

Impact of Estimating Software on Student Performance for Simple Quantity Takeoff Calculations

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The use of technology has been increasing in the construction industry. As its use increases, the software will eventually be integrated into academic curricula. However, industry personnel and students use the software much differently. An industry expert might use software to increase their efficiency (less time to complete the same task), while a student uses it to calculate an answer without a detailed understanding of what it is they are calculating. This exploratory study isolates student performance in terms of accuracy of simple takeoff quantity calculations in a timed environment. Students were divided into two equally-sized groups, and completed a hard copy estimating assignment and a software estimating assignment (a total of four data sets). The students were only provided with a cursory introduction of the estimating software and no hands-on demonstration prior to the labs. The results show almost no difference of takeoff quantities between the actual values and the hard copy and software student groups. The software student groups finished an average of 4.4 percent faster than their hard copy student group counterparts.

Key Words: Education, Estimating Software, Student Performance, Classroom Technology, Quantity Takeoff

Introduction

Background and Problem

The use of technology in the construction industry has been increasing, and has dramatically improved over the past several years (Shrestha, Shields, Oparaugo & Pradhananga, 2011). Consequently, this new technology is also being integrated into the classroom, albeit at a delay from the industry's adoption of particular software (Gier, n.d.). However, an industry person's and a student's use and perception of the software are much different. Industry people may have years of experience that provide them with the intuition to know what the correct solution is to a problem. They generally use software as a way to decrease task completion time and become more profitable (Shrestha, Shields, Oparaugo & Pradhananga, 2011). A student, however, does not have this experience: their knowledge of a particular task or construction activity is based solely on the pedagogy of academia. Therefore, assessments based on a student's proficiency with software may not measure their overall capability as a potential construction professional.

Research Scope and Variables

The researchers conducted a study of an undergraduate estimating course at a major university in the United States as a cursory overview of the impact software can have on a student's ability to accurately calculate quantity takeoffs. Several previous studies were reviewed, and found that comparative data on student performance was not included. This exploratory paper isolates student performance as a result of using quantity takeoff software. The researchers found that more of their program's graduates rely on quantity takeoff software for their daily tasks than BIM software, which is why quantity takeoff software was the focus of this study. Student performance was defined as a combination of two factors: variance from the actual takeoff quantities and time to completion. This approach is unique from previous studies due to its reliance on quantitative data (versus qualitative observations alone).

Literature Review

Over the last three decades, the construction industry has taken advantage of the advancements made in the field of information technology (IT). The first application of IT in construction estimating was the use of spreadsheets to automate redundant mathematical formulas. While an improvement by itself, spreadsheets still do not improve accuracy or maximize productivity. Today almost all contractors use computers in some form or another, and 70 percent of that use comes from estimating and scheduling software (Shrestha, Shields, Oparaugo & Pradhananga, 2011). On-Screen Takeoff and Microsoft Excel were the main tools identified for completing the quantity takeoff portion of a project estimate.

A survey of architects, engineers and contractors found that “ninety-one percent of industry respondents felt that CM students must receive significant software training as part of their undergraduate program”, and estimating was one of the specific areas requested (Shrestha, Shields, Oparaugo & Pradhananga, 2011). Construction Management (CM) programs across the United States have incorporated estimating, scheduling and building information modeling (BIM) software into their curricula due to the large demand by the industry for graduating students to possess these skills. One of the earliest studies into the effects of using takeoff software to teach CM students estimating comes from Iowa State University (ISU) (Federle & Harmelink, 1992). The ISU study was purely observational in nature, and many of the challenges that they encountered have become minimized due to the advances in information technology over the past decade. Since 1994, Stanford University has been continuously expanding its use of BIM in graduate level. Consequently, students spend less time calculating quantities, and more time focusing on the conceptual components of pricing (Miller & Mills, 2002; Peterson, Hartmann, Fruchter & Fischer, 2011).

In the Fall semester of 2007, a study was conducted at California State University, Chico to quantitatively measure the impact that software tools have on students’ ability to learn and comprehensively understand estimating (Gier, n.d.). In the study, students conducted a quantity takeoff and were given the choice to perform the quantity takeoff using only paper documents, a hybrid of paper documents and On-Screen Takeoff (OST) or BIM, or either OST or BIM exclusively. The results of the study found that students using software had the same accuracy as those using paper, but finished 25 percent faster.

The literature review identified two potential improvements for the current body of research. The first improvement is to develop tests or experiments that confirm observational findings. Some of the literature reviewed directly identifies the need for future work that compares student outcomes between traditional estimating and software-based estimating (Sylvester & Dietrich, n.d.) A second improvement would be to minimize the amount of information provided to the students prior to their completion of a lab assignment. That is, student responses might be more representative of their understanding of the subject if they are not first provided with the correct answers to a problem, before they attempt to solve the problem.

Research Methodology and Data Collection

The researchers teach a junior-level estimating class at a major research university based in the United States. First, the class of approximately 35 students was divided such that their overall performance in the class up to this point (all assignments prior to conducting this study) was nearly equal. Each group completed two timed assignments (Lab 1 and Lab 2) within a two hour and 10 minute period, with a maximum of 45 minutes allotted for each lab. Group A completed Lab 1 using the takeoff software, and Group B completed the same lab with manual takeoff (calculators, rulers, hard copy plans). At the completion of the time limit, both groups switched. Group A completed a new assignment (Lab 2) using hard copy takeoff, and Group B completed it with the software. Both labs required students to calculate total concrete and rebar for select footings and slabs on the plans.

There are two phases of the research methodology: (1) selection of student groups and creation of lab assignments and (2) data collection from the labs.

Phase One – Creation of Student Groups and Lab Assignments

Each student’s individual grade in the class was used to determine which group they were placed. The researchers designed the groups such that average student performance in each group was nearly equal. The students were placed in ascending order by their class grade then placed into one of two groups using the following formulae;

$$i = \text{odd}; (i - 1)N + n$$

$$i = \text{even}; iN - n + 1$$

where *i* equals the current iteration, *N* equals the number of student placements per iteration (in this instance, two), and *n* equals the order of student placement during the first iteration ($n = 1$ for Group A, $n = 2$ for Group B). Five class assignments have been given at the point when this study was conducted. Each assignment grade is based on the number of points earned divided by the total point value of a particular assignment (thus, each assignment was given a percentage grade). A student grade, for the purpose of this study, was the average of each of the first five assignment grades. If a student did not submit a particular assignment, they were given a score of zero percent. The average student grade of Group A was 73.0 percent, and Group B's performance was 73.6 percent.

However, in spite of the researchers' prep work and group design efforts, not all students showed up to class and so the groups were not as evenly distributed as originally intended. The actual students' performance and their performance are shown below in Table 1.

Table 1

Group Characteristics

Characteristic	**Group A**	**Group B**
Average student grade in class	72.8%	79.8%
Total number of students in group	14	14
Hard copy assignment	Lab 1	Lab 2
On-Screen assignment	Lab 2	Lab 1

At the time when this study was conducted, the students had been instructed on the following construction estimating concepts:

- Labor – Evaluation of labor cost and duration of tasks by using labor rates, crew costs, administrative fees, and opportunity costs.
- Site Work – Quantity takeoff of work and materials related to site work activities, and application of the proper costs to the quantities to produce an estimated cost of performing the specified work.
- Earthwork – Shrink, swell, total cut, total fill, net cut/fill, and haul load calculations using the cross-section method, grid method and the 'quick 'n dirty' method.
- Concrete (Foundations) – Identification of various types of isolated footing, continuous footings and slab-on-grade conditions to perform quantity takeoffs for concrete and rebar.
- Concrete (Formwork) – Identification and takeoff square feet of contact area, studs and wales, as well as calculate the required amount of lumbar in board feet.
- Masonry – Differences between concrete masonry unit (CMU) and brick, as well as mortar, grout, and various types of lateral and vertical reinforcement calculations. Identification and calculation of unique conditions such as lintels, bond beams, and half-block to produce a complete masonry estimate.

In short, most students had a working knowledge of conducting simple footing and concrete slab takeoff calculations.

The researchers' intent in creating two lab assignments was to give each student an opportunity to use the software, but also directly measure accuracy of hard copy and software takeoff calculations. While both labs were straightforward, Lab 2 was intended to be a bit complex (and thus was given after the completion of Lab 1). Each student was instructed to work individually. Students in both labs were provided with the same pages from the plans, although in the appropriate format relative to the lab version they were completing (software assignments included the TIFF image files and hard copy assignments included 11" by 17" paper copies). The labs were not more complex due to the class' two hour and 10 minute constraint and the students' only having a working understanding of On-Screen Takeoff's basic tools and functions. Table 2 provides some additional information about each lab.

Table 2

Lab Assignment Characteristics

Characteristic	**Lab 1**	**Lab 2**
Project scope	Office building being constructed to accommodate the management and operations of the onsite fuel farm on the Marine Corps Air Station in Yuma, Arizona.	Youth Center to accommodate a partnership with The Boys & Girls Club of America to provide youth and teen programs to the families of Marine Corps Air Station in Yuma, Arizona
Total number of plan pages	24	17
Type of plans included	Architectural, Civil, Structural, and Title	Architectural, Structural, and Title
Takeoff assignments	Footing 1, Wall Footings 1 – 3, Concrete Slab, and required rebar for these takeoffs	Footings 1 – 4, Wall Footing 1, Concrete Slab, and required rebar for these takeoffs

Phase Two – Data Collection

Nine days before Labs 1 and 2 were assigned, one of the researchers gave a one hour On-Screen Takeoff demonstration to the class covering basic functions of the program, including how to measure lengths, areas, and counts. The demo was provided in a typical classroom with a computer and projector – the students did not actively participate during the presentation. This demonstration was the first time students would have been exposed to electronic quantity takeoff programs, with exception to internships or full-time jobs within the industry. Four days after the lecture (five days before the labs), each student was provided with their own copy of OST that they could choose to install on their personal computer. Figure 1 shows OST's basic user interface.

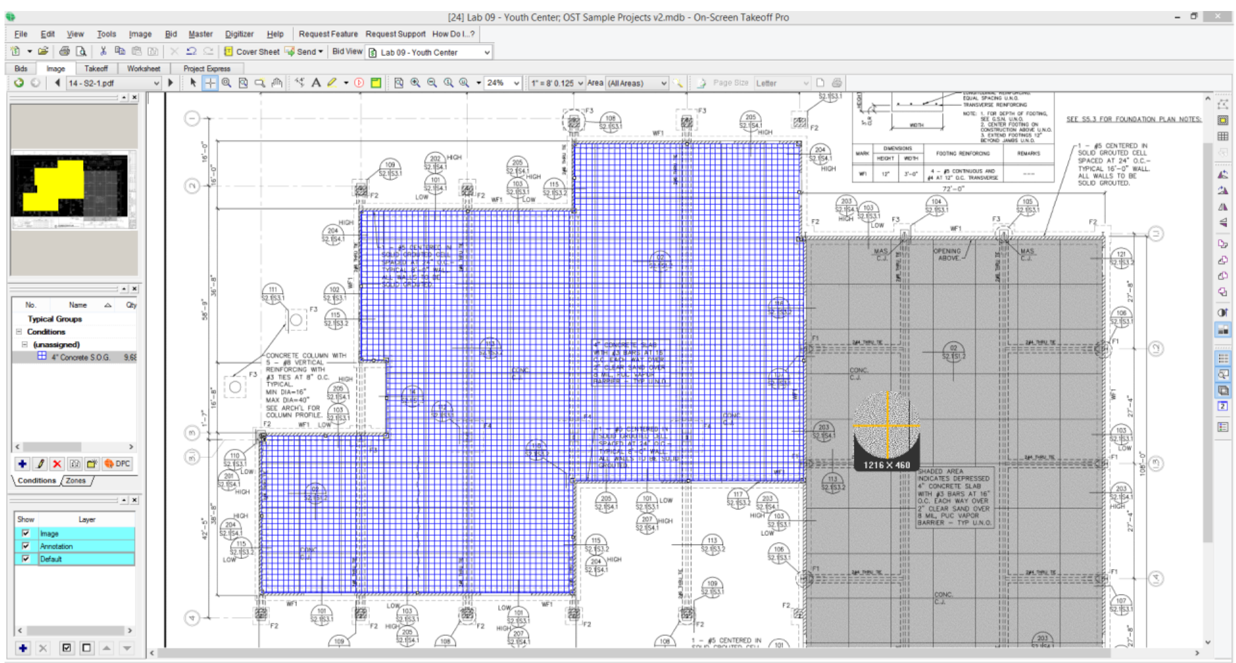

Figure 1: Screenshot of On-Screen Takeoff user interface.

On lab day, each group (for each lab) was provided with a table to fill in the requested data, as well as the option of utilizing spreadsheet software (Microsoft Excel) for calculations during the OST lab. The answer tables in each lab were the same for both the hard copy and software labs. While a professional estimator would likely not be provided with a specific list of takeoffs, the researchers wanted to ensure the students provided their responses in a consistent manner. Figure 2 shows the takeoff response tables for each lab.

Lab 1

Mark	CY – Concrete	Tons – Rebar
F1		
WF1		
WF2		
WF3		
Slab		

Lab 2

Mark	CY – Concrete	Tons – Rebar
F1		
F2		
F3		
F4		
WF1		
Slab		

Figure 2: Takeoff Response Tables for Each Lab.

Two instructors facilitated each lab separately (two different classrooms). The software classroom also had two teaching assistants to help answer questions. The software classroom instruction team was briefed ahead of time that assistance was only to be provided on using the software itself (creating takeoff conditions, locations of certain functions within the program, and so on). This was done to minimize the impact of learning the software, and attempt to isolate a student's overall estimating ability.

Each instructor noted the start time for each lab. The instructors wrote the time on each student's lab (rounded to the nearest minute) as they were handed in. Thus, the researchers could use this information to calculate each student's completion time for their lab. Before starting the software lab, the instructor reviewed the major functions of OST – the students also followed along on their own computer. The reviewed functions included scale calculation, linear condition creation, area conditions (with grid) creation, and bid exportation. Each student was also provided with a bid package that contained the correct image files for their specific lab.

Results

The researchers analyzed two factors to better understand the impact of estimating software in a university setting: accuracy of quantity takeoff and assignment duration in minutes. The Lab 1 takeoff quantities of the hard copy (Group A), software (Group B), and actual are shown in Table 3. Each takeoff quantity is shown in cubic yards (CY) of concrete and tons of rebar. Cubic yards are rounded to the nearest CY, tons are rounded to the nearest thousandth of a ton, and minutes are rounded to the nearest minute. Lab 2 results are shown in Table 4.

Table 3

Average Student Results for Lab 1

Takeoff Quantity	**Hard Copy (Group A)**		**Software (Group B)**		**Actual**	
	CY (Concrete)	Tons (Rebar)	CY (Concrete)	Tons (Rebar)	CY (Concrete)	Tons (Rebar)
Footing 1	2	0.302	2	0.050	2	0.044
Wall Footing 1	16	0.425	16	0.141	16	0.154
Wall Footing 2	1	0.007	1	0.010	1	0.009
Wall Footing 3	1	0.007	1	0.014	1	0.008
Slab	31	0.717	30	1.031	32	0.732

Completion time	42 minutes	40 minutes	Not Applicable

Table 4

Average Student Results for Lab 2

Takeoff Quantity	**Hard Copy (Group A)** CY (Concrete)	Tons (Rebar)	**Software (Group B)** CY (Concrete)	Tons (Rebar)	**Actual** CY (Concrete)	Tons (Rebar)
Footing 1	2	0.081	2	0.070	2	0.063
Footing 2	8	0.280	8	0.250	8	0.256
Footing 3	8	0.259	8	0.409	8	0.298
Footing 4	9	0.226	9	0.269	9	0.284
Wall Footing 1	83	2.334	83	1.312	78	2.059
Slab	211	5.688	190	4.205	212	4.848
Completion time	39 minutes		37 minutes		Not Applicable	

On Lab 1, all footing concrete takeoffs were identical between the hard copy, software, and actual. The hard copy slab concrete takeoff was one cubic yard less than the actual, while the software group was two cubic yards less than the actual takeoff. Likewise for Lab 2, the footing calculations (with exception of Wall Footing 1) between each group (hard copy, software, and actual) were equal. Both groups incorrectly added five cubic yards to Wall Footing 1. The rebar calculations, however, show much differential between both groups, and the actual takeoffs. There were a total of 11 takeoff tasks between the two labs. The hard copy labs had six takeoff quantities closer to the actual (versus the associated software takeoff quantity), while the software labs had five.

On both labs, the software group finished an average of two minutes faster (4.4 percent) and Lab 2 was finished an average of 3 minutes faster (6.7 percent).

Discussion and Limitations

In general, the concrete takeoff quantities are quite similar between the hard copy, software, and actual groups. This particular calculation is very simple, given that only three factors must be determined (length, width, and depth). The rebar calculation is slightly more complex and involves more factors (linear feet for continuous footings, counts of isolated footings, and especially tile counts for concrete slabs). The software provides all of this basic information (and students can calculate it with relative ease with the hard copy plans), but determining rebar quantity requires additional skills and resources (i.e., pounds-per-foot schedule for rebar). Both labs required, at most, two pages from the plan set (foundation plan and general notes). In an actual estimate or on more complex assignments, multiple pages (various details and notes) would be required. In this situation, the researchers surmise that the student accuracy with the software would decrease, due to their unfamiliarity with conceptual estimating and all of the associated components. This initial study, however, was only looking at the impact that software would have on simple takeoff calculations in an academic setting. The limited size of the data set is not sufficient to identify any potential trends.

There were two primary limitations of this study. The first is that the plan quality (physical and digital copies) was different. Lab 1 was less clear at higher zoom levels. Figure 2 shows the differences at a 100 percent zoom level. Note that the Figure 3 only shows a very small portion of the pages, but is representative of all other pages in the plan (including details).

Lab 1 Lab 2

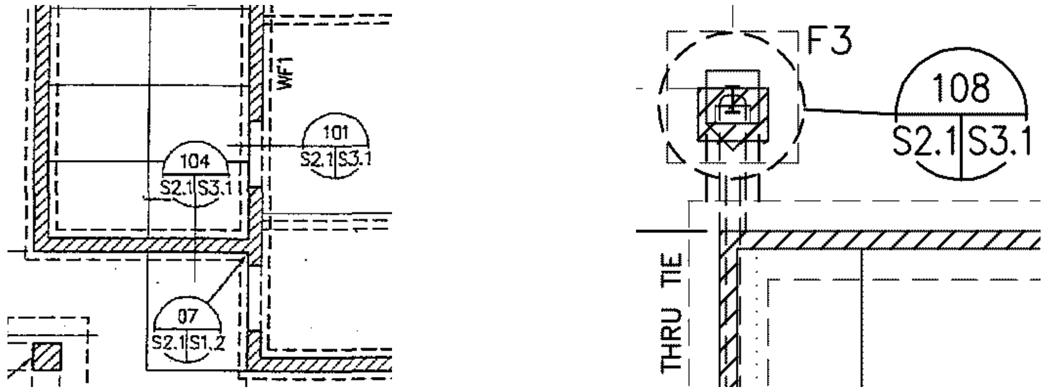

Figure 3: Differences in Plan Image Quality.

A second limitation is how the completion times were measured. The instructors only annotated completion time once a student physically handed in their assignment. Some students may have packed up their class materials first before handing in their assignment. Though likely negligible, the time measurements in this study should be used as a relative comparison between groups, and not indicative of the expected completion time for a particular estimating task (i.e., concrete slab takeoff).

Conclusions and Further Research

The use of software to augment construction tasks has been increasing. Software is typically used to improve efficiency (decrease time with the same, or fewer, resources). It does not, however, replace the human ingenuity or problem solving ability. As the industry adopts new software or information systems, academia will usually integrate the training into curricula. This particular study considered the ability of estimating software (On-Screen Takeoff) to impact a student's ability to accurately calculate simple takeoff quantities in a timed environment. The results showed that, for simple takeoffs, there was minimal difference of takeoff quantities between hard copy and software student groups. Rebar calculations showed more differential, but this is likely related to the student's overall skill level in calculating rebar (neither the software nor the hard copy groups provide direct measurements of rebar). The software student groups did, however, finish an average of two minutes (4.4 percent) faster than the hard copy student groups. It is worth noting that the software student group's time also includes the student's time to become acclimated with the software, along with performing their regular task of quantity takeoffs. It is possible that a greater variance in completion time would exist between the hardcopy student groups and the software student groups if the software student groups possessed a slightly higher level of proficiency with the software being used.

Further research should be conducted on the impact of estimating software for more complex tasks that involve the use of detail sheets and other pages throughout the plan. Additionally, study should be conducted on an individual student's performance and examine any correlation between a student's academic proficiency and their capability to effectively use software.

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