Development of a Transactional Data Standard for Demand Responsive Transportation: A Case Study of Sweden

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ABSTRACT

Demand responsive transportation (DRT) is a rapidly growing subset of passenger transportation due to increasing use of paratransit services and opportunities unlocked by new mobile technologies. This research examines a specific technical element of DRT operations, which is transactional data specifications. Transactional data are created by each ride request and contain trip details pertinent to booking a trip. A common specification for this transactional data could facilitate requested trips being assigned to one of several transportation suppliers. Yet there are few initiatives that have implemented transactional data specifications in practice, and none that have been described in the North American context. To help fill the gap, this paper presents an in-depth case study of a DRT transactional data standard used in Scandinavia, known as SUTI (Standardiserat Utbyte av Trafik Information). The case method is used to describe the development and adoption of the SUTI standard and draw lessons that may be applicable to the North American DRT market. Three main conclusions are drawn from the case study. First, the adoption of transactional data specifications can improve DRT services as more providers enter the market. Second, technical data specifications and standards must be adaptable over time as demand for data change with demands for services. Third, the Swedish government played a key role in pushing for the SUTI standards and opening the DRT market. These results have important implications for policymakers, technology firms, and transportation providers with interest in sharing transactional DRT data.

INTRODUCTION

Demand responsive transportation (DRT), also known as door-to-door transportation, are services where riders schedule trips through a dispatcher who then assigns the trip to a transport provider. The Federal Transit Administration defines DRT thusly: "a *demand response system* is one where passenger trips are generated by calls from passengers or their agents to the transit operator, who then dispatches a vehicle to pick the passengers up and transport them to their destinations *(1).*" The assigned vehicles include accessible vans, taxicabs, ridehailing, and other small vehicle services. Together, these services provide many types of services to a wide variety of passengers, including mobility impaired travelers and rural communities.

Demand responsive transportation is also an area where transit providers, private technology firms, and other service providers see tremendous potential for improvement in both operations and ridership. Currently, DRT services are expensive to provide and are largely limited to elderly, disabled or rural populations, whether for medical or non-medical travel *(2).* These are crucial services, but operators recognize that the services are not particularly efficient and are rarely robust enough to meet demand. Services are often characterized by limited availability with inflexible scheduled dispatch services and high costs per trip.

Mobile technology has ushered in new interest in DRT, with the hope that existing riders can be better served and new markets can be opened. To open new markets for DRT, key technological issues must be overcome. This research focuses on one technological aspect: transactional data. Transactional data are the data created by each ride request that contain pertinent trip details, such as origin and destination information *(3).* These data are then used to assign the appropriate vehicle and service for a trip, be it with or without trained medical technicians, wheelchair access, or other details specific to a trip.

It is rare for transportation providers to adhere to any particular specification for DRT trip request data, and many firms have developed their own data management software. The problem then is that each provider has (effectively) bespoke data specifications that inhibit sharing across platforms; this is currently the case throughout North America.

One of the only examples of a transactional data specification that is used in practice is in Sweden. Therefore, this research presents a case study of the SUTI (Standardiserat Utbyte av Trafik Information) standards *(4)*, which were developed in the early 2000s. These transactional data specifications were critical to the development of FlexDanmark, which is an extensive DRT system that operates throughout Denmark and accommodates over 15,000 rides daily *(5).*

This paper proceeds as follows. First, background information about specific characteristics of and challenges for DRT transactional data specifications are discussed to motivate this paper. Then, the specific objectives are set forth and the case study methodology is discussed. Finally, key findings from the SUTI case study are presented and areas for future research are discussed.

MOTIVATION FOR DRT TRANSACTIONAL DATA SPECIFICATIONS

Technical standards for transactional data are important to improve and create new opportunities for demand responsive transportation. Over the past decade, there has been an enormous increase in the availability and quality of data describing public transportation services and real-time operating information. What has primarily made this data "explosion" of value to consumers (i.e., riders) is the fact that these data – particularly static schedule data for fixed route transit services – have been generated in conformance with data standards established by a trusted entity. The primary example of this is the General Transit Feed Specification (GTFS), which was initially established by Google. These data, when generated by a public transit organization and made easily available for dissemination, can be used by any organization with appropriate technical resources and capabilities. As a result, public transportation organizations that conform to the GTFS format can expect that third-party technology providers will be able to use that data as a core element of consumer-facing software applications that are of value to potential customers and existing riders of the public transportation system *(6, 7).*

The GTFS standard were not adopted without controversy, however. Even though the initial feed was limited to published transit routes and schedules, transit operators resisted participating on the grounds that their data were copyright protected. While transit operators were not opposed to their data being disseminated in ways that were better for riders, their real concerns were that there were many private firms jockeying for access to their data, and many of these firms were entering into contracts to collect and manage the agencies' data feeds. Google's GTFS ultimately won out as a source of data in part because Google developed the standards with the help of Portland's TriMet transit agency *(8).* Cities and transit agencies quickly shifted their positions from long-held restrictions on data availability to principles of open data to improve public services *(9).*

Characteristics of DRT Transactional Data

Demand responsive transportation (DRT) services for public transportation have not yet been able to take advantage of developments in data availability. There are numerous reasons for this. First, the GTFS standard cited previously is for descriptive, static data — information on traditional fixed routes with static schedules; comparable standards do not currently exist for DRT and other flexible transit services. However, efforts are well advanced to formalize data standards to describe DRT and other flexible transit services in terms of geographic coverage, hours of service, type of service, and locations that are served on a schedule — the so-called "GTFS-Flex" standard *(10).* However, this effort focuses on the "discovery" of trip possibilities but does not include all of the information needed by providers for ***booking*** demand responsive trips.

Additionally, DRT service providers in the U.S. are licensed locally so individual providers will be able to pick up and drop off passengers only in places where they are licensed to do so. This means that managing trips across providers requires detailed ***origin and destination data for the rider and provider*** to ensure that DRT trips do not result in inefficient deadheading or high costs.

Third, DRT and other flexible transit services are fundamentally different from fixed route transit in that DRT services typically require that trips be ordered prior to its delivery to the customer. In other words, there is a "booking" process whereby the customer informs the service provider where they want to be picked up and delivered and when (including as soon as possible). The implication of this is that the specific details of a DRT operation can only be known after the booking process since there are no routes or timetables; in other words, each vehicle's itinerary and schedule are determined ***dynamically*** by the requests for service from customers.

Fourth, the details of the specific DRT transactions are important not only because they affect vehicle schedules, but because ***customer characteristics*** will affect how the service must be delivered. These data are part of the transactional record. For example, if a customer uses a wheelchair, loading that customer onto a vehicle will typically take much longer than for an individual who is fully ambulatory, and the presence of the wheelchair often means that only certain types of vehicles can be used to transport the customer. If a different service provider were to agree to transport such a customer, it would need to have available all such relevant data about them and their trip. Hence, transactional data are essential to fully capture what is expected to occur —and does occur— with DRT services and to also enable specific DRT services to inter-operate with other such services. The latter is often an explicit objective of mobility management programs.

In summary, the "transactional" data — which describes the customer's trip request — are the underlying basis for the actual delivery of service in a DRT system. When the service is delivered, specific details of some transactional elements (e.g., actual pickup time) will be generated, but even when the trip is reserved, the data associated with the scheduled transaction are known (e.g., scheduled pickup time).

Challenges for DRT Transactional Data Specifications

Development of transactional data specifications for DRT is a challenging objective. From its origins 45 years ago, DRT services have been based on computerized technology. Yet DRT service has existed in the USA for that entire time span without data standards or specifications of any type. The result has been technology development for DRT services proceeding in diverse directions with multiple technology providers each devising their specific approach to integration of transactional data both within their own technology ecosystem and, much less frequently, when inter-operating with other technology vendor's ecosystems. Not only has this produced much disparity between data systems of different DRT technology providers, and significant barriers to interoperability of software systems, but any truly useful specification for DRT transactional data must also encompass the data needs of two closely related demand responsive transportation industries, namely privately provided on-demand services (e.g., "transportation network companies" such as Uber and Lyft) and the taxi industry. Each of these industries has their own set of technology vendors and systems and data needs. The current state of practice, therefore, is not one for which there exist obvious and simple pathways to reaching agreement on specifications for transactional data.

OBJECTIVES

In light of the challenges to development of a transactional data specification for DRT services in North America, this research aims to learn from a successful example of a DRT transactional data standard. The example selected for this analysis is the SUTI standard that was developed in Sweden and has been widely deployed as part of FlexDanmark. A detailed case study of the SUTI standard is conducted to answer the following overarching question: ***how and why did the Scandinavians create and implement the SUTI standard?*** Emphasis is placed on the technical details of the SUTI standard to better understand how this has been implemented to help inform DRT operators, technology companies, and policies makers in North America who would like to pursue a DRT transactional data specification.

CASE STUDY METHODOLOGY

This research draws primarily from a single case for analysis. Single case research is typically favored when the intent is to create an in-depth understanding of a particular issue *(11).* Case studies are an applicable research method for situations that meet the following three criteria:

1. The research seeks to answer a "why" or "how" question,
2. The research focuses on contemporary events, and

3. The researchers lack control over events relevant to the research *(12)*.

Given the previously stated objective to answer "why" and "how" questions of present-day decisions made by the Swedish to develop the SUTI data standard, the case study methodology is most appropriate. The selection of the SUTI case is largely motivated by the fact that it exists—allowing study of its history from development through implementation—and is used in practice, which is no small feat in the DRT industry. While seamless travel across platforms and providers has been hoped for over the past few decades, there has been little progress made towards this goal in North America.

CASE STUDY FINDINGS

The case study is described in the following sections. First, background on the history of the SUTI standard is presented. This is followed by a specific example of use of the SUTI standard in Denmark by FlexDanmark. After this, a technical description of the SUTI standard is given. Finally, shortcomings of the standard and areas for future development are discussed.

SUTI History and Background

SUTI, which is an abbreviation of the Swedish text "Standardiserat Utbyte av Trafik Information", was formalized in 2002. Today it is the dominant standard throughout Scandinavia for the exchange of demand responsive transportation information between clients (e.g., the organizations that are responsible for DRT services) and providers (i.e., contracted vehicle operators). As of 2015, more than 30 million orders were organized and executed in SUTI-communication in Nordic countries *(13)*.

Since the initial creation of SUTI, the standard has evolved and expanded significantly. The scope of the standard initially included 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 trips with multiple pick-ups and drop-offs, as well as economic settlements and real-time status messages, such as arrivals or no shows. It also includes real-time GPS information.

The Swedish government — as primary funder of social services that also necessitate transportation service for citizens — was instrumental in the development and nationwide adoption of SUTI. The Swedish government's primary motivation was to ensure that the local governments who were responsible for organizing state-funded DRT services would have access to standardized technologies. Such technologies helped service providers by including the entire spectrum of functionality needed for demand responsive transportation. One effect of the standardized technologies was that it was simple and cheap, and thus accessible, for any transport provider to access the "marketplace." Central planning systems benefited from this situation since the market did not get monopolized, which ultimately reduced costs of providing DRT services.

The key role of the Swedish government in this process cannot be over-emphasized. Even 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), 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, and meant there would be no turning back from this comprehensive framework.

An Example: FlexDanmark and the SUTI Standard

The Denmark situation provides an example of technical specifications of exchangeable data, in that particular context via use of the SUTI standards. FlexDanmark started in a small region in Denmark using the technological 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 if any resistance to the use of SUTI. On the contrary, major stakeholders such as Trapeze and Halda agreed that this was the way forward. The main reason for this was that it was a Nordic standard covering Sweden, Norway, Finland and Denmark, so it could save time and money on implementation.

FlexDanmark aggregates demand for point-to-point transportation from many sources — municipal transportation services, school trips, hospital trips, human service agency trips — in its technology platform and then uses the platform's planning engine to determine which service providers to allocate trips to. Those trips are described for the service provider (i.e., contracted vehicle operator) in terms of the SUTI specification using the concept of "telegrams." ***Telegrams*** consist of a specific message type that includes certain standard mandatory and optional data elements *(14)*. Table 1 explains the telegram variable *(15)*.

TABLE 1 SUTI Message; Adapted from *(15)*

Message	MSG 2000: Order
Description	MSG 2000 is sent from the Client to the Provider and transfers all order data from the Client to the Provider. MSG 2000 contains all data that the Provider needs to dispatch proper resource, start, carry out and finish transportation ordered by the Client. MSG 2000 shall refer to an agreement that exists between the Client and the Provider. If the order complies with the referred agreement, the Provider shall accept the order by sending MSG 2001. This indicates to the Client that the Provider has received, unpacked, generated an order in the provider system and checked it against the referred agreement. If the order does not comply with the referred agreement or the Provider doesn't have the resources to carry out the order, the Provider can reject the order by sending MSG 2002.
Sender	Client
Received	Provider
Response Required	Yes
Response MSG	MSF 2001 or MSF 2002
Client Action	1) Make the order readable by the Provider 2) Make the order understandable by the Provider 3) Make the order in compliance with the referred agreement 4) Send the order in due time giving the Provider time enough to process the order and dispatch necessary resources 5) Ensure the order contain all needed information to the Provider
Provider Action	1) Ensure the order is received in full 2) Ensure the order is unpacked in full 3) Ensure the order is generated in the provider system in full 4) Make the order in compliance with the referred agreement 5) Immediately respond MSG 2000 with either MSG 2001 if the order is accepted or with MSG 2002 if the order is not in accordance with the referred agreement and therefore rejected.
Source: Description of SUTI Messages, page 13 (15)	

A "new trip" message, for example, will include specific types of information about the passenger's origin and destination, when they are to be picked up, if they are using mobility aids, and other relevant data about the passenger trip. This message is sent electronically in a specific format — defined by SUTI — from the FlexDanmark technology platform to a specific service provider's dispatching (or scheduling) system, which — since that system is SUTI-compliant — then contains software that examines the message, determines the message type, extracts the data elements it needs, and then forwards the message on to a SUTI-compliant 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 on the vehicle tour, such as when picking up this passenger is the next action for the driver and vehicle to perform.

At every step, the data are checked for consistency with the message type and then integrated with the software system that the service provider uses to manage and control their vehicles, including the commands and information displayed to the drivers on their devices. As trips are performed, the device in the vehicle records data from "sensors" (e.g., time stamps for when the passenger was picked up and then delivered, GPS readings at the pickup and drop off points), associates this data with a specific trip, and also transmits this data back to the server of the software that is controlling the vehicle. That software system in turn transmits the data to the server that is running the FlexDanmark system. All of this is accomplished via data transmissions that are compliant with the SUTI specifications in terms of both the message types and the specific data that are being transmitted. With up to 15,000 trips per day being delivered, a huge volume of exchangeable data is generated and managed by software applications that are SUTI-compliant.

Technical Description

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 *(16).* The development and maintenance of the standard is driven by member demands. A technical committee receives cases from its members. The cases can be either simple attribute cases or bigger projects. In order to be able to start work for bigger projects, the technical committee needs approval from the board. New versions of SUTI are limited to a yearly version.

The standards have developed a set of asynchronous XML messages that can be exchanged between a client and a provider. In this case, the "client" 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.

Prior to adoption of the SUTI standards, when an organization wanted to engage large fleets of vehicles, they needed some form of standardization between the planner (the client, which does the scheduling) and the vehicles (from the providers). Vehicles were usually provided by private companies (typically taxis) and the planner (or scheduler) was typically a public entity claiming the different kind of trips. The planning (scheduling) system would send orders to different type of vehicles, starting with a simple trip from point A to point B.

The need for the SUTI standard arose when one planning (scheduling) system wanted to have a connection to a different vehicle system without having to start the development process all over again for each vehicle system. This ability to scale trip requests and assignments promoted the growth and adoption of the standards.

The parts of the SUTI standard including date, time, and location (start and end place) are relatively simple and straightforward. However, there are many other cases that become more detailed and are more complicated. For example, there is an ongoing discussion about the level of information that is being provided to the drivers, which depends on the type of trip. The standard can accommodate both planned trips (pre-booking) and real-time trips; pre-booking includes a mechanism to update the information closer to the time of the trip.

The SUTI standard currently includes many different fields in a clear XML structure. It can accommodate many different types of planning (scheduling) systems. The planner (scheduler) can make a "self-declaration," which defines the values in a certain field. The vehicle system then adapts to this *(16)*.

The logic and telegram flow between the planning system and transportation provider (operator) are described in Figure 1 *(17)*. This figure shows that SUTI was intended as a point-to-point integration, but many have chosen an implementation where a shell is added around an existing system, and perform SUTI conversion as an additional module.

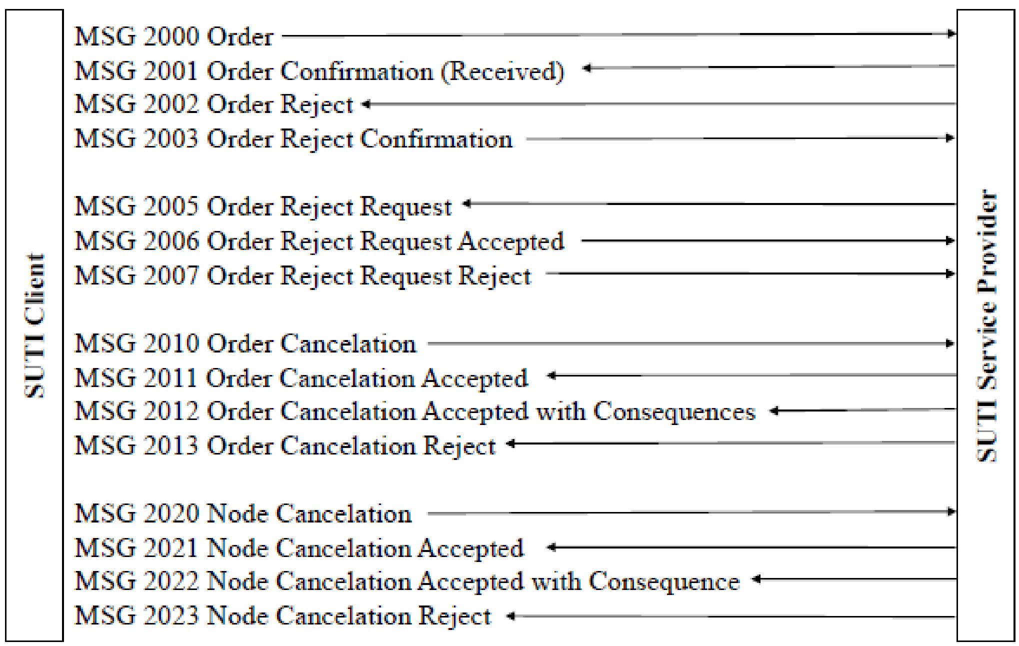

FIGURE 1 SUTI Message Flow; Adapted from *(17)*.

A transportation resource can be requested in two different ways from the client system:

1. dedicated vehicle or
2. non-dedicated vehicle.

A ***dedicated vehicle*** is linked to one particular resource. It is always the same physical vehicle that runs scheduled tours. The planning system knows the coach, space, business hours and all other conditions about the vehicle that are essential for appropriately booking trips. In this type of resources, it is not necessary to check whether the vehicle associated with the resource can perform the scheduled tasks because all restrictions about the unit are known in advance.

A ***non-dedicated vehicle*** is not linked to a single physical resource. In other words, there is not a specific physical vehicle linked to the tours that are planned. In this type of planning, only the client (planning) system knows the type of vehicle in advance. Shortly before the vehicle needs to leave the garage, the provider (operator) system decides which vehicle gets assigned; it is picked from a group of registered vehicles which satisfy the minimum requirements to run the tours that are scheduled. It is the contractor/provider who chooses the physical vehicle. Only when the resource is linked to a physical vehicle may extra trips be scheduled because this depends on the vehicle's capabilities.

Shortcomings and Areas for Further Development of SUTI

While the SUTI standard provides a good example of a widely adopted standard for DRT transactional data, the standard has some noteworthy shortcomings and potential areas for improvement in the future. Arguably the primary weakness of the SUTI standard is that it is based on XML telegrams that only define the variables and not the possible values. The only values that are defined are date and GPS. This means that each client system must define their own values for each system, which does not give a uniform description of a trip across multiple systems.

Additionally, the majority of the processes are handled digitally (i.e., route optimization, resource planning and dispatching), but there are still parts of the DRT transactional process that are handled by manual entries into the system, which have high costs in terms of labor resources. Digitization of the remaining manual processes is a developing area that is crucial for the efficiency of DRT services.

CONCLUSIONS

This paper presented an in-depth case study of the Swedish standard for demand responsive transportation (DRT). The development of transactional data specifications is feasible, as shown by the SUTI standard, which was established in Sweden in 2000-2002. Moreover, not only have the SUTI standards existed for more than 15 years, but in Denmark they have been a foundational element in the development of technology for one of the most extensive DRT systems in the world called FlexDanmark, which operates DRT throughout Denmark (in six regions) via its technology platform. That platform and the technology in the vehicles that deliver the DRT service rely on the SUTI standards in multiple important ways to handle transactional data for 15,000 rides per day.

Three main conclusions are drawn from this case. First, there are clear and measurable benefits from the widespread adoption of transactional data specifications. 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. Second, technical specifications must be responsive to changes over time. Throughout the 15-year period where SUTI has been used, the standards have been adapted to new demands from users; however, the underlying technology — in this case XML — has limits that have developed as the demand for services has grown. Last, the role of the Swedish government in acting as a champion for the development of SUTI standards was critical. The success of SUTI was, in part, its openness. The government was in a unique position to enforce data standards and also stood to benefit from lower barriers to entry to the DRT market.

FUTURE RESEARCH

This research describes the technical development of a successful specification, but is potentially limited in reach to the Scandinavian market. It is not clear that the case presented here is generalizable to different contexts. As such, an important direction for future research is to assess the viability of a SUTI-type specification. This is particularly true for the North American DRT market, which is characterized by regulatory mandates, complex health insurance payments and coverage, private firms and public agencies.

Future research directions should focus on two parallel tracks, broken down by how transactional data are used and why transactional data are adopted. First, continued development of technical specifications is worthwhile. Mobile technologies, privacy concerns and service capabilities all change rapidly, and current era specifications need to be flexible enough to accommodate changes to the underlying technology. Second, a better understanding of how a specification may be disseminated and adopted is needed. This second avenue of research is more dependent on qualitative research that involves talking with those active in the DRT market. Transactional data specifications are subject to proprietary claims, interoperability, data ownership and privacy concerns, all of which are as challenging as the technological aspects. It is unknown if the public role that the Swedish government took with SUTI is both necessary and sufficient for development of similar specifications elsewhere. While transactional data specifications can help improve DRT experiences for operators and riders, it is also not clear that such specifications will be widely adopted through voluntary coordination absent state involvement. The GTFS example for fixed route transit services suggests that the state is not required, but the SUTI case suggests that it is.

There are also local concerns that may affect the generalizability of SUTI-type technical details. In the United States, DRT services are commonly used for medical-related travel and involve billing insurance companies. More importantly, as these services are used as part of health care, transactional data specifications must adhere to HIPAA and stringent privacy regulations. The addition of insurance bureaucracies to the development of transactional data specifications is daunting, but necessary for such specifications to work in the United States.

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