ASC Proceedings of the 38th Annual Conference
Virginia Polytechnic Institute and State University - Blacksburg, Virginia
April 11 - 13, 2002 pp 33-40

Teaching Paperless Detailed Quantity Take-off and Estimating

Kevin R. Miller
Brigham Young University
Provo, UT

Thomas H. Mills
Virginia Polytechnic Institute and State University
Blacksburg, VA

Electronic bid documents are available from a variety of sources. Historically, contractors have printed the electronic documents and then performed their takeoffs. Takeoff viewers are now available that allow the contractor to perform their takeoffs directly from the electronic documents. Several software companies that produce takeoff viewers are listed and features of takeoff viewers are described. An example is provided on how takeoff viewers have been successfully used in an estimating course and student feedback is discussed.

Keywords: Estimating, Teaching, Quantity Takeoff, Electronic Documents

Detailed Estimating

Detailed estimating is a time consuming process intertwining quantitative aspects of a science with qualitative principals characterized by the art of estimating. The art and science of estimating can be more aptly expressed as the creative versus the calculable sides in estimating. Detailed estimating is directed at two fundamental functions, 1.) quantity take-off and, 2.) pricing. Teaching of estimating in an academic environment involves not only take-off and pricing, but teaching the techniques and practices of organizing the take-off, developing techniques for measuring and recording quantities, and finally recapping these quantities so that hypothetical cost can be assigned. The time consumed by students in implementing these mechanics leaves less time for exploring the more creative aspects of estimating, that of determining work breakdowns, developing crew structures, assessing equipment selection, and ultimately considering smarter production processes. Experienced estimators are able to intuitively develop creative work process solutions as they estimate. Several academic programs consider these creative aspects of construction as outside the realm of estimating and address these points in production planning, or scheduling courses.

This is unfortunately shortsighted in that estimating allows the first mental construction of the project. It is during the take-off and estimating phase, that work process are codified based on units of material, labor, equipment, productivity and ultimately measured by price and cost. The ability to synthesize during this process allows a smarter work plan and ultimately a more competitive bid price. Therefore techniques that allow improvements in efficiency and accuracy in estimating can provide students with more time to explore the creative side of estimating while working to develop their basic skills in organizing quantity take-offs. On-screen take-offs using electronic drawings is capable of enhancing this learning process by assisting in the development of an organizational structure; by counting, measuring and calculating; and then by producing an exportable spreadsheet.

Techniques

The "art" of estimating has matured significantly in the past twenty years. The advent of the personal computer has reduced the drudgery and alleviated many of the error prone aspects of estimating. The use of computer spreadsheets has contributed significantly to reducing tedious mathematical calculations and constant error checking to an efficient "plug and punch" routine when extending quantities and applying prices.

Although construction documents are largely prepared using computer assisted drafting and design (CADD) they are still frequently issued for bidding and almost exclusively for construction in paper format. Several companies, led by Timberline Estimating have created a hybrid system of quantity take-off and estimating that mixes electronic spreadsheets, digitizing tablets and paper drawings to count, measure and extend quantities and prices. These processes involve pasting down a paper drawing and using a touch sensitive stylus to point, measure and record data within an electronic spreadsheet used for quantity extension and pricing. Only recently have electronic bid documents become available throughout the construction industry.

In 1995, the Army Corps of Engineers began distributing their construction documents in electronic format. (Peters, 1996; Watson, 1998). Many plan rooms nationwide including F. W. Dodge and regional plan rooms in Florida, Washington and Virginia, in addition to state governments are offering construction documents to their clients electronically. (http://www.fwdodge.com/). Additionally, the Associated General Contractors (AGC) is forming alliances with virtual plan room companies to help their members take advantage of Web-enabled on-line bid documents. (Winston & Tuchman, 2001).

To take advantage of electronic and on-line bid documents, "takeoff viewers" have been created by software companies that allow the

estimator to perform electronic take-offs directly from these electronic documents. Thus the best of both worlds is developing, CADD produced documents, distributed in electronic format, and then viewed and used in electronic format to do quantity take-offs for automatic conversion into spreadsheets that do the appropriate extensions and pricing. Among these "take-off viewers" are:

Product	Company	URL
On-Screen Takeoff	On Center Software.	www.oncenter.com
Takeoff Tool	US Cost Inc.	www.uscost.com
Max View	MaxView Corp.	www.maxview.com
BidScreen XL	Vertigraph Inc.	www.vertigraph.com
FastBid	Builders Exchange of Washington, Inc	www.bxwa.com

Each company in the list above typically offered a 30 day trial period where a person could try the software and make an evaluation of the product. On Center Software also offers a free viewer that is downloadable that allows the electronic documents to be printed to scale. *On-Screen Takeoff, MaxView,* and *Takeoff Tool* are stand alone programs that can operate independent of any other software package. *BidScreen XL* is a Microsoft Excel add-in, and *FastBid*, is a plug-in for an internet browser.
Definitions:

To aid the reader throughout the remainder of this paper several definitions are presented below.

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.
Highlight:	Adding notes or calling attention to a particular area of a drawing. This is commonly performed on paper documents with colored markers or pencils. This may also refer to marking what has been taken off
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.

Application Issues

There are several issues that must be understood and considered when using take-off viewers for teaching estimating in an academic environment. Among these issues are:

Document Creations: Both drawings and specifications can be obtained electronically and compiled either on a compact disc (CD) or posted online to a web server for student access. Approval from the designers will usually be required but at most may require a letter of request stating the academic purpose. Faculty in consultation with the designer team can usually work this issue out. One university has made both a CD version and an online version available of both drawings and specifications. In the event electronic format documents are unavailable, scanned documents can be used. Scanned documents are generally of a reduced quality as compared to electronically generated.

File Types: File type conversions must be considered. Several formats that work best and are commonly supported by takeoff viewers are Continuous Acquisitions and Life-cycle Support (CALS) typically used by the Corps of Engineers, and Tagged Image File (TIF), commonly found in plan rooms. Additionally .bmp, .dwg, .pdf, and .dxf are supported by several of the software applications. The most preferable file format for an academic environment are cals, tif, .pdf, .dxf, and when available .dwg. Both TIF and CALS file formats produce documents comparable files in terms of size and readability. When creating CALS files from AutoCAD the output size is in terms of papers size (e.g. A, B, C, D, and E), where as the TIF output size is in terms of pixels.

Using the TIF, CALS, or PDF file formats offer the advantage of the files being read-only in nature. Not only does this alleviate some concerns voiced by the A/E's, the read-only file formats prevent the professional or student estimator from intentionally or unintentionally modifying the original drawing files. In a professional environment this should reduce the potential for claims being made based upon document alterations, and in an academic environment it mitigates the electronic version of my dog ate my homework.

Specifications are typically distributed electronic in portable document format (PDF) (Adobe Acrobat Reader, 2000). This file format typically has a small file size that can include text and graphics. A free viewer is available from www.adobe.com easing the use of these documents by students. The PDF files should be compiled as read-only and may also contain indexes, bookmarks and can be searched by word or phrase to make navigation through the specifications easier. The PDF files can be loaded in the background with the drawings and accessed quickly as the take-off is progressing.

If word-processing specification files are unavailable the specifications can be scanned into an electronic format, but the scanned image is typically not as readable as the original word processing document. Another drawback is that scanned images, typically cannot be edited, to modify the specifications between semesters.

Monitor and Image Screen Size

Obviously the bigger the better in monitors when considering appropriate screen size. Unfortunately students are usually limited to 15-17" monitors. Some of this limitation can be overcome by increased monitor resolution. With the monitor size limitation the overall comprehension of the project becomes diluted. This can be overcome by the use of paper documents to initiate an understanding of the overall scope of the project and assist in the ability to review the details on the drawings for quantity take-off.

Several of the take-off viewer applications provide a thumbnail image of the overall drawing to assist the estimator in their work. Utilization of this technique, if properly considered, may also work toward overcoming monitor size limitations. Regardless, the thumbnail is an attractive feature that enhances the power of takeoff viewer application.

Cost or Productivity Databases

Beyond these takeoff viewers ability to assist in quantity takeoff is their ability to assist in the summation of quantities and subsequent cost application and extension. The measurements obtained from the takeoff viewer can typically be copied and pasted or exported into other estimating applications. The student can utilize either self-created or commercially available cost or productivity databases to extend derived quantities with applied cost or labor hours. Commercially available Means Estimating Guide and Timberline's estimating databases are both compatible with the majority of takeoff viewers through cut & paste methods. This provides a quick and convenient method to incorporate existing cost databases into the estimating process.

Assignment Types

Assignments can vary in intensity but a strategy might incorporate the following.

1. Begin with simple count functions to allow the student a grasp of the software.
2. Upon several exercises using the simple count feature, sheet overlays, notation, and summation of a more extensive take-off can be pursued.
3. Counts can involve duplex receptacle, phone outlets, diffusers, VAV boxes, steel columns, doors, windows, toilets, etc.

The next assignment could expose the students to linear measurements and unit cost. The assignment could takeoff, linear feet of curb, moldings, piping, ductwork, etc. Once the lineal measurements are mastered, the students have a working familiarity with the processes involved and a confidence with the application to allow a more complex assignment to be pursued.

The next assignment could include area take-off of the slab, walls, roofing, paint, etc can be pursued in the assignment. Once these are mastered the ability to work in zones, and fix a take-off for subsequent revision or change management can be pursued. Several of the software applications allow a fixing of the take-off and then an ability to do a revision to the original and print out the deviations from one document to another, much the way a revision and change order estimate might occur. A sample assignment using takeoff viewers can be found at: http://www.et.byu.edu/~kmiller/cm411/help/OST/OST.html.

Takeoff Application in the Classroom

When teaching estimating many estimating software applications end up driving how estimating is taught. Just as in manual take-off, organizational processes must be developed that use the tools appropriately instead of the tools driving the student estimator. From a survey conducted among students the best method is to have an initial teaching session using paper documents. This becomes important as it is quickly obvious that overall project familiarity is easier for students to initially grasp from a set of paper documents. Once overall project scope is identified, specific techniques can be explained breaking the documents down into manageable elements, or work packages, that can be used to proceed into a detailed take-off using takeoff viewers. The takeoff viewers itemized capture and subsequent summary features can be used to explain some of the basic elements of take-off and estimating. The overall objective in an academic environment is to free the student from the mechanics of take-off. This allows more creative endeavors of redefining the work process to contribute to an efficient and extended understanding of construction process improvement.

One example of a take-off viewer might involve continuous footings. When highlighting or marking typical F1 footings, their lengths can be digitized and simultaneously the software package queries for the width, height of the footings, then ask for the variables concerning concrete strength, formwork, rebar, etc. F1 footings are followed by taking off the F2 footings. While taking-off the F2 footings; an F1 footing that was originally missed is discovered. The estimator/student is then required to go back to the F1 footings and enter the additional length. This interrupts the workflow and becomes a distraction to the take-off process.

When using electronic documents, all the footings on the screen can be measured and highlighted, and documented. This allows the student estimator to focus on the footing sequences, and minimizes the mechanics of counting, highlighting, converting, and documenting. It allows an understanding of the work being estimated and not just answering of questions from the estimating software. An additional feature of the electronic take-off is the ability to hyper-link to details and schedules so that as take-off continues and a detail needs to be viewed the hyperlink can be clicked and the takeoff viewer will jump to that detail. This change of work flow and free flowing access to other components of the bidding documents has decreased the amount of time required to perform the takeoff and made the workflow seem more natural. (Miller, 2001) This allows the mechanics of estimating to be minimized and better concentration applied to other aspects of estimating.

Takeoff Viewer Features

Takeoff viewers offer core features similar to digitizers plus additional features that help structure the takeoffs and assists in the takeoff review process. The features that are similar to digitizers are the count, lineal and area measurements. The features that go beyond digitizers are that the plans are marked with colored line or hatched area (marked-off) as the measurements are being taken. Additionally, the measurements can be modified by adjusting the marked-off measurements. The marked-off measurements and notations can be done on a separate a layer that prevents the document from becoming cluttered. Notes can be placed on the drawings to help transfer information to others reviewing the documents and section, notes, or details can be color-coded with a highlighter to indicate that the section has been reviewed or to indicate that further questions need to be answered in the area highlighted. As noted below, this feature also provides an enormous advantage for faculty in checking, evaluating and providing feedback to student learning.

Figure 1 below is a screen shot showing area takeoff, lineal measurements and counts. Areas are shown and recorded as shaded overlays, linear measurements are shown overlaid on the shaded areas as colored lines, while counts are represented by small solid ticks.

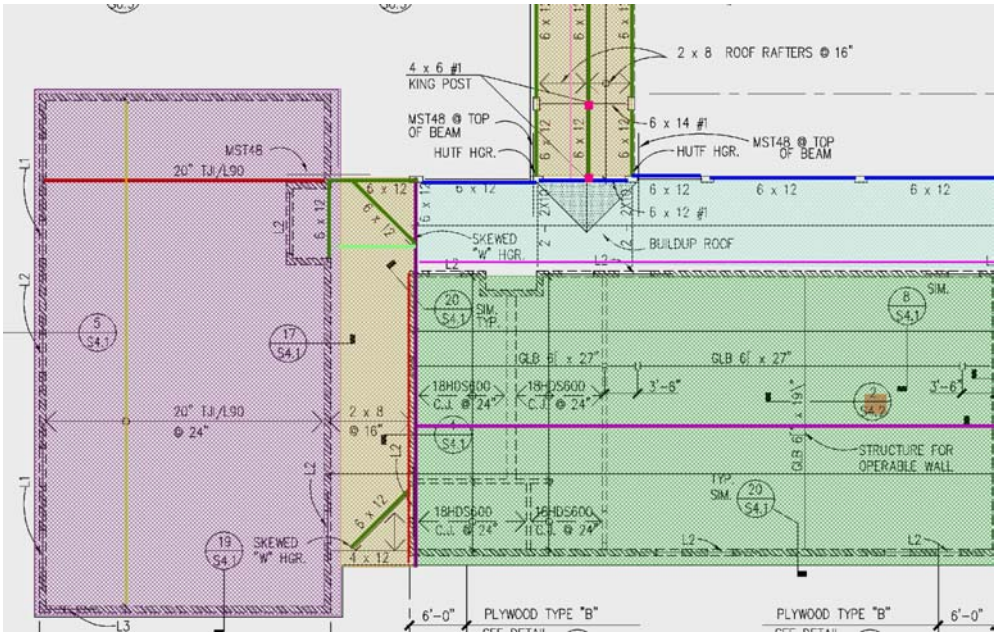

Figure 1 Screen shot with areas, lengths, and counts highlighted

The use of the takeoff viewer also helps the student learn how to appropriately organize the takeoff for continuing the estimate. Folders and subfolders can be created and used to organize the takeoff according to building number, zones, CSI code, or Work Breakdown Structure (WBS) code or self-defined combinations. The organization of the takeoff data allows detailed data in the estimate to be quickly found, reviewed and/or modified. These folder creations can be saved as templates and used in subsequent project estimates.

Finding Errors

The use of takeoff viewers makes faculty review of student's homework easier. The highlighted layers and or completed take-off and estimate can be saved as a separate file and emailed to the instructor if desired. These files can be an overlay to the drawings on the

faculty's computer allowing a visual comparison of what has been included in the takeoff. After homework has been submitted and corrected, students want to know what they missed. The file can be returned via email and the student can look at the separate noted, highlighted layer and quickly identify the areas where items were missed, should not have been included, or where organizational structure could be improved.

It is no longer a guessing game locating the extent of student errors; rather it can be pulled and reviewed. Through an "evaluation layer" the faculty can visually explain to the student their weakness. This helps students to do a visual self-diagnostics on their take-offs and estimates and confirm the magnitude of their errors. If necessary the file can be opened and reviewed with a single student or multiple students through the use of digital overhead projectors.

Instructional Sequence

One strategy for incorporating takeoff viewers in an estimating course or module is as follows.

1. Secure the electronic documents for use.
2. Convert the documents to an appropriate electronic format.
3. Make available the documents in paper format for project overview and distribution.
4. Initiate fundamental take-off techniques and procedures in paper format, either 11"x17" or another size.
5. Develop organizational techniques for identifying, extending and summarizing work.
6. Execute a simple paper based assignment that allows for take-off, extension, and summarization.
7. Introduce On-Screen Takeoff with a short training session of the mechanics of the takeoff viewer and discuss its effects on estimating techniques.
8. Reinforce the techniques with a continuation for the remainder of the semester using only given electronic documents and concentrate on fundamentals and creative components of take-off and estimating, notably, work breakdown, crew structure, equipment and labor productivity.

Case Study Results and Students Responses

At Brigham Young University in the senior level, second estimating course, electronic documents were used Fall Semester 2001. For the first half of the semester, the course focused on student learning how to use Timberline's Precision Estimating software with the students using paper plans for their estimating projects. About the midway point of the semester, the students were given an exercise that introduced them to the features of the takeoff viewer. The introductory assignment was to takeoff a portion of a project that they had previously done in the semester. The takeoff included the length and area features of the software. Initially, the students thought that it was cool but really didn't get very excited. Most approached the assignment as a one-time exercise and exerted little effort in trying to understand how the software worked. To the student's surprise, for the next project the students were only given the documents in an electronic format. The project consisted of a four building complex with seven alternates. The estimate in Timberline Precision Estimating had to be sequenced according to the alternates and then by the CSI codes. The takeoffs were focused mainly on lumber takeoffs. The students quickly realized that the takeoff viewer could be a great help to them if they used the folder, subfolder, and highlighting layer features. The folders were typically organized according to the alternates and the sub folders described the type of items being measured. Examples of subfolder names are as follows: wall framing, backing, roof trusses, roof sheathing, misc. roof framing, etc. Once these were created for the base bid, the subfolders were then copied to the other alternate folders saving the time of creating the subfolders again.

The assignment was challenging for the students. Additional time was given to complete the assignment because of the challenging nature of the assignment. However, during this assignment, it was felt that the students were starting to understand that the organizational structure of the estimate was an important aspect of the assignment and saw the real world application of the assignment.

To obtain feedback from the students concerning their feelings about using electronic documents, a questionnaire was given to them that included the following question. "On the woods takeoff, would you have preferred to have paper documents instead of using the takeoff viewer?" Two of the students responded that they would have preferred to use paper documents. Twelve of the students would have preferred to use paper documents to obtain an overall feel for the project and then use the takeoff viewer for their takeoffs. Sixteen of the students felt comfortable using the takeoff viewer entirely for the project. For the instructor, a major benefit was when students asked to see why their takeoff quantities were different, the markup file could be opened and areas of incorrect takeoff or inaccuracies could be shown thus improving a students understanding of the plans.

The student computer lab had Windows based Pentium III processors with 128 Meg of memory connected through the college network. The 17" monitor size was adequate although a larger monitor would have made the takeoffs even easier for the students. A 15" monitor would make the takeoffs considerably more difficult. With any size of monitor, the screen resolution should be set as high as possible while maintaining a screen refresh rate above 70 to help prevent eye fatigue.

Conclusion

Using a takeoff viewer in an estimating course teaches students new skills while at the same time reinforces proven strategies and

techniques for estimating. The takeoff viewers offer features equivalent to digitizers with additional features such as layering and organizational structures. Simple assignment can be given that introduce students to the capabilities of the software. After the students have completed the introductory assignment, the takeoff viewers can be used on other assignments that offer several advantages to the instructor. First, takeoff viewers can assist the instructor in helping students understand where they have made errors in their takeoffs. Second, document reproduction costs are greatly minimized. Takeoff viewers have been successfully incorporated into a university estimating course and should be considered for use in most university Construction Management programs.

References

Adobe Acrobat Reader. (2000). [Internet]. Adobe Systems Incorporated. Available: http://www.adobe.com/products/acrobat/readermain.html [2000, December 5].

Chandler, H., Greene, M., Smit, N., & Willard, J. (Eds.). (1991). Means illustrated construction dictionary. Kingston, MA: R. S. Means Company, Inc.

Miller, K. R. (2001). Electronic Documents: Saving Contractor's Time & Money (Report): http://www.et.byu.edu/~kmiller/files/BCIACReport.pdf, Brigham Young University.

Peters, K. M. (1996, September). Bidding farewell to paper. Government Executive, 28, 68-70.

Watson, M. S. (1998, August). A new spin on bid sets. *Civil Engineering, 68,* 55-57.

Winston, S., & Tuchman, J. L. (2001, April 2, 2001). New AGC alliances bring web-enabled services to members. ENR, 246, 11.