendix is intended for audiences with background in software development and/or information technology.

Appendix E—XML Listing of Specification contains the XML listing of the specification.

Appendix F—Validation Tool describes the tool created during this project to validate the specification. The tool is publicly available on a website whose URL is published in the appendix.

Appendix G—Marketing Document provides a short (one-page) marketing document that can be given to managers at transit agencies and other DRT service providers. It briefly explains what a DRT data specification is, and why DRT providers should adopt it. It is written in a nontechnical manner.

Appendix H—Request for Proposals (RFP) Language presents two sets of text that could be used in a request for proposal (RFP) for paratransit scheduling software that would adhere to the proposed DRT transactional data specification. The first could be used by a transit agency or other DRT service providers in an RFP for procuring software; the second could be used in an RFP to assure that procured DRT services operate with technology that is compliant with the specifications.

CHAPTER 2

Principles and Considerations in Developing the Transactional Data Specification

This chapter begins a more in-depth discussion of the general principles and considerations applicable to data specifications for software applications, as well as functional and technical factors relevant to a demand-responsive transportation transactional specification.

The focus changes in this chapter from all stakeholders to those stakeholders who will actively use the specification and most likely be involved in some manner in the process of specification development, formal adoption, and subsequent governance. This focus on the stakeholders who will directly use the specification continues through Chapter 4.

This chapter first describes core principles for designing the specification then discusses market considerations. Next, the specific functional requirements for a DRT transactional data specification are explained; a model of the trip lifecycle is presented to organize functional schema. Technical models for implementing a DRT transactional data flow are described next, and finally, a preferred technical approach for data communication of specification-compliant transactional messages is selected.

Several key terms concerning transactional data specifications are frequently used. They are related but distinct. Whichever specific term is being used, readers should understand that the overall context is always one of data specifications that are relevant to transactional processes.

- *Specification*—A set of documented requirements to be satisfied by a material, design, product or service; the act of identifying something precisely or stating a precise requirement.
- *Data specification*—A set of requirements for the types of data and the format of the required data elements for a specific data domain, typically related to a specific functional area.
- *Transactional data specification*—A data specification focused on enabling functional transactions that require the flow of data among two or more software systems.
- *Standard (specifically referencing technical standards)*—An established norm or requirement, usually a formal document, that sets forth uniform technical criteria, methods, processes, and practices. Formal technical standards will typically have been ratified by an organization that represents the interests of the entities to which the standards apply.

2.1 Core Principles for Successful Specification Approaches

The six core principles guiding the development of a successful specification are shown in Figure 2-1 and discussed in this section.

- *Sufficiency*—Sufficiency means that (1) the specification covers all typical transactions that occur among parties; and (2) for each transaction covered, the specification incorporates

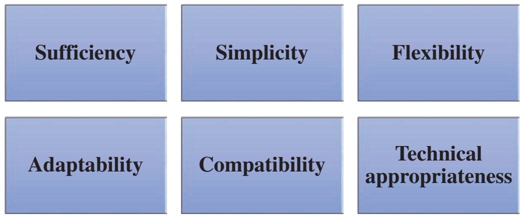


Figure 2-1. Core principles for the specification development.

all the data elements needed for each party to accomplish that specific transaction. A specification is sufficient if it is capable of handling all "use cases" that typically occur within its transactional domain; each "use case" describes a scenario in which two or more parties interact for purposes of transacting among themselves or exchanging information.

- *Simplicity*—Simplicity in the context of a transactional data specification largely connotes the absence of complexity in the message typology and message contents. Ideally, message types are simplified so that no further subdividing of the message would also produce useful messages. At the same time, each fundamental step in the transactional process should be able to be accomplished via a single message (and when appropriate, followed by an acknowledging response).
- *Flexibility*—A specification has flexibility when it can accommodate variations in transactional needs among participants. The same message types can support transactions in which only basic data elements are exchanged as well as those in which more detailed, albeit optional, data can be exchanged.
- *Adaptability*—A specification has adaptability when it can be modified to meet new needs without being fundamentally altered. For example, if new message types are added to handle transactional situations that are new or different from prior practice, there should be no need to modify existing transactional interchanges that are not related to the new situations. In more technical terms, the changes should be "backwards compatible": what currently works continues to work after the specification is modified.
- *Compatibility*—A specification can be said to be compatible with existing practice when the types of data interactions it supports—encompassing data elements, types of data, functional reasons for exchanging data, and means by which parties exchange data—are already occurring and rely upon existing technical approaches and protocols broadly consistent with those defined in the specification. A specification is not compatible with existing practice if it includes a data transmission approach and/or many data elements not commonly used in current practice in the domain which is its focus.
- *Technical appropriateness*—A specification is technically appropriate when it employs the computer languages, technical terminology, and technical approaches to data exchange that are in common use in the industry sector which is its focus, with particular reference to the software applications and computer systems of the major participants in that sector.

2.2 Market Considerations

In addition to the importance of the specification's fidelity to the core principles, it is important that specifications work effectively for the groups that will use them in their day-to-day activities and work well with existing technology. The research team identified two important market considerations that could affect the type of specification proposed:

- Major DRT service providers and DRT technology suppliers must be supportive or at least neutral toward specifications.

- Specifications must build on trusted relationships and provide gatekeeping mechanisms to mediate collaborative system-to-system interactions among parties.

Given their potential—and often actual—impact on technology suppliers and their customers, new specifications in particular are the opposite of business as usual. They require significant buy-in from the leading parties, particularly the technology organizations. They also must provide for the detailed information needed by diverse DRT providers so they are functional. The development process needs to include expertise and strong industry/sector understanding on the part of those directly involved.

Market Is Supportive of or Neutral Toward Specifications

Data specifications that are successfully developed and adopted must have the support of the key organizations that they directly affect. The organizations principally affected are:

- DRT service providers that use the technology systems or components that are the focus of the specification (including public and private providers, private transit service contractors, taxi companies, and ride-hailing services); and
- Technology suppliers that work directly with the technology systems, e.g., software applications, hardware and other devices, computing infrastructure. Their products typically have functionality for booking, scheduling, vehicle routing, and/or dispatching. This also includes companies whose technologies are complementary to the core software systems, such as in-vehicle devices and fare-payment solutions.

The public-sector organizations that fund public transit and human service transportation are also key organizations, but their overriding interest is that specifications exist rather than their specific form and details—hence, they are not a factor in this consideration.

If service providers and/or key technology suppliers strongly support a proposed new specification, this will significantly enhance the likelihood that agreement among participants can be reached on structure and details of the specifications. In interviewing key players, the research team found that the DRT technology industry is neutral about investing in development of specifications, with some in favor but also some large players that do not see the effort as in their interest. Providers, on the other hand, would generally like to have the benefits of transactional specifications but typically do not individually have the knowledge, resources, or organization to effect the change.

Trusted Relationships and Gatekeeping Mechanisms

In many industries, specification development and evolution are common and include individuals from service and technology companies that are veterans of the process. This can greatly facilitate the achievement of a positive outcome. Unfortunately, that is not the case for the DRT sector, given the absence of prior experience with developing sector-wide specifications.

When starting a new specification process with no prior history, the process itself will need to create the foundation of trust among participants. There may be an enhanced need for mechanisms that provide some assurances that technical and business collaboration will proceed in a smooth, business-like manner and lead to actual results. Third parties who are considered neutral and objective domain experts can be useful in launching the specification process.

The use of such perceived neutral third parties and domain experts are examples of the gatekeeping mechanisms that are important to mediating collaborative interactions among parties. This will extend to the actual technical details of system-to-system interactions, and there will be a strong need to ensure that concerns such as data privacy and security are handled appropriately by the technical solution. In some cases, transactions can be routed through certified gateways, such as with standards-compliant payment processors. In other cases it is the trust among the parties themselves that serves as the gatekeeping mechanism. As such trust cannot be automatically assumed in a situation of developing new specifications, the ability to structure a process in which interactions among the parties create such trust becomes very important.

Since a data specification typically requires changes to technology systems, the organizations whose systems are affected have an incentive to minimize resources required to achieve compliance with the specification. In practice, this means that compatibility with such factors as the vocabulary describing transactions; the data elements usually included in transactions; and the mechanisms for transmitting data among different applications/systems used by the major firms in the market represent the technical path of least resistance for advancing toward agreement on the many detailed elements of the specification.

2.3 Functional Requirements for DRT Data: The Trip Lifecycle

In determining the scope of transactional data specifications, it is essential to consider functional requirements that must be supported by the software systems. The specification must support the trip from inception to completion—the trip lifecycle—and enable the different organizations involved in its booking, planning, and execution to share and view all relevant data about the trip during this process. The trip lifecycle is represented with five steps that are shown in Figure 2-2.

Each of these five steps requires data to be exchanged by participants in the process. Some organizations require more data for the transactional process than others, but there is a core set of mandatory data elements needed to support each phase of the trip lifecycle.

Step 1—Trip Booking (Reservation)

In a trip reservation, data must be generated about the pickup and drop-off locations (addresses) of the traveler; when they wish to travel—which could be a requested pickup time or desired delivery time; if they have any special mobility needs (e.g., use a walker or wheelchair) or are using a mobility aid of some type; how many people are making the trip; and if there are any special instructions for the service provider or its driver, for example, "pick up customer at back door." In addition to these mandatory data items, other data elements may be desirable or necessary for some organizations, such as the purpose of the trip or whether it is associated with a specific funding source.

Step 2—Scheduling/Dispatching

For trip scheduling, the organization responsible for delivering the trip will determine when the vehicle will arrive at the pickup location, generate an estimate of when it will arrive at the delivery location, and provide information on time windows associated with the pickup and

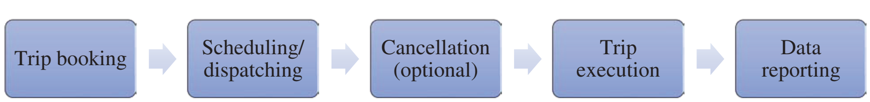


Figure 2-2. Trip lifecycle steps.

delivery times. Later in the scheduling process, a specific vehicle will be assigned to the trip. The information about the trip will then be dispatched to the vehicle, or more specifically, some type of digital device in the vehicle capable of receiving data messages about the passenger trips assigned to the vehicle and displaying this information to the driver.

Step 3—Cancellation (Optional)

To cancel a trip, the only essential data elements are the time when the cancellation occurred and whether it is due to customer request or the inability of the operator to deliver the service.

Step 4—Trip Execution

In executing (delivering) a trip, the mandatory data elements are the identity of the traveler, the actual locations and times for pickup and drop off, how many passengers boarded the vehicle, what fare was paid, and the identity of the service provider, vehicle, and driver that handled the trip. It may also be important to know whether a wheelchair or other mobility aid is used. The real-time location of the vehicle (via GPS readings) during trip execution is also important information for the service provider, and can be used as an input to the functional ability to inform the customer of when the vehicle is likely to arrive at their pickup location.

Step 5—Data Reporting

In the final step, all pertinent data from the trip execution phase must be generated and sent to the entity that is responsible for the customer's trip. In addition, the service provider must also communicate the cost (price) of the trip to the organization or individual responsible for the payment of the customer's trip. The actual financial transactions associated with the trip, namely the payment to the service provider by the trip sponsor or individual responsible, are clearly important to participants in the system but extend beyond the operational elements of DRT services. As such, actual financial transactions are currently outside the scope of the specifications described in this report.

2.4 Models for Transactional Data Flow

A transactional data specification is a document that contains the necessary information for software developers and technology providers to construct data messages that make it possible for two or more computer applications to interoperate. While the specification will typically have a precise syntax, with a defined message set and required and optional data elements for each message, there is more than one paradigm for how the applications/systems could interoperate.

Although the specification syntax itself does not depend on which model is used, the technical approach to specification enforcement (i.e., validation of specification adherence) is strongly influenced by the application interaction paradigm used. There are several useful models for this type of application/system interaction. Three are explained briefly here, as they are the most directly relevant to a transactional data specification for DRT.

Model 1—Request/Response

In a request/response model, one computer software program—call it Application A—sends a data message to another computer software program—call this Application B—requesting that the latter perform some specific action(s) related to a business transaction or potential transaction. For example, on a stock exchange, the computer system of a financial firm—Application A—may send a request to the stock exchange's computer system—Application B—to purchase 10,000 shares of Acme Widget stock at the current market price. Application B acts on the request—it attempts to match the potential buyer's request with that of one or more sellers of Acme Widget stock to fulfill the order for 10,000 shares—and responds to Application A with confirmation that the request has been fulfilled. Alternatively, if there are no available sellers of Acme Widget stock, Application B will respond that the request has been unsuccessful.

In this model, Application A cannot make any assumptions about the status of its request until it receives the response, which can be as simple as merely confirming that the request was received. For example, it might be the case that the protocol defined by the specification is for Application B to first acknowledge the request, namely that Application A's buy order has been properly received by the stock exchange computer system. Application B would then in a separate message respond with the status of the request, for example, purchase request fulfilled or unsuccessful. Application A must wait until it receives acknowledgment that its message was properly received, and take appropriate action if it does not receive such an acknowledgment, until it can update the message status to "delivered" and then expect a response directly regarding the disposition of its request.

In this model, each of the collaborating software applications must manage the dialog between them. The advantage of the request/response paradigm is that both applications can essentially guarantee that they have a consistent view of the status of messages. Only by receiving a response can the initiating application be sure that its message has been received and acted upon and what the disposition of its request was.

The request/response approach does not necessarily imply a direct point-to-point data communication relationship between two applications. A message exchange or transaction broker could mediate between two applications and serve as the clearinghouse for message notifications and transmission; it would use the request/response paradigm to communicate with the endpoint applications.

In this example, there could be a third application, Application C, which operates for another financial firm and which also communicates with Application B (the stock exchange). Application C might send a message asking if there are any current potential buyers for Acme Widget stock. Application B can then serve as the transactional intermediary (which is essentially what a stock exchange is) between Applications A and C, sending messages to each to enable them to bring the transaction to a conclusion; each interaction in the process involves a request/response sequence of messages.

An example relevant to DRT would be that of a trip exchange, such as has been developed in Denver and is discussed in Chapter 3. In the trip exchange situation, a DRT provider's technology system—Application A—would send an unfulfilled trip request to the exchange—Application B—with the objective of having another DRT provider actually provide the service for the trip in question. Using a request/response approach, the trip exchange would inform Application A via a message that it had successfully received and processed Application A's message, enabling the latter to know that there was no issue with the data transmission nor the contents of its message. If Application A did not receive a confirmation, it would be programmed to send the message again. Another DRT provider's technology system, Application C, would then be able to make a request to the trip exchange to send it any new trip postings since its previous request, and the trip exchange would respond with the trip posted by Application A (and any others that might have been posted). And this process would continue with requests and responses from the interacting software applications.

Model 2—Publish and Subscribe

In a publish and subscribe model, an application registers with another system/application—similar to an individual signing up for an online service that requires them to provide an email address and mobile phone number as part of their account—and subscribes to a service that informs it of events of interest. The events can be of specific interest to the external application or more general in nature. For example, an individual with an online account for a national news service might wish to be notified only of the posting of new stories about the city they live in, whereas other account holders might be notified of every new posting. It is the responsibility of the external application to determine what to do when it is notified that an event of interest has occurred and it has received the data about that event.

For example, consider a situation in which a trip exchange exists that enables service providers and other organizations that have DRT service requests they cannot fulfill themselves, to buy service from another service provider with available capacity. The external DRT software applications can post trip requests to the trip exchange that are "visible" to any other software applications capable of connecting to the trip exchange (this bears obvious similarities to the stock exchange situation described previously). Each trip request is specific to a service zone in the region in which the trip exchange operates.

Using the publish and subscribe model, the trip exchange would send a message to all subscribers to a particular service zone, notifying them whenever a new trip request for that zone is posted to the exchange. (Additional criteria could also be used to qualify the entities to which the notification is sent.) Depending on the design of the notification service, it might simply notify the external systems of the existence of a new trip—alerting those systems that they should request the new trip information—or it might include the actual trip request message from the originating system—that message being in the transactional specification format. In the latter case, this broadcast functionality would be a core feature of the trip exchange's publish and subscribe approach.

The advantage of the publish and subscribe model is that each participating software application is only notified of, or sent the messages for, events in which it has interest. In the absence of such a notification function, the external applications would need to periodically interrogate the trip exchange (or other source of potential transactions) and determine if the trip requests are ones they are already aware of, or new requests. It can easily be imagined that this could become quite complex if there are a large number of trip requests whose status is frequently changing. With the publish and subscribe model, an application knows that only new or updated requests are published—and will be delineated as such—and it becomes simpler to manage what could be a large number of events of interest.

The publish and subscribe model is robust and has been used in many large-scale data interchange systems, such as for financial markets. It is particularly appropriate for exchange-type systems in which there are many transactions (or opportunities to transact) of potential interest, but different applications are focused on different subsets of those events. A brokerage approach—essentially an exchange-like hub which also makes transactional decisions such as which provider to purchase a trip from (as opposed to merely facilitating transactions in which the endpoint applications are the decision-making points)—could also make good use of the publish and subscribe model.

Model 3—Open API Framework

An application programming interface (API) is a software module that enables external applications or software systems to interoperate with the software application providing the API.

Over the past 25 years, APIs have become the most common method for business applications to communicate with external software systems/applications. An open API is simply one in which the technical details of the API are published and available to a large community of other systems. Open APIs are not the same as open source software. There may be certain restrictions on what type of entities qualify to use the API, and those entities are likely to be required to agree to terms of service, but in general an open API provides the external world with the ability to transact in some fashion with the host system/application.

With an open API approach, each external application is fully responsible for managing its interactions with the system/application that provides the API (i.e., the host system). The host system API makes possible the transactional data flow, typically via a published set of function calls (i.e., message requests) that external applications can invoke to initiate a specified action or to retrieve certain types of information. It bears emphasizing that while the host system API defines the available functionalities, it does not typically manage transactions for the external systems.

A directly relevant example of an open API that is heavily used is the Uber platform for ride-hailing services. Uber publishes the specifications for its ride-hailing platform's API services, which provide external systems with the capability to request and manage trips and obtain information about those trips. (Uber has recently restricted access to those that can use its API.)

In essence, all of the transactional services directly available to a consumer via the Uber app on their smartphone are also available to third parties via their own software applications: trips can be requested, estimated vehicle arrival times can be obtained, the identities of the vehicle and driver assigned to the trip are available and can be sent to the customer, and so on.

The major advantage of the open API approach is that a large ecosystem of applications can interoperate without any formal structure for coordination (beyond the simple permissions to use another software system's API). The obvious disadvantage is that in the absence of a universal API for a particular industry or sector, technology providers will find it necessary to support many external APIs in order to interoperate with actual or potential transactional partners. In fact, this can make common data specifications difficult if not impossible except on the terms of an entity that dominates the field, such as Google with its Google Maps API.

One further aspect of interest concerning open APIs is that they impose no formal structure on how each external application manages transactional processes. This is a strength, as it provides a great deal of flexibility for the external application in how it implements its own transactional approach, within the constraints of the functions and data made available via the host system's API. However, each host system and external application may have a different transactional paradigm, meaning that across many such applications the view of transactions is unlikely to be identical. If more than a few applications are involved in the transactional ecosystem, this is likely to result in barriers to sector-level transactional specifications, as well as the necessity of complicated software solutions to enable transactional data exchanges among multiple applications.

These three models are summarized briefly in Figure 2-3.

2.5 Recommended Approach for Specification Transactional Flow

Given the relatively undeveloped status of transactional data interaction in the DRT sector, it is prudent to begin with a specification implementation approach that is both agnostic—that is, does not build on the transactional data practices of a dominant entity—and prescriptive.

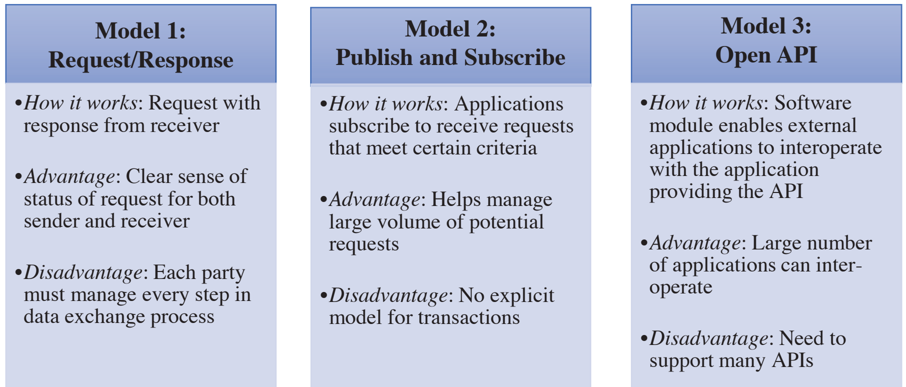


Figure 2-3. Three models for transactional data flow.

The latter means that each step in the process is well-defined and that all entities using the specification must adopt the same approach in their external-facing transactional interactions. Moreover, given that this is the first step toward a common transactional data specification, the approach should be relatively granular and support data interchanges that are atomic, meaning each transactional step is self-contained.

These considerations point toward the use of a request/response approach as the core paradigm for managing transactional interactions at this stage of specification implementation. While this is a somewhat older style approach for system-to-system data interaction, it has the advantage that it enforces certainty in transactional data flow, verifying that each step in the process has in fact occurred.

Moreover, the request/response approach has proven itself over many years in real-life conditions in the demand-responsive transportation sector in the Nordic countries. It is also the transactional data backbone of the most advanced multi-participant DRT system in the world, that of FlexDanmark in Denmark. Six regional public transit entities, more than 500 transportation service providers, and many local governments and healthcare organizations use this technology approach to provide up to 24,000 trips per day. The approach relies on the SUTI standard (introduced in Chapter 1 and discussed in some detail in Chapter 3) and embodies the request/response model of transactional data interchange.

In addition, the request/response paradigm is flexible; it can coexist with the use of publish and subscribe models of transactional data flow. This means that both bilateral, direct data exchange between two applications, and multilateral, in which an exchange-type mechanism enables multiple applications belonging to DRT service providers and trip sponsors to participate in transactional data flows, application interactions can be supported with an appropriate system design. The request/response model can be used for the former, and the publish and subscribe model can be used for the latter. In fact, the trip exchange that has been developed in Denver uses elements of both approaches, as is discussed in Chapter 3.

2.6 Summary

This chapter described the core principles and considerations required for development of a transactional data specification. Data specifications should strive to be as parsimonious as possible (simplicity) while maintaining flexibility. Such flexibility is important, as the specification must be compatible with existing data systems but also meet the needs of different suppliers and users today and in the future. Market conditions and technical functionality that will affect the development of a transactional data specification for the DRT industry were also discussed; industry buy-in and governance considerations will be critical to the overall success of development and adoption of a specification for DRT transactional data. Finally, different models for supporting data interaction for transactional purposes were considered, and the request/response model selected as most appropriate for the initial implementation of a transactional data specification.

CHAPTER 3

Examples of Transportation Industry Data Specifications

Companies and organizations in many industries use formal data specifications and data standards and commonly agreed upon data formats. This chapter presents five examples of data specifications and common data formats from the transportation industry. The first is from the airline industry. The second and third examples pertain to the General Transit Feed Specification (GTFS) that is commonly used to provide information about fixed-route transit services and a new extension for flexible transit services. The last two examples—one from the Denver region and another from Scandinavia—are most relevant to this project and present examples specific to demand-responsive transportation (DRT) transactional data.

Each example includes a short technical description of the data format and a discussion of the process of developing the specification. The manner in which data is communicated—request/response, publish and subscribe, or API—is noted for each situation. These examples are explained in a nontechnical manner so they are accessible to those without significant information technology experience.

The key difference in terminology between *specification* and *standard*, as initially described in Chapter 2, is important. Specifications are documented technical requirements generally considered working or business documents. Standards are documented technical requirements that have been agreed upon by consensus or established by a neutral third party.

Some of the examples in this chapter, such as DRT data specifications in Scandinavia, involve formalized standards, whereas others focus on data specifications that are widely used but have not gone through a formal standard-setting process (e.g., GTFS). While all of these examples involve data specifications, not all involve transactional data—notably, the GTFS does not.

3.1 Example 1—Airline Reservation Data Specification (Request/Response)

Despite being much larger in size than the DRT industry, the airline industry provides an example of data specifications for airline reservations that has many important similarities. Notable similarities include a market with multiple key players and differences in perspectives among key participants in how transactional data interoperability should best be achieved. Moreover, the airline industry has undergone huge technological evolution over the past 50 years that has challenged the approaches to transactional data specifications and data integration.

Since the 1960s, the air travel industry has made use of a standardized means of structuring data about airline flights to enable computer reservations systems to share information about reservations and tickets. The need for data specifications arose due to interlining requirements, in which a passenger's travel itinerary involved one or more airlines other than the airline that the itinerary was booked on. There was a need to transmit the data for the flights on the other airline(s) to the computer reservation systems of those airlines, where a new record could be created in the other airline's system that included data from the original booking record. This booking data could then be retrieved in the second airline's computer system just as if the ticket had been originally booked on that airline.

In response to this need, a detailed and comprehensive set of data message specifications was developed that focused on what is known as the passenger name record (PNR). These message specifications are managed by Airlines for America (A4A), the trade association for the U.S. airline industry, and the International Air Transport Association (IATA), the industry association for airlines worldwide. The data message specifications for PNRs are referred to as the ATA/IATA Reservations Interline Message Procedures—Passenger (AIRIMP). Somewhat surprisingly, there is no general industry standard for the layout and content of a PNR. Each airline reservation system, typically referred to as a computer reservation system (CRS), has its own proprietary standard for these messages. However, common industry needs, including the need to map PNR data easily to the messages, have resulted in many similarities in data content and format among all major airlines' PNRs.

Key PNR contents include

- Record locator (identifier), a six-character value;
- Name of the passenger;
- Contact details for the travel agent or airline office;
- Ticketing details, either a ticket number or ticketing time limit;
- Itinerary of (at least) one segment, including origin and destination airports, airline, flight number; and
- Name of person providing the information or making the booking.

A PNR is created in an airline's CRS when a passenger books an itinerary. The PNR is identified by a record locator, an alphanumeric value consisting of six characters. If portions of the travel itinerary are to be provided by airlines other than the holder of the master PNR, then the PNR information is sent to the CRSs of the other airlines included in the booking. These other airline systems create copies of the master PNR in their own database—with a record locator specific to their own system—to manage the portion of the itinerary for which they are responsible. Many airlines have their CRS hosted by a third party, which allows easy sharing of PNRs. The record locator(s) of the copied PNRs are communicated back to the CRS that holds the master PNR, so all records will be tied together. This enables exchanging updates of the PNR when the status of the trip changes. For example, if the departure time of a connecting flight on another airline changes, this information will be sent to the master PNR of the originating airline.

The PNR-focused system of data messages continues today and has been extended to hotel and rental car reservations booked in conjunction with airline travel. A substantial amount of optional data items not related to actual travel often need to be transmitted as part of the messages using the PNR framework. Consequently, the PNR system must be adaptable and flexible to handle optional data items that include:

- Fare details and any restrictions that may apply to the ticket;
- Tax amounts paid to the relevant authorities involved in the itinerary;
- Form of payment used;
- Frequent flyer data; and
- Seat allocation.

More recently, governments began requiring airlines to provide further information to assist investigators tracing criminals or terrorists, such as gender, passport information, and redress number, if applicable.

CASE STUDY Airline Reservation Data Specification	**Who?** International Air Transport Association (IATA) and Airlines for America (A4A), which are trade organizations for the airlines
	What? Data about individual passenger itineraries (e.g., flight number, origin airport, destination airport)
	Why? Passengers can travel on more than one airline in an itinerary, so data needs to be shared between airlines.
	How? Passenger name record (PNR)
	Lessons Learned The "golden rule": those who have the gold (money) set the rules. Those who managed airline ticket transactions in their own computer systems, either major airlines or global distribution systems, were the impetus behind the PNR system, not technology companies.
	Governance Structure for Data Standards IATA publishes and maintains PNR data specification document and coordinates additional data specification initiatives.

Figure 3-1. Summary of airline PNR example.

Changes to the data specifications system used by airlines are more complicated today because there are more players in the market than when the PNR system was developed over 50 years ago. While the record systems for airline reservations and PNRs remain proprietary, many other organizations, including online travel agencies such as Expedia or Orbitz, now handle PNR data and need access to airline data to provide consumers with information.

Despite the advent of the online travel agencies, with much more modern computer technology and data systems, the long-standing PNR system is still a core component of the data specifications used by the industry. There is an entrenched set of systems organized around this legacy data specification that are difficult to change.

One example of a proposed modification to this data system includes the recent changes in airline pricing practices, most notably the "unbundling" of fares so that specific services (e.g., preferred seats, early boarding, checked bags) can be added to the ticket price. The current PNR system does not have the ability to handle these newer forms of pricing tickets that separate prices for specific services rather than charging a single price for the ticket and seat. Other initiatives—brought together and formalized under IATA, the governance body for the PNR specification—have extended specifications to these areas. This demonstrates the importance of a formal means to achieve consensus on key transactional data specifications over time as changes occur.

Figure 3-1 summarizes important aspects of the airline reservation data specification.

3.2 Example 2—General Transit Feed Specification for Fixed-Route Transit (Publish and Subscribe)

This example is from fixed-route transit services, and the data specification is known as the General Transit Feed Specification (GTFS). GTFS describes fixed-route transit service schedules and stop locations. There is also an extension of the specification named GTFS-Real Time that enables transit organizations to publish the real-time location of their vehicles and their schedule adherence on the web. The example here is focused on the core GTFS system.

This specification was established by Google in partnership with Portland, Oregon's public transit agency, the Tri-County Metropolitan Transportation District of Oregon (TriMet). Google and TriMet worked together to create a data specification so that transit stop and schedule information could be presented in Google Maps using the trip-planning feature Google Transit. This collaboration resulted in the Google Transit Feed Specification. In 2005, TriMet became the first transit agency to publish its data in GTFS format. Since then, hundreds of transit agencies have published their fixed-route transit information in this format, and their data has been integrated into Google Transit, such as the example of Chicago shown in Figure 3-2.

Subsequently, the Google Transit Feed Specification was renamed the General Transit Feed Specification, and it is maintained now by a community of transit agencies, software developers, transit planners, and other stakeholders. This specification is not set in stone; the community that maintains it can make proposals to extend the specification to enable new functionality, and changes do occur somewhat regularly.

GTFS datasets are composed of a series of comma-separated value (CSV) tables in text format collected in a ZIP file. Six mandatory tables and seven optional files contain particular aspects of a transit service, such as routes, trips made by vehicles along a route, and stops along a route. The six required files (agency, routes, trips, stops, stop times, and calendar) are shown in Figure 3-3, which includes a brief description of each.

Typically, each transit agency or operator creates its own GTFS feed, which is usually updated whenever the transit agency changes its schedule (generally three or four times per year). These

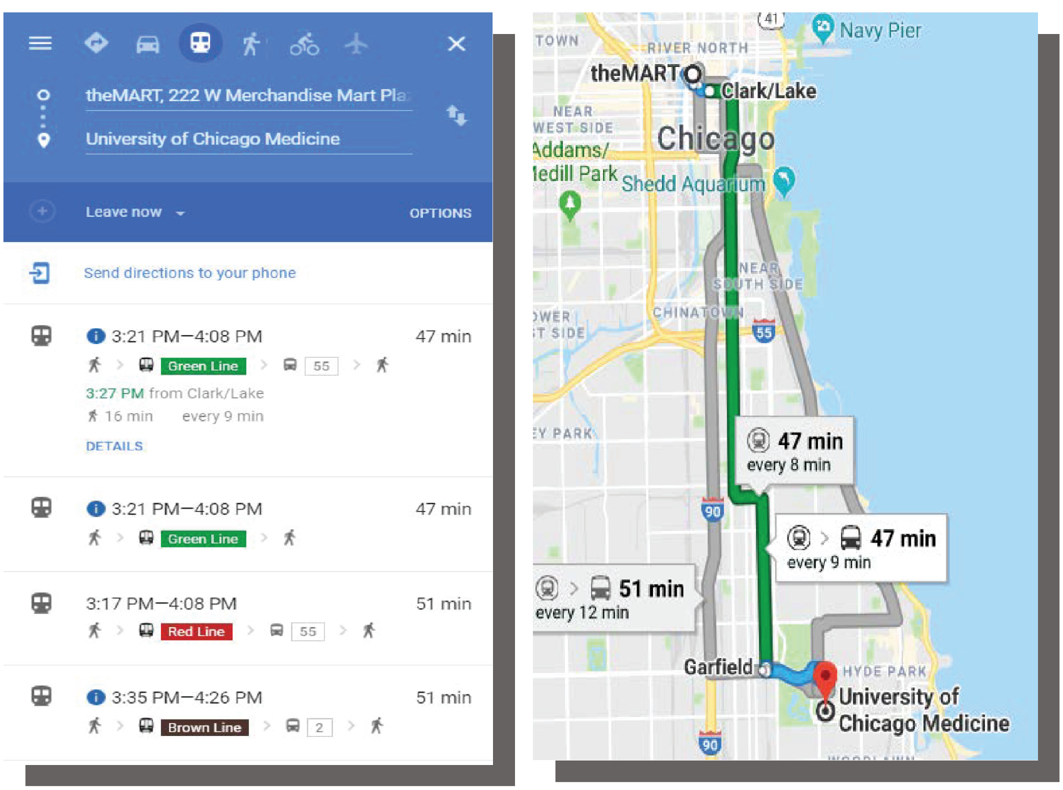


Figure 3-2. Google Transit interface, which relies on GTFS data.

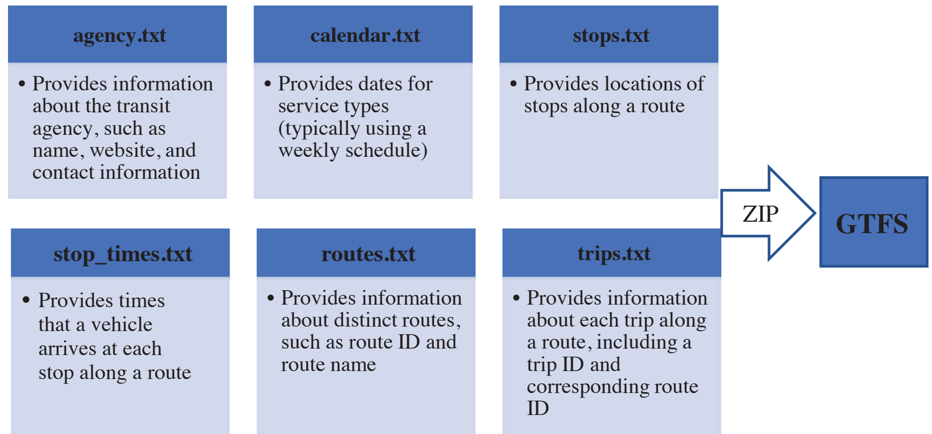


Figure 3-3. Mandatory GTFS content.

static GTFS feeds are then provided directly to Google for use in Google Maps. GTFS datasets are often made public by transit agencies and can usually be downloaded from the internet free of charge. Because GTFS datasets are easily available, they can be used by any organization with appropriate technical resources and capabilities. As a result, public transportation organizations that conform to the GTFS format often find that third-party technology providers make use of that data as a core element of consumer-facing software applications (or "apps") that are of value to potential and existing riders of the transit system.

GTFS can be used in applications such as Google Transit to convey different possibilities for fixed-route transit trips to passengers. Because it simply describes transit services to potential passengers, it is referred to as *discovery data*. Discovery data is information about what services exist, their configuration, and possibly their current status, for example, "The next bus on Route 12 arrives at Elm Street at 9:35 AM." In contrast, *transactional data* includes all the information travelers need to actually book and schedule a specific trip, including payment information. These differences are discussed in more detail in the next case study on an extension of GTFS for flexible services, which include DRT. The GTFS example is summarized in Figure 3-4.

CASE STUDY Fixed Route Transit Information in the General Transit Feed Specification (GTFS)	**Who?** Google and TriMet (Portland's transit agency)
	What? Fixed route transit stop and schedule information
	Why? To integrate transit trip planning, maps, and schedule information into software applications, such as Google Transit
	How? General Transit Feed Specification (originally known as the Google Transit Feed Specification)
	Lessons Learned Openly published data in a common format has resulted in many third-party apps that benefit transit riders.
	Governance Structure Google-organized interest groups oversee specification process; ultimate authority resides with Google.

Figure 3-4. Summary of GTFS example.

3.3 Example 3—General Transit Feed Specification for Flexible Transit (Publish and Subscribe)

This example is an in-progress, proposed extension of GTFS known as the General Transit Feed Specification for Flexible Transit. GTFS-flex accommodates certain forms of demand-responsive transportation services, demonstrating that specifications are not static, but continue to evolve. GTFS-flex will transmit some information (e.g., eligibility requirements) that could interface with DRT transactional specifications in the future. It is an example of how a specification can be changed and the challenges in doing so.

The intent of GTFS-flex is to allow any non–fixed-route transit service to be described precisely in terms of its service characteristics, location and methods of customer access, and temporal availability. This can include traditional address-to-address DRT services as well as variants such as checkpoint DRT (in which passengers access the service only at designated points), route deviation service, and any other transit-like service with flexible elements that enables the path of the vehicle—and potentially its schedule—to be determined at least in part by customer requests.

While this proposed extension of GTFS is specific to DRT and other flexible services, it is restricted to discovery data and does not include transactional data. Typically, GTFS-flex data would be used by a prospective traveler who enters their origin and destination in a trip-planning application; the system then informs them of services that are available and where and how they can be accessed. It would provide the customer with the service's operating hours, where pickup points are located if only discrete locations are served, and a telephone number or website URL so that a trip could actually be booked. But GTFS-flex only provides basic information and cannot tell the customer if they can actually schedule their trip because it has no access to transactional data, such as where vehicles are currently located or vehicle availability for a specific time or from a specific origin.

GTFS-flex proposes a few noteworthy changes to the original GTFS format to accommodate demand-responsive and flexible transit services. GTFS-flex introduces a new file known as "area.txt," which accommodates the fact that many DRT services operate within a specific geographic area. In addition, three of the mandatory files (stop_times, routes, and trips) from the original GTFS format are modified to accommodate various types of DRT services (see Figure 3-5).

For example, some DRT services can be organized as checkpoint services or have point deviations, which occur when vehicles serve demand-responsive requests at specific stops (there could be many) within a zone without any regular path between stops. This is accommodated by changing the structure of the "stop_times.txt" file, which previously required stops to be served in a specific order. Similarly, a form of DRT service is based on route deviations, in which vehicles operating on a regular schedule with defined stops and an implicit path

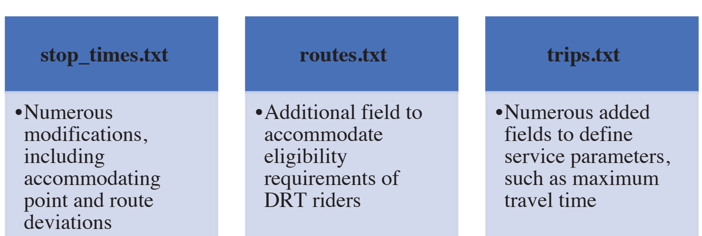


Figure 3-5. Examples of changes to mandatory GTFS files in GTFS-flex.

will deviate to serve on-demand requests within a service zone encompassing the route. The information that defines the feasible deviations is also accommodated by a change in the "stop_times.txt" file.

Two other noteworthy changes have been made. Many flexible transit services have service parameters for maximum or expected travel times, which are incorporated into the proposed GTFS-flex specification by additions to the "trips.txt" file. Additionally, some DRT services are only available to certain types of people (e.g., the elderly, Medicaid recipients); these eligibility requirements are accommodated in GTFS-flex by an additional field in the "route.txt" file. Additional modifications can be found in the proposed specification for GTFS-flex on GitHub at the following link: https://github.com/CUTR-at-USF/gtfs-flex/blob/master/spec/reference.md

Some of the initial concepts for GTFS-flex were developed at a workshop called GTFS for the Rest of Us in November 2013. Since then, interested parties regularly communicate via a Google Group, and efforts are under way to try to formalize GTFS-flex. GTFS-flex is still in a prototype phase, which included a recent alpha launch on DRT services in the state of Vermont. The launch is being led by the Vermont Agency of Transportation (VTrans), Trillium Transit, and Cambridge Systematics, and it will demonstrate the capabilities of the proposed GTFS-flex extension for DRT discovery data. The transit agency in Denver intends to incorporate GTFS-flex into its trip-planning capabilities and has initiated the necessary process.

To help manage extensions or changes to GTFS, a process is used to formalize proposed modifications or additions to the specification. One of the key hurdles to implementation of a proposed GTFS change or extension is that at least one GTFS producer (e.g., a transit agency) and one GTFS consumer (e.g., an app or web-based application) must have implemented the proposed change. In the case of GTFS-flex, the prototype release took place in Vermont and, for actual services, an implementation led by the large consulting firm Cambridge Systematics is committed to this new specification.

Until GTFS-flex is officially implemented by the transit agency in Denver, there may not be any moves to seek formal inclusion of GTFS-flex in the official GTFS specifications. In fact, it remains unclear just how Google will handle the final steps of formally incorporating GTFS-flex into the GTFS specifications. This example demonstrates the challenges to both gaining transit agency support and achieving formal official status for new specifications merely for DRT discovery data; formal transactional data specification implementation would appear to be a larger challenge.

The example of GTFS-flex is summarized in Figure 3-6.

3.4 Example 4—DRT Transactional Data in the Denver Trip Exchange Project (Hybrid of Request/Response, Publish and Subscribe, Open API)

The Trip Exchange, a web-based system developed as part of an FTA-funded Mobility Services for All Americans (MSAA) project, is the next example. The origin of the Trip Exchange software (not the concept, which had been discussed in Denver since 2010) was an actual implementation developed for Ride Connections in Portland several years ago; for a variety of reasons that software was not used for production purposes. Nonetheless, it provided a good real-life model for the functionalities and processes needed for a trip exchange system, and the Denver Trip Exchange follows its paradigm in many ways. At the same time, the core software developed for the Denver system is a completely separate implementation (even a different programming language) whose features are not identical to that of the Ride Connections software (e.g., the latter did not use web-based APIs), and is designed for more fully automated processes.

CASE STUDY General Transit Feed Specification for Flexible Transit (GTFS-flex)	
	Who? GTFS curators, Vermont Agency of Transportation, Trillium, Cambridge Systematics
	What? Demand-responsive/flexible services descriptive data for trip planners
	Why? To extend scope of GTFS to non–fixed route services
	How? GTFS-flex proposed extension to GTFS
	Lessons Learned Creating specifications is easier than achieving their real-world implementation; transit agencies are key to supporting implementation.
	Governance Structure Same as for GTFS, Google as curator plus advisory group

Figure 3-6. Summary of GTFS-flex example.

The Trip Exchange software was implemented by late 2017 and is in the early stages of use by DRT providers in the northern Denver region. This encompasses an area extending from central Denver northward to Broomfield and Boulder counties, including the city of Longmont. The Trip Exchange enables multiple transportation providers—each with its own DRT software system for reservations, scheduling, and dispatching—to share data with other providers to enable transactions among them.

Four DRT providers are involved in the project:

- Denver's regional public transit agency, the Regional Transportation District (RTD), which provides an extensive set of general public DRT services as well as ADA paratransit;
- The City and County of Broomfield, which provides transportation to eligible community residents;
- Two human services transportation providers:
  - Seniors' Resource Center, the largest senior citizens program in the Denver area; this organization mostly provides service to its own clientele.
  - Via Mobility Services, a large human service transportation operator focused on providing DRT services under contract to public and private nonprofit agencies; also a major contractor for the RTD's general public DRT program (note that this is not Via, the shared-ride van TNC company that operates in several U.S. cities).

Two technology companies are also involved in the project: DemandTrans Solutions and RouteMatch Software.

The organizations are summarized in Table 3-1.

The Trip Exchange works as follows:

1. The DRT providers—and soon other human service organizations that need transportation for their clients—submit customer trip requests in the form of electronic trip tickets. These trip tickets specify when and where the customer needs to travel and any special needs—such as wheelchair accommodation or an accompanying escort or service animal—of the traveler.
2. Providers are able to offer their services for unmet customer travel needs of other providers by claiming trip tickets.

Table 3-1. Parties involved in the Trip Exchange project.

PARTNER	ROLE
Via Mobility Services	Mission is providing specialized transportation in Boulder County. Also operates RTD-contracted DRT services.
Denver RTD	Regional transit operator; provides DRT services to general public and persons with disabilities (separate services).
Broomfield–Easy Rides	Mission is providing demand response service to the elderly and disabled in the City and County of Broomfield.
Seniors' Resource Center (SRC)	Mission is specialized transportation in Jefferson County and the northwest metro area.
DemandTrans Solutions	Develops Trip Exchange hub; interfaces its DRT technology platform (for RTD DRT services) to Trip Exchange hub.
RouteMatch	Adapts RouteMatch software, used by all providers other than RTD, to interface with Trip Exchange hub.

3. The Trip Exchange identifies potential matches between providers with capacity and unmet customer travel needs based on the following: date and time of trips, location of providers and trip makers, mobility requirements, and service eligibility.
4. When a provider is capable of fulfilling a trip ticket submitted by another provider, the Trip Exchange makes that trip ticket visible to the potential claimant and activates the functionality that enables it to claim the ticket.
5. The claiming process can be either manual on the website—a user interface enables providers to see all unclaimed trips relevant to them and determine if they wish to claim any of them—or automated, in which the computer system of the provider is directly responsible for claiming trips. In the case of automated claiming, the provider's computer system will use the data on the trip ticket to first determine if the trip will fit into the provider's vehicle schedule for the date and time of the trip, and only claim trips that do so.
6. If the trip is actually delivered (it is possible that the trip request will be cancelled by the trip maker in the originating provider's system, in which case it notifies the Trip Exchange which, in turn, invalidates the trip ticket) the trip provider (claimant) sends the trip execution data results back to the Trip Exchange shortly after trip execution.
7. When the trip has been delivered, the Trip Exchange sends the trip execution results back to the entity that submitted the trip ticket. Members of the Trip Exchange will see the status of their clients' trips move from *Posted* to *Claimed* to *Executed*.

DRT service providers can interact with the Trip Exchange system in two ways:

1. Providers can log on to the Trip Exchange and use its functionality—available via a web browser—to perform a variety of actions, including claiming trips.
2. Providers can set up automated machine-to-machine communication between their software system and the Trip Exchange to post trip tickets and claim trip tickets based on available capacity on their service and established relationships among "trusted partners"—those that have previously agreed to transport each other's clients on a routine basis without trip-by-trip approval. Each provider can program its own system to claim trips based on criteria specific to its mission and operating objectives. The Trip Exchange merely executes its requests.

The Trip Exchange hub is designed to work with any external software system through application programming interface (API) connections. An API is a software module that enables one computer system to interact and exchange data with another computer system; the two systems can be anywhere as long as they can connect via the internet.

The Trip Exchange hub transfers information among its participants through structured messages that include only the minimum amount of information needed for a provider to decide if it is able to accept the trip and fulfill its requirements. The messages are designed to include all essential information that transportation providers need to make a decision about whether they can accommodate the trip, such as pickup and drop-off addresses, requested pickup time, whether the passenger is traveling with a mobility aid such as a wheelchair or walker, and whether they are traveling with companions or service animals.

The Trip Exchange has its own data specifications. It requires participants' software systems to communicate with the hub using a standardized set of messages with defined data elements. Some data elements are mandatory, and others are optional. The APIs of the Trip Exchange are designed to work with the data specifications, and the Trip Exchange documentation specifies the required data elements. Figure 3-7 shows schematically how the Trip Exchange hub works in its fully automated mode.

The Trip Exchange is currently set up only with the basic functionality to exchange trip information and facilitate DRT transactions. In addition, several different reports can be run, such as a monthly report of trips delivered by provider. Enhancements are planned for 2020 (using funds from another federal transportation project obtained by the Denver region) to address billing and financial requirements and to provide more options for multilateral business relationships among participants. For example, when trips are claimed, the provider's price to perform the trip will be calculated and presented to the agency that posted the trip, and the latter can decide whether to accept or decline the claim.

An important characteristic of the Trip Exchange system is that it does not require a brokerage or centralized reservation system to determine if trips can be shared. Control over whether or not trips are posted and claimed resides with individual participating organizations. As such, it is designed for a decentralized system in which individual providers have their own methods of booking and scheduling trips. This means that the exchange allows human service transportation providers to see trip requests (visually or via automated mechanisms) and determine if

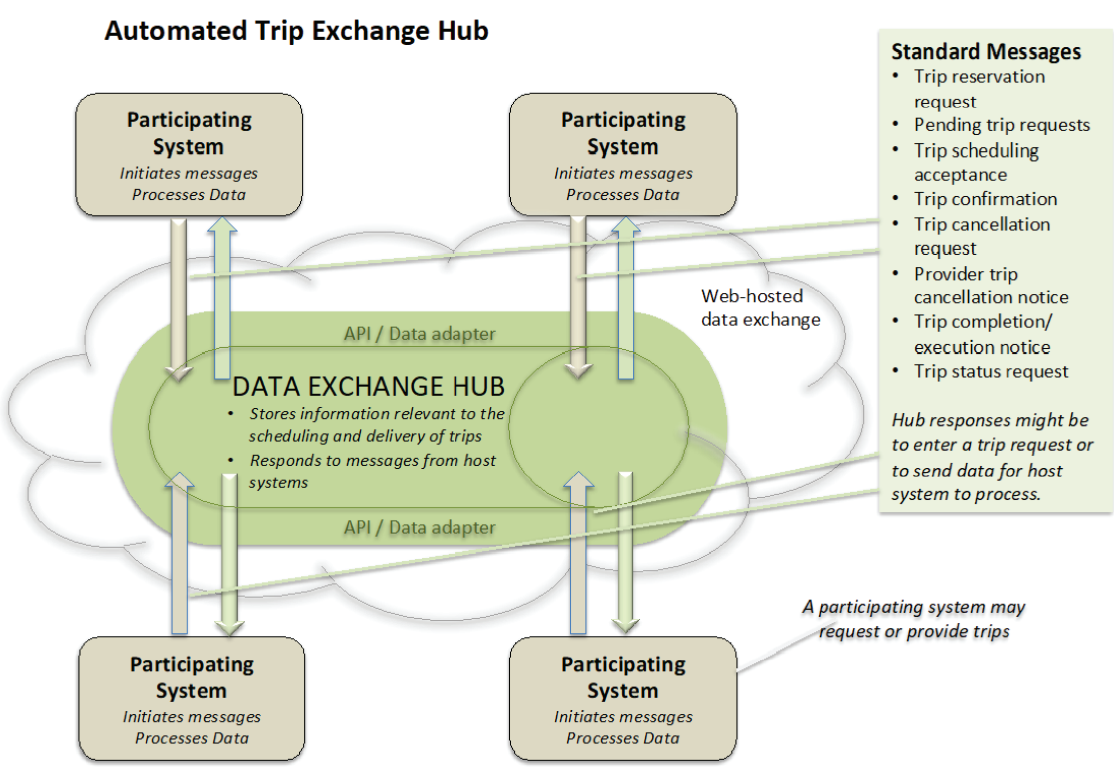


Figure 3-7. Denver Trip Exchange hub structure.

CASE STUDY Denver MSAA Trip Exchange Project	
	Who? Denver RTD, Via Mobility Services, Seniors' Resource Center, City of Broomfield, DemandTrans Solutions, RouteMatch
	What? Trip Exchange for transactional DRT trip coordination between organizations that need additional transportation services and those that can offer services
	Why? Coordination of transportation services to use resources more cost-effectively and expand service
	How? Building a trip exchange technology platform using data specifications
	Lessons Learned DRT service providers agreed on the design of a technology platform for transactional-based service coordination, which demonstrates that a trip exchange is feasible.
	Governance Structure Steering committee of agencies and companies who oversaw development of Trip Exchange

Figure 3-8. Summary of the Denver Trip Exchange example.

they can add a trip to an existing vehicle run, which is important given limited vehicular and driver resources. This supports the goal of providing more rides to more people using existing resources.

While the Trip Exchange is still in its formative stages, it is operational and demonstrates that multiple interested and motivated parties can work together to develop a common platform to enable interoperability among DRT systems. The data specification developed for the Trip Exchange is fundamental to its workings and represents the result of a collaborative process involving many months of work by both technology-focused and operations-focused participants.

While that specification is different from the one developed in this study, it also explicitly supports the trip lifecycle and transactional processes and shares some important commonalities about core messages and the data they need to contain. In addition, the Trip Exchange's data communication paradigm—a hybrid of a published API to enable software systems to transmit data to and from the Exchange, a request/response mechanism to advance transactions, and a publish and subscribe mechanism to notify participants when new trips of potential interest are posted to the Exchange—illustrates the importance of the three data communication models as organizing concepts for enabling transactional data flows.

With the current data foundations of the Trip Exchange in place, the organizations that participated in its creation, and others in the Denver region, are ready to move on to adding more functionality to the system, to build on what they perceive to be a solid platform for enabling transactions among the participating entities.

The example of the Denver Trip Exchange is summarized in Figure 3-8.

3.5 Example 5—DRT Transactional Data Standards in Scandinavia (Request/Response)

The final example is the Scandinavian standard for DRT transactional data, known as SUTI (Standardiserat Utbyte av Trafik Information). This is the only known widely used data specification for DRT, and therefore it is particularly relevant to this project. SUTI today is the standard throughout Sweden, Norway, Finland, and Denmark for the exchange of DRT information between providers (i.e., contracted vehicle operators) and their clients (i.e., the organizations responsible for DRT services). During 2015, more than 30 million orders were organized and executed using SUTI-compliant data communications. Notably, this transactional data specification was critical to the development of FlexDanmark, which is one of the largest—possibly *the* largest—public DRT systems in the world. It operates in six large service zones encompassing all of Denmark, averaging 16,000 rides daily with up to 24,000 rides per day.

SUTI was formalized in 2002, and the role of the Swedish government in this process was crucial. Because the Swedish government is the primary funder of social services that involve transportation service for citizens, the Ministry of Transport was instrumental in the development and nationwide adoption of SUTI. Prior to the formal adoption of SUTI in 2002, there were strong pressures exerted on technology vendors by local governments and the national government to ensure interoperable end-to-end functionality of the key components of DRT technology: reservations systems; vehicle scheduling systems; taxi dispatch systems (almost all DRT in Sweden was delivered by the taxi industry prior to 2000); in-vehicle technologies (driver display units, card-based payment terminals, and vehicle location units); and payment systems. National-level adoption of SUTI was the culmination and formalization of developments in this DRT ecosystem that stretched back more than a decade.

The SUTI standard is utilized extensively in Denmark by FlexDanmark, a government-chartered service manager that aggregates demand for point-to-point trips from many sources, including municipal transportation services, school trips for students with special needs, hospital and other healthcare–related trips, and human service agency trips. FlexDanmark started in one region in Denmark using the technology solutions previously developed in Sweden. Through a strategy of expanding one geographic area at a time, the FlexDanmark system gradually took over operations of DRT in Denmark, with limited resistance to the use of SUTI. Major stakeholders such as Trapeze and Halda agreed that this was the way forward. The main reason for this was that SUTI rapidly became a Nordic standard covering Sweden, Norway, Finland, and Denmark, so these technology companies could save time and money on system-by-system implementation.

The SUTI standard is a set of documents that are mostly open access; however, some documents about use cases and SUTI attributes are exclusive to SUTI members. The development and maintenance of the standard is driven by member demands. A technical committee receives cases from its members—simple attribute cases or bigger projects. To work on bigger projects, the technical committee needs approval from the board. New versions of SUTI are released on a yearly basis.

The SUTI standard has evolved and expanded significantly. The scope of the standard initially focused on the simple task of ordering a taxi for demand-responsive transportation from point A to point B. Over time, it has expanded to include the entire route of vehicle trips with multiple pickups and drop offs, as well as financial transactions and real-time status messages, such as arrivals or no-shows.

In the SUTI standard, trips are described for the service provider (i.e., contracted vehicle operator) using the concept of *telegrams*. Telegrams consist of a specific message that includes certain standard mandatory and optional data elements. A new trip message, for example, includes specific types of information about the passenger's origin and destination, pickup time, use of mobility aids, and other relevant data about the passenger trip. This message is sent electronically in a specific format defined by SUTI to a specific service provider's dispatching (or scheduling) system, which contains software that examines the message, determines the message type, extracts the data elements it needs, and forwards the message to a SUTI-compliant

CASE STUDY SUTI in Scandinavia	**Who?**	Swedish Ministry of Transport and FlexDanmark, which is one of the largest public DRT systems in the world
	What?	Transactional data standards for demand-responsive transportation in Scandinavia
	Why?	To achieve financial benefits for local governments in Sweden and indirect benefits for technology providers
	How?	Implementation of the SUTI standard by Swedish government; subsequent adoption by other Scandinavian DRT providers, including FlexDanmark
	Lessons Learned	Transactional data standards for demand-responsive transportation are feasible and can have beneficial impacts for all affected parties.
	Governance Structure	Swedish Ministry of Transport–organized governance committee of agencies, service providers, and technology companies ultimately responsible to government agency.

Figure 3-9. Summary of the SUTI standard example.

device in the vehicle to which the trip has been assigned. The software running on the device can then display the trip information to the driver at the appropriate time.

The SUTI standard has developed a set of XML messages that can be exchanged between a client and a provider. XML, the eXtensible Markup Language, is a textual data format, readable by both machines and humans, that defines a set of rules for documents. It is commonly used for exchanging data between applications. In this case, the "client" has the travel demand information, which includes trip requests from customers wanting to use the demand-responsive transportation system. To fulfill these demands, the client can use one or several DRT service providers to fulfill the trips; it sends messages to request service. The current SUTI standard includes many different fields in a clear XML structure.

Three main conclusions can be drawn from this example. First, the role of the Swedish government as a champion for the development of SUTI standards has been critical. The government was in a unique position to enforce data standards and stood to benefit from lower barriers to entry to the DRT market. Second, there are clear and measurable benefits from the widespread adoption of a transactional data specification. The SUTI specifications helped standardize trip request data across multiple platforms and service providers, which in turn helped lower costs of entry into the market and lower costs of DRT services overall. Last, this case study shows that the development of a transactional data specification is feasible, as the SUTI standard has been the foundation for all system interoperability in the Nordic countries.

The example of the SUTI standard is summarized in Figure 3-9.

3.6 Comparison and Conclusions

This chapter presented five examples of common data specifications or standards in the transportation industry. Some common themes and conclusions can be identified.

Recognition of Benefits

One common theme from the five examples is that interested parties will pursue data standardization if they readily perceive how it benefits their organization, particularly financially.

In every case in which the data standards or specifications advanced, organizations were involved that clearly saw the concrete benefits of such standards and had a financial incentive to support their implementation and further development. For example, the airline industry could not function without the ability of airlines to exchange data on customer itineraries that involve multiple airlines. The airline industry participants all recognize the importance of the data exchange and have worked to achieve collective benefits from the framework that has existed for over 50 years.

Similarly, Google Transit—a widely used application that works in conjunction with Google Maps—served Google's financial interests because the more interest attracted to these applications, the more advertising Google can sell. Only by developing a universal data specification for fixed-route public transit services could Google make it feasible for hundreds of transit agencies to feed their data to Google Transit so that its consumer benefits could become widely accessible.

In Denver, government-funded entities providing transportation recognized that without a data specification, transactional collaboration is not feasible; this led to a willingness to push forward with a specification process to obtain the benefits afforded by transactional capabilities.

While benefits of transactional specifications for DRT may be recognized by DRT providers, individually they do not have the resources to pursue development and implementation. The entities with the resources—the public agencies that fund public transit services and those human service and healthcare programs that may require substantial DRT services for their clients—may not yet have recognized the benefits of a transactional specification for DRT.

Role of Government

Another noteworthy lesson is the important role of government in the Scandinavian case. The Swedish national government had a strong financial incentive to make it possible for any local government responsible for transportation services for older adults—services largely funded by the national government—to use any software system that could connect to any transportation provider so that services could be provided in the most cost-effective manner and promote a competitive transportation marketplace that would constrain costs in the future. FlexDanmark simply adopted the SUTI standards as a way of doing business and made it clear to its operational partners that they had to use SUTI-compliant technology in their business. The huge FlexDanmark market for transportation services, involving more than 500 operators, is only feasible because there is a common mechanism for moving data through the system.

Successful implementation of a transactional specification in the U.S. context is likely to require similar motivations among participants in the DRT sector. If government-led initiatives similar to SUTI are not undertaken in the United States, what would induce transportation organizations to advocate for common data standards? Perhaps the prospect of lost potential revenues due to nonadoption of a specification would incentivize some private organizations to join with others to develop and implement a common specification in their technologies.

In contrast, the now 5-year process to achieve official GTFS status for the GTFS-flex extension largely reflects a lack of strong support by local public agencies, of which only VTrans and Denver's regional transit agency have been active. There is no discernible opposition to this extension of the specification, but with limited resources and the implementation requirement of the GTFS process, it has proven difficult to surmount the relatively modest hurdles to adoption.

Time to Implementation and the Evolution of Specifications

Another common theme is the time required for implementation: how long it may take to develop, adopt, and integrate specifications into day-to-day activities and the evolution of specifications (or standards) over time. Initial development, adoption, and widespread adoption can take a decade or more. The passenger name record (PNR) system in the airline industry, GTFS, and the SUTI standards each evolved significantly over time; this points to the importance of developing a flexible, adaptable specification. It also points to the importance of a governance process that approves changes while maintaining the integrity of the specification.

Technical and market considerations must also be taken into account, as discussed in Chapter 2.

CHAPTER 4

Summary of the Specification

This chapter presents an overview of the recommended transactional data specification. The objectives of the specification are to (1) establish the common language that entities use to communicate with each other; and (2) provide the technical approach for how that data communication will occur among the interoperating computer systems.

The chapter covers the following areas:

- Definitions for key terms and concepts.
- The telegram paradigm, a critical concept in the proposed specification.
- Telegrams contained in the specification: 11 specific telegrams, 4 of which are described in detail.
- Potential approaches to implementing specification-compliant data communication. How data is transmitted among entities and how the system validates that the transmitted data complies with the specification. A control module approach is recommended for the specification.
- Other data considerations necessary for government-funded transportation services such as ADA paratransit service.
- A short discussion of data structures.

Additional detail on the specifications may be found in Appendices E and F.

4.1 Key Concepts

The proposed transactional data specification is organized around messages—specifically, a set of agreed upon message types—and data elements, as defined here. Messages can be of many different types, with each type designed to perform a specific function in the transmission and/or exchange of data among interoperating parties. For example, there may be a message type to send a trip request to one or more service providers and another message type to send trip-specific data (e.g., passenger name and pickup location) to a device in a vehicle. These messages will be referred to formally as telegrams when appropriate in this chapter.

These are key concepts that this chapter will use:

- *Telegrams*—Different types of messages designed to transmit specific transactional requests and acceptance/confirmation of these requests. (*Message type* is a generic synonym for a specific type of telegram; *message* is a synonym for an individual telegram. Both sets of terms are used interchangeably in the remainder of this chapter.)
- *Data elements*—The specific data items contained in each message that collectively communicate all the information the recipient needs to act upon the specific request from the transmitter of the message.

- *Data communication approach*—The specific mechanism by which system-to-system (machine-to-machine) data communication occurs so that messages are reliably transmitted from requestor to recipient(s)/respondent(s) to enable transactions to occur.
- *Specification validation approach*—The means by which the *syntax* of messages and their data elements are determined to meet the requirements of the specification; the confirmation or rejection of the messages' validity is transmitted to the transmitter and/or recipient(s) of the messages.

4.2 Telegram Paradigm for DRT Trips

This report refers to message types and their corresponding data elements as telegrams. This term comes from the SUTI data standard developed in Sweden and used in Nordic countries. There can be many different types of telegrams. Telegrams are sent from one party to another—or more precisely, from the computer system of one party to the computer system of the other party—to advance a transaction involving a passenger trip. All valid telegrams are composed of a predefined message type whose message contents must include all of the data elements required for that type of message. Telegrams may include valid optional data elements as well. Key characteristics of telegrams are:

- Telegrams have a defined structure;
- Telegrams have a specific vocabulary;
- Telegrams encompass all essential steps in the trip ordering and trip execution process; and
- Telegrams imply a request/response approach to data communication concerning transactions.

This proposed specification is based on a strict request/response approach to transactional data flow. In contrast, the more loosely coupled API-based schemes that are often used in contemporary system-to-system (or application-to-application) data communication typically do not enforce a consistent, accurate view of the state of a transaction across the systems. (API-based approaches use their own form of request/response data communication to return data to a system that requests some action from another system that may involve a transaction or knowledge of a transactional state.) As discussed in Chapter 2, while the open API approach has many virtues, it places the responsibility for transactional certainty on each entity in the process. Each system maintains its own internal view of the transaction's status, and while this transactional state can usually be discovered by the other system as necessary, there is no standard method for categorizing this transactional state. In contrast, the request/response approach recommended by this specification enforces certainty in transactional data flow and makes possible a standard approach to knowing the state of a transaction.

Given the relatively undeveloped status of transactional data interaction in the demand-responsive transportation sector in the United States, it is prudent to begin with a specification approach that verifies that each step in the transactional data flow has in fact occurred, and which enables an application to know the current status of the transaction using a standardized categorization approach and vocabulary.

Process of a DRT Transaction

At different stages in the transactional process of a DRT trip, the primary focus varies among the following:

- *Rider*—Individual wishing to make the trip.
- *Entity taking the trip order*—Service provider itself or an entity that organizes the service but does not actually operate it, such as a trip exchange or the brokers that are common with Medicaid.

- *Service scheduling entity*—Service provider or an organization that handles vehicle scheduling and routing for one or more service providers and instructs them on how to deliver service.
- *Service provider and/or vehicle performing the trip order*—With a specific focus on the trip delivery information.
- *Payer/funder*—Organization that pays for the trip; could include the traveler indirectly.

Figure 4-1 shows the process for typical DRT transactions. Each time that information crosses a line in Figure 4-1, a telegram must be sent containing the data necessary to advance the transaction to the next step. ("Planning" in this diagram includes passenger request and booking.) Moreover, the transactional flow is not simply one-directional as the figure may suggest (from planning through execution and payment), but also includes exchanges of information (data) that go both ways. The telegrams presented in Section 4.4 of this chapter represent the minimum information needed for requesting and confirming activities among the entities while covering all essential steps from ordering to executing a trip. Certain internal activities of the service provider may not be included in the transactional specifications, as they are relevant only to that entity.

For each scenario (or *use case*) in which the specification is employed, the interacting computer systems use the telegrams to communicate the data informing each system of what the other system is requesting, offering, or confirming. From a functional perspective, the basic use case for a transaction has four steps.

1. *Requested trip*—A request (or order) for transportation from the trip's pickup address to the drop-off address with information about pickup and/or drop-off time requirements and any customer mobility aid needs.
2. *Confirmed order*—Order assignment specifying which means of transportation (e.g., wheelchair-accessible vehicle required) will be used and the service level for the customer (e.g., acceptable waiting time for service).
3. *Route/trip task*—Description of the schedule/route to be performed by the vehicle, including expected arrival times at stops.
4. *Completed job*—Data on actual trip pickup and delivery details, to be returned for financial settlement and operational quality assessment.

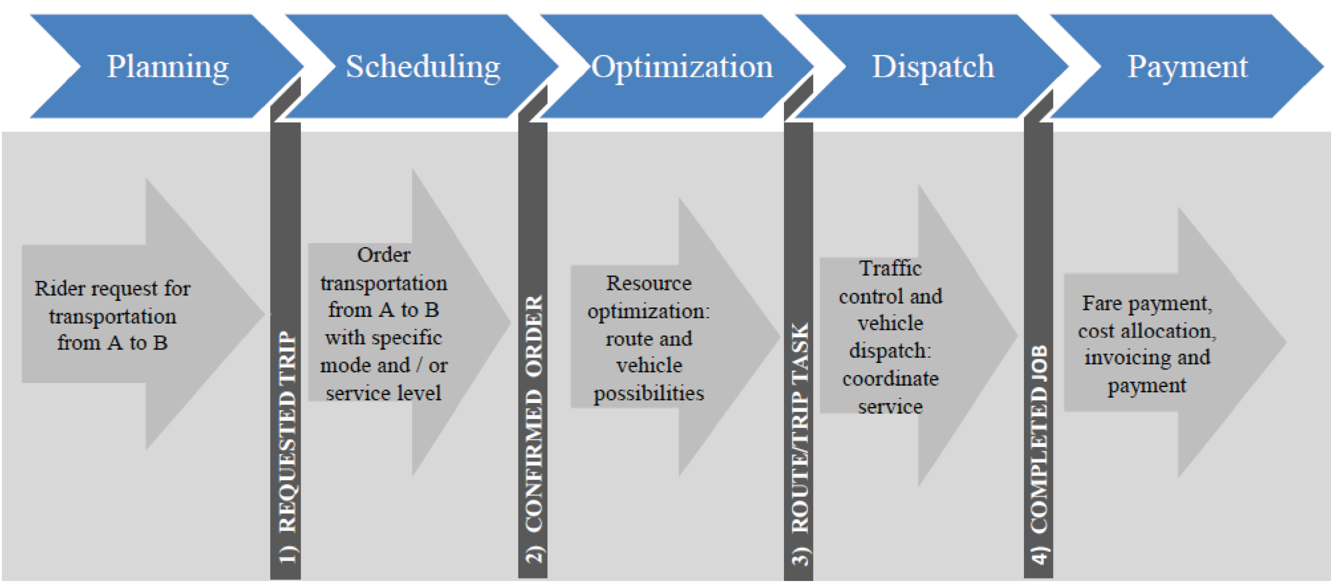


Figure 4-1. DRT trip process from initial request to execution and payment.

From this perspective, there is no requirement to transmit customer-identifying information, simply functional requirements and a set of tasks to be performed on behalf of customer requests. (Basic customer-identifying data such as name will eventually be included in the data messages, but such data is not essential to advance the transactions prior to actual service execution.) The basic data elements needed to support these functional requirements are shown in Figure 4-2.

The telegrams enable the computer systems to move through the transactional steps summarized; this is described and shown in terms of process flow in Section 4.3. Some steps require a transaction to take place between the entity ordering the trip (possibly an application used directly by the trip maker) and the transportation service provider or other entities. Others might be messages communicated between two service providers or between a provider database and the vehicle's mobile data terminal/in-vehicle device that hosts an application directing the driver's activities for delivering service to the rider.

Required Versus Optional Data Elements

Telegrams describe each step in the process of ordering and executing a DRT trip. There are a large number of data elements that could be included in the different steps of this process, but many possible data items apply only in specific circumstances or for certain rider types. For this reason, the telegrams include a comprehensive set of potentially relevant data items, but most are not mandatory. Each service provider and DRT software system must determine which optional data elements are necessary to interoperate with its own system.

Business relationships and system requirements determine which data elements must be exchanged in specific transactional settings and are not the focus of the specification. Rather, the intent of the specification is to provide the functional scope within which a wide range of entities can exchange transactional data to support interoperability among their technology systems.

For example, a typical TNC rider orders a trip by indicating the trip's origin; destination; number of passengers; and desired level of service, for example, exclusive use of the vehicle with the quickest possible response time or shared use of the vehicle with a willingness to wait as much as 15 to 20 minutes to be picked up. In this booking process, little information is provided about the rider.

In contrast, a nonemergency medical transportation (NEMT) service provider does not provide the customer with any options about its level of service, but it often needs information

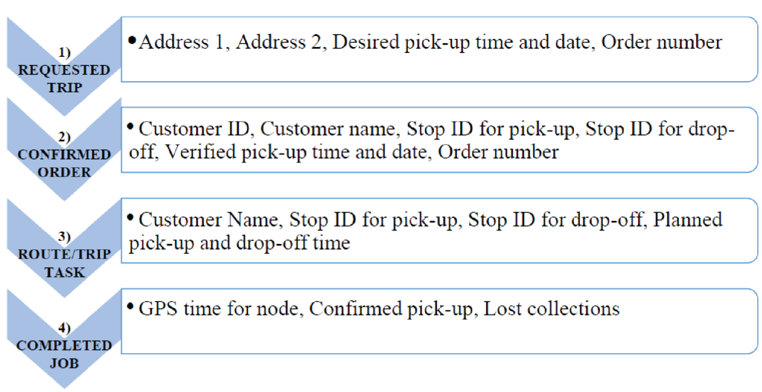


Figure 4-2. Basic data elements needed for the DRT trip process.

regarding special needs and mobility aids to send the appropriate vehicle and driver for a customer. In addition, the entity booking the trip typically wants to know the time of the medical appointment, as arriving too early imposes inconvenience on the customer and arriving late may cause the appointment to be canceled by the healthcare provider. Moreover, some NEMT providers may require more information about customer trips than others, and different NEMT service organizers may request more or less customer or trip information: for example, a customer might be expected to pick up prescription medication on the return trip from an appointment.

The decisions about which data elements are essential for all trips and which are optional can be left up to the groups establishing business rules for interactions involving one or more service providers or those occurring via multi-provider system clearinghouses. The specification is not designed to support any one approach to how interacting entities organize themselves to enable the ordering, delivery, and payment of demand-responsive transportation services.

As emphasized at the beginning of the chapter, the objectives of the specification are simply to establish the common language that entities use to communicate with each other and provide the technical approach for how data communication will occur among interoperating computer systems.

4.3 Telegram Descriptions and Typical Data Flow

The proposed transactional data specification is based on the request/response model (as described in Chapter 2) using a set of telegrams. Telegrams are described in terms of the relevant parties sending or receiving each telegram:

- *Client*—Individual or entity associated with the trip request;
- *Service provider*—Organization that provides the trip, typically a transit agency or a company under contract; and
- *Vehicle node*—Vehicle and driver assigned by the service provider to complete trip.

There are 11 telegrams in the proposed specification, covering five basic activities. The numbering of the telegrams describes not only the activity but also the path the messages follow; this informs which telegram to expect next. Not all messages are used in each transaction.

Table 4-1 lists each telegram and describes the basic tasks linked to each activity.

Table 4-1. Telegrams and their roles.

Activity	Task Accomplished and Flow of Information	Telegram
Planning	Request Trip (rider/client to service provider)	Telegram 1A
	Confirm Trip Request (service provider to client/rider)	Telegram 1B
Confirm Scheduling Details	Confirm Order (client/rider to service provider)	Telegram 2A
	Rider Details (optional) (client/rider to service provider)	Telegram 2A1
	Confirm Trip Scheduled (service provider to client/rider)	Telegram 2B
	Confirm Vehicle (optional) (service provider to client/rider)	Telegram 2BB
Schedule Vehicle	Route/Trip Task Information (service provider to vehicle)	Telegram 3A
	Confirm Route/Trip Task (vehicle to service provider)	Telegram 3B
Trip Completion	Completed Job Data (service provider to client/rider)	Telegram 4A
	Completed Job Confirmation (service provider to client/rider)	Telegram 4B
Reporting	Vehicle Performance Information (vehicle to service provider)	Telegram 5

All 11 telegrams are needed to encompass the full set of core functional needs for a demand-responsive transportation transaction. Over time, additional telegrams can be added as participants wish to add more detail for certain aspects of transactions.

Figure 4-3 illustrates the flow of telegrams among the ordering client (the individual or agency requesting a trip), the transportation service provider, and the vehicle delivering the trip.

Decisions on the telegram structure depend on how the actors involved in the specification process wish to organize the data flow and the transactions. For example, the SUTI standard discussed in Chapter 3 has 71 telegrams to handle every detailed aspect of its transactions. This is due in part to the history of DRT service in Sweden, which was frequently built around taxi

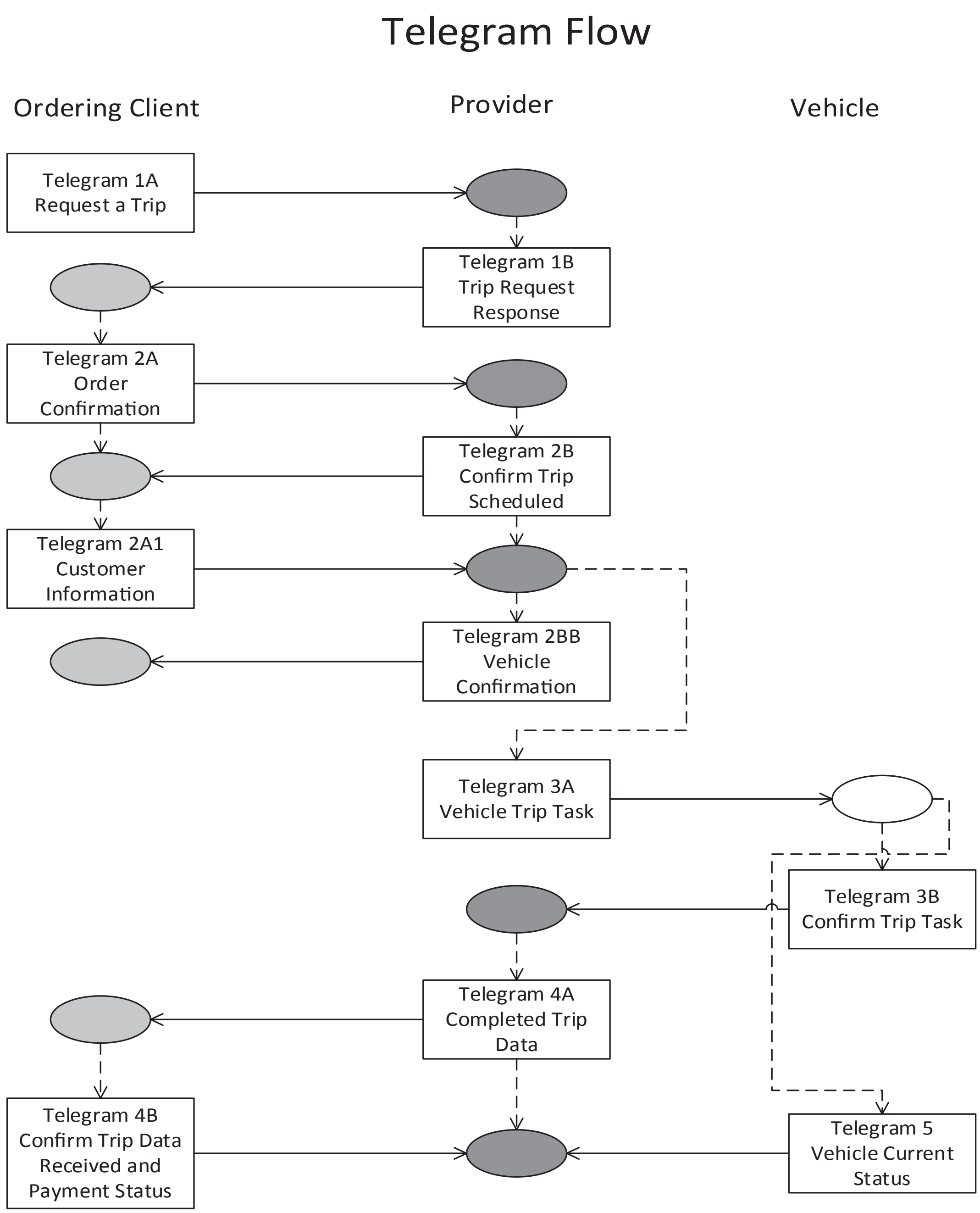


Figure 4-3. Telegram flow.

services. The public agency trip-booking software was commonly distinct and separate from the software used by taxi companies that handled their vehicle operations and customer interface. As a consequence, it was necessary to have numerous telegrams to enable data flow among all of the different software systems and components involved in trip booking, vehicle scheduling, trip dispatching, and driver communications. In the contemporary DRT context, this level of transactional disaggregation is much less essential. This is due to the greater convergence of functionalities—and greater data integration among component technologies—in the technology systems used by service organizers and providers currently compared to two decades ago when the SUTI standards were initially established.

Appendix D provides detailed descriptions of each of the 11 telegrams and the data elements that are included in the recommended transactional specification. Appendix E includes the XML description of each telegram.

4.4 Examples of Telegrams

The following portion illustrates how 4 of the 11 telegrams work. The first sample telegram is to request a trip; the second is to confirm the trip request; the third is to send trip information; and the fourth is the telegram used to confirm trip completion.

Sample Telegram 1: Request a Trip

The first step is to request a trip. The trip could be requested directly by the rider, or an organization such as a human service agency may request the trip on behalf of the rider. This request is described by data elements in Telegram 1:A shown in Table 4-2. The number of data elements would depend on the rider and/or provider needs. For this telegram, and all others presented

Table 4-2. Telegram 1:A—Request a trip.

Telegram 1:A	REQUISITION - Requested trip
From:	Ordering client
To:	Provider(s)
Purpose:	Query for trip availability
XSD Complex Type Name	tripRequest

Data Element	Explanation	Mandatory	Field Type
Pickup address	Address with both street number & name and geocode	YES	Address
Drop-off address	Address with both street number & name and geocode	YES	Address
Pickup time	Requested time of pickup	YES or next	Time
Appointment time	A medical or other appointment time	NO	Time
Drop-off time	Intended drop-off time	NO	Time
End of pickup window		NO	Time
Accessible vehicle required	Yes/No only	YES	Binary
Number of passengers		YES	Numeric
Start of pickup window		NO	Time
Permissible detours		NO	Factor/binary
Negotiated pickup time	The start of the time window that both rider and provider agreed to	NO	Time
Hard constraint on drop-off	Yes or no if the rider must be dropped off at the requested drop-off time	NO	Binary
Hard constraint on pickup	Yes or no if the rider must be picked up at the requested pickup time	NO	Binary
Special attribute	List of special attributes	NO	Special Attribute List
Transport services	List of transport services to use	NO	Local List
Open attribute	Local use	NO	Local List

in this chapter, a YES or NO in the "Mandatory" column indicates whether this is one of the minimum required data elements needed to conduct a transaction. Some entities may require one or more of the additional, nonmandatory data elements in the telegram for it to be valid to transact with their specific service/clients. The data types in Table 4-2 whose definitions are not obvious, e.g., address, special attribute, are defined in Appendix D.

Sample Telegram 2: Confirm Trip

The second step is to confirm the trip. Table 4-3 shows the next telegram, named Telegram 1:B. This sets forth the elements of a message sent from a provider to the client who ordered the trip to confirm that the provider can fulfill the needs requested in Telegram 1:A. Telegram 1:B may include any number of responses from a provider if they have multiple trip options available that fulfill the needs described in Telegram 1:A.

Sample Telegram 3: Send Trip Information to Vehicle

A subsequent telegram deals with sending the trip information to the vehicle. This information is transmitted to a driver application in the vehicle, and that application will guide the actions of the driver. Telegram 3:A, shown in Table 4-4, presents the data that the transportation service provider would send to the specific vehicle (driver) in advance of the trip so that the driver has all information needed to perform the trip at the required level of service.

Sample Telegram 4: Confirm Delivery of Trip

The next step is for the transportation service provider to obtain confirmation from the vehicle that the trip has been delivered. A software application that operates on an in-vehicle device (such as a tablet computer or mobile data terminal) and interfaces with the driver—typically referred to as the driver application—for the purpose of receiving orders and displaying the trip manifest, sends a confirmation to the service provider once the trip has been completed. Confirmation is in the form of Telegram 3:B, shown in Table 4-5.

This specification does not require a telegram to be sent from vehicle to provider when the passenger is picked up, only when delivered. In practice, the driver application associated with

Table 4-3. Telegram 1:B—Trip request/response (confirmation).

Telegram 1:B	**CONFIRMATION - options - Requested trip**
From:	Provider
To:	Ordering client
Purpose:	List of trip options - 1 to many reply on Telegram 1:A
XSD Complex Type Name	tripRequestResponse

Data Element	**Explanation**	**Mandatory**	**Field Type**
Confirmation of vehicle availability	Yes/No response only	YES	Binary
Scheduled pickup time		NO	Time
Pickup address	Address with both street number & name and geocode	YES	Address
Drop-off address	Address with both street number & name and geocode	YES	Address
Transfer zones/points	Coordination	NO	Location/geocode
Fare type	Cash, credit card, fare card	NO	List
Fare amount	Cost/fare of trip, local definition	NO	Numeric
Transport services	Transport service type (from list)	NO	Local List

Table 4-4. Telegram 3:A—Vehicle/trip task.

Telegram 3:A	**REQUISITION - Route/trip task**
From:	Provider
To:	Vehicle
Purpose:	Control Vehicle
XSD Complex Type Name	trip Task

Data Element	Explanation	Mandatory	Field Type
Trip ticket	Unique ID from ordering client	YES	String
Trip/route task ticket	Unique ID from provider	YES	String
Rider pickup location in vehicle performance sequence		YES	Numeric
Pickup node address/geocode		YES	Address
Pickup node scheduled time		YES	Time
Pickup location detailed description		NO	Long text
Rider drop-off location in vehicle performance sequence		YES	Numeric
Drop-off node address/geocode		YES	Address
Drop-off node scheduled time		NO	Time
Drop-off location detailed description		NO	Long text
Rider mobile phone		NO	Numeric
Rider name		YES	String
Other (free field)	Rider: Service Needs	NO	Long text - for driver
Special attribute	List of special attributes of passenger trip	NO	List
Number of other reserved passengers		YES	Numeric
Fare type	Cash, credit card, fare card	NO	List
Fare amount	Fare to collect from passenger	YES	Numeric

Table 4-5. Telegram 3:B—Confirm trip task.

Telegram 3:B	**CONFIRMATION - Route/trip task**
From:	Vehicle
To:	Provider
Purpose:	Vehicle performance
XSD Complex Type Name	trip Task Confirmation

Data Element	Explanation	Mandatory	Field Type
Trip ticket	Unique ID from ordering client	YES	String
Trip/route task ticket	Unique ID from provider	YES	String
Rider drop-off location in vehicle performance sequence		YES	Numeric
Node performed time		YES	Time
Trip status	Performed, no show, no pickup	YES	List
Vehicle number		YES	String
Driver ID		NO	String

the provider's scheduling and dispatching systems will almost always send a data message from the vehicle to the central system when a passenger is picked up. As it is not clear that other systems need the pickup information in real time, the proposed specification does not make this a required telegram. A telegram could be added to the specification if there is a consensus that such information is essential for the real-time transactional data flow. Actual pickup time information is a data element in the telegram that transmits data about the completed trip.

4.5 Approach for Specification-Compliant Data Communication

The specification for demand-responsive transportation includes not only the details of the telegrams and the data elements, but also the approach for transmitting data among the entities involved in the transaction. Those entities are usually a service requestor (e.g., client entity) and a service provider. It is necessary as part of the specification development process to recommend an approach for validating that the transmitted data complies with the specification. This section presents four potential approaches to exchanging trip data in a way that it can be validated as specification-compliant.

Model 1: Point-to-Point

The point-to-point approach to data communications requires all parties to agree upon and share a common protocol for data exchange. Every entity agrees to use the same message set and data elements—telegrams—to communicate with another entity at each point in the process. Figure 4-4 shows how this point-to-point approach works. All participants must have their own software (or embedded system, in the case of devices) that can "talk" directly to other participants using the message set and data elements specified by the data protocols. As a result, the data protocols are internalized in each technology provider's system. The SUTI system that is widely used in the Nordic countries is a point-to-point approach.

Model 2: Point-to-Point via Internal Translator

The second model is a point-to-point via internal translator approach, shown in Figure 4-5. In this approach, each software system and device can use its own data communication approach.

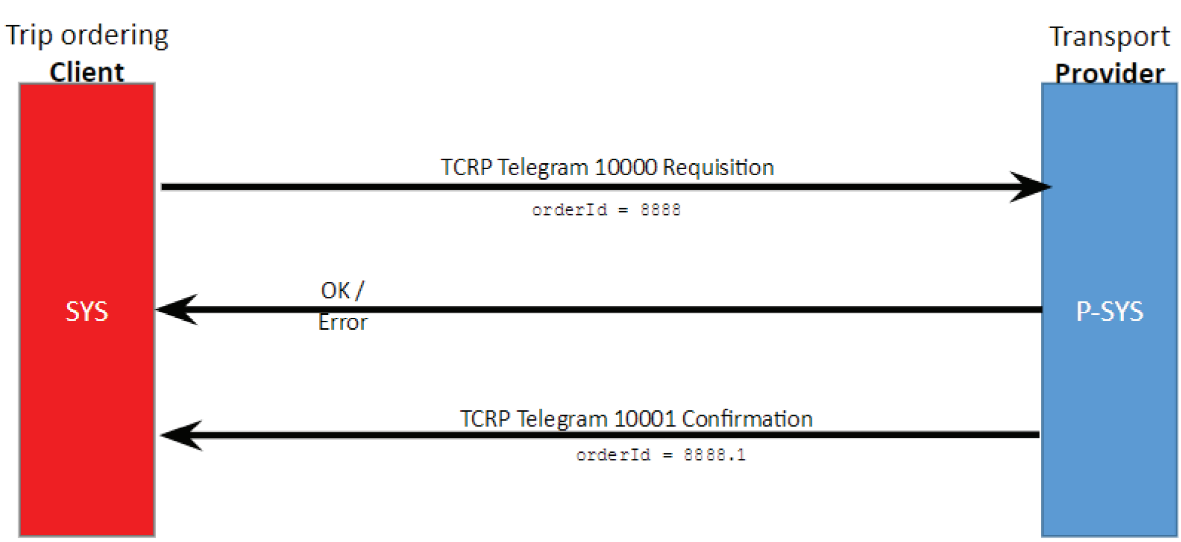


Figure 4-4. Point-to-point communication approach.

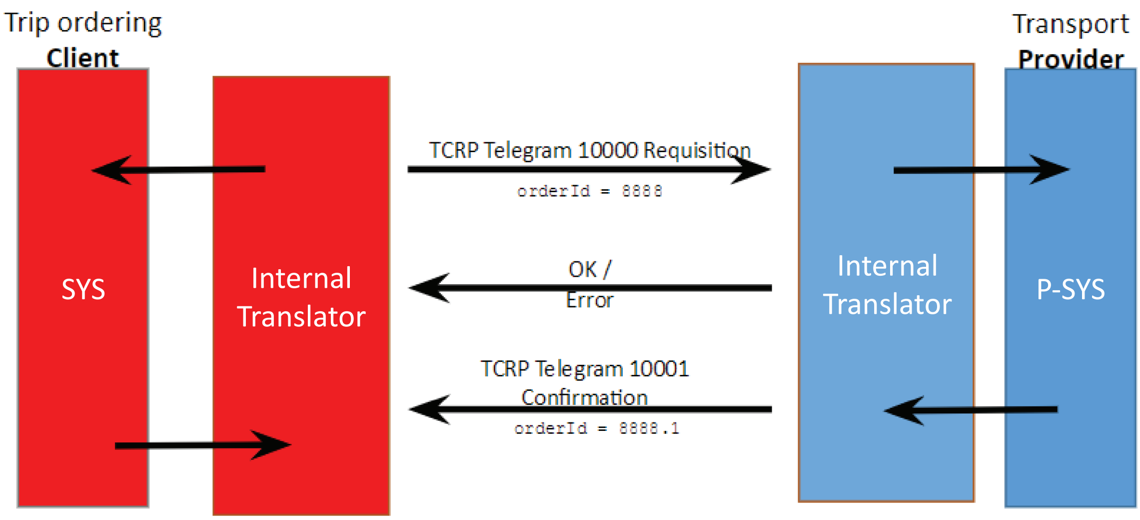


Figure 4-5. Point-to-point with internal translator approach.

It then interfaces with an internal data translator that transforms the data messages and their elements into the common data protocol. In essence, this is an internal API (application programming interface) for each technology system that enables it to talk in the transactional language when it needs to communicate with other systems. Functionally, it is virtually identical to the Model 1 point-to-point approach, but it relies on a somewhat different—and conceptually more flexible—technology approach for the participating systems.

Model 3: Broker Control

The third approach is broker control, shown in Figure 4-6. This approach also uses a shared API, that of the translation broker. Technology systems use the broker's API to transmit messages to one another via the broker. These messages can be passed along to any other participant that also has an interface to the broker's API and can therefore receive standardized messages.

This approach introduces a need for another significant piece of software, the translation broker. The function of the translation broker is to provide the APIs used by the endpoint systems

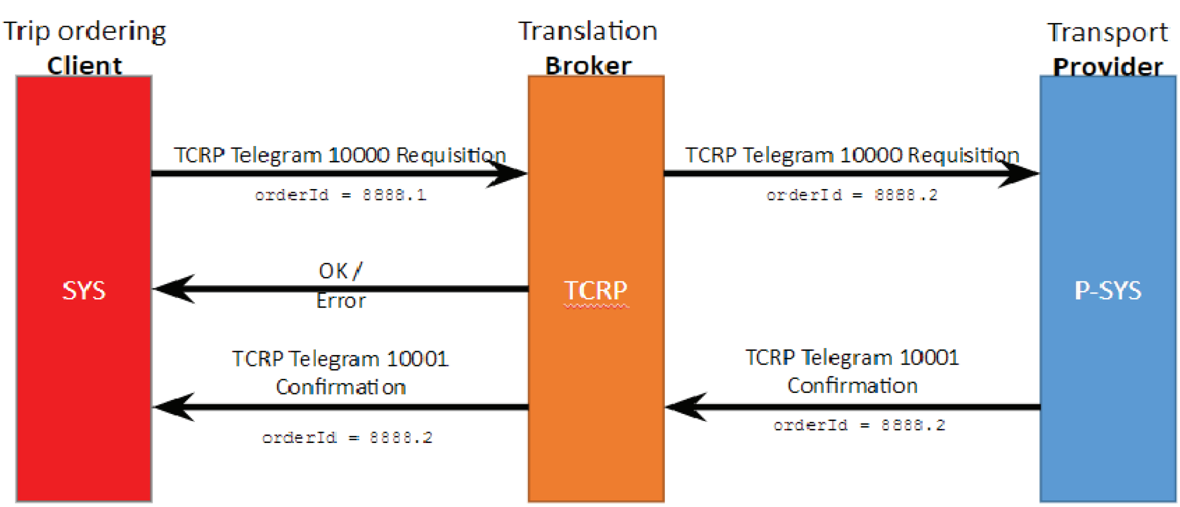


Figure 4-6. Broker control approach.

and translate the data into the common protocols used for communication. There is also a comparable amount of technical work for the external technology systems; they must translate data between the agreed upon common specification—the language that the broker speaks—and their respective internal data schemes.

Model 4: Control Module

This approach uses a control module in which both sides can test the telegrams and ensure their mutual validity. This control module approach (see Figure 4-7) ensures a level of centralized specification control without requiring a fully centralized brokerage approach that could require substantially more time and money to implement initially, as well as significant ongoing expenditures. As in Model 2, each participating system is responsible for making the translation between its internal representation of data and transactional functionality and that of the specification, but this approach adds a centralized module that ensures that all transactional communication is compliant with the specification. In principle, if each party's message is validated by the control module then the other party can translate it with assurance that it will be syntactically correct and meaningful.

Advantages and Disadvantages of Each Model

The four models each have specific advantages and disadvantages.

Model 1 (Point-to-Point)

Advantages—All software systems and devices use the same data protocols internally in their systems; therefore, the technology vendors are responsible for all of the work needed to maintain the data specification. This also promotes lock-in to the specification, since significant changes or the move to another specification would be costly and disruptive.

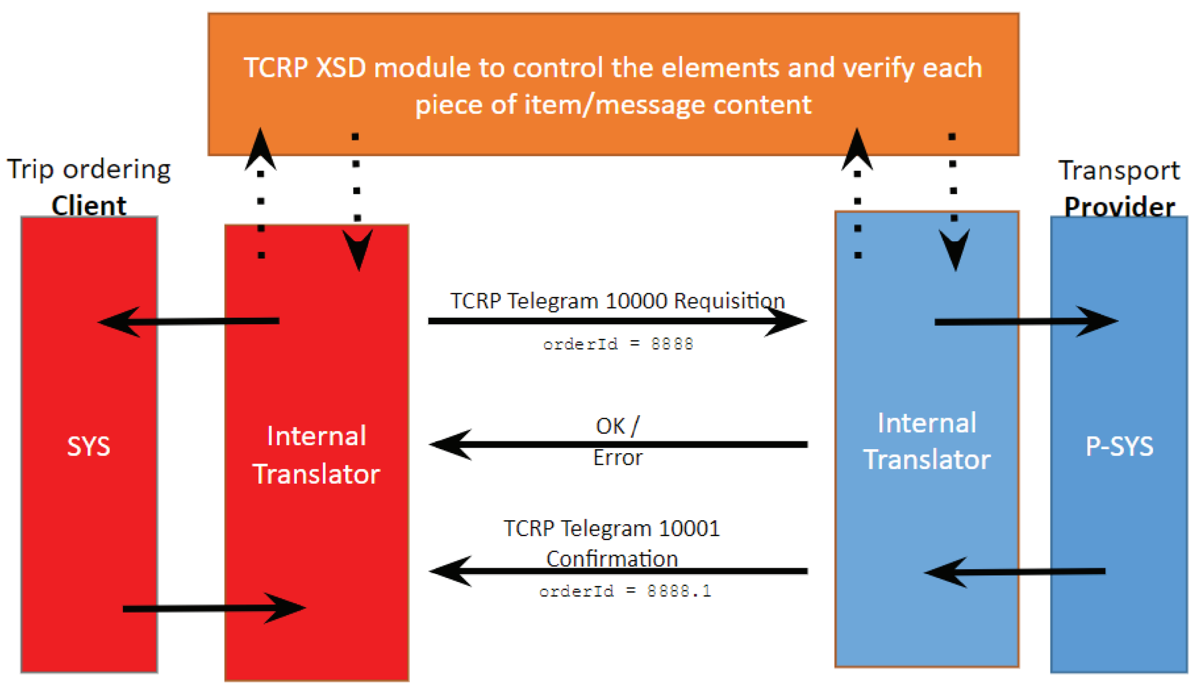


Figure 4-7. Control module approach.

Disadvantages—The disadvantage is the converse: all systems must use a similar internal representation of data—or in essence have an internal translation capability—and all changes in the specification must be adopted by all parties before interoperability can be assured across the entire ecosystem of participants. The latter is the disadvantage of this approach to achieving specification lock-in.

Model 2 (Point-to-Point via Internal Translator)

Advantages—This model enables a completely flexible technology approach by each participant in how it achieves specification compliance. Many internal technology schemes are feasible, and each technology provider will use the one that fits best.

Disadvantages—Each technology system is responsible for performing its own specification validation of incoming messages. If it determines that there is an issue of some type, the system is responsible for informing the message originator that their message has been rejected, and why. This opens the door to potential inconsistency among how participants enforce the specification and what they communicate to other systems. With a small number of participants this might not be a major problem—and it resembles the actual situation in the airline industry due to the presence of a small number of core systems—but it could prove to be unwieldy and complicated in an ecosystem with a large number of technology systems.

Model 3 (Translation Broker)

Advantages—The translation broker represents one approach to avoiding the issues inherent in Model 2. The technology systems do not change anything internally, but rather they may need only to translate their existing data outputs into the proposed specification to communicate with the broker. It affords the opportunity to have a single point for data specification validation in multiparty service integration solutions, such as a marketplace for trips or vehicle capacity. The broker solution gives even more access to transport markets, allowing small providers to participate in competitive markets without excessive technology costs for data flows.

Disadvantages—The research team had initially assessed that a standards-based broker function would ensure the best functionality and the best chance of successful adoption of a transactional specification. However, after substantial discussion with the industry advisory panel, it became clear that the dependence on a third party inherent in this approach represented a major disadvantage and, at this initial stage of specification development, could pose a substantial barrier to implementation because of the additional dependence and cost.

Model 4 (Control Module)

Advantages—The advantage of the control module approach is that it ensures a level of centralized specification control—as in Model 3—without requiring a fully centralized brokerage approach. The translation broker approach (Model 3) is likely to require substantially more time and money to implement and may also require significant ongoing expenditures. The control module approach thus overcomes the issues inherent in Model 2 and Model 3 while providing the technology vendors with the flexibility that is potentially constrained in Model 1.

The recommended approach uses a control module (Model 4), in which both parties involved in the transactional data communication can test the telegrams and ensure their mutual validity. However, a formalized specification validation approach is not mandatory for implementing the specification. Organizations that wish to use the specification could do so and devise their own specification validation approach on a bilateral or multiparty basis. If the largest players did so, theirs would likely become the de facto standard(s). But at this initial stage of specification implementation, a formalized approach to validation seems the most appropriate way forward.

Disadvantages—The primary disadvantage of the control module approach is that it requires an additional element compared to the point-to-point approaches, but does not eliminate the need for a syntax-checking step compared to the translation broker approach. At the same time, while syntax checking is a necessary step in the message data flow, it can be handled by the control module, which will determine whether the syntax is acceptable—in which case the message can be processed successfully. If the message cannot be processed, the message initiator or recipient will terminate the conversation. The other party will know only that the message has not been accepted and will not know why.

4.6 Other Considerations for Government-Funded DRT Services

Most types of demand-responsive service have a common set of data elements. However, certain specialized types of service require additional categories of data. These services are often government-funded and/or intended for a targeted set of riders. In the United States, the most common of these services is ADA complementary paratransit.

The recommended specification does not, for the most part, require telegrams or mandatory data elements within telegrams which directly support these specialized types of DRT services. At the same time, it is important to acknowledge the need of certain government funding programs to obtain data—or to use and transmit such data—on these specific program needs. The specification has accordingly included many nonmandatory data elements in the telegrams so that it is possible for organizations that have these more comprehensive data needs, to exchange data with other entities using only the specification data fields—albeit optional as well as mandatory fields. In such cases, the involved organizations could specify that their transactional partners must also provide certain optional data elements in their data messages.

Rider Attributes

Many of the telegrams in the proposed specification include special attributes to describe the rider and/or their needs in more detail. Table 4-6 and Table 4-7 present lists of potential special

Table 4-6. Special attributes—service needs.

Code	Attribute
D2D	Door to door
DA	Driver alert
DTD	Door through door
HIP	Hearing impaired person
IDD	Intellectually or developmentally disabled
MH	Other mental health concerns
MIP	Memory impaired person (Dementia)
NDD	Neurologic and degenerative diseases
NLA	Never leave alone
O	Oxygen
SA	Service animal
SD	Seizure disorder
SI	Speech impaired
TD	Temporary disability
U	Unstable, needs assistance
VIP	Vision impaired person

Table 4-7. Special attributes—mobility aids.

Code	Attribute
A	Ambulatory
AL	Ambulatory, needs lift
C	Cane
CU	Crutches
E	Electric wheelchair
S	Scooter
W	Wheelchair
WA	Walker
WAK	Knee walker
WE	Extended leg wheelchair
WT	Wheelchair, can transfer

attributes. Some of these describe the mobility aid that the rider may be using (and bringing onto the vehicle). Other attributes describe types of disabilities or special service needs. These attributes are important for determining what type of vehicle is needed and whether the trip requires a driver with special training (or requires that the driver be cognizant of any special needs before pickup and while performing the trip). These special attributes may have codes—such as those shown, which are merely suggestive—to translate among different platforms as needed.

Trip Purpose for Reporting/Reimbursement

Another trip characteristic that some DRT services capture is the trip purpose. Some programs report the trip purpose for various reimbursement rules or human service agency reporting needs. Possible trip purposes and codes are shown in Table 4-8. Typically, both legs of a round trip are viewed as having the trip purpose of the initial leg, for attaching such codes to trips.

4.7 Data Structure

One other important aspect of the transactional data specification approach is how the data is structured to move from computer system to computer system. There are two approaches typically used to implement this: one uses the JavaScript Object Notation (JSON) and the other using eXtensible Markup Language (XML) with tags. Both approaches create a structured set of data that a receiving computer program can decode from a description of the data received

Table 4-8. Trip purpose codes (examples).

Code	Meaning
A	Adult day program
D	Dialysis
E	Employment
G	Grocery
HR	Health related (includes dentist, pharmacy, etc.)
M	Medical
P	Personal
R	Recreation
T	Transfer to/from public transit

from the transmitting computer program. The JSON approach has become more widely used in recent years and is probably the most appropriate way of handling the actual data transmission.

The fundamental difference between the two approaches is that XML is a markup language, whereas JSON represents objects. In principle, the specification can be kept in both languages, however choosing one reduces the overhead work for entities to work together. Using the control module approach, XML allows the two sides to validate and enforce the telegrams before they are sent from ordering system to provider system (or vice versa). Both XML and JSON specifications will be available, although the "official" specification is based on XML.

4.8 Summary

This chapter presented the technical essentials of the recommended transactional data specification for DRT. The telegram paradigm, in which discrete messages—telegrams—composed of specific data elements are sent to advance a transaction from beginning to conclusion, is the core organizing approach to the specification. The proposed specifications include 11 telegrams which encompass the full range of the trip lifecycle, from initial service request to the telegram transmitted after the execution of the trip and containing all the completed trip data. While the data elements specified for each message/telegram are comprehensive, only a subset of the data elements are mandatory; others will only be used for transactions involving specific organizations for whom they are a requirement. This will be determined by business relationships among the entities involved in actual or potential DRT transactions.

The relationships among the full set of telegrams were shown diagrammatically and examples involving 4 of the 11 telegrams were presented, including all mandatory and optional data elements. The entire set of detailed transactional data specifications is contained in Appendix D.

Four approaches were considered for ensuring the verification and validation of telegrams/messages sent among transactional participants. The recommended approach uses a control module in which both sides can test the telegrams and ensure their mutual validity. A software control module accessible to all participants is used to verify that data messages they receive are compliant with the specifications and can be processed with expected results. This project has developed a software tool that is similar to an external validator and can be used as such for testing purposes.

Finally, the data structure for the specifications was considered. It was decided to make available both XML-based and JSON-based specifications, with the official specification based on XML. Appendix E includes a listing of the XML-based specification.

CHAPTER 5

Conclusions and Future Considerations

This research focused on developing an implementable transactional data specification for demand-responsive transportation. The proposed specification—set forth in its entirety in Appendix E—is intended to be an initial step in enabling efficient data interoperability among the software systems used by DRT service providers. This would enable coordination for organizations that want to share resources, carry more passengers, and be more cost-effective. But data interoperability is only likely to be feasible on a widespread basis if a common set of data specifications—such as those developed in this research—are available to be used by the interacting systems. Specifications-based transactional data interactions are commonplace in other transportation industries such as airlines, and have been well established for many years for DRT services in Sweden and Denmark.

This concluding chapter has two purposes. First, a summary of the most important elements of this research is presented, highlighting the key findings and conclusions from the prior chapters. Second, we discuss the way forward—or more accurately, the possible ways forward—to actually implement a transactional data specification for the DRT industry so that the potential benefits of standardized data exchanges can be realized.

5.1 What Was Learned from the DRT Industry Advisory Panel

A panel of 22 industry experts was formed to advise the development of the specification. This group, which included all of the key types of stakeholders discussed in Chapter 2, is referred to as the industry advisory panel. The research team engaged the advisory panel for two primary purposes. In the early stages of the research, team members conducted semi-structured telephone interviews with industry advisory panel members to determine their perspectives on the importance of data specifications and how such specifications might come into being and be governed. Second, throughout the project, the industry advisory panel members took part in six virtual meetings, via conference call/web meeting, to provide input on the specification approach and the specifications themselves as they were developed. The detailed results of these two activities are presented in Appendix B. A list of the industry advisory panel members can be found in Appendix A.

The industry advisory panel process resulted in four key findings.

1. There is general agreement with the objectives of a transactional data specification.
2. This is coupled with a high level of awareness of the multiple challenges that must be worked through if such a specification is to come into being on an industry scale.
3. There appears to be an absence of strong advocates within the DRT industry prepared to assume a leadership role in getting an adoption process under way—panel members liked

the concept of specifications, but few seemed interested in taking a direct role in making specification implementation occur.

4. The development of a governance structure that can take ownership of the proposed specification is perceived to be a critically important need.

5.2 Key Lessons from Transportation-Related Examples of Data Specifications

The case studies of the transportation-related data specifications revealed four important lessons concerning the objective of actual implementation of DRT specifications.

First, Data Specifications Can Produce Game-Changing Results

Transactional data specifications make possible not just data interoperability, but also business interoperability—organizations can readily concert their activities in ways that are mutually beneficial. The airline industry adopted this approach decades ago, setting in motion an evolutionary process involving specification-based data exchange for mutual business advantage that continues to this day. The SUTI standards are a major factor in the remarkable success of the FlexDanmark system. The FlexDanmark technology platform connects to several hundred organizations that sponsor and fund trips and more than 500 transportation service providers using many diverse technologies, all of which are SUTI-compliant, exchanging data with that platform and enabling it to manage DRT vehicle operations that collectively deliver up to 24,000 trips per day.

Second, and Equally Important, the Ability to Achieve Specification Implementation Is Strongly Tied to Key Stakeholders Perceiving Financial Benefits or Other Direct, Concrete Benefits from Specification Adoption

The actual implementation of the specification in organizations' software systems requires the expenditure of resources, possibly significant resources. There is also substantial effort needed to enhance or simply maintain the specification. There must be a business reason for a specification for organizations to voluntarily agree to make such resource commitments. "Nice to have" will almost certainly not be adequate to convince organizations to adopt a specification.

A business reason is clearly seen in the airline industry example, where the financial benefits of interlined ticketing were clear to all participants and resulted in the PNR specification for data exchange. Similarly, in the initial development of the SUTI standards there was a strong business reason—based on financial considerations—for the Swedish government to mandate a specification approach. The national transport ministry wished to ensure that the local public-sector organizations that received transportation funds would be able to procure technology systems that by design worked well together, avoiding the need for expensive custom integrations that would also result in vendor lock-in and lack of competition.

While business reasons do exist for a DRT transactional data specification, they have not been clear to agencies funding a significant amount of DRT. Also, individual agencies that may understand the business reasons for using a specification do not have the power to effect change for the industry as a whole, for what is actually a national issue.

Third, the Pace of Specification Development and Adoption Is Strongly Influenced by the Resources Under the Control of the Specification's Proponents

The contrast between how quickly GTFS came into widespread use once Google put its resources behind it, and the many-year process of developing GTFS-flex to a point where it might soon be adopted, is very telling. Google could devote substantial resources to an ambitious specifications development undertaking that in a relatively short period of time fundamentally changed how public transit data was structured and exchanged. In contrast, the developers of GTFS-flex have had limited and only episodic access to financial resources for developing specifications and promoting their adoption. Similarly, it has taken 9 years to move the Denver Trip Exchange—which includes DRT transactional data specifications—from concept to what is still only a partial reality, with comprehensive operations probably not occurring until late 2020. In both the GTFS-flex and Denver Trip Exchange cases the concepts for standardized data approaches made sense, but the proponents lacked the authority and financial resources to induce other key actors to make commitments that could have led to adoption in a few years.

Fourth, Authoritative Actors, Whether They Are the Government or Private Companies that Are Major Players in an Industry or Sector, Make All the Difference in Achieving Specification Implementation

While a voluntary, industry-initiated process is the most typical approach to specification development, an alternative pathway is for an organization with authority over industry participants to mandate that specifications be adopted, as occurred with the Swedish government and SUTI standards. Market leaders do not have the same formal authority as governmental entities, but their ability to influence outcomes is similar. If an industry leader proposes technical specifications for how software systems interoperate, smaller competitors are likely to feel compelled to follow suit for fear of losing business otherwise. When FlexDanmark required all service providers to adhere to the SUTI standards, its status as both a quasi-governmental actor and as the gateway to public-sector funding of DRT services in Denmark meant that technology companies and service providers had no alternative to specification adherence, if they wanted to be part of the DRT sector. Google's promulgation of the GTFS specification and the fact that Google Transit—available only via Google Maps—would only work with this data meant that transit agencies were essentially forced to publish their data in this format if they wanted information about their services to be widely available.

5.3 Considerations in Developing the Specification

The research team focused the core technical elements of the DRT transactional data specification on supporting the trip lifecycle. As described in Chapter 2, the trip lifecycle includes the following steps:

1. *Trip reservation request*—Focuses on customer logistics such as pickup and drop-off locations, requested pickup/drop-off times, and any relevant information about a passenger's ambulatory status.
2. *Trip scheduling*—Pertains to the assignment of a service provider and vehicle (or vehicle run) to the trip and determination of estimated pickup and drop-off times.
3. *Trip cancellation*—Optional step that occurs if the passenger cancels the trip request, including removing the assignment of transportation resources allocated to the trip.
4. *Trip execution (delivery)*—Includes actual deployment of the vehicle/driver to service the trip and the pickup and drop-off of the passenger to the destination, including fare payment when appropriate.
5. *Trip reporting*—Provides a full record of the trip from the request through trip delivery for data reporting and possible financial purposes.

At this initial stage of specification development, sufficiency and simplicity are key to meeting the basic needs of DRT services for transactional purposes. The recommended specification ensures full coverage of the trip lifecycle, with a concise set of mandatory data elements and a much larger set of optional data elements. This ensures that service and technology providers will be capable of interoperating across the entire range of data and technology boundaries relevant to a DRT trip. The level of detail necessary for transactional purposes for any set of business relationships can be determined by the parties to the transaction; the specifications support both basic and detailed data exchanges.

5.4 Key Elements of the DRT Transactional Data Specification

Two key elements of the proposed DRT transactional data specification are highlighted here.

First, in recognition of the proven capabilities of the SUTI approach to DRT data specifications in Sweden and Denmark, this research has borrowed heavily from technical aspects of the SUTI standard. Most fundamentally, the proposed specification is based on the concept of telegrams, which is at the core of the SUTI approach. Telegrams consist of a specific message type that includes certain standard mandatory and optional data elements. The 11 telegrams proposed are intended to provide the essential data exchanges among software systems needed to support a DRT trip from end to end.

Second, given the many potential participants in DRT transactions from an industry-scale perspective, the data communication approach underlying transactional data exchanges should also be standardized to ensure reliability. In particular, given the importance of specification validation during data exchanges, the research team concluded that an "internal translation with external validation" approach was most likely to be successful.

Recommended Approach

The recommended approach uses a control module that enables organizations sending and receiving messages to test their telegrams and ensure their mutual validity. In this approach, each technology provider is responsible for implementing a software system that produces specification-compliant telegrams. The providers are also responsible for ensuring that the messages sent and received are valid—the control module provides them with the ability to do that, but they must develop the software that interfaces with the control module for that purpose.

To support this approach, the research team developed a basic software tool that can be used as an initial working version of the control module for validating that data are nominally compliant with the transactional data specification. This can be used by any software system needing to verify that its telegrams are syntactically correct. A description of this validation tool can be found in Appendix F.

Alternate Approach

If sufficient resources could be assembled, a translation broker approach would be preferred, in which the broker software is responsible for ensuring that each message (telegram) is specification-compliant. After successful verification, the broker transmits the message to its recipient, which can be assured that it will process a specification-compliant message. This reduces the amount of work each DRT software system must do to ensure that transactional messages are specification-compliant. Unfortunately, the translation broker is a substantial software application that is likely to cost many tens of thousands of dollars (or more) to develop. It is not prudent to construct a specification approach on the assumption that the resources to develop this software will be available in the same time frame as specification implementation. If resources could be obtained to create the translation broker, this would be the recommended approach to data communication of the telegrams.

5.5 Implementation—Potential Scenarios

Developments in the DRT industry and advances in technology—with particular emphasis on the heightened importance of technology platforms—have created opportunities for improved DRT service outcomes if the software systems controlling these services can routinely interoperate. The experiences in Sweden and Denmark offer evidence that such potential benefits are achievable, and transactional data specifications are a key element in making this possible.

At the same time, it is clear from this research that developing a set of recommended specifications is necessary but not sufficient for achieving the desired objective. Successful implementations elsewhere have had consciously guided and organizationally supported implementation processes, with incentives to induce technology organizations in the DRT industry to adopt those specifications. In Sweden, the government was an authoritative advocate for SUTI transactional data specifications. In Denmark, FlexDanmark was a motivated market leader. Similarly, Google was motivated to develop GTFS because of potential business prospects.

A core industry need does not exist in DRT as it does in the airline industry. While a transactional data specification would definitely produce benefits for some organizations that organize and fund DRT services—as the example of FlexDanmark makes clear—it is likely to be of limited value to others. Moreover, the industry advisory panel indicated no immediate prospects for leadership to arise from within the DRT industry.

This means that another way forward is necessary if the benefits of transactional data specifications are to be brought to DRT industry participants in the near term. Rather than the typical top-down approach to specification development and implementation, bottom-up approaches are likely to be more promising, given current conditions. Multiple possible scenarios exist for advancing DRT transactional data specifications at the local, regional, or subindustry level.

Local or regional initiatives may provide opportunities, as may well-funded pilot projects using federal, state, or regional funds. The Denver Trip Exchange is an example of how this could occur. The initial data specifications developed for that initiative have some similarities to those developed in this project, and it is conceivable that within the next year the Denver specifications could be superseded by the ones set forth in this report.

The recommended data specifications and other technical outputs of the research presented in this report represent important technical and business resources that can be put to immediate use by those who perceive the importance of transactional interoperability among DRT technology systems. The specifications now exist, and are accompanied by a technically viable approach for data communication and specification validation. If the involved parties want to engage in interoperable/coordinated DRT transactions and choose to use the specifications developed in this project, they can do so by following the process set forth in Table 5-1. The approach presented can be quickly put in place if organizations are motivated to act.

With the publication of this report and access to the included materials, such as the specification XML and the specification validation software tool to which there is a link in Appendix F, interested organizations now have the tools needed to make DRT service interoperability possible. What the tools cannot do is provide either the motivation to act or the institutional resources necessary to implement a process that results in transportation service providers and technology providers working together to implement and use the specifications for transactional purposes.

To help motivated parties address institutional aspects in the near term, the research team developed communications-related items that may be useful for encouraging adoption and

Table 5-1. Steps to implementing the DRT specification.

Step	Description
1	Organizations wishing to interchange data for transactional purposes determine which optional data elements need to be present in the messages that will be transmitted.
2	Each party's technology provider makes changes to its software system so it can generate specification-compliant data messages to an external location.
3	Each technology provider establishes a connection to the external validator software and adds a protocol in its own system so that outbound and inbound transactional messages to/from other entities are validated before being transmitted or consumed.
4	The two (or more) organizations—and their technology systems—test transactional messages to determine if their data interchange is working properly. If problems are detected, they are fixed by the technology providers.
5	Organizations begin exchanging transactional messages, and new approaches to delivering service become feasible.

implementation of the proposed specification. To help facilitate possible strategies, two documents were created and included as appendices to this report:

- Appendix G is a one-page marketing document that can be given to managers at transit agencies and/or other DRT service providers. Written in nontechnical language, it explains what a DRT data specification is and why DRT providers should adopt it.
- Appendix H provides sample language that a transit agency or DRT service provider can include in an RFP that requires use of the transactional data specification.

Over time, this bottom-up approach can lead to wider adoption across the transit industry and other DRT providers, as agencies take their lead from early adopters. However, in the longer term, a more formal approach to governance for managing and adapting the specification is needed.

5.6 Toward a Formal Governance

Numerous potential organizing models for implementing and managing the transactional data specification were identified during the research. It is clear from the interviews and research that advocacy of the specification by one or more large organizations in this sector is important in catalyzing movement toward widespread, formal specification adoption. Table 5-2 sets forth eight governance models for the DRT specification, and Table 5-3 summarizes the strengths and weaknesses of each.

- *Model 1: Federal government mandates specification.* Some interviewees suggested that the federal government might need to mandate a specification for it to be widely adopted. The agency that was mentioned by numerous interviewees was the FTA.

Table 5-2. Potential models for governance of the specification.

Number	Description
Model 1	Federal government mandates specification
Model 2	International organization manages specification
Model 3	One or more large local agencies agree on specification
Model 4	Large company puts forth specification
Model 5	Professional organization manages specification
Model 6	University research center manages specification
Model 7	Consortium of private-sector players agrees on specification
Model 8	Develop and manage specification as open source project

Table 5-3. Governance models with key strengths and weaknesses.

Number	Description	Strength	Potential Weakness
Model 1	*Federal government mandates specification*	Helps to encourage wide adoption of specification	Concerns about government mandate
Model 2	*International organization manages specification*	Many software developers and operators are not U.S.-based	Difficult to oversee and manage
Model 3	*One or more large local agencies agree on specification*	Specification based on actual needs and experience of local agencies	Difficult to coordinate across independent cities and agencies
Model 4	*Large company puts forth specification*	Based on GTFS model for fixed-route service	Difficult to identify analogous company in DRT
Model 5	*Professional/industry organization manages specification*	Known organizations that have created other industry specifications	May not have needed technical expertise
Model 6	*University research center manages specification*	Nonpartisan and have technical expertise	Would likely need ongoing funding source
Model 7	*Consortium of private-sector players agrees on specification*	Based on successful model of the GTFS Best Practices Working Group	Would require high degree of initial and ongoing coordination among multiple parties
Model 8	*Develop and manage specification as open source project*	Technical advancements open to all able and interested groups	Lack of coordination may lead to multiple specifications

- *Model 2: International organization manages specification.* Another suggested model was having an international organization or collaboration manage the data specification. One technology provider noted that many of its clients are international, and there would be benefits of coordinating this effort beyond the United States.
- *Model 3: One or more large local agencies agree on specification.* Collaboration among a few large public agencies could result in a means of managing a future specification for DRT transactional data. A few large public agencies (e.g., New York, Los Angeles, and Chicago) could come together to make a standard happen; they could then release RFPs requiring that vendors use the standard. Or a few innovative transit agencies could work together and agree on a specification.
- *Model 4: Large company puts forth specification.* The noteworthy example is Google and GTFS, in which a large company worked with a public agency to create a de facto standard. It is an open question, however, whether there is a company that is sufficiently large in the demand-responsive transportation industry to develop a standard and convince a large part of the market to adopt it.
- *Model 5: Professional organization manages specification.* APTA or CTAA could be appropriate forums for managing a specification for transactional data. It is not clear whether either organization has sufficient technical expertise to play such a role.
- *Model 6: University research center manages specification.* A university research center might play a central role in developing and maintaining a DRT data specification. The Center for Urban Transportation Research (CUTR) at the University of South Florida was cited as a possibility. However, this would likely require a dedicated funding source.
- *Model 7: Consortium of private-sector players agrees on specification.* A possible model mentioned by several advisory panel members was a consortium of predominantly private-sector players. This could follow the model of the GTFS Best Practices Working Group that was recently convened; this effort was funded by the Rocky Mountain Institute, which encourages interoperable data standards.
- *Model 8: Develop and manage specification as open source project.* The specification could become the focus of an open source project, as a stand-alone initiative or in combination with another model.

While authoritative government involvement in the specifications situation—Model 1—would almost certainly result in specification adoption, as was the case in Sweden, it is unlikely to occur in the United States. Rather, industry associations and the leading organizations in these industries are typically the key to successful development of technical specifications. These organizations can be private sector, public sector, research focused (including academic), or some combination.

A key challenge is to find mechanisms and opportunities to engage these entities to help catalyze the development of a governance structure for the specification. Such a governance structure is likely to be the key to widespread adoption of transactional data specifications for DRT and ongoing evolution of such specifications, as has occurred in Europe with the SUTI standards.

While this is clearly the desired end state of this specification development process, there are multiple challenges to its achievement. In the immediate term, a more productive focus may be on maximizing discrete opportunities to implement these or similar specifications in as many situations as possible when conditions are favorable. Nothing will be more important in building momentum for an industry-level approach to adoption and governance of specifications than a number of successful examples of their deployment and utilization in situations of a more limited scope.

Bibliography

Craig, T. *"Alpha Release" of the Flexible Trip Planner*. https://trilliumtransit.com/2017/09/01/alpha-release-of-the-flexible-trip-planner/. Accessed December 13, 2018.

FTA. *Mobility Services for All Americans (MSAA): Case Studies in Advancing Universal Mobility*. https://www.its.dot.gov/presentations/2018/MSAA_KTT_3_CaseStudy.pdf. Accessed December 13, 2018.

FTA. *Demand Response Fact Sheet, 2013*. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/Demand_Response_Fact_Sheet_Final_with_NEZ_edits_02-13-13.pptx. Accessed December 13, 2018.

FlexDanmark. *FlexDanmark SUTI Selvdeklaration, 2015*. https://www.flexdanmark.dk/web/om-os/publikationer/download/1547/2198/16. Accessed December 13, 2018.

GitHub. GTFS-flex. https://github.com/CUTR-at-USF/gtfs-flex. Accessed December 13, 2018.

Goodwill, J. A., and H. Carapella. *Creative Ways to Manage Paratransit Costs*. Report No. BD 549 RPWO 28. USF Center for Urban Transportation Research, 2008.

Google. *GTFS Static Overview*. https://developers.google.com/transit/gtfs. Accessed December 13, 2018.

Google. *GTFS Flexible Transit Working Group*. https://groups.google.com/forum/#!forum/gtfs-flexible-wg/. Accessed December 13, 2018.

Hillsman, E. L., and S. J. Barbeau. *Enabling Cost-Effective Multimodal Trip Planners through Open Transit Data*. Report No. USF 21177926, 2011.

International Air Transport Association. *Reservations Interline Message Procedures—Passenger (AIRIMP), 36th Edition*. 2012.

Larsen, N., R. Teal, D. King, and C. Brakewood. *Development of a Transactional Data Standard for Demand Responsive Transportation: A Case Study of Sweden.* Proceedings of the 97th Annual Meeting of the Transportation Research Board, Washington, D.C., 2018.

Lave, R., R. Teal, and P. Piras. *TCRP Report 18: A Handbook for Acquiring Demand-Responsive Transit Software*. Transportation Research Board, Washington, D.C., 1996.

Metro. Request for Proposals No. 303911. General Transit Feed Specification for Real-Time (GTFS-RT) Data System. Issued July 26, 2018. Austin, Texas.

Needleman, R. *Who Owns Transit Data?* cnet.com. August 24, 2009. https://www.cnet.com/news/who-owns-transit-data/. Accessed December 13, 2018.

O'Neil, S., and R. Teal. *TCRP Web-Only Document 62: Standardizing Data for Mobility Management*. Transportation Research Board, 2016.

Rojas, F. M. *Transit Transparency: Effective Disclosure through Open Data*. Transparency Policy Project, Ash Center for Democratic Governance, Harvard University, 2012.

Schmidt, C. *Best Practices for Technical Standard Creation: Guidelines for the Design, Socialization, Formalization, and Adoption of New Technical Standards.* MITRE Corporation, April 2017.

SUTI. *About Us*. http://u3545014.fsdata.se/blogg/about-us/. Accessed December 13, 2018.

SUTI. *Description of SUTI-Messages, 2017*. http://u3545014.fsdata.se/blogg/?media_dl=325. Accessed December 13, 2018.

SUTI. *Document Relations in SUTI Standard, 2017*. http://u3545014.fsdata.se/blogg/?media_dl=324. Accessed December 13, 2018.

SUTI. *Standard Protocol for Demand-Responsive Transport Services. Welcome to SUTI*. http://u3545014.fsdata.se/blogg/. Accessed December 13, 2018.

SUTI. *SUTI 2017 In Progress Message Flow, 2017*. http://u3545014.fsdata.se/blogg/?media_dl=326. Accessed December 13, 2018.

Teal, R. *First Mile/Last Mile Shared Ride Services: Technology Enables New Business Models*. Presentation at the 2015 TransITech Conference, 2015. https://www.apta.com/mc/revenue/program/Documents/First%20Mile%20Last%20Mile%20Shared%20Ride%20Service%20Technology%20Enables%20New%20Business%20Models%20-%20Roger%20Teal.pdf. Accessed December 13, 2018.

Wong, J., L. Reed, K. Watkins, and R. Hammond. *Open Transit Data: State of the Practice and Experiences from Participating Agencies in the United States*. Proceedings of the 92nd Annual Meeting of the Transportation Research Board, Washington, D.C., 2013.

Abbreviations and Glossary

Abbreviations

AIRIMP	A4A/IATA Reservations Interline Message Procedures
API	application programming interface
CSV	comma-separated value
CUTR	Center for Urban Transportation Research
DRT	demand-responsive transportation
DRT-SV	demand-responsive transportation—shared vehicle
GPS	Global Positioning System
GTFS	General Transit Feed Specification
GTFS-flex	General Transit Feed Specification—Flexible Transit
HIPAA	Health Insurance Portability and Accountability Act
JSON	JavaScript Object Notation
MaaS	Mobility as a Service
MSAA	Mobility Services for All Americans
NEMT	nonemergency medical transportation
PNR	passenger name record
RFP	request for proposals
RTD	Regional Transportation District
SUTI	Swedish: Standardiserat Utbyte av Trafik Information; English: Standard Protocol for Demand Responsive Transport Services
TNC	transportation network company
VTrans	Vermont Agency of Transportation
XML	eXtensible Markup Language
XSD	eXtensible Markup Language Schema Definition

Glossary

application programming interface (API) APIs are software intermediaries that allow two applications to talk to one another.

booking In this document, booking refers to a formal reservation (date and pickup time) for a demand-responsive transportation (DRT) trip that will be fulfilled by a DRT provider. The terms *booking* and *reservation* are essentially synonymous for DRT.

broker In this document, a broker refers to a piece of software that receives a DRT trip order and then passes that trip request along to a DRT provider. This piece of software has the capability to translate the initial trip request into a specified message format before passing it along to providers. The software is capable of determining which providers to send it to.

client In this document, a client is an organization that has the travel demand information, which includes trip requests from customers on the demand-responsive transportation system. To fulfill these demands, the client has contracted one or several "providers." The provider (or operator) has access to vehicles and drivers that will actually fulfill the trips.

data element A data element is a unit of data with a precise meaning. It typically has a name, definition, and one or more representations.

demand-responsive transportation (DRT) Transportation services in which a rider requests (orders) a trip through an automated or human-based system that schedules each ride onto a vehicle controlled by that system. Vehicles are scheduled and routed in accordance with the demand, including specified origin, destination, desired pickup time, and/or desired arrival time.

demand-responsive transportation—shared vehicle DRT services (see previous definition) in which the vehicle is shared with one or more unrelated passenger trips.

Denver Regional Transportation District (RTD) The Denver Regional Transportation District (RTD) is a government agency that provides bus, rail, and demand-responsive public transit in the metropolitan Denver, Colorado, region. This organization is a partner in the trip exchange discussed in Chapter 3.

discovery data In this document, discovery data refers to datasets that describe potentially available transportation services to passengers. This differs from transactional data because it does not include all the information necessary for a trip maker or a transportation service provider to book and schedule a specific trip. An example of discovery data for fixed-route transit is General Transit Feed Specification (GTFS); an example for DRT services is GTFS-Flexible Transit (GTFS-flex).

dispatch In demand-responsive transportation services, dispatch is the control process (human or virtual) that sends a vehicle to fulfill a trip and monitors vehicle operations.

eXtensible Markup Language (XML) The eXtensible Markup Language (XML) is a textual data format that defines a set of rules for encoding documents in a format that is both machine- and human-readable. It is one of two commonly used formats (along with JSON) for exchanging data among applications.

eXtensible Markup Language Schema Definition (XSD) The eXtensible Markup Language Schema Definition (XSD) specifies how to formally describe elements in an XML document. In this document, the proposed transactional data specification uses XSD.

General Transit Feed Specification (GTFS) The General Transit Feed Specification (GTFS) describes fixed-route transit service schedules and stop locations. This is a de facto data standard in the public transit industry because the specification is being used by many public transit providers in the United States and throughout the world.

General Transit Feed Specification—Flexible Transit (GTFS-flex) The General Transit Feed Specification for Flexible Transit (GTFS-flex) is a proposed extension—expected to soon be formally adopted—of the General Transit Feed Specification which can be used to describe demand-responsive transportation (DRT) services. It is an example of discovery data because it enables DRT passengers to identify trip possibilities, but it does not contain sufficient information for DRT providers or trip makers to complete the DRT trip booking.

Global Positioning System (GPS) Global Positioning System (GPS) is a satellite-based navigation system that provides geolocation information to receivers. GPS devices are commonly installed on transit and paratransit vehicles.

Health Insurance Portability and Accountability Act (HIPAA) The Health Insurance Portability and Accountability Act is the federal legislation statute governing the exchange, transmission, and privacy of an individual's medical information.

JavaScript Object Notation (JSON) JavaScript Object Notation (JSON) is a textual data format that is both machine- and human-readable. It is one of two commonly used formats (along with XML) for exchanging data among applications.

message In the context of transactional data, a message is a way that data is transmitted between two parties, such as a DRT client and a DRT provider. It includes an agreed upon type of message with corresponding data elements. For example, there may be a message type to send a trip request to another transportation system and another message type to send a trip to a device in a vehicle.

Mobility Services for All Americans (MSAA) The Mobility Services for All Americans (MSAA) is a U.S.DOT initiative to promote partnerships among public, private, and nonprofit organizations to share data and manage resources to improve mobility services. In Chapter 3 of this report, an MSAA project in the Denver region is discussed as an example.

nonemergency medical transportation (NEMT) Nonemergency medical transportation (NEMT) refers to transportation service for individuals seeking medical care who are not in an emergency situation. The Medicaid program provides funding for NEMT services for eligible persons enrolled in Medicaid, and such services can include demand-responsive services such as taxi trips and transportation provided by organizations operating wheelchair-accessible vehicles.

paratransit Paratransit originally referred to all shared, flexible transportation services: intermediate between the private automobile and fixed-route public transportation, including DRT services. In the United States, paratransit now commonly refers to DRT services for individuals with disabilities, elderly, and other riders with special needs.

passenger name record (PNR) Used by the airlines, the passenger name record (PNR) refers to a data specification describing an airline passenger and their flight itinerary, including items such as the passenger's name, flight number, and airline.

point-to-point data communications In this document, point-to-point refers to data communications in which different parties (and their respective software systems) communicate directly with one another via an agreed upon protocol for data exchange.

provider (transportation provider) The provider refers to the operator of transportation services. This could be a taxi company, transportation network company, public agency, or other private or government-funded entity that provides demand-responsive transportation services.

request for proposals (RFP) A request for proposals (RFP) is a document set forth by an agency or company interested in procuring services or items. Potential service providers or suppliers can then respond to the solicitation with a business proposal.

specification A specification is documented technical requirements generally considered working or business documents.

standard In this report, a standard refers to technical specifications that have been agreed upon by consensus or established by a neutral third party via a formal process or organizing body.

SUTI specification SUTI is a Swedish acronym that stands for "Standardiserat Utbyte av Trafik Information." SUTI is a transactional data standard for demand-responsive transportation.

telegram For this transactional data specification, a telegram refers to a message that transmits data with a specific structure and wording (data elements).

transactional data Transactional data is shared among two or more organizations to conduct some form of transaction. In the context of demand-responsive transportation (DRT) services, transactional data includes all the information necessary for a transportation service provider to schedule and complete a specific DRT trip.

transportation network company (TNC) Transportation network companies (TNCs) are providers of ride-hailing (or ride-sourcing) services. They typically arrange rides for customers via a smartphone application and a technology platform that connects riders and vehicle drivers.

use case Use cases are commonly identified in software and systems engineering to define and organize system requirements. A use case is typically made up of a sequence or set of interactions to a particular goal.

validator For this transactional data specification, the term validator refers to a software tool that allows interested parties, such as DRT service providers, to test transactional data messages in the format of the proposed data specification to verify that the data messages are correctly formatted and to identify any issues associated with the data message's specification or implementation.

Vermont Agency of Transportation (VTrans) The Vermont Agency of Transportation (VTrans) is a government organization in the state of Vermont that is responsible for planning, constructing, and maintaining transportation infrastructure. VTrans is discussed in Chapter 3 of this report in an example of GTFS-flex.

APPENDIX A

Industry Advisory Panel Members

Name	Category
Izzy Aala	Technology provider
Sarah Anderson	Researcher/consultant
Daniel Andrlik	Technology provider
Aaron Antrim	Technology provider
Chad Ballentine	Public agency
David Block-Schachter	Public agency
Christopher Bryan	Private transportation operator
Emily Castor/Paul Davis	Transportation network company
Kevin Chambers	Researcher/consultant
Jarrod Clark	Technology provider
Elaine Collins	Public agency
Tom Coogan	Technology provider
Alex Fay	Technology provider
Ray Lowrey	Private transportation operator
Bob Nixon	Technology provider
Louis Pappas	Transportation network company
Peter Pistek	Private transportation operator
Andrew Salzberg	Transportation network company
Bruce Schaller	Researcher/consultant
Judy Swystun	Private transportation operator
Arjan Van Andel	Technology provider
Steven Yaffe	Public agency

APPENDIX B

Engaging Industry Experts

The research team engaged a group of leaders drawn from the demand-responsive transportation industry as an external industry advisory panel during this project. The purpose of this industry advisory panel was to assess the current state of practice, learn about challenges and opportunities that currently exist, and discuss implementation and management issues for adoption of transactional data specifications. This appendix describes these activities and the analysis that was produced. The appendix begins with a description of the industry advisory panel approach and composition, then presents key findings from interviews and meetings with the advisory panel, and last, includes a discussion of governance of the proposed data specification, which was a key concern among the industry panel members.

Industry Advisory Panel Approach and Composition

The paratransit industry involves a variety of organizations with unique specializations. The industry can be described in a general manner as follows:

- Demand-responsive transportation service and technology providers range from small, independent services to large, international software firms and contractors
- Provisions and service requirements for demand-responsive transportation are affected by a mix of local, state and federal regulations
- Transit agencies have varying degrees of resources dedicated to demand-responsive transportation

This collection of providers and regulations results in a fragmented market with operating characteristics adapted to each region. This patchwork of regulations and services is one challenge to widespread use of transactional data specifications. In light of these industry conditions, the research team identified experts to participate in an advisory panel to explain the nuances of the demand-responsive industry - including the differences across service providers, software companies and local market characteristics - and to help achieve agreement on a transactional data specification that can be implemented in the demand-responsive transportation industry.

The industry advisory panel was comprised of members from representative organizations within the industry. The individuals and firms invited to participate were deliberately selected to represent a full picture of participants providing services within the demand response industry.

The panel composition represents public agencies, private firms, and nonprofit groups. The research team recruited a total of 22 members for the industry advisory panel, who are listed in Appendix A; each member can be classified in one or more of the following categories:

- Transit agency managers (4)
- Private transportation operators (5)
- Transportation network companies (3)
- Technology providers (8)
- Researchers in demand-responsive transportation and/or transit/DRT data systems (2)

The industry advisory panel was involved in two types of activities. First, industry panel members participated in interviews with the research team. The interviews explored common themes, challenges and opportunities in the existing paratransit market, plus detailed discussion of how transactional data specifications could be introduced and managed within the market. Second, the panel convened for regular meetings held virtually throughout the project, during which the research team presented and discussed project development. These activities are discussed in the following sections, beginning with the industry advisory panel interviews.

Industry Advisory Panel Interviews

At the beginning of the project, the research team assessed the current state of practice, opportunities, and challenges for potential transactional data specifications through in-depth phone interviews with industry advisory panel members. The first part of each interview aimed to summarize the current state of the industry and provide background information about each participant. The second part asked about key benefits of a common specification for transactional data, and the third part focused on challenges to adopting a common specification. The last part of the interview asked participants to envision what a future specification would look like and the process for managing the specification in the future. Refer to the last section of this appendix for the interview protocol that research team members used to guide the interviews with industry advisory panel members.

Interview Process

Members of the industry advisory panel were invited to participate in an approximately 45-minute phone interview with one or more project team members in the summer of 2017. The interviews were semi-structured: team members had a set of discussion topics, pursuing those topics for each interview that yielded the most relevant information and opinions for this research. See the last section of this appendix for the interview protocol. Participation in the interview process was voluntary for advisory panel members; some declined participation and others were willing to participate but were not available during the timeframe when the interviews took place. Interviews were recorded and transcribed for accuracy. Overall, a total of 14 panel members participated in the interviews.

Interview Findings

This section presents the key findings from the interviews. The first part discusses general trends in the industry and roles of the various players. The second and third sections describe key benefits and challenges, respectively, of transactional data specifications identified by panel members, and the final section presents a brief summary.

Interview Findings on Industry and Roles

Participants first discussed how their organization was using transactional data for demand-responsive transportation services. Three key findings are summarized here.

- *Finding 1—Many private-sector players have developed internal systems that interface with different vendors' proprietary systems*. There are several large-sized software providers in the demand-responsive transportation industry (e.g., Trapeze, Routematch, Ecolane), and numerous interviewees worked with more than one of these vendors. In order to facilitate working with multiple technology companies across different regions, some private-sector players have developed internal systems capable of integrating with multiple products. This is happening at numerous companies (particularly technology providers and transportation service providers) with various levels of sophistication and integration. For example, one transportation service provider said that for the most part, it uses a single vendor (Trapeze) for its systems; however, it also works with two other vendors (Ecolane and Routematch) in a small number of locations. It then takes the data from each system and brings the data back to its own system, and it tries to standardize it so that it can run reports across locations. Similarly, one consultant said that for one of their products used in numerous locations, paratransit trips can be booked through three different systems (Ecolane, Trapeze, and an open source platform). Because each of these systems is slightly different, each booking is translated into one of three different languages on the backend to process these requests.

- *Finding 2—There are a small number of very innovative pilot projects and programs*. The first was the Denver Regional Transportation District (RTD) project, which included members of this TCRP research team. The second is a Vermont Agency of Transportation (VTrans) project that was using General Transit Feed Specification (GTFS) Flex in Open Trip Planner. The third was in the state of Pennsylvania, where customers used the "One Click" system to book trips; a noteworthy characteristic of this was that Pennsylvania Department of Transportation was working to streamline eligibility and payment rules for demand-responsive transportation services throughout the state. These three initiatives may warrant further study and future collaboration since they are particularly innovative projects in the demand-responsive transportation industry.

- *Finding 3—Some agencies are conducting pilot programs with TNCs that make standardized transactional data increasingly relevant*. Public-sector participants in this project are seeking new, more flexible means of providing demand-responsive transportation services, and some transit agencies are currently partnering with transportation network companies (TNCs) to provide new demand-responsive transportation options to customers. These new partnerships create data-related challenges that make efforts to standardize transactional data increasingly relevant. For example, the research team interviewed one transit agency that was conducting a pilot program with Uber and Lyft for its ADA complementary paratransit services. While this project had numerous potential benefits (including cost reduction), one key challenge was that there is no central clearing house for transactional data, which goes directly to the TNCs. A specification for transactional data could facilitate data sharing. Another transit agency that was interviewed was conducting a pilot program that provided demand-responsive transportation to the general public in a partnership with Via. Via provides an application (app) and the software, and the transit agency provides the vehicles, which are also used for the agency's traditional ADA paratransit service. However, Via's system is completely separate from this transit agency's existing ADA paratransit software system. A specification for transactional data could facilitate integration of these systems.

Interview Findings on Benefits

The potential benefits of moving to a common specification for transactional data in demand-responsive transportation were discussed at length during the interviews. The interview responses varied somewhat across the industry advisory panel members. Through an analysis of interview content, the research team identified four broadly shared benefits.

- *Benefit 1—Reducing operating costs*. A key benefit that multiple parties repeatedly cited during the interviews was the potential for reducing the costs associated with software solutions for demand-responsive transportation services. In the interviews, one transit agency stated that controlling costs of paratransit service was a key benefit. Similarly, one technology provider said if there was a common data format, it would probably save them significant labor costs.

- *Benefit 2—Facilitating data sharing*. A common specification for transactional data could facilitate data sharing among public agencies that provide demand-responsive transportation services. For example, one transit agency said that it currently participates in a benchmarking group with approximately 20 other international agencies, and each year they provide data to this group. Its reporting could be streamlined if a data specification existed for paratransit services.

- *Benefit 3—Increasing flexibility of DRT services*. During the interviews, numerous parties stated that they envision demand-responsive transportation services becoming increasingly flexible in the future, and standardizing transactional data is a step in this direction. For example, one transportation service provider explained during his interview that the industry is moving to a more flexible system, where passengers have more control over their own rides and can get same-day rides. This is a model similar to that of the TNCs applied to the paratransit market. There are unique challenges to coordinating this for paratransit, but data standards would help. Another transit agency said that it envisioned procuring a more dynamic and flexible system for operating demand-responsive trips in the future. It wanted it to be more TNC-like, and it was preparing for an RFP process in the near future to procure a new system.
- *Benefit 4—Increasing availability of passenger apps*. Another benefit of a more TNC-like paratransit industry is having simpler mobile applications that passengers can use to book trips. These would likely be easier to develop if there were common specifications for transactional data. In the interviews, one transportation provider said that a key benefit for passengers would be rolling out one application across all of their locations. Then, tech-savvy paratransit customers would benefit from this (similar to GTFS and Google Maps, which are used in many locations).

Interview Findings on Challenges

Interviewees also discussed the challenges of moving to a common specification for transactional data in demand-responsive transportation services. Five key concerns are highlighted.

- *Challenge 1—Wide variation in business rules and operational practices*. Nearly all interview participants stated that a key challenge to developing a common specification for transactional data is the many differences in business rules and/or operational policies across service providers and agencies. For example, one transportation service provider said that if there was one universal system for providing demand-responsive transportation services, then it could easily standardize across all of its locations. However, there are challenges because each transit agency has different rules and different vehicles. Similarly, one transit agency noted that big agencies tend to have different ways of doing things from smaller agencies. One technology provider stated that some people may say that technology is the barrier, but the real barrier is the operational needs and policies. Last, a consultant noted that everyone seems to have different rules in different regions.
- *Challenge 2—Lack of incentive to standardize*. Some interviewees noted that without some sort of financial incentive to standardize, it is unlikely that major players in the demand-responsive transportation industry will adopt a common specification for transactional data. For example, one transportation service provider stated in the interview that a common specification is actually against the interests of some of the software companies.

Similarly, one technology provider noted that the biggest threats of adopting common specifications are to the incumbents in the industry.

- *Challenge 3—High costs of switching to a new specification*. Another key challenge to adopting a common specification for transactional data is the switching costs of moving from existing systems, which are often highly customized, to a new system. For example, one transit agency said that a major challenge would be the changes to its internal reporting systems. Right now, the transit agency has many customized reports based on its own naming conventions; changing the data naming conventions would require changing its reporting system, which would likely require significant in-house resources. One technology provider also noted that it will likely cost more for its clients the first time they order a new product; a standard could require extra development and testing, which would increase costs initially.

- *Challenge 4—Possible privacy issues for healthcare–related data*. A small number of interview participants suggested that there may be some concerns with medical-related data for some trip requests. The data privacy provisions of the Health Insurance Portability and Accountability Act (HIPAA) are important considerations. The HIPAA considerations could be considered an additional layer of data exchange in an XSD module (as proposed in an approach discussed in Chapter 4), and several healthcare technology start-ups are exploring solutions to this challenge. The need for coordination of health care and healthcare transportation is important, as reflected by it being the subject of other ongoing TCRP studies (including TCRP B-44: Examining the Effects of Separate Non-Emergency Medical Transportation (NEMT) Brokerages on Transportation Coordination; and TCRP B-45: Transportation to Dialysis Centers: Health/Transportation Policy Intersection). Bringing experts in both industries together to solve this problem—potentially using tokens/keys to communicate sensitive information among healthcare providers' and transportation providers' systems end points—makes true coordination a formidable challenge.

- *Challenge 5—Mis-specification*. Some interview participants noted that a key challenge to this effort is making sure that the specification for transactional data has an appropriate scope. If the specification is too detailed or too broad, it may not work as intended. For example, one technology provider stated that he was concerned with diluting the standard. The standard might have a certain number of data fields, but more fields may be required for certain situations. On the other hand, another technology provider noted that if the standard tries to encompass everything in a paratransit environment for all agencies, there would be so many variables, it would become too complicated and unwieldy.

Summary of Interviews

This section graphically summarizes the key findings of the industry advisory panel interviews. Findings on the state of the DRT industry and implications for this project that aims to develop common transactional data specifications are shown in Table B-1. The most frequently mentioned benefits and challenges to this TCRP effort are shown in Table B-2.

Table B-1. State of DRT industry and implications for this project.

Finding		Implication
Private-sector players have developed internal systems to work with other vendors' proprietary systems.	→	Companies have various levels of sophistication and integration, which complicates adoption of new specifications.
Few existing innovative programs and projects are relevant to transactional data specifications.	→	Limited ability to learn from other successful projects.
Pilot programs with TNCs raise the importance of common transactional data specifications.	→	DRT services risk creating "walled gardens" of proprietary systems that do not communicate with each other.

Table B-2. Benefits and challenges of common data specifications.

Benefit	Challenge
+ Reduced operating costs	- Business rules vary widely
+ Facilitate data sharing	- Lack of incentives to standardize
+ Increased flexibility in DRT services	- Costs of switching specifications
+ Increased availability in passenger apps	- Privacy concerns for healthcare data
	- Mis-specification of future standards

Industry Advisory Panel Quarterly Meetings

The second activity of the industry advisory panel was participation in six meetings held throughout the project period. These meetings took place in the form of conference calls approximately once each quarter to allow the industry panel members to receive updates on the research and to provide suggestions for development of the specification. All panelists were invited to participate, and in some cases two calls were scheduled for the same presentation to increase attendance. For all meetings, attendance was less than the full panel. Contemporaneous notes and recordings provide records of each discussion.

The six industry advisory panel meetings took place on the following dates:

- Meeting 1 April 18 and 21, 2017
- Meeting 2 June 2 and 6, 2017
- Meeting 3 October 18 and 20, 2017
- Meeting 4 December 4, 2017
- Meeting 5 May 17, 2018
- Meeting 6 August 20, 2018

For each meeting, the project team presented an overview of progress made and solicited direct feedback about specific issues. Most of the issues brought up in the panel meetings mirrored what was discussed in the interviews, which were summarized in the previous section. What the panel meetings highlighted beyond what was covered in the interviews was the issue of how to manage future specifications and what might a governance structure look like.

The content of the quarterly meetings progressed concurrent with the project. Meetings held earlier were focused on helping the project team understand the DRT market and what elements were required of transactional data specifications. In the middle and later parts of the project, meetings focused on feedback of draft transactional data specifications developed by the project team and a discussion of potential models of governance for managing the specification after completion of this project. The following list provides a brief description of the meeting topics.

- *Meeting 1*
  This meeting was used to introduce the project to the industry advisory panel. Much of the meeting was a presentation by the project team describing an existing example of DRT transactional data standards used in Scandinavia known as SUTI and discussing their applicability to transactional data specifications in the U.S. context.

- *Meeting 2*
  This meeting covered some of the issues crucial for the successful development and implementation of a DRT data specification. This included specifications used in other countries (e.g., SUTI), and essential versus optional components of the specification ("must have" versus "nice to have"). The research team also queried members of the industry advisory panel on the challenges with their previous attempts at integration. There was a wide range of perspectives—particularly the level of effort and different objectives of public and private operators.

- *Meetings 3–6*
  In each of these meetings, the research team presented updated approaches to the DRT transactional data specifications to the industry advisory panel. The research team then incorporated comments from industry panel members into the specifications. In Meeting 5, the research team presented the full draft of the proposed data specifications. In Meeting 6, the final specifications were summarized, and a key topic identified for continued discussion was governance of the specification, which is the focus of the following section. Appendix C includes the presentation provided to the industry panel members at the final meeting (#6), which summarizes many key aspects of this project.

Governance of the Specification

As mentioned in the previous section, a key issue that came out of the industry panel meetings was the appropriate entity to manage the DRT data specifications moving forward. Governance of the transactional specifications was widely viewed as critical for the short- and long-term successful adoption and use. Based on the industry advisory panel interviews and quarterly meetings, eight possible models of governance were identified. The research team and industry advisory panel discussed the pros and cons of each potential governance model at length; however, there was no consensus as to the best approach. These models are listed in Table B-3 and described in the following paragraphs.

Table B-3. Potential models for governance of the specification.

Number	Description
Model 1	Federal Government Mandates Specification
Model 2	International Organization Manages Specification
Model 3	One or More Large Local Agencies Agree On Specification
Model 4	Large Company Puts Forth Specification
Model 5	Professional Organization Manages Specification
Model 6	University Research Center Manages Specification
Model 7	Consortium of Private-Sector Players Agree on Specification
Model 8	Develop and Manage Specification as Open Source Project

- *Model 1: Federal Government Mandates Specification*
  Some interviewees suggested that the federal government might need to mandate a specification for it to be widely adopted. The specific agency that was mentioned by numerous interviewees was the FTA; however, there were some concerns about a government-mandated approach.

- *Model 2: International Organization Manages Specification*
  Another model that was suggested was having an international organization or collaboration manage the data specification. One technology provider noted that many of its clients are international, and there would be benefits of coordinating this effort beyond the United States.

- *Model 3: One or More Large Local Agencies Agree on Specification*
  Multiple interviewees suggested that collaboration among a few large public agencies could result in a means of managing a future specification for demand-responsive transactional data. For example, one technology provider suggested that a few large public agencies (such as the transit agencies that serve New York, Los Angeles, and Chicago) could come together to make a standard happen; then, they could release RFPs requesting that vendors use the standard. An interviewee from a transit agency suggested that a few innovative transit agencies work together and agree on a specification. However, it could be challenging to coordinate across cities.

- *Model 4: Large Company Puts Forth Specification*
  Numerous interviewees mentioned the example of Google and GTFS, which was a case in which a large company worked with a public agency to create a de facto standard. However, interviewees were not able to suggest a company that is sufficiently large in the demand-

responsive transportation industry to develop a standard and convince a large part of the market to adopt it.

- *Model 5: Professional Organization Manages Specification*
  Many interviewees suggested that either APTA or CTAA would be an appropriate forum for managing a specification for transactional data. One interviewee from a transit agency favorably recommended APTA because the organization is well known in the industry. They would likely be able to convince their board that using a common specification is worthwhile if APTA is backing it. On the other hand, some private-sector players were skeptical of the role that APTA or CTAA could play due to a lack of technical expertise.

- *Model 6: University Research Center Manages Specification*
  At least one interviewee mentioned involving a university research center in the process of developing and maintaining the data specification. One possibility may be the Center for Urban Transportation Research (CUTR) at the University of South Florida. However, this would likely require a dedicated funding source.

- *Model 7: Consortium of Private-Sector Players Agree on Specification*
  Another model that was mentioned by several interviewees was gathering a consortium comprised of predominantly private-sector players. This could follow the model of the GTFS Best Practices Working Group that was recently convened; this effort was funded by the Rocky Mountain Institute, which is encouraging interoperable data standards.

- *Model 8: Develop and Manage Specification as Open Source Project*
  A final model that was mentioned by interviewees was an open source project. For example, one technology company cited the example of Android and Google. This could be in combination with another model or separate from the previously mentioned methods of managing the specification.

Conclusions from Industry Advisory Panel Involvement

In summary, engaging a panel of industry experts was a key component of this research project. Through individual interviews and regular online meetings, the research team was able to glean more nuanced knowledge of the issues at hand and began to work toward initial consensus on a common specification for transactional data. Overall, the industry advisory panel saw many benefits to having a common data specification in the demand-responsive transportation industry. Key challenges and concerns varied from organization to organization, yet there was generally broad support for this initiative.

Given the input and ideas from the industry advisory panel, the research team next sought to investigate “lessons learned” from other data specifications implemented in the transportation industry to help guide this effort toward a meaningful and implementable specification; these examples are the focus of Chapter 3.

Interview Protocol

The protocol is for semi-structured interviews by phone, with each interview taking approximately 45 minutes. Two TCRP project team members participated in each interview, one to ask questions and one to focus on taking notes. With permission, we audio recorded the interviews for accuracy. These recordings will not be published in any way or shared outside of the project team. Responses will be used to inform TCRP project reports and academic journal articles. Responses will not be tied to individuals. Rather, responses will be attributed to industry affiliations (e.g., technology providers, transportation service providers, public agencies, etc.). We assured each interviewee that participation in these interviews was voluntary and would not affect participation in the Advisory Board activities moving forward.

The semi-structured interviews focused on the following four topics:

Current State of Practice

Please describe your organization's current method for demand-responsive transactions (in as much detail as you feel comfortable sharing).

- Probe for knowledge of current industry practice for interoperable data (e.g., GTFS-Flex).
- What current or potential DRT projects is your firm working on, including use of APIs?
- Description of any actual experiences with data sharing and/or data transactions with other organizations in process of delivering service—probe for obstacles, issues, outcomes of any such experiences.

Potential Future Specification

- How does your organization envision a DRT transactional specification evolving in the future?
- Who would they expect to lead this initiative (what type of organization and/or specific organization)?
- What would they expect would be the scope of the specification?
- Can you describe this future specification or the process that would be needed to create it?
- What would you anticipate that the specification would look like?

Advantages

- What are the advantages for your organization of adopting a widely used specification?
- What are the perceived disadvantages, if any, of adopting a specification?
- What are the needs of your organization vis-à-vis any such specification? Probe for specific areas or examples.

- Probe about specific topics: operational advantages, options for using multiple service providers, ridership increases, etc.

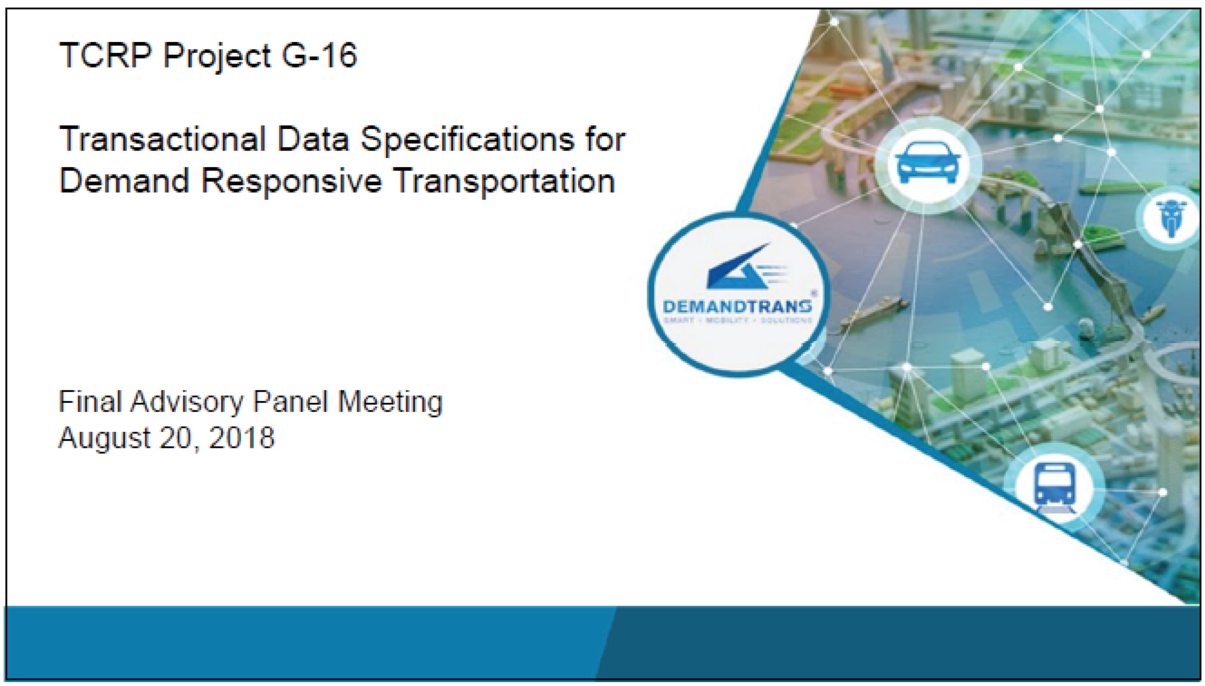
Challenges

What are the challenges for your organization of adopting a transactional data specification?

APPENDIX C

Industry Advisory Panel Final Meeting Presentation

The following slides were presented to the industry advisory panel during the last meeting of the project, which took place in August 2018. This presentation summarizes key project activities and highlights important next steps toward advancing a common specification for transactional data in the DRT industry.



Key Project Objectives

- Develop set of specifications that are functionally complete and will support most likely transaction scenarios
- Develop feasible approach to technical implementation of specifications in action (i.e., how they are actualized in data communication flows)
- Engage key sector participants—technology providers, transportation service providers, public transportation/taxi/TNC industries, planning consultants—in process of specification development and dissemination
- Devise approaches—including governance suggestions—to move proposed specifications towards implementation by sector participants

Challenges to Achieving Project Objectives

- No existing industry forum for specification process
- Diverse set of actors—technology companies, public agencies, private contractors, taxi companies, TNCs, consultants, etc.
- Lack of any prior organizational structure or convening process, contrast to GTFS process
- Lack of any dominant industry player that encompasses entire sector
- Difficult role for government as standards organizer in American system
- Multiple technology paths forward
- Can a recommended specification catalyze forward motion?

Challenges: Diverse Set of Actors

- Technology companies—DRT booking/scheduling, taxi dispatching, in-vehicle systems, etc.
- Public transit agencies
- Private transportation contractors—ADA paratransit, small city DRT, NEMT, human service transportation are all target markets
- Taxi companies—large variation in capabilities
- TNCs—Uber, Lyft, Via, others
- Consultants—advisors to cities, transit agencies
- Think tanks—"public service" orientation

Challenges: Authority Structures Limited

- Federal government needs justification to intervene, no compelling reason in this situation
- States play limited role in local transportation, mostly funding
- Local governments have no mandate to reach beyond jurisdictional bounds
- Standards are almost always set by industry groups or dominant players in an industry sector
- Government standards are usually prescriptive, not detailed (e.g., CAFE)
- Swedish government role in SUTI situation has limited foundation in USA

Challenges: Catalyzing Action via a Project

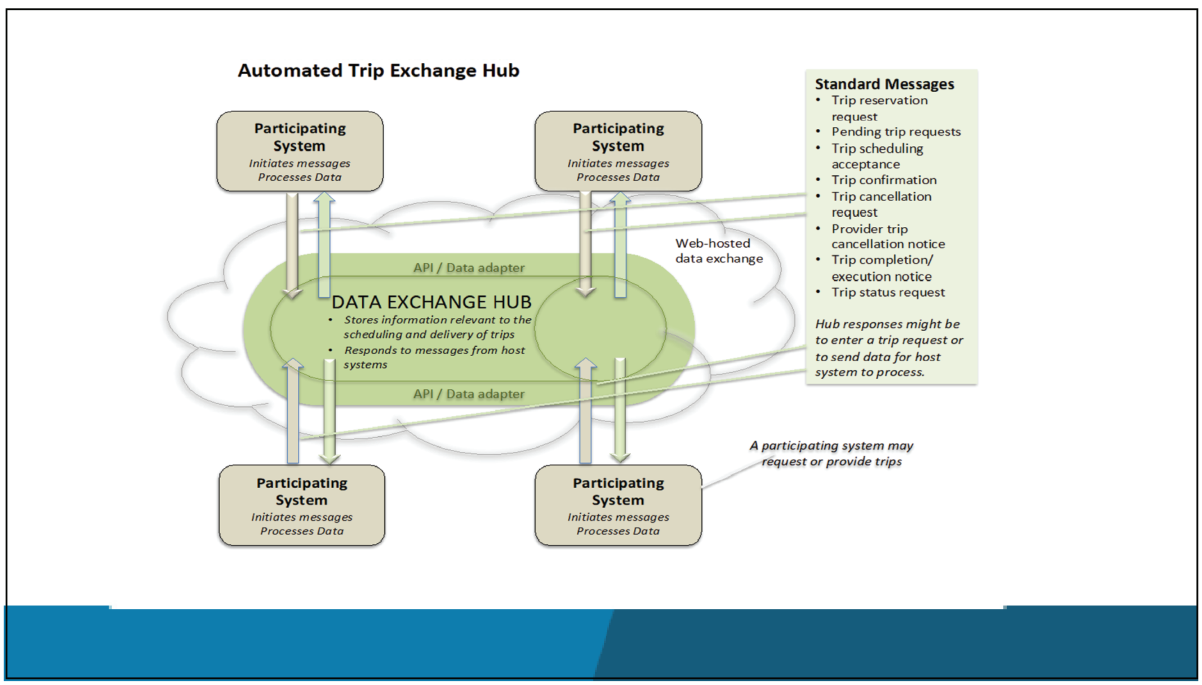
- Can recommended specification catalyze action in sector with a diversity of actors with overlapping but different interests?
- Why would market leaders want to standardize data and facilitate transactions?
- Cross-platform transactions? Cross-provider transactions? Cross-funding source transactions? Which is most important motivator?
- Will public agencies pick up these specifications and make them requirements in RFPs? What would cause this to occur?

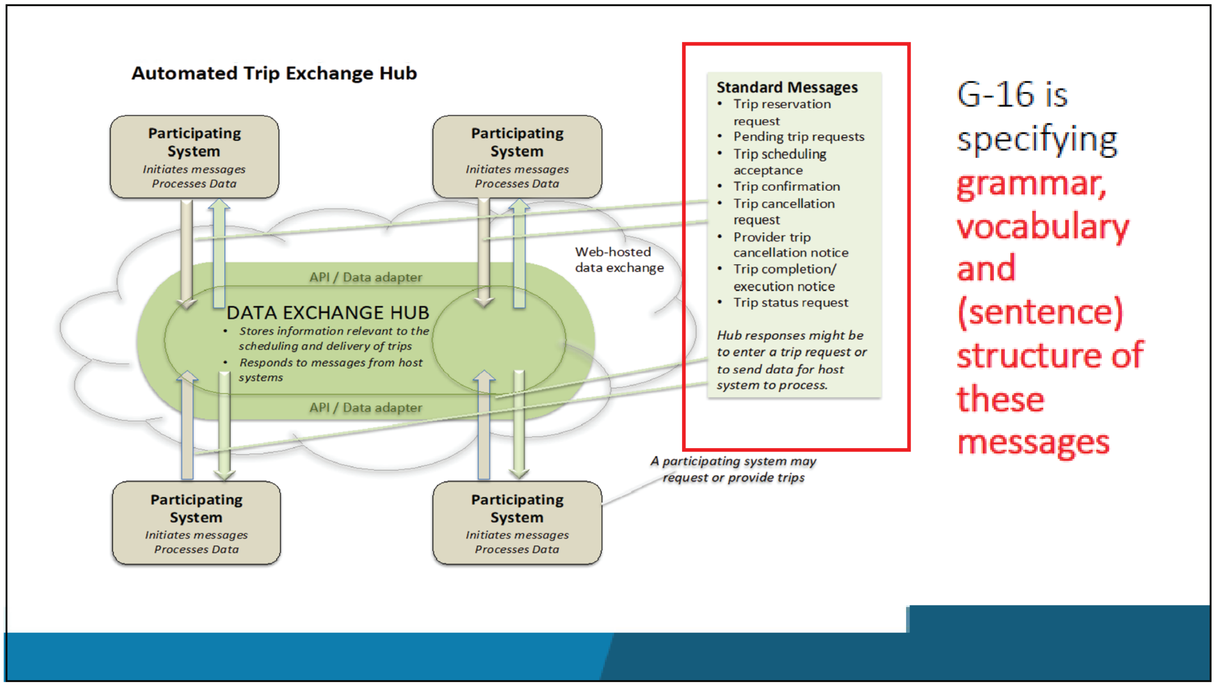
Despite challenges, there are

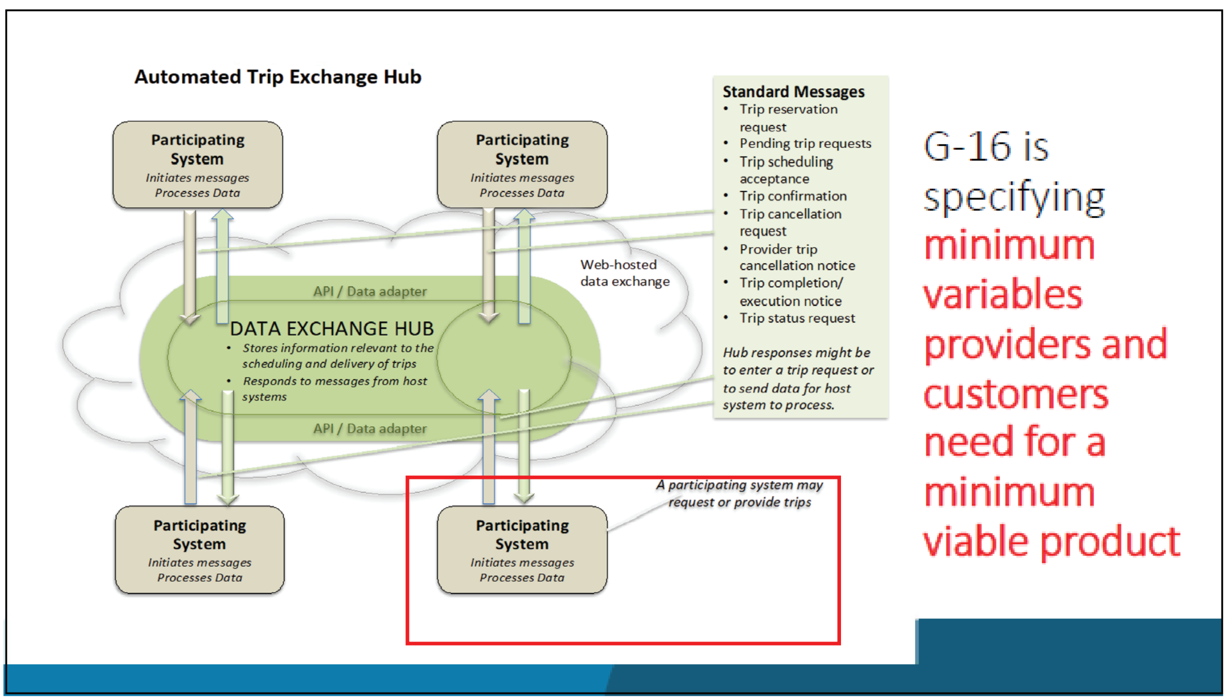
Opportunities

What Specifications Can Lead To: Trip Exchanges

- Specifications can support bi-lateral or multi-lateral "commerce"
- Trip Exchange is a scheme that enables transactions among multiple transportation seekers and providers
- Trip requests can be matched to suitable available capacity
- End result is transactions between willing parties and exchange of funds in return for trip delivery
- Specifications are essential for Trip Exchange to function
- Trip Exchanges not essential, bilateral transactions work too




Automated Trip Exchange Hub
Participating System
Initiates messages
Processes Data
Participating System
Initiates messages
Processes Data
API / Data adapter
DATA EXCHANGE HUB
Stores information relevant to the scheduling and delivery of trips
Responds to messages from host systems
API / Data adapter
Web-hosted data exchange
Participating System
Initiates messages
Processes Data
Participating System
Initiates messages
Processes Data
A participating system may request or provide trips
Standard Messages
Trip reservation request
Pending trip requests
Trip scheduling acceptance
Trip confirmation
Trip cancellation request
Provider trip cancellation notice
Trip completion/ execution notice
Trip status request
Hub responses might be to enter a trip request or to send data for host system to process.
G-16 is specifying grammar, vocabulary and (sentence) structure of these messages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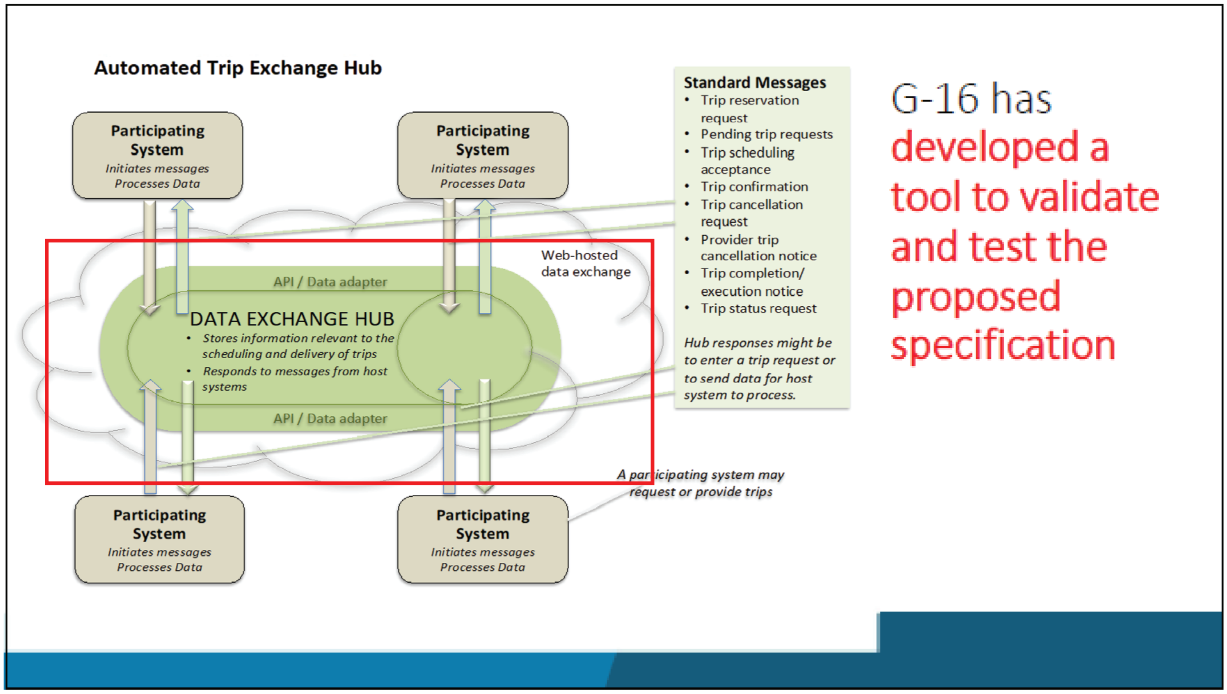
Trip cancellation request
Provider trip cancellation notice
Trip completion/ execution notice
Trip status request
Hub responses might be to enter a trip request or to send data for host system to process.
G-16 is specifying minimum variables providers and customers need for a minimum viable product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Trip scheduling acceptance
Trip confirmation
Trip cancellation request
Provider trip cancellation notice
Trip completion/ execution notice
Trip status request
Hub responses might be to enter a trip request or to send data for host system to process.
G-16 has developed a tool to validate and test the proposed specification


DEMANDTRANS
A key challenge that has been identified is
Governance

Governance Questions Remain …

- Who should manage the transactional specification?
- How to finance the specification?
- How to participate as a service provider?
- Why will organizations want to participate?

Possible Models for Governance

1. The federal government mandates a specification.
2. An internal organization manages the specification.
3. One or more large local agencies agree on a specification.
4. A large company puts forth a specification.
5. A professional organization (e.g., APTA) manages the specification.
6. A university research center manages the specification.
7. A consortium of different parties (e.g., private companies) agree on a specification.
8. The specification is developed as an open source project.

No existing industry/sector forum

- No industry group for standards or specifications
- APTA and TLPA have never initiated or led such efforts
- Specifications are typically set by:
  - Historical precedence
  - Software provider preferences
- No equivalent (or even close) to the Internet Engineering Task Force (IETF)

Lack of any dominant player that encompasses entire sector

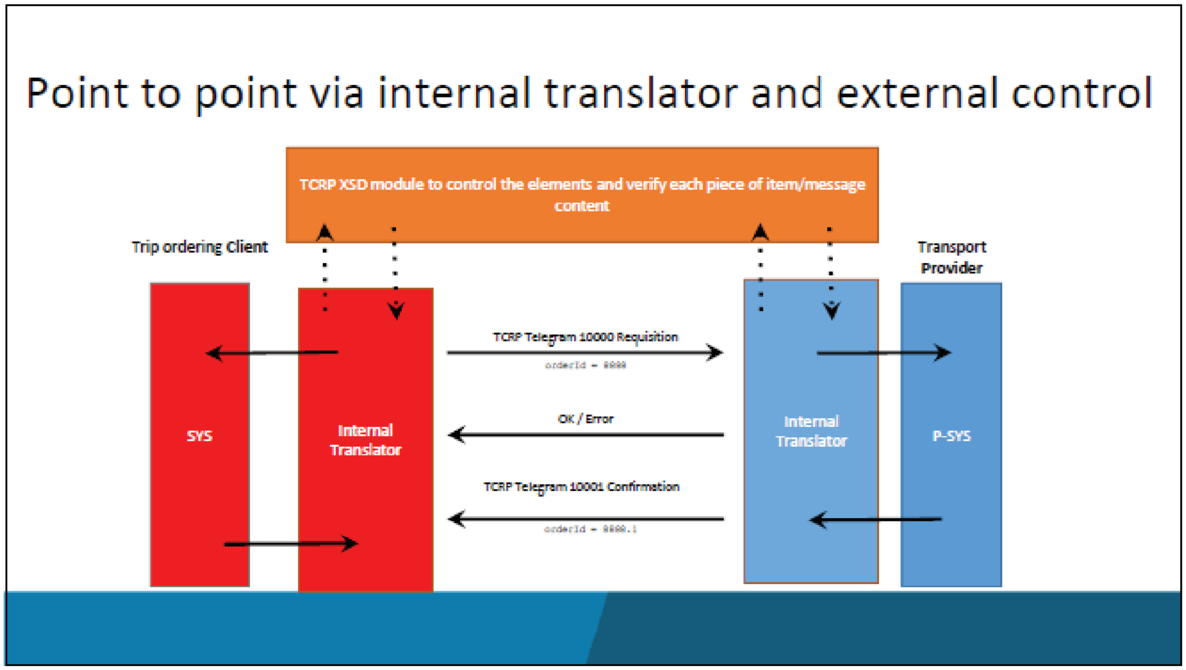
- The demand response industry is fragmented
- Small number of large software providers, many small-medium companies
- Small number of major private transportation providers
- Many diverse public agencies of all sizes
- New development—service organizers (TNCs, new generation technology companies)—with different focus and aims, often with large resources
- Service providers (clients of technology companies) offer local service
- Software providers serve client interests
- Often means doing things the way they have always been done

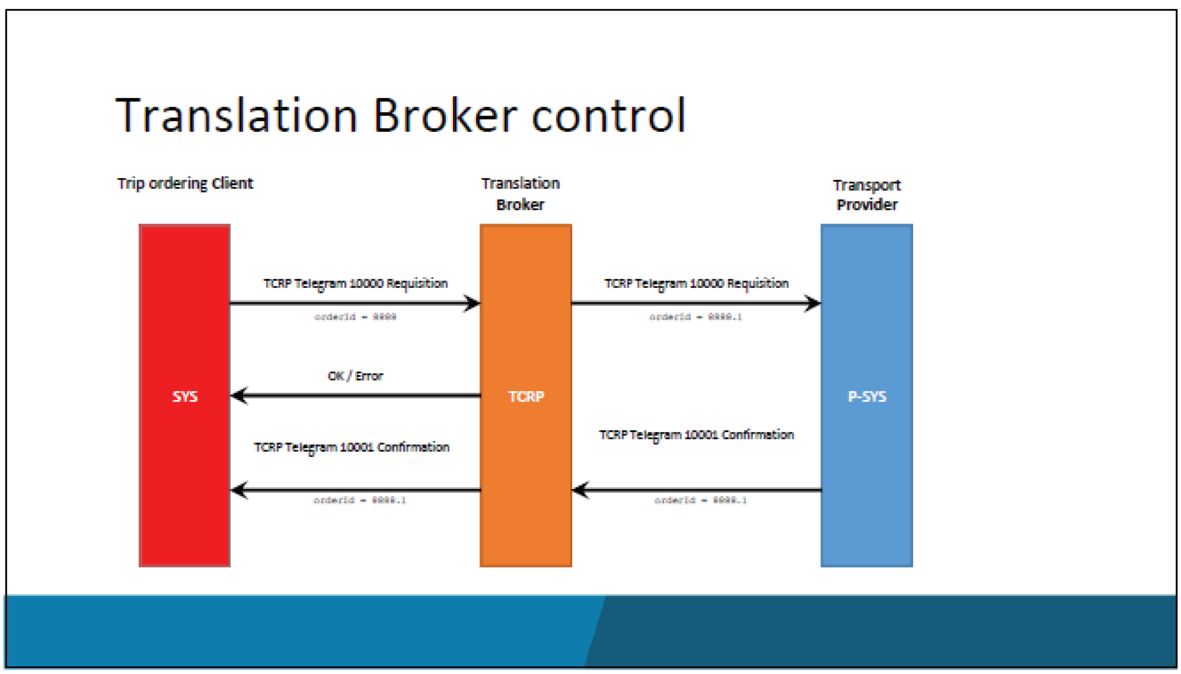
The Technical Aspects of Specifications

Multiple Possible Technology Paths Forward

2 different potential logical set-ups for data communication:

- Internal translator with external validation
- Translation Broker
- G-16 team has recommended first approach
- Can be implemented without major additional resources or creation of formal governance structure
- But not as technically contemporary as translation broker, and more work for software providers


Point to point via internal translator and external control
TCRP XSD module to control the elements and verify each piece of item/message content
Trip ordering Client
Transport Provider
SYS
Internal Translator
TCRP Telegram 10000 Requisition
OK / Error
TCRP Telegram 10001 Confirmation
Internal Translator
P-SYS


Translation Broker control
Trip ordering Client
Translation Broker
Transport Provider
SYS
TCRP Telegram 10000 Requisition
OK / Error
TCRP Telegram 10001 Confirmation
TCRP
TCRP Telegram 10000 Requisition
TCRP Telegram 10001 Confirmation
P-SYS

Trade-Offs Between Preferred Approaches

- Technical preferences
  - Point to point data communication is inherent in any scheme, including brokerage
  - How spec adherence is managed as part of data flow is the issue
  - Simple, single point of control is typically preferred by software providers
  - Minimization of initial and on-going efforts to achieve spec compliance is important
- Contemporary practice
  - API-centric approaches are common
  - "Open" APIs are needed for broad eco-systems of participants (Uber as example)
  - Controls still apply, but based on willingness to agree to rules of the game

Trade-Offs Between Preferred Approaches

- Telegram approach is somewhat dated
  - Imposes dialog model on system to system interactions
  - API-based approaches typically have looser request-response paradigms, albeit with certain mandated requirements to accomplish actual transaction
- Burden on software providers
  - Internal translation/external validation approach requires software providers to implement both message structures and data mappings to spec requirements
  - SUTI has 71 telegram messages, G-16 has opted for less than 20 to reduce burden
  - Translation broker approach requires messaging functionality for software vendor, but broker software can handle data translations and other functions

Trade-Offs Between Preferred Approaches

- **Resource requirements and governance considerations**
  - Internal translation/external validation approach can be implemented with little additional work by spec "governors" and on case by case basis
  - Software providers would need to create new modules for their systems that do work of internal translation—not a trivial effort
  - Translation broker approach is more compatible with current technical preferences
  - BUT ….. Requires significant additional resources to develop APIs and backend functionality that implements translation for arbitrary software systems
  - AND ….. Requires sector-approved governance structure to ensure that key participants are in alignment with details of technical approach

What's Next?

- Recommend Requiring Specifications in Future Agency Procurements
- Track Actual Adoption of Recommended Specifications:
  - Transit Agencies
  - Software Vendors
  - Other Transportation Operators (TNC, Taxi, Transit Contractors)
- Identify/Confirm Organization to Oversee Specification Management/Modification

APPENDIX D

Detailed Specification Description

This appendix presents the proposed specification for demand-responsive transportation transactional data. A brief introduction to the overall approach is presented first; this approach centers around the concept of "telegrams," which are messages sent between entities. The remainder of the specification describes each of the individual telegrams in detail. A total of 11 telegrams are proposed. Last, special attributes of passengers that may be applicable in some cases and additional items that may be needed for reporting purposes are described.

Approach

The proposed transactional data specification is organized around "messages" (and specifically, a set of agreed upon "message types") and "data elements". Messages can be of many message types, with each type designed to perform a specific function with respect to the transmission and/or exchange of data among interoperating parties. For example, there may be a message type to send a trip request to another transportation system and another message type to send a trip to a driver application running on a device in a vehicle.

Message types and their corresponding data elements can be referred to as ***"telegrams."*** These telegrams will be interchanged by entities participating in transactions. Figure D-1 shows the steps for demand-responsive transportation transactions from left to right in the figure. The entities involved in this transaction include the rider, the organization taking the order, the entity doing route planning, the vehicle performing the order, and the payer or funding entity.

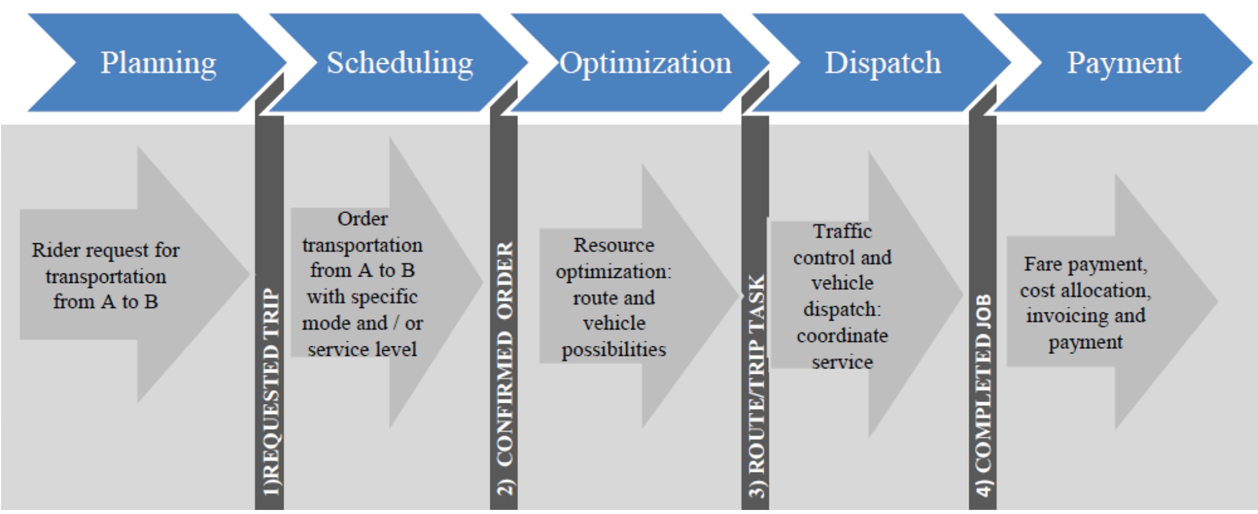


Figure D-1. Steps for a DRT trip from ordering to completion and payment.

Each time information crosses a line in Figure D-1, a telegram must be sent containing the data necessary to advance the transaction to the next step. Since some telegrams confirm the receipt of information, this means the transactional flow is not necessarily one-directional as Figure D-1 would suggest (from planning through completion and payment); exchange of information can go in both directions. The telegrams that follow in the next section represent the bi-directional information needed for requesting and confirming activities among the entities.

The telegrams describe each step in the process of ordering and executing a trip as in Figure D-1. There are many data elements that could be included in this process, but many of the data fields may not apply to different customer types or in different situations. For this reason, the telegrams define a set of potential data items, most of which are not mandatory; it is the decision of each provider and ordering client to determine which data elements are essential in their system.

For example, a typical transportation network company (TNC) customer orders a trip by indicating their origin, destination, number of passengers, and desired level of service. It is also possible to indicate a future pickup time. In contrast, a nonemergency medical transportation (NEMT) service provider needs to know information regarding special needs and mobility aids to send the appropriate vehicle and driver. Thus, trips being sent to a TNC provider need not contain the same level of detail as a trip being sent to an NEMT provider. By extension, some NEMT providers may require more or less information about a customer, and some customers may need to convey more or less information. These decisions could be left up to the groups establishing business rules for interaction on one or more clearinghouses; the goal of this project is to establish the language these groups use to communicate with one another.

The processes in Figure D-1 can in turn be described in terms of functional needs or requirements, as shown in Figure D-2.

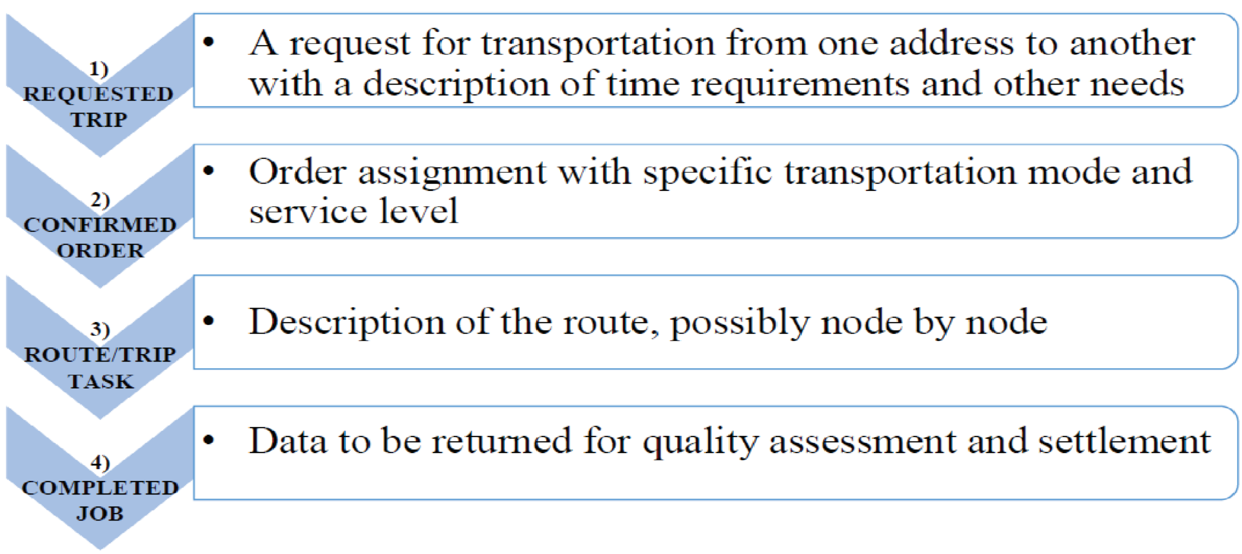


Figure D-2. Functional needs for a DRT trip use case.

The functional needs are specified in terms of data elements that describe a specific situation, as in Figure D-3. The collective set of functional processes involved and the data describing each process define the DRT trip use case.

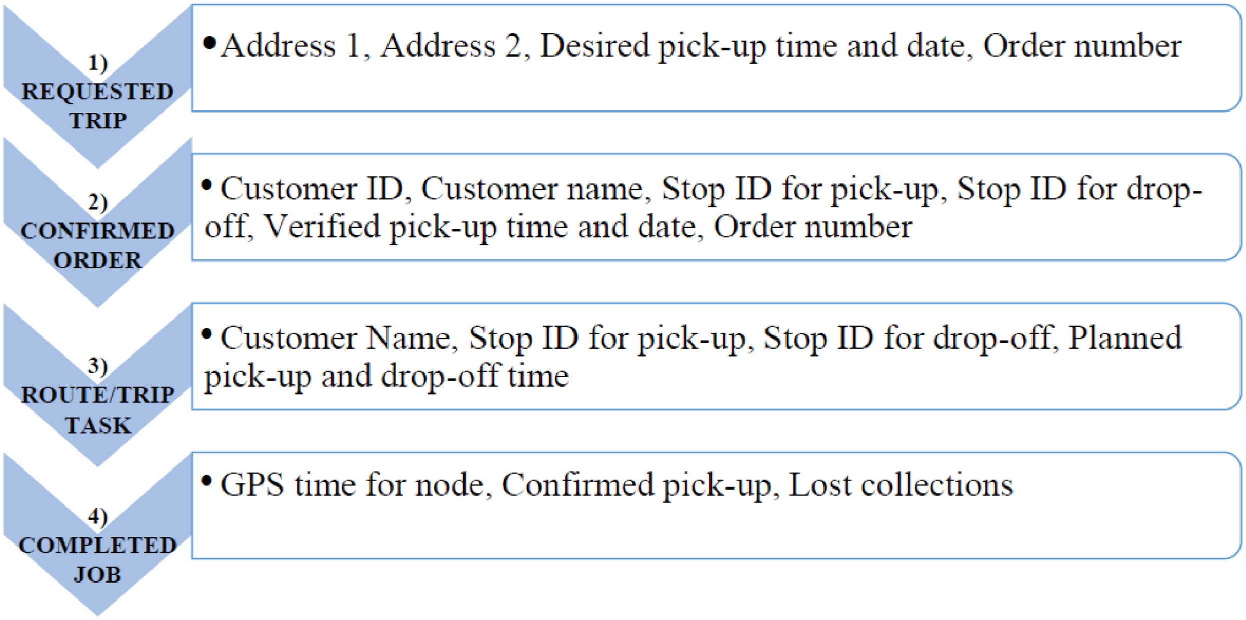


Figure D-3. Data needs for a DRT trip use case.

For each use case in which the specification is employed, the interacting computer systems will use the telegrams to communicate the data that informs each system of what the other system is requesting or offering. The telegrams described in the following sections enable the computer systems to move through the transactional steps shown in Figure D-1 where some steps require a transaction to take place between the trip ordering client and transportation service providing entity while others might be messages communicated between the provider database and the vehicle's mobile data terminal or similar in-vehicle device that hosts the application that directs the driver's activities for delivering service to the rider.

Flow of Telegrams

The process of ordering and completing a DRT trip is separated into 11 unique telegrams (numbered as Telegram 1A to Telegram 5). Figure D-4 illustrates the flow of telegrams between the ordering client, provider and vehicle that would be necessary to complete a transaction. In the following section, each telegram is explained on a separate page with the variables listed in a table, beginning with Telegram 1A to request a trip.

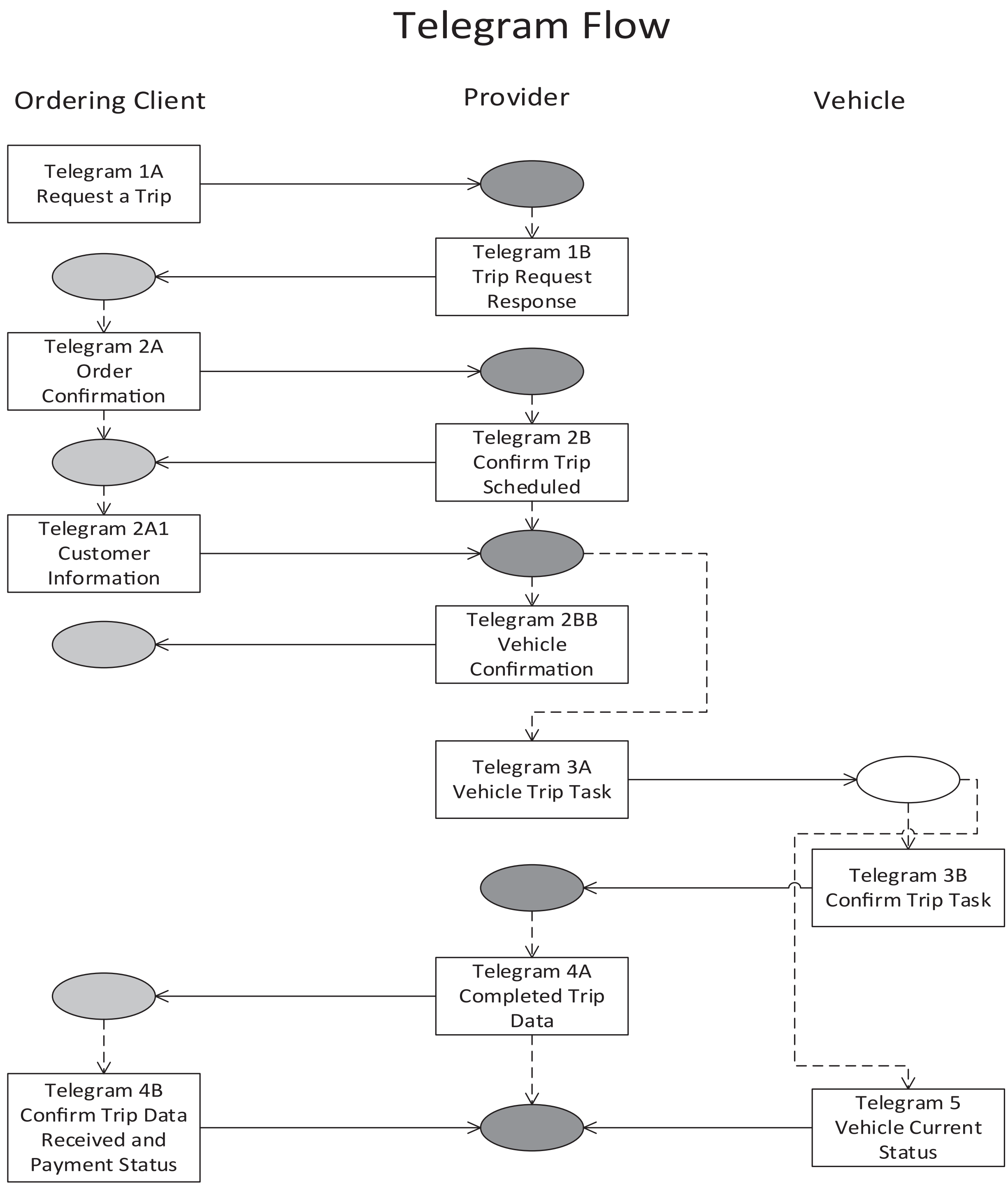


Figure D-4. Telegram flow.

Telegram 1:A – Request a Trip

The first step in most transactions is to request a trip. The trip could be requested directly by the customer, or it might be requested by an organization on their behalf (such as a human service agency or healthcare provider). A trip request is described by the data elements in Telegram 1:A, which is shown in Table D-1. Depending on the customer needs, more or less variables would be considered. For all telegrams, a YES or NO in the "mandatory" column indicates whether this is the minimum variable required to conduct a transaction in general. Specific entities (ordering clients or providers) could require additional variables to be considered a valid message to transact with their specific service/clients.

Table D-1. Telegram 1:A – Request a Trip

Telegram 1:A	REQUISITION - Requested trip		
From:	Ordering client		
To:	Provider(s)		
Purpose:	Query for trip availability		
XSD Complex Type Name:	tripRequest		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Pick up address		YES	Location/geocode
Drop-off address		YES	Location/geocode
Pick up time		YES or next	Time
Appointment time	A medical or other appointment time	NO	Time
Drop-off time	Intended drop-off time	NO	Time
End of pick up window		NO	Time
Start of pick up window		NO	Time
Permissible detours		NO	Factor/binary
Negotiated pick up time	The zero of the time window that both customer and provider agreed upon	NO	Time
Hard constraint on drop-off	Yes/no if the customer must be dropped off at the requested drop-off time	NO	Binary
Hard constraint on pick up	Yes/no if the customer must be picked up at the requested pick up time	NO	Binary
Special attribute	List of special attributes	NO	List
Transport services	List of Transport service to test	NO	Local List
Open attribute	Local use	NO	Local List

Telegram 1:B – Trip Request/Response

The second step is to confirm the trip. The next telegram is the trip request/response or acknowledgment that would be sent from a provider to the ordering client to confirm that the provider can fulfill the needs requested in Telegram 1:A. This is called Telegram 1:B and it can include any number of responses from a provider if they have multiple trip options available that fulfill the needs described in the request Telegram 1:A. The data elements of Telegram 1:B are shown in Table D-2.

Table D-2. Telegram 1:B – Trip Request/Response

Telegram 1:B	CONFIRMATION - options - Requested trip		
From:	Provider		
To:	Ordering client		
Purpose:	List of trip options - 1 to many reply on Telegram 1:A		
XSD Complex Type Name:	tripRequestResponse		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Confirmation of trips availability		Yes	Binary
Scheduled pickup time		NO	Time
Scheduled Pick up point		YES	Location/geocode
Scheduled Drop-off point		YES	Location/geocode
Transfer zones/points	Coordination	NO	Location/geocode
Fare type	cash, credit card, Travelcard	NO	List
Fare amount		NO	Numeric
Transport services	Transport service	NO	Local List

Telegram 2:A – Order Confirmation

The next step is that the client system confirms the trip and sends a trip ticket ID. The ordering client sends Telegram 2:A to the chosen provider or providers to confirm additional details for the selected trip. This telegram could include additional information related to constraints on the time window and detailed information about pickup and drop-off location. The data elements of Telegram 2:A are shown in Table D-3.

Table D-3. Telegram 2:A – Order Confirmation

Telegram 2:A	REQUISITION - confirm order		
From:	Ordering client		
To:	Provider(s)		
Purpose:	Order confirmation		
XSD Complex Type Name:	clientOrderConfirmation		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Trip ticket	Unique ID from Ordering client	YES	String
Pick up address		YES	Location/geocode
Drop-off address		YES	Location/geocode
Pick up time		YES or next	Time
Appointment time	Medical/other appointment time	NO	Time
Drop-off time	Intended drop-off time	NO	Time
End of pick up window		NO	Time
Start of pick up window		NO	Time
Permissible detours		NO	Factor/binary
Negotiated pick up time	Zero of time window agreed to	NO	Time
Hard constraint on drop-off		NO	Binary
Hard constraint on pick up		NO	Binary
Detailed drop-off location description		NO	Long text
Detailed pick up location description		NO	Long text
Funding entity	Funding ID	YES	Local list
Customer key	Customer ID	NO	String
Customer name		YES	String
Customer mobile phone		NO	Numeric
Customer location in drop-off sequence		NO	Number
Number of other reserved passengers		NO	Numeric
Fare type		NO	String
Fare amount		NO	Numeric
Trip Purpose		NO	List--Trip Purpose

Telegram 2:A:1 – Customer Information

The next, nonmandatory step is that the ordering client provides additional details about the customer's trip. This is basically the same functionality as Telegram 2:A, but with customer information added so the provider can update the customer's information in their system. The ordering client may need to send even more detailed information about the customer to the provider if there are special considerations. This would be sent as a follow-up message only for cases where it applies as Telegram 2:A:1, and much of this information would need to be communicated to the driver at the appropriate time to execute the trip. The data elements of Telegram 2:A:1 are shown in Table D-4.

Table D-4. Telegram 2:A:1 – Customer Information

Telegram 2:A:1	REQUISITION Customer data - confirm order		
From:	Ordering client		
To:	Provider(s)		
Purpose:	Customer info for trip		
XSD Complex Type Name:	customerInfo		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Customer key	Customer ID	NO	String
Customer name		NO	String
Customer home address		NO	Location/geocode
Customer home phone		NO	Numeric
Billing address (customer)		NO	Location/geocode
Billing information (funding entity)		NO	String
Funding type	Indicators for different billing groups (e.g., Medicaid)	NO	String
Gender		NO	Factor
Caregiver's contact information		NO	String
Customer's emergency phone number		NO	Numeric
Customer's emergency contact name		NO	String
Comment about care required (hands-off)		NO	Long text - to call center
Date of birth/Age		NO	Date
Fare type		NO	Factor
Other (free field)	Customer: Service Needs	NO	Long text – for driver

Telegram 2:B – Confirm Trip Scheduled

The next step is confirmation of the order details. Regardless of whether the ordering client sends information in Telegram 2:A:1, the provider needs to confirm information contained in Telegram 2:A. This response is Telegram 2:B, which confirms the scheduled pickup and drop-off information, fare information, and vehicle information. The data elements of Telegram 2:B are shown in Table D-5.

Table D-5. Telegram 2:B – Confirm Trip Scheduled

Telegram 2:B	CONFIRMATION - confirm order		
From:	Provider		
To:	Ordering client		
Purpose:	Confirm trip is scheduled		
XSD Complex Type Name:	providerOrderConfirmation		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Trip ticket	Unique ID from Ordering client	YES	String
Scheduled pickup time		YES	Time
Scheduled pickup point		YES	Location/geocode
Scheduled drop-off point		YES	Location/geocode
Transfer zones/points	Coordination	NO	Location/geocode
Fare type	cash, credit card, travelcard	NO	List
Fare amount		NO	Numeric
Transport services	Transport service	NO	Local List
Vehicle number		NO	String or Local List
Driver ID		NO	String or Local List
Vehicle information		NO	String or Local List

Telegram 2:BB – Vehicle Confirmation

If special needs were communicated in Telegram 2:A:1, the next step is to confirm those special needs. For the special needs that could have been communicated in Telegram 2:A:1, Telegram 2:BB is the appropriate response confirming the features of the provider (vehicle and driver) that will be sent for this customer. This includes a description of the vehicle that will be sent to the ordering client. The data elements of Telegram 2:BB are shown in Table D-6.

Table D-6. Telegram 2:BB – Vehicle Confirmation

Telegram 2:BB	CONFIRMATION - Vehicle information - confirm order		
From:	Provider		
To:	Ordering client		
Purpose:	Confirm vehicle		
XSD Complex Type Name:	vehicleConfirmation		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Vehicle number		NO	String
Driver ID		NO	String
Vehicle information		NO	String
Availability for service		NO	Time
Fuel range		NO	Numeric
Ambulatory space points		NO	Numeric
Large/full wheelchair space points		NO	Numeric
Ramp present		NO	Binary
Lift present		NO	Binary
Standard/manual wheelchair space points		NO	Numeric
Luggage/cargo space points		NO	Numeric
Vehicle ID		NO	Numeric
Vehicle model		NO	Factor/string
Conversion factor for ambulatory points to standard wheelchair points (specific to model)		NO	Numeric
Conversion for ambulatory points to large wheelchair points (specific to model)		NO	Numeric
Flat floor		NO	Factor
Owner		NO	String/factor
Ride quality/vibration		NO	Factor

Telegram 3:A – Vehicle Trip Task

At this point, the provider has confirmed that the trip will take place to the ordering client. This trip now needs to be dispatched. Therefore, the next step is to send the trip information to the vehicle. This message, Telegram 3:A, is what the transportation service provider would send to the specific vehicle (driver) at the appropriate time in advance of the trip so that the driver has all information needed to perform the trip at the required level of service. The data elements of Telegram 3:A are shown in Table D-7.

Table D-7. Telegram 3:A – Vehicle Trip Task

Telegram 3:A	REQUISITION - Route/trip task		
From:	Provider		
To:	Vehicle		
Purpose:	Control Vehicle		
XSD Complex Type Name:	tripTask		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Trip ticket	Unique ID from Ordering client	YES	String
Trip/route Task ticket	Unique ID from Provider	YES	String
Customer Pickup location in vehicle performance sequence		YES	Numeric
Pickup Node address/geocode		YES	Address
Pickup Node scheduled time		YES	Time
Pickup Location detailed description		NO	Long text
Customer Drop-Off location in vehicle performance sequence		YES	Numeric
Drop-Off Node address/geocode		YES	Address
Drop-Off Node scheduled time		NO	Time
Drop-Off Location detailed description		NO	Long text
Customer mobile phone		NO	Numeric
Customer name		YES	String
Other (free field)	Customer: Service Needs	NO	Long text - for driver
Special attribute	List of special attributes at end of document	NO	List
Number of other reserved passengers		NO	Numeric
Fare type	cash, credit card, Travelcard	NO	List
Fare amount		NO	Numeric

Telegram 3:B – Confirm Trip Task

The next step is for the transportation service provider to confirm that the trip has been delivered. In response to Telegram 3:A, the transportation service provider's vehicle application (that is, the in-vehicle device and software that receives orders and displays the trip manifest) sends a return confirmation once the trip has been completed in the form of Telegram 3:B. The data elements of Telegram 3:B are shown in Table D-8.

Table D-8. Telegram 3:B - Confirm Trip Task

Telegram 3:B	CONFIRMATION - Route/trip task		
From:	Vehicle		
To:	Provider		
Purpose:	Vehicle performance		
XSD Complex Type Name:	tripTaskConfirmation		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Trip ticket	Unique ID from Ordering client	YES	String
Trip/route Task ticket	Unique ID from Provider	YES	String
Customer drop-off location in vehicle performance sequence		YES	Numeric
Node performed time		YES	Time
Trip status	Performed, No show, no pickup	YES	List
Vehicle number		YES	String or local list
Driver ID		NO	String or local list

Telegram 4:A – Completed Trip Data

The next step is that the transportation service provider sends trip information to the ordering client. As soon as the service provider receives Telegram 3:B from the vehicle indicating the trip was completed, the provider can send information pertaining to the completed order to the initial ordering client as Telegram 4:A. The data elements of Telegram 4:A are shown in Table D-9.

Table D-9. Telegram 4:A – Completed Trip Data

Telegram 4:A	REQUISITION – Completed job		
From:	Provider(s)		
To:	Ordering client		
Purpose:	Performed trip data		
XSD Complex Type Name:	tripTaskCompletion		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Trip ticket	Unique ID from Ordering client	YES	String
Cost	Ordering client payment	YES	Numeric
Pick up address		NO	Location/geocode
Pick up time		YES	Time
Drop-off address		NO	Location/geocode
Drop-off time		YES	Time
Scheduled pickup point		NO	Location/geocode
Scheduled pickup time		NO	Time
Scheduled drop-off point		NO	Location/geocode
Scheduled drop-off time		NO	Time
Performed pickup point		NO	Location/geocode
Performed pickup time		NO	Time
Performed drop-off point		NO	Location/geocode
Performed drop-off time		NO	Time
Permissible detours		NO	Time
Transfer zones/points	Coordination	NO	Location/geocode
Fare type	cash, credit card, Travelcard	NO	List
Fare amount	Rider payment	NO	Numeric
Transport services	Transport service	NO	Local List
Special attribute	List of special attributes	NO	List

Telegram 4:B – Confirm Trip Data Received and Payment Status

The next step is that the ordering client confirms receipt of completed trip details. The ordering client then confirms that the details of the completed trip were received for that trip ticket and whether the payment was completed (the ordering client pays the provider) in Telegram 4:B. The data elements of Telegram 4:B are shown in Table D-10.

Table D-10. Telegram 4:B – Confirm Trip Data Received and Payment Status

Telegram 4:B	CONFIRMATION - Completed job		
From:	Provider		
To:	Ordering client		
Purpose:	Confirm trip data received		
XSD Complex Type Name:	tripScheduledConfirmation		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Trip ticket	Unique ID from Ordering client	YES	String
Data Received		YES	Binary
Payment Rejected		NO	Binary

Telegram 5 – Vehicle Current Status

The final, optional step is that the information is sent from the vehicle to the provider for reporting purposes. Finally, the specifications could define a telegram whereby the vehicle sends information to the service provider in order to record information that may be useful for reporting in Telegram 5. The data elements of Telegram 5 are shown in Table D-11.

Table D-11. Telegram 5 – Vehicle Current Status

Telegram 5:	INFO		
From:	Vehicle		
To:	Provider		
Purpose:	GPS and trips status		
XSD Complex Type Name:	tripTaskStatus		
Data Elements:	**Explanation**	**Mandatory**	**Field Type**
Vehicle number		YES	String
GPS		YES	Geocode
Timecode		YES	Time
Driver ID		NO	String
Driver hours	current value	NO	Float
Odometer readings	current value	NO	Float
Passenger miles	current value	NO	Float
Vehicle hours	current value	NO	Float
Vehicle miles	current value	NO	Float
Boardings and alightings at trip ends		NO	String
Other fleet variables		NO	String
Trip/route Task ticket	Unique ID from Provider	NO	String

Customer Attributes

Many of the telegrams in the proposed specification listed a "Special Attribute" for the customer. A list of potential special attributes is detailed below in Table D-12. These attributes would be key to evaluating what sort of vehicle is needed and whether the trip requires a driver with special training (or requires that the driver be cognizant of any special needs before pickup and while performing the trip). These special attributes could have key codes to translate among different platforms as needed.

Table D-12. Special Attributes

Code	Meaning	Category
A	Ambulatory	Mobility Aid
AL	Ambulatory lift	Mobility Aid
C	Cane	Mobility Aid
CU	Crutches	Mobility Aid
D2D	Door to door	Service Needs
DA	Driver Alert	Service Needs
DTD	Door through door	Service Needs
E	Electric wheelchair	Mobility Aid
HIP	hearing impaired	Service Needs
IDD	intellectually or developmentally disabled	Service Needs
MH	Mental health	Service Needs
MIP	Dementia (memory impaired)	Service Needs
NDD	Neurologic and degenerative diseases	Service Needs
NLA	Never leave alone/no leave alone	Service Needs
O	Oxygen	Service Needs
S	Scooter	Mobility Aid
SA	Service Animal	Service Needs
SD	Seizure disorder	Service Needs
SI	Speech impaired	Service Needs
TD	Temporary Disability	Service Needs
U	Unstable needs assistance	Service Needs
VIP	Vision impaired	Service Needs
W	Wheelchair	Mobility Aid
WA	Walker	Mobility Aid
WAK	Knee walker	Mobility Aid
WE	Extended leg w/c = Extended Leg Wheelchair	Mobility Aid
WT	Wheelchair, can transfer	Mobility Aid
WW	Wide wheelchair	Mobility Aid

Reporting Trip Purpose

Finally, it may be necessary in some cases to report the trip purpose for various reimbursement rules or human service agency reporting needs. Trip purpose codes are given in Table D-13.

Table D-13. Trip Purpose Codes

Purpose Code	Meaning
A	Adult Day Program
D	Dialysis
E	Employment
G	Grocery
HR	Health related (includes dentist, pharmacy, etc.)
M	Medical
P	Personal
R	Recreation
T	Public transit

APPENDIX E

XML Listing of Specification

The specification is presented in XML, which is commonly referred to as a “markup” language. A markup language is a computer language that uses **tags** to define elements within a document. It is human-readable, meaning markup files contain standard words, rather than typical programming syntax. XML is the acronym for "E**X**tensible **M**arkup **L**anguage" since custom tags can be used to support a wide range of elements.

An XML “document” is comprised of a series of data elements that are typically comprised of other data elements. These data elements are embedded and nested in the structure of each data element, which has a name and a type. Each element begins with a **“<”** and ends with a “/>”, which are the **tags,** and has a **name,** which follows the “/>” tag. By reading the information between the tags, it is usually relatively easy to understand each data element. Each specific data element also has a **“type,”** which can be something simple like a string (a series of characters) or an integer. A data type can be specifically defined for a situation such as “addressType.” The latter may have multiple elements itself and will be defined elsewhere in the specific XML document (as with this one at the end of the XML listing) or in a standard reference document that all XML messages can use for more complex but standard data types such as “time”.

The XML for each telegram in the proposed specification is shown below. It begins with a listing of the telegrams and provides the type name of each, followed by a complete listing for each specific telegram beginning with Telegram #1A. There is a blank line between the telegrams. The XML listing can be “deciphered” relatively easily by knowing how the data is structured.

```
<?xml version="1.0" encoding="utf-8"?>
<xsd:schema xmlns:tcrp="http://www.tcrp.gov/schema"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified">

  <xsd:element name="tripRequest" type="tripRequestType"/>
  <xsd:element name="tripRequestResponse" type="tripRequestResponseType"/>
  <xsd:element name="clientOrderConfirmation" type="clientOrderConfirmationType"/>
  <xsd:element name="customerInfo" type="customerInfoType"/>
  <xsd:element name="providerOrderConfirmation" type="providerOrderConfirmationType"/>
  <xsd:element name="vehicleConfirmation" type="vehicleConfirmationType"/>
  <xsd:element name="tripTask" type="tripTaskType"/>
```

```
  <xsd:element name="tripTaskConfirmation" type="tripTaskConfirmationType"/>
  <xsd:element name="tripTaskCompletion" type="tripTaskCompletionType"/>
  <xsd:element name="tripScheduledConfirmation" type="tripScheduledConfirmationType"/>
  <xsd:element name="tripTaskStatus" type="tripTaskStatusType"/>
  <xsd:complexType name="tripRequestType"> [This is the first telegram]
  <xsd:annotation>
  <xsd:documentation>Telegram #: 1A; From: ordering client; To: trip provider(s); Purpose:
query for trip availability</xsd:documentation>
  </xsd:annotation>
  <xsd:sequence>
  <xsd:element name="pickupAddress" type="addressType"></xsd:element>
  <xsd:element name="dropoffAddress" type="addressType"/>
  <xsd:element name="pickupTime" type="time"/>
  <xsd:element name="appointmentTime" type="time" minOccurs="0"/>
  <xsd:element name="dropoffTime" type="time" minOccurs="0"/>
  <xsd:element name="pickupWindowStartTime" type="time" minOccurs="0"/>
  <xsd:element name="pickupWindowEndTime" type="time" minOccurs="0"/>
  <xsd:element name="detoursPermissible" type="xsd:boolean" minOccurs="0"/>
  <xsd:element name="negotiatedPickupTime" type="time" minOccurs="0"/>
  <xsd:element name="hardConstraintOnPickupTime" type="xsd:boolean" minOccurs="0"/>
  <xsd:element name="hardConstraintOnDropoffTime" type="xsd:boolean" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="specialAttributes" type="specialAttributesList" use="optional"/>
  <xsd:attribute name="transportServices" type="valueList" use="optional"/>
  <xsd:attribute name="openAttribute" type="xsd:string" use="optional">
  <xsd:annotation>
  <xsd:documentation>open attribute for local use</xsd:documentation>
  </xsd:annotation>
  </xsd:attribute>
  </xsd:complexType>

  <xsd:complexType name="tripRequestResponseType">
  <xsd:annotation>
  <xsd:documentation>Telegram #: 1B; From: trip provider; To: ordering client; Purpose: reply
to telegram 1A</xsd:documentation>
  </xsd:annotation>
  <xsd:sequence>
  <xsd:element name="tripAvailable" type="xsd:boolean" minOccurs="0"/>
  <xsd:element name="scheduledPickupTime" type="time" minOccurs="0"/>
  <xsd:element name="scheduledPickupPoint" type="addressType" minOccurs="0"/>
  <xsd:element name="scheduledDropoffPoint" type="addressType" minOccurs="0"/>
  <xsd:element name="transferPoint" type="addressType" minOccurs="0"/>
  </xsd:sequence>
  <xsd:attribute name="paymentTypeList" use="optional"/>
  <xsd:attribute name="fareAmount" type="xsd:float" use="optional"/>
  <xsd:attribute name="transportServices" type="valueList" use="optional"/>
  </xsd:complexType>
```

```
 <xsd:complexType name="clientOrderConfirmationType">
 <xsd:annotation>
 <xsd:documentation>Telegram #: 2A; From: ordering client; To: trip provider(s); Purpose:
order confirmation</xsd:documentation>
 </xsd:annotation>
 <xsd:sequence>
 <xsd:element name="tripTicketId" type="xsd:string">
 <xsd:annotation>
 <xsd:documentation>unique ID from ordering client</xsd:documentation>
 </xsd:annotation>
 </xsd:element>
 <xsd:element name="pickupAddress" type="addressType"/>
 <xsd:element name="dropoffAddress" type="addressType"/>
 <xsd:element name="pickupTime" type="time"/>
 <xsd:element name="appointmentTime" type="time" minOccurs="0"/>
 <xsd:element name="dropoffTime" type="time" minOccurs="0"/>
 <xsd:element name="pickupWindowStartTime" type="time" minOccurs="0"/>
 <xsd:element name="pickupWindowEndTime" type="time" minOccurs="0"/>
 <xsd:element name="detoursPermissible" type="xsd:boolean" minOccurs="0"/>
 <xsd:element name="negotiatedPickupTime" type="time" minOccurs="0"/>
 <xsd:element name="hardConstraintOnPickupTime" type="xsd:boolean" minOccurs="0"/>
 <xsd:element name="hardConstraintOnDropoffTime" type="xsd:boolean" minOccurs="0"/>
 <xsd:element name="detailedDropoffLocationDescription" type="xsd:string" minOccurs="0"/>
 <xsd:element name="detailedPickupLocationDescription" type="xsd:string" minOccurs="0"/>
 <xsd:element name="customerName" type="xsd:string" />
 <xsd:element name="customerMobilePhone" type="xsd:integer" minOccurs="0"/>
 <xsd:element name="customerLocInDropoffSequence" type="xsd:positiveInteger"
minOccurs="0"/>
 <xsd:element name="numOtherReservedPassengers" type="xsd:integer" minOccurs="0"/>
 <xsd:element name="fundingEntityId" type="xsd:string"/>
 </xsd:sequence>
 <xsd:attribute name="customerId" type="xsd:string" use="optional"/>
 <xsd:attribute name="paymentType" type="paymentTypeList" use="optional"/>
 <xsd:attribute name="fareAmount" type="xsd:float" use="optional"/>
 <xsd:attribute name="tripPurpose" type="tripPurposeList" use="optional"/>
 </xsd:complexType>

 <xsd:complexType name="customerInfoType">
 <xsd:annotation>
 <xsd:documentation>Telegram #: 2A1; From: ordering client; To: trip provider(s); Purpose:
customer info for trip</xsd:documentation>
 </xsd:annotation>
 <xsd:sequence>
 <xsd:element name="customerName" type="xsd:string" minOccurs="0"/>
 <xsd:element name="customerAddress" type="addressType" minOccurs="0"/>
 <xsd:element name="customerPhone" type="xsd:integer" minOccurs="0"/>
 <xsd:element name="customerMobilePhone" type="xsd:integer" minOccurs="0"/>
 <xsd:element name="customerBillingAddress" type="addressType" minOccurs="0"/>
```

```
<xsd:element name="fundingEntityBillingInformation" type="xsd:string" minOccurs="0"/>
<xsd:element name="fundingType" type="xsd:boolean" minOccurs="0"/>
<xsd:element name="gender" type="xsd:string" minOccurs="0"/>
<xsd:element name="caregiverContactInformation" type="xsd:string" minOccurs="0"/>
<xsd:element name="customerEmergencyPhoneNumber" type="xsd:integer" minOccurs="0"/>
<xsd:element name="customerEmergencyContactName" type="xsd:string" minOccurs="0"/>
<xsd:element name="requiredCareComments" type="xsd:string" minOccurs="0"/>
<xsd:element name="dateOfBirth" type="xsd:date" minOccurs="0"/>
<xsd:element name="customerId" type="xsd:string" minOccurs="0"/>
<xsd:element name="paymentType" type="paymentTypeList" minOccurs="0"/>
<xsd:element name="notesForDriver" type="xsd:string" minOccurs="0"/>
</xsd:sequence>
</xsd:complexType>

<xsd:complexType name="providerOrderConfirmationType">
<xsd:annotation>
<xsd:documentation>Telegram #: 2B; From: trip provider; To: ordering client; Purpose:
confirm trip is scheduled</xsd:documentation>
</xsd:annotation>
<xsd:sequence>
<xsd:element name="tripTicketId" type="xsd:string">
<xsd:annotation>
<xsd:documentation>unique ID from ordering client</xsd:documentation>
</xsd:annotation>
</xsd:element>
<xsd:element name="scheduledPickupTime" type="time"/>
<xsd:element name="scheduledPickupPoint" type="addressType"/>
<xsd:element name="scheduledDropoffPoint" type="addressType"/>
<xsd:element name="transferPoint" type="addressType" minOccurs="0"/>
</xsd:sequence>
<xsd:attribute name="paymentType" type="paymentTypeList" use="optional"/>
<xsd:attribute name="fareAmount" type="xsd:float" use="optional"/>
<xsd:attribute name="transportServices" type="valueList" use="optional"/>
<xsd:attribute name="vehicleNumber" type="xsd:string" use="optional"/>
<xsd:attribute name="driverId" type="xsd:string" use="optional"/>
<xsd:attribute name="vehicleInformation" type="xsd:string" use="optional"/>
</xsd:complexType>

<xsd:complexType name="vehicleConfirmationType">
<xsd:annotation>
<xsd:documentation>Telegram #: 2BB; From: trip provider; To: ordering client; Purpose:
confirm vehicle</xsd:documentation>
</xsd:annotation>
<xsd:sequence>
<xsd:element name="vehicleNumber" type="xsd:string" minOccurs="0"/>
<xsd:element name="driverId" type="xsd:string" minOccurs="0"/>
```

```
 <xsd:element name="vehicleInformation" type="xsd:string" minOccurs="0"/>
 <xsd:element name="availabilityForService" type="time" minOccurs="0"/>
 </xsd:sequence>
 <xsd:attribute name="fuelRange" type="xsd:float" use="optional"/>
 <xsd:attribute name="ambulatorySpacePoints" type="xsd:integer" use="optional"/>
 <xsd:attribute name="largeWheelchairSpacePoints" type="xsd:integer" use="optional"/>
 <xsd:attribute name="hasRamp" type="xsd:boolean" use="optional"/>
 <xsd:attribute name="hasLift" type="xsd:boolean" use="optional"/>
 <xsd:attribute name="standardWheelchairSpacePoints" type="xsd:integer" use="optional"/>
 <xsd:attribute name="cargoSpacePoints" type="xsd:integer" use="optional"/>
 <xsd:attribute name="vehicleId" type="xsd:integer" use="optional"/>
 <xsd:attribute name="vehicleModel" type="xsd:string" use="optional"/>
 <xsd:attribute name="conversionFactorForAmbulatoryPointsToStandardWheelchairPoints"
type="xsd:float" use="optional"/>
 <xsd:attribute name="conversionFactorForAmbulatoryPointsToLargeWheelchairPoints"
type="xsd:float" use="optional"/>
 <xsd:attribute name="flatFloor" type="xsd:string" use="optional"/>
 <xsd:attribute name="owner" type="xsd:string" use="optional"/>
 <xsd:attribute name="rideVibrationQuality" type="xsd:string" use="optional"/>
 </xsd:complexType>

 <xsd:complexType name="tripTaskType">
 <xsd:annotation>
 <xsd:documentation>Telegram #: 3A; From: trip provider; To: vehicle; Purpose: control
vehicle</xsd:documentation>
 </xsd:annotation>
 <xsd:sequence>
 <xsd:element name="tripTaskId" type="xsd:string">
 <xsd:annotation>
 <xsd:documentation>unique ID from provider</xsd:documentation>
 </xsd:annotation>
 </xsd:element>
 <xsd:element name="tripTicketId" type="xsd:string">
 <xsd:annotation>
 <xsd:documentation>unique ID from ordering client</xsd:documentation>
 </xsd:annotation>
 </xsd:element>
 <xsd:element name="customerPickupLocInVehPerformanceSequence"
type="xsd:positiveInteger"/>
 <xsd:element name="pickupNodeAddress" type="addressType"/>
 <xsd:element name="pickupNodeScheduledTime" type="time"/>
 <xsd:element name="detailedPickupLocationDescription" type="xsd:string" minOccurs="0"/>
 <xsd:element name="customerDropoffLocInVehPerformanceSequence"
type="xsd:positiveInteger"/>
 <xsd:element name="dropoffNodeAddress" type="addressType"/>
 <xsd:element name="dropoffNodeScheduledTime" type="time"/>
```

```
<xsd:element name="detailedDropoffLocationDescription" type="xsd:string" minOccurs="0"/>
<xsd:element name="customerMobilePhone" type="xsd:integer" minOccurs="0"/>
<xsd:element name="customerName" type="xsd:string"/>
<xsd:element name="numOtherReservedPassengers" type="xsd:integer" minOccurs="0"/>
</xsd:sequence>
<xsd:attribute name="notesForDriver" type="xsd:string" use="optional">
<xsd:annotation>
<xsd:documentation>Free-form long text field for notes to driver concerning customer service
needs</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
<xsd:attribute name="specialAttributes" type="specialAttributesList" use="optional"/>
<xsd:attribute name="paymentType" type="paymentTypeList" use="optional"/>
<xsd:attribute name="fareAmount" type="xsd:float" use="optional"/>
</xsd:complexType>

<xsd:complexType name="tripTaskConfirmationType">
<xsd:annotation>
<xsd:documentation>Telegram #: 3B; From: vehicle; To: trip provider; Purpose: confirm
vehicle performed task</xsd:documentation>
</xsd:annotation>
<xsd:sequence>
<xsd:element name="tripTaskId" type="xsd:string">
<xsd:annotation>
<xsd:documentation>unique ID from provider</xsd:documentation>
</xsd:annotation>
</xsd:element>
<xsd:element name="tripTicketId" type="xsd:string">
<xsd:annotation>
<xsd:documentation>unique ID from ordering client</xsd:documentation>
</xsd:annotation>
</xsd:element>
<xsd:element name="customerLocInDropoffSequence" type="xsd:positiveInteger"/>
<xsd:element name="nodePerformedTime" type="time"/>
<xsd:element name="vehicleNumber" type="xsd:string"/>
</xsd:sequence>
<xsd:attribute name="tripStatus" use="required">
<xsd:simpleType>
<xsd:restriction base="xsd:string">
<xsd:enumeration value="performed"/>
<xsd:enumeration value="no show"/>
<xsd:enumeration value="no pickup"/>
</xsd:restriction>
</xsd:simpleType>
</xsd:attribute>
<xsd:attribute name="driverId" type="xsd:string" use="optional"/>
```

```
</xsd:complexType>

<xsd:complexType name="tripTaskCompletionType">
<xsd:annotation>
<xsd:documentation>Telegram #: 4A; From: trip provider(s); To: ordering client; Purpose:
performed trip data</xsd:documentation>
</xsd:annotation>
<xsd:sequence>
<xsd:element name="tripTicketId" type="xsd:string">
<xsd:annotation>
<xsd:documentation>unique ID from ordering client</xsd:documentation>
</xsd:annotation>
</xsd:element>
<xsd:element name="cost" type="xsd:float"/>
<xsd:element name="pickupAddress" type="addressType" minOccurs="0"/>
<xsd:element name="pickupTime" type="time"/>
<xsd:element name="dropoffAddress" type="addressType" minOccurs="0"/>
<xsd:element name="dropoffTime" type="time"/>
<xsd:element name="scheduledPickupPoint" type="addressType" minOccurs="0"/>
<xsd:element name="scheduledPickupTime" type="time" minOccurs="0"/>
<xsd:element name="scheduledDropoffPoint" type="addressType" minOccurs="0"/>
<xsd:element name="scheduledDropoffTime" type="time" minOccurs="0"/>
<xsd:element name="performedPickupPoint" type="addressType" minOccurs="0"/>
<xsd:element name="performedPickupTime" type="time" minOccurs="0"/>
<xsd:element name="performedDropoffPoint" type="addressType" minOccurs="0"/>
<xsd:element name="performedDropoffTime" type="time" minOccurs="0"/>
<xsd:element name="detoursPermissible" type="xsd:boolean" minOccurs="0"/>
<xsd:element name="transferPoint" type="addressType" minOccurs="0"/>
</xsd:sequence>
<xsd:attribute name="paymentType" type="paymentTypeList" use="optional"/>
<xsd:attribute name="fareAmount" type="xsd:float" use="optional"/>
<xsd:attribute name="specialAttributes" type="specialAttributesList" use="optional"/>
<xsd:attribute name="transportServices" type="valueList" use="optional"/>
</xsd:complexType>

<xsd:complexType name="tripScheduledConfirmationType">
<xsd:annotation>
<xsd:documentation>Telegram #: 4B; From: trip provider; To: ordering client; Purpose:
confirm trip is scheduled for vehicle</xsd:documentation>
</xsd:annotation>
<xsd:sequence>
<xsd:element name="tripTicketId" type="xsd:string">
<xsd:annotation>
<xsd:documentation>unique ID from ordering client</xsd:documentation>
</xsd:annotation>
</xsd:element>
```

```
<xsd:element name="dataReceived" type="xsd:boolean"/>
</xsd:sequence>
<xsd:attribute name="paymentRejected" type="xsd:boolean" use="optional"/>
</xsd:complexType>

<xsd:complexType name="tripTaskStatusType">
<xsd:annotation>
<xsd:documentation>Telegram #: 5; From: vehicle; To: trip provider; Purpose: GPS and trip
status</xsd:documentation>
</xsd:annotation>
<xsd:sequence>
<xsd:element name="vehicleNumber" type="xsd:string"/>
<xsd:element name="GPS" type="geographicLocation"/>
<xsd:element name="timecode" type="time"/>
<xsd:element name="driverId" type="xsd:string" minOccurs="0"/>
<xsd:element name="tripTaskId" type="xsd:string" minOccurs="0">
<xsd:annotation>
<xsd:documentation>unique ID from provider</xsd:documentation>
</xsd:annotation>
</xsd:element>
</xsd:sequence>
<xsd:attribute name="driverHours" type="xsd:float" use="optional">
<xsd:annotation>
<xsd:documentation>current value</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
<xsd:attribute name="odometerReading" type="xsd:float" use="optional">
<xsd:annotation>
<xsd:documentation>current value</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
<xsd:attribute name="passengerMiles" type="xsd:float" use="optional">
<xsd:annotation>
<xsd:documentation>current value</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
<xsd:attribute name="vehicleHours" type="xsd:float" use="optional">
<xsd:annotation>
<xsd:documentation>current value</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
<xsd:attribute name="vehicleMiles" type="xsd:float" use="optional">
<xsd:annotation>
<xsd:documentation>current value</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
```

```
<xsd:attribute name="boardingsAndAlightingsAtTripEnd" type="xsd:string" use="optional"/>
<xsd:attribute name="otherFleetVariables" type="xsd:string" use="optional"/>
</xsd:complexType>
```


XML Data Types


```
<xsd:complexType name="addressType">
<xsd:annotation>
<xsd:documentation>The address known to receiving system</xsd:documentation>
</xsd:annotation>
<xsd:sequence>
<xsd:element name="manualDescriptionAddress" type="manualDescriptionType"
minOccurs="0" maxOccurs="unbounded"/>
<xsd:element name="geographicLocation" type="geographicLocation" minOccurs="0"/>
<xsd:element name="idAddressName" type="idType" minOccurs="0"/>
<xsd:element name="idStreet" minOccurs="0">
<xsd:complexType mixed="false">
<xsd:complexContent>
<xsd:extension base="idType"/>
</xsd:complexContent>
</xsd:complexType>
</xsd:element>
<xsd:element name="idPostalCode" type="idType" minOccurs="0"/>
<xsd:element name="idCommunity" type="idType" minOccurs="0"/>
<xsd:element name="idCountry" type="idType" minOccurs="0">
<xsd:annotation>
<xsd:documentation>Id identifying Country. Source (src) shall refer to ISO 3166-
1</xsd:documentation>
</xsd:annotation>
</xsd:element>
<xsd:element name="idZone" type="idType" minOccurs="0" maxOccurs="unbounded">
<xsd:annotation>
<xsd:documentation>Id of a used Zone or zoneset. Source (src) shall refer to either a general
zone defined between sender and receiver or to a zoneset used by one or both of the
systems.</xsd:documentation>
</xsd:annotation>
</xsd:element>
<xsd:element name="idMap" type="idType" minOccurs="0" maxOccurs="unbounded">
<xsd:annotation>
<xsd:documentation>Used map. Source (src) shall refer to map used</xsd:documentation>
</xsd:annotation>
</xsd:element>
</xsd:sequence>
<xsd:attribute name="addressName" type="xsd:string" use="optional"/>
<xsd:attribute name="street" type="xsd:string" use="optional"/>
<xsd:attribute name="streetNo" type="xsd:positiveInteger" use="optional"/>
```

```
  <xsd:attribute name="streetNoLetter" type="xsd:string" use="optional"/>
  <xsd:attribute name="location" type="xsd:string" use="optional"/>
  <xsd:attribute name="community" type="xsd:string" use="optional"/>
  <xsd:attribute name="postalNo" type="xsd:string" use="optional"/>
  <xsd:attribute name="country" type="xsd:string" use="optional"/>
  <xsd:attribute name="mapPage" type="xsd:string" use="optional"/>
  </xsd:complexType>

  <xsd:complexType name="geographicLocation">
  <xsd:annotation>
  <xsd:documentation>The coordinates for the address and potentially a known
zone</xsd:documentation>
  </xsd:annotation>
  <xsd:sequence>
  <xsd:element name="vehicleDistance" type="vehicleDistance" minOccurs="0"
maxOccurs="unbounded"/>
  </xsd:sequence>
  <xsd:attribute name="zone" type="xsd:string" use="optional"/>
  <xsd:attribute name="typeOfCoordinate" use="required">
  <xsd:annotation>
  <xsd:documentation>Shall be of type WGS84.</xsd:documentation>
  </xsd:annotation>
  <xsd:simpleType>
  <xsd:restriction base="xsd:string">
  <xsd:enumeration value="WGS84"/>
  <xsd:enumeration value="WGS-84"/>
  <xsd:enumeration value="RT90"/>
  </xsd:restriction>
  </xsd:simpleType>
  </xsd:attribute>
  <xsd:attribute name="lat" type="xsd:float" use="required">
  <xsd:annotation>
  <xsd:documentation>See documentation in Use Cases.</xsd:documentation>
  </xsd:annotation>
  </xsd:attribute>
  <xsd:attribute name="long" type="xsd:float" use="required">
  <xsd:annotation>
  <xsd:documentation>See documentation in Use Cases.</xsd:documentation>
  </xsd:annotation>
  </xsd:attribute>
  <xsd:attribute name="precision" type="xsd:integer" use="required">
  <xsd:annotation>
  <xsd:documentation>Precision shall be from GPS-unit in vehicle and measured in meter. This
is the deviation in position measured by the GPS-unit.</xsd:documentation>
  </xsd:annotation>
  </xsd:attribute>
```

```
 <xsd:attribute name="speed" type="xsd:float" use="optional">
 <xsd:annotation>
 <xsd:documentation>Speed shall be from GPS-unit in vehicle and measured in meter per
second.</xsd:documentation>
 </xsd:annotation>
 </xsd:attribute>
 <xsd:attribute name="speedSource" use="optional">
 <xsd:annotation>
 <xsd:documentation>Speed measured at GPS or VEHICLE.</xsd:documentation>
 </xsd:annotation>
 <xsd:simpleType>
 <xsd:restriction base="xsd:string">
 <xsd:enumeration value="gpsunit"/>
 <xsd:enumeration value="taximeter"/>
 </xsd:restriction>
 </xsd:simpleType>
 </xsd:attribute>
 <xsd:attribute name="direction" type="xsd:integer" use="optional">
 <xsd:annotation>
 <xsd:documentation>Direction shall be from GPS-unit in vehicle and measured in degrees (0 -
360 degrees).</xsd:documentation>
 </xsd:annotation>
 </xsd:attribute>
 <xsd:attribute name="height" type="xsd:float" use="optional">
 <xsd:annotation>
 <xsd:documentation>Height shall be from GPS-unit in vehicle and measured in meter. May be
measured in meter with decimals.</xsd:documentation>
 </xsd:annotation>
 </xsd:attribute>
 <xsd:attribute name="deviationSpeed" type="xsd:float" use="optional">
 <xsd:annotation>
 <xsd:documentation>Deviation in speed.</xsd:documentation>
 </xsd:annotation>
 </xsd:attribute>
 </xsd:complexType>
 <xsd:complexType name="time">
 <xsd:annotation>
 <xsd:documentation>Should normally be the local time.</xsd:documentation>
 </xsd:annotation>
 <xsd:attribute name="timeAccuracy" type="xsd:string" use="optional">
 <xsd:annotation>
 <xsd:documentation>Used to indicate accepted deviation in attribute
time</xsd:documentation>
 </xsd:annotation>
 </xsd:attribute>
 <xsd:attribute name="timeZone" type="xsd:integer" use="optional">
```

```
<xsd:annotation>
<xsd:documentation>Timezone used in communication. Default is local timezone. See ISO 8601
for more information.</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
<xsd:attribute name="time" type="xsd:dateTime" use="required" form="unqualified"/>
<xsd:attribute name="dwellTime" type="xsd:int" use="optional">
<xsd:annotation>
<xsd:documentation>Time used to finish this node</xsd:documentation>
</xsd:annotation>
</xsd:attribute>
<xsd:attribute name="timeType" use="optional">
<xsd:annotation>
<xsd:documentation>Type of time. See enumerations</xsd:documentation>
</xsd:annotation>
<xsd:simpleType>
<xsd:restriction base="xsd:string">
<xsd:enumeration value="2101"/>
<xsd:enumeration value="scheduledtime"/>
<xsd:enumeration value="2102"/>
<xsd:enumeration value="estimatedtime"/>
<xsd:enumeration value="2103"/>
<xsd:enumeration value="promisedtime"/>
<xsd:enumeration value="2104"/>
<xsd:enumeration value="actual"/>
<xsd:enumeration value="2105"/>
<xsd:enumeration value="scheduled"/>
<xsd:enumeration value="2107"/>
<xsd:enumeration value="estimated"/>
<xsd:enumeration value="2106"/>
<xsd:enumeration value="promised"/>
<xsd:enumeration value="2108"/>
<xsd:enumeration value="asap"/>
<xsd:enumeration value="estimatedEndtime"/>
<xsd:enumeration value="estimatedStarttime"/>
</xsd:restriction>
</xsd:simpleType>
</xsd:attribute>
</xsd:complexType>

<xsd:simpleType name="paymentTypeList">
<xsd:list>
<xsd:simpleType>
<xsd:restriction base="xsd:string">
<xsd:enumeration value="cash"/>
<xsd:enumeration value="card"/>
```

```
<xsd:enumeration value="account"/>
<xsd:enumeration value="ticket"/>
<xsd:enumeration value="noShow"/>
<xsd:enumeration value="providerCompensation"/>
</xsd:restriction>
</xsd:simpleType>
</xsd:list>
</xsd:simpleType>

<xsd:simpleType name="specialAttributesList">
<xsd:list>
<xsd:simpleType>
<xsd:restriction base="xsd:string">
<xsd:enumeration value="A">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Ambulatory</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="AL">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Ambulatory lift</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="C">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Cane</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="CU">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Crutches</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="D2D">
<xsd:annotation>
<xsd:documentation>Service Needs: Door to door</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="DA">
<xsd:annotation>
<xsd:documentation>Service Needs: Driver Alert</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="DTD">
<xsd:annotation>
<xsd:documentation>Service Needs: Door THROUGH door</xsd:documentation>
```

```
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="E">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Electric wheelchair</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="HIP">
<xsd:annotation>
<xsd:documentation>Service Needs: hearing impaired</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="IDD">
<xsd:annotation>
<xsd:documentation>Medical: intellectually or developmentally disabled</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="KD">
<xsd:annotation>
<xsd:documentation>Medical: Kidney disease</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="MH">
<xsd:annotation>
<xsd:documentation>Medical: Mental health</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="MIP">
<xsd:annotation>
<xsd:documentation>Medical: Dementia (memory impaired)</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="NDD">
<xsd:annotation>
<xsd:documentation>Medical: Neurologic and degenerative diseases</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="NLA">
<xsd:annotation>
<xsd:documentation>Service Needs: Never leave alone/ no leave alone</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="O">
<xsd:annotation>
<xsd:documentation>Service Needs: Oxygen</xsd:documentation>
</xsd:annotation>
```

```
</xsd:enumeration>
<xsd:enumeration value="S">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Scooter</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="SA">
<xsd:annotation>
<xsd:documentation>Service Needs: Service Animal</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="SD">
<xsd:annotation>
<xsd:documentation>Service Needs: Seizure disorder</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="SI">
<xsd:annotation>
<xsd:documentation>Medical: Speech impaired</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="TD">
<xsd:annotation>
<xsd:documentation>Medical: Temporary Disability</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="U">
<xsd:annotation>
<xsd:documentation>Service Needs: Unstable needs assistance</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="VIP">
<xsd:annotation>
<xsd:documentation>Medical: Vision impaired</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="W">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Wheelchair</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="WA">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Walker</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
```

```
<xsd:enumeration value="WAK">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Knee walker</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="WE">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Extended leg w/c = Extended Leg
Wheelchair</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="WT">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Wheelchair, can transfer</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="WW">
<xsd:annotation>
<xsd:documentation>Mobility Aid: Wide wheelchair</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
</xsd:restriction>
</xsd:simpleType>
</xsd:list>
</xsd:simpleType>

<xsd:simpleType name="tripPurposeList">
<xsd:list>
<xsd:simpleType>
<xsd:restriction base="xsd:string">
<xsd:enumeration value="A">
<xsd:annotation>
<xsd:documentation>Adult Day Program</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="D">
<xsd:annotation>
<xsd:documentation>Dialysis</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="E">
<xsd:annotation>
<xsd:documentation>Employment</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="G">
```

```
<xsd:annotation>
<xsd:documentation>Grocery</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="HR">
<xsd:annotation>
<xsd:documentation>Health-Related (includes dentist, pharmacy, etc.)</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="M">
<xsd:annotation>
<xsd:documentation>Medical</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="P">
<xsd:annotation>
<xsd:documentation>Personal</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="R">
<xsd:annotation>
<xsd:documentation>Recreation</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
<xsd:enumeration value="T">
<xsd:annotation>
<xsd:documentation>Public transit</xsd:documentation>
</xsd:annotation>
</xsd:enumeration>
</xsd:restriction>
</xsd:simpleType>
</xsd:list>
</xsd:simpleType>

<xsd:simpleType name="valueList">
<xsd:list itemType="xsd:string"/>
</xsd:simpleType>

<xsd:complexType name="idType">
        <xsd:annotation>
            <xsd:documentation>General type identification-
element</xsd:documentation>
        </xsd:annotation>
        <xsd:attribute name="src" use="required">
            <xsd:simpleType>
                <xsd:restriction base="xsd:string"/>
```

```
                </xsd:simpleType>
            </xsd:attribute>
            <xsd:attribute name="id" use="required">
                <xsd:simpleType>
                    <xsd:restriction base="xsd:string"/>
                </xsd:simpleType>
            </xsd:attribute>
            <xsd:attribute name="unique" type="xsd:boolean" use="optional"
default="true"/>
        </xsd:complexType>

<xsd:complexType name="manualDescriptionType">
            <xsd:annotation>
                <xsd:documentation>Any text aimed for operators, drivers
etc</xsd:documentation>
            </xsd:annotation>
            <xsd:sequence>
                <xsd:element name="idActionText" type="idType" minOccurs="0"/>
                <xsd:element name="textTimestamp" type="time" minOccurs="0"/>
            </xsd:sequence>
            <xsd:attribute name="sendtoInvoice" type="xsd:boolean" use="required">
                <xsd:annotation>
                    <xsd:documentation>True = message shall be sent to
invoicing</xsd:documentation>
                </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="sendtoVehicle" type="xsd:boolean" use="required">
                <xsd:annotation>
                    <xsd:documentation>True = message shall be sent to
vehicle</xsd:documentation>
                </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="sendtoOperator" type="xsd:boolean" use="required">
                <xsd:annotation>
                    <xsd:documentation>True = message shall be sent to
operator</xsd:documentation>
                </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="manualText" type="xsd:string" use="required"/>
            <xsd:attribute name="vehicleConfirmation" type="xsd:boolean" use="required">
                <xsd:annotation>
                    <xsd:documentation>True = confirmation that the recipient has
been notified shall be sent to client.</xsd:documentation>
                </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="sendingOperator">
```

```
                    <xsd:annotation>
                        <xsd:documentation>Attribute to send identity of the operator that
has sent this manual text.</xsd:documentation>
                    </xsd:annotation>
                </xsd:attribute>
        </xsd:complexType>

        <xsd:complexType name="vehicleDistance">
                <xsd:sequence>
                    <xsd:element name="startTime" type="time">
                        <xsd:annotation>
                            <xsd:documentation>The time period to propose car
starts</xsd:documentation>
                        </xsd:annotation>
                    </xsd:element>
                    <xsd:element name="stopTime" type="time">
                        <xsd:annotation>
                            <xsd:documentation>The time period to propose car
stops</xsd:documentation>
                        </xsd:annotation>
                    </xsd:element>
                </xsd:sequence>
                <xsd:attribute name="range" type="xsd:int">
                    <xsd:annotation>
                        <xsd:documentation>The distance within which an unoccupied
vehicle shall be proposed </xsd:documentation>
                    </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="rangeUnit" use="optional">
                    <xsd:annotation>
                        <xsd:documentation>Type of unit in range.</xsd:documentation>
                    </xsd:annotation>
                    <xsd:simpleType>
                        <xsd:restriction base="xsd:string">
                            <xsd:enumeration value="meter"/>
                            <xsd:enumeration value="seconds"/>
                        </xsd:restriction>
                    </xsd:simpleType>
                </xsd:attribute>
        </xsd:complexType>

</xsd:schema>
```

APPENDIX F

Validation Tool

The research team developed a software tool hosted on a publicly accessible website that enables interested parties to test transactional data messages that could be transmitted among interacting software systems which manage demand-responsive transportation services. These transactional data messages can be sent using either XML or JSON data structures, in accordance with the data specification that is included with this document (see Appendix E). The website that hosts the data validation service is found at the following URL: http://tcrp.demandtrans.com

This data validation service aims to provide interested parties with the following capabilities:

(1) The ability to test the proposed data specification and identify any issues associated with either the specification or its implementation.
(2) The ability to simulate how their software system could interoperate with other software applications that manage demand-responsive transportation services.

In order to implement the transactional functionality of the data specification generated by this project, the research team has recommended a "**control module**" approach to data communication among software systems. This control module approach is briefly explained below.

Each software system and device used by demand-responsive transportation services will have its own internal data communication approach and protocols. When a software system needs to interoperate with another software system, it will do so via an interface with an internal or external "data translator" that transforms its internal data messages and their elements into the common transactional data protocol. This data translator in essence performs the function of an internal/external API (application programming interface) for each technology system, enabling it to "speak" in the transactional language when it needs to communicate with other systems.

The **"control module"** approach, which is shown in Figure F-1 and also found in Chapter 4, ensures an element of centralized specification control without requiring a fully centralized translation broker approach. The control module is essentially a data specification validation service. The purpose of this software tool is to enable interested parties to test the proposed data specification. Any organization that uses this software tool will be emulating the process that the proposed transactional data specification approach will support.

The control module approach necessitates that software systems using the specification be able to internally translate their transactional data into the message types and data elements of the proposed specification. To use the validation service tool described in this document, it is possible for interested parties to generate test data messages without actually modifying their software systems. However, the data that they transmit to this project's data validation service will need to be translated—by whatever means is necessary—into the required form of the proposed transactional data specification.

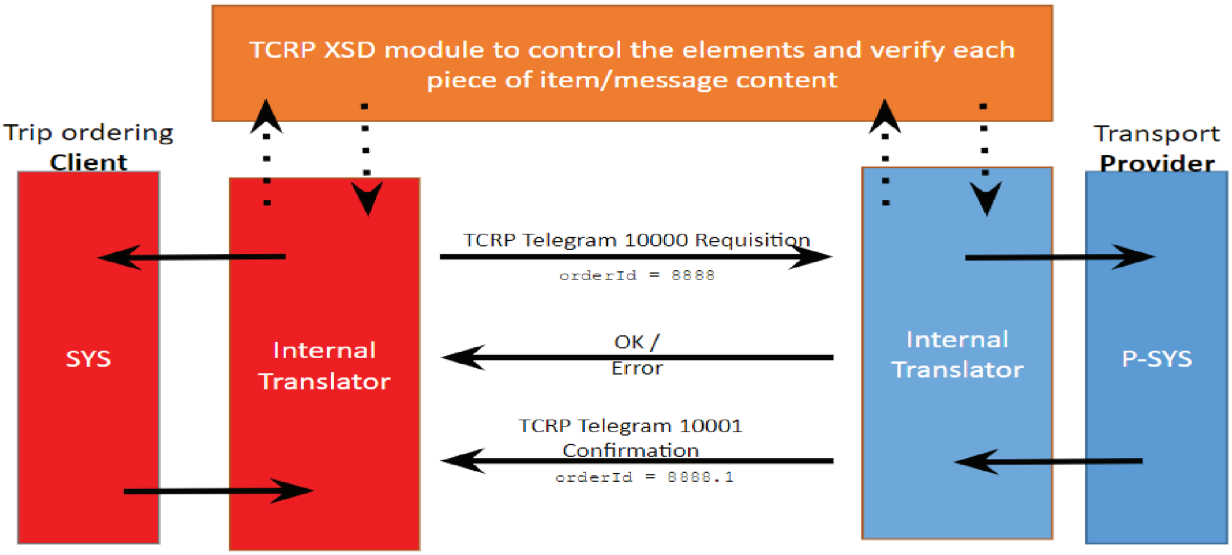


Figure F-1. Control module approach.

The website that hosts the data validation service is shown in Figure F-2 below and can be found at the following URL: http://tcrp.demandtrans.com

Figure F-2. Screenshot of website with the transactional data specification validator.

The following is a sample piece of XML that could be sent to the validation service:

```
<tripTask xmlns="http://www.tcrp.gov/schema"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
   <tripTaskId>tripTaskId0</tripTaskId>
   <tripTicketId>tripTicketId0</tripTicketId>
   <customerLocInDropoffSequence>10</customerLocInDropoffSequence>
   <nodeAddress>
   </nodeAddress>
   <nodeScheduledTime time="2016-05-04T18:13:51.0"/>
</tripTask>
```

The following is a sample piece of JSON that could be sent to the validation service:

```
{
  "tripTask": {
   "tripTaskId": "tripTaskId0",
   "tripTicketId": "tripTicketId0",
   "customerLocInDropoffSequence": "10",
   "nodeAddress": "
   ",
   "nodeScheduledTime": { "time": "2016-05-04T18:13:51.0" }
  }
}
```

A typical API call to this validation service would have the following format:

[Http POST]

http://tcrp.demandtrans.com/api/Validator/validate?schema={schema}&inputType={inpu
tType}&input={input}

Questions or concerns about the validator can be sent via email to roger.teal@demandtrans.com.

APPENDIX G

Marketing Document

This is a short marketing document that can be given to managers at transit agencies and/or other DRT service providers. It briefly explains (1) what a DRT transactional data specification is and (2) the benefits of adopting it.

A New Specification for Demand-Responsive Transportation Data

As a manager, you may consider new techniques and technologies that will improve service for your riders while balancing the availability of financial resources and the time of your staff. You may also seek better ways to use the wealth of data available to monitor service and make decisions. A recent Transit Cooperative Research Program (TCRP) study called ***Development of Transactional Data Specification for Demand-Responsive Transportation*** includes a good candidate for your consideration. This study presents a more standardized format for data in demand-responsive transportation (DRT or paratransit), which has many potential benefits.

To explain the overall idea, parallels can be drawn with recent developments in fixed-route transit service. Numerous transit agencies—both large and small—have adopted a common format for their fixed-route data, known as the ***General Transit Feed Specification*** (GTFS). Since many transit agencies use GTFS, software developers see value in creating a range of applications (or "apps") for use on the web and via smartphones—usually at no cost to the transit agency—that utilize this data and enable riders to easily plan transit trips. This TCRP project sets forth a similar specification for DRT data that includes the data needed by riders to plan a DRT trip, as well as all of the trip details needed to schedule and complete a DRT trip on the provider side.

The widespread adoption of a common data specification for DRT service can provide your organization with a range of benefits, potentially including those in the following table.

Benefit	How?
#1: Facilitate Data Sharing	*This can make data sharing easier among your organizations if other organizations also use the same data format.*
#2: Reduce Operating Costs	*Using a common data format could reduce costs related to the development and maintenance of DRT software.*
#3: Increase Flexibility in DRT Services	*The DRT industry is moving to more flexible operations—such as offering same-day rides—similar to Uber and Lyft. Common data formats can advance adoption of these technologies.*
#4: Increase Availability in Passenger Apps	*It is easier for software developers to create more smartphone apps for passengers using a common data specification, similar to GTFS for fixed-route services.*

For more information, see the TCRP G-16 Report entitled "Development of Transactional Data Specification for Demand-Responsive Transportation"

APPENDIX H

Request for Proposals (RFP) Language

Moving into the digital age requires that the software used by transit agencies be able to seamlessly exchange data. Agencies procuring software are the ones that must require this capability, opening up the future for an array of technological solutions. There are costs for a vendor to adapt its software to a standardized data format, but once incurred this cost can be amortized across all agencies that procure software. This means that the costs for an individual agency will be small but it will open up many possibilities for sharing data across platforms.

This appendix contains two sets of text that could be edited and used in a request for proposal (RFP) that would adhere to or support the use of the proposed DRT transactional data specification in procuring paratransit/DRT/microtransit scheduling software. The first part is language for use by a transit agency and/or other DRT service providers in a request for proposal for procuring a paratransit or DRT/microtransit service provider where the provider will include a paratransit/DRT/microtransit scheduling system as part of the services provided. The second part is language that could be used by an agency that is procuring DRT software and/or a technology vendor. [Brackets] indicate text that should be inserted prior to use.

SCOPE OF SERVICES: Service Provider

The following RFP language can be adapted based on what the transit agency has in place, intends to implement over the period of the service contract, and is purchasing through the RFP. One year is suggested for when the software adaptations are required to be in place but this may be adjusted to reflect the needs of the transit agency.

CASE 1-A: Transit/Paratransit agency does not provide software and requires service provider to bring a scheduling/dispatch solution as part of the service proposal.

CASE 1-B: Transit/Paratransit agency has software licenses for their directly operated services but allows the proposer to bring a different dispatch platform for the contracted services.

[*Transit agency name*] is adopting the [**TCRP G-16 transactional data specification**] for demand-responsive transportation service trip reservations, scheduling, and dispatching. Over time this will enable [*Transit agency name*] to use the data in a variety of technology applications and to readily share data between our agency and the service contractor and with other agencies such as grant or funding partners or coordination partners. Over the term of the agreement resulting from this RFP, [*Transit agency name*] may begin reporting such data to the state or may use a mobile app to support first- or last-mile trips.

CASE 1-A:
The trip data in the [**TCRP G-16 transactional data specification**] includes all data elements needed for a provider to successfully schedule and dispatch a trip (e.g., rider name, scheduled pickup/drop-off times and locations, fare to be collected, vehicle type needed, notes, phone number). The scheduling system proposed must be capable of sharing such data electronically via an export file (e.g.,.xls or.csv format) or through an application programming interface (API). Proposers are strongly encouraged to present solutions that use the [**TCRP G-16 transactional data specification**] to enable integrated trip data sharing. This must be in place by the beginning of year 2 of the contract. The [*Transit agency name*] also requires (1) proposers to retain independent trip records for backup and auditing purposes and (2) for the successful proposer to use terminology consistent with the [**TCRP G-16 transactional data specification**] data descriptions in all reporting and forms.

CASE 1-B:
The trip data in [*transit agency's existing paratransit software*] includes all data elements needed for a provider to successfully schedule and dispatch a trip (e.g., rider name, scheduled pickup/drop-off times and locations, fare to be collected, vehicle type needed, notes, phone number). This data can be shared electronically via an export file (e.g.,.xls or.csv format) or through an application programming interface (API). However, proposers may also bring in their own dispatch platform. If a separate dispatch platform, proposers are strongly encouraged to present solutions that use the [**TCRP G-16 transactional data specification**] to enable integrated trip data sharing between [*transit agency's existing paratransit software*] and the proposer's dispatch platform, including the capacity to share vehicle locations, estimated time of arrivals, and trip performance status (e.g., scheduled, completed, canceled, no show). The [*Transit agency name*] also requires (1) proposers to retain independent trip records for backup and auditing purposes and (2) for the successful proposer to use terminology consistent with the [**TCRP G-16 transactional data specification**] data descriptions in all reporting and forms.

Proposers that do not currently use any dispatch software to accomplish the above data integration may still respond to this RFP but should indicate how they will ensure that trip data provided by [*Transit agency name*] will be dispatched accurately and in a timely manner, as well as how they will communicate trip status updates, report on historical performance, and generate/audit invoices. Proposers that do not have sufficient dispatch technology are also encouraged to partner with other potential service providers to leverage a common dispatch platform that can accomplish the above data integration.

All proposers are strongly encouraged to format the data and data transactions used for this service such that the data are readable and usable by any other software that also makes use of the [**TCRP G-16 transactional data specification**].

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SCOPE OF SERVICES: Software/Technology Vendor

The following language can be included in an RFP for procuring DRT trip scheduling and dispatch software. How this language is adapted for your RFP will be determined by what the transit agency has in place, intends to implement over the period of the service contract, and is purchasing through the RFP. One year is suggested for when the software adaptations are required to be in place but this should be adjusted to reflect the needs of the transit agency. For example, if the procuring agency intends to use the data immediately as part of a coordination project, the RFP language should specify both the timing and form in which data needs to be exported. If the agency intends to, at a later time or an unspecified time, undertake a project that requires shared data (e.g. developing a mobile app that will allow riders to identify if any DRT vehicles could be used for a first-mile or last-mile trip or sending data directly to a grant funding partner such as the state), this too should be stated and may result in allowing a longer time to adapt the software.

[*Transit agency name*] is adopting the **[TCRP G-16 transactional data specification]** for DRT trip reservations, scheduling, and dispatching. Over time this will enable *[Transit agency name]* to use the data in a variety of technology applications and to readily share data between our agency and the service contractor and with other agencies such as grant or funding partners or coordination partners. Over the period the [*Transit agency name*] intends to use the dispatch software being procured through this RFP, [*Transit agency name*] may begin reporting such data to the state or may use a mobile app to support first- or last-mile trips.

The trip data in the **[TCRP G-16 transactional data specification]** includes all data elements needed for a provider to successfully schedule and dispatch a trip (e.g., customer name, scheduled pickup/drop-off times and locations, fare to be collected, vehicle type needed, phone number). This data can be shared electronically via an export file (e.g.,.xls or.csv format) or an application programming interface (API). Proposers are strongly encouraged to present solutions that use the **[TCRP G-16 transactional data specification]** to enable integrated trip data sharing among dispatch platforms, including the capacity to share vehicle locations, estimated time of arrivals, and trip performance status (e.g., scheduled, completed, canceled, no show).

Proposers that do not currently use any dispatch software to accomplish the above data integration may still respond to this RFP. If this is the case, the proposer shall indicate how it will ensure that trip data provided by [*transit agency name*] will lead to trips that will be dispatched accurately and in a timely manner, as well as how it will communicate trip status updates, report on historical performance, and generate/audit invoices. A proposer that does not have sufficient dispatch technology is also encouraged to partner with other potential service providers to leverage a common dispatch platform that can accomplish the above data integration.

Proposers must retain independent trip records for backup and auditing purposes. Separate trip records and reports must also be maintained for premium service trips (if applicable), as these trips may be reserved directly with the provider and may not be scheduled by [*transit agency name]*.

Abbreviations and acronyms 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
FAST	Fixing America's Surface Transportation Act (2015)
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
TDC	Transit Development Corporation
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

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