Autodesk Infrastructure Solutions

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CAD and GIS—Critical Tools, Critical Links

Removing Obstacles Between CAD and GIS Professionals

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Introduction

Engineering design and geographic analysis are extremely important to the organizations that employ CAD and GIS. These distinctive technologies deliver mission critical answers and excel at discipline specific-tasks that the other performs poorly or not at all. However, there is increasing demand for CAD and GIS software that is well integrated. Integration helps professionals throughout a project lifecycle to exchange data and collaborate more efficiently. This Strategic White Paper sheds light on this topic with technical details, highlighting the specific strengths of two technologies and the important need for integration.

Professionals design, map, and analyze infrastructure constantly, from roads and utilities to land development and land ownership. These professionals rely on digital geographic and design data to perform their tasks. Furthermore, data is not static; it moves and evolves, from creation to editing to management. Today, engineering, GIS, surveying, and IT departments are collaborating and sharing geographic and design data more often and more smoothly, and Autodesk® is leading the industry in making this change possible. Integrated CAD and GIS solutions make a whole organization more effective and profitable, not just a single department.

Key topics surrounding this discussion include

- CAD and GIS, while distinct technologies with discipline-specific tools, are inseparably linked by one thing – the very infrastructure they both portray and analyze
- Translating data between CAD and GIS software can introduce errors of precision and accuracy
- Organizations profit when data moves smoothly, without errors or precision loss, back and forth between a CAD and GIS

CAD and GIS: A Historical Overview

Historically, CAD has been identified with powerful precision data entry and editing tools for engineering design, and GIS has been associated with spatial analysis and mapping. Many organizations employ both CAD and GIS tools in different departments because these tools offer different specific features. Data from original CAD drawings was frequently imported or digitized for use in the GIS mapping environment. Unfortunately, this was often a one-way trip, with data losing connectivity, accuracy, and geometric precision, and users incurring potential liabilities for these errors. Rarely did the GIS software support the engineering precision and accuracy required in case the data needed to move back to a CAD for further design tasks. These were the fundamental problems of early CAD and GIS integration, which are being addressed today.

Engineering and GIS professionals and their clients now require much tighter integration—they need precision data capture, creation, and maintenance tools, whether for surveying, mapping, or engineering design. And these tools must be fully integrated with database and analysis capabilities. They also want full process and lifecycle integration, so they can pass digital geographic or design data transparently between project team members at any point, and, later, to downstream users, such as operations managers, facility managers, field technicians, and, in some cases, the general public.

For the traditional GIS vendors, the move to lifecycle and data integration has been more difficult because of their historical focus on polygon analysis without precision engineering support. In addition, many software vendors have focused on one or two of the disciplines of GIS, engineering, surveying, and infrastructure management. One company may specialize in infrastructure management by developing an electric utility management system, but they rely on other vendors for surveying and data capture tools that are rarely well integrated. Similarly, traditional GIS vendors generally do not have a complete understanding of the requirements of civil engineers. These companies form partnerships, but the result is a mixture of poorly integrated systems where data cannot move freely from surveyors to mappers to engineers to network managers and back again.

In the mid-1990s Autodesk entered the GIS industry with its flagship mapping and civil engineering products Autodesk Map™, Autodesk® Land Desktop, and Autodesk® Civil Design. Shortly thereafter, Autodesk acquired and launched a powerful mapping system designed for use on the Web, Autodesk MapGuide®. These Autodesk products were well accepted, in large part because they easily integrated data formats that were previously incompatible into a single display and analysis tool. Since then, Autodesk has expanded this family of tools for survey, specialized transportation design, mobile data distribution, centralized server storage, and much more. Indeed, Autodesk is the only vendor with a complete solution for all disciplines and platforms.

CAD Defined

CAD (Computer-Aided Drafting/Design) is defined as the use of computers for creating and editing drawings. Before the 1980s, most drawings, including maps, floor plans, and engineering designs, were created using paper and ink or drawn using expensive time-sharing CAD systems. In 1982, Autodesk introduced AutoCAD® software, bringing CAD to the PC and changing the design world forever. Many of the first CAD applications were in the manufacturing, architectural, and mapping realms, and many cadastral base maps were created using PC-based CAD solutions.

CAD software was initially file based, and the drawings were frequently organized in layers. Drawing entities took their attributes (color, linetype, and feature type) from the layer on which they were created, which was a simple and effective way to organize data but required careful quality control to ensure consistency. CAD was also characterized by powerful tools for designing real-world objects. These tools enabled users to create precise geometric objects and move and edit them with no loss of precision. Because CAD comes from a world where engineering tolerances of fractions of a centimeter or inch are important, full attention is given to managing data without losing precision.

Accuracy and Precision

Although often used interchangeably, the terms *accuracy* and *precision* mean different things. For example, the statement "The Eiffel Tower is in France" is accurate but not precise. To say "The Eiffel Tower is in Paris, France" increases the precision but not the accuracy. "Using geographic coordinates, the Eiffel Tower is located at North 48° 51.494 East 002° 17.661." This last statement is just as accurate as the first two statements but is far more precise. In a mapping context, a world map at a small scale may be accurate, but it certainly isn't precise, whereas an engineering drawing typically needs to be extremely precise as well as accurate.

Civil engineers and surveyors, for whom precision and accuracy are also of primary importance, quickly adopted CAD to speed data input and computations for design projects. Tools such as COGO (coordinate geometry) became integrated with CAD as a method of precision input for surveyors and civil engineers. CAD became the primary tool for engineering teams to design water and sewer projects and telecommunication facilities, and for surveyors to produce topographic plans and subdivision layouts. In some cases, they brought in the underlying land base from a GIS, and in others they used the CAD system to create the land base. These users often exported their completed engineering designs and boundary plans to a GIS, demonstrating the need for data to move in and out of these systems more than once.

Early attempts to use CAD for GIS data creation and management were hampered by several limitations, including

- Lack of data connectivity and topology
- File-based storage of data
- Single-user access to data and associated information
- Crude methods for attaching attributes to features

However, new software has successfully integrated CAD and GIS by overcoming these limitations and combining accurate data entry, precision design and editing tools, and GIS data management and analysis. Additionally, this software enables users to migrate or transfer data from one system to another and back again without risking data loss.

Historical CAD Limitation—Lack of Data Connectivity

Lack of data connectivity was a major limitation of early CAD with GIS systems. For example, a parcel in the land base might be created as four independent lines in a CAD system, with no connectivity or polygon topology, and therefore no indication that the four lines formed a parcel. This approach would cause problems if one corner were moved, because all adjoining lines are not updated automatically in most CAD systems. Exporting parcels to a GIS also caused problems because technicians must edit the linework again in the GIS and create the polygon topology, making the GIS version of the parcels functional but potentially affecting the accuracy of the original surveyed information.

GIS

Geographic Information Systems (GIS) are electronic systems for the storage, retrieval, manipulation, analysis, and display of geographically referenced data. GIS began to emerge commercially in the 1970s, continuing in the early 1980s with the launch of off-the-shelf GIS software.

Because of the GIS industry's early focus on land analysis and polygons, the arc/node topology model became widespread and persists to this day. The arc/node data model is useful for polygons because of its efficient data storage and the ease of computing polygon overlays. Also, an arc/node model enables users to determine whether an object is inside or outside a polygon, a necessary feature for many spatial analyses.

The arc/node topology model uses a series of points and short line segments to represent a geometric arc, whereas a CAD geometric model uses a mathematical formula to generate true arcs. Traditional GIS was aimed at general cartography and broad land-use analysis, not precision design for the construction and management of real-world projects. Although the arc node model can approximate the geometry of designed objects or "entities" in projects such as roads and communications networks, it cannot represent them with the geometric precision that many engineers demand.

Traditional GIS companies have recognized the limitations of their technology and have employed complex databases to model real-world objects. These databases can create a logical model of features and networks. However, they are still built on points, lines, and polygons and cannot store other geometric objects such as true arcs and road spirals.

Early use of GIS for design projects was characterized by several limitations, including

- Loss of geometric accuracy and precision of features
- Limited data editing tools
- Limited engineering drawing entry and data migration capabilities

Historical GIS Limitation—True Geometry and the Loss of Precision
Let's take the example of an arc used to describe a cul-de-sac in a subdivision or a curve in a road. Most CAD systems create and store an arc using an exact, double-precision mathematical description of its center point, radius, beginning point, and endpoint. This arc can later be intersected with other objects or a tangent or offset to the arc with no loss of precision or accuracy. In contrast, polygon-oriented GIS systems convert the arc to a polyline with many vertices, creating lined segments to approximate its shape, thus introducing positional error. The original arc, along with its geometry, is destroyed.

In a modern GIS workflow, data moves from its original sources to government agencies, inspectors, design firms, environmental consulting firms, construction firms, facility managers, and so forth. At each step, the data may be converted from one format to another and is often printed, handed off, and subsequently entirely re-entered. Data conversion tools introduce problems as data moves from one system to another, from geometry to vertices, and from double to single precision. For example, a user may convert double-precision Autodesk Map™ files into a double-precision GIS tool, but a proprietary spatial database (ESRI's Spatial Database Engine or SDE, for example) supports only integer data storage. When the data is extracted as a double-precision CAD layer and sent to an engineering firm, precision and accuracy are often lost. Further increasing the chance for errors, engineers may assume that the double precision is still available since the source file was a design drawing. Newer integrated software has overcome these limitations of traditional GIS by managing both CAD and GIS features in a seamless and precise database environment.

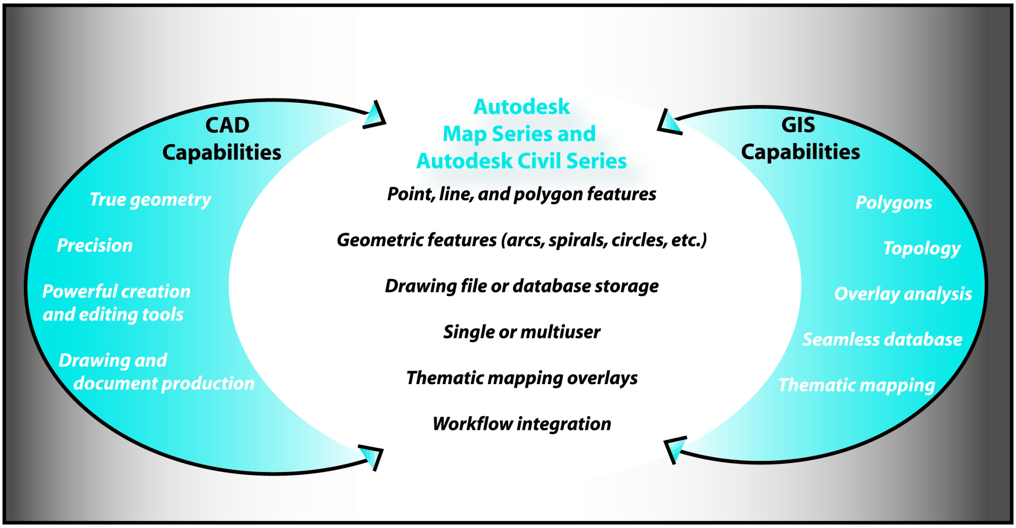
Precision Mapping and Civil Engineering from Autodesk

Historically, most CAD products were broad-based technologies used in industries such as manufacturing, architecture, surveying, civil engineering, and GIS. Partners and users built industry-specific components on top of the CAD engine to serve specialized needs, but the underlying CAD product was not targeted at any particular application.

In the 1990s Autodesk, realizing that GIS and precision CAD tools should work more smoothly together while still maintaining their distinct features, began the work of building a truly integrated solution. The Autodesk Map™ Series, including Autodesk Map software, now in its seventh release, integrates GIS functionality (multiuser editing, polygon overlay and analysis, topology, thematic mapping, and more) with a mature CAD environment and an Oracle® Spatial database. Autodesk Map also integrates data sources from a variety of CAD and GIS vendors seamlessly and effectively, without tying customers to one or the other. A powerful GIS tool, Autodesk Map sits at the crossroads of several mapping and engineering systems, delivering the best of both disciplines without compromising functionality or data integrity. For more technical details about Autodesk's premier precision mapping solution, read the white paper *Destroying Seven Myths of Autodesk GIS*.

The Autodesk® Civil Series extends the integration to civil engineers. Autodesk's civil solutions integrate the power of CAD for precision engineering tasks like site, roadway, and hydrological design with the spatial analysis tools and data management of GIS. Autodesk has recently enhanced its civil engineering solutions by acquiring CAiCE software, a high-end highway and transportation engineering software suite. In addition, Autodesk provides Autodesk MapGuide for web-based publishing, Autodesk Envision™ for visualization and analysis, and Autodesk® GIS Design Server for scalable enterprise applications. All products maintain full data precision throughout the project workflow.

Many organizations, such as government agencies, cities, design firms, and utility companies, need both GIS and engineering software. These users choose Autodesk software because Autodesk understands and integrates the CAD and GIS worlds, encouraging the collaboration of multiple departments within a single organization.



Both the Autodesk Map Series and Autodesk Civil Series combine the traditional capabilities of CAD and GIS tools with common spatial management features.

Autodesk has recognized that

- Users need to be able to create both traditional GIS features (points, lines, and polygons) as well as features with true geometry, including arcs and circles.
- Data passes through a lifecycle or workflow, from surveying and mapping to design to construction to management, and the same data is used in many ways by many people.
- Data is integrated from many sources, including CAD and GIS environments, spreadsheets, and databases.
- CAD tools are often the best choice for data creation because of their precision, ease of use, and the millions of software users familiar with the technology.
- Whether printed or published on the Web, design documents need to be accurately rendered with the symbology and appearance that users expect.

Conclusion

Autodesk offers integrated CAD and GIS solutions for surveying, mapping, civil engineering, and infrastructure lifecycle management. These solutions create, integrate, and manage CAD and GIS features with no loss of precision or topology. Autodesk CAD and GIS solutions support customers like the City of Vancouver, which use every Autodesk civil engineering, GIS and mapping, and infrastructure management software tool across their complete city workflow. These solutions help users to combine multiple data formats in a single display and perform analysis from a single product. Autodesk tools read most CAD and GIS data formats natively, minimizing migration problems. Autodesk also continues to drive the development of the Open GIS Consortium (OGC) and LandXML in close collaboration with other organizations to facilitate the exchange of data created during the land planning, civil engineering, land survey, and mapping process.

Users are also demanding that their vendor support open systems and open data formats. This becomes more important as the GIS industry consolidates, leaving fewer alternatives to single-source, proprietary systems that keep your data locked away. Data is expensive to create, and generating a return on investment requires that the data be used well into the future with the newest solutions.

Some vendors will continue to sell expensive, high-end CAD and GIS tools for specific analysis and design tasks, as if the professionals who use these separate tools do not interact with each another. However, within most organizations these mapping and engineering professionals must work together efficiently to be successful. Autodesk solutions help to make the complete organization more profitable, not just a single department.

About the Author

With a PhD in photogrammetry and information science from the University of California at Berkeley, Sean Curry has more than 24 years' experience in the GIS industry. He has worked for Autodesk as a GIS product manager and senior director of business development, for ESRI as senior manager of enterprise spatial systems, for Trimble Navigation as director of software development, and for Pacific Bell as technical director of spatial technologies. He is currently a consultant and industry analyst based in the Pacific Northwest.

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Autodesk, Inc.
111 McInnis Parkway
San Rafael, CA 94903
USA