The Adoption of Transit Communications Interface Profiles in the Transit Industry

Factors Inhibiting Adoption and Recommendations for Moving Forward

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Final Report — July 12, 2016

FHWA-JPO-17-432

U.S. Department of Transportation

Produced by The Intelligent Transportation Society of America
U.S. Department of Transportation
ITS Joint Programs Office

Notice

Technical Report Documentation Page

1. Report No. **FHWA-JPO-17-432**	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle The Adoption of Transit Communications Interface Profiles in the Transit Industry: Factors Inhibiting Adoption and Recommendations for Moving Forward		**5. Report Date** July 11, 2016 **6. Performing Organization Code**
7. Author(s) Anthony J. Shaw		**8. Performing Organization Report No.**
9. Performing Organization Name And Address The Intelligent Transportation Society of America 1100 New Jersey Ave. SE Suite 850 Washington, DC 20003		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** DTFH61-13-D-00017-T0022
12. Sponsoring Agency Name and Address ITS Joint Program Office Office of the Assistant Secretary for Research and Technology (OST-R) 1200 New Jersey Avenue, SE Washington, DC 20590		**13. Type of Report and Period Covered** White paper **14. Sponsoring Agency Code**
15. Supplementary Notes		

16. Abstract

This report identifies the institutional and economic reasons that have impeded the adoption of TCIP standards into the public transit industry. Overall, there is a fundamental tradeoff to be made in the adoption of technology standards such as TCIP, a tradeoff between short-term benefits which accrue to individual actors, and long-term benefits which accrue to the industry at large. Furthermore, vendors are reluctant to develop TCIP-based products without a customer base on which they can rely for future sales, and transit agencies are reluctant to issue RFPs for TCIP-compliant systems if there are no TCIP-compliant products already on the market. The nature of the transit industry compounds this problem in that the market for transit business systems is not a technology-driven market, and TCIP creates important economic disincentives for vendors, consultants, and transit agencies who may be early adopters of the TCIP standards. Additional considerations inhibit the adoption of TCIP, such as inconsistent support from various Federal Transit Administration (FTA) departments, rapidly changing information technologies, and the rapid rise of the open transit data movement, through which other transit data standards may have stolen some of inertia and interest away from TCIP.

For these reasons, it appears unlikely that TCIP will be widely adopted in the short term by the transit industry. The most significant reasons are economic rather than technical, however, which suggests that TCIP may still have a role to play in enabling interoperability among and between transit business systems. Assuming that TCIP is still technically feasible, and that transit industry stakeholders wish to continue to promote its adoption, this report offers two general recommendations that address some of the barriers to adoption articulated herein: (1) a large-scale demonstration of TCIP, and (2) enhanced documentation and knowledge transfer of TCIP benefits, challenges, and interface engineering resources.

17. Key Words Transit, ITS, TCIP, technology, data, communications, standards, interface	**18. Distribution Statement**

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages** 24	**22. Price**

Form DOT F 1700.7 (8-72) **Reproduction of completed page a**

Acknowledgements

ITS America would like to acknowledge Jeffrey Spencer (formerly of the Federal Transit Administration) and Robert Sheehan (of the ITS-Joint Programs Office) for initiating this report through the Multimodal Stakeholder Outreach task. We would also like to thank all those whom the ITS America research team interviewed for this report – your knowledge, experience, and willingness to speak with us are greatly appreciated. Finally, we would like to extent our particular appreciation to Dr. Brendon Hemily, who reviewed the initial draft of this report and offered many important suggestions. Thank you all.

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Executive Summary

Despite the tremendous effort invested in the Transit Communications Interface Profiles (TCIP) suite of standards over the last 15 years or so, the transit industry has not adopted TCIP as widely or as quickly as hoped. Due to the minimal extent to which TCIP has been adopted, the standards have not produced the desired interoperability between agencies and among agency systems, nor have the TCIP standards produced desired “network effects” that often result from the adoption of interface standards in other industries.

Main Findings

This report identifies the institutional and economic reasons that have impeded the adoption of TCIP standards into the public transit industry. Overall, there is a fundamental tradeoff to be made in the adoption of technology standards such as TCIP, a tradeoff between short-term benefits which accrue to individual actors, and long-term benefits which accrue to the industry at large. This tradeoff, common to standards adoption in many industries, is the central factor constraining TCIP adoption in the transit industry. Unfortunately, benefits tend to accrue to individuals only over the long term, as network effects accrue slowly at first but more rapidly as a standard approaches market saturation. Moreover, while early adopters tend to bear a disproportionate share of costs, effort, and risk, the late adopters of a technology standard tend to reap the benefits at far lower costs. This issue is especially critical in a “closed” market like that for transit business systems, in which there are a constant number of customers and no dominant vendor which can push adoption on the industry at large.

Furthermore, a circular, “chicken or the egg” problem inhibits the initiation of the adoption process. That is, vendors are reluctant to develop TCIP-based products without a customer base on which they can rely for future sales, and transit agencies – the customers – are reluctant to issue RFPs for TCIP-compliant systems if there are no TCIP-compliant products already on the market. The nature of the transit industry compounds this problem. Crucially, the market for transit business systems is not a technology-driven market, as new technology tends to propagate slowly through the transit industry. The industry is characterized by a constant number of customers, long product life cycles, and significant procurement costs. Within the procurement environment, a lack of technical expertise, over-reliance on consultants, and a limited number of suppliers are all factors which also hinder initial adoption.

TCIP creates important economic disincentives for vendors, consultants, and transit agencies who may be early adopters of the TCIP standards. Proponents of TCIP argue that the standards can mitigate the negative effects of vendor “lock-in”; however, this requires from vendors the investment of up-front development costs which are hard to justify without a clear pool of customers. The current system, with its reliance on proprietary structures, creates financial rewards for vendors who “lock in” at a client site over time, and in the absence of network effects of widespread TCIP adoption, there are no obvious direct benefits over the short term that might compensate for these disincentives. Economic disincentives also appear to inhibit independent consultants from adopting the standard in their specifications, as consultants would need to invest the time and effort necessary to learn the standard and to re-engineer their pre-existing specifications for each new project. Consultants tend not to see a market advantage accruing from this investment in time and effort because, as with vendors, there is no clear pool of customers from whom consultants may recoup these costs. For their part, transit agencies lack a clear demonstration of how these standards will immediately benefit their agencies, and without clear short-term incentives for early adopters, agency champions of TCIP are unlikely to successfully convince their superiors to procure TCIP-compliant systems.

Additional considerations inhibit the adoption of TCIP, such as inconsistent support from various Federal Transit Administration (FTA) departments, rapidly changing information technologies, and the rapid rise of the open transit data movement, through which other transit data standards may have stolen some of inertia and interest away from TCIP. The most important considerations, however, are the market forces and organizational challenges that inhibit the initiation of the “snowball effect” of standards adoption. Without short-term economic incentives for early-adopting transit industry stakeholders, the market forces and organizational challenges have been too difficult to overcome.

Recommendations

For these reasons, it appears unlikely that TCIP will be widely adopted in the short term by the transit industry. The most significant reasons are economic rather than technical, however, which suggests that TCIP may still have a role to play in enabling interoperability among and between transit business systems. Assuming that TCIP is still technically feasible, and that transit industry stakeholders wish to continue to promote its adoption, this report offers two general recommendations that address some of the barriers to adoption articulated herein: (1) a large-scale demonstration of TCIP, and (2) enhanced documentation and knowledge transfer of TCIP benefits, challenges, and interface engineering resources.

Assuming that FTA, the ITS-Joint Programs Office (ITS-JPO), and the American Public Transportation Association (APTA) continue to press for the adoption of TCIP, transit agencies may benefit from a large-scale demonstration of TCIP that clearly illustrates the benefits of adoption. The large scope of the standard seems to beg for TCIP demonstrations that could (1) show transit agencies that TCIP works as intended, (2) establish the data production and data consumption benefits that stem from TCIP adoption, and (3) allow vendors to exhibit their capacity to develop “plug-and-play,” TCIP-compliant systems.

This report also recommends enhancing the content of TCIP outreach materials and the manner in which these materials are disseminated. In order to further facilitate the adoption of TCIP, transit experts interviewed for this report stress the need for enhanced dissemination of all information regarding TCIP pilot interfaces, training materials, procurement resources, and, potentially, TCIP demonstrations. Interviewees note that a smaller-scale research project examining all pilot deployments, assessing the challenges encountered, and explicating the benefits derived from these pilot interfaces would be of value to the industry. Additionally, future research could include a project to make explicit the benefits to date, and to potentially identify sub-elements that may merit greater dissemination. Interviewees affirm that such documentation would be of immense value for agencies who wish to implement TCIP interfaces in their own systems.

The dissemination of all information regarding TCIP, including the documentation of any demonstrations or pilot interfaces, should be pursued more aggressively and targeted at specific stakeholder groups. This may be accomplished through enhanced dissemination methods that build on resources already in place at APTA, the National Transit Institute (NTI), and ITS-JPO. Importantly, interviewees suggest that NTI training courses could be reviewed and updated based on the experiences of attendees, perhaps through substantive interviews or surveys of attendees. Interviewees also note that increasing the support for TCIP within FTA regional offices is an important factor in quickening the adoption of TCIP. This could also be done through NTI trainings or workshops. This is an internal issue for FTA to address, however, and may require internal FTA policymaking. Finally, a “TCIP Users Group” should be set up to support those who adopt TCIP, as such a user group would create a venue in which users could share experiences, benefits, and challenges resulting from the TCIP implementations in which they have been involved. Such a user group may also help identify areas of TCIP which may require enhancements after users gain practical implementation experience, and may be akin to that which supports the users of the General Transit Feed Specification (GTFS), a widely used transit data specification.

Introduction

The U.S. Department of Transportation has long supported the development of standards for intelligent transportation systems. One such effort is the development of a group of interface standards, for use in the transit industry, known as Transit Communications Interface Profiles (or TCIP). Initially developed as part of the National Transportation Communications for ITS Protocol (NTCIP) family of standards under the Institute of Transportation Engineers (ITE), the American Association of State Highway and Transportation Officials (AASHTO), and the National Electrical Manufacturers Association (NEMA), the responsibility for developing TCIP was transferred to the American Public Transportation Association (APTA) in 2001, under which most of the development work was completed.

The goal of this effort was to develop standards that would allow transit agencies to procure business systems (like CAD/AVL, scheduling, and GIS systems, for instance) that could exchange information with each other directly through interfaces built with standardized elements. The TCIP standards provide common "building blocks," if you will, with which to develop the interfaces. Proponents of TCIP maintain that interfaces built following the standards will support interoperability among an agency's systems, as well as between the systems of different agencies. Additionally, proponents argue that widespread adoption of the standards will reduce the extent to which transit agencies rely on technology vendors and consultants in the technology procurement process by reducing vendor lock-in and switching costs, and by allowing agencies to choose systems based on criteria such as price and performance, rather than on compatibility with "legacy" systems.

Despite the tremendous effort invested in the TCIP standards over the last 15 years or so, the transit industry has not adopted TCIP as widely or as quickly as hoped, as only a few small interfaces between transit subsystems have been implemented at a handful of agencies nationwide. Due to the minimal extent to which TCIP has been adopted, the standards have not produced the desired interoperability among agencies and between agency systems, nor have the TCIP standards produced desired "network effects" that often result from the adoption of interface standards in other industries. This report identifies the institutional and economic reasons that have impeded the adoption of TCIP standards into the public transit industry. After a discussion of the benefits of standards in general, and of the intended benefits of TCIP in particular, this report delves into the fundamental issues that inhibit the adoption of interface standards like TCIP. The discussion of these issues comprises the bulk of this report. Finally, this report suggests some recommendations that may be undertaken to move forward the adoption of TCIP.

To identify the range of factors affecting the adoption of TCIP, and to determine which of these factors are of primary importance, the ITS America research team conducted semi-structured telephone interviews with expert stakeholders including transit agency representatives, technology vendors, independent consultants, and other individuals involved in standards development. The research team also reviewed the standards themselves, various public presentations made at conferences and workshops, and the small amount of research literature on TCIP. The expert interviews conducted for this report are listed along with select references at the end of the report.

The Case for Standards

Interface Standards Generate Network Effects

According to the Institute of Electrical and Electronics Engineers (IEEE), a well-established professional association and standards development organization (SDO), standards are "published documents that establish specifications and procedures designed to maximize the reliability of the materials, products, methods, and/or services people use every day."[1] Indeed, successful technology standards play a sometimes unnoticed role in making our everyday lives easier. For example, consider that your computer connects to any Wi-Fi router, your USB thumb drive fits into every USB port, and the keys on every keyboard on which you type are organized in a specific fashion (the familiar QWERTY layout). To get a sense of the importance of technology interface standards, imagine the counterfactual cases in which standards such as those mentioned above do not exist – envision, for instance, the unnecessary difficulties that would arise if your keyboard layout varied according to manufacturer.

Not all standards are officially sanctioned by official standards development organizations like ITE, APTA, or IEEE. A *de facto* standard is one that has achieved a level of market penetration that results in network effects like interoperability, lower costs, and/or easier product development, regardless of who developed the standard or whether the standard is published by an official SDO. The QWERTY keyboard layout is a *de facto* standard with which most people are familiar. In the transit world, the General Transit Feed Specification (GTFS), a way for transit agencies to format and publish their schedule data, is a prime example of a *de facto* standard in that it was not published by an official SDO but has nevertheless been widely adopted by the transit industry, producing benefits that are manifest in the myriad transit trip planning apps available on the web and on your smartphone. *De facto* standards that are not published by an SDO are sometimes referred to as "specifications" instead of as "standards." A standard that has been developed, approved, and published by an SDO, on the other hand, may be labeled a *de jure* standard, as such standards are officially recognized by a representative body such as an SDO. Despite the effort invested in standards development, however, not every *de jure* standard has been adopted by manufacturers and consumers in the marketplace. TCIP is an example of a *de jure* standard that has not become a *de facto* standard.

Theory holds that as a standard is adopted across an industry, industry stakeholders can reap network effects when a sufficiently large number of stakeholders adopt the standard. There are a number of different types of network effects that may result from the adoption of technology standards. Direct network effects, in which the benefits that accrue to a user of a technology standard increase in direct proportion to the industry-wide usage of that standard, are commonly associated with communications networks like telephones and the internet. Indirect network effects relate to the extent to which the consumption of a standardized good results in the increased consumption of other

[1] IEEE website, "What are standards?" https://standards.ieee.org/develop/overview.html

supporting, interoperable, or peripheral goods – which may in turn increase the value of the original standardized good. For instance, the availability and utility of smartphone apps for a given type of operating system – Android or iOS are the prime examples here – can influence the rate at which those platforms are adopted by consumers. In a related manner, two-sided network effects occur when the consumption of a standardized good increases the value of a peripheral good for an entirely *different* set of users. Finally, local network effects occur when benefits accrue to a small subset of the user base, rather than to the entire industry. Local network effects represent an especially useful paradigm through which to consider technology standards adoption in the transit industry, as technology decisions made by one transit agency in a particular region may be influenced considerably by technology decisions made by other agencies operating in the same region. To this end, local network effects are manifested in regional ITS architectures.[2]

While network effects may appear abstract at first, proponents of TCIP realized that network effects which stem from transit data exchange standards can have tangible benefits for the entire transit industry. Those involved in the development of TCIP specifically designed the standards to result in direct and local network effects. Specifically, the developers of TCIP intended the standards to achieve the following:

- Enhance the quality of products through technical consistency;
- Encourage flexibility through "plug and play" – interoperability or interchangeability – which reduces the need to re-engineer solutions each time a system is designed and implemented;
- Enhance adoptability and speed of deployment through more standardized designs, standardized testing and acceptance, and ease of knowledge dissemination;
- Give customers increased power in the marketplace through the ability to choose products based on price or performance, rather than on compatibility;[3] and
- Generate competition, especially by enhancing the ability of smaller manufacturers to enter the market.[4]

Perhaps most importantly for the transit industry, standards such as TCIP are designed to reduce reliance on proprietary supplier solutions and the negative effects that result. As many transit industry stakeholders point out, proprietary solutions for major transit business systems such as CAD/AVL and scheduling systems lead to vendor lock-in, a situation in which a transit agency must rely on continual vendor-specific support in order to maintain the long-term operability of the system procured from that vendor. Moreover, proprietary solutions tend to inflate the price of transit business systems, because without the plug-and-play nature of standardized systems, all modifications or additions over the life of the system must be purchased from the existing vendor at prices they determine.[5] Proprietary

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[2] Landon Reed, "Real-time Transit Passenger Information: A Case Study in Standards Development," PhD diss., Georgia Institute of Technology, 2013, 24. For an extended discussion of the different types of network effects, see also: Arun Sundararajan, "Network Effects," personal website at New York University. http://oz.stern.nyu.edu/io/network.html

[3] Janet Abbate, *Inventing the Internet,* The MIT Press (Cambridge), 1999, 147.

[4] Abbate, *Inventing the Internet,* 147.

[5] This became particularly obvious when new uses for CAD/AVL data started to appear in the context of real-time passenger information. The transit industry did not anticipate this as a potential use for CAD/AVL data,

systems also reduce flexibility, since all modifications need to be based on the proprietary architecture and data structure (which also suffer from associated limitations). The industry-wide reliance on proprietary systems creates huge barriers to entry for new vendors who may seek to enter the market, since existing suppliers have an enormous advantage given their locked-in client base. This situation has the deleterious effect of stifling innovation since there is little incentive for existing suppliers to compete on quality and since market share is predominantly determined based on existing marketing relationships. As a result, competition between technology vendors in the transit industry tends to be based on marketing efforts rather than on the characteristics of the product.

Transit Communications Interface Profiles: An Extremely Flexible System

Technology interface standards such as TCIP are specifically intended to mitigate some of the negative effects that result from the dominance of proprietary solutions in the transit technology marketplace. To do this, those involved in the development of TCIP designed the standards to promote the interoperability between the components of a transit agency's technology systems and subsystems. Specifically, the TCIP standards can be used to define interfaces between transit systems of eight different business areas:

1. Scheduling
2. Passenger information
3. Onboard systems
4. Common public transport
5. Control center
6. Fare collection
7. Spatial referencing
8. Transit signal priority

To facilitate the construction of standardized interfaces between these business systems, TCIP provides the building blocks with which engineers can build custom interfaces between systems of any of the above business areas. That is, at the lowest level of the hierarchy, TCIP defines "data elements" which can be organized into units labeled "data frames." These frames can then be organized at the next highest level of the hierarchy into "messages," and these messages can be sent as "dialogs" for real-time data exchange, or as simple file transfers for batch data transfers. Importantly, TCIP allows for messages and dialogs to be customized according to the specific operational needs of the agency procuring the interface. Thus, the idea behind TCIP was that engineers could use the standards to build interfaces between a newly-procured scheduling system, for example, and the other preexisting legacy systems with which the new scheduling system would need to communicate. [6]

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and existing suppliers were able to extract fees for development of new APIs and/or the use of their proprietary data.

[6] Reed, 62.

Depending on the architecture of a transit agency's business systems, interfaces may need to be replaced between any number of these business systems and a newly procured system; realizing this, the developers of TCIP built a standard that was customizable and which allowed engineers to choose which of the predefined data elements, frames, messages, and dialogs were to be implemented and where. "This extremely flexible system," states Landon Reed, author of a civil engineering dissertation on transit data standards, "allows for an immeasurable number of combinations and permutations for systems to communicate with one another."[7]

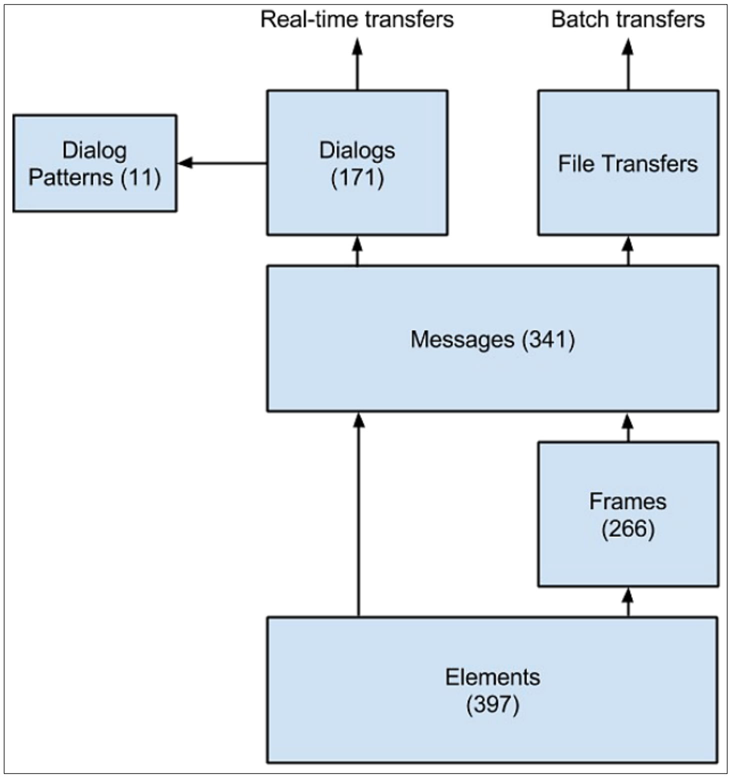

Figure 1: Conceptual Hierarchy for TCIP Building Blocks [Source: Landon Reed, "Real-time Transit Passenger Information: A Case Study in Standards Development," PhD diss., Georgia Institute of Technology.][8]

TCIP is a landmark achievement and represents a way to introduce efficiencies into how transit agencies use technology now and in the future. Unfortunately, interoperability via interface standardization is a goal that has not been met in the transit industry. Only a handful of TCIP-based interfaces have been implemented in the U.S.; notable examples include interfaces installed at King County Metro in Seattle, LYNX in Orlando, and WMATA's CoABE/FeS project in Washington, DC. As many interviewees readily admit, the extent to which the industry has adopted TCIP is very low, especially given the long development history of the standard. Nevertheless, some agencies continue to express interest, seeking trainings from APTA, NTI, and ITS-JPO in TCIP and in transit data

[7] Reed, 62.
[8] Reed, 63.

standards in general. However, the low knowledge of and/or interest in TCIP from vendors and transit agencies alike suggests that TCIP is unlikely to be adopted widely without additional effort.

There remains a need for technology interface standards in the transit industry, however. Increasing interest in multimodal transportation services, from both the traveling public as well as from industry stakeholders, suggests the need for a greater degree of integration between transit agencies and relative newcomers like bikesharing, carsharing, and transportation network companies (TNCs), all of which offer solutions to the first mile/last mile problem common to transit agencies all over the country. Additionally, the adoption of interface standards such as TCIP could benefit transit agencies which participate in multimodal programs such as integrated corridor management (ICM), in which the standardized exchange of operational data is critical to successful coordination with other modal agencies. Indeed, those who originally developed the TCIP standards from 1999 to 2000 intended TCIP to facilitate such data exchange between transit and other types of agencies, as the first versions of TCIP were developed under the National Transportation Communications for ITS Protocol (NTCIP) family of standards by ITE, the American Association of State Highway and Transportation Officials (AASHTO), and the National Electrical Manufacturers Association (NEMA), before being transferred to APTA.[9]

A small degree of data standardization exists already, as evinced by the widespread adoption of GTFS. Although GTFS is a one-way data publication standard that only represents schedule data at the stop and route levels, GTFS data is digestible by a large number of third-party applications which have proved to be of utility to agencies and travelers alike. The success of GTFS suggests that additional opportunities to standardize transit data exist in the U.S. Indeed, the forecasted rise of multimodal travel may even demand it.

[9] NTCIP Library: 1400 – Transit Communications Interface Profiles. http://www.ntcip.org/library/standards/default.asp?documents=yes&standard=1400

Main Findings

If there is a need for interface standardization in the transit industry, and if such a standard already exists, why, then, has that standard not been widely adopted? The success of a *de jure* standard is determined by the extent to which it becomes a *de facto* standard. This process, in which vendors develop products according to the standard, and in which customers purchase those products in ever-larger quantities, implies that both suppliers and consumers derive enough utility from the adoption of the standard to sustain its prevalence in the market. The stakeholders involved in the development of a standard must avoid or overcome significant challenges in order for the transition from *de jure* to *de facto* to occur. In the case of TCIP, these challenges were not overcome to a satisfactory degree, and the standard was therefore not widely adopted.

A Fundamental Tradeoff Must Be Made

The following fundamental tradeoff must be made when an industry decides to adopt a technology standard: that industry must sacrifice short-term benefits that accrue for individual actors in favor of long-term benefits that accrue for the industry as a whole. The "tragedy of the commons" metaphor can illustrate this fundamental issue. As the metaphor goes, there is a limited pool of resources – the "commons" – to which all members of a community have access. Community members who use the commons typically do so in a way that maximizes their short-term gain. The "tragedy" occurs when community members use up this fundamentally limited pool of resources through the short-term maximization of individual utility, creating a shortage of that resource, whatever it happens to be.[10]

To address the tragedy of the commons, controls are placed on their use. These controls can take the form of policies that regulate how the commons are used and by whom, licenses that allow only certain community members to use the commons, or even outright prohibitions on the use of the commons. Regardless of the forms they take, however, these controls reduce the utility the commons provide to individuals over the short term so that the commons survive to provide sustained utility over the long term.

The tradeoff between short-term utility for individuals on the one hand, and long-term, community-wide benefits on the other is the same tradeoff that must be made when an industry adopts a standard. Unfortunately, the benefits of standardization typically do not accrue to the initial adopters of the standard; instead, the benefits accrue to those who adopt the standard after the rest of the market (the "late adopters"). In this way, late adopters reap the advantages of network effects – a crucial economic motivation behind the adoption of interface standards like TCIP – while avoiding some of the risks associated with the initial development of compliant products. As Reed explains:

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[10] Garrett Hardin, "The Tragedy of the Commons," S*cience* 162, no. 3859 (1968): 1243-1248.

> ...consider an agency in isolation. Developing a system to deliver [real-time passenger] information may take significant investment in labor and/or capital to build the system from scratch. In the absence of standardization, adding additional agencies to this model does not decrease individual agency investments to provide real-time information. However, standardization drives down these costs because the costs (and benefits) of development begin to be distributed across the network.[11]

As noted by many stakeholders in the transit industry who are familiar with TCIP, the benefits of TCIP include inter- and intra-agency interoperability, reductions in the degree to which transit agencies rely on vendors and consultants, and eventually, reduced technology procurement costs for transit agencies.[12] The transit industry cannot realize these advantages of TCIP, however, because the advantages accrue only as a result of the network effect. That is, TCIP will not benefit the transit industry until a relatively large portion of the industry uses the TCIP interface standard, and until the standards become embedded in widespread industry practices.

In the transit industry, therefore, early adopters receive none of the network-effect benefits and incur a disproportionate share of the development costs. These costs tend to inhibit the adoption of interface standards like TCIP. In the transit industry, the short-term disincentives to interface standardization are most apparent to technology vendors who must absorb development costs for building TCIP-based interfaces. The development of such products carries significant risks, as the short-term market potential for such products is relatively small. Additionally, the proponents of TCIP intended interface standardization to challenge certain market mechanisms that work in the favor of technology vendors – in particular, the vendor lock-in advantage in which proprietary solutions force resource-constrained transit agencies to rely on vendors for technical support over long periods, thus creating a revenue stream which vendors have a vested financial interest to retain.

Thus, not only do the benefits of standardization *not* accrue to the early adopters, but the industry as a whole benefits from efforts that may actually be costly to the first adopters. Furthermore, those adopters may only truly see the benefits after the standard is common industry practice and can be applied to a subsequent procurement. In the case of TCIP, long-term benefits such as lower costs, interoperability, and less reliance on vendors and consultants never accrued because the initial barriers to adoption – the amortization of product development costs, the lack of a customer base, and the lack of buy-in from consultants, among others – were not adequately addressed.

These considerations have resulted in a standard that has not met its goals. The barriers that impede the transit industry from adopting TCIP, and the characteristics of the transit industry that make them so formidable, are the main findings of this report. The next section of this report presents a discussion of these barriers.

A Circular Problem Inhibits the Adoption Process

The initial adoption of technology standards can be characterized as a “snowball” pattern in which the rate at which a standard is adopted picks up momentum over time. In this pattern, the rate at which the market adopts a given technology standard increases over time (as a snowball increases in size

[11] Reed, 23.
[12] Reed, 60.

and gains momentum as it rolls down a hill) until the market reaches an inflection point, at which time the adoption rate slowly decreases until the standard effectively saturates the market (when the snowball reaches the bottom of the hill). In theory, this adoption pattern results in an "S"-shaped adoption curve, illustrated in Figure 2 below.

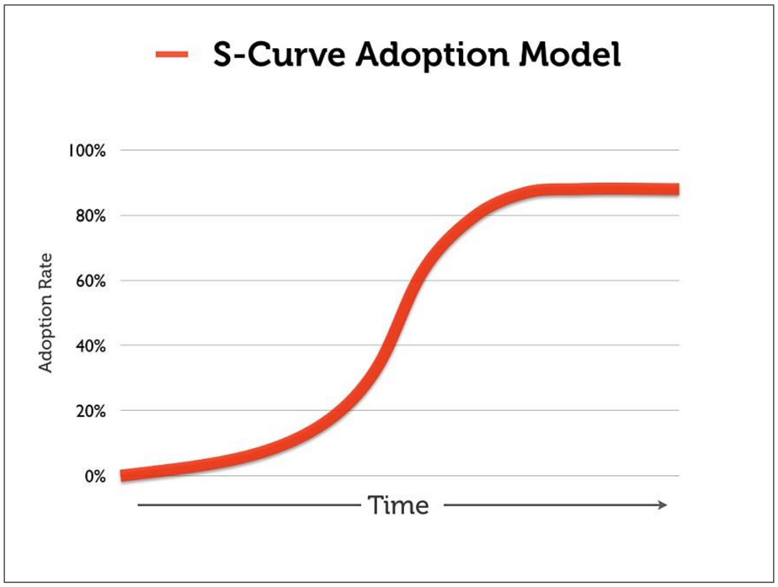

Figure 2: S-Curve Adoption Model [Source: Nathan Ensmenger, "Dangerous S-Curves Ahead!," Thecomputerboys.com.][13]

In reality, the exact shape of the adoption curve depends on the standard itself and on the market forces at play. Although there are a few TCIP interfaces in a handful of cities across the U.S., the current adoption curve for TCIP is near zero and essentially flat. That is, the forces spurring the adoption of TCIP never gained the necessary momentum to produce the network effects that could in turn maintain momentum until market saturation.

The suppression of the snowball effect can be attributed in part to a circular, chicken-or-the-egg-type of problem which must be overcome if any technology standard is to begin producing network effects. This problem can be illustrated through the lens of the technology procurement process as it plays out in the transit industry. Transit agencies typically begin the procurement process by hiring a consultant and looking at the current market offerings. As interviewees note, however, there are few (if any) current vendors offering off-the-shelf, TCIP-compliant products. This means that agencies interested in procuring TCIP-compliant systems essentially have no products from which to choose. Therefore, transit agencies and their consultants omit TCIP compliance as a requirement in their RFPs, because from the customer's point of view, there is no reason to ask vendors for a product that vendors do not make. Furthermore, there is little financial incentive for an agency to step up as an "early adopter" and ask a vendor to build a TCIP-compliant product, since if an agency did so, that agency would most likely bear much of the cost the vendor would incur when developing such a system without accruing

[13] Nathan Ensmenger, "Dangerous S-Curves Ahead!," Thecomputerboys.com, April 23, 2014. http://thecomputerboys.com/?p=676

any of the network effects that are the main reasons for procuring a standards-based system. Finally, there is little in the way of well-documented pilot demonstrations of TCIP interfaces that would not only confirm to risk-averse transit agencies that a TCIP-compliant interface will indeed work as intended, but that would also clearly demonstrate the benefits of TCIP standards. These conditions create a circular situation that inhibits the initiation of TCIP adoption, as agencies are hesitant to ask vendors for a product the vendor does not already make, and vendors have little incentive to develop a product that their main market is hesitant to ask for.

Compounding this situation is the assumption that technology suppliers probably have the most to lose from TCIP adoption. One intended effect of TCIP adoption is to reduce lock-in and switching costs for transit agencies. As interviewees point out, however, lock-in and switching costs represent two important revenue streams for technology vendors. Vendors also do not seem willing to invest in the research and development necessary to re-engineer their systems unless compelled by either market demand or by governmental requirements. Given the lack of a clear customer pool, it is hard for vendors to justify such costs. These economic disincentives are explored in more detail later in this report.

Consultants stand to lose from TCIP adoption as well, as their market advantage is rooted in their ability to reuse existing, proven specifications. To procure a TCIP-compliant system, consultants must re-engineer their specifications, a process which results in a sunk cost that does not, at least at first, directly increase revenues or market share. Moreover, the plug-and-play nature of TCIP is intended to cut down on the proportion of resources transit agencies must expend on tasks such as acceptance testing. Thus, vendors and consultants have little short-term incentives to initiate and maintain the snowball adoption of TCIP because TCIP adoption creates up-front costs for early adopters, while the benefits accrue to late adopters. The challenges that inhibit vendors and consultants from adopting TCIP are also explored in additional detail later in this report.

The Nature of the Transit Industry Compounds the Circular Problem

The very nature of the transit industry tends to inhibit the adoption of wide-ranging interface standards like TCIP by compounding the circular problem described above. Generally speaking, the transit industry is not a technology-driven industry, in that the characteristics of the transit market do not facilitate the initial uptake and widespread adoption of new technologies. Since they slow the rate at which a new technology propagates through the industry, these characteristics constrain the adoption of TCIP and reduce the chance that it will move from a *de jure* standard to an effective *de facto* standard. The paragraphs that follow illustrate these characteristics by drawing connections, where appropriate, to the consumer electronics industry and to the adoption of the General Transit Feed Specification (GTFS). Although GTFS is not designed to have capabilities similar to those of TCIP, it is helpful to juxtapose the rapid adoption of GTFS with the slow adoption of TCIP so that we may better understand the dynamics of how technology standards, and in particular standards related to data exchange, are adopted in the transit industry. Furthermore, some of these differences in device turnover rates and market size between the transit and consumer electronics industries should temper the expectations for the adoption of wide-ranging standards such as TCIP.

General characteristics of the transit industry

First, replacement rates for business systems in the transit industry are low. Transit agencies replace systems such as CAD/AVL, scheduling, and passenger information systems infrequently, reducing the opportunities for agencies to implement TCIP interfaces. This is due in part to the relatively high unit cost of these business systems – especially when compared to products in the consumer electronics industry – as well as to the resource-constrained and risk-averse nature of transit agencies in general. In cases where the adoption of standards does not require the procurement of new technology, network effects may occur much sooner. The adoption of passenger information standards like GTFS, for instance, requires agencies to procure little to no additional hardware or software. Typically, adopting GTFS requires only staff time to publish schedule data in the GTFS format. The speed at which data standards like GTFS can be adopted expedites the initiation of the snowball adoption pattern and, therefore, the network effects that result therefrom.

Next, the market for transit business systems is a “closed” market with a constant number of customers and a relatively small number of vendors. The customer base consists of a few large transit agencies and a larger number of medium-sized to small agencies, most of which have faced significant financial constraints for years; thus, there is little to no growth in the customer base, further restricting the rate at which technology systems get replaced. In addition, no dominant vendor has initiated the snowball adoption pattern through a unilateral decision to implement TCIP for that vendor’s products. Other industries that use interface standards, such as the consumer electronics industry, can have hundreds of millions of customers with hundreds of millions of devices – consider the widespread Wi-Fi standard that supports wireless computer networks. The family of standards defining Wi-Fi connections for consumer devices (the 802.11 family under the IEEE naming convention) has reached the market saturation point and provides near-maximum network-effect benefits to customers as well as producers, in large part because the market for Wi-Fi-based devices is so large that network effects quickly accrue to all stakeholder groups. In contrast, the closed nature of the transit industry restricts opportunities to deploy TCIP interfaces and therefore limits the extent of potential network effects.

Finally, applications which can consume data from TCIP interfaces largely do not exist. Perhaps the most illustrative example of an application that consumes standardized transit data is Google Maps (originally Google Transit). The development and widespread adoption of GTFS enabled transit passengers to plan transit trips using applications like Google Maps that have ingested schedule data in GTFS format. Soon after the development of web-based trip planners like Google Maps, third-party application developers began to build competing smartphone-based transit trip-planning apps in large numbers. Google Maps and other transit trip planning apps that consume schedule data formatted by transit agencies in the GTFS format have created the type of network benefits that are the hallmarks of a successful standard. Unfortunately, applications which use TCIP to interface with, and ingest data from, transit agency business systems do not exist on the scale necessary to create network effects and impel further adoption of the standard.

Risks and procurement costs from the transit agency perspective

As interviewees point out, many transit agencies are risk-averse when procuring technology systems, due in no small part to the pressures placed on agency budgets. As noted above, transit agencies already face significant costs when procuring off-the-shelf business systems; when procuring TCIP-compliant systems that require additional engineering effort from vendors, procurement costs are likely to increase to levels that are not justifiable to many agencies. Given that there are no large-scale demonstrations which exemplify the benefits of TCIP, transit agencies are understandably skeptical towards implementing TCIP-based interfaces across all their business systems. Passenger information standards like GTFS, on the other hand, are much simpler to implement and have already demonstrated their benefit. Therefore, transit agencies consider the benefit-risk ratio associated with publishing schedule data using the GTFS format to be much higher than that for implementing TCIP interfaces, especially considering the length of time it would take for TCIP to be adopted across an appreciable portion of the transit industry.

Additionally, transit agencies interested in procuring TCIP-compliant products must ensure that their purchases actually comply with the standards. Assuming that a transit agency procures a new system that features one or more TCIP-compliant interfaces, as has happened in a small number of pilot projects, agencies do not necessarily have the resources to enforce vendor compliance with the standard. According to interviewees, the inability to enforce compliance stems in part from the same resource constraints that inhibit agencies from investing in TCIP in the first place, constraints which include the lack of available staff time to devote to learning the standard, a lack of financial resources with which to hire knowledgeable staff, a lack of a large pool of consultants on which to rely, and the inability to justify investments in TCIP expertise in the face of competition from other agency priorities. The TCIP Implementation Requirements and Capabilities Editor (TIRCE) tool was specifically designed to assist with the assessment of TCIP compatibility. Although interviewees acknowledge that there are some resources on which agencies can draw in order to increase their knowledge of TCIP, such as training resources and the TIRCE tool, knowledge and use of these tools is generally scant within the industry.

It is important to note here that TCIP *compliance* is not the same thing as *interoperability*. TCIP was intentionally designed to provide standardized building blocks with which agencies, consultants, and vendors could develop customizable interfaces geared to local data exchange needs. For example, a TCIP-compliant interface between a GIS and a scheduling system at one transit agency may have a different dialog pattern or exchange different data elements in its messages when compared to another agency. This customizability is necessary to account for the differing needs of transit agencies, which often vary according to local architectures and legacy systems; however, this customizability also allows for variations among interfaces, complicating agency-to-agency interoperability.

Although TCIP interfaces are not necessarily interoperable, proponents of TCIP expect that all compliant interfaces are built with the same building blocks. This complexity complicates the procurement and compliance processes, introducing an additional barrier for transit agencies seeking to adopt the standard. As interviewees note, transit agencies are often unwilling or unable to invest staff time in accruing in-house expertise in many technologies – a main reason why agencies rely on consultants for technology procurement in the first place. While not an insurmountable challenge, mastering the complexity of TCIP requires even more agency staff time and resources than mastering passenger information standards like GTFS, for example. Comparing the complexity of GTFS with the complexity of TCIP is not appropriate, as GTFS is purposely limited to the format of schedule data, explicitly reducing its scope and complexity. Standardizing the interfaces of such a wide range of transit business systems is a wholly different endeavor from standardizing passenger information data and requires inherently complex standards. As interviewees suggest, overcoming this barrier is more of an organizational challenge than a technical challenge. Unfortunately, most transit agencies don't have the resources or initial incentive to overcome this barrier, nor do they have the support of consultants who are TCIP experts – for economic reasons discussed later in this chapter.

Finally, TCIP's supporting documentation presents significant challenges to resource-constrained transit agencies. As Reed notes, TCIP is considered an open standard, and the documents of which it consists are freely available on the APTA website in zipped Microsoft Word format.[14] Unfortunately, the extreme length of these documents, some of which run in the hundreds of pages, makes it very difficult for agencies to thoroughly examine the standards, especially when agency staff may not be familiar with the topic and when staff time must be carefully allocated. As interviewees argue, this inhibits many transit agencies from using the published standards to identify the benefits that TCIP may bring, thus reducing the chance that transit agencies may dedicate staff resources from developing the requisite expertise in the standards.

Economic disincentives from the technology vendor perspective

Although technology vendors have the technical capacity to develop TCIP-compliant interfaces for their products if necessary, very few TCIP-based products exist on the market, if any at all. Interviewees acknowledge that these same vendors face strong economic arguments against the adoption of far-reaching technology standards like TCIP, and thus choose not to invest in the development of TCIP-compliant products in the first place. Interviewees note that even if vendors were to develop TCIP interfaces, development costs will most likely be apparent to early adopters in the form of increased unit prices over the short-term, making it difficult for highly resource-constrained transit agencies to justify the selection of such a product. As TCIP adoption increases, however, market pressures will reduce costs, but this is little consolation to any transit system that is an early adopter and that has to absorb the initial cost. Vendors are therefore reluctant to develop TCIP-compliant interfaces for their products because they fear that the price tag will scare off agencies which may be compelled to accept the lowest-cost option – thus reducing the likelihood of returns on investment, especially over the short term.

Interviewees suggest that assessing the costs of developing TCIP interfaces on a life cycle basis may make this business decision easier to justify to transit agencies and to amortize over time. This problem could be mitigated if there were a leading vendor in the transit business system marketplace. In theory, a dominant vendor could initiate the snowball adoption pattern by unilaterally adopting TCIP, creating the short-term benefits and local network effects necessary to initiate wider adoption across the industry. Such a vendor would also in theory be large enough to offset their up-front development costs. In the absence of such a vendor, however, the problem of cost amortization inhibits product development and the initiation of the snowball effect of standards adoption in the closed transit technology market.

Interviewees also posit that vendors are concerned that TCIP will disrupt long-term components of their market advantage –particularly switching costs and lock-in at client sites. One of the main reasons for developing TCIP in the first place was to reduce the extent to which agencies rely on the proprietary solutions offered by vendors. Developing standardized interfaces, the argument goes, would allow agencies to more easily pick and choose from the products offered by vendors. While this would reduce the degree to which agencies rely on their technology suppliers, it would also reduce the market advantage that vendors have built up through the development of their own proprietary interfaces. This argument, repeatedly articulated by interviewees, is a clear signal to vendors that the

[14] Reed, 66. The documents themselves may be found here: http://www.aptatcip.com/Documents.htm

widespread adoption of TCIP would probably erode their market advantage. This is a particular concern in technology markets with high product costs, low system turnover, and small market size – characteristics exhibited by the transit industry. That is, the benefits of interface standardization do not accrue very quickly for vendors because there are a limited number of customers at any given time, the cost of installing a new system is high relative to other standardized technologies (such as cell phones and Wi-Fi routers), and the rate of product replacement is low (CAD/AVL and other transit business systems are not replaced very often). In the absence of strong market or regulatory signals, the low rate at which vendors expect the network benefits of interface standardization to accrue essentially erases their willingness to adopt a standard which will likely disrupt important revenue streams.

Economic disincentives from the consultant perspective

The consultants on whom transit agencies extensively rely during the specification and procurement processes also play an important role in the adoption of standards such as TCIP. Unfortunately, however, interviewees agree that there is not a large pool of consultants with the requisite technical knowledge of the standard to help agencies procure TCIP-compliant systems. A main reason for this, interviewees note, is that consultants have no economic incentive to invest in acquiring this expertise. Consultants tend to derive benefits from the reuse of existing specifications which require minimal modification; effort expended in re-engineering their pre-existing specifications using TCIP requires resources which are unlikely to be recovered from new customers, since there are no TCIP-based commercial-off-the-shelf products and no transit agencies willing to ask for them. As long as their customers do not ask for TCIP products or require TCIP expertise, consultants have little justification for acquiring proficiency with TCIP. Moreover, interviewees note that consultants may consider TCIP as a standard which is designed to erode their role in the engineering process over the long term. TCIP was therefore intended to reduce the extent to which transit agencies rely on outside parties like consultants and technology vendors to implement new technology systems. Thus, consultants may be less than inclined to develop an expertise in TCIP.

The Federal Transit Administration plays a role in incentivizing adoption

Interviewees suggest that the circular, chicken-or-the-egg-type problem in which vendors cannot seem to justify developing TCIP-compliant systems unless agencies ask for them, while agencies cannot seem to justify asking for TCIP-compliant systems given the risk involved, could have been addressed (at least in part) by increased pressure from regulatory bodies like the Federal Transit Administration.

Interviewees note that transit agencies began to insert statements requiring TCIP compliance into RFPs in the early 2000s, before the standard was fully developed; however, interviewees also note that this may have occurred in response to messaging from FTA that suggested that future funding streams may be tied to TCIP compliance – a requirement that never materialized. Regardless of whether or not FTA required TCIP compliance, interviewees posit, FTA did not put enough pressure on transit agencies and the consultants who help write their specifications. According to interviewees, this lack of pressure may be due to changes in the degree to which TCIP was supported by internal FTA staff. The TCIP standards were sponsored and promoted by FTA's Office of Research, Demonstration and Innovation (TRI) and by the ITS-Joint Programs Office (ITS-JPO). However, procurement regulations and practices, and enforcement thereof, are the responsibility of the Grants Office and Regional Offices of FTA. According to interviewees, there is insufficient knowledge of TCIP in these divisions to expedite the adoption of TCIP. Any effort to promote the use of TCIP would require a significant effort to educate the FTA regional staff that oversees the capital grants process. To be clear, the FTA's role is not the only reason why TCIP has not caught on, but stronger, more consistent pressure from various FTA offices upon transit agencies and their consultants to learn the standard, identify the benefits the standard would provide, and incorporate into RFPs clearly written and enforceable requirements for TCIP-compliant interfaces could have helped initiate the snowball process of widespread TCIP adoption.

Additional Barriers to Adoption

Rapidly changing IT environment

The fact that the information technologies underpinning the business systems in most (if not all) of the domains of TCIP underwent rapid technological change in the late 1990s and early 2000s made it challenging to develop interface standards for transit business systems. One example of such technological change cited by interviewees was the development of the extensible markup language (XML). First published in 1998, two years after the TCIP development process started at ITE, XML rapidly became a dominant data formatting language. XML-based messages and data elements were incorporated into the TCIP standards under APTA in 2003, requiring TCIP standards developers to translate preexisting binary-encoded ASN.1 data structures (from previous versions of TCIP) into text-encoded XML structures.[15] The concurrent development of TCIP and XML – as well as the development of numerous other technological advancements in web services, application programming interfaces (APIs), geographic information systems (GIS), etc. – meant that those responsible for developing TCIP also had to account for frequent changes in the ways that data could be formatted and consumed *while at the same time developing standardized interfaces among numerous types of IT business systems*. Standardizing data exchange protocols in the face of such technological change was a fundamental challenge that developers of TCIP had to overcome.

Furthermore, interviewees note that the XML schema used to encode TCIP messages sometimes does not meet the technical needs of those for whom the standards are intended to benefit. In particular, the size and completeness of the messages defined in TCIP for the passenger information business area create a burden for passenger information systems, especially real-time passenger information. According to interviewees, the length of these messages requires more time to transmit these messages, creating latencies in passenger information systems in which vehicle locations and statuses may need to be updated in seconds. In contrast, competing passenger information standards such as GTFS, GTFS-RT, and SIRI appear in practice to be much more nimble in terms of outputting data to passenger information systems. These alternative passenger information standards may also be simpler to implement than TCIP, thus providing a clear incentive for transit agencies to adopt these alternative specifications. There are no alternative standards for internal data communications between an agency's business systems, however, as interviewees readily point out.

From the vendor's perspective, the high rate of technological advance has created additional considerations that may discourage vendors from developing TCIP-compliant interfaces. Interviewees

[15] American Public Transportation Association, "TCIP Status Report (Old TCIP Report)," TCIP Archives. http://www.aptatcip.com/Archives_files/01212005_173923APTA_TCIP_Status_Report.doc

suggest that in particular, some larger technology providers may have leapfrogged over the need to develop interfaces between all transit agency business systems. Recent advances in cloud-based computing, web services architecture, centralized data warehouses, and APIs offer new solutions to the old problem of interoperability among transit agency business systems. While interviewees also point out that these advances have yet to be widely deployed across the transit industry, they acknowledge that such advances may lead to technical solutions in the relatively near future that reduce the need for the type of direct interfaces between transit business systems and subsystems that TCIP supports.

Open transit data movement

Interviewees also point to a connection between the growth of the open transit data movement and the lack of adoption of TCIP. Interviewees suggest the possibility that agencies are now more focused on standardizing data for passenger information systems than they are on standardizing the internal exchange of data for operational purposes. This shift in emphasis may be due in part because agencies see releasing their data to the public in a standardized format as an easy way to improve public perception of customer service and travel reliability, as well as to potentially increase ridership. Publishing standardized schedule and vehicle location data is beneficial in the sense that other data standards, particularly GTFS, are widely available, easily implemented, and are consumed by a large number of third-party applications such as Google Maps that provide immediate utility to many transit customers. By providing their schedule data in the GTFS format to third-party applications – or even by the simple act of making that data available via the web – agencies can provide immediate utility to their customers at very little cost. Thus, interviewees suggest that it is possible that any momentum to standardize operational data exchanges and data flows within an agency by implementing TCIP was undercut in the mid to late 2000s by the move to publish transit data. This consideration may be especially relevant for smaller transit agencies, or agencies facing particularly stringent financial constraints.

It must be noted that this short-term prioritization of open transit data does not remove the long-term need to create standardized interfaces between various transit business systems, however. The adoption of GTFS does not improve the internal functioning of transit agencies (at least, not immediately). Adopting GTFS is more akin to opening a window into transit schedules through which more people can look, and look more easily. Despite the positive impact GTFS seems to have had, GTFS does not address the issues which TCIP was intended to address, such as lowering the cost and increasing the interoperability of transit business systems over the long term. At this point, TCIP is the only *de jure* standard in the U.S. that addresses the interfaces between a comprehensive set of transit business systems, and as such, is the only standard with the potential to introduce operational improvements within (and over the long term, among) transit agencies.

Summary of Findings

Overall, there is a fundamental tradeoff to be made in the adoption of technology standards, a tradeoff between short-term benefits accruing to individual actors and long-term benefits accruing to the industry at large. Theory states that the industry as a whole benefits from interface standardization over time, but individual actors may not – at least, not at first. Benefits tend to accrue to individuals only over the long term, as network effects accrue. Moreover, while late adopters benefit, early adopters tend to bear a disproportionate share of costs, effort, and risk. This issue is especially critical in a closed market like the market for transit business systems, in which there are a constant number of customers and no dominant vendor which can push adoption on the industry at large.

Furthermore, a circular, “chicken or the egg” problem suppresses the initiation of the adoption process. That is, vendors are reluctant to develop TCIP-based products without a customer base on which they can rely for future sales, and transit agencies – the customers – are reluctant to issue RFPs for TCIP-compliant systems if there are no TCIP-compliant products already on the market. The nature of the transit industry compounds this problem. Crucially, the market for transit business systems is a not technology-driven market, as new technology tends to propagate slowly through the transit industry. The industry is characterized by a constant number of customers, long product life cycles, and significant procurement costs. Within the procurement environment, a lack of technical expertise, over-reliance on consultants, and a limited supplier market inhibits initial adoption as well.

TCIP creates disadvantages for early-adopting vendors. Proponents of TCIP argue that the standards can mitigate the negative effects of vendor lock-in; however, this requires the investment of up-front development costs which are hard to justify without a clear pool of customers. Moreover, the current system, with its reliance on proprietary structures, creates barriers to entry for new suppliers. In the absence of network effects of widespread TCIP adoption, there are no obvious direct benefits over the short term that might compensate for these economic disincentives. Without clear short-term incentives for vendors, the outlook for getting the snowball effect rolling is poor.

Economic disincentives also appear to inhibit consultants from adopting the standard in their specifications. First, consultants would need to invest in the time and effort necessary to learn the standard and to re-engineer their pre-existing specifications for each new project. The complexity of the standard comes into play here, but is not a critical challenge. Consultants do not see a market advantage accruing from this investment in time and effort because, as with vendors, there is no clear pool of customers from which consultants may recoup these costs. Finally, the use of the TIRCE tool for assessing and comparing proposals, as well as the plug-and-play nature of TCIP, would most likely simplify testing and acceptance and thus reduce the labor and compensation consultants receive on a per-project basis.

Transit agencies also face significant barriers to adoption. Individual transit agencies, and the transit industry as a whole, will benefit only when a significant number of agencies adopt TCIP and force consultants and suppliers to modify their specifications, processes, and products. That is, the reduction of barriers to market entry will encourage product innovation and price competition. In the short-term, however, early adopters will face all the risks and costs but accrue none of the benefits. This situation is compounded by the transit industry's natural inclination to be conservative with respect to technology. Without a clear demonstration of how these standards will benefit their agencies, and without clear short-term incentives for early adopters, agency champions of TCIP are unlikely to successfully convince their superiors to procure TCIP-compliant systems.

Additional considerations conspired to inhibit the adoption of TCIP, such as inconsistent support from various FTA departments, rapidly changing information technologies, and the rapid rise of the open transit data movement, through which GTFS may have stolen some of inertia and interest away from TCIP. The most important considerations, however, are the market forces and organizational challenges that inhibit the initiation of the snowball effect of standards adoption. Without short-term economic incentives for vendors and consultants to adopt the standard, the market forces and organizational challenges have been too difficult to overcome.

Recommendations

For these reasons, it appears unlikely that TCIP will be widely adopted in the short term by the transit industry unless the industry takes significant action. The main reasons are economic rather than technical, however, which suggests that TCIP may still have a role to play in increasing interoperability among and between transit agencies. Assuming that TCIP is still technically feasible and that transit industry stakeholders wish to continue to promote its adoption, this report offers two general recommendations that address some of the barriers to adoption articulated herein: (1) a large-scale demonstration of TCIP, and (2) enhanced documentation and knowledge transfer of TCIP benefits, challenges, and interface engineering resources.

The Need for a Large-scale Demonstration of TCIP

Assuming that the FTA, ITS-JPO, and APTA continue to support the adoption of TCIP, interviewees suggest that transit agencies may benefit from a large-scale demonstration of TCIP to clearly illustrate the benefits of adoption. Although transit agencies have seen the benefits of opening their data and adopting data publication standards (of which GTFS is the prime example), potential early adopters of TCIP have not overcome the short-term organizational barriers to TCIP adoption. Interviewees suggest that this may be due in part to the lack of any large-scale demonstrations that clearly establish that TCIP interfaces can produce value propositions that justify the investment of time and resources that agencies, vendors, and consultants would need to make in order to adopt the standard.

The large scope of the standard seems to beg for TCIP-based system demonstrations that could (1) show transit agencies that TCIP works as intended, (2) demonstrate the data production and data consumption benefits that stem from TCIP adoption, and (3) allow vendors to demonstrate their capacity to develop plug-and-play TCIP-compliant systems. Such demonstrations should have the following characteristics:

- Be specifically designed to overcome burdens on early adopters and to objectively assess the challenges and benefits of implementation;
- Address the interfaces between multiple types of transit business systems;
- Involve an objective before/after evaluation process by an independent party;
- Include a significant financial match to encourage two or three transit systems to adopt a TCIP-based ITS procurement to overcome the short-term barriers to adoption from transit agencies; and
- Be a multi-year project to extend the window in which agencies and vendors may participate in the demonstration.

In the absence of such a demonstration, there is the perception that there is no clearly documented set of benefits with which an agency can justify the resource expenditures necessary to adopt and implement TCIP interfaces. Moreover, there are manifold risks for early adopters, risks which at this time are not mitigated by the network effects that would otherwise accrue from a widely-implemented standard – benefits such as lower procurement costs, straightforward compliance certification, manageable testing, enhanced operational efficiencies and, potentially, interoperability. Such a demonstration may also have the benefit of increasing competition from smaller technology vendors, as a demonstration that includes a financial match may also entice smaller vendors who may not have the capital to develop TCIP interfaces on their own. In the absence of a demonstration of these benefits, the risks outweigh the potential gains that would in theory accrue from interface standardization, especially for early adopters.

Enhanced Outreach and Information Dissemination

This report also recommends updating the content of TCIP outreach materials as well as the manner in which these materials are disseminated. In order to further facilitate the adoption of TCIP, interviewees emphasize the need for enhanced dissemination of all information regarding TCIP pilot interfaces, training materials, procurement resources, and potentially, TCIP demonstrations.

Despite the existence of small-scale pilot interfaces since the mid-2000s, interviewees lament that such documentation from the small-scale pilots has not been widely circulated (or even released) to the larger transit community. In particular, interviewees note the lack of full documentation of how the messages and dialogs for previous TCIP pilot interfaces were developed, as well as the lack of documentation of the code used in the pilot. Interviewees assert that a smaller-scale research project examining all pilot deployments, assessing the challenges encountered, and explicating the benefits derived from these pilot interfaces would be of value to the industry. Additionally, future research could include a project to make explicit the benefits to date, and to potentially identify sub-elements that may merit greater dissemination. For example, the TIRCE module has been recommended as a tool for developing the systems engineering requirement for procurement, regardless of whether TCIP is used as a basis for the procurement. Interviewees affirm that such documentation would be of immense value for agencies who wish to implement TCIP interfaces in their own systems.

Finally, the dissemination of all information regarding TCIP, including the documentation of any demonstrations or pilot interfaces, should be pursued more aggressively and targeted at specific stakeholder groups. This may be accomplished through enhanced dissemination methods building on resources that are already in place at APTA, NTI, and ITS-JPO. With regards to consultants, any demonstration project should attempt to overcome reluctance by consultants to re-engineer their specifications and develop expertise. This could be accomplished by reducing or waiving NTI fees charged to private sector stakeholders for TCIP training. Interviewees also note that increasing the support for TCIP within FTA regional offices is an important factor in quickening the adoption of TCIP. This could also be done through NTI trainings or workshops for relevant FTA personnel. This is an internal issue for FTA to address, however, and would probably require internal FTA policymaking. Interviewees suggest that NTI training courses could be reviewed and updated based on the experiences of attendees, perhaps through interviews or surveys of attendees. Last, a “TCIP Users Group” should be set up to support those who adopt TCIP, as such a user group would create a venue in which users could share experiences, benefits, and challenges from the TCIP implementations in which they have been involved. Such a user group may also help identify areas of TCIP which may require enhancements after users gain practical implementation experience, and may be akin to that which supports the users of GTFS.

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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
API	Application programming interface
APTA	American Public Transportation Association
AVL	Automated vehicle location
CAD	Computer-aided dispatch
FTA	Federal Transit Administration
GIS	Geographic information systems
GTFS	General transit feed specification, formerly Google transit feed specification
ICM	Integrated corridor management
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
ITS	Intelligent transportation systems
ITS-JPO	ITS Joint Programs Office
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communications for ITS Protocol
NTI	National Transit Institute
RFP	Request for proposals
SDO	Standards development organization
TCIP	Transit Communications Interface Profiles
TIRCE	TCIP Implementation Requirements and Capabilities Editor
TNC	Transportation network company
USB	Universal serial bus
WMATA	Washington Metropolitan Area Transit Authority
XML	Extensible markup language

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