Development of the Digital Design Environment ProjectWise™ – Phase 1

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16. Abstract
The goal of this research was to develop a project document management system capable of managing Connecticut Department of Transportation (CTDOT) Capital Road and Bridge Program. Primary targets of research and development included the system, contract design deliverables (plans, specs and estimates), digital signing, project submission, submittals, legacy archiving and a portal for construction inspection document management.
The resulting implementation of the Cloud based ProjectWise (PW) Online from Bentley Systems Inc. has delivered CTDOT a robust project and asset document management system. The system is integrated with CTDOT authoritative project and asset tracking data to automate project and asset storage and security management. The Cloud solution offers easy secure access for Department's one hundred plus Consultant Engineers and state forces. The hosting offered a tremendous cost savings of server, backup, disaster recovery and VPN acquisition and maintenance going forward. Contract plan sheets underwent a welcomed transformation from wet signed Mylar's to a digitally signed PDF contract set. Major asset documents (Bridges and Traffic Signals) installed or rehabilitated within capital projects are managed through their unique ID's tagged to the capital projects, eliminating the need to parse out the documents from the capital project. A Real Time Kinematics (RTK) system for GPS construction inspection allowed the digital design environment to justify 3D model deliverables. In addition, an open source Web-GIS was developed, which offers intuitive interactive maps with hyperlinking to project and asset documents. This integration includes active, completed and legacy project information.

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PREFACE

This study was the idea of Eric Bergeron of Connecticut Department of Transportation AEC Applications unit within the Bureau of Engineering and Highway Operations. It began with the challenge of developing a digital design environment where transportation design plans, specifications and three dimensional models could be submitted and shared for project delivery and repurposed during construction.

METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

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CHAPTER 1 Introduction and Background

Prior to this study, Connecticut Department of Transportation (CTDOT) had no clear mechanism in place to maintain electronic Computer Aided Design (CAD) data and general project data (correspondence and other data) that have been paid for under professional consulting services. Electronic data from large corridor projects had been lost and data was typically not conforming to standards. Past CAD policies never addressed the standardization and delivery of electronic data. Considering consulting services handles a majority of project designs at CTDOT, it had become apparent that maintaining the "status quo" was not an acceptable means of doing business given the advances in technology. Following were the existing conditions at the time of the initiation of this study:

1.1 Electronic Data Standards

Professional consulting services handle the majority of contracts for CTDOT. In the past, CTDOT did not emphasize the importance of standardizing CAD designs, and organizing the electronic data for both internal design and consultant services. Furthermore, there had never been a cost effective delivery process to obtain the electronic data that the State of Connecticut and Federal Government pays for. Improvements in these areas were necessary to advance operational efficiency and project delivery. Electronic data for projects was stored in "Silos of Data;" multiple disciplines divided network drives or on individual user computers. This processes led to loss of project data and inefficiency throughout the entire project development process and into construction.

1.2 Contract Drawing Reproduction

The reproduction of engineering drawings and documents was one of CTDOT's most expensive document processes. This was required for both design review and delivery of engineering drawings and documents for contractors to prepare project bid proposals. To improve this process and reduce reproduction costs, CTDOT needed to begin developing the necessary applications that will allow In-house Engineers and Consultant Engineers to deliver a common standardized design package of plans, specifications and estimates in electronic format.

1.3 Wet Signing of Mylar's

Mylar contract drawings, manually-signed, were not indestructible and could be modified. Mylar's could be edited, copied and scanned, and the CTDOT Mylar storage area is not under

high security. Electronic document technologies such as Portable Document Format (PDF) offered a more secure environment for contract drawing usage.

1.4 Design Submittals

The pre-study design development process was heavily dependent on paper. Typically, design submittals, including preliminary design, semi-final, final etc., required 18 sets of paper plans and corresponding design reports. Furthermore, at times project data and critical correspondence was lost or forgotten as the project progressed from design through construction.

1.5 *Problem Statement*

The federal transportation bill (The Safe, Accountable, Flexible, Efficient, Transportation Equity Act: A Legacy for Users (**SAFETEA**-**LU**)) and CTDOT stewardship agreement strives to promote greater oversight and efficiency in the delivery of transportation projects. Furthermore, Governor Rell's Executive Order Number 3, issued December 15, 2004, called for transparency in the state contracting process and to provide for a single location on the internet for all contract and agreement related documents.

At the outset of the project, CTDOT did not have the capability to fulfill the "total" requirements of the Executive Order, which called for plans, specs and estimates to be available in a centralized internet portal environment. This project addressed and remediated this situation.

CHAPTER 2 Research Approach

The overall objective of this project was to improve CTDOT project delivery by streamlining and improving the quality of the designs; to reduce the time needed to access plan archives; and, to submit and review engineering documents and drawings electronically. Installation of a digital design environment encompassing electronic document generation, management, signatures, project advertisement and support services was planned. The result would be a secure, efficient, standardized project design platform to help reduce project costs, decrease project development times, and provide both accountability and storage for project documents.

Ideally, the system would keep all project related data together for all disciplines throughout the entire project lifecycle using ProjectWise (PW) Online by Bentley Systems which is an integrated engineering content management system. Bentley Systems enables project teams to work cohesively and share their project information and tools. The system is hosted by Bentley Systems Inc.

This led to creating a production environment of PW Online and using the system on pilot transportation infrastructure projects to facilitate digital submissions and the transfer of active and legacy projects on CTDOT's server infrastructure to the ProjectWise production environment. ProjectWise Online now serves as CTDOT's primary Engineering Content Management System (ECMS).

2.1 Develop a Technical Committee

The CTDOT AEC Applications group is comprised of engineers from multiple disciplines within the Department. These disciplines include Highway Design, Traffic Engineering, Bridge Design and Survey. This multidisciplinary group collaborated with Consultant Engineers, contracts personnel and others to discuss, develop and implement digital design enhancements for the project.

2.2 Legacy Plan Archive

Digitizing the information about legacy projects was an important task of this project. State forces were utilized for scanning services for the development of a ProjectWise archive system for the legacy construction plans. Additional post processing added project attribution, asset tagging and geospatial project location.

2.3 Publishing Application

A system/application for digital plan sheet management and indexing was developed. This is a production tool/application designed to improve the management/organization of CAD contract sheet files and how they are published to PDF. The proposed application would significantly decrease the amount of time required to generate/modify contract sheet files and publish PDF contract sheet files.

2.4 Deploy and Pilot

The developed application(s) were deployed and tested on selected pilot projects involving both Consultant Engineers and In-house Engineers.

2.5 Electronic Design Reviews (EDR)

EDR is a PDF application in the design environment for reviewing, commenting, collaboration and As-Built drawing creation. A customized interface specifically designed for CTDOT's typical design review workflow was developed and the applications were tested on selected pilot projects. The interface integrated ProjectWise with Microsoft Outlook™ and incorporated the functionality of Bluebeam's™ collaboration /commenting features. The goal of the collaboration system was to streamline workflows, retain comments and improve communication in CTDOT's design review process.

2.6 QA/QC of CAD and PDF Standards

CTDOT's CAD standards (in-progress) and custom applications were developed for both In-house and Consultant Engineers. These custom applications automatically configured remote clients PC's to CTDOT's future CAD Standards to serve as a quality control mechanism and reflect the latest CAD standards in CAD Design and PDF contract sheets.

2.7 Project Geospatial Attribution

A ProjectWise geospatial infrastructure was developed to display project locations and other Department assets geospatially on a web-map. Hyperlinking provided dynamic linking from project or asset location directly to the stored documents within PW Online.

2.8 Document Control

This project goal allowed the Department to research the integration of ProjectWise with a document control system that is capable of better facilitating digital communication of change orders, RFI's, shop and working drawings electronically and project scheduling and management. Pilot testing of ProjectWise was performed on the Q-Corridor Projects and the New Haven Rail Yard. With the use of a document control system (Primavera Contract Manager) on these projects, it became evident that there is a need for better interoperability of ProjectWise with a document control and project management system.

2.9 Corrected GPS Technology and Construction Inspection Techniques

The CTDOT CORS GPS base stations were upgraded to provide real time corrections in support of the Department's GPS Construction Inspection initiative. E-Construction initiatives continue to develop in this area. 3D model design deliverable requirements evolved into a proof of concept that continues to date, with plans for a future requirement.

CHAPTER 3 Results/Findings/Implementation

3.1 The System – PW Online

Initially the CTDOT's Office of Information Systems setup a host of virtual servers and a proof of concept system was established within the CTDOT firewall. Initial difficulties with development, configuration and testing led to the determination that a hosted solution was preferable due to the cost of start-up, scalability, maintenance and connectivity to our business partners outside of CTDOT's network. This required that an application for System Development Methodology (SDM) be submitted to Connecticut's DOIT (Department of Information Technology). CTDOT's Office of Information Systems (OIS) and AEC Applications worked together on the submission and attended meetings and demonstrations until an approval to procure the ProjectWise Online (Cloud) solution was issued and the system implemented in 2008. The system, hosted by Bentley Systems Inc. in Exton, PA, has become the standard shared repository for all engineering and construction project documentation with users throughout CTDOT

PW Online is a Cloud based database with access through both a thick and thin client interface. The thick client interface uses the client software ProjectWise Explorer that offers integration with Microstation, InRoads, Bluebeam and Microsoft Office and is primarily used within the CTDOT main office in Newington. The thin client interface is accessed through the internet, increasing mobility to external users and Consultant Engineers.

PW Online gives CTDOT robust document management and workflow utilities to maintain version control and eliminate document duplication. Additionally, PW Online allows for robust securities, accessibility through the Cloud and a geospatial dynamic link to projects and assets.

Along with current design and construction plans; specifications; and, other contract documents, there is a large data set of as-built recorded legacy project plans. In addition to project data, bridge and sign support structure inventory inspection information is managed by the Office of Asset Management for project tagging using PW.

As the system was piloted, it was determined that some of the CTDOT satellite offices required an upgrade of their communications infrastructure to accommodate the volume of electronic files being transmitted during the pilot projects. Under the direction of OIS, these offices were retrofitted with updated networking infrastructure to accommodate the increase in band width. CTDOT's first pilot project was completed in 2009 with CTDOT Project 0092-0532, I-95

Q-Bridge Replacement (Contract B) in New Haven, CT. The project offered a large quantity of digital plans that tested the performance of the Cloud based system. The system performed quite well and was considered to be acceptable; however, CTDOT was not satisfied with the format of the contract plans and work continued on evolving that format.

Additional performance testing revealed that our network infrastructure at our centralized design offices in Newington, CT, was more than adequate to work without requiring additional local caching servers. When working with PW thick client, the workstation caches the documents during the management process which adds better performance of larger documents.

A subscription to PW Online for CTDOT employees and the hosting services is the largest part of this system being studied. Smaller tasks of consultant services had been procured for development and documentation of electronic data standards. Software was procured for integration of PDFs across the project delivery timeline, replacing Mylar and paper for a digital project submission workflow.

To date, PW Online has been a successful document management system (Engineering Content Management System). With the retirement of Mylar contract drawings (May, 2011), the CTDOT has developed a complete electronic workflow for digitally signed contract plans, specifications and miscellaneous contract documents at design delivery. This entire process is documented for production within CTDOT's Digital Project Development (DPD) manual.

PW is currently being piloted as a distributed engineering solution as well. CTDOT has the New Haven - Hartford - Springfield (NHHS) High Speed rail project in design. The project is using PW as the storage and sharing of Bentley Systems Inc. Microstation and InRoads modeling files. PW Online is integrated with these two applications allowing sharing across distributed offices. Managed workspaces were developed to manage standard and project configurations for this work.

PW has also become a dependable document management solution for CTDOT's bridge assets. CTDOT maintains an accurate database of their bridge inspection information. Through importing of xml information, a storage solution was developed that allows each bridge to be attributed with its respective inspection information. All documents stored within that bridge folder, inherit those inspection attributes allowing for a variety of queries (Fig. 3.1). PW integration with current CTDOT business workflows continues to move forward.

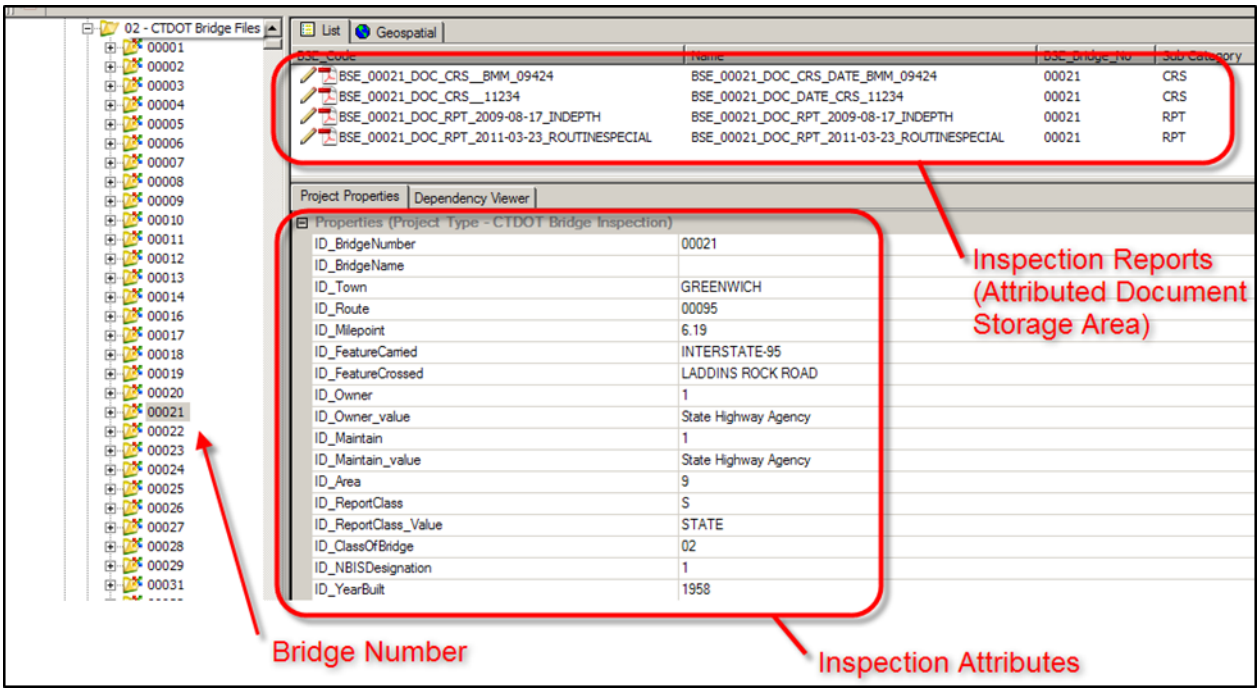

Figure 3.1 ProjectWise Bridge Documents

3.2 Legacy Plan Archive

CTDOT's Support Services archives legacy contract plans and other documents. The development of an electronic solution was accomplished and currently managed within PW Online. The legacy contract plans (Mylar and Linen) are screened for priority and scanned to a PDF. A technician determines the geospatial project limits and registers the project spatially in CTDOT's open source GIS system Asset/Project Tracking and Location System (ATLAS). The technician then identifies the project attribution for the project and populates the information within a spreadsheet which gets bulk loaded to ATLAS. Attribution includes project number, project title, route, bridges, traffic signal, contractor, construction completion date and other data.

3.3 ACORN - UCONN

In June 2010, CTDOT partnered with the Department of Natural Resources and the Environment at the University of Connecticut (UCONN) to upgrade the CTDOT CORS GPS base stations. The upgrade provided real time corrections in support of the Department's GPS

Construction Inspection initiative. The real-time network is known as Advanced Continuously Operating Reference Network (ACORN) and is hosted at UCONN. The network consists of nine base stations located across the state; data is also being received from three additional base stations located in the bordering states of New York and Massachusetts and soon an additional base station located in Rhode Island. This service is free of charge to the public or any government agency.

This GPS initiative utilizes the electronic engineering data to perform construction inspection activities. This Electronic Engineering Data (EED) is being made available on the State's contracting portal (along with the contract plans, specifications, and estimates) to the contractors and inspectors at advertisement for select pilot projects.

The construction inspection activities include using the hand-held GPS equipment as an approved method of measurement for pay items, verification of layout, and the automated production of as-built drawings. Typically, all of these functions utilize the same set of data points, which are easily collected in the field using a rover versus using the more cumbersome "wheel and tape" method. This results in a tremendous reduction of time spent collecting and processing field measurements.

This system is also currently being used to accurately collect CTDOT asset data. Likewise, it can be used by the contractors for automated machine control/guidance of heavy construction equipment.

After approximately 40 pilot projects over the last seven years, the use of EED along with the ACORN CORS network has proven to be very successful for the Construction Inspection initiative.

Additional hardware, hosting and consulting services were procured to study the use of corrected GPS technologies used in advanced construction inspection techniques. The task studied the repurposing of engineering by product data like digital terrain models, alignments, geometry, drainage databases and contract items. This data is also known as High Value Data.

Tablets were purchased to study and develop project management and streamlining efficiencies from remote locations.

3.4 Developed Procedures

A majority of the procedures developed for this study included streamlining and modifying existing workflows along with developing new ones. A subject matter expert for each process

was requested to document current workflows. From there electronic components would replace existing manual or paper operations. After workflow development and testing, piloting of the electronic workflows were commenced and modified, as required. Upon workflow acceptance, documentation was developed and published to the CTDOT's DPD manual.

3.5 Bluebeam PDF and Digital Signing

Two primary contributors to CTDOT's digitally signed PDF Contract Plan Set template are the AEC Applications group and Bluebeam Software, Inc. Bluebeam was discovered at a conference attended by our AEC team. It was a startup of engineers to build a better PDF product for the AEC industry. At the time, CTDOT was not getting adequate support for their Contract Plan Set initiative from Adobe Inc., who had developed the PDF under their Acrobat product. Bluebeam developers adopted innovative ideas initiated by our AEC team that led to a PDF Contract Plan Set and specific applications to manage contract document modifications like addenda, construction change orders and as-built, all within the same signed PDF set.

Many of the documented procedures in the DPD manual are performed within the PDF editing software Bluebeam. The developed procedures returned performance gains and better consistency of PDF plans and specifications. The continued progressive development of Bluebeam offers future advantages to CTDOT and the AEC industry.

Amongst the PDF processes that evolved, CTDOT developed procedures for digital signing and certifying of the PDF contract plan files. Our first digitally signed contract plan prototype was not very different than the original wet signed Mylar. This close adherence was due to concern of the radical change expressed by the State and Consultant Engineers. However, after continued discussion and opportunity, we progressed into a much more design discipline friendly contract plan format, very similar to the building industry's architectural type plans. We divided out discipline subset contract plans and their digital signing responsibilities to each of the different disciplines within a project. Lead Designer responsibilities became the umbrella of design plan governance covering all the discipline subsets. **The model for CTDOT's digitally signed contract plans is one of the most important developments of this research. The well documented processes within the DPD manual and the QA/QC of the PDF checking application allow CTDOT to partake in progressive discussions like Civil Integrated Management (CIM) and 3D modeling.**

Representatives from CTDOT AEC Applications demonstrated the procedure as a policy change on signing plans to the Professional Engineers at the Connecticut Department of Consumer

Protection, which at the time did not cover digital signing. CTDOT AEC Applications was asked to review and comment on new policy for digital signing and certification which was later implemented. Included here is the link for Connecticut's new policy for Professional Engineers and Land Surveyors, "The Use of Electronic Signatures by Professional Engineers and Land Surveyors".

3.6 Electronic Design Reviews (EDR)

With the heavily paper oriented process of design reviews, it was certainly a challenging to develop an EDR process. An intuitive, enterprise solution was sought that was integrated with PW Online to manage the documents and review process. This process is captured in Section 10, "Digital Review and Commenting" in the DPD manual. The application is part of the Bluebeam product and is integrated with PW. Individuals developing the review session are required to have a production license of Bluebeam, but reviewers only require a free viewer. The session is started in PW and the subject documents are transported to Bluebeam's studio portal, where the review process and progress tracking takes place via managed services. Every comment is associated with its owner and summary reports can be created; example: all comments on a page or all comments by John Doe. These review sessions and resulting commented PDF contract plans are then transported back to PW through the application for a clean record of that review session.

3.7 QA/QC of CAD and PDF Standards

With more intelligent contract plans being developed and required for submission by Consultant and State Engineers, it became important to develop automation to check the plans for compliance. This process is captured in Section 6.2, "PDF Checker – Contract Plans" in the DPD manual. AEC consulted with Altiva™ to develop a product that worked within PW Online. The Designer responsible for submitting contract plan PDF's could run the QA/QC checker to determine if the PDF contract plan met the specification. If the PDF contract plan passed muster, document attribution within PW would get updated with results. When Contract Processing Engineers start their review of the bid documents, they would look to these attributes for document compliance. The intelligent features of the PDF's that are inspected included the digital signature, sheet size, searchable text, layers, flattened, engineers stamp, attribution, proper sheet numbering and labeling.

3.8 Document Control

During this research project, CTDOT was administering what the industry terms as “Mega Projects”. These are very large projects requiring dedicated document managers for all the necessary project submissions. Most of these Mega Projects had incorporated a contract item for document control. The Contractors that bid these projects mainly used Microsoft SharePoint for this work. CTDOT AEC Applications consulted Bentley Systems Inc. to develop integration between PW and Microsoft SharePoint. Two applications were developed. One of the integrations allowed a SharePoint project to see directly into a PW project eliminating the need to copy large documents and manage them in two places. The second integration allowed a document that has reached approval or maturity in SharePoint to be dropped into a SharePoint library and be sent directly to its project container in PW for purposes of document retention. The document attribution from SharePoint traveled with the document as well.

CHAPTER 4 Benchmarking and Performance Improvements

The implementation of PW was the Department's first step in providing the necessary infrastructure to allow the advancement of innovative Cloud based digital document processes.

Taking this step has allowed the Department to implement improved business processes related to project delivery, construction and asset management.

Providing PW along with other software, such as Bluebeam and DocuSign has allowed the Department to implement more effective and efficient digital document processes, such as but not limited to digital contract documents, digital signatures, and collaborative digital reviews.

The implementation of digital documents and their corresponding digital workflows has greatly improved document generation times, review and issuance times, reduced the time required to locate critical a document and has reduced the amount of paper used.

The following are examples of cost savings based on reduced staff hours required to complete the new digital process versus the replaced paper-based process.

(The following data used is based on engineering and project management judgement.)

Table 4.1 Digital Contract Plans, Specifications and Supplemental Documents

Process	Hours Before	Hours After	Number of Projects per year	Hourly Wage	Cost Savings per year
30%,60% & 90% Review	20	18	100	$100	$20,000 Per review Total = $60,000
Sheet numbering and signing of project plans	3	1	100	$100	$20,000
Packing of plans and delivery to lead designer	3	0	100	$100	$30,000 per discipline Average project has 3 disciplines Total = $90,000
Packaging and delivery of plans to processing	3	1	100	$100	$20,000
FDP to DCD plan review process	4	1	100	$100	$30,000

Providing regulatory agency (FHWA) copies of contract documents	4	0	100	$100	4 x 100 x $100 = $40,000 This quantity only represents one occurrence per project
Searchable plans and specifications. All plans and specifications are available on line for digital searching. Reduces time required to locate and identify items, details, etc.	2	0.5	100	$100	1.5 x 100 x $100 = $15,000 This quantity only represents one occurrence per project
Proposal estimate, federal estimate, calendar, permits, agreements, commitment list, DA Letter, etc. are available in the Cloud. Delivering, locating and consuming information is much faster for all staff.	2	0.5	100	$100	1.5 x 100 x $100 = $15,000 This quantity only represents one occurrence per project
Hydraulic, Scour, Floodway, Geotechnical, Environmental Compliance reports are created and signed digitally; and, stored in PW instead of a file cabinet. This makes them available to everyone. Saves engineers time requesting and having hydraulics find the report to scan and send them a copy.	3	0.5	100	$100	2.5 x 100 x $100 = $25,000
					Total = $315,000

Table 4.2 As-built Digital Contract Plans

Process	Hours Below	Hours After	Number of Projects per year	Hourly Wage	Cost Savings
Manually stamping each sheet can be done all at once now	4	1	100	$100	3 x 100 x $100 = $30,000
Mark-ups and filing	3	1	100	$100	$20,000
Delivery to CTDOT's Support Services is no longer required.	2	0	100	$100	2 x 100 x $100 = $20,000
					Total = $70,000

Table 4.3 CAD Processes using ProjectWise

Process	Hours Before	Hours After	Number of Projects per year	Hourly Wage	Cost Savings
Supporting one CAD workspace for consultants and in-house engineers as opposed to supporting a zip folder for the consultants and our server in-house. Saves AEC Applications time preparing and documenting how to use the zip folder for consultant use.	80	0	N/A	$200 - 2 users	80 x $200 = $16,000
Consultant workspace support	300	200	N/A	$200 – 2 users	100 x $200 = $20,000
					Total = $36,000

Table 4.4 shows the cost savings due to eliminating 30%, 60% and 90% plan sets for review and reducing the final paper sets of specifications and plans distributed for continued project support. These numbers only estimate the cost savings achieved from the Department's consultant designed projects.

Table 4.4 Paper Reduction

Paper	Sheet Count	Number of Sets Eliminated	Number of Projects per year	Unit Cost	Cost Savings
Final Spec Package	200	20	100	$40.00	$80,000
Final Full Scale Plans	100	10	100	$100.00	$100,000
Final Half Scale Plans	100	10	100	$50.00	$50,000
Spec Review Package	200	20x3 Submission	100	$40.00	$240,000
Plan Review Package	100	20x3 Submissions	100	$50.00	$300,000
					$770,000

TOTAL SAVINGS PER YEAR = Approximately $1,200,000

Using PW Online, which is the Department's digital document management solutions, has enabled the Department to develop, test and implement various levels of digital document procedures. This has significantly improved the Department's overall performance.

Additional savings in time and resources has also been identified in the following areas, but have yet to be quantified:

- The Office of Construction now uses PW and mobile tablets as part of their e-construction business processes. This office has also reduced the amount of paper used in their processes.
- Digital document retention for the Department has the potential to reduce funding required to house and manage paper documents. This is currently being performed by providing full time staff and a facility.
- PW is being used to store critical asset documents, making it easier for all staff to access and consume these documents.

- Engineering project schedules are currently being stored in PW. This allows the Department to run reports on the schedule health of each project. The transparency is critical in keeping project schedules, budgets and scope healthy.

- Some of the Department's projects are leveraging PW by collaborating in the Cloud across many internal units and outside agencies. They collaborate by making CAD files and project documents available across disciplines, regardless of location.

CHAPTER 5 Conclusions

Digitally signed contract plan PDF files, EDRs, legacy plan archives and QA/QC of CAD and PDF standards make up the bulk of the CTDOT's digital design environment. Web-GIS with hyperlinking to PW contract plan and asset documents provide excellent opportunity to share documents with business partners. As described herein, the savings and efficiencies of these applications are impressive, even in a smaller state like Connecticut. The most revealing benefit is that, the system of a developed PDF contract plan format with digital signatures has worked across CTDOT's portfolio of projects. 75% of the work for CTDOT projects is performed by Consultant Engineers, which includes collaborative efforts of both small and large teams with both small and large projects. The success has allowed CTDOT time to focus on other FHWA initiatives such as Everyday Counts etc. These include e-Construction, 3D Modeling and Civil Integrated Management (CIM). The digital design environment becomes an easy opportunity to accommodate design delivery of these initiatives.

CTDOT's 800 users of PW Online and Bluebeam within the digital design environment have provided an estimated savings of $1.2 million per year delivering the capital programs. With expenditures of the PW annual subscription of $150,000, Bluebeam initial purchase and annual maintenance averaged over five years of $32,000, this delivers an impressive 6.6:1 benefit/cost ratio.

Going forward with the required asset management and safety analysis on our road networks, all DOT's will require better data stewardship, governance and the ability to manage the change in their data inventories. CTDOT sees the adoption of CIM for capital projects and capturing of maintenance activities as a direction that must be navigated. The digital design environment has allowed CTDOT to move in the proper direction to accommodate this paradigm shift.

APPENDIX

Connecticut Department of Transportation Digital Project Development (DPD) Manual

The manual encompasses the preparation, review and delivery of capital project documents from project initiation to project completion as well as design phase scheduling.

Below is the link to the manual.

http://www.ct.gov/dot/lib/dot/documents/aec/Digital_Project_Development.pdf