Construction/Architecture's Past Forecasts for the Future: Estimating and Electronic Documents

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From an evaluation of past cultures, one can see the many different influences upon the architecture and construction of emerging societies. Past cultures have helped shape the architecture and construction of today. Based upon the influence of historical cultures on today's construction industry, we can forecast the issues that will affect the future of architecture and construction. The historic evolution of construction documents shaped the current methods used today. Electronic documents have now become an important informational tool to assist the architecture/construction industry and provide benefits to both the designer and the contractor. This paper addresses these advantages with particular emphasis on the estimating stages of a project.

Key Words: Electronic Documents, Takeoff Viewer, Documents, Architecture

Introduction

We depend upon history to make relevant decisions for the future. The past brings meaning to our present. Cultural aspects and needs of societies motivate the development of community including architecture and construction technologies. Egenter (1992) stated,

"We now have a sound, scientific basis on which to build an architectural anthropology. If further research will demonstrate that architecture contributed essentially to the genesis of man, this will mean that built form handed down since times immemorial can again -- and now scientifically or in terms of anthropology -- be understood in its great values. Architectural form would have contributed greatly to the creation of culture."

Architectural anthropology relates to the study of the buildings of mankind and their origins and development as related to prevailing cultures, customs and beliefs. Therefore, the genesis or beginnings of man is highly related to the anthropology of architecture in that the cultures of man developed and influenced his habitat. The habitat, or built environment of man was inspired and created by his predominate culture. We see this phenomenon depicted by cultures and great societies of the past, which continue to influence our present and mold our architectural future.

Culture Drives Building Technologies: What is Learned from History

During the early era of man, the culture exhibited a tribal and nomadic environment. Most organized humans belonged to their respective tribes and traveled about from one area to another in search of better habitats for their people, animals, and general welfare. These nomadic people survived off of what they could generate within their respective groups and also what they could barter for with other tribes. Bartering became a cultural aspect of society. Because of the cultural need to barter, exchange, gain, and interact, trade communities were built at strategic locations for these nomadic tribes to congregate and barter or trade with others. These communities were built to accommodate the cultural trade need and consisted of the community leader’s abode located central to all trade and other lower level building, mostly residential for those who would work to facilitate the diverse trade actions. A great wall generally surrounded the city to protect it from robbers or nomadic bands that survived on looting and pillaging. The city would guarantee the different traders and tribes an environment suitable for trade while offering protection from outside threats. Thus began really the first organized community. Social stability matured and buildings were built that were meant to be permanent. The buildings were built to entertain, provide comfort of living, and protect their inhabitants. Bodo Cichy (1966) stated,

"The human race, despite all its diverse traits, is closely interlinked, in the beginning there existed only small isolated communities, which, having no intercommunication, reacted upon their environment in quite different ways and developed into highly individualistic material and spiritual groups, it was through an ever-increasing commercial contact between those isolated cultures that in course of many thousands of years conditions favouring a world civilization were established/the true foundations of culture were not laid, however, until man had abandoned his passive, parasitic role and set himself against nature, becoming instead an independent being. When about 10,000 years ago he built himself houses, when organized communities lived together in villages, when plants were cultivated and animals were domesticated, when he stored the harvest and engaged in barter it meant that he finally left 'Paradise' behind". 
At the meridian of time, the world experienced several changes to dominate cultures. The Roman Empire represented one era of cultural dominance. Their architecture and buildings depicted their lifestyles and portrayed the culture. Lavish living, art, and education formalized a culture and produced architecture that had a lasting impression upon cultures to follow. They built a great city and organized a great society of trade and Rome became the center of the world at that time. People flocked to Rome for trade, art, architecture, culture, and entertainment. The great Colosseum, fountains, baths, aqueducts, and the Forum a place of trade, culture and politics, were all aspects of the Roman age of dominance. The Pantheon was the first temple constructed using a combination of concrete and masonry construction. The Romans were some of the first people to experiment with concrete construction.

Upon the fall of the Roman Empire and emergence into the dark ages another culture evolved. This was an era of great contention, confusion, and struggle. The world was in a quandary and people struggled to establish identity. The culture diverted to its almost nomadic past. "At the Council of Clermont in 1095, Pope Urban II calls for a holy war to wrest control of Jerusalem from Muslims, which launches the First Crusade, one of at least eight European military campaigns... (Infoplease, 2000)." Wars and contention, the Christian crusades, and king fighting against king created a culture of dark survival. Buildings and architecture of the time reflected this culture. Their form fitted their function. Fortresses were needed to protect the clans from intruding or conquering campaigns. High towers of stone, stone and wooden walls of protection, and stone/wood buildings with thatched roofs for the clanspeople. The cultural needs directed the architectural and building trends of the diverse communities. Castles and the culture that drove their existence occupied a major part of the world’s history (Mfeinberg, 1997).

"The castle first appeared in Britain after 1066, when William the Conqueror won the Battle of Hastings. The use of castles spread throughout Britain, and many new castles appeared. They served a defensive purpose, but also as the center of a lord's domain and as an administrative center. Castles were built for over two centuries, but following the Crusades, new varieties were adopted. Castles of all types were built, and rebuilt, and added on to for over 500 years, but in the 16th century, they lost their favor. The common use of gunpowder on the battlefield made the castle an ineffective defense."

From the exiting of the dark times of war, about 1300 BC came the emergence of the Renaissance Era beginning in the early 1400’s and spanning through the 1600’s and the subsequent Baroque period. "The term Renaissance, adopted from the French equivalent of the Italian word rinascita, meaning literally 'rebirth,' describes the radical and comprehensive changes that took place in European culture during the 15th and 16th centuries, bringing about the demise of the Middle Ages and embodying for the first time the values of the modern world (WebMuseum, 2000)." This was a time of rebirth of art and architecture, congregation, and cultural solidification. Europe at this time became the real entity of a world being unified. Although there were still a significant amount of muscle flexing and dreams of world conquering, nations began, cultural dynasties began, and people gained a sense of place.

Europe was an old country, torn and tattered by centuries of war and contention. London had burned to the ground, purging it from the fifth of a dark age urbanism and allowing a new opportunity to rebuild. They had learned many hard lessons. As with London, some of these lessons reflected their building styles and architecture. Living on a relatively small portion of land for thousands of years established a great appreciation for available resources. They had all but destroyed their forests and trees, polluted their water supplies, and exhausted their resources. They learned masonry construction as a result of cultural need and environmental appreciation. During the 15th century there existed a great excitement for world travel and exploration. The Americas were discovered and mainly pioneered by the European people. When they experienced the new world, they saw a land with a seemingly endless amount of trees, fresh water, gold and other precious ores, a great supply of resources, it was like starting all over again.

The migration to the New World brought with it another generation of cultural development. Societal needs among the new inhabitants were different than those that most of them had left behind. Weslager (1969) put it this way,

"Englishmen, Dutch, Swedes, Finns, Germans, Swiss, Welsh, and Scotch-Irish carried to the American seaboard individual concepts of their own domestic housing which varied by nationality. As time went on, there was a melding of those nationalities, creating a new social fabric having its own cultural traits in which there persisted strong threads of the past a specialized kind of dwelling ultimately made its appearance - the American log cabin."

Family farms spread throughout the eastern parts of the new United States and extended westward into the Mississippi valley. Families built their log cabins with the logs from the abundance of trees available in the land of their new home, and lived on the family farm. Communities were places of social gathering, trade, and small-scale industry. Most of the businesses in the local communities were renditions of the log cabin construction form with few differences. Weslager (1969) further stated,

"(The early American man) lived in a log dwelling, kept his livestock in a log stable, cured his meats in a log smoke house, stored his farm implements in a log shed, sent his children to a log schoolhouse, worshipped in a log church, served on a jury in a log courthouse, and sentenced the law infractors of his society to terms in a log jail. He split logs and set them up in a zig-zag configuration to build what he called worm or snake rail fences around his property, and he adapted the whole log for a number of domestic uses ranging from stools, tables and benches, to chopping blocks, corn mortars, pirogues, corduroy roads, and even cradles made by roughing logs."

"The Industrial revolution was a time of drastic change and transformation from hand tools, and hand made items to machine manufactured and mass produced goods... The government, the arts, literature, music and architecture and man’s way of looking at life all changed during the period (Essay, 2000). With the advent of many modern inventions and the ushering in of the industrial age, the
culture in the United States began to change; therefore, the building needs for its people also changed. Technology, the assembly line, and modernized industry began to have a major influence on society and the culture. Major corporate entities became dominant and began to buy the family farms from Americans, enticing them with more money than they had ever seen to move to the city, but exposing them to an unfamiliar way of life. With corporations conglomering farms to grow and harvest more with machinery and factories, mass-producing farm products, and also with the potato famine in Europe and a great movement of poorer migrants emigrating to the United States came the Great American Dream and work in America. The social and cultural makeup of this country altered. As a result of the changing culture, another need for building emerged. Cities got larger to accommodate the exodus to urbanism.

Major production cities grew to greater proportions as farmers and immigrants migrated with their families to urban living. The fast pace of this exodus created an immediate need for housing, schools, shopping, and recreation. Neighborhoods of row housing became common and popular residential accommodations. The type of row house construction required three to four story deep and narrow buildings that housed several families. Many of the new row houses incorporated a new type of construction. These buildings used wood framing components but were different than the log style of construction and also the traditional post and beam framing. A new form of framing called balloon framing evolved to satisfy the new building needs. The method of balloon framing satisfied a need created by the changing culture of our society around the time of the industrial age.

The United States began to grow, gold was discovered in California and the government encouraged people to explore the west. "Go west young man go west" and Manifest Destiny was the cry. Land being given away along the railroad passage to the west and the great land run in the Oklahoma territory were all happening. The opening of the Indian lands in Oklahoma Territory was of great interest to people across the United States . . . The unassigned lands were laid out in 160 - acres homesteads, and on 22 April 1889, it was opened to white settlement in the 'Run' for farms and town lots, which has become one of the most dramatized episodes in western history (Oklahoma Land Openings, 2000). A new culture evolved with the sprawling west and free land. Common terms we know in the building industry today came from that era. Terms such as the Texas spread and the rambler came from the new type of construction techniques that were born as a result of lots of room to build upon. The industrial age produced pre-cut and nominal lumber for balloon framing, which also assisted the implementation of a new style of building for a new era, appropriately named after its cultural impetus deemed western or platform framing.

Affects of Past Cultures and Techniques on Building Construction Today

Today is representative of all past cultures, an evolution of construction practices. The structural steel frames that support today’s skyscrapers are representative of the cultural directions of the past. Cultural needs instigated the concept of building higher.

"As the organization of business became more complex, companies discovered the advantages of locating themselves near other companies related to their work. They often wanted to be in the same building together. For instance, the Standard Oil certainly would have preferred to have been housed in the same building the railroad companies that transported its product. The office spaces and the locations of companies within buildings mirrored, to a certain extent, their set of economic relationships . . . More and more corporations were being founded . . . Architecture was a kind of public relations (The History Channel, 2000)."

Chicago began the move upward in building for the United States following the Chicago Fire of 1871. The local government banned the building of wooden structures as industrial revolution arrived and Chicago’s urban growth boomed. The first Chicago skyscraper was finished in 1882 and stood at ten stories high. The city’s earliest surviving steel-framed skyscraper was built in 1891 (Chicago Landmarks, 2000).

History of Construction Documents

The study of the process that conveys building ideas into reality shows cultural adaptations to timely issues. Before technology made it possible to feasibly reproduce construction documents, there existed an arduous method of conveying the ideas. Drawings and documents had to be copied tediously by hand and traced to make available additional copies for various workers. Price (1994) stated "Ink (was) the defining medium in most architectural drawings made prior to 1860 . . . The early drawings, composed of thin, uniformly inker ruled lines, were generally done to a small scale and included very little detail. Some included dimensions and indications of material, but many did not."

During the Baroque era, the ultimate responsibility for the design and execution of projects rested with the professional architect. He apprenticed as a cementer, stonecutter, and then became a master mason. By the middle of the thirteenth century, the master mason had clearly become the designer or the architect.

The definition of the architect, who primarily was the builder charged with the supervision of the building, emerged from artists and sculptors. However, this all began to change with the inclusion of certain technologies and changes of philosophy. Price added that

"Decisions like the profile of moldings, the trim around windows and doors, and the design of decorative brick work were left to the discretion of the builder or made during the construction process through informal consultation. This abbreviated design process was possible because of the nature of eighteenth and early nineteenth century aesthetic assumptions and
building practices. These principles and sources were well understood and familiar to both client and builder . . . With the emergence of the architectural profession by 1830, the design and construction functions became increasingly separate and fewer decisions were left to the discretion of the builder. With changes in style, building technology and craft practices, the assumptions of the eighteenth and early nineteenth centuries that had united the master-builder and client in a single vision no longer existed.”

During the period of time from the early 1900’s to the mid part of the century, modern architects would produce drawings upon light translucent media. These drawings could then by using the blueprint process be reproduced several times. This process that resembled white lines on a blue background became obsolete when the Diazo process reversed the graphics and produced blue lines on a white background. During the 1970’s a significant technical advancement occurred that began to once again change the method of producing construction documents.

The first electronic graphic system was built in mid 1950 by the United States air defense system. In 1960, McDonnell Douglas Automation Company was founded. It played a major role in Computer-Aided Design (CAD) developments with the introduction of a CAD program. The first CAD programs used simple algorithms to display patterns of lines at first in two dimensions and then in 3-D. By 1969 Computervision and Applicon companies were founded. Computervision was created to produce systems for production drafting and in the same year it sold the first commercial CAD system to Xerox (CAD History, 2001). Today CAD plays an integral part of construction documents. Electronically prepared drawings with the incorporation of electronically created specifications enhance the construction document process by minimizing many mistakes involving human error and maximizing the use of time.

Getting the project completed as quickly as possible with the least amount of problems all relates to the current “time is money” philosophy. For instance, Il Duomo cathedral in Milan, Italy began construction in 1386 and was finished some time in 1887, consuming over 500 years to build (Zeta International Milan Guide, 2000). By contrast, the Empire State Building, using relatively new and innovative construction practices, began construction on January 22, 1930 and took only one year and forty-five days to complete. World Wide Plaza, a $550 million project and one of the latest major projects in the city of New York, took about four years to build (Skyscraper, 1990).

Implications for the Future of the Construction Industry

In our society today, information exchanges at a rate far greater than ever before in the history of the world. The clogged communication pipeline that had once been a hindrance to the construction process has now been replaced with electronic advancements that have made communication one of the industry’s strengths, allowing for the saving of valuable time. In one case Opfer (1999) indicated that

"Continual decreases in the price of communications and personal computers with a very high speed data transmission rates combined with decentralized construction operations make Intranets a sound solution for the construction industry. Workflow on a construction project not only depends on tools, personnel and material but information. Intranets allow contractors to break down the barriers between itself, clients, vendors, and subcontractors. Construction projects are a team effort. With Intranets providing all information in a readily-viewable form, cross firm collaboration is fostered on the project. The return on investment from Intranets makes it one of the soundest investments that contractors can make in today's competitive marketplace. Architectural firms can exchange and transfer electronically all documents including drawings, shop information, specifications, contracts, addenda, change orders, communications, and memorandums to consultants, contractors, building departments, owners, and inspection agencies allowing for much quicker responses. Construction sites are online allowing for immediate updates available to all parties. On-site cameras and hand-held palm technology also facilitate immediate communication possibilities. These advancements are producing powerful implications for the future of the industry."

Because time is so important to today’s economy, the construction industry must analyze their operations and evaluate how time can further be saved to remain competitive. Full use of available technology becomes the tool to assist in this endeavor. Christofferson (1999) stated, "To increase their profitability in a market that continually is becoming more competitive, builders must find ways to use the tools of technology to improve the effectiveness of their communication." Technology is so cost and time effective that even the small town builders or small time architects are mandated to incorporate it or risk losing business. From Opfer and Christofferson’s comments, it is evident that electronic information technology is a cultural norm that dictates the direction of construction as cultural influences have demonstrated throughout history.

Electronic Documents Used for Estimating

A new technology available to the construction industry is the takeoff viewer. The takeoff viewers interpret drawing files in typically the CALS or TIF file formats. These types of file documents were originally distributed by owners such as the Army Corps of Engineers (Winston & Tuchman, 2001), state agencies, and/or designers to decrease their document reproduction costs. While this method did indeed save the designers/owners money, it also basically shifted the reproduction cost to the contractors.

Contractors started looking for ways to perform their takeoffs directly from these files rather than printing them out. Takeoff viewers provide software packages that allow the estimator to perform their takeoffs directly from the electronic documents, saving the contractor the cost of reproducing the documents.
To begin a study of the use of electronic documents used in estimating, some definitions are needed.

**Electronic Documents:** Computer image files that contain the same information as paper construction documents. The drawings, specifications, and other documents are included in the scope of the term electronic documents. They are in digital format and may or may not be available on-line through a web browser.

**Takeoff:** The process of obtaining the dimensions and calculating the quantities from the plans and specifications (Chandler, Greene, Smit, & Willard, 1991).

**Takeoff Viewer:** Software that is developed to aid the estimator in the takeoff process using electronic drawings. In addition to the viewing and highlighting construction documents an estimator can obtain counts, lengths, and area measurements while maintaining a running total of these quantities.

**Viewer:** Software that is developed to view electronic documents. The design intent of this software focuses solely on viewing and highlighting the documents but typically not on measuring or quantifying the materials on a construction project.

### Features of the Takeoff Viewer

The basic features of the takeoff viewer include the measurement of counts, line segments, continuous lines, and areas. As each measurement is taken, mark-off can be placed on the documents indicating where the measurement had been taken. The mark-off typically consists of symbols and/or text. The changeable attributes of the mark-off typically consist of changing the font, shape, color, and size.

The ability to store the mark-offs on electronic documents is a common feature that estimators currently using electronic documents cited as a major advantage of the takeoff viewer. Most software packages allow mark-offs to be stored.

The takeoff viewers also allow the estimator to continue to use tried and true estimating techniques such as the following:

- Checklists and organizational structures to ensure that items of work are not overlooked.
- Color mark-offs to identify which items have been taken off or require further evaluation.
- Viewing the plan view, elevation, and details simultaneously (using multiple monitors), allowing the estimator to visualize the items to be included in the takeoff.

### The Study

To determine if electronic documents were ready for mainstream use by estimators, the following items were performed as part of a study for the Building Construction Industry Advisory Committee (BCAIC) of Florida:

- Estimators using electronic documents were interviewed.
- Computer software and hardware were used to simulate the estimating environment with electronic documents.
- Estimators who had never estimated with electronic documents were given instruction and then allowed to use electronic documents with additional feedback provided.

The study helped to answer the following items:

- What features are available in this type of software?
- Are the feature sets developed to a point that they could be used in the real world application of takeoff?
- What hardware is required to use the takeoff viewer?

Four takeoff viewers were found by searching the Internet and trade magazines. Each company offered a downloadable trial program that is typically usable for 30 days. The On-Screen Takeoff required an activation code from the company that would make all the features of the software available. This code was easily obtained from the companies.

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Interviews

Interviews were conducted with estimators using electronic documents to perform their takeoffs. Most of the estimators currently using electronic documents were subcontractors. The estimators who used the electronic documents preferred their use over paper documents. When some of these estimators received paper documents, they would pay to have the paper documents scanned, allowing them to use the takeoff viewer software. The main benefits cited of using electronic documents by these estimators were the following:

- The ability to have a complete set of documents
- The ability to store the documents with their mark-offs on the documents
- The ability for increased communication with project management

The sources of the electronic documents used by these firms were the Internet, scanning, and then CD’s. The features that were found most beneficial to them when using the takeoff viewers were the following:

- The generation of color code mark-offs during the takeoff can be printed and given to project management which greatly enhances the communication between estimating and project management, saving a tremendous amount of time.
- The ability to reaffirm what was taken off a month ago
- The measuring tools for area, counts, lengths, and the mark-off of the drawings
- The autoscaling and measuring tools
- The overall ease of use of the software
- The cost savings of the copying and obtaining the plans
- The ability to store the project because there is no guessing on what was taken off
- The savings of time and the accessibility of the documents

Some drawbacks of using the electronic drawings were the following:

- The screen size and all the panning that is required (The panning makes the takeoff longer, but the colored printouts save time with the project management coordination.)
- The initial learning curve
- It becomes tiresome looking at the screen.
- The time to download the documents

Two of the estimators responded that there were no readability issues with the electronic documents. One estimator said only minor readability issues had been encountered, and two estimators said sometimes there were readability issues. One of the estimators who said that sometimes readability was an issue also stated that the scale shown on the electronic drawings was not always correct. Therefore, the estimator used the autoscale feature of the software rather than use the stated scale on the electronic drawings. The autoscale feature allows the estimator to click on the endpoints of a known distance and then enter the distance between the two points. From this input, the program then calculates the scale for the drawing sheet. This calculated scale can then be used to perform measurements for the items on the drawing sheet.

All five estimators responded that they stored the electronic documents for future reference. Four of them stored the marked-up electronic drawings and the other estimator stated that he printed out the marked-up drawings for storage. Two of the estimators stated that addenda are easier to receive by electronic documents. Two of the estimators also stated that their plan deposit fees had decreased because of electronic documents.

Frustrations that estimators have had with electronic documents include the following:

- The scanner breaks down, delaying conversion of paper documents to electronic documents.
- Handwritten changes to the documents are not shown on the electronic drawings.
- Flipping through the pages on the screen can be frustrating.

The above frustrations could be overcome by rescanning the sheets with the handwritten changes. To overcome the frustration of flipping through the pages on the screen, one of the firms used paper copies as well as the electronic copies. Estimators hang the sections or elevations on the wall next to the estimator while the estimator takes off the lineal measures from the floor plan on the screen. Using a second monitor and then displaying the details and section on the second monitor may also overcome this frustration.

Another draw back noted by an estimator was that while the electronic documents have made it easier and faster to obtain the project documents, he missed the personal contact with the people when he received the documents.

Hardware

It was found from the interview that none of the companies used multiple monitors. Two of the companies used 21" monitors, two firms used 19" monitors, and the remaining company used a 17" monitor. The computers used by these companies range from a Pentium to a Pentium III computer with a minimum of 64 Meg of RAM.

For the study several of the following monitor configurations were used: 17", 20" viewable, a dual monitor system using both monitor sizes, and a projector. While a single 17" monitor was acceptable, the larger the monitor the more comfortable the estimator was when performing the takeoff. A resolution setting on the monitor of 1600 x 1200 or above also aided the estimator in the takeoff process. A second monitor, while not required, made it more convenient for performing the takeoff because the takeoff viewer could be opened on one monitor while the estimating program was open on the other monitor.

The takeoff viewers were typically more accurate than digitizers. The study found that the takeoff viewers were .5 to .75 percent more accurate than digitizers (Miller 2001). The takeoff viewer also allowed for the measurements to be altered whereas the input from a digitizer cannot be altered.
New Estimator Exposure

When this software was shown to an estimator who had never been exposed to the takeoff viewers, he requested that the software be installed on six other estimator’s computers so they could also evaluate it. Within a matter of weeks, the company purchased a takeoff viewer.

The following is a summarized list of benefits from the estimator shown the takeoff viewer:

- A better means of distributing the documents to subcontractors
- An alternate means of takeoff that operates similarly to a digitizer, yet more accurate and modifiable
- A means of archiving the plans for the projects that have been bid without requiring a warehouse for storage
- Easier archival of the plans for which the company has submitted estimates
- Improved coordination of estimating and project management

(B. Briggs, personal communication, October 10, 2001)

Conclusions

Past cultures have shown us that change and adaptation are part of our industry’s heritage. To increase their profitability in a current market that operates on the "time is money" philosophy and to remain competitive, builders of today must find ways to fully utilize the tools of technology to improve communication and accuracy. Takeoff viewers have been developed to a point that estimators can use them effectively to perform takeoffs. With the clear advantages demonstrated by the use of takeoff viewers over the traditional methods of architectural/engineering scales and/or digitizers, takeoff viewers are ready for mainstream implementation. The feature sets are developed beyond that of digitizers and allow for the electronic files to be used for estimating, saving the contractor the document reproduction costs.

With the wide availability of electronic documents from sources such as the Army Corps of Engineers, Associated General Contractors (AGC), state agencies, and designers, contractors can either printout the documents and use traditional methods or contractors can use takeoff viewers and save the reproduction costs while also utilizing a better method for takeoff.

A full copy of the study can be found at the following URL:
http://www.dca.state.fl.us/fhcd/fbc/committees/building/bldg_research/bldg_research_files/grant_r00-4/R-004-FinalRpt.pdf

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