The Role of SMARTR – A GIS Based Solution in Denver Public Schools

Author: Tripti Agarwal

The SMARTR...for Schools Transportation Module™ is a powerful stand alone automated bus routing system utilizing the foundation of the ESRI™ Geographic Information System (GIS). Denver Public Schools (DPS) Transportation Department has improved efficiency and built upon the GIS platform, compatible with departments throughout the DPS enterprise. SMARTR creates bus routes automatically and dynamically, utilizing 74,000 geocoded students, bus stops, and school addresses at DPS. Utilizing the SMARTR application, bus routes have been generated and optimized, providing the logistics of transportation service for approximately 22,000 students. The database and easy to use interface facilitate the tracking of student information, special education students, bus information, and an accident tracking and analysis utility. The system also provides capability for interfacing with a Global Positioning System (GPS) utility, custom reporting and Route Optimization for organizing runs into the most optimal routes.

Introduction

Denver Public Schools, the second largest district in the state of Colorado, is comprised of approximately 74,000 students, 148 schools, and 1,455 bus routes running 6,930 bus stops. This paper describes implementation and use of “SMARTR...for Schools Transportation Module™“ - a stand alone software system that utilizes the ESRI Geographic Information System (GIS) platform to provide a fully integrated transportation Routing Management system at DPS. DPS uses this Transportation Module to create bus routes with geocoded students, bus stops, and school addresses. Additionally, the District uses SMARTR to support approximately 7,143 special-ed students and coordination of 1,745 high school students utilizing the public transportation from the Regional Transportation District (RTD). SMARTR allows efficient and easy calculation of walk zones, run schedules, and management of students-to-stops assignment. The system also provides capability for interfacing with a Global Positioning System utility, custom reporting and Route Opt for organizing runs into the most optimal routes. SMARTR is being used by more than 50 districts across the country.

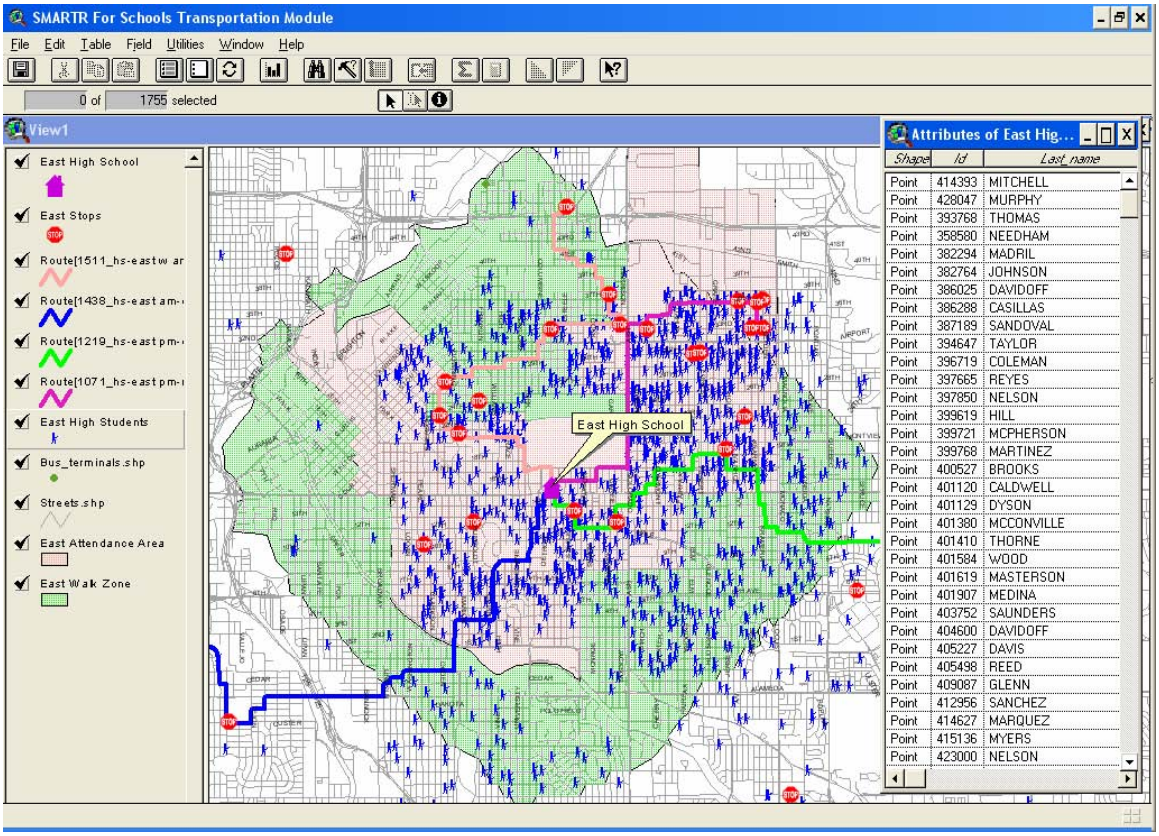
Compatibility with the ESRI GIS Platform

SMARTR is built upon the ESRI Platform. The system comprises ArcView GIS, ArcView Network Analyst, and a vehicle management utility. SMARTR brings GIS functionality to mapping, managing, and analyzing data regarding school transportation, utilizing student, bus, routing, accident, and other vital information. SMARTR uses an interface similar to ArcView 3x, with some additional features.

DPS utilizes an ESRI district site license, which provides ARCGIS and its various extensions to unlimited desktops throughout the District. The District’s Transportation

and Planning & Research departments were the pioneers in obtaining the ESRI district site license, which is available to all departments on an as needed basis. This gives DPS unlimited use of specified ESRI software, including ArcGIS, ArcSDE and ArcIMS, providing functionality needed to post map information to the Internet. This allows the District to graphically display boundary information across the web. It is anticipated that this initiative will facilitate expanded use of the GIS utility, providing opportunities for reducing costs, which benefit students, their parents, and District administration. SMARTR is also consistent with the DPS general operations, technology platforms and architecture, complementing its strategy of being an educational partner with ESRI.

Figure 1: SMARTR Interface similar to ArcVIEW 3.x



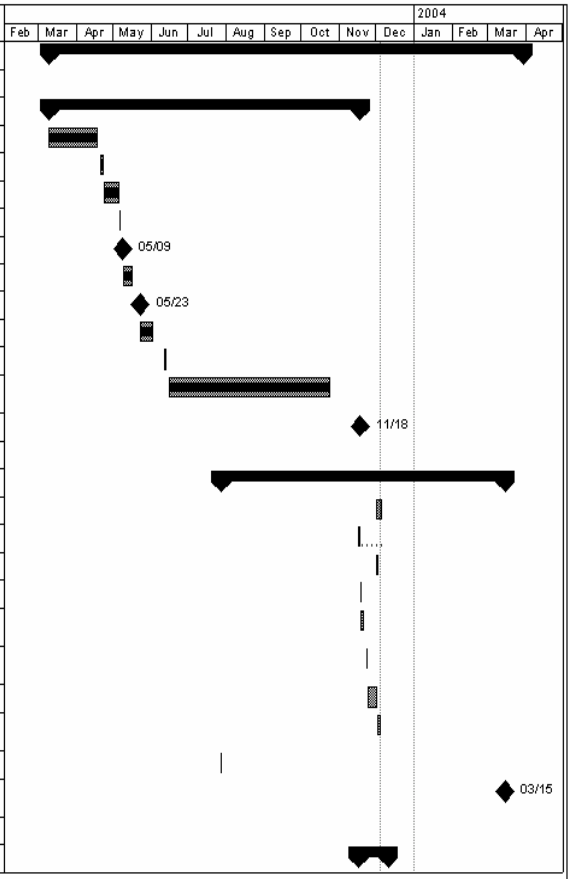
Implementation

With the District's implementation of GIS data to improve the management and logistics of transportation and student information, the decision was made to evaluate compatible transportation routing utilities. All groups in DPS including Student Services, Technology, and Planning & Research were consulted, which after detailed comparable analysis, selected SMARTR by Education Planning Solutions. This was coupled with the decision to no longer use MapNet, which DPS considered cumbersome to administer. Key to this decision was the issue that MapNet had no real interface with the Districts' GIS platform. Additional due-diligence was performed to clarify functionality and standard integration with the formal effort kick-off on 12-05-03. The required go-live

was fixed at 03-1-04 due to the MapNet license expiration. A timeline for the SMARTR kick off was prepared to replace the old MapNet system.

Figure 2: SMARTR Implementation Timeline.

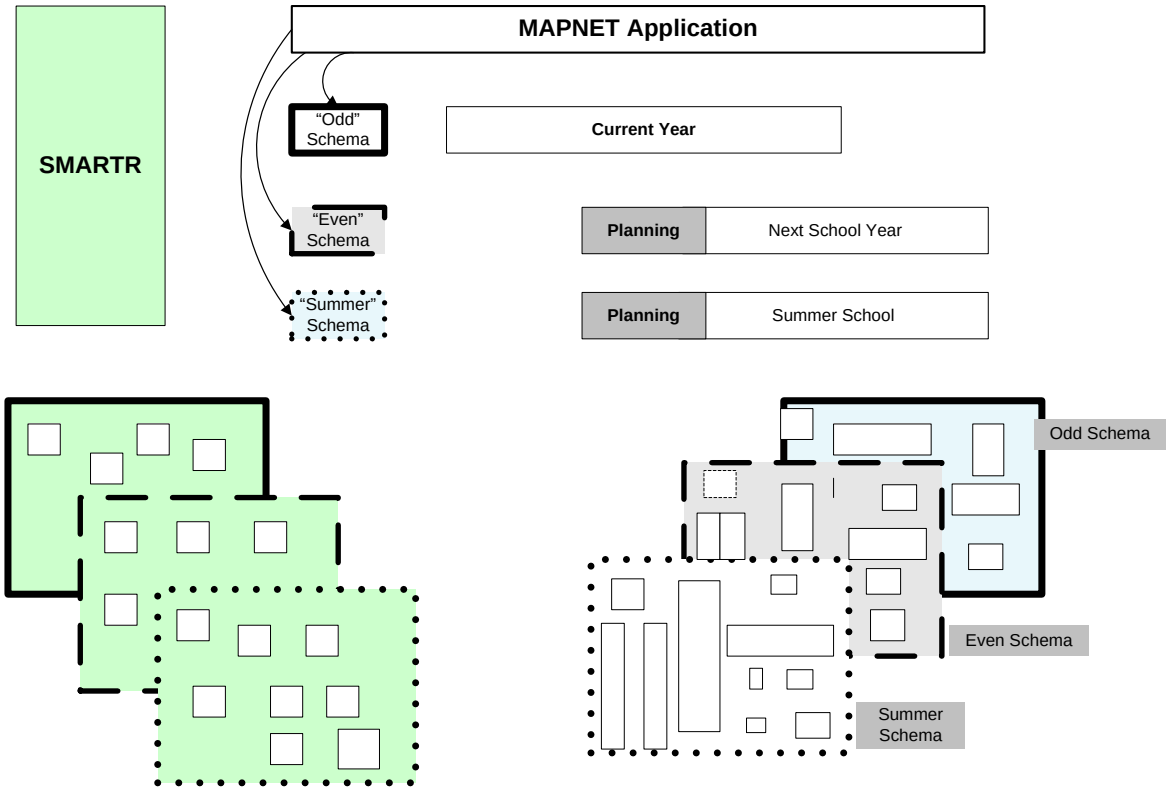
ID	Task Name	Duration	Start
1	SMARTR Implementation	272 days?	03/10/03
2			
3	Build Requirements for RFP	181 days?	03/10/03
4	Develop Draft Request for Proposal (RFP)	30 days	03/10/03
5	DoTs Review of RFP	3 days?	04/21/03
6	Final Draft of Requirements	8 days?	04/24/03
7	RFP Delivered to Purchasing	1 day?	05/06/03
8	Distribute RFP to Vendors	0 days	05/09/03
9	Deadline for Vendor Questions to Purchasing	6 days?	05/09/03
10	Proposal Deadline to Purchasing	0 days	05/23/03
11	Evaluation of RFP by Implementation Team	7 days?	05/23/03
12	Vendor Demonstrations	2 days	06/12/03
13	Due Dilligence of vendor proposal and client history	95 days	06/16/03
14	Award Contract	0 days	11/18/03
15			
16	Project Documentation	159 days?	07/28/03
17	Project Initiation Documentation	5 days	12/01/03
18	Define Project Team	2 days	11/17/03
19	Develop Project Timeline and Plan	2.5 days	12/01/03
20	Project Kick-Off Meeting	0.11 days?	11/19/03
21	Project Team review and approval of project documentation	3 days	11/19/03
22	Signoff of Project Documentation by Project Sponsor	1 day?	11/24/03
23	Preparation of TARC submission	5 days	11/25/03
24	Preliminary review of TARC submission with DoTS & Student Services	3 days	12/02/03
25	Submit SMARTR Implementation through TARC	0.5 days	07/28/03
26	Submit SMARTR Implementation to Change Control	0 days	03/15/04
27			
28	System Requirements (First Build Cycle)	18 days?	11/17/03



Migration Challenges

In general, the biggest challenge in migrating from the MapNet-based system to that based on SMARTR, was the daily management and output of Route planning, and delivery of route reports. A new system was needed to be designed and gradually brought on-line, while the old one needed to be kept operational for day-to-day work. Since the project was initiated in December, the holiday season and vacations needed to be accounted for. As planning commenced, implementation timeline of only 6 weeks emerged. As a result, only cursory review of business processes was conducted. The following diagram explains how MapNet Schemas were migrated into the corresponding folder system for SMARTR.

Figure 3: Mapnet to SMARTR Migration Diagram.



The following are some major migration challenges that the Routing Group faced during implementation:

- **Server connectivity**: While four separate data builds were created, tested and validated, each was only a subset of the total database to be delivered in the production roll-out. The difference between test and production database, resulted in server connectivity and multi-user environment issues. It was found that a 100 megabit connection was required to support the amount of data passed from the server to the desktop.
- **Database Architecture**: There was no standard Data Architecture or table structure provided by the SMARTR vendor, EPS. The Routing Group had to design the detailed Data Architecture as an internal action. While the District would have been satisfied to implement from pre-fabricated architectural templates, considerable and valuable time was required in designing the right architecture and performing a number of optimization efforts.

- **Lack of Documentation:** There was a lack of formal documentation for operational procedures and user guidelines. While implementing, the Routing group spent some time completing documentation to provide direction, instruction, and general communication of Routing operations and procedures.

- **Multi-user environment**: Current releases of the SMARTR application and its design with ArcView do not support a multi-user environment. Since the District updates its students data daily, data administration and need for "check-in/out" procedures were deemed critical to counter that.
- **Duplicate Stop_id**: During data migration a unique stop id was migrated from the old Mapnet Routing system to SMARTR. Then, the SMARTR application also generated a unique stop id with an AM or PM stop id on a student record based on the time of day. This minor utility briefly addressed in training sessions as not utilized correctly, causing data corruption, duplicate records, and general delays in meeting the needs of the Routing Department.

While the SMARTR application had been installed and was operational as of March 1, 2004, limited capability existed due to data issues noted above. As a result, during the month of March, Routing personnel were challenged in providing timely analysis while responding to the issues listed above.

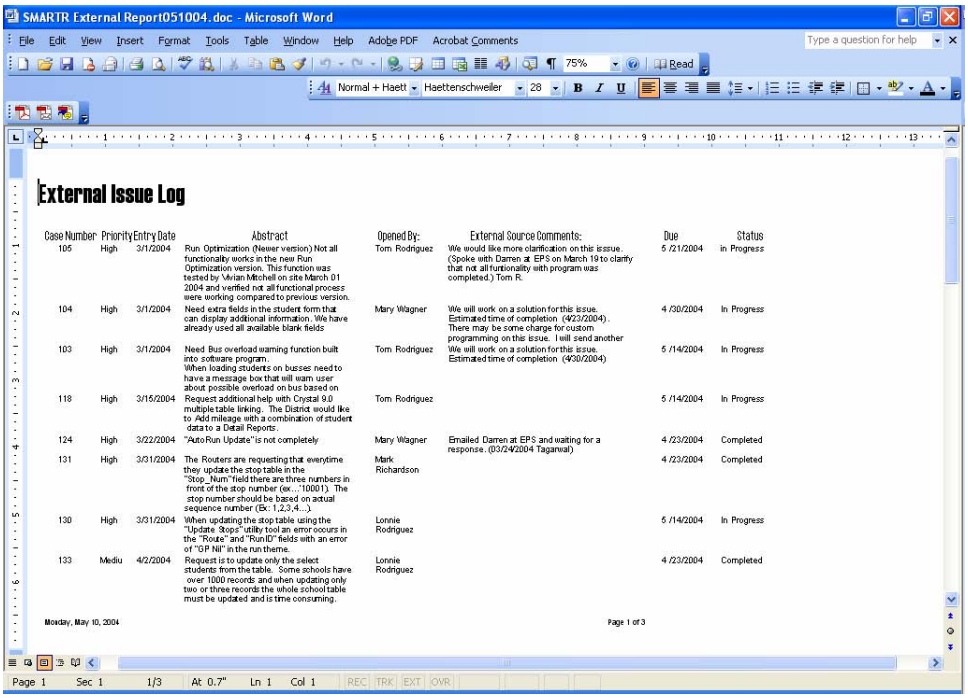
Additional Functionality - Enhancements

Core implementation was quite basic. The District quickly uncovered the need for a number of additional advanced functionality soon after MapNet expired and SMARTR came on-line. The following functionality was provided by the vendor over the ensuing nine months.

- PM pickup/dropoff fields in the Students database
- Script that shows duplicate Students_Id and Stop_Id
- Detailed documentation on Route Optimization & efficiency
- Utility to add merge runs and populate miles
- Time stamps on student data
- Update-Stop error utility along with Auto run update
- Compile update function
- Capability of editing text of special education run and regular run schedule

SMARTR Issue logs: Internal, and External Issue logs were created to collect issues to ensure effective and timely communication of problems encountered or recommended improvements. The internal Issue logs were designed to collect all the issues related within the Transportation department internally. External Issue log was designed to disseminate any and all issues related to the SMARTR application itself.

Figure 4: SMARTR Issue Log Example



SMARTR External Report051004.doc - Microsoft Word

External Issue Log

Case Number	Priority	Entry Date	Abstract	Opened By:	External Source Comments:	Due	Status
105	High	3/1/2004	Run Optimization (Newer version) Not all functionality works in the new Run Optimization version. This function was tested by Vivian Mitchell on site March 01 2004 and verified not all functional process were working compared to previous version.	Tom Rodriguez	We would like more clarification on this issue. (Spoke with Darren at EPS on March 19 to clarify that not all funtionality with program was completed.) Tom R.	5 /21/2004	in Progress
104	High	3/1/2004	Need extra fields in the student form that can display additional information. We have already used all available blank fields	Mary Wagner	We will work on a solution for this issue. Estimated time of completion (4/23/2004). There may be some charge for custom programming on this issue. I will send another	4 /30/2004	In Progress
103	High	3/1/2004	Need Bus overload warning function built into software program. When loading students on busses need to have a message box that will warn user about possible overload on bus based on	Tom Rodriguez	We will work on a solution for this issue. Estimated time of completion (4/30/2004)	5 /14/2004	In Progress
118	High	3/15/2004	Request additional help with Crystal 9.0 multiple table linking. The District would like to Add mileage with a combination of student data to a Detail Reports.	Tom Rodriguez		5 /14/2004	In Progress
124	High	3/22/2004	"Auto Run Update" is not completely	Mary Wagner	Emailed Darren at EPS and waiting for a response. (03/24/2004 Tagarival)	4 /23/2004	Completed
131	High	3/31/2004	The Routers are requesting that everytime they update the stop table in the "Stop_Num" field there are three numbers in front of the stop number (ex...'10001'). The stop number should be based on actual sequence number (Ex: 1,2,3,4...).	Mark Richardson		4 /23/2004	Completed
130	High	3/31/2004	When updating the stop table using the "Update Stops" utility tool an error occurs in the "Route" and "Run ID" fields with an error of "GP Nil" in the run theme.	Lonnie Rodriguez		5 /14/2004	In Progress
133	Mediu	4/2/2004	Request is to update only the select students from the table. Some schools have over 1000 records and when updating only two or three records the whole school table must be updated and is time consuming.	Lonnie Rodriguez		4 /23/2004	Completed

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The Transportation Analyst was responsible for communicating with SMARTR Support in the administration of any issues and their resolution. SMARTR/EPS support worked ardently and shoulder-to-shoulder with the Analyst and DPS Team to resolve issues and provided updated patches for installation. Transportation dedicated a separate environment with DPS test data, with Test Scripts developed by Transportation to test the resulting new releases. After testing approximately 10 SMARTR patches, the Routing Group finalized a release of version 4.0. The SMARTR Routing group's desktop PC's were upgraded with this new release which has proven to be much more stable and efficient.

Benefits of SMARTR

The following are some major benefits of SMARTR:

- **Improved Organizational Integration**: With the SMARTR application, the District has been able to share transportation and school related information across its departments, and with agencies such as the City and County of Denver, RTD, etc. Also, with implementation of SDE (Spatial Database Engine) and the creation of a shared database, departments can benefit from each other's work – data can be collected once and used many times.
- **Routing information available through web server:** Schools can access the bus routes through a secure web server. This eliminates the need for sending changes to the schools through interdepartmental mail. Additionally,

Transportation now has the ability to make the SMARTR database elements available such as stops, bus and accidents via the ArcIMS website to the users.

- **Incorporate data from various departments**: The District will be able to incorporate accident and driver's data within the SMARTR application from Safety and Training department. Also, we will be able to convert safety and security issues related CAD drawings into SMARTR from the Facilitates department. The system also has a Fleet management tool that can track maintenance on vehicles.
- **Better Decisions**: Sharing common data and software tools, such as SMARTR, has allowed the District to make better decisions relative to forecasting needs of new schools, special programs and student analysis in heavily populated areas. All the departments now share and view the common map data. The Run Optimization tool will help increase the efficiency of the District's transportation by optimizing bus load factors, and hence, optimizing the number of buses and drivers required. The SMARTR application provides tools to query, analyze, and map data in support of the decision making process.
- **Making maps:** Making maps within the SMARTR application is much more flexible such as aerial, bus route, walk zones, parcels, and hazards related maps.
- **New Open system / flexibility:** The previous Transportation Routing system was a closed system that did not allow on demand geocoding or analysis of features with any census or spatial map data. The new SMARTR system is an open system that allows flexible changes on any table, layers and allows the user to add additional fields for analysis.
- **Ad-Hoc-Reporting:** The new system allows users to customize their report with Crystal Reports. It is now much easier to design Bus cards and Transportation exception templates within Crystal Reports. Additionally, Crystal Reports generates PDF documents detailing bus times and route change information for school office support and departments.
- **Real Time Bus Tracking:** The District is investigating implementing a real-time bus tracking GPS system and considering the SMARTR's extension/utilities.
- **Data Accuracy:** With the SMARTR application, the data has proven to be much more accurate than the MapNet data. Specifically, issues previously encountered with MapNet include accurate time, speed and mileage on the reports.

Return of Investment Examples

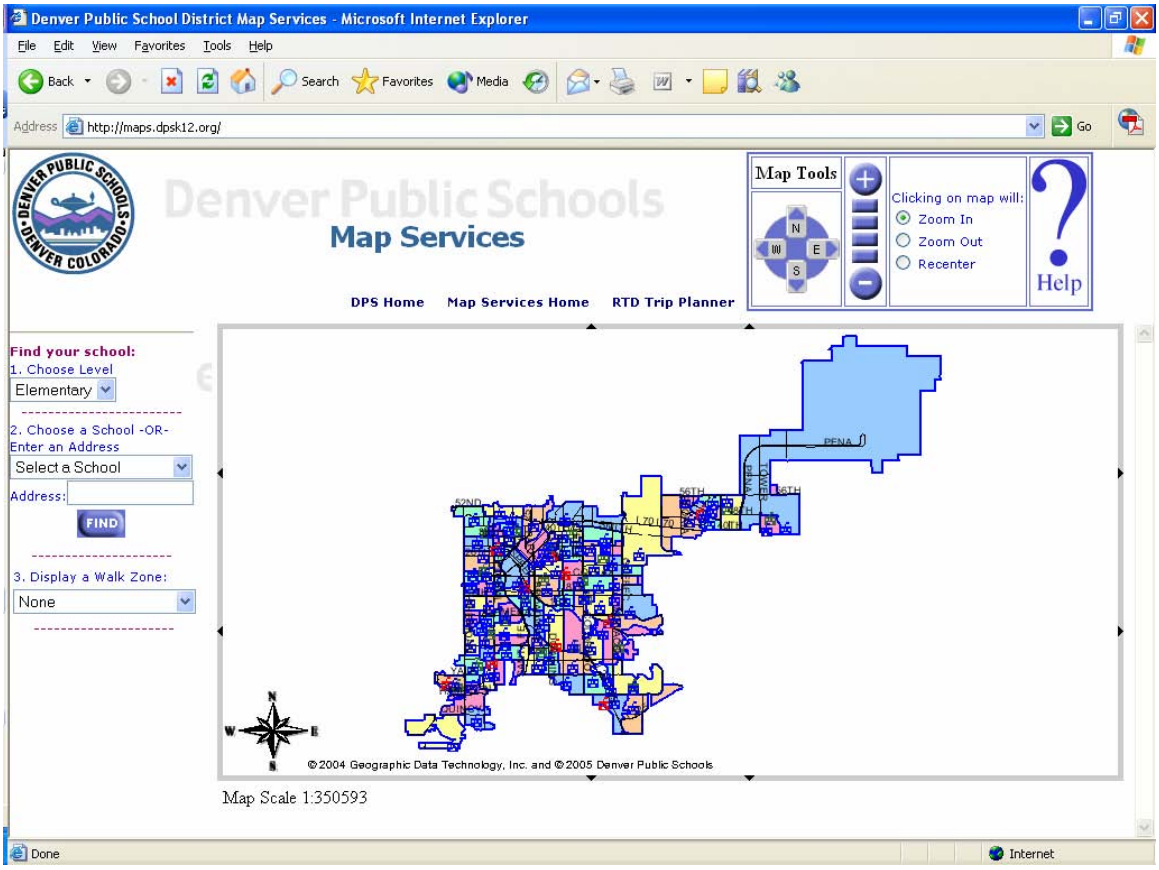
The following are some early indicators regarding early Return on Investment with SMARTR.

1. **RTD Bus Pass Assignment Process:** To give high schools flexibility in starting their days and offering additional academic opportunities to students, the Board of Education decided on March 18th 2004 that DPS would rely on the Regional Transportation District (RTD) system to transport high school students to their school or magnet program beginning with the 2004-2005 school year. RTD bus pass assignment in SMARTR is faster than the old MapNet system. It is quite easy to query all the students who are eligible from outside of 3.5 mile walkzones and assign those to RTD Bus passes. Given the ease-of-use of SMARTR to accomplish this,

DPS projects savings resulting from this resource optimization.

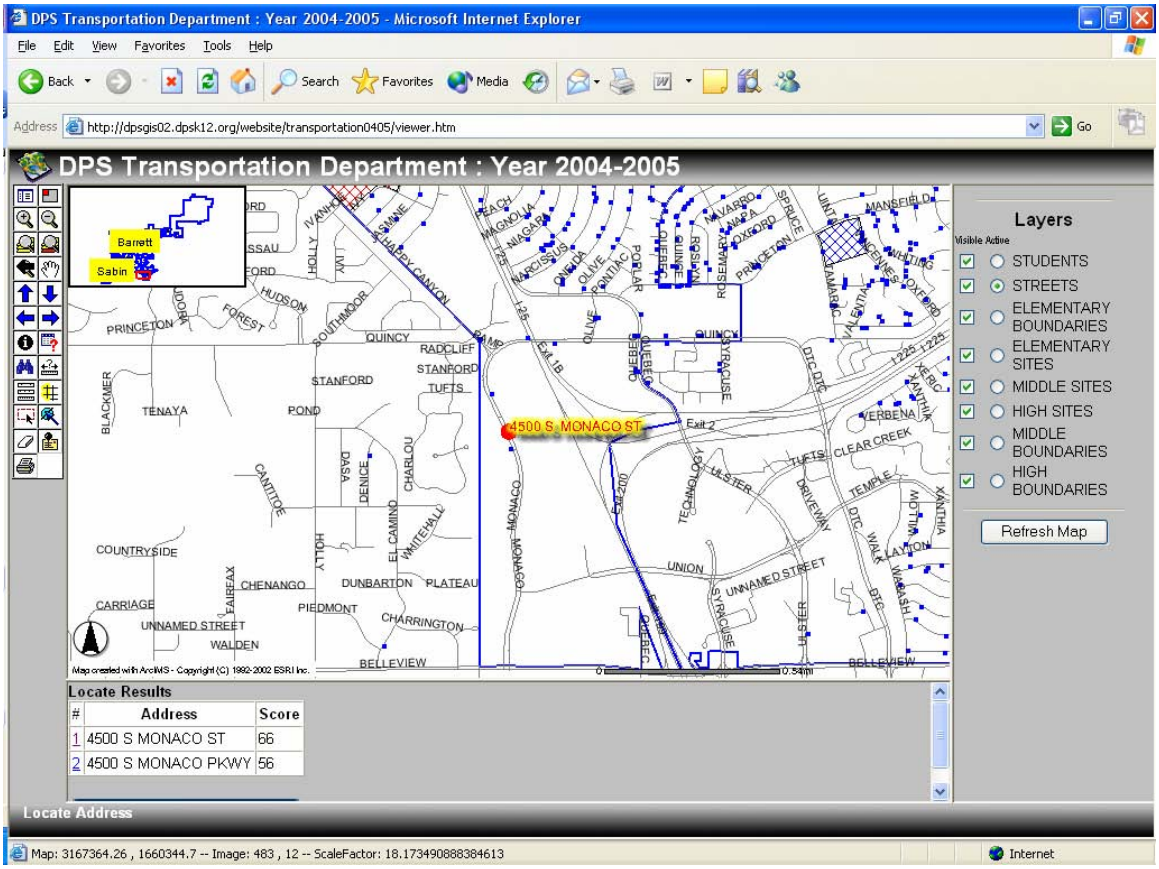
2. **Map Services Website:** The DPS GIS Project Team created a Map Services website. This new tool allows schools to locate neighborhood schools and give them a visual representation of addresses in relation to the school of attendance. This website uses walk zones created from SMARTR, allowing information sharing with schools and other departments. If the address entered in the website is within this school's walk zone, transportation will not be provided to the schools. One can view the visual representation of the walk zone by selecting any school from the Walk Zone dropdown. This self-service mode of communication has made it easy to provide up-to-date information to interested parties while reducing the overhead for communication, and increasing target user satisfaction.

Figure 5: DPS Map Services website



3. **Transportation ArcIMS Website:** This website (separate from Map Services Website) is designed for the Dispatch/ Terminal managers and supervisors to locate addresses or emergency phone numbers for any students. The Transportation Student database is uploaded every morning through SDE, which is accessed by ArcIMS tools to provide the ability to query student data. Dispatch can now access the information directly without invoking time-consuming calls to Routing.

Figure 6: Transportation ArcIMS Website



4. **Sharing streets map across departments:** Easy sharing of the street map with other departments is extremely important towards providing a unified GIS system. With the old MapNet, a number of divergent mapping systems existed, each with its costs associated with obtaining and maintaining data. Now, different departments use the same Streets data which helps tremendously with reducing inconsistencies and data maintenance costs. The method used to update the metadata required cumbersome hours of manual edits using the MapNet tool as a source to draw when street reconciliation was necessary. This rudimentary method of drawing maps forced Transportation to sacrifice the level of accuracy expected in an x, y coordinate grid overlay system.
5. **PDF Report Distribution:** The reporting structure in MapNet was inefficient, and reports were provided manually – with drivers carrying them physically over to each school or by mail. SMARTR has better reporting capabilities and outputs utilizing Crystal Reports as PDFs which are simply emailed to the schools.
6. **Cost Projection for a new Attendance area:** There was a significant time savings with the cost projections utilizing SMARTR. Attendance area proposals took more time in MapNet and are much quicker in SMARTR. The data in SMARTR is also much more accurate.

Road Ahead

Overall, SMARTR is emerging as a success for Denver Public Schools. It fits with the District's general strategy of implementing GIS-based sub-systems that are compatible with corresponding state-wide systems. It also feeds the Transportation ArcIMS website that is now able to produce student emergency contact information, saving Dispatchers multiple time-consuming calls to the Routers to obtain basic data. Another immensely popular feature is SMARTR's ability to produce PDF documents such as route reports, transportation exception reports, bus cards and mailing labels.

DPS is now working to establish best practices work-flow with business processes using its GIS. We expect this effort to lead to quick generation of What-if Scenarios and Run-Optimization functions. Denver Public Schools is in the process of implementing Arc SDE for all the departments to move to a multi-user editing environment. The GIS Project Team is also working on establishing SDE connection with the existing Data warehouse. DPS will redefine Geo-database Design model in new ArcGIS SDE environment including topology, domains, and relationship classes with the impending "SMARTR for ArcGIS 9.0" version. Eventually, DPS would like to create various ArcIMS websites for different departments and receive data from the SDE along with the data warehouse.

The SMARTR implementation project has required flexibility and adaptation by the existing GIS systems and the people managing them. While a lot of work remains to be done, it is clear that DPS is moving its transportation planning strategy in the right direction with the help of SMARTR.

Acknowledgment

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Kerry Somerville, CEO EPS
Darren Watson, Support EPS

References

www.SMARTR.com, “Education Planning Solution” website.

Author Information

Tripti Agarwal
Transportation Operations Analyst II
Denver Public schools
Transportation and Hilltop Services
2909 W 7th Ave
Denver, CO 80204
Ph No: 720 423 4675
Fax: 303 575 4615
Email: tripti_agarwal@dpsk12.org