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Engineering Document Management

Conversion of Paper-based Engineering Archives

by David J. Wilson

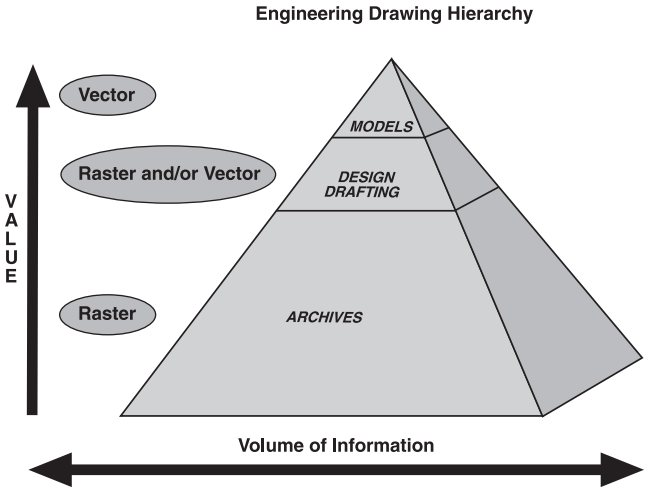
To compete in today's world, a company has to survive in a fast-growing, technologically driven environment. *How does a company deliver the best product or service to market at a fair price in the shortest time?*

To maintain a competitive edge, a company must leverage its information assets, which can include a tremendous amount of engineering documents. Tools and processes to efficiently manage, distribute, and modify these assets are essential.

International Data Corporation and Document Management Magazine estimate that there are more than 8 billion drawings worldwide, of which fewer than 15 percent are in a CAD format. This leaves an astonishing 85 percent of drawings maintained in non-electronic format, mainly paper-based engineering archives. Considering that each successive stage in a product development cycle, including design, production, and support services-uses substantially more documentation than its predecessor, the benefits of integrating this information grows exponentially.

The need to capture, modify, and distribute existing paper designs within the environment of today's computing technology predates CAD technology itself. The intent of this article is to provide an insight into the issues, benefits, and strategies for capturing paper-based assets into an open archive environment.

The Value of Engineering Drawings



The Archive

Many companies have large quantities of designs that must be preserved throughout the life cycle of the product or service. Even though archived information may only be needed for reference or legislative purposes, it is highly valuable to the company that created it. Archived documentation also represents the largest quantity of information. At any time, a drawing can become active due to maintenance of an older design or because a new design resembles information created in the past.

Scanning these archives into a digital raster format has emerged as the most affordable and effective environment for maintaining vast quantities of drawings and related documents. Once captured, their value increases immediately as Engineering Document Management (EDM) and Product Data Management (PDM) systems can be used to manage these and other electronic files. Efficient revisions are also possible as they are now closer to CAD.

The Revised Drawing

Drawings within the revision cycle represent active changes or work in process. These are typically the result of an engineering change order or notice (ECO/ECN) or as-built designs. CAD provides the most productive environment in which to manage and modify engineering documents. Newer designs are almost exclusively modified within the proven environment of CAD, however, a large portion of drawings are based on paper archives. These are still modified manually due to the perceived costs associated with getting drawings into CAD.

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Integrating these older designs into CAD has created two potential environments: hybrid raster CAD and vector CAD. The hybrid raster CAD environment offers tremendous payback to the user as it leverages the past (paper engineering drawings) with raster imaging, and the present with full CAD construction and editing.

Engineering Models

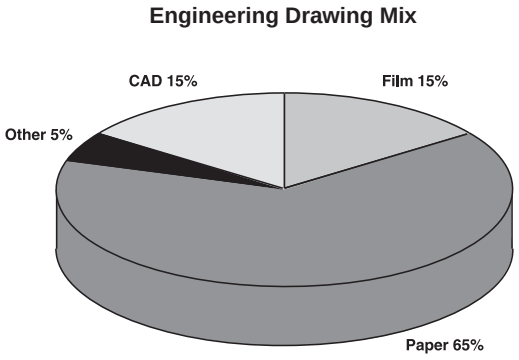
Drawings with the highest corporate value are those used within the modeling and analysis environment found in CAE tools. These models require a vector database in order to perform analytical functions such as driving NC equipment, parametric modeling, automated mapping, and/or facilities planning.

Integrating paper-based archives into truly intelligent models requires the conversion from paper to raster to vector CAD or vectorization. This process has brought about high expectations from users due to the promises of converting to an intelligent database.

Getting Started

It starts with a scan. Scanning is perhaps the most overlooked factor in the conversion process. Today's scanners provide more advanced image enhancement features, including adaptive thresholding and DSP technologies to produce better quality raster files. This is the single most valuable feature in starting the conversion process and is far more valuable than increased resolution.

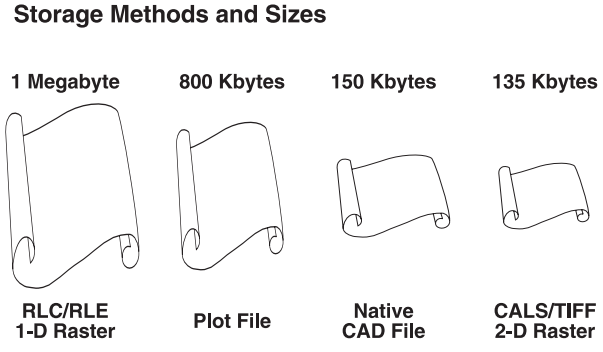
It is important to note that eighty percent of all new designs are based on old drawings. Scanning these archives into compressed raster format allows them to be enabled for faster revisions and improved distribution. This process can be painless and cost-effective. Good separation of text, quality line representation, and smooth raster geometry are also important aspects that should be considered in more detail when selecting your solution. Conversion to full vector CAD format is the most sensitive to a well-scanned image.



Viewing

A viewer is a software package that allows you to look at documents without having to use the application that created them. Viewing technologies offer a natural approach to integrating paper archives and CAD in a distribution function.

In many cases, companies already maintain an active non-graphical database of drawing revisions. This database can be leveraged and "viewer enabled" to provide the graphical link between paper and CAD-based designs. As movement is made toward EDM/PDM, the viewer can be integrated at an API level for direct communications with EDM/PDM systems. Introducing a viewer is a simple, inexpensive way to link scanning with the ongoing build of your total solution.



A small investment in powerful viewing software package offers immediate benefits with little capital outlay and minimal training time. The right viewer helps increase access to information, speed time to market, streamline workflow, comply with ISO 9000 and OSHA standards, and review and process change requests rapidly.

The ECO/ECN (Engineering Change Order/Number) process can benefit by introducing users to the concept of redlining (marks indicating where a change is to be made) and integrating redline annotations on all drawings (raster and vector CAD-based) that are now contained online.

More sophisticated editing systems can use the approved redlines as tools to facilitate accurate and timely revisions. As workflow is introduced, the process is enhanced further with a more controlled approval procedure.

Coming Together: Raster and CAD

With the drawing now scanned, viewing processes in place, raster or hybrid-based drafting can be added allowing CAD systems to make revisions to existing paper drawings. The result is increased value from CAD even before a full EDM/PDM system is in place. As EDM/PDM is implemented, full management of the ECO/ECN process can be realized.

Re-engineering the Paper Trail

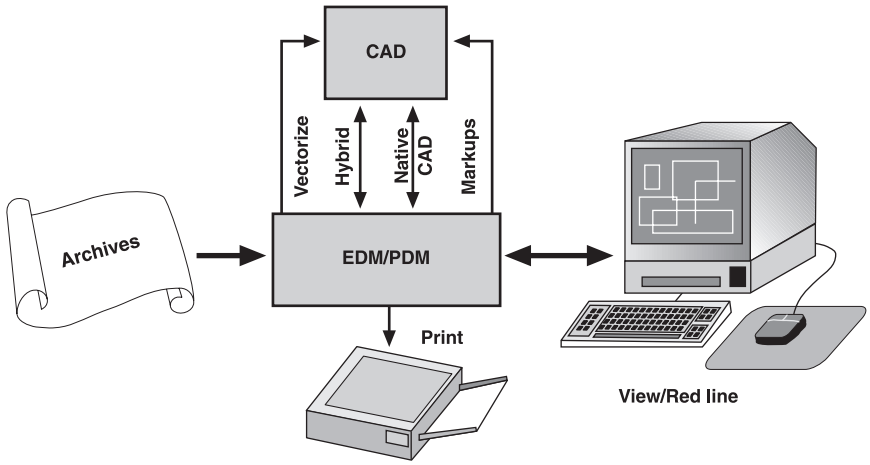
Considering that seven to ten percent of a company's operating expenditures are spent on a manual document management process, re-engineering the flow of information, or paper trail, throughout an or-

ganization can result in tremendous savings. Designs can be produced more efficiently, customer support expanded, and rightsizing demands met through the leverage of information assets and reinvestment strategies.

The Archiving Advantage

With the implementation of a managed engineering archive, searching time, as well as re-engineering time, become past history. This translates into real dollar savings. Substantial savings can also be realized through a managed revision process. The reliance on manual drafting and control of drawing revision on older documentation can be put to rest.

Paper Integrated CAD/EDM/PDM



The CAD Advantage

CAD has already proven itself as a tool to design and maintain product and service documentation. Applying this tool to archived resources allows the CAD advantage to be applied completely. These electronic drawings can then be easily revised, modified, plotted, or copied in a fraction of the time it takes to modify paper designs. The design process can become highly streamlined, providing improved product quality, and faster time to market.

The Document Management Advantage

Once files are in electronic format, document management can be used to further increase and enhance productivity. Options range from a simple file storage system with limited revision tracking, to a system that securely controls viewing, editing, and distribution of all engineering-related information.

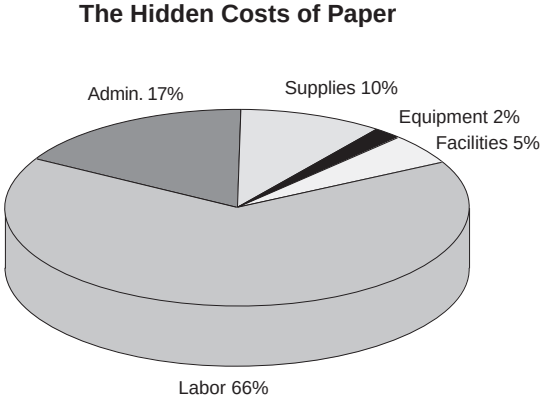
Many organizations are required to comply with standards and regulations that virtually necessitate electronic document management. According to the British Standards Institute, 47 percent of ISO certification failure is due to poor documentation control.

Cost and time justification can be realized by improving the ECN/ECO process and achieving ISO 9000 certification. In addition, AEC firms are feeling regulatory pressures for process safety management, and OSHA 1910 regulations are demanding improved management of document control processes.

The Workflow Advantage

Workflow tools provide even greater value in meeting OSHA and ISO demands. Cost benefits of workflow products are far greater than those provided by document management tools alone. Workflow is the final enhancement to a paperless environment, enabling company-wide document management from scanning the document to viewing, redlining, tracking, and archiving.

The Hidden Costs of Paper



The Hidden Costs of Paper

Manual methods for handling, storing, and maintaining paper drawings are difficult, time-consuming, and costly since most information is still in paper form. The following are some of the most obvious problems with maintaining paper archives:

- **Paper drawings, mylar, bluelines, and other media are susceptible to aging and damage over time.**
- **Manual-based revisions are costly, particularly with drawings requiring frequent updates.**
- **Paper is slow to distribute. It takes longer to copy and distribute a single piece of paper than it takes to distribute or reproduce several documents electronically.**
- **A company may be fully modernized, with a full suite of CAD**

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software, but what about their contractors, subcontractors, and business partners? Many transactions between companies are inefficiently conducted with manual archives even when the originals may have been CAD files.

- **Paper is cumbersome. It is often hard to find specific information in specific documents. Electronic searching is more efficient and faster.**

- **Paper is restricted in format. It is limited to graphics and text, while electronic documents can contain hyperlinks, audio, and video.**

- **Paper is static. It can be out of date even before it is distributed because of lengthy release cycles. The added concern of "who has the most recent revision?" exacerbates this problem.**

- **Facility costs for the storage and maintenance of paper archives can be substantial. Justifying a document management system can be based on significant reductions in facility costs alone.**

- **Paper gets lost. It is estimated that five to seven percent of technical assets are lost or misfiled using manual procedures for handling paper drawings.**

Integrating Paper with CAD

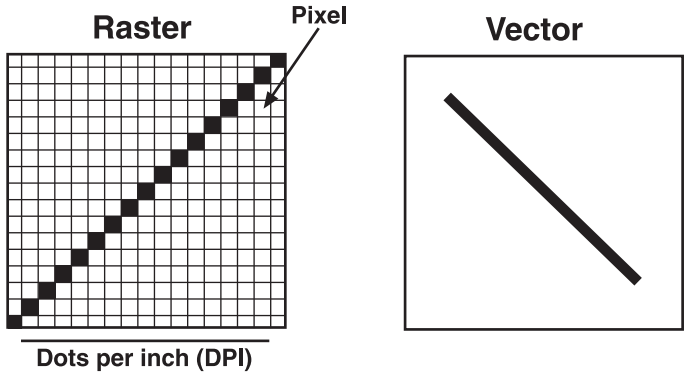
The earliest implementation of computer-aided design (CAD) was conducted in the 1950s for one simple reason; to modify existing drawings electronically. A flying spot scanner converted microfilm data into an electronic image. While scanning remained a cost-prohibitive option, interactive computer graphics and CAD evolved into an enormous tool for creating newer designs.

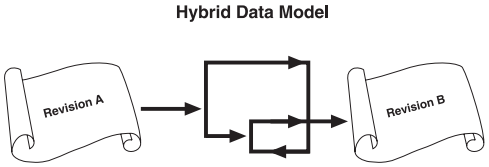
With the emergence of standards for storing drawings in raster format and cost-effective scanning hardware and services, the raster environment came of age in the early 1990s. Today there are a number of methods that can be used to get paper archives or pre-CAD designs into the design and drafting environment of a CAD system.

Manual Redraw

To manually redraw means exactly that; using original drawings for reference, they are redrawn from scratch using a CAD system. A complete redraw of the original drawing is, and will always be, the most accurate method of conversion. However, it is extremely time-consuming and a poor use of a CAD system.

A Comparison of Raster vs. Vector File Formats





Digitized Drawing

Drawings are placed on a digitizer tablet and traced with an electronic drawing 'puck' into the CAD system. This method is faster than just redrawing the design, but it is prone to errors, and still labor-intensive and slow.

Outsourcing to Service Bureaus

Many factors including labor rates, availability of staff, security concerns, volume of drawings, time frame required, graphic enhancement and indexing needs may impact the decision to outsource. Outsourcing can save on resources, and capital outlay for equipment is little to none. Contracting with a service bureau is a common method for handling backfile conversions, pilot projects, or quick turnarounds.

Scanning Paper Drawings

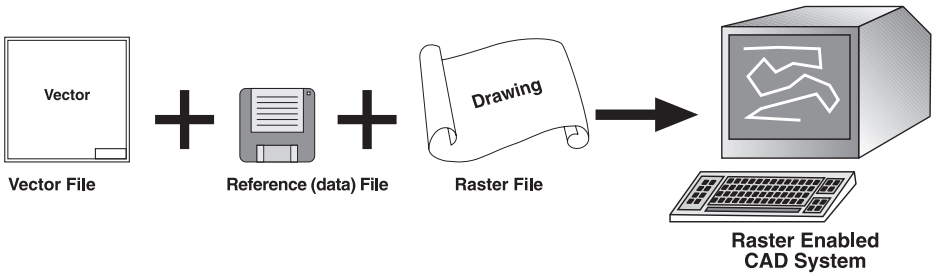
Scanning paper drawings to work within the proven environment of CAD and the emerging environment of Engineering Document Management or workflow offers the most control in the transition from paper. The scanning process can be customized to fit an individual drawing or its application. In-house scanning has been successfully implemented in both large and small companies to solve integration problems between paper and CAD.Once the drawings have been scanned, their value increases because of the three principal ways to use the newly scanned design in a CAD system. What follows is an outline of the three revision methods available.

Raster vs. Vector

CAD Systems use vector files; scanners produce raster files. What's the differ-

ence? Raster files are fundamentally different than vector files *(see graph at bottom of page 4)*. If a line is drawn with CAD software, it is stored as a vector primitive. The software knows the starting and ending points and the line thickness. The line is "intelligent" because any part of the line "knows" it is part of the line, and "knows" what the rest of the line looks like.

Hybrid Data Model



When a drawing is scanned, it is broken down into row after row of dots or pixels. A scanned line is "dumb" because it is made of dots or pixels forming the shape of a line, and the dots do not "know" that they are part of a line. For scanned data to be used and modified like CAD data, it has to be made intelligent.

The Revision Cycle

Raster Editing or Drafting
Raster editing or drafting is the simplest and most productive way to modify scanned paper drawings. It's the lowest cost method for moving the drawings into a format where changes can be made electronically. This is supported by the availability of scanning service bureaus, and recent price decreases of large-format scanners. Raster drafting works best when simple updates are required in non-dimensioned or analysis-oriented drawings.

There is significant differentiation within the software products found in today's market in terms of features, functionality, and positioning. The more advanced products are capable of snapping to, or selecting and manipulating, raster "entities", just like vector CAD entities. Some packages are specifically positioned for niche applications, such as mapping, which requires distortion correction to update drawings for world-coordinated systems.

Conversion to Vector
Drawings with the highest degree of corporate value are those used within Analysis and Modeling systems. These need to be in a fully vectorized format. Some examples: a company may need to develop a 3-D model from an old drawing and run FEM or interference checks within the model; or a city planner is looking at developing a new building and needs to use 3-D terrain models from old paper drawings. Both environments require vector CAD models in their purest form and consequently require full conversion to vector.

The process of automatically converting the scanned image into a CAD drawing is called raster-to-vector conversion, or vectorization. Tools are available to perform this function in an unattended batch manner, or operator-assisted with line following or selective conversion processes. Conversion software will not produce an unattended 100 percent conversion. It is best used as a component of the conversion process rather than a total solution.

The Tools used to Vectorize are:

• Overlay Tracing
This is often referred to as heads-up digitizing. A scanned image is loaded into the CAD system as a backdrop and the image is "traced" over with CAD entities. This is very similar to the idea of digitizing but a digitizer table is not needed.

Overlay tracing is quicker than a complete redraw, but is still labor-intensive, tedious, and time-consuming. It is a good option when working with poor-quality drawings. Raster snapping and heads-up digitizing improve throughput and accuracy over traditional hand-digitizing methods which are still widely used.

• Batch Conversion
Batch tools work with a set of predefined rules to recognize unique settings such as text classification, width separations, and geometrics. This works best when drawing quality is very good, drawings are consistent, and the desired result is basic primitives. Results of batch systems will often require clean-up to ensure the converted drawing meets the needs of the user.

• Selective or Interactive Conversion
This is the most promising of the CAD conversion techniques. It combines the intuitive knowledge of the user with an interactive line-following or selective conversion process. These tools allow an operator to isolate selected geometry and text, then work within the limiting factors of the technology.

As an example, a topographical map is converted by selecting a raster contour, then the software vector traces it to an intersecting or gap position. This process is repeated for the entire trace. Then an elevation is assigned to make it a 3-D model for the GIS system to take over.

• Hybrid Process
A fully hybrid approach is one where

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scanned archives and CAD systems are maintained for a drawing. The term hybrid in this case means a combination of both raster (scanned) and vector (CAD) drawings. Hybrid editing means using both raster data and vector data simultaneously. Changes can be made within either environment. Information can be exchanged back and forth between two distinctive formats, thus offering the most efficient method for modifying the old within the new.

Calibration between the raster database and vector drawing model is typically provided with a reference or resource file. This file contains scaling and coordinate data to provide a real-world coordinate system for an otherwise unintelligent raster drawing.

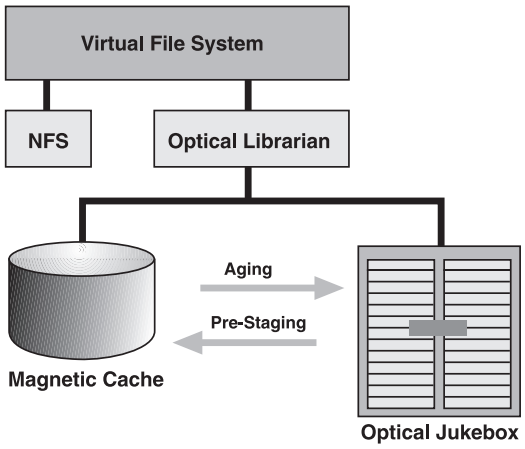
Deteriorated drawings can be scanned, cleaned up, and stored in raster. Modifications can be made to the drawing in raster or areas of the drawing can be converted into CAD vectors as it becomes necessary.

This combination of raster and vector can also be plotted and stored within more advanced EDM/PDM (Engineering Document Management/Product Data Management) systems.

Working in a hybrid environment allows use of the scanned drawings immediately. Decisions to modify, plot, or vectorize can be made as needed. Investing time and money to convert existing drawings can be done on a "just in time" basis.

With reduced labor costs and improved usage of CAD, the benefits of revising drawings electronically are clear. What may not be clear is the trade-off of investing in the upfront conversion to full CAD vs. taking advantage of lower cost hybrid and raster CAD systems.

Mass Storage Architecture



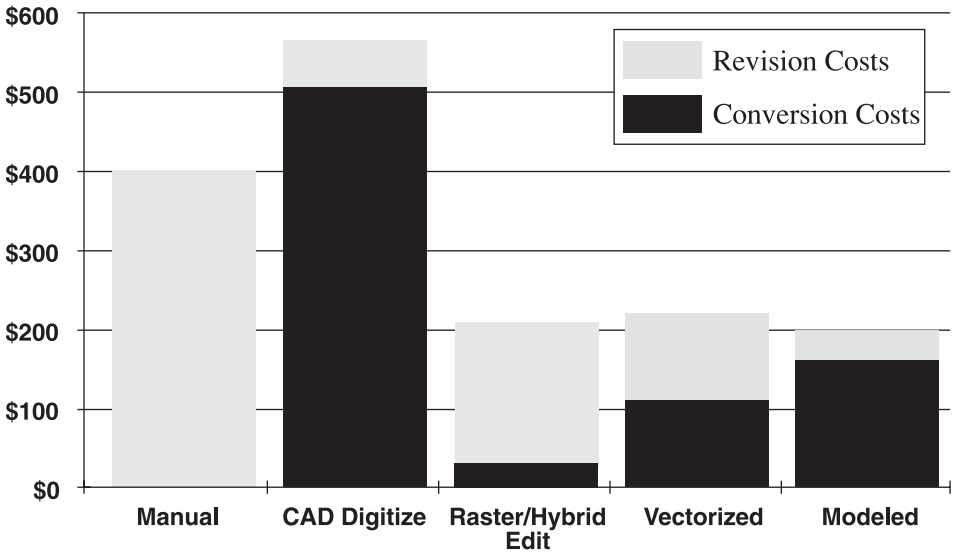
Integrating Paper with EDM and PDM

The promise of capturing, managing, digitally reproducing, and distributing documentation has long been a goal of organizations such as manufacturers, utilities, and AEC firms. EDM and PDM have reached a point of necessity for companies to remain competitive, improve product quality, and meet rightsizing requirements.

Re-Engineer the Paper Process

While companies have focused on improving the individual productivity gain by implementing task-oriented tools like CAD or word processing, scanning a company's paper assets and implementing EDM/PDM can enhance the business process. Reduced product cycle times and lower cost goods represent the kind of business process issues affected by implementing an EDM/PDM system.

Cost Analysis of Various Revision Methods



Reduce Drawing Life Cycle Costs

Creating an open environment for drawing archives requires a one-time cost of scanning paper archives into an electronic environment. However, once implemented, savings are realized throughout all phases of the product life cycle.

Cost-Benefit Analysis

Scanning drawings to digital raster format is essential to realize benefits from the methods provided in this analysis. The justification for scanning to a raster image can be easily made when looking at the value of managing the documents, savings in facility costs, and improved

document accessibility throughout the organization. Cost justification of the various technologies described in this article is most measurable when based on labor savings in the revision process, and improved information access and management.

Revision Costs Savings

The costs associated with revising drawings are dependent on the method and solution used. The four methods presented here include manual, CAD digitize, hybrid raster/CAD, and full vectorization to CAD.

Costs are incurred with each individual revision and include the cost associated with capturing the document to a digital form unless the manual method was used. Therefore, the true cost is calculated by combining labor rate and time spent on each revision plus the digital transformation expense.

The following is a benefit analysis of the inherent costs to recreate and revise a complex drawing, using each of the methods previously discussed. The comparison includes both the initial capture time, various labor rates, and the time associated with making revisions to the drawing once it has been captured.

The hybrid raster/CAD approach, which eliminates the redraw, cleanup, and verification processes, offers the greatest immediate cost benefit for the first revision and beyond. Drawings required in a vector CAD environment are best served by full conversion methods.

A simple cost-benefit example in which a company has 100 drawings with 20 ECOs to perform each month can be used to give an example of the benefits of the raster-enabled approach presented in this paper. Various labor rates are used for each discipline. Actual numbers should be determined for individual organizations.

Paper Trail Savings Example:

Action	Times/Month	Manual	Raster Enabled	Burdened Rate	Savings
Find a Drawing	100	1	.05	$50	$4,750
Find related ECO	20	1	.05	$50	$ 950
Approve ECO	20	4	.5	$50	$3,500
Update to Revision B	20	3	.1	$50	$2,900
Confirm Changes	20	1	.1	$25	$ 900
Distribute Latest Revision	20	3	.1	$25	$1,450
*Formula for this chart: (*times/month x manual factor x burdened rate*) less the sum of (*time/month x raster enabled factor x burdened rate*) = Savings*				**Monthly Savings**	$14,450 per month

Example:
Finding a Drawing

Manual: (100 x 1 x $50) = $5,000
Raster Enabled: (100 x .05 x $50) – 250
Monthly savings: $4,750

Intangible Benefits

The direct benefits of integrating paper within EDM/PDM and CAD are based on labor savings in the revision cycle. However, there are many intangible benefits which include:

- **An increase in the value of CAD by eliminating its use for tedious redraw. CAD can now be used for productive design and analysis functions.**
- **A common electronic database**
- **Reduced retrieval and print times for documents with a document management solution.**
- **Improved information flow with workflow and E-mail tools.**
- **Improved conformance to the ISO 9000 or OSHA regulations by instituting better document control procedures.**
- **Increased value of paper drawings through integration with CAD and EDM/PDM tools.**
- **Fewer lost, damaged, and misfiled documents.**
- **Immediate availability of accurate information.**
- **Streamlining of the change process.**
- **Improvement in the time to market.**
- **Increased quality.**

Add Value to Drawings

The overall benefit of scanning paper drawings is an increase in the value of the company's most important asset; information. Once captured into electronic form, drawings can be used for many functions, such as maintenance and material control, project management, quality assurance, and purchasing.

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Making it Work

Once an implementation decision is made, how does a company ensure the success of enabling their paper drawing archives or EDM/PDM system?

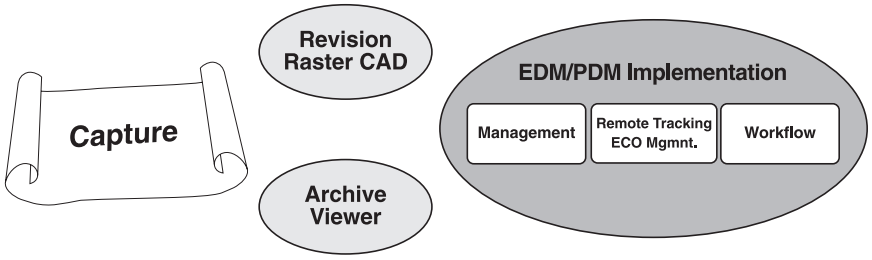
With long implementation cycles for an enterprise-wide EDM/PDM system, payback and user-acceptance can drag and stall throughout the initial stages of a full-scale implementation. The integration of manual paper-based archives as a first step can help companies to successfully implement such a system. An incremental approach can produce a more immediate payback and faster end user buy-in.

Plan Globally, Invest Incrementally

This simply means that companies should look at the broader business issues related to the life cycle of paper drawings. They can select the most critical business issues and implement the appropriate technology while planning for the bigger issues of document management and workflow systems.

A paper-enabled approach incorporates elements of EDM/PDM before deploying a full-blown system. This step-by-step process allows payback benefits to be realized while addressing the integration of the vast amounts of paper designs within CAD and introducing an electronic distribution environment.

Paper-Enabled Approach to EDM/PDM



The value of the drawings increases along with existing drafting systems by implementing hybrid or raster CAD systems. This allows scanned archives to be manipulated within the same toolset used for newer design work

A more critical evaluation of the EDM/PDM backbone can be accomplished while enabling the initial conversion process. Users have more time to model workflows, design ECO/ECN processes, define security requirements, and determine other control issues best handled by EDM/PDM.

Paper-Enabling PDM

Companies with more progressive document management strategies may have already implemented PDM to help manage their existing CAD/CAE environment. Most PDM systems can be expanded by adding raster-literate viewers and hybrid raster editing systems to allow paper archives to be managed by the same system in place to manage CAD.

About the Author

David J. Wilson is principal of Open Archive Systems, OASys, specializing in paper-enabling consulting services and proven solutions for companies implementing document management and raster/CAD systems. OASys clients include reseller partners, manufacturing firms, utilities, state and local government, and architectual firms that require raster-enabled solutions. Currently, David Wilson works with major accounts including NYNEX, General Dynamics, Cummins Engine, Southern New England Telephone, Dresser Rand, Motorola, and AEG/Modicon, providing consulting and technological services.

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