IDEA

Innovations Deserving Exploratory Analysis Programs

Transit IDEA Program

Dynamic Timetable Generator

Final Report for Transit IDEA Project 39

Prepared by:
Paula Okunieff
Systems & Solutions, Inc.
Boston, MA

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TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Innovations Deserving Exploratory Analysis (IDEA) Programs Managed by the Transportation Research Board

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IDEA Programs
Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001

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Transportation Research Board
National Research Council

Prepared by

Paula Okunieff
Systems & Solutions, Inc.
Boston, MA
and
N-Squared Associates
Seattle, WA

March, 2006

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Paula Okunieff, President, Systems & Solutions, Inc. was the principal investigator. The other researchers and authors of this report are Paul Slonaker, now Principal at Transformative Software; and Nancy Neuerburg, Principal, N-Squared Associates.

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Finally, Harvey Berlin of TRB's Transit IDEA program graciously provided oversight and assistance throughout the project.

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EXECUTIVE SUMMARY

The objective of the "Dynamic Timetable Generator" (DTG) project was to develop a tool that enables transit agencies to dynamically generate timetables for customer web access directly from "raw" schedule data. This enables transit agencies to present changes to their schedules immediately to their riding public via electronic dissemination methods. Most, transit agencies must plan well in advance to design and develop their customer schedules. Due to these long lead times, transit agencies cannot always present their customers with updated schedule information when changes to the schedules occur due to mid-shake-up changes such as detours, special events, and changes in service demand (e.g., opening of a new mall along a route) or emergencies. This project developed and tested a new tool that will allow transit agencies to provide timely and accurate schedule data on a web site.

Three public transportation organizations partnered with the project team to complete this project. TriMet, New York State Department of Transportation (NYSDOT, with Suffolk and Dutchess Counties) and Chicago RTA (representing CTA, PACE and METRA) participated in this project by providing: feedback on the requirements, work flow process and nuances of timetable design; providing data sets; and testing the application.

These three organizations represent various sized agencies: small, medium and large, they represent various types of organizations (individual, regional and state), and they provided datasets in various formats: fully relational database, scheduling output format (flat file), and general dataset (e.g., Microsoft Access database). The wide range of these general characteristics helped test and support the proof of concept.

The DTG Project consisted of three stages:

- Stage 1: Requirements,
- Stage 2: Proof-of-Concept, and
- Stage 3: Production.

Stage 1 consisted of working with our public agency partners to understand their business requirements and the technical requirements for the demonstration. In this Stage 1 the project team identified the information requirements for the public schedule information and web usability requirements as well as the technical design. A formal systems engineering approach was used to develop the Concept of Operations, High Level and Detailed Requirements, as well as the Design documents. A brief industry review and interviews were conducted to identify the initial set of requirements for the Concept of Operations. In addition, the Federal Transit Administration (FTA) sponsored TransitWeb Usability Guidelines were reviewed and adopted as the display format for the project. The Project Team reviewed the existing Transit Communications Interface Profile (TCIP), made recommendations to ensure that it met the detailed project requirements and met with the APTA TCIP Technical Working Groups to discuss the lessons learned. Finally, the project team working with the APTA consultant and TWGs to ensure that the project requirements were incorporated into the newly released version of the TCIP standard.

The primary accomplishments of this stage included:

- Providing training to agency Partners on Transit Industry standards such as TCIP and TransXchange, and Information Technology Standards such as Extensible Markup Language (XML) and XML Style Sheets and Transformation (XSLT).
- Developing a Concept of Operations and Detailed Requirements document that
  - supports a "best practices" user interface
  - represents a generic automated work flow that supports the back office practices of the organizations
  - describes a detailed data interface requirements to meet the best practices user interface requirements
- Designing a DTG XML Schema (with revisions to TCIP 2.x) that meets the detailed data interface requirements.
- Planning and producing a Draft Test Plan that is linked to the detailed requirements.

The Stage 2 (Proof-of-Concept) resulted in a demonstration application that was developed and deployed on an active web site. The proof of concept DTG reads data sets from different sources, transforms the data into the transit industry standard TCIP, and presents the information using a standard template based on the TransitWeb's "Website Usability Guidelines".

The primary accomplishments of the second stage include:

- Deploying the DTG on an active web site using "open source" software
- Building transformation tools to read three native formats from different source files (e.g., flat file, Access, Oracle) including a database
- Evaluation by Transit Agency participants
- Testing of application

Secondary benefits were discovered by the Agency partners when the information was presented. These include:

- The ability to view the data all at once.
- The ability to check the data for accuracy
- Recognition that automation brings the schedulers closer to the end user.

Stage 3 (Product) consisted of developing a strategy to offer the DTG application as a product that could be freely distributed and modified by transit agencies. The goal was explored by providing the software to one of the Agency partners to customize and modify, while researching a mechanism to manage testing and versioning of modifications.

The primary accomplishments of this stage were:

- Provided technical assistance to the partnering Agency on the design and approach for modification.
- Researched open source licensing issues and collaborative web environments as a site to maintain the DTG software and User Manual.
- Replicated demonstration with Dutchess County Transit who maintains their schedule data in the same format as Suffolk County Transit.

From initiation of the project, the DTG Project Team and partnering Transit Agencies, agreed to explore a framework design that would ensure that the software remains freely available to the transit industry. To ensure interoperability as well as to extend the custom features needed to support different transit agencies, access to the code is needed. In addition, the software needed to be trusted as reliable by skilled Transit information technology staff, and innovations, modifications and enhancements be incorporated into the original code in a formal configuration controlled environment. To that end, the project team agreed to explore an open solution and propose a framework to support continued development of the DTG by the transit industry.

In researching the options, the documented extent of the worldwide acceptance and use of Open Source Software (OSS) was remarkably high. There is a large OSS user and development community, a wide range of resources available to open source developers, and positive impacts of OSS on business development. Different OSS models for licensing software are available for use or customization. Among the resources are tools and forums communicating, managing, implementing and distributing open software enhancements and customizations.

CHAPTER 1 IDEA PRODUCT

The objective of the "Dynamic Timetable Generator" (DTG) project was to develop a tool that enables transit agencies to dynamically generate timetables for customer web access directly from "raw" schedule data. Transit agencies must plan well in advance to design and develop their customer schedules. Due to these long lead times, transit agencies cannot always present their customers with updated schedule information when changes to the schedules occur due to mid-shake-up changes such as detours, special events, and changes in service demand (e.g., opening of a new mall along a route). This project developed and tested a new tool that allows transit agencies to provide timely and accurate schedule data on a web site.

CHAPTER 2 CONCEPT AND INNOVATION

PRODUCT SCOPE

Transit agency's are always looking for more efficient ways to automate the update of timetable data to accommodate these changes. They expend significant staff time and resources in making minor changes to their web sites or reformatting timetables due to these changes. The public, when not informed of changes to the transit schedules, label transit service as inconvenient or unreliable. The problem of providing timely updates is even greater for regional organizations that are responsible for managing timetable data for multiple service providers. Often each data set from the different transit agencies has its own unique format and meaning, each with a different "look and feel." New technologies such as web sites, kiosks, and internet-enabled cell phones support the rapid dissemination of timetable updates, however, agency's still encounter delays in efficiently organizing, translating and laying out the data to populate these media. The Dynamic Timetable Generator will enable any transit agency or regional transit organization to use their schedule data in its native format, and share the information is a branded, consistent format. In addition, the DTG product will be freely available to redistribute and modify. It will be posted in an Open Source collaborative web site.

PROJECT CHARACTERISTICS

New technologies enabled the development of a tool that can dynamically load timetable data from a batch file or from a database, translate the data to a standard content and format, and then present the information to the public in specified languages and in a variety of accessible displays. Using new industry standards and off-the-shelf tools, this project built and tested a general purpose "Dynamic Timetable Generator" tool that automates the loading of timetable information. An important aspect of the project's approach was to use information technology (IT) standards to provide a solution that is applicable to a wide range of agencies. This project used a standards based approach to loading the information including eXtensible Markup Language (XML), eXtensible Stylesheet Language and Transformation (XSLT), and Transit Communications Interface Profile (TCIP).

PARTICIPANT CHARACTERISTICS

Three public transportation organizations partnered with Systems & Solutions, Inc. to complete this project. TriMet, New York State Department of Transportation or NYSDOT (with Suffolk and Dutchess Counties) and Chicago RTA (representing CTA, PACE and METRA) participated in this project by providing: feedback on the requirements, work flow process and nuances of timetable design; providing data sets; and testing the application.

These three organizations represent various sized agencies: small, medium and large, they represent various types of organizations (individual, regional and state), and they provided datasets in various formats: fully relational database, scheduling output format, and general dataset (e.g., Access, Excel). The wide range of these general characteristics helped test and support the proof of concept.

CHAPTER 3 INVESTIGATION

The Dynamic Timetable Generator Project researched and incorporated findings on the electronic use of timetable data from a survey of the web and interviews, which are discussed below in the State of the Art Summary. This chapter also includes a description of the DTG functional requirements and the implementation of the DTG, including a technical overview and the testing process.

This project was designed with the following three stages:

- Stage I (Requirements Analysis) of the project was to identify the requirements, including interface requirements and access methods for translating and presenting the timetables and to produce a preliminary design.

- In Stage II (Proof of Concept), a prototype was developed. The participating transit agencies supplied data and the Project Team implemented the approach agreed upon in Stage 1. In addition, the Project Team was able to implement an objective of Stage III in this stage by translating data directly from a database. Staff from each transit agency was interviewed to help evaluate the application. The software and documentation were developed by the Project Team.

- In Stage III (Production Application), the application was deployed at one of the partner agencies, TriMet. TriMet staff is currently testing the system on their web site. The Project Team is providing technical assistance to them during their installation and production period. In addition, research was conducted on how to license the product to allow free distribution of the tool to transit and how to develop a model for future modifications and enhancements of the product.

STATE OF THE ART SUMMARY

A limited survey of electronic information provided by transit agencies was conducted via the Web. The TCRP Synthesis 43 document, *Effective Use of Transit Web Sites,* found that 97% of transit web sites had schedule data available to the user. The project team reviewed the "top transit websites" as identified by FTA on the TransitWeb (www.transitweb.its.dot.gov), as well as others. The TransitWeb site presented a wealth of information, not only on techniques currently used by transit agencies, but also on recommended usability guidelines for transit schedules or timetables.

This State of the Art Summary section discusses the usability guidelines for transit schedules, some observations on existing web-based transit schedules and related technical deployments.

Graphic Interface Guidelines

After an interview with the author of the Usability Guidelines for Transit Web Sites, Michael Zuschlag of Volpe, the DTG project adopted the guidelines completely and requested Volpe's participation on the project's Review Panel. In addition to the recommendations offered by the usability guidelines located at http://www.transitweb.its.dot.gov/guidelines/main.asp?chap=7&id=7, the project team determined that some additional guidelines would be needed. Some layout issues would need to be resolved that were not covered by the usability guidelines. For example, guidelines were not developed on how to designate and display notes or route map graphics related to the schedule.

Review of Web Based Transit Schedules

Many web based transit schedules were reviewed to help determine timetable reporting requirements and issues. Schedules from the following agencies, among others, were reviewed:

- CTA
- Denver RTD
- Golden Gate Transit and Phoenix Transit (template developed by Beige Technologies)
- King County Metro (WA)
- MBTA
- METRA (IL)
- Metropolitan Transportation Commission (MTC), San Francisco Bay Area
- New Jersey Transit
- PACE
- Pierce County (WA)
- Santa Clara Valley Transportation Authority (CA)
- SEPTA (Philadelphia)
- Suffolk County (NY)
- TriMet (OR)

Most of these agencies had developed their web sites before the guidelines were developed, so they did not follow the guidelines set forward by Transit Web. As a result, many of the schedules reviewed were published in PDF format. Most of the schedules displayed in PDF format suffered from a variety of problems for the user. Problems included an inability to view headers and trip times together, poor display performance, and problems with printing the schedule on a standard sheet of paper (8" by 11") since the content was a copy of the print schedules. Even if printed, the schedule times were so small that they could not be easily read.

A key recommendation made to us in an interview with the TransitWeb author was to ensure a match between the route "stick map" stops/designated locations and the timetable header row. Although not initially in the scope, the Project Team included route map data for one of the examples.

Technical Deployments

Although used extensively by commercial applications, few transit agencies have implemented web sites with database or flat file driven information. The majority of those implementing this approach used the database to drive service bulletin information. Only one transit organization that we reviewed, MTC, included database driven timetables.

The MTC back office system is composed of a centralized database, which includes the regional transit agency service datasets. Native transit agency datasets are translated and stored in a consistent format. When a user requests a timetable, application software queries for the data and displays the results. The application supports notes, accessible displays, and horizontal or vertical display of the timetable. It does not pair stick maps with the timetable, however. This application is tightly coupled with its backend data model.

DYNAMIC TIMETABLE GENERATOR FUNCTIONAL REQUIREMENTS

The set of requirements for this project were developed based on two sources, which included the information requirements set forth by the transit agencies and the TransitWeb Guidelines. At the time of design, the current TCIP message did not include key features identified in the transit requirements such as:

- Header fields that are associated with stops along each direction of the route; the header information may consist of a timepoint (or other location) reference, customer recognized name and description;
- Attributes and notes for timepoints and trips;
- Trips that can be categorized by day type (e.g., weekday, Saturday and Sunday/Holiday);
- Stick map files or links to stick maps; and
- Optional features supported by agencies (transfer stops and related routes, rider alerts, etc.)

Using TCIP data elements and frames from TCIP Standard Version 2.4, a revised message was developed that supports the project requirements.

The project team discussed and designed the software required to support the business logic. This effort consisted of developing a detailed set of requirements that are traceable to the Concept of Operations. The project team adopted a Use Case approach to develop the Concept of Operations/ Requirements. The Concept of Operations and Requirements document describes the how the system works from the user perspective and includes detailed business logic, presentation, error processing, and special handling requirements for the DTG. The Use Case Methodology is derived from the Unified Modeling Language (UML) methodology which is widely supported by the IT industry. This particular Use Case template was promoted by the National Transportation Communications for ITS Protocols (NTCIP) standards development organization and Bureau of Transportation Statistics (BTS) who led the Geo-Spatial One Stop Transit group.

The timetable presentation format, upon which the stylesheet is based, incorporates the TransitWeb Guidelines format. Some additional features are added, such as a pop-up "Note" feature, and horizontal and vertical scrolling bars.

Additional characteristics requested by technical staff from the partner transit agencies include:

- Compliance with ADA
- Ability to print a HTML version on a single page
- Improved presentation performance
- Reduction of "hits" on the database by caching timetables
- Ability to use stop names in the table header
- Ability to use real-time data for presenting schedule information

Some of these features were incorporated in the demonstration, however, most of them were out of scope of the project's Statement of Work.

The Use Case approach facilitates development of the test plan and procedures; the test matrix fields are based on the Use Case detailed requirements. Each detailed requirement will be verified and validated to ensure that the function, alternative scenarios and data input/output requirements are met.

The Test Plan includes:

- Functionality and Usability Testing
- Integration Testing

IMPLEMENTATION OF THE DYNAMIC TIMETABLE GENERATOR

The Team, designed, coded and implemented a prototype Dynamic Timetable Generator. In addition, the Team worked closely with the three transit agencies to produce datasets that could be loaded into the Dynamic Timetable Generator. The demonstration web site was launched in mid-December of 2004, with the first production ready CTA data set (sponsored by the RTA) posted before Christmas. Preliminary comments from the Expert Panel were reviewed and incorporated into the Demonstration version of the DTG.

DTG Technical Requirements

The demonstration web site operated using Linux, with an Apache web server, Tomcat Java Servlet Engine and MySQL database. The DTG application was written in Java, using World Wide Web standards XML Schema and XSLT. Three styles of datasets were used: formatted text file, Access database and Oracle database. The datasets that resided in the database applications were transferred from their original databases to MySQL which resided on the web. This process was seamless, although not fully automated.

The Dynamic Timetable Generator architecture was refined during the process of developing the prototype. Figure 1 shows the detailed framework of data flow and web components. The general processing flow of the DTG is as follows:

1. The controller receives a request for a timetable. After validating the request, the controller passes it to the Business Logic module.
2. The Business Logic module queries either the internal data store or the database to retrieve the relevant schedule data, filters and sorts it to respond to the request, and composes an XML document containing the requested timetable data.
3. The View Page transforms the timetable XML document using the presentation template in order to produce the formatted timetable in Hyper Text Markup Language (HTML) that is returned to the user.

Data sources consisted of three types:

- CTA PTT files
  - Three flat files exported from the Hastus scheduling application
- Suffolk County Transit Data Maintenance System (DMS) data
  - The data was from a Microsoft Access database application developed for NYSDOT to support the collection of schedule data from small transit providers
- TriMet Oracle
  - Extract from the TriMet database

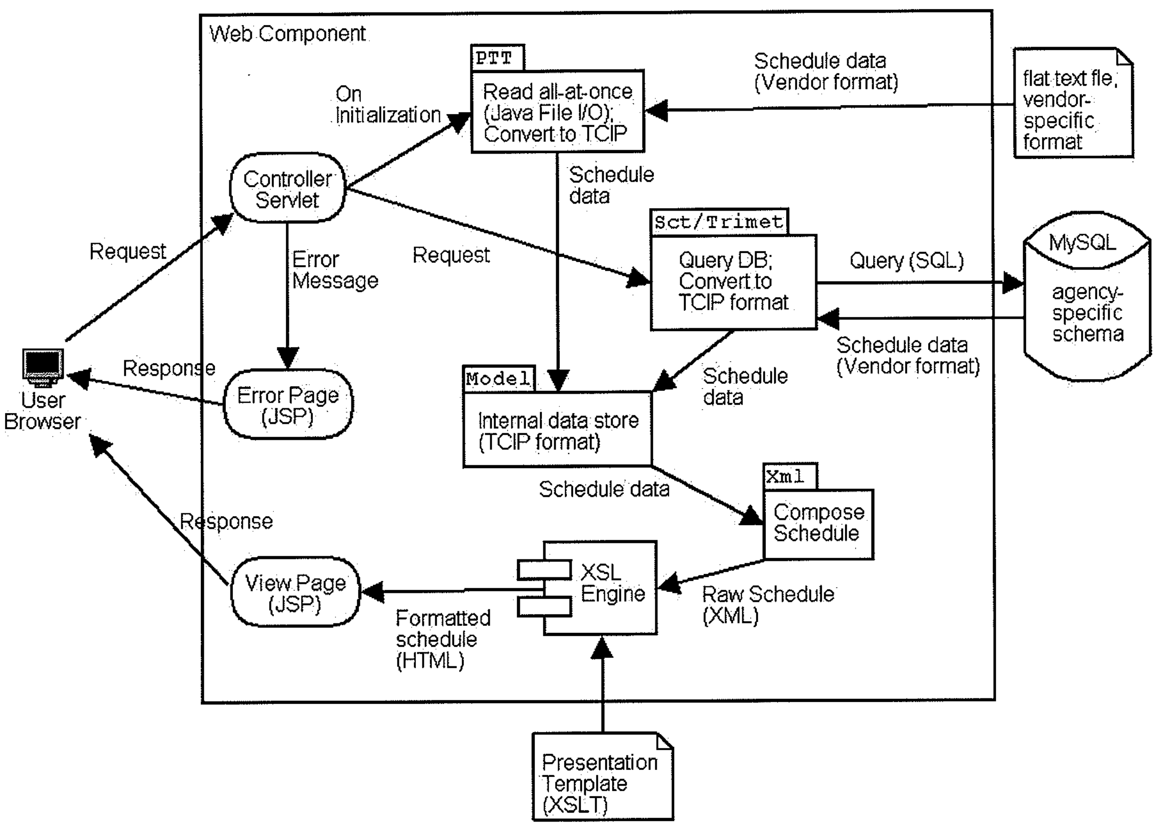

Figure 1: Dynamic Timetable Generator Computing Architecture

The PTT file is loaded directly from the flat file source, the Access and Oracle formats were replicated into MySQL and extracted from MySQL. In the future, new data such as real-time bus information, may be added directly to the production database to present real-time schedules. The procedures for loading the information are described in the *Installation, Operations and*

Maintenance User Manual. In addition, the update processes for other information related to the TCIP DTG schema and parameter files are also described in the *User Manual.*

DTG TESTING AND EVALUATION

The Project Team performed comprehensive data testing, based on an agency-reviewed Test Plan and Test Matrix. Agency staff was able to do preliminary tests of the data without needing to be formally trained. In addition to quick, preliminary testing of the data by the transit staff, they were also interviewed. The evaluation questions were targeted to users, developers, and implementers. The questions dealt with the transit staff's assessment of format, content and usability of the prototype application and website, as well as identifying other issues and improvements.

Finally, Project Team members met with the APTA TCIP Technical Working Groups (TWG) on Passenger Information and Scheduling and worked closely with the APTA TCIP consultant. The Project Team met a few times with the groups, first to introduce the project and afterwards to describe the lessons learned and evaluation results. The TCIP XML message that was used to implement the DTG was presented to the TCIP TWG and was incorporated *as is* into the latest version of the draft standard.

General Evaluation Results

In general, the transit participants were very positive about the demonstration citing that it met their expectations and met the demonstration objectives. They saw the DTG's usefulness for saving time, for facilitating the translation of schedule data to new formats such as ADA formats, and for providing a new tool to spot checking the quality of their database. An unexpected benefit of this project was to make data issues visible for some of the transit partners.

The interviewees saw potential in pursuing the use and enhancement of the DTG prototype after the demonstration. They made valuable suggestions for improvements and expressed their desire to participate in the final Stage of this project. Many of the suggestions pertained to the layout and "look" of the data. All of the agencies were please that the XML style sheet approach would allow them to easily change the presentation of the timetable data to a style consistent with their organization's colors and graphics on their web site. As mentioned above, they also understood how easy it would be to change the XML style sheet to produce the data in an ADA readable format as well. A summary of their evaluation feedback is included in Appendix B: Evaluation Results.

Technical Lessons Learned

The most difficult task for the Project Team was mapping the native format of the data into TCIP. The issue was not so much matching the data format to an equivalent data format, it was ensuring that the relationships among the data were referentially correct, and that the data was sequentially ordered, matching the table header (in each direction). Some extra effort was also needed to make the data aesthetically ready for publication, since the tool uncovered a number of data inconsistencies when standards had not been consistently applied (e.g., mixed case). Once the data was in the TCIP format, the rest was relatively easy.

Specifically, some key data issues include the following:

- Schedule time values should map unambiguously to a 36-hour clock. We recommend using integer values in units of seconds, measured from midnight. A number of scheduling applications typically manage time using this convention. Although the rollover from 12 pm to 1 pm (e.g., am to pm) and from 12 am to 1 am (e.g., pm to am) can be easily detected *within* a trip, however, the rollover between two trips (12 pm trip and 1 pm trip), even when they are sorted, may be ambiguous.
- The set of possible time points for a route should be explicitly sorted – i.e., maybe include an explicit "sequence number" – and the time points for a trip should reference that number. This helps to reduce ambiguity between cases where a trip may visit the same time point location more than once.
- The trips for a particular direction and day type should be explicitly sorted in time order. Since there are often cases where trips for the same route have different starting points, it can be difficult to sort trips based on their time point times alone.
- Sorting of trips in time order could be done in two ways. First, the trips could be assigned a trip number that increases with time. Second, trips could be assigned a nominal start time that somehow accounts for different start points. The second approach is preferable if there is a need to combine trips from day types.
- Information that is to be displayed to the user, such as customer-route-name, route-direction-description, and time point display-name, should be in an aesthetically appeasing format.

Based on the findings in this demonstration project, a key recommendation is that a reference data model be developed that explicitly identifies the relationship among schedule data. With a good reference model, multiple applications, when mapped to that model, can use TCIP schedule data directly from its native source or from a file that serves as an XML database.

CHAPTER 4 PLANS FOR IMPLEMENTATION

The development of a Dynamic Timetable Generator was proposed to save transit agencies time and resources as they reformat their schedule information for presentation via the Web. Furthermore, transit expends these resources over and over again not only for each schedule change period but also when they translate the timetable into different languages or accessibility formats. There are hundreds of transit agencies that can benefit from a software application that efficiently pulls their schedule data from its raw state, reformats the data to a consistent form, and then applies the data to a presentation template of their design for any target population. Open standards support this vision, but they are not sufficient.

In the DTG project, we built code that scaled to small, medium and large transit agencies. Where possible, the project used Open Source Software (OSS) to develop the DTG prototype. In general, the reason that OSS was used was because the open source infrastructure code scaled better and supported the different requirements for each of the transit agency data sets.

This Transit IDEA project clearly demonstrated that a Dynamic Timetable Generator could be built and used to display transit timetable data on a web site without significant manual effort. The DTG worked for both large and small transit agencies in the demonstration project. The partner transit agencies were all interesting in further use of the software after it had been customized to better match their specific agency's web site "look and feel." The DTG can also be used by other transit agencies, although the biggest barrier to easy use is that many transit agencies need a better data reference model to facilitate the transformation of their data to the industry TCIP standard, before loading their data into the DTG. To further facilitate the wide spread use and enhancement of the DTG, the possible role of open source software licensing and development models for the product should be explored.

Several of the participating transit agencies plan to use the DTG to deploy timetables in an automated fashion from "raw" schedule data. Key transit agencies in the downstate NY region reviewed and augmented the Concept of Operations developed for the IDEA 39 project. The software will be reviewed and new procedures developed to extract and present the data to their customers. This project is expected to be deployed in late 2006. TriMet is reviewing the TCIP message set. In a review that focused on related TCIP dialogs, TriMet identified several problems with delivering information using TCIP XML.

OPEN SOFTWARE AND LICENSING

From initiation of the project, the DTG Project Team, subcontractors and partnering transit agencies, agreed to explore a framework design that would ensure that the software remains freely available to the transit industry. To ensure interoperability as well as to extend the custom features needed to support different transit agencies, access to the code is needed. In addition, the software needed to be trusted as reliable by skilled Transit information technology staff, and innovations, modifications and enhancements be incorporated into the original code in a formal configuration controlled environment. To that end, the project team agreed to explore an open solution and propose a framework to support continued development of the DTG by the transit industry.

In researching the options, the documented extent of the worldwide acceptance and use of OSS was remarkably high. There is a large OSS user and development community, a wide range of resources available to open source developers, and positive impacts of OSS on business development. Different OSS models for licensing software are available for use or customization. Among the resources are tools and forums communicating, managing, implementing and distributing open software enhancements and customizations.

When using OSS in the Dynamic Timetable Generator project and researching alternatives, we discovered that transit agencies must be better educated about OSS. Further, transit must develop policies on use and modification of OSS. Transit industry software developers and their funding bodies must facilitate the implementation of formal processes, institutional and organizational structures to support the effective use of OSS, while simultaneously enabling a grassroots technical organization to evolve. To implement these recommendations, it will require resources and commitment from public sector agencies for the full benefits of OSS to be realized.

COMMON OSS BENEFITS

As demonstrated by different industries that use Open Source Software (OSS), OSS can:

- Leverage multiple agency resources to develop and maintain software;
- Provide a forum to share best practices and develop tools based on those approaches;
- Build open standards-based applications that are interoperable;
- Identify and build key technologies and functionality that provide the most benefit to the most agencies;
- Build tools that are scaleable to serve small, medium and large transit agencies;
- Foster a community of transit IT professionals and consensus on industry best practices;
- Reorient the industry to a service-based commercial model, where vendors repackage, redistribute and compete on service and enhancements to industry developed software;
- Promote competition to improve software quality and lower costs.

OSS BACKGROUND

OSS started with a simple license that allows free distribution and modification of software. It is now an industry with multiple license types. A significant and growing number of organizations and web sites now support OSS development and distribution. These OSS development web sites host tools to support application development and foster communication among a community of programmers, users, and observers. The tools provide transparency into the development and maintenance processes to meet key system engineering and software development best practices.

Open systems and open standards are sometimes confused with open source. Open source software is associated with a class of license agreements that follow the requirements described in the Open Source definition (www.opensource.org). Open standards are standards that are developed and promulgated in an open, consensus based environment by industry experts. Open systems are standards-based products that may be hardware or software, open source or proprietary. One may view open source software products as a "more pure and open" form of open systems software. Many open source and open systems products use open standards and in so doing help promote these standards and build markets for the standards.

Today, there are OSS applications that command over 60% of the market in some infrastructure software business areas. Examples of well known OSS products include Apache Web Server, Linux, Firefox and Perl. Both Apache Web Server and PERL are currently used within the transit industry. Some OSS, such as Linux, is developed by a group of ad hoc software programmers who have an interest in reusing software that is offered on one of the OSS web sites. Other applications are developed by a company and put out on the web for redistribution and modification, for example, Firefox, developed by Netscape. The Apache Software Foundation (ASF), a non-profit organization, develops "branded," open source software.

The governance structure of ASF defines a process to ensure community interest, trains project managers, and ensures acceptable software maturity prior to its introduction on a project site. This formal, wholly volunteer effort supports over 25 projects producing several applications under each project umbrella. ASF is organized to pool individual and corporate operating funds. The funds are used to support the operations and the infrastructure only. No funds are used to procure software development support.

RELEVANCE TO TRANSIT

Transit agencies employ many different types and sizes of software applications in the course of doing business, from legacy personnel and payroll systems to modern ITS applications. Some of these applications are purchased proprietary systems and others are developed in-house. The following quote summarizes, from the open source perspective, the differences between proprietary Commercial Off-The-Shelf (COTS) software and OSS.

> "It's partly a question of business models. Proprietary companies sell packages for money and see support as a cost. Open source companies give away packages and see support as the cash cow." [zdnet]

According to researchers, the majority of software used by businesses today is developed in-house; only about 30% of software is proprietary COTS. Some economists think that 30% is overstating the COTS market [perens]. In a quick survey of a few transit agencies, we found that between 50 to 60 % of software was developed in-house or had significant modules that were developed in-house.

For businesses, there are three classes of software acquisition – proprietary COTS, open source and custom developed. Given the statistics, the majority of software is developed and maintained by in-house or contract resources. The public sector transit industry is no different than other industries; many of its applications are too small and too unique for large software companies to profitably develop and sell, so they are developed in-house or by contracted developers. Also, the transit-specific software market is not large enough to attract as many vendors as some other industries.

Small, medium and large transit agencies have all found it necessary to develop some of its software in-house. In-house, non-OSS software misses out on the benefits of sharing the development costs and the burdens of bug fixes and enhancements. The other benefits of a broader developer support group are also missed.

APPROACHES FOR A TRANSIT OSS DEPLOYMENT

Any software developed under an OSS license may be subject to confusing ownership rules. Some "communities of interest" form non-profit organizations to hold the license of the product. This approach centralizes the license as opposed to the alternative, where each developer owns the license for each individual line of code. Although not feasible for the DTG project, the long-term DTG product may benefit from a transit open source software initiative that manages transit software OSS licenses, and supports an OSS collaborative development environment.

INTEREST IN PRODUCTION APPLICATION PHASE

All of the transit partners were interested in participating in some way in the Production Application stage and wanted to track the evolution and future enhancements of the DTG. TriMet was selected to implement the DTG on their agency web site. They are currently in the process of testing a customized version of the DTG . Other agencies who have seen the demonstration have also expressed interest in the project, particularly in the development of a stylesheet that renders the route schedules into an accessible format.

The transit partners wanted a mechanism to ensure that the DTG software could remain available to transit agencies that were interested in using it or customizing it to meet their needs. They requested and supported the development of the research paper on licensing impacts and constraints. The licensing issues will be discussed in more detail in the next chapter.

CHAPTER 5 CONCLUSIONS

The project clearly demonstrated the value of the Dynamic Timetable Generator. In addition, it showed the benefits of using information technology and ITS standards in developing the DTG. The project also tested the "Web Site Usability Guidelines" developed by Volpe and demonstrated their value in clearly portraying transit schedule data.

Based on this project's successful development of a Dynamic Timetable Generator to assist transit agencies in rapidly and accurately displaying timetable data on a web site, an opportunity exists for transit to further benefit from the project. Some additional related research and development would facilitate the transit industry's easy and widespread use of the tool. For example, the industry would benefit from the development of additional stylesheets that supports accessible route schedule formats.

Further research and development on a transit reference data model would make the conversion of agency specific schedule data to a TCIP format easier. The development of standard policies or guidelines for entering some of the scheduling data, such as timepoint names that head the columns of timetable data would also help. In addition, there appear to be clear opportunities for transit in the area of OSS. Given the newness of the topic to transit, however, education and outreach, lessons learned and a proof-of-concept need to be addressed before OSS will be viewed as a viable option on a wide-spread basis.

CHAPTER 6 INVESTIGATOR PROFILE

Paula Okunieff, Principal Investigator, Systems & Solutions, Inc. Ms. Okunieff has over 25 years experience in managing and building navigation and transportation information systems that use GPS, geographic information systems (GIS), IT and communications systems. For over 15 years, she has been involved in defining ITS standards specifically for transit. She was the architect and editor of the NTCIP Transit Communications Interface Profile family of standards. She has successfully managed software development activities and developed "mapping" strategies of TCIP to the European Union public transport standard Transmodel and portions of various transit agency databases.

Contact Information:
Paula E. Okunieff, Principal Investigator
Systems & Solutions, Inc.
43 Jamaica Street
Boston, MA 02130

617-983-3364 tel
okunieff@sasi-technology.com

Paul Slonaker, Lead Software Developer. Mr. Slonaker has over 22 years of software development and management experience. He developed a similar customer, data-driven XML/Java application for the education industry. Mr. Slonaker also worked with Ms. Okunieff in developing the methodology behind the *APTS Map Database User Requirements Specification* (March 1994). That methodology was later used to derive the requirements for TCIP.

Nancy Neuerburg, Policy Issues, N-Squared Associates. Ms. Neuerburg has over twenty-five (25) years of providing technical assistance in the areas of information systems, research and technology development. She has 12 years of transit management experience with responsibility for technology, strategic planning, research and management information projects in all business areas of transit. As part of King County Metro Transit's senior management team, Ms. Neuerburg had responsibility for implementing and maintaining Metro's automated systems, corporate databases and networks; managing the Automatic Passenger Counter, GIS and automatic vehicle location functions; customer research; product/program review and evaluation; fare policy and pricing analyses; and strategic planning for Transit management. Examples of regional, multi-agency ITS initiatives included a seven agency Smartcard project, Ridematch and Trip Planning projects. Examples of customer research projects included Customer Expectation and Satisfaction Surveys, program evaluations, focus group testing of timetables and other customer information.

GLOSSARY AND REFERENCES

[zdnet] Blankenhorn, Dana. "I don't want you to talk, Mr. Gates." General Development, http://blogs.zdnet.com/open-source/, Posted 10:27 am, 3 May 2005.

[Perens] Perens, Bruce. "The Emerging Economic Paradigm of Open Source." http://perens.com/Articles/Economic.html. February 16, 2005. p., 2.

APPENDIX A: ACRONYMS

ADA	American Disabilities Act
BTS	Bureau of Transportation Statistics
CTA	Chicago Transit Authority
DTG	Dynamic Timetable Generator
FTP	File Transfer Protocol
HTML	Hyper Text Markup Language
J2EE	Java 2 Platform, Enterprise Edition
JSP	Java Server Page
METRA	Northeast Illinois Regional Commuter Railroad Corporation
MVC	Model-View-Controller
NTCIP	National Transportation Communications for ITS Protocols
NYSDOT	New York State Department of Transportation
ODBC	Open Data Base Connectivity
PACE	Suburban Bus Division of the Chicago RTA
PDF	Portable Document Format
RDBMS	Relational Data Base Management System
RTA	Chicago Regional Transit Authority
SCT	Suffolk County Transit
SDMS	Schedule Data Maintenance System
SQL	Structured Query Language
TCIP	Transit Communications Interface Profile (TCIP)
TWG	Technical Working Group
UML	Unified Modeling Language
XML	eXtensible Markup Language
XSLT	eXtensible Stylesheet Language and Transformation

APPENDIX B: DTG EVALUATION RESULTS

SCHEDULE FORMAT

1. How easy and intuitive is it to navigate the Schedule Format? Why?	▪ Mostly easy ▪ Mostly easy. Drawbacks included sideways scrolling caused by too many timepoints and/or long headers. ▪ Mostly easy
2. Please describe what you **like** about the Schedule Format.	▪ Fairly straightforward ▪ Seems to work ▪ Liked second set of headers when they scrolled down, but they appeared odd at first glance. Recommend that the website should explain why the multiple headers are inserted. ▪ Liked that it's easy to Change Direction or change Day of Week after you select a route. The buttons are well placed and easy to find.
3. Please describe what you **do not like** about the Schedule Format.	▪ Bland, generic. Wanted to customize it. ▪ Having to back up through the webpage to get to a different location. ▪ Explain what **bolded text** means (pm). Bolding without explanation is alarming. ▪ Distracted by the **negative space** that separates every 5 trips, although its value is understood. Recommend that it be done in a more aesthetic way. ▪ Distracted by the **headers** that separates every 15 trips, although its value is understood. Recommend that it be done in a more aesthetic way. ▪ Distracted by having the **headers** centered in the column over times that were right-justified. ▪ Recommend that an explanation of the **bold text** be included. Recommend that it be done in a more aesthetic way. ▪ Some of the schedules are for long routes and it causes **sideways scrolling**. Can the program autoformat to minimize the sideways scrolling? (Don't do bus stop headers on the side, it's not as intuitive and especially don't do some horizontally and some vertically to make them fit. ▪ It was **not** always obvious what schedule is being looked at because sometimes the **headers vanished** off the computer screen. The route, day of week and direction should always be present on the screen. [Some of the RTA **headers were so long** that they got very tall as the header text wrapped multiple times. As a result, the header row often disappeared off the screen. In other words, although the program inserted a header row after every 15 lines of

	schedule data, most of the header would vanish from the screen when the header was tall (equivalent of several+ rows).] ▪ Didn't like the negative space to separate rows and columns. Would have liked better contrast to make them stand out
4. How would you improve the Schedule Format or the presentation of the data?	▪ Notes should be included on times and/or timepoints ▪ Needs a legend in a very obvious place, not at the bottom ▪ Be able to hit the "Change Direction" button and toggle to the other option, instead of having to pick the other option then having to hit the Change Direction button as well. ▪ Certain policies were not recognized like inserting a dash "-" between the Route Name and Route Number ▪ Recommend removing "Route" to keep the page as clean as possible ▪ TriMet found it interesting that the default type of day and direction were "Weekday" and "Outbound". Riders on their system currently have to select all options at the same time. ▪ They noted that some users are new to computers and don't realize that there are drop down options behind a button or window. ▪ Identified a new study on printed timetables from the University of Florida (November 2004). ▪ Remove "Submit" for the "Direction" and "Select" button ▪ Recommend a "route select" button on the "route" view ▪ Recommend vertical display for routes with too many timepoints to fit across the web page ▪ Ability to change default of "Change Day of Week" ▪ Areas that were recommended for agency customization include: o Graphics parameters o Hit "submit" buttons or automatically change (dynamic or deliberate) o Define a set of Guidelines to set up data so that the application works more better o Need better rules for laying out headers (e.g., caps, mixed case, minimize header names) ▪ Route header should stay frozen (e.g. Route 3 has the headers vanish) ▪ Even if the route headers show, the route number, weekday and direction don't show after you start scrolling. ▪ Also the left-side info vanishes when you scroll horizontally. ▪ To minimize horizontal scrolling, maybe the left-side info could be put on the bottom to give more room horizontally for the headers ▪ More consistent use of fonts (upper/lower case) on headers ▪ Maybe smaller font on headers to minimize scrolling

SCHEDULE DATA CONTENT

5. How well does the Schedule information fit the format? Are there special routes or data issues at your agency that affect how well the Schedule information fit the format? If so, what are they?	▪ Needs capability for adding notes. ▪ It fits because it is basic. ▪ One problem is with longer routes, so it requires horizontal scrolling.
6. Is the Schedule information displayed accurately by the Dynamic Timetable Generator prototype? If not, are there general issues or problems that you can identify?	▪ Seems accurate

OTHER ISSUES

7. Did the Dynamic Timetable Generator prototype turn out how you expected? If not, why not?	▪ Yes, it meets the project objectives ▪ No surprises ▪ Yes, the project did what it said it would do. It's a promising start, but we want more. ▪ Better aesthetics. Volpe rules may be too restrictive.
8. Have there been any unexpected benefits from this project?	▪ Helped identify data quality issues; issues are easier to spot (also faster QC tool, good for comparing to printed timetable, faster to find missing trips) ▪ It is good that multiple operators will have a consistent look for the schedule data across the region. ▪ The application can be generic, but transit operators can do their own customization. ▪ Believe that this tool will help small operators keep their schedule data up to date (and present up to date schedule data to their customers). ▪ Highlighted some header label inconsistencies (i.e., QC tool) ▪ If it works, it will be great for translating data for wireless applications, productivity, etc. ▪ May be easier to convert to ADA format.
9. What challenges or barriers do you expect will be encountered in the next phase of the project?	▪ What is the next phase? Can we include other agencies? ▪ Current approach to make schedule data ADA compatible will have to change (e.g., transform the data to ADA readable)
10. What other feedback can you provide to help improve the next version of the Dynamic Timetable	▪ Recommend including a print version. ▪ Want to identify transfer points ▪ Want to include other agencies and acquire more diverse feedback

Generator prototype and/or the next phase of this project?	▪ Provide information on how to customize the tool and the presentation (editor's note: this is part of Stage 3) ▪ Although agency is not ready, this could be used for real-time data and PACE data ▪ Keep us informed, want to know progress and learn from the other implementations ▪ Am willing to continue providing feedback to the project ▪ Great Product ▪ Very exciting ▪ Can we have the tool?