

Arizona's New GIS Partnership for a Composite Roadway Framework

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ABSTRACT

Arizona Department of Transportation (ADOT), in conjunction with the State Cartographer's Office and the Arizona Geographic Information Council (AGIC), is building a partnership among government agencies in Arizona. The intent is to update and further develop the GIS framework database of Arizona's surface transportation network.

The updated GIS source inputs are the best available network databases, as contributed by the local data owners. These are amalgamated by ADOT into a single statewide coverage that represents each agency with their own best data. This statewide coverage will eventually represent Arizona's surface transportation network in TIGER so that federal and commercial applications will contain the same source data as the local-maintained databases.

ADOT has developed the Arizona Transportation Information System (ATIS) model, as well as technology for local agency integration procedures, over the last few years. A host of applications (e.g. highway inventory, motor vehicle crash, bridge, and more) already exist. Some are already available as inventory and analysis tools to benefit any government agency in Arizona. Over the past 12 months (April 1998-March 1999) a field operational test has been conducted to prove the efficiency and validity of the developed procedures. Next ADOT will begin working with several agencies (local, state, tribal, and federal) to integrate their individual centerline databases into a composite mosaic of the entire state.

This paper will briefly summarize the history of Arizona's GIS program on its 25th birthday. Developments of the past year, including this partnership among agencies at multiple levels of government, will be detailed. An outlook for the coming years of development is also presented.

HISTORY

The beginning – Arizona DOT initiated the development of their modern day geographic information system centerline coverage in 1969 when for the Accident Location Identification Surveillance System (ALISS) called for a link-node centerline model for plotting crash locations and identifying traffic safety hazards. Mapping of the entire state began in 1971 and was essentially complete by 1975, making Arizona's GIS base map 25 years old as of this writing.

Source and Staff – The centerline model was created by digitizing photogrammetric maps and orthophotos (1:12,000 urban and 1:24,000 rural). The process of naming the roadways and assigning ownership (after digitizing) involved extensive cooperation of state and local agencies through marking up link-node diagrams and entering the attributes into the IBM mainframe database. The coverage matured with consistent maintenance until 1991 by a crew of three staff (as many as 20 staff during early peak period) in ADOT's photogrammetry shop.

Rural Concerns – Disparate levels of growth (as well as staffing support) in urban vs rural agencies led that many of the rural areas received little, if any, centerline maintenance updates in the post-deployment years after 1975. Even though Arizona's growth rate resulted in a negligible amount of new rural road building, there were still significant issues in rural areas with regard to road re-naming due to annexations or general name changes that weren't being updated.

Urban Updates – Urbanized areas like Phoenix, Tucson and Sierra Vista received more attention regarding updates. In fact, when Maricopa County entered the GIS arena in the early 1990s, they began by jointly and cooperatively working with ADOT to update ADOT's centerline file. This was the first example of what would later (i.e. presently) become a workable model for interagency data coordination. Maricopa County then took a clipped portion of the then current file and proceeded with it's own centerline maintenance program.

Reorganization – By 1992, the governor's Statewide Long-term Improved Management project (SLIM) focused on reorganizing ADOT's priorities. Staff with

expertise either left ADOT or were needed for other priority efforts leaving Photogrammetry without the staff and expertise to continue maintenance of roadway centerlines. The ALISS tabular database continued on the course of routine data input but maintenance of centerlines in the GIS link-node map took a back seat to general technology updates.

Prescription – The intent of Project SLIM was not to eliminate the link-node map or the ALISS database, but rather to stimulate ADOT into acquiring higher technology solutions for accomplishing the same tasks with significantly less manpower. This resulted in the migration of the ALISS database to a Sybase (and then SQL Server) environment by 1997. Within the same period of time, the link-node map migrated to an Arc/Info coverage and was named *ATISroads* (for Arizona Transportation Information System roads coverage). While these systems were migrating (using contractors rather than full-time employees), centerline maintenance to improve content remained essentially stagnant.

REBIRTH OF GIS

Project-based Development – During the period of 1992-95 the link-node map migrated into a coverage format to provide continued support of the ALISS database. Meanwhile, ADOT took a “reserved” position on agency-wide GIS, reflecting on expensive or unsuccessful startups in other states, the ever transitioning GIS technology, and the lack of manpower in the Photogrammetry shop. Instead, ADOT fostered a concept of grass-roots “project-based” GIS development. This allowed that all (if any) GIS development could grow out of a by-product, end product, or consequence of “other” approved database development projects using GIS.

HPMS Projects Lead the Way – In 1995, the FHWA’s Highway Performance Monitoring System mandated that all states begin reporting “linear referencing” attributes for roadways on the principal arterial system. This led ADOT Data Section leaders to consider using the new Arc/Info coverage version of the link-node map to satisfy the mandate. Therefore, ADOT began developing its robust linear referencing system with funding supplied by FHWA for HPMS annual reporting. The project was not a GIS project per se, but instead used GIS to achieve an end result, thereby producing the first of many low-profile success stories.

A Model is Born – Recurring annual submittals of HPMS data gave ADOT an opportunity to program several successive defined 6 to 9 month projects that were mandated to produce database results and yet exploit linear referencing technology and GIS. ADOT stayed away from extended-term, multi-player, strategic GIS planning to the *n*th degree. Ironically, with project-based

GIS and ADOTs consistent use of the same 4-5 person “think-tank” to guide the projects, Arizona’s GIS architecture evolved into one of the most robust among states.

Other Database Projects Follow – Once the HPMS data needs exploited the use of GIS in the agency, several other areas of data development also required (or directly benefited from) the continued use and development of the GIS base centerline coverage. Over the course of 1995 to late-1998, several GIS success stories involving the ALISS crash database, the Highway Inventory Log, the Highway Video Log, the National Bridge Inventory, the Pavement Management System, the Highway Closures and Restrictions System, and the Priority Programming Process led to more general acceptance of GIS in the agency.

Centerline Precision becomes an issue – As GIS became more generally accepted within ADOT, the accuracy of the centerline position as well as the location of the reference (mile) markers became an issue of increasing awareness. Hence, the Data Section initiated a GPS centerline acquisition program designed to generate GIS-grade (i.e. sub-meter) traces of centerlines as well as reference marker locations.

FINALLY, A FUNDING SOURCE

TEA-21 to the rescue – By October 1998, ADOT realized a significant gain in federal funding for transportation planning issues as a result of the newest transportation legislation passed in Washington DC. The influx of new planning money meant the agency finally had a funding capacity to consider GIS base map development. Hence, ADOT would let its first dedicated GIS development contract in years. ADOT put out a RFP for programming the future development of the centerline coverage to meet the future GIS needs of local, state, and federal agencies.

Approach – The successful proposal for providing technical assistance for the *Centerline Update Project* satisfied a multi-faceted approach required by ADOT. This approach would allow the centerline coverage to grow in accuracy and completeness at the same time the robust linear referencing system evolves to satisfy the many clients of the GIS coverage. The approach included:

- Research to identify the best road/street centerline data available (if any) for all areas of Arizona.
- Development of GPS data collection procedures for local agencies to contribute to the statewide effort.
- Development of methods of bulk incorporation of “best-source” GIS centerline files into the *ATISroads* coverage.

- Development of methods for piecemeal incorporation of GPS traces and reference markers gathered by ADOT or local agencies.
- Sustainance and improvement of the robust linear referencing system and geocoding procedures.
- Re-registering (i.e. conflating) older data sets to the upgraded linear referencing system.
- Conformance for anticipated future issues such as address geocoding, tourist map, vehicle (best) route algorithms, and improved integration with the Photo Log van.
- Making the coverage comply with Federal Geographic Data Committee requirements.
- Instituting sound quality control procedures.

The project was funded at \$275,000 for a 12-month period ending in late-March 2000. (Additionally, ADOT funded another \$75,000 for GIS technicians provided by the contractor to alleviate a then current man-power crunch.) Sustained development was anticipated to require two additional funding years at best. Over the course of the 3-year development and update cycle, the GIS centerline coverage is expected to reach a level where only routine day-to-day maintenance is required.

PARTNERSHIP UPDATE EFFORT

Philosophy – ADOT’s philosophy in GIS centerline acquisition is that nobody other than the local government agencies can provide good solid information on the naming, ownership, etc. of individual roadways. Therefore, a statewide effort to update and maintain the roadway centerlines will have to include extensive cooperation and input from local agencies. However, many local governments cannot acquire spatially accurate centerlines. ADOT would bring potential partners into the fold by providing the technology and training so that local agencies can use ADOT-provided GIS and GPS tools to acquire centerline traces and properly attribute them for inclusion into the statewide coverage. ADOT had previously developed integration tools for adding and attributing centerline traces and storing the work as transactions to be applied the *ATISroads* coverage. This integration happens after the agency has acquired the centerlines from any adequate source or preferably differential GPS (technology/training by ADOT).

Bulk Processing for Established GIS databases –

Larger agencies already accept that GIS is a required tool for transportation and facility planning in the present day. Many of these agencies have already established partial or full-blown GIS capability and have existing centerline files. With such agencies, ADOT’s objective is to process existing GIS centerlines and bulk-integrate the locally owned roads into ADOT’s GIS centerline cover, maintaining ADOT’s (GPS-collected) version of its own roadways and exchanging ADOT’s out-of-date

representation of local roads for the local agency’s own centerlines. The ownership of the data integrity is thereby retained within the local agency.

A Common Set of Tools – ADOT provides the tools, technology, and a flexible set of guidelines that encourage the small and large local agencies to adapt to a grander regional or statewide philosophy for GIS for transportation planning. Once an agency supplies its data to ADOT for *ATISroads*, ADOT processes and returns the data conforming to statewide standards. ADOT aims to retain the characteristics of the local-derived centerline files to satisfaction of the local “bulk-integration” agency. The key is to build a flexible foundation for all agencies to share and benefit from statewide GIS – supported by ADOT but fueled by local concerns. The tools built for (or by) one agency are intended to be useful for any agency and the local technology assistance provided through interagency cooperation gives all agencies an advanced capability for transportation GIS.

INTEGRATION SO FAR

Bullhead City – ADOT’s first pilot effort was to work with Bullhead City to acquire centerline traces for what turned out to be 100 miles of city streets that had been constructed since the previous update of that area for the *ATISroads*. ADOT traveled and collected the required information in about 18 hours. Since 40 hours were allotted for field data collection, all of the other streets in Bullhead City were also acquired in the remaining 22 hours. With this complete GPS data, all the original digitized centerlines *could* be replaced with GPS-derived traces, if desired, by the local agency.

Another 40 hours was spent scrubbing the traces (mending and removing curves at intersections) and attributing the missing arcs with the minimum amount of information (including address ranges) to satisfy ADOT requirements. Then ADOT met with Bullhead City and showed them what was accomplished. Twelve hours was spent training a CAD technician from Bullhead City.

At this point, ADOT could have taken the centerline transactions and integrated then into *ATISroads* to provide and updated representation of that area. However, ADOT had 8 months left in the contract period and instead gave control of the data to the Bullhead City technician so the local agency could process the entire city with address ranges and supply 100% GPS-derived traces for the transaction file. The overall process is estimated to require 40-80 hours of time from a skilled GIS technician. However, the Bullhead City technician has existing work activities and hasn’t been able to apply a significant duration of time toward the GIS centerline task.

This “institutional” issue is hard to evade in small agencies. However, it does represent fallibility in the methodology of depending too much on the local agency. If patience is a virtue, our experience with Bullhead City is expected to result in an eventual benefit because the local agency is being very meticulous in assembling the data. In addition to the GPS trace sources, the local agency is also using COGO from CAD drawings and brand new aerial photography to aid in the validity of the GIS centerline coverage. In this case, the local agency CAD technician is a part time fireman and expects to use the product to develop the City’s E-911 system. Therefore, we expect that a comprehensive and highly accurate GIS centerline file will evolve from this pilot experience once Bullhead City applies the proper resources, and/or ADOT supplies some additional technical assistance.

Navajo County – Our experience with Navajo County followed too shortly after the experience with Bullhead City. In retrospect, we strongly recommend that the entire process (collection to scrubbing to integration) be concluded before launching into a second pilot study area. The reasoning for tackling both agencies in series was for comparison of city (small area and high density) versus county (large area but low density) areas.

We collected 363 centerline miles of unrecorded corporate roadway in Navajo County in approximately 4 tech-days of drive time. This was a much better rate for a county due to the higher speed limits in most areas. We spent another three days in the area collecting additional GPS traces in other “previously mapped” areas for comparison and eventual use by the county – should they desire. The previously unrecorded data was reduced by ADOT to centerlines (but addresses were not added – as they were in Bullhead City) in about one tech-week of time.

The end effect of the Navajo County pilot program is relatively the same as in Bullhead City. ADOT showed the data to Navajo County and they took over the quality control following a 12-hours of training over 2 days. Navajo County’s intent was to conform their rural addressing scheme to the GIS methods of centerline attributing and adopt the new information as their corporate centerline file. As could have been expected, the County has not able to apply enough specialized resources to the task without interruption by other pre-existing activities. ADOT would have integrated the data immediately after collection and initial scrubbing if it had been known that it would take a lengthy time to get locally QA/QC’d results back from the local agencies. As of this writing, ADOT still expects results in form of a quality centerline file just as soon as County staff can address the task and/or ADOT lends further assistance.

Once the GIS information is received, it will take about ten hours to integrate into the statewide centerline GIS and copy back to Navajo County complete with full-blown linear referencing capabilities.

Pima County – With Pima County, ADOT planned a “bulk integration” to gather the latest version of the entire county centerline cover and procedurally combine the best representation of state-owned roads (from ADOT’s coverage) with the best representation of non-state-owned roads (from Pima County’s coverage). However, there were some significant positional accuracy issues that kept ADOT from “throwing out” their own outdated (but highly positional accurate) centerlines of the local system for the purpose of acquiring a more updated and complete (but less accurate) line work. Current Pima County centerlines are assumed from the parcel GIS base.

So instead of combining the two data sources into a the statewide coverage, ADOT instead skipped over the integration effort and was able to retrofit Pima County’s coverage with ADOT’s own robust linear referencing system so that the data would work well inside of existing ADOT-provided applications. This was accomplished quite easily (a matter of a few day’s time) and proved that ADOT’s technology was advanced enough to allow the statewide system to work within the County-derived data – without integration. This means that any local GIS centerline can be made to appear to be part of the statewide system without actually being conjoined in the same coverage.

ADOT’s current stance with Pima County is to demonstrate the robust linear referencing system and associated tools to the county so that they can benefit from free linear referencing technology – a desire and need of the agency. ADOT hopes that such an approach may spur the agency into working towards improving the spatial accuracy and attributes of their centerline file. In absence of Pima County conforming to these suggestions, the statewide program can still carry on with ADOT’s data **or** the local data for Pima County. This is because the statewide GIS tools provided by ADOT will allow for either data set to represent Pima County. Through encouragement and the example of more successful experiences (such as Cochise County below), ADOT hopes to persuade all government entities of the usefulness and importance of one statewide integrated centerline GIS supported by linear referencing.

Cochise County – The surprise findings of the early research phase of the project was when we discovered that Cochise County was soon completing a GIS centerline acquisition project of their own that would allow them to replace the old and inaccurate centerlines that their GIS infrastructure was previously built upon.

Cochise County was able to provide highly accurate data to ADOT at the very time that ADOT realized that the Pima County data was not going to be desirable for complete integration into *ATISroads*. Therefore, ADOT was able to carry on with the “bulk integration” pilot development and prove that their integrative technology for different data sources was indeed a feasible and cost-efficient solution to maintaining a composite roadway framework. The current version of the ATIS CD Reference Library contains four versions of Cochise County:

1. The original version (circa 1998) because conflation of living databases such as HPMS has not yet occurred.
2. The version after bulk integration called the “hybrid” version. This is ADOT’s ultimate target product.
3. A copy of the “hybrid” version that is projected in Cochise County’s own desired projection, so that the county can use it with their other GIS databases.
4. A copy of Cochise County’s local centerlines with Cochise County centerlines of state-owned facilities – projected in their own desired projection.

The purpose of keeping so many versions of the same county (at least for the short term) is to promote the idea that everybody can have their own flavor of GIS that is banded together by linear referencing technology. Of course, the objective is to maintain a single master file, but then allow up to two versions of any jurisdiction to exist. One of those versions will be projected in the statewide desired projection while the other will be projected in the local jurisdiction’s desired projection (if different).

PROJECTING TO THE FUTURE

Satisfying the Needs - ADOT has big plans for the use of GIS in nearly every area of the transportation business. Many of the business needs transcend the state-owned right-of-way and involve local government issues. Therefore, the need for partnering to develop the composite roadway framework is essential for reducing the burden that GIS might otherwise create on multitudes of agencies.

Looking at the 2nd Year – With continued support of the Federal Highway Administration, ADOT has accepted the challenge of promoting and coordinating with those agencies that wish to benefit from low cost, highly efficient GIS for transportation. As the project prepares for its second year of implementation, the counties of Mohave, Coconino, Maricopa, and Yavapai are making preparations for supplying their existing data, or going out to collect their own data with GPS. Likewise, the Navajo Nation, cities like Flagstaff, and the council of governments that represents Pinal and Gila counties are anxiously awaiting the opportunity to share with and benefit from the composite roadway framework.

Statewide Applications - Furthermore, specialized applications that previously had been developed and been available only for managing state-owned facilities are now being made available for other government agency use. For example, the maintenance management system developed by ADOT will soon be fitted with linear referencing attributes compliant with *ATISroads* so that ADOT’s 13-million-record maintenance history will be available in GIS format. This same system will then be scaled for local government use (first) in Cochise County, where the GIS is arriving at a new height of usefulness and efficiency, thanks to Arizona’s Partnership for a Composite Roadway Framework.

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FURTHER INFORMATION

This paper represents the 9th formal paper/presentation at GIS-T in six years regarding ADOT’s GIS development program. Information on most previous articles can be obtained by contacting the principal author, or by visiting: <http://www.gisworks.com/library>

For more general information about the Arizona Transportation Information System, visit: <http://map.azfms.com>

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