COMPARING TIME AND ACCURACY OF BUILDING INFORMATION MODELLING TO CURRENT MEASUREMENT PRACTICES USED IN QS FIRMS IN IRELAND

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ABSTRACT

The majority of Irish quantity surveyors (QS) are trained with, and continue to use, manual and 2D computer-aided measurement (CAM) in the production of bills of quantities (BOQ's). The purpose of this thesis was to determine the extent to which Irish QS' and firms could potentially increase the efficiency and accuracy of the core QS task of measurement, as a result of implementing a process entitled Building Information Modelling (BIM). This BIM process promises major improvements by providing a platform for automating the laborious task of quantity takeoff, overcoming the limitations of the traditional manual procedures which have required QS's to allocate an large portion of their time to one single task, with no guarantee of accuracy. BIM also offers QS's the potential to improve their professional service delivery through capabilities such as enhanced project visualization and the reduction of errors and emissions.

The literature review highlighted that there is substantial literature available on estimating with BIM, its applications and benefits. There is however, little documented information of its use within the context of construction measurement in Ireland. After critically analysing how measurement practices and tools have evolved, a questionnaire was sent to a number of Irish QS firms in an attempt to gauge the current level of measurement software use, and determine their knowledge and understanding of BIM processes and software. Finally, a self-observation case study was conducted on a small industrial building in order to gain a greater understanding of the benefits and challenges of quantification using a BIM model.

In compiling the results from the survey and case study, the hypothesis was proved to be accurate in respect of efficiency. Yet quantity accuracy was not improved, it remained consistent with that of the findings in the manual and 2D CAM conventions. However, implementing BIM for measurement is not without important concerns, such as the considerable cost of BIM software and how some automated quantities within a BIM model will not satisfy the measurement rules laid down in the current Irish standard method of measurement (SMM), the ARM4.

The research concludes with recommendations designed to increase the awareness of BIM among Irish construction professionals and puts forward possible remedies for the above mentioned concerns of utilizing BIM for quantity takeoff.

DECLARATION

I hereby certify that this thesis which I now submit for assessment on the program of study leading to the award of a Bachelor of Science in Construction Economics and Management is a presentation of my own original research work and has not been taken from the work of others. Wherever contributions of others are involved, every effort has been made to reference and acknowledge this clearly.

This thesis was prepared according to the regulations of Dublin Institute of Technology and has not been submitted in whole or in part for an award in any other Institution.

Signed:_____ Date:_____

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Finally, I wish to express my appreciation and thanks for the love and support of my parents and girlfriend as without them, this would not have been possible.

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TERMINOLOGY

2D Two Dimensional

3D Three Dimensional

4D Four Dimensional. Leveraging BIM for project time allocation and construction sequence scheduling

5D Five Dimensional. Leveraging BIM for cost and simulation of construction, focusing on building sequence, cost, and resources

AEC Architecture, Engineering and Construction

BIM Building Information Modelling was coined in early 2002 by industry analyst Jerry Laiserin to describe virtual design, construction and facilities management. BIM processes revolve around virtual models that make it possible to share information throughout the entire building industry.

CAD Computer Aided Design.

CAM Computer-aided measurement..

Clash detection A process of discovering the building system conflicts and issues by collaborating in 3D during the MEP model coordination process

CIF Construction Industry Federation.

CIOB Chartered Institute Of Building.

CITA Construction I.T. Alliance group set up in Ireland to promote the benefits of BIM to the Irish construction industry

DWF Autodesk Design Web Format file.

DWFx is an Autodesk DWF XPS Document. Autodesk has teamed with Microsoft to integrate DWF technology with Windows Vista.

DXF or Drawing Exchange Format, is an open sourced CAD data file format developed by Autodesk.

Families Parametric 3D building components used in Revit software programs.

IFC Industry Foundation Class is a data exchange method that specifies elements that are used in building construction in an agreed manner that define a common language for construction. It is an object-oriented file format to facilitate interoperability in the building industry, and is a commonly used format for BIM. The format is known as ifcXML. ifcXML2x3 (current version) is currently supported by Autodesk, Graphisoft, Nemestchek and Bentley.

JPEG or Joint Photographic Experts Group. It is a standard method of compressing photographic images.

KPIs Key Performance Indicators.

Parametric Modelling is defined by rules and constraints, which define aspects of the building and their relationships to each other. Variables control behaviour in 3D geometry.

PDF a Portable Document Format is a file format developed by Adobe as a means of distributing compact, platform-independent documents.

CHAPTER 1: INTRODUCTION

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1.1 Background

The current on-going economic challenges have tightened the margins between success and failure for Irish QS firms and the construction industry in general. By the end of 2012, output in the industry will have fallen by 82% from its peak in 2007. This has resulted in construction and consultancy firms tendering for vastly reduced volumes of work at prices that are below cost (BruceShaw Handbook, 2012). Therefore, in the opinion of the author, the survival of Irish QS firms will become dependent on their ability to adapt to change, particularly technological change that promises both improvement in the firms competitiveness in a depressed market whilst also improving the efficiency and accuracy in their execution of the core services in which they offer.

The uptake of Information Technology (I.T.) and more specifically BIM in construction offers considerable potential for improving professional service delivery. BIM is defined as '*a process which involves the production of reliable and co-ordinated construction documentation from a virtual 3D model of a building project'* (Montague, cited in Munn, 2011). Furthermore, according to Olatunji and Sher (2010), the integration of BIM and CAM tools and applications "provide robust opportunities" for process improvement within QS procedures.

This thesis evaluates Irish QS firm's use of CAM and BIM for Quantity Takeoff, examines the most widely used measurement applications of BIM and CAM software, and asks why it has not been adopted among most Irish QS firms and whether or not it should be. The author will also document how construction measurement has evolved from the use of traditional paper based practices to the sophisticated computer packages that are gradually becoming more widespread within the Irish construction industry.

1.2 Rationale for the Research

The limitations of manual estimation processes are evident in the extensive time QS's spend on certain energy-sapping procedures. The time spent by on quantification varies by project, but perhaps 50-80% of the time needed to create a cost estimate or bill of quantities (BOQ) is spent just on quantification (Autodesk, 2007). Traditional two-dimensional measurement systems are vulnerable to omissions, conflicts, uncertainties, information dissipation and frustration of work relationships, while the accuracy of

BOQ's/estimates generated using manual processes leaves a lot to be desired (Olatunji and Sher, 2010).

Recent indicators such as the UK government decision to make BIM compulsory on all public projects by 2016 suggest that the construction industry is beginning to imitate other industries such as the manufacturing industry, which have been revolutionized by the adoption of digital technology. "*For efficient production in companies such as Boeing and Toyota, digital models have been placed at the centre of their collaborative, concurrent engineering processes for a long time, using them to support each stage of a project's life cycle"* (Munn, 2011). This approach can be applied to the construction industry and BIM promises to fill this void, positively influencing the future of the industry.

The literature review that follows will examine the evolution of measurement practices used in Ireland, from paper-based, spreadsheets and specialist estimating software packages to the potential impact of BIM in terms of improving consistency, accuracy and efficiency of construction measurement. For QS's of the future, it may be capable of re-engineering the ways in which the core skill of quantity takeoff is carried out on projects.

Little is known of its actual success in Ireland, as there are few, if any, projects or firms that have entirely relied upon BIM for quantification. Therefore, I feel it is an opportune time to conduct research into the feasibility of using a BIM model for automated quantity takeoff and highlight the results, in respect of time and accuracy compared to manual practices, to Irish QS firms.

1.3 Scope of the Research

This study centers on examining the attributes of BIM and its potential for its use by Irish QS firms for more efficient and accurate quantification of materials in the production of a BOQ or cost estimate. Emphasizing how measurement practices and tools have evolved, current measurement practices used in Ireland and firm's awareness and attitudes to BIM are also explored.

There is little primary information available on the experiences of Irish QS's use of BIM for quantity takeoff. Therefore, the goal of this study is to perform an experiment to obtain an accurate and reliable account of the potential efficiency gains by the process's use, and highlight any findings to Irish QS firms so they may be able to take

advantage. The proposed study will also investigate the software used in BIM and establish how these applications can aid quantity surveyors in various ways, consequently increasing efficiency. The limitations of BIM for use in construction measurement will also be considered. The benefits of BIM are measured in terms of Key Performance Indicators (KPIs) and these are: time saved in the production of BOQ's/estimates and material measurement accuracy. These indicators will be examined throughout the study, firstly illustrating the factors that affect them in the literature review, and then using them to measure the extent to which the overall project performance is affected from the use of BIM.

The research is limited to performing a quantity takeoff on certain key elements of a small commercial building. The research, therefore, is on a relatively small scale and although primary research will be used in an attempt to obtain accurate findings, the study will not claim to be a definitive or comprehensive measurement of efficiency.

1.4 Aims and Objectives

The aim of this thesis is to examine the extent to which Irish QS firms can increase efficiency and accuracy when performing a quantity takeoff on projects with the use of a BIM model. According to Olatunji and Sher (2010), overcoming the effects of inefficient construction estimating procedures is an "Achilles heel of the industry". The author aims to show how by utilizing ever evolving and sophisticated applications been developed specifically for estimators, such inefficiencies can be greatly reduced. In order to achieve this, the following objectives have been set out;

- Investigation into the evolution of measurement and measurement software.
- To identify the software used by QS firms in Ireland and to ascertain their willingness to adopt new technologies such as CAM/BIM.
- To undertake a desk study comparing traditional and CAM practices to the use of BIM in quantity take-off.
- Highlight the findings of the desk study to QS firms in Ireland under 2 main KPI's;

  (1) Will my quantities be accurate? (2) Will I save time?

1.5 Research Hypothesis

"Performing a quantity takeoff using a BIM model will increase efficiency and accuracy compared to manual or 2D CAM conventions"

1.6 Outline Methodology

This preliminary research methodology briefly outlines the research methods that were adopted to complete the aims and objectives set out above. There research methods used during the course of the author's study is of a mixed method approach. The linkage between the thesis objectives and the chosen research method is shown in Table 1.1 below.

Thesis objective	Focus	Appropriate Research Methodology	Relevant Chapters
1	Evolution of measurement software	Literature Review	2
2	Identify the software used by QS's in Ireland	Survey	3
3	Comparison of traditional and BIM quantity takeoff methods	Case Study	4
4	Highlight the findings of the desk study to QS firms in Ireland	Case Study	5

Table 1.1 Linkage between thesis objectives and research methods (Adapted from Munn, 2011)

The author began the research process by reviewing literature on the topic, which included measurement software and BIM. A deep understanding of research was the result of reviewing a combination of different sources including books, journal articles, white papers, product catalogues and numerous on-line sources of which only the most reliable were referred to in the literature review. This information was used to establish a firm understanding of the subject area and to query many more aspects of the subject, which were developed to form the basis of the research design.

The research methodology set a path to the completion of each objective. A Survey and case study was carried out to establish primary information that could not be determined through the literature review. The survey was sent out to QS firms around the country. The basic aim of the survey was to establish how firms are performing quantity takeoffs, there choice of software used in this task and their awareness of BIM. Other questions relevant to the study such as the size of the firm were also asked.

A case study was then undertaken by the author in order to gain further primary information not found in the literature. The study consisted of completing a quantity takeoff of two significant elements of a small commercial building both in the traditional paper based method and by the use of a BIM model. The results of this study were then analyzed with respect to the KPI's of time and accuracy.

1.7 Structure of Thesis

Chapter One

Chapter one provides the reader with a background to the study, justifies the need for this investigation and defines the scope of the research. This chapter also includes the aim and objectives that are central to the study.

Chapter Two

The literature review describes how construction measurement has evolved from the traditional practice of using a scale rule and dimension paper, to the advent of specialized computer programs and tools that are now commonplace and asks how building information modelling software can improve the efficiency and accuracy of quantity takeoff. The limitations of BIM and construction measurement will also be discussed.

Chapter Three

Chapter three outlines the research methodology utilised in this thesis. Firstly it examines what research is, it then outlines the research design and the techniques that were exercised for the purpose of meeting the aims of this thesis.

Chapter Four

Chapter four describes the case study the author performed in order to evaluate if using BIM for quantity takeoff is more efficient and as accurate as a quantity takeoff performed using the traditional method.

Chapter Five

Chapter five presents the results of the survey and case study. The implications of the findings to QS firms in Ireland where also discussed.

Chapter Six

The final chapter brings together what has been discussed throughout the project in order to form relevant conclusions. An assessment is carried out in respect of the completion of each objective and the practicality of implementing a building information modelling system for quantity takeoff is determined. Finally, recommendations are suggested to promote the implementation of BIM.

CHAPTER 2: REVIEW OF THE LITERATURE

CHAPTER 2: REVIEW OF THE LITERATURE

2.1 Introduction

According to Cartlidge (2006), the construction industry is in the midst of an information technology revolution that is now evolving at a breathtaking speed. He also points out that QS's are now been greatly impacted by this revolution owing to the fact, that due to the core duties of the QS profession, in particular measurement or taking off quantities, involve calculations and quantification which to a great extent lend themselves to computerization. Brandon (1992) also states that advances in technology have forced consultants to reconsider their traditional approaches in order to harness the potential of the computer. Smith (2003) further expands on this subject by predicting that measurement is fast becoming automated to the point that human intervention will become minimal.

With these points in mind, the author aims to explore how the core duty of measurement preformed by QS's has evolved from traditional paper based practices to the abundance of specialized estimating software packages currently available. These software packages allow computer aided measurement, and asks how developments in construction software and BIM will impact on measurement and quantity take-off.

The author would like to state that it is not the author's intention to recommend any of the software packages discussed but rather to provide an objective assessment of each.

2.2 Traditional Construction Measurement Practice

Packer states that, "the principal purpose of measurement is to provide a Bill of Quantities (BQ) which can be used as the basis for the preparation of tenders for construction work" (Packer, 1996, p. 29). The traditional paper based method of preparing a BOQ can be broken down into two main processes;

2.2.1 "Taking-off"

According to Packer (1996), the measurer takes off quantities by either reading or scaling dimensions from the drawings. Hore et al, (2009) similarly describes taking-off in which dimensions are scaled or read from drawings. Dimensions are then recorded on specially lined paper called "dimension paper", in which an example is detailed in figure 2.1. This A4 paper is divided vertically into two identical halves which each halve containing four individual columns.

A	1	2	3	4	1	2	3	4

Fig2.1 Typical Dimension sheet layout (Hore. A.V. 2007)

- Column A: Binding column. The column should be kept clear to allow for binding of the dimension sheets.
- Column 1: Timesing column. Used as a means to multiply a group of dimensions set against a particular description.
- Column 2: Dimension column. Used to record the actual dimensions. All dimensions are entered to two decimal places.
- Column 3: Squaring column. Total length, area or volume – obtained by multiplying together the figures in columns 1 and 2.
- Column 4: Description column. Used to write out the descriptions of the items of work. Waste calculations can be shown on the right-hand side of this column.

2.2.2 "Working-up"

The process of working-up entails the transfer of the resultant dimensions into a convenient order for billing (Hore et al, 2009). This stage has also been described by Cartlidge (2006) as the "abstract stage" when quantities are transferred from the dimension paper and grouped together. During the billing operation the QS must accurately describe the work items quantified and must present these in a suitable order under work sections or elemental headings. This is echoed by Packer (1996), who states that once the effort of assembling was completed all that remained is for the descriptions and quantities to be presented in a structured and consistent fashion.

According to Hore et al, (2009) the most common approach used in Ireland is the "Direct Billing" method. This is where the QS will quantify each item of work in the project in sequence using the applicable Standard Method of Measurement (SMM) as a guide. The most widely used SMM in Ireland is currently the Agreed Rules of Measurement, 4th edition (ARM4). This document comprehensively covers the items of building work routinely encountered, as well as, providing a standard template for the wording of billed items in order to prevent ambiguity as to the nature and extent of the works.

The QS will present his quantities and descriptions in a standard form on "billing paper". This paper is similar to that of dimension paper (i.e. it is ruled vertically in columns), however it also provides columns for contractors to enter their rates and prices against each described and quantified item, an example of which is shown in figure 2.2.

Many authors have remarked (Cartlidge, 2009; Holm et al. 2005; Schuette and Liska, 2004) that this traditional approach to measurement is the most tedious, time-consuming and labour intensive part of a QS's role. With advances in I.T. however, the use of dimension/billing paper has now become the exception rather than the normal method of use, although measurement using a scale rule is still in widespread use in Ireland as outlined in the survey results in Chapter Five. According to Burnside and Westcott (1999), "*The provision of the 'traditional' QS technical service of bill production is increasingly being undermined by factors such as automated billing and question-marks over the continuing validity of BOQs".*

				€	c
	CONCRETE WORK: IN-SITU CONCRETE				
	Concrete lean mix (1:10)				
A	Filling cavities	2	m^3		
	Concrete: (1:3:6 – 19mm aggregate)				
B	Foundations Poured on or against earth or unblinded hardcore	9	m^3		
	Concrete: (1:2:4 – 20mm aggregate)				
C	Beds Not exceeding 150mm thick: reinforced	5	m^3		
	Reinforcement mesh: BS 4483				
D	Fabric reinforcement Ref B196; 3.05kg/m2; 150mm side and end laps	31	m^2	10	
	BRICKWORK AND BLOCKWORK: BRICKWORK/BLOCKWORK				
	Concrete blockwork; IS 20; solid; type 5N; 440mm x 220mm x 100mm; stretcher bond; in cement and sand (1:3)				
E	Walls in trenches 100mm thick	71	m^2	20	
	Element (19) – Substructure Page 19/3				

Fig 2.2 Typical Billing page layout (Hore. A.V. 2007)

2.3 Advancements in Construction Measurement

The QS profession has experienced significant changes over the past decade in terms of scope and type of services provided within and outside the construction sector (Smith, 2003). These changes, which include the acceleration of BOQ production among various other services, have evolved due to the introduction of Information Technology. Advances in technology have the potential to impact on how BOQ's are prepared. While there is a need for QS's to be able to complete a take-off in the traditional manner, it is unlikely a he or she would undertake the task of bill preparation today, without the use of a computer.

2.3.1 Spreadsheets

According to Cartlidge (2006), the data and information management aspect of the QS duties makes it amenable to employ some general-purpose software such as a Microsoft Excel spreadsheet. Shen et al, (2003) were of the opinion that Excel is not designed for estimating, however it can be cleverly adapted using the spreadsheet functions for estimating. Spreadsheets can be very useful in organizing and calculating the quantity takeoffs. They use cells organized into rows and columns to enter material quantities and descriptions. Formulas can be placed in these cells to perform any needed calculations (Alder, 2006). A survey carried out by Odeyinka and Doherty (2008), documenting quantity surveying software usage in Northern Ireland revealed that 100% of the total respondents used the Microsoft Office suite of products in some capacity, in particular the core application of Excel. An example of how the Excel spreadsheet can be adapted for measurement purposes as detailed in figure 2.3.

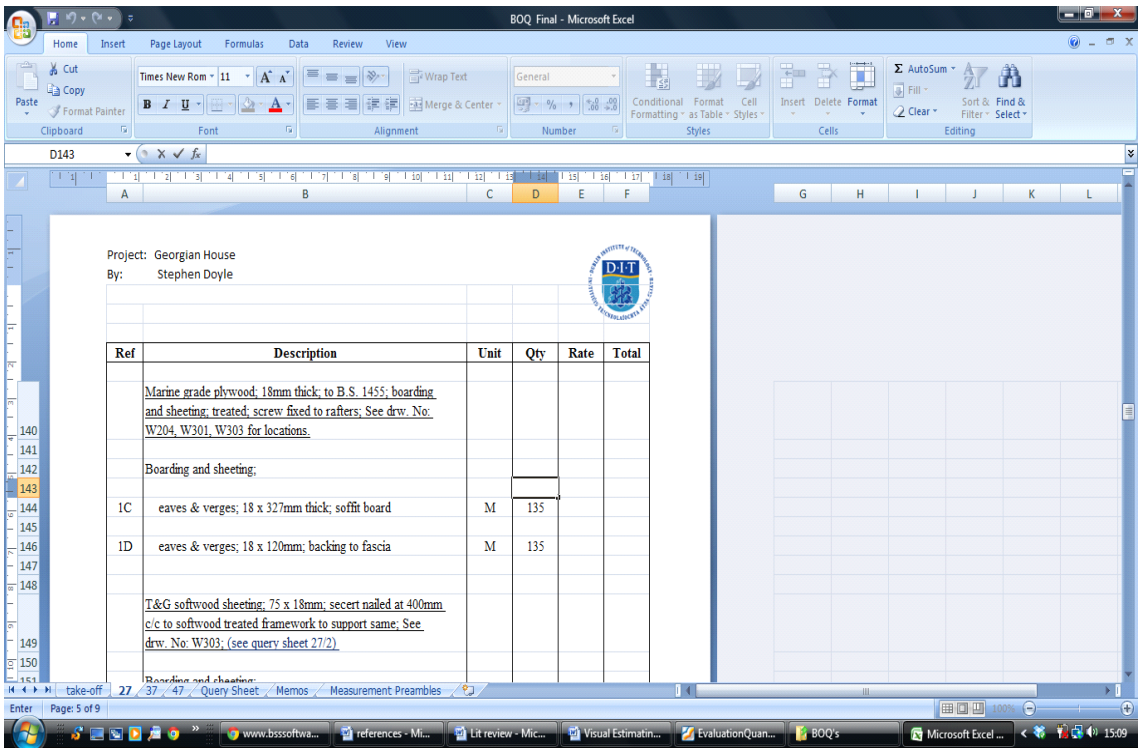


Fig 2.3 Example of BOQ produced using Microsoft excel

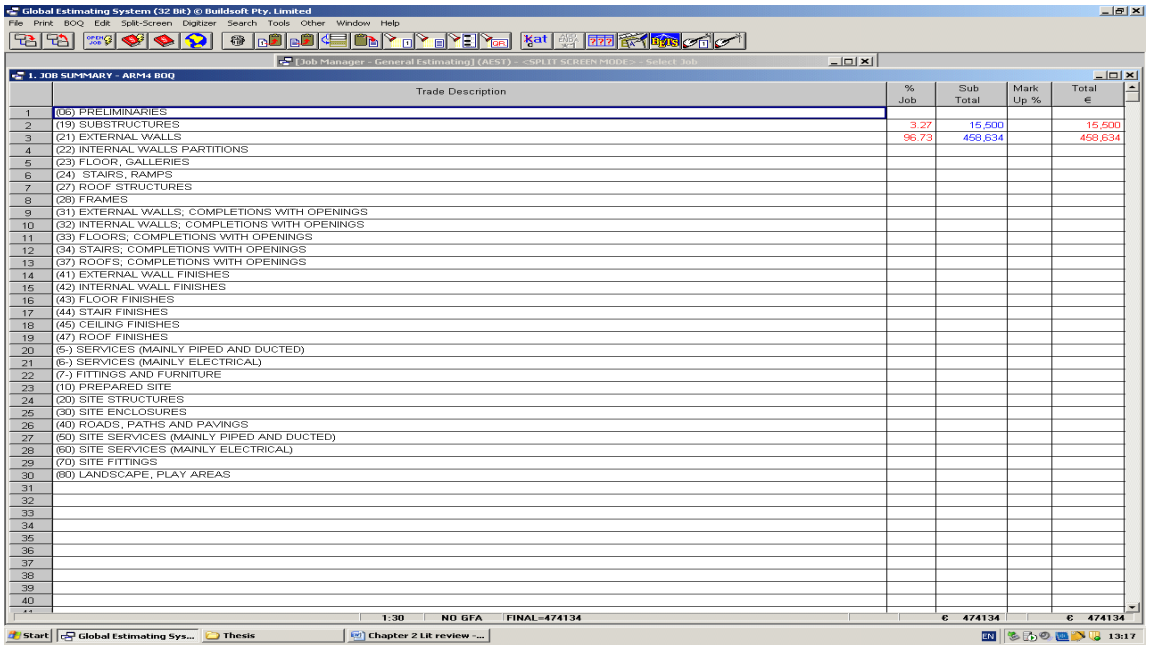
There are at present many specialist software applications available for estimating, cost planning and BOQ production. Doherty (2007) provided a review of the major commercially available QS software in the UK construction sector. These include: Masterbill Elite, BuildSoft, Conquest, Valesco Estimating and Esti-mate. Hore et al (2009), similarly lists a number of examples of BOQ software packages within Ireland targeted at aiding the QS in the course of BOQ preparation. These authors further state that the most commonly used application is the Buildsoft estimating system. The author will now demonstrate the process involved in the effective use of the Buildsoft and Esti-mate estimating software's.

2.3.2 Buildsoft software services

The Buildsoft estimating system is a multi-levelled estimating system providing a package capable of measuring quantities, pricing those quantities and providing detailed analysis of the same quantities. The main capabilities of the package include;

- Measuring quantities direct to the computer
- Producing BOQ's, cost plans and detailed estimates
- Printing the final product to user preferences
- Providing detailed analysis of historical data (www.BSSsoftware.com)

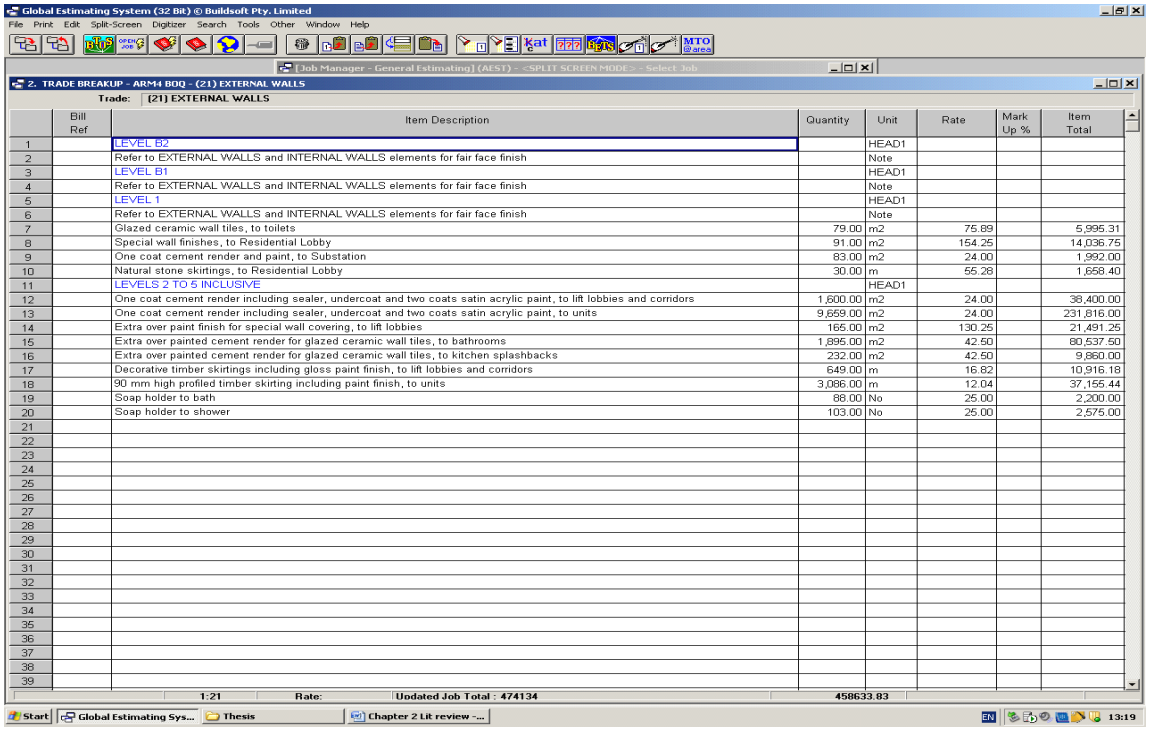
The system consists of three main layers or screens used when taking off quantities. The first of these is the “Job Summary” sheet shown in figure 2.4, which in effect is a summary page of an estimate, in that it shows the totals transferred from the trade sections or ARM element headings used in that project.



	Trade Description	% Job	Sub Total	Mark Up %	Total €
1	(06) PRELIMINARIES				
2	(19) SUBSTRUCTURES	3.27	15,500		15,500
3	(21) EXTERNAL WALLS	96.73	458,634		458,634
4	(22) INTERNAL WALLS PARTITIONS				
5	(23) FLOOR, GALLERIES				
6	(24) STAIRS, RAMPS				
7	(27) ROOF STRUCTURES				
8	(28) FRAMES				
9	(31) EXTERNAL WALLS; COMPLETIONS WITH OPENINGS				
10	(32) INTERNAL WALLS; COMPLETIONS WITH OPENINGS				
11	(33) FLOORS; COMPLETIONS WITH OPENINGS				
12	(34) STAIRS; COMPLETIONS WITH OPENINGS				
13	(37) ROOFS; COMPLETIONS WITH OPENINGS				
14	(41) EXTERNAL WALL FINISHES				
15	(42) INTERNAL WALL FINISHES				
16	(43) FLOOR FINISHES				
17	(44) STAIR FINISHES				
18	(45) CEILING FINISHES				
19	(47) ROOF FINISHES				
20	(5-) SERVICES (MAINLY PIPED AND DUCTED)				
21	(6-) SERVICES (MAINLY ELECTRICAL)				
22	(7-) FITTINGS AND FURNITURE				
23	(10) PREPARED SITE				
24	(20) SITE STRUCTURES				
25	(30) SITE ENCLOSURES				
26	(40) ROADS, PATHS AND PAVINGS				
27	(50) SITE SERVICES (MAINLY PIPED AND DUCTED)				
28	(60) SITE SERVICES (MAINLY ELECTRICAL)				
29	(70) SITE FITTINGS				
30	(80) LANDSCAPE, PLAY AREAS				

Fig 2.4 Buildsoft “Job summary” sheet

The “trade break-up” sheet shown in figure 2.5 is the second sheet in the system. It will hold all the items in the trade and each item will have a quantity and a rate which can be entered directly or calculated from the next level sheet.



	Bill Ref	Item Description	Quantity	Unit	Rate	Mark Up %	Item Total
1		LEVEL B2		HEAD1			
2		Refer to EXTERNAL WALLS and INTERNAL WALLS elements for fair face finish		Note			
3		LEVEL B1		HEAD1			
4		Refer to EXTERNAL WALLS and INTERNAL WALLS elements for fair face finish		Note			
5		LEVEL 1		HEAD1			
6		Refer to EXTERNAL WALLS and INTERNAL WALLS elements for fair face finish		Note			
7		Glazed ceramic wall tiles, to toilets	79.00	m2	75.89		5,995.31
8		Special wall finishes, to Residential Lobby	91.00	m2	154.25		14,036.75
9		One coat cement render and paint, to Substation	83.00	m2	24.00		1,992.00
10		Natural stone skirtings, to Residential Lobby	30.00	m	55.28		1,658.40
11		LEVELS 2 TO 5 INCLUSIVE		HEAD1			
12		One coat cement render including sealer, undercoat and two coats satin acrylic paint, to lift lobbies and corridors	1,600.00	m2	24.00		38,400.00
13		One coat cement render including sealer, undercoat and two coats satin acrylic paint, to units	9,659.00	m2	24.00		231,816.00
14		Extra over paint finish for special wall covering, to lift lobbies	165.00	m2	130.25		21,491.25
15		Extra over painted cement render for glazed ceramic wall tiles, to bathrooms	1,895.00	m2	42.50		80,537.50
16		Extra over painted cement render for glazed ceramic wall tiles, to kitchen splashbacks	232.00	m2	42.50		9,860.00
17		Decorative timber skirtings including gloss paint finish, to lift lobbies and corridors	649.00	m	16.82		10,916.18
18		90 mm high profiled timber skirting including paint finish, to units	3,086.00	m	12.04		37,155.44
19		Soap holder to bath	88.00	No	25.00		2,200.00
20		Soap holder to shower	103.00	No	25.00		2,575.00

Fig 2.5 Buildsoft “Trade breakup” sheet

The third sheet is the "calculation sheet" illustrated in figure 2.6. This is where the quantity of a trade item is calculated. The user can enter dimensions using timesing (factor), sidecasts (formulae), length (linear), length x width (m^2), and length x width x depth (m^3) (Hore et al, 2009). Both addition and deduction of values is also possible.

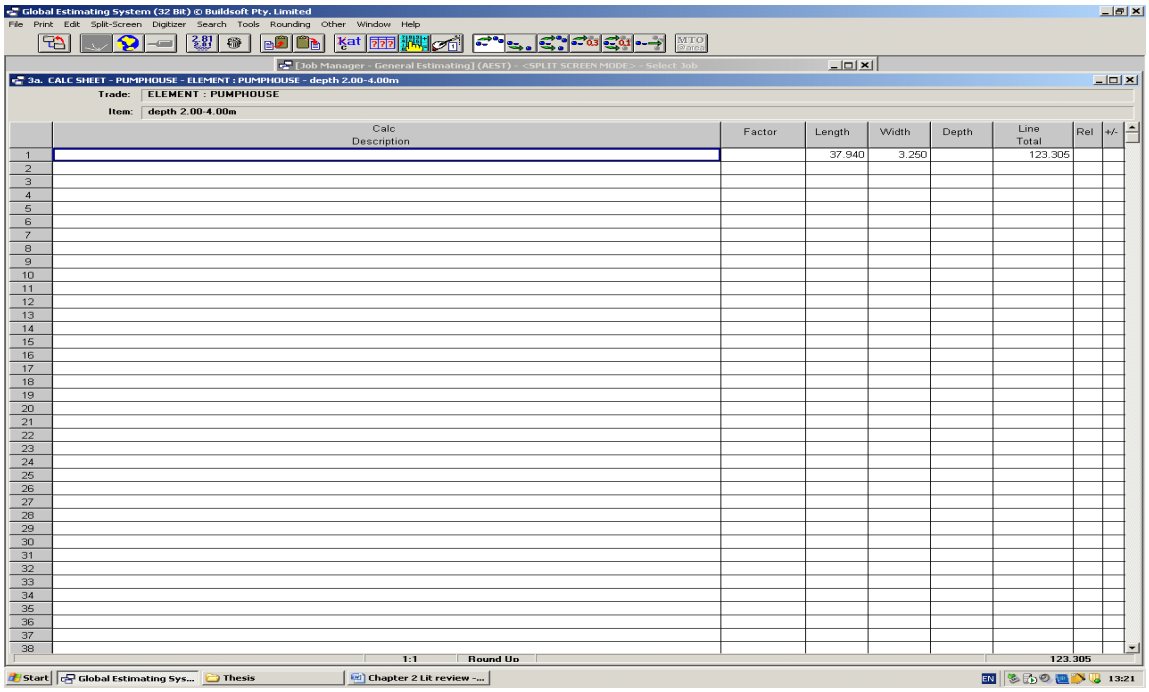


Fig 2.6 Buildsoft "Calculation sheet"

Once the take- off is complete, the user can then print out the BOQ as outlined below in figure 2.7.

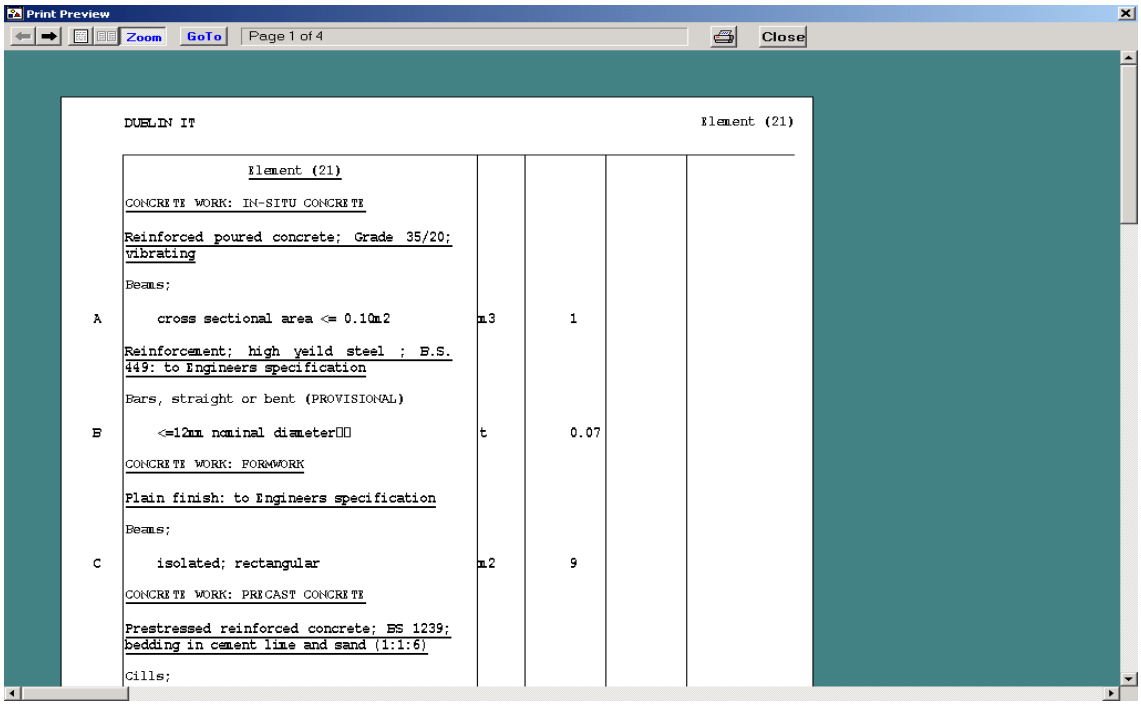


Fig 2.7 Printout of BOQ in Buildsoft

2.3.3 Esti-mate

Esti-mate software package produces quotations and traditional BOQ's with descriptions and prices created from a priced database (www.ajk.ie). The software was developed by Worldwide Software and is distributed in Ireland by ALK Ltd. The main capabilities of this system include;

- Priced libraries for rapid creation of elements
- Includes facilities for BOQ's, cost plans, bill import and post-contract valuations
- Full analysis of the job is provided, including resource schedules and elemental analysis
- Can interact with digitizers for electronic measurement

Once a project has been started, the software's main estimate screen will appear as in figure 2.8. To begin inserting items to form the BOQ, the user clicks the 'add' button.

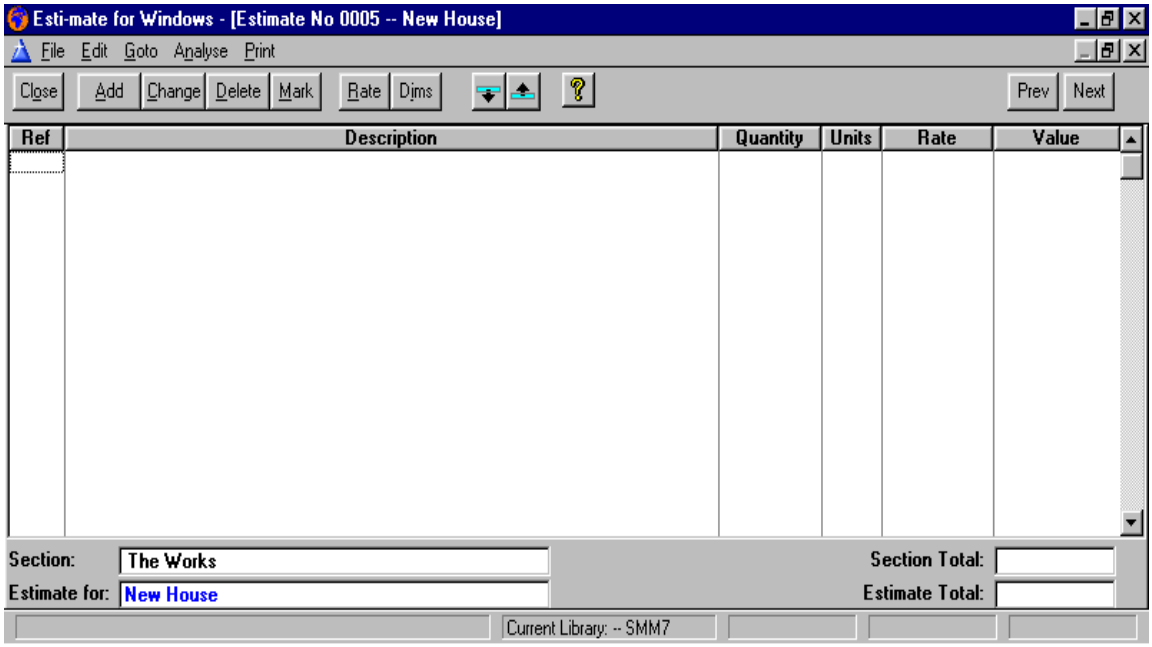


Fig 2.8 Main estimate screen (taken from Esti-mate presentation)

The user can now choose a work item or trade heading from the pre-installed library that conforms with the ARM headings as detailed in figure 2.9, which is the standard method of measurement used in Ireland. There is also an option to create your own unique library.

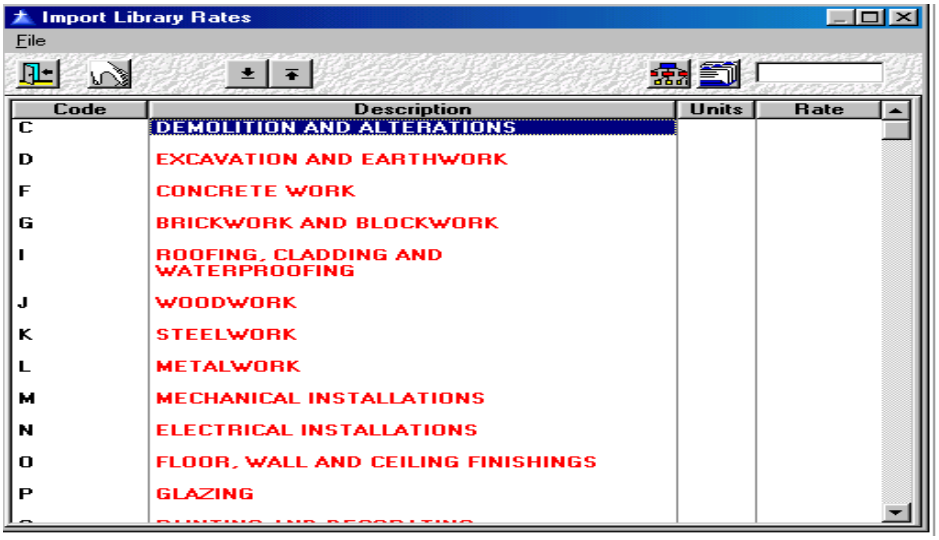


Fig 2.9 ARM Library screen (taken from Esti-mate presentation)

After selecting the ARM4 heading, the user will be prompted by way of various sub-category pop-up screens as shown in figure 2.10, to choose components in order to produce a suitable description required for the item been quantified. The library contains over 7000 material items.

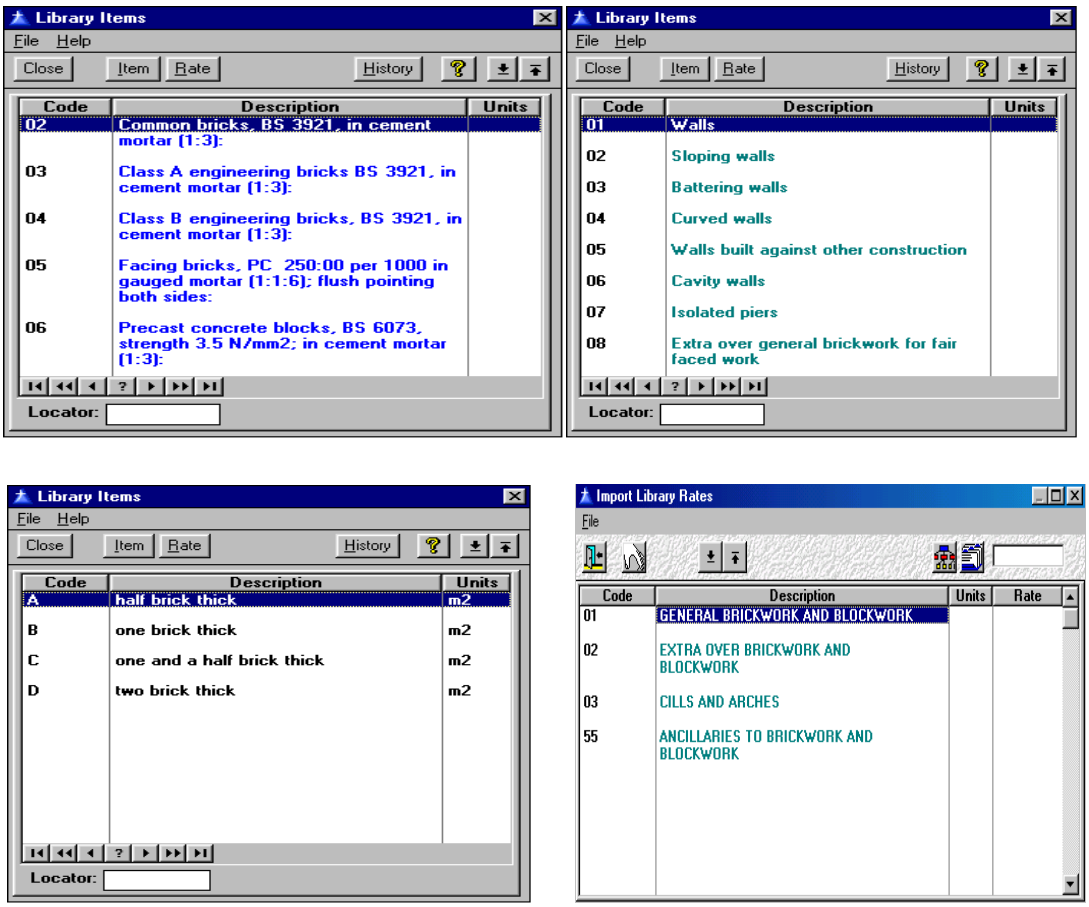


Fig 2.10 Sub-category screens (taken from Esti-mate presentation)

When the description(s) options are finalised, Esti-mate returns to the main screen and automatically writes out descriptions, leaving only the dimension(s) to be inserted. This is done by clicking the 'dims' button and entering the dimension gained from the traditional quantity take-off method (fig 2.11). These steps can then be repeated until the BOQ is complete.

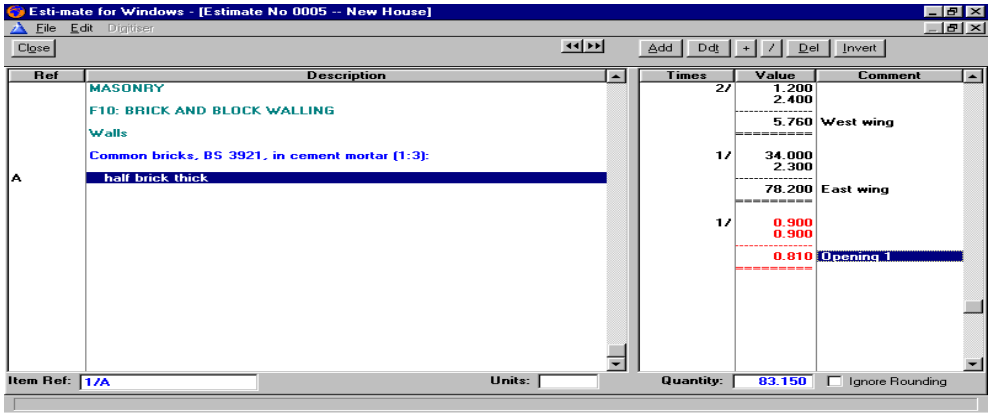


Fig 2.11 Dims screen

Buildsoft, Esti-mate and the other specialist software mentioned earlier are generically similar. They are spreadsheet-based programs aimed at assisting the QS in compiling and sorting data. There are efficiency gains using these programs mainly through the ability the user has to develop templates containing material descriptions. These can be re-used on future projects and eliminate the need for repeatedly writing out descriptions, in regards to someone producing a BOQ with the use of hand-written dimension sheets and billing paper. However, the use of these programs still requires traditional manual quantification using a scale rule, which as outlined earlier is a time-consuming process.

2.4 Computer-aided Measurement (CAM)

According to Williams (2007), it has long been recognised that developments in I.T. are increasing the capabilities of software to automate the estimating process. Estimating software programs have evolved to such an extent, that they now allow automated quantity take-off. The driving factors behind the adoption of digital technology and automated measurement for use by QS firms is the desire for improved speed, accuracy and interoperability in traditional work processes (Olatunji et al, 2010). Furthermore, Smith (2010) argues that electronic or CAM is arguably the key area QS firms should be embracing in terms of IT development. CAM is commonly available in two forms as detailed in the next section;

2.4.1 Digitizers

A digitizer consists of a hand-held cursor, a flat tablet and a sophisticated electronic tablet (fig 2.12) which contains a precise grid of conductors located inside the tablet. As the cursor is moved over the tablet surface, the digitizer's electronics determine its precise location and send coordinate data to the computer. Computerized measurement with a digitizer allows the QS to quickly takeoff precise measurements from drawings which are then calculated and integrated into computer estimating software to create accurate quantity take-offs. According to Alder (2006), digitizers can accelerate the take-off process especially in respect of earth/ground works. *"As the operator traces the contours, the digitizer creates a three-dimensional map of the proposed versus the existing contours, helping to quantify cut and fill"*. (Johnston & Mansfield, 2001 cited in Alder, 2006). However, as most drawings are now distributed electronically via email, internet or a disk, digitizers are obsolete when working with CAD and image files such as PDF, DWG, etc. For this reason, (Vertigraph Inc., 2004) recommends that on-screen, mouse driven take-off tool would be more beneficial for quantity take-off.

Fig 2.12 Digitizer (Courtesy of GTCO)

2.4.2 On-Screen Take-off Tools

On-Screen take-off software allows paperless methods of measurement by automatically calculating quantities from scaled CAD documents (Williams, 2007). The measurements are preformed using a mouse rather than a scale or digitizer. Some of the more popular programs of this type in use in Ireland are CADMeasure, CostX and Buildsoft Take-off System (BTOS). These software applications allow scaled drawings in multiple formats including DWG, DXF, JPEG and PDF to be used to transfer lengths, areas and volumes to estimating programs. The author will now briefly describe each of the specialist automated quantities software mentioned above;

CADMeasure (CATO Enterprise)

CADMeasure was developed by Causeway Technologies Ltd, who are based in the UK. It allows the user to extract quantities directly from CAD drawings. It can be used as a standalone product or as an add-on to Causeway's CATO Enterprise package which is a program which produces BOQ's. When used in conjunction with CATO Enterprise, the measurements are exported into the dimension sheets of CATO Enterprise by simply "dragging" and "dropping" from one program to the other, as highlighted in figure 2.13 below. The program supports multiple file formats and enables true automated measurement.

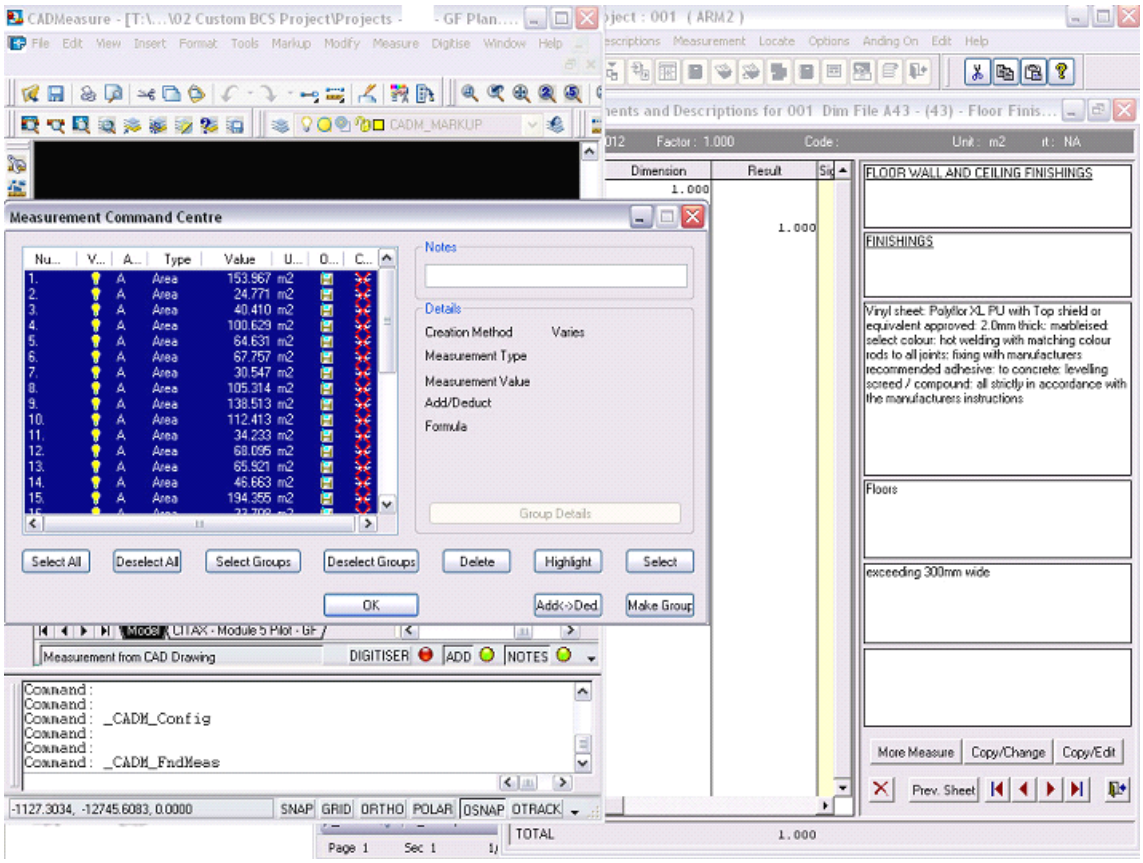


Fig 2.13 CATO Enterprise (Drag and Drop screen taken from CITAX report)

Cost X (Exactal)

Cost X, which was developed by "Exactal Precision Software" in Australia, allows non-CAD users to measure from PDF or CAD files without having CAD software, and creates detailed workbook documents such as estimates, cost plans or BOQ's. The program boasts fully automatic measurement capabilities and supports all standard drawing formats.

This CostX software is comprised of two modules which are outlined below;

1. The Dimension View:

This module is a drawing viewer where CAD files can be viewed and where detailed and accurate dimensions can be quickly taken from 2D drawings by using electronic measurement tools as shown in figure 2.14 (CostX, 2012). CostX also provides automatic reports of changes between drawings. This report highlights what has been measured, what is new and what may be missing. This allows the user to skip the task of re-measuring revised drawings. The program also allows users to isolate items to be measured by de-activating the "layers" in the CAD file, e.g. only show slabs, etc. These items can also then be hidden which can prevent double counting.

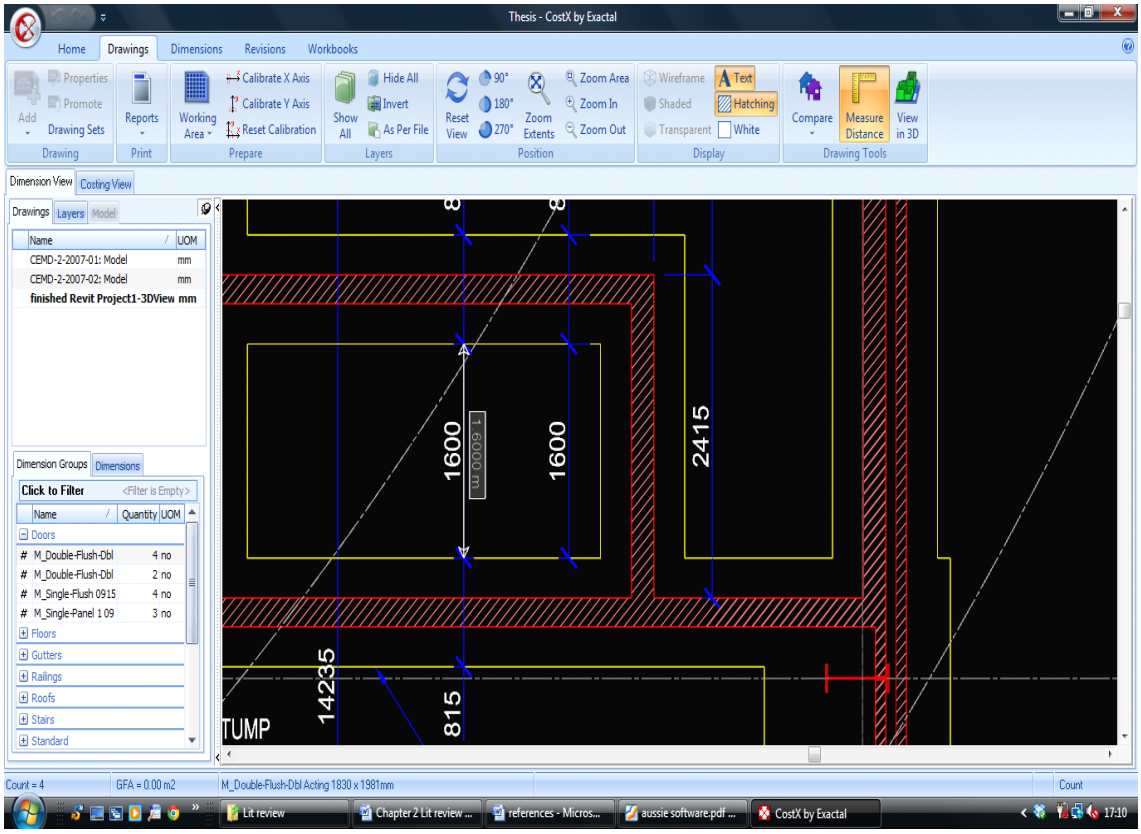


Fig 2.14 Dimension view

2. The Costing View:

The costing view is a spreadsheet-based workbook where the BOQ's are developed (fig 2.15). The user can alternate between the modules at any time, and are always able to see the items that have been measured, as the measurements on the costing view are highlighted on the dimension view.

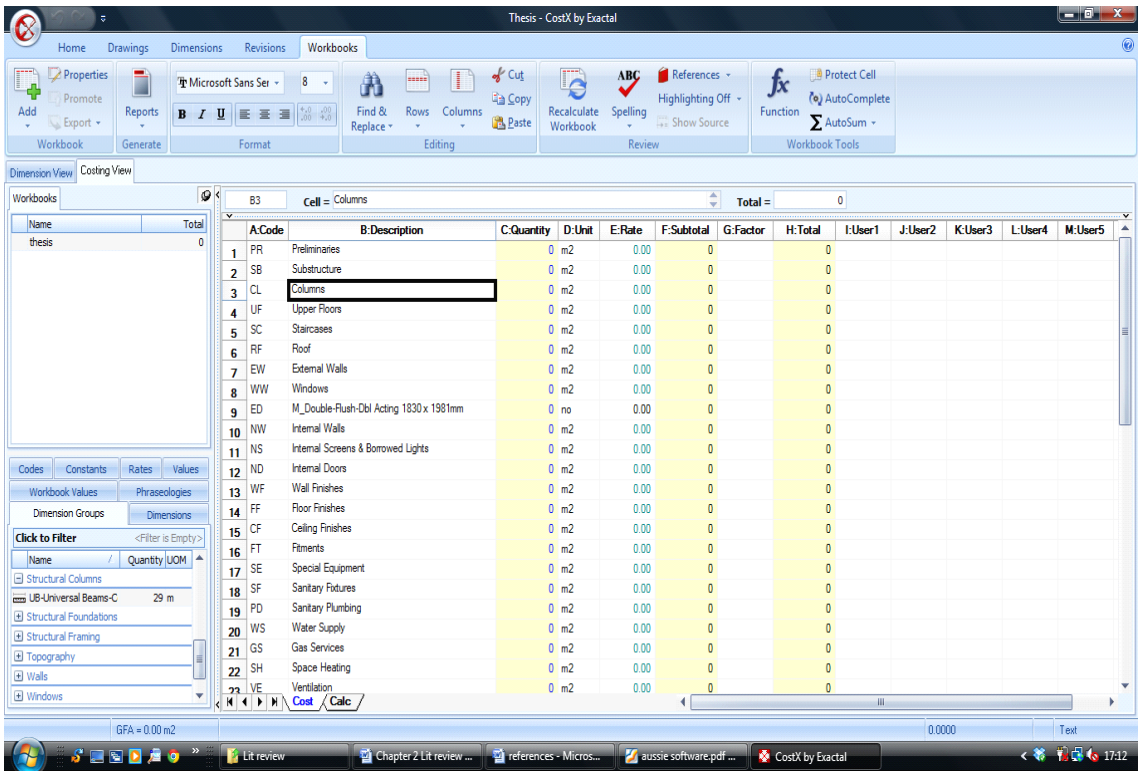


Fig 2.15 Costing View

Buildsoft Take-Off System (BTOS)

Similar to CADMeasure, BTOS is an automated quantities on-screen takeoff system illustrated in figure 2.16, that can be used as a "stand-alone" product or as an "add -on" module to the Buildsoft estimating system. BTOS is distributed in Ireland by "Building Software Services" (BSS). The general procedure involved in using the program is highlighted in five steps, namely;

1. Select the result type required (e.g. linear, area, volume)
2. Load the drawing or image
3. Check the scale (if a CAD file) or set the scale (if a PDF file etc...)
4. Select item(s) to be measured, and
5. Finally, exit the module and the measured value(s) will export to the estimating system

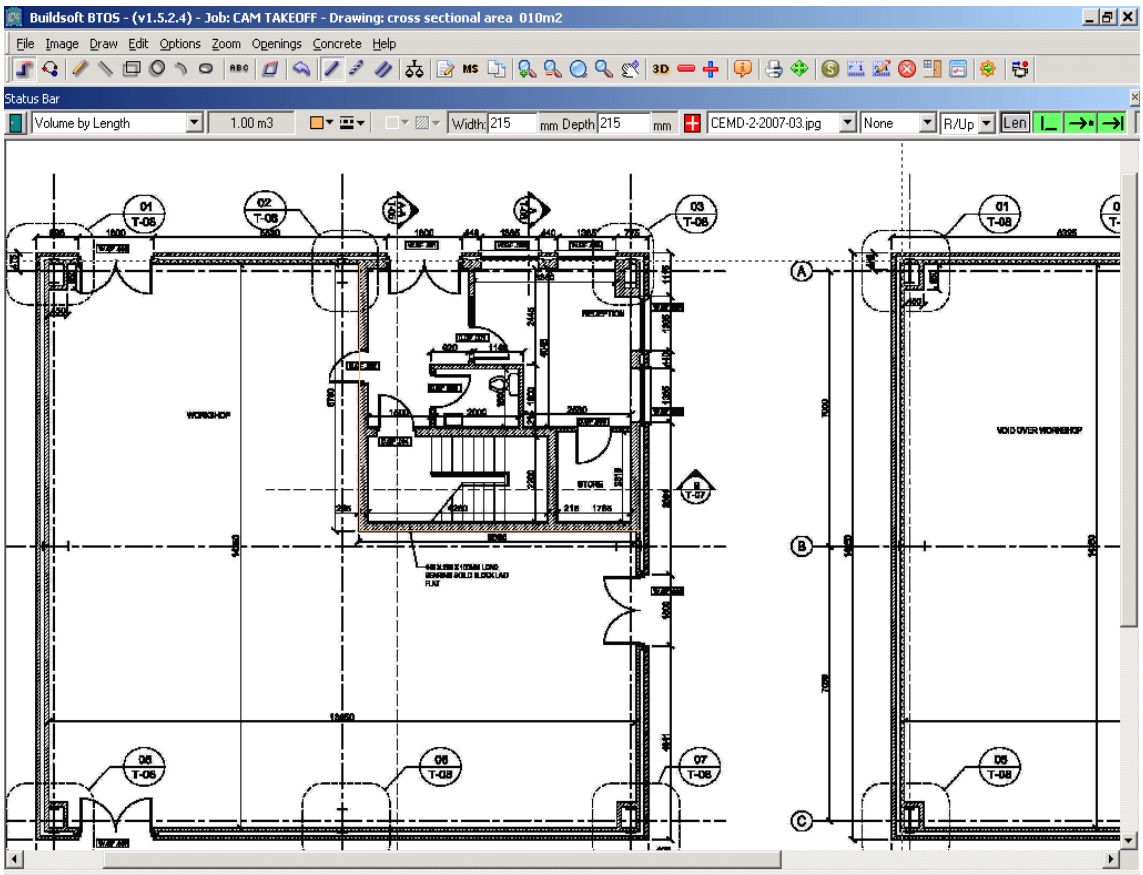


Fig 2.16 BTOS

In a study published for the Construction IT Alliance (CITA) titled *"CITAX Project Module 5 – Computer-aided Measurement"*, four private QS firms were requested to carry out a comparison between traditional measurement practices and CAM. The study was intended to practically examine if CAM improved the speed and accuracy at which quantity takeoffs can be accomplished. The main findings of the study revealed firstly, that electronic measurement is more efficient. The study found that time-savings of between 57% and 70% can be realized when used in suitable projects which have the following characteristics:

- Large-scale projects with a lot of measurement activity.
- Complex shapes, particularly curves.
- Drawings that can be provided in an agreed layering convention.

Secondly, the firms found primarily that the accuracy of their quantities were not compromised and improvements were found in certain instances. An example of this was the ability to switch off layers in the drawing that in turn allows elements such as slabs, walls etcetera to be hidden once they were measured. This meant that once the screen went blank everything had been measured and therefore prevented double

counting. It was also found that complex areas and shapes could also be measured with more accuracy with CAM tools.

However, the teams also concluded that there is no improvement in measurement efficiency in buildings or projects, which are small and simplistic. In fact, the teams performed the quantity take-off faster when done manually.

In a separate study undertaken by Miller (2003) cited in Alder (2006) resulted in a significantly different outcome to that of the previous study. The findings of the principal study indicated no significant difference in the amount of time to obtain the dimensions for a quantity takeoff, nor in the accuracy of the dimensions gathered between the paper-based and electronic measurement methods. The study did outline other benefits of CAM, namely that electronic drawings may save costs of both reproducing construction drawings and distribution costs.

2.5 BIM and Measurement

BIM is a technological process which is rapidly been recognized by the construction industry as the future standard by which buildings are been designed, built and operated. According to (Olatunji and Sher, 2010), BIM promises major improvements that overcome both design and construction process limitations, compared to conventional paper-based or 2D methods currently in use. BIM offers new possibilities to accurately estimate quantities and costs, within a live environment. The automation of the process promises to dramatically improve productivity.

2.5.1 What is BIM?

BIM has numerous definitions from a vast wealth of industry bodies, authors, professionals and practitioners. In effect these authors argue that BIM means different things to different people. However, two of the more generally cited definitions of BIM stem from the National Building Information Model Standard (NBIMS) and Eastman et al., (2008). The former defines BIM as:

> *"A digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition."*

Eastman et al., (2008), argue that BIM is not simply a technology, but a new process and way of working within the construction industry. He defines BIM as:

> *"A modeling technology and associated set of processes to produce, communicate and analyze building models". (p13)*

Eastman et al., (2008) further expands on the definition of BIM by outlining the characteristics of a building model, namely;

- **Building Components (walls, doors etc...)** are depicted by intelligent parametric objects that "know" what they are.
- **Components that include data** needed for analysis and work processes by different stakeholders, that express have they behaved (e.g. quantity take-off).
- **Consistent and Non-redundant data** enables a model to define objects parametrically. This ensures when changes are made to the model, all the corresponding views and associated documents are updated in line with the model (e.g. schedules, elevations, plans).
- **Coordinated data** such that all views of a model are represented in a coordinated way.

2.5.2 Why is BIM important?

Eastman (2009) argues that BIM can potentially benefit all stakeholders in the construction process, from architects, engineers and other consultants to facility operators and owners. These benefits are by way of time and cost savings, while also improving a buildings performance and control. Owners in particular are, upon grasping the potential that BIM offers, find themselves increasingly requiring and insisting upon the use of a BIM model for their projects.

This was highlighted in June 2011, in where the Government Construction Clients Board chaired by Paul Morrell, published a report communicating the UK Governments intention to require the use of BIM on all public sector projects over £5m by 2016. This strategy report for the UK Government Construction Client Group was devised around a hypothesis which defined a scenario in which the Government client would have an estate that was smarter and better equipped to face a low carbon economy, with associated reductions in delivery and carbon emissions.

From a QS perspective, BIM promises, among other benefits, automated measurement, robust and integrated information, enhanced project visualization and greater interoperability among team members (Olatunji and Sher, 2010). BIM is of benefit to QS's as between 50%-80% of time required to create a cost estimate is spent calculating quantities (Bowen, 2011a). By automating the task of calculating quantities, BIM allows quantity surveyors to use the time saved to focus on higher value project-specific factors such as risk management, cost planning, time management and ensuring value for money. This in the author's opinion the real value QS's bring to each project. The following table 2.1, adapted from (Bowen, 2009) further illustrates the reason BIM will be of great importance at different stages of a project life cycle for the QS profession.

Stages	**Importance of BIM to Surveyors**
Benefits at all stages	Clients are demanding more in less time
	Less repetitive and mundane work
	Increased cost efficiency and reduced cost spending on projects
	BIM promotes earlier collaboration of multiple disciplines
	BIM promotes coordination of subcontractors & services
	Increased demand for the use of I.T. by surveyors
	Reduction in software, hardware, broadband & storage costs
	Quantity surveyors can work together from different cities & offices
	Reduction in paper, printing & distribution costs
Concept & Pre-Contract Stage	Allows for efficient error checking
	More accurate and quicker cost plans / estimates
	Model elements can be linked to cost database
	Ability to view 3D model as it develops in to 4D & 5D model
	At concept stage, surveyor has a better understanding of building shape and function
	Improved energy efficiency / sustainability (Useful for life-cycle costing estimates)
	Procurement can be synchronised with design and construction
	Design errors and omissions can be discovered before construction (clash detection)
	Reduced tendering & procurement costs
Post-Contract & Construction Stage	Reduced turnaround for interim valuations (measures of work done to date etc)
	Reduction in programme duration
	Reduced changes to design once project is on site
	Surveyor can react quicker to design team change requests
	Reduced time for final re-measures of provisional quantities

Table 2.1 Benefits of BIM to the QS profession (Adapted from Bowen (2011b))

2.5.3 BIM applications

In this section, the author offers a brief overview of the most popular tools used in the BIM process. Although these tools are primarily used for design, the author feels QS's must be familiar with them for collaborative purposes. Kymmell (2008) notes that BIM software falls into two broad categories;

- Surface modelers
- Solid Modelers

2.5.3.1 Surface Modelers

Surface modelers are defined as "models consisting only of surfaces (that have no thickness) to give a 3D look to their hollow forms" (Kymmell, 2008, p95). The main function of these models is visualization, but some software packages have evolved to facilitate multiple uses. Software programs of this type include:

Navisworks (Autodesk) is a model viewer as shown in figure 2.17, with several useful functions. It is perhaps best known for its "clash detection" capabilities (i.e. it finds where model parts take up the same space in the model). The program also allows these "clashes" to be managed until they are rectified or re-designed. The program also addresses other major difficulties faced by a BIM team;

1. Interoperability (it can read almost any 3D file)
2. File size (by changing solid models to surface models it can handle massive file sizes)
3. It can combine multiple differing file types into the same file

Fig 2.17 Navisworks Manage (courtesy of Autodesk)

SketchUp (Google) is an easy to use, powerful and affordable surface modeler. Kymmell (2008), points out that SketchUp is not a BIM tool per say; however, it can be used as one providing the user understands and knows its limitations. A SketchUp model can be imported into Navisworks where it is possible to perform clash detection or use it in Time-Liner, which is a tool used for project sequencing purposes. Figure 2.18 shows a building modelled using SketchUp.

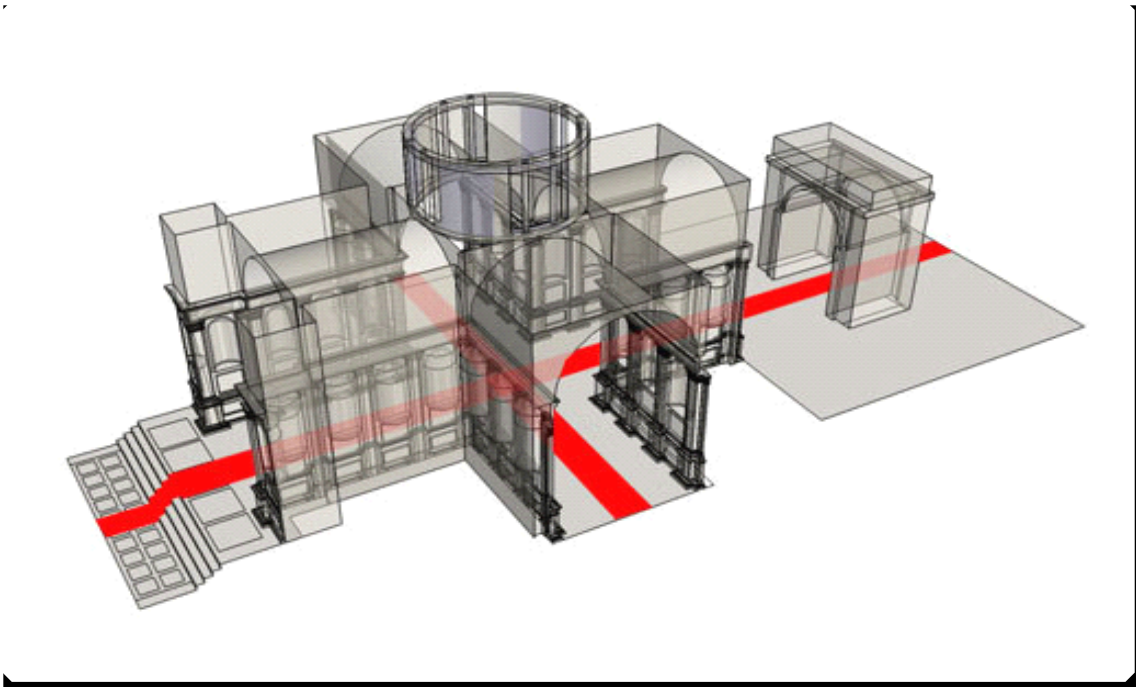


Fig 2.18 Google SketchUp (courtesy of Google SketchUp)

2.5.3.2 Solid Modelers

Solid modelers can be defined as *"actual representations of real objects in 3D space, having the correct dimensions, location, and ability to contain other information about the object characteristics"* (Kymmell, 2008, p.100). The software tool options will specialize in the particular discipline that it serves, for example, architectural tools will differ in strengths and weaknesses to that of specialist mechanical, electrical or structural tools. The following is a non-exhaustive list of some of the solid modeling BIM tools.

- Autodesk Revit
- Bentley Systems
- ArchiCAD (Graphisoft)
- Digital Project (Gehry Technologies)
- Vectorworks
- Tekla Structures

In order for the reader to gain an insight into the capabilities of solid modelling tools, the author will briefly describe two of the more widely used modelling platforms:

Revit (Autodesk) 2012

According to both Eastman et al., (2011) & Kymmell (2008), Revit is the most widely used modelling platform. Revit has a family of integrated products which serve most aspects of the construction industry including Revit Architecture, Revit Structure and Revit MEP. Revit is especially strong due to its range of supporting applications allowing it to integrate with differing discipline specific software's. It can be linked to programs such as MS Project and Syncro for scheduling purposes, to Ecotect and Green Building Studio for environmental analysis, and has the ability to export material quantities for quantity takeoff to software such as Exactal CostX and Autodesk QTO (Eastman et al., 2011). Figure 2.19 shows buildings modelled using Autodesk Revit.

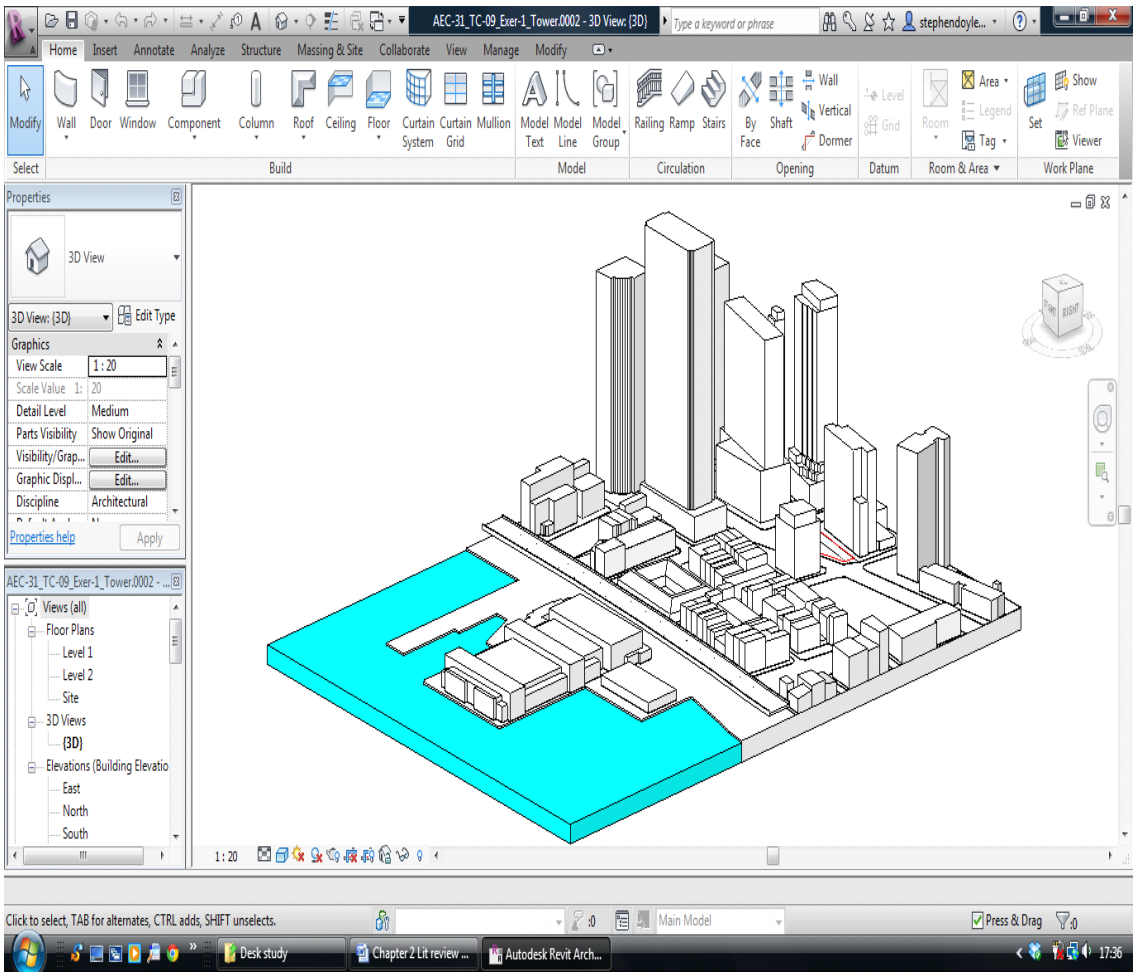


Fig 2.19 Revit Architecture (Image courtesy of Autodesk Student Expert program)

Bentley Systems (V8i) is similar to Revit in respect of its functionality and offering a wide range of integrated products, many of which are in support of its civil engineering products. Bentley also provides products for architecture, infrastructure and facilities management (Eastman et al., 2011). As a tool, Bentley has both strengths and weaknesses compared to that of Revit. Some examples of its strengths include, its ability to handle large complex projects due to its lower reliance on memory (Revit slows down your computer with files over 300Mb), it supports modelling of complex curved surfaces and it has a vast array of modelling tools. There are some weaknesses within the Bentley Systems that stem from the fact the program is difficult to master and due to its large number of integrated systems, a user may have to convert differing drawing formats from one Bentley application to another (Eastman et al., 2011). Figure 2.20 shows a building modelled using Bentley Architecture.

Fig 2.20 Bentley V8i (Model of Aviva Stadium, Dublin. External facade designed using V8i – Courtesy of Bentley)

2.5.4 BIM Quantity Takeoff Software

> *"By using a building information model instead of drawings, the takeoffs, counts, and measurements can be generated directly from the underlying model. Therefore the information is always consistent with the design. And when a change is made in the design – a smaller window size, for example – the change automatically ripples to all related construction documentation and schedules, as well as all the takeoffs, counts, and measurements that are used by the estimator."* (Rundell, 2006)

There are a variety of extracting quantities and material definitions out of a BIM model. According to Eastman et al., (2011), the three primary options are;

1. Export building object quantities to estimating software (Excel, Access, Buildsoft etc)

2. Link the BIM tool directly via plug-in to the estimating software (CostOS, Innovaya, Vico) and

3. Use a BIM quantity takeoff tool (CostX, QTO, BIMmeasure)

However, for the purpose of this report, the author will analyse a selection of BIM quantity takeoff tools now available (option 3).

2.5.4.1 BIM Quantity takeoff Tools

Autodesk Quantity Takeoff 2012 (QTO) is used for calculating quantities as it has several additional functions over Autodesk Revits own internal quantity takeoff function, which primarily outputs material schedules. Within this software, the user can define a design protocol, such as a work breakdown structure (WBS) or SMM template in order to group relevant activities/elements together that enables measurement of a building in accordance with ARM4. The software allows both automatic quantity takeoff and manual digitizing in both 2D and 3D. In addition to obtaining quantities, the user can also use the built in spreadsheet to add additional information to the quantities such as rates and material specifications. QTO can also measure from non-intelligent formats such as JPEG or PDF image files. Quantities and quantity reports can then be exported to Excel/Access for further purposes (Autodesk QTO Brochure).

Another notable feature of QTO is its ability to save past projects and automatically reassign similar items in future projects. This means that once an ARM4 template is set up for one project, which initially is time consuming, it can be integrated into QTO for future take-offs. QTO can also quantify items not typically modelled, but need to be under ARM4, such as concrete formwork.

The initial model take-off is done by going to the "Takeoff" drop down menu and selecting "Model". This reads all elements exported from a Revit model and includes information associated with these elements for use in the QTO reports as shown in figure 2.21. However, the Revit file must firstly be converted to the 3D DWF file as QTO is yet to read RVT files directly. The user can also perform a "search takeoff", this quantifies items entered into the search scope such as all windows and doors. Items can then be assigned from the takeoff to the ARM4 catalogue elements that have all cost and assembly information associated with them. (Bowen, 2011b)

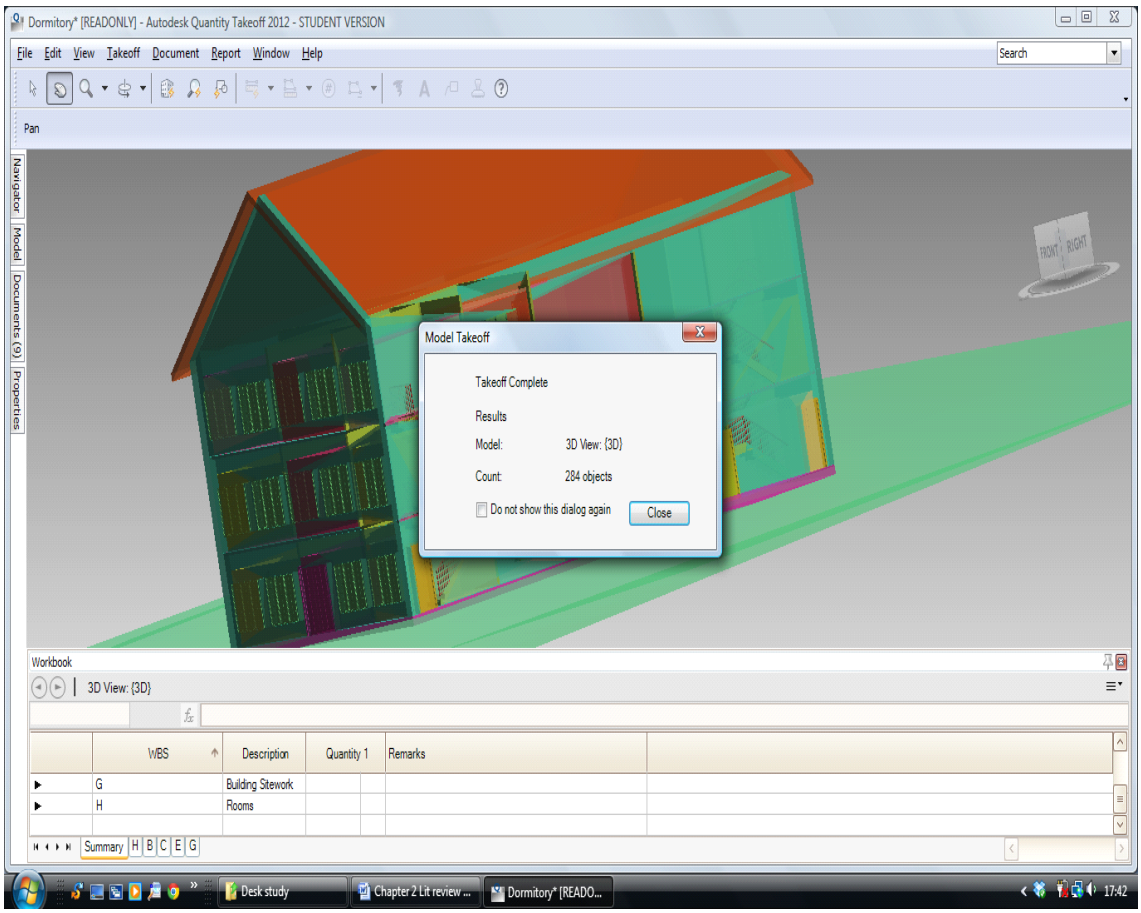


Fig 2.21 Autodesk QTO 2012

Exactal CostX v.3.30 has the ability to extract quantities and object properties from BIM models as well as measuring from 2D drawing files as outlined earlier. It reads parametric design models such as those from Autodesk Revit files (via a DWFx export) and open format Industry Foundation Classes (IFC) files. Day (2008), notes that CostX allows quantities to be automatically updated on the whole project if any changes to project drawings occur whilst also offering analysis tools to compare and contrast these changes by way of isolating or hiding changes to the object.

Quantities from the model can be transferred to the workbook in the "costing view". There are two mains ways to complete this. Firstly, you can create a workbook in a standard format based on a previous project or SMM template, this then allows users to drag and drop dimensions extracted from the BIM model into the appropriate cells of the workbook (e.g. m^2 of brickwork under appropriate ARM4 heading). Secondly, the user can create a workbook from the dimension groups as extracted from the model. This will generate a two-level workbook with "live linked quantities" which will automatically update the project quantities with any changes to the drawings. The initial take-off can be performed by selecting one of the following options by way of clicking their respective buttons as shown in figure 2.22;

1. “Add Dimension Group” – this selects specific BIM properties to measure individual objects such as doors, walls etc.

2. “Import Dimensions from BIM Properties” – displays all model object quantities using a standard CostX BIM template.

3. “Import Dimensions using Model Maps” - displays all model object quantities using a user defined model map.

Reports can then be produced in a professional presentation quality from the software or alternatively can be exported to Microsoft Excel/Access. (Exactal, 2012)

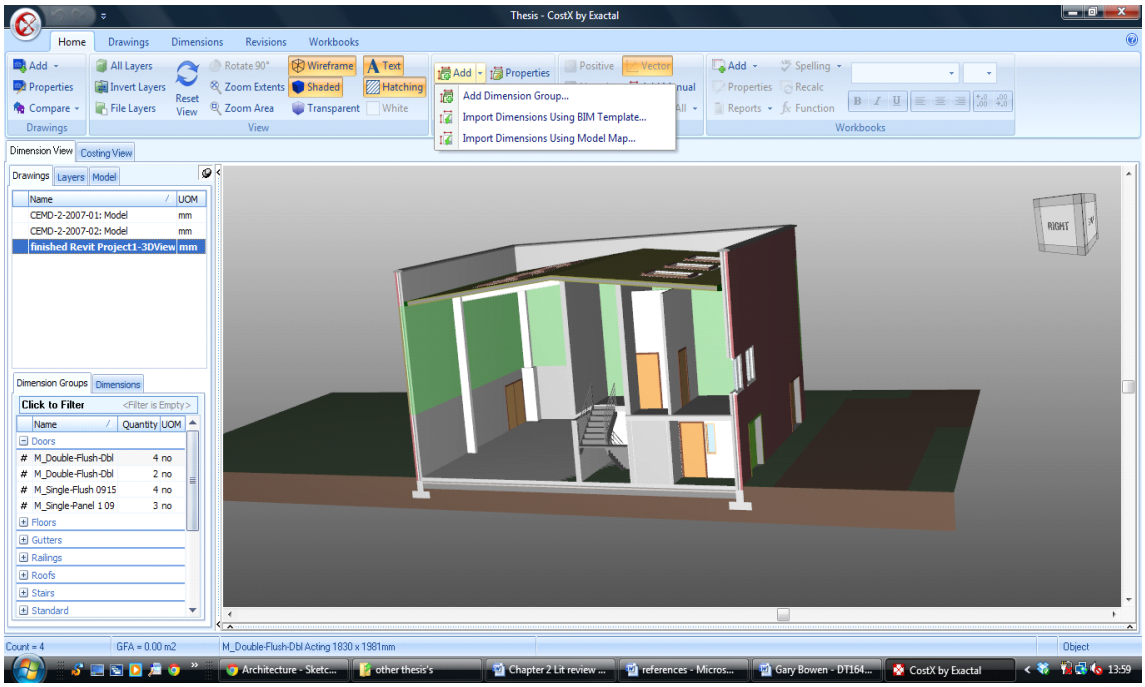


Fig 2.22 Exactal CostX v.3.30 BIM takeoff options

2.6 Limitations of BIM Quantity Takeoff

Although numerous professionals within the construction industry seem to favor the systematic adoption of BIM, from a measurement and quantity surveyor’s perspective there are several limitations of existing software that will need to be addressed if QS firms are to fully and confidently commit to implementing BIM measurement applications. These include;

- The model has to be created in such a way as to extract quantities that are configured to QS’s needs. It is not enough to just to “count” the building elements, because in reality quantity surveyors group materials/elements together and the model must allow for this. A framework must be put in place to

overcome this such as a work breakdown structure (WBS) or SMM. (BIM Journal, 2009).

- A BIM model does not quantify non-modelled items such as three-way and four-way intersections for plasterboard partitions. These must be calculated manually. (Bowen, 2009)
- The initial capital cost of BIM capable measurement software and staff training costs are formidable barriers for QS firms. (Olatunji and Sher, 2010).
- The inability of applications to auto-alert QS's of errors and omissions, and complications which may arise from incorrect results triggered by faulty commands and defaults. (Olatunji and Sher, 2010).
- The specification of the objects within the model may have to be altered to suit specific material descriptions.
- QS's alone cannot drive the adoption of BIM. It will need all stakeholders, particularly design professionals to drive innovation in the construction industry. Client demand will also play a pivotal role in the implementation of BIM.
- Traceability and trust are also major concerns for QS's with regards using a BIM model for quantity takeoff. If conflicts arise a model will not show how a QS came to the quantity/figure that was extracted from the model.
- There are legal and contractual disputes regarding ownership of the models and each stakeholder's role must be agreed from the beginning of the project.

2.7 Conclusion

Throughout this literature review, the author sought to identify the evolution of measurement/quantity takeoff techniques and tools used by quantity surveyors in the Irish construction industry. This review identified time consuming traditional paper based practices and how the evolution of the use of computer based measurement tools and further IT developments have resulted in changing how QS's perform the core skill of measurement. Cartlidge (2011) has predicted that the development of I.T. packages designed specifically for measurement and quantification will fundamentally change QS work practices. This shift from manual hand-based techniques has already seen increased productivity as highlighted by the results contained in Chapter Five. BIM has further potential to revolutionize the once labour-intensive BOQ preparation process.

The literature review also detailed how BIM is more than 3D drawing or software. It is a collaborative tool that holds design, construction and maintenance information combined in one convenient model that can be shared with all the stakeholders. For QS's, the BIM process promises consistency in documentation, allows greater project visualization, promotes collaboration among project participants and offers many applications that can be used to improve both efficiency and accuracy in construction measurement.

Despite the obvious benefits of BIM there are a number of multiple complications and limitations pertaining to its use, which left unresolved, will continue to hinder the potential of the BIM process in Ireland. The barriers preventing Irish QS firms from adopting automated measurement applications where shown to be extensive as outlined above, and as a result the majority of Irish QS firms surveyed still rely on manual measurement to takeoff quantities. It will warrant a seismic shift in attitudes within the Irish construction industry as a whole from all professions and departments in order to harness the full capabilities and potential BIM offers for automating the measurement process.

CHAPTER 3: RESEARCH DESIGN

3.1 Introduction

This chapter of the report outlines the research design and the techniques that were used for meeting the aims and objectives of this thesis. The author has used a mix of quantitative and qualitative primary research, in the form of a survey and self-observation case study and secondary research in the form of a literature review. This style of research is in the author's opinion necessary, for examining the potential of BIM software to increase productivity within Irish QS firms.

3.2 Research Strategies

The majority of research strategies fall into two categories; qualitative and quantitative Table 3.1. The purpose of the study and the type of information required by the researcher determines which category of research will be selected.

Naoum (2007), states that quantitative research is objective in nature. It is based on the testing of a theory or hypothesis, not to develop one. A hypothesis is defined by Fellows and Liu (2003) as *"a statement, a conjecture, a hunch, a speculation, an educated guess".* The researcher asks specific, narrow questions and collects data from participants who answer the questions. The researcher analyzes the data and the results determine whether the theory or hypothesis was confirmed or unconfirmed.

Qualitative research however, is subjective in nature. According to Naoum (2007), it emphasizes meanings, experiences and descriptions. This form of research asks broad questions from participants usually in an interview setting and collects word data from which the researcher will look for themes and descriptions of information, which is exclusive to that set of participants. Qualitative research is commonly classified under two headings, exploratory and attitudinal. Exploratory research is used when the researcher has a limited understanding of a subject and therefore engages experts/professionals in that field in order to "pick their brains". Attitudinal research is defined by Naoum (2007, p.41) as "*used to subjectively evaluate the 'opinion', 'view', or the 'perception of a person towards a particular object'.*

However, Creswell (2006) argues that combining quantitative and qualitative research approaches provides a better understanding of research problems and may prove valuable in certain projects. Spratt et al. (2004) expands on this view, by adding that the use of this approach can capitalize on the strengths of each approach while offsetting

their different weaknesses. The combination of the two strategies is referred to as mixed-method research. This form of research can be defined as

> *"Mixed methods research is a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analyzing, and mixing both quantitative and qualitative data in a single study or series of studies"* (Creswell, 2006. p.5).

For the purpose of this thesis, the author utilized a mixed method approach as outlined in Table 3.1. This consisted of a combination of an industry survey as described in detail below and a self-observation case study (outlined in Chapter 4) comparing differing construction measurement techniques in respect of time and accuracy.

Tend to or Typically.	Qualitative Approaches	Quantitative Approaches	Mixed Methods Approaches
Use these philosophical assumptions	Constructivist/advocacy/ participatory knowledge claims	Post-positive knowledge claims	Pragmatic knowledge claims
Employ these strategies of enquiry	Phenomenology, grounded theory, ethnography, case study, and narrative	Surveys and experiments	Sequential, concurrent, and transformative
Employ these methods	Open-ended questions, emerging approaches, text or image data	Closed-ended questions, predetermined approaches, numeric data	Both open and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data analysis
Use these practices of research as the researcher	Focuses on a single concept of phenomenon Brings personal values into the study Validates the accuracy of findings	Observes and measures information numerically Uses unbiased approaches Employs statistical procedures	Collects both quantitative and qualitative data Develops a rationale for mixing Employs the practice of both qualitative and quantitative research

Table 3.1 Qualitative, quantitative and mixed method approaches - Source: Munn (2012)

3.3 Primary Research: Survey

3.3.1 Introduction

One of the main objectives of this research was to identify the software used by QS firms in Ireland and to ascertain their willingness to adopt new technologies such as CAM and BIM. In this chapter the author will investigate this objective by the use of an online survey questionnaire (Appendix A) which was distributed to QS firms across Ireland. The author will also describe the tool used to translate the results of the investigation into software usage by QS's. In order to produce reliable and valid information the author has carefully designed the survey in six separate steps (fig 3.1) as originally designed by Hynes (2011).

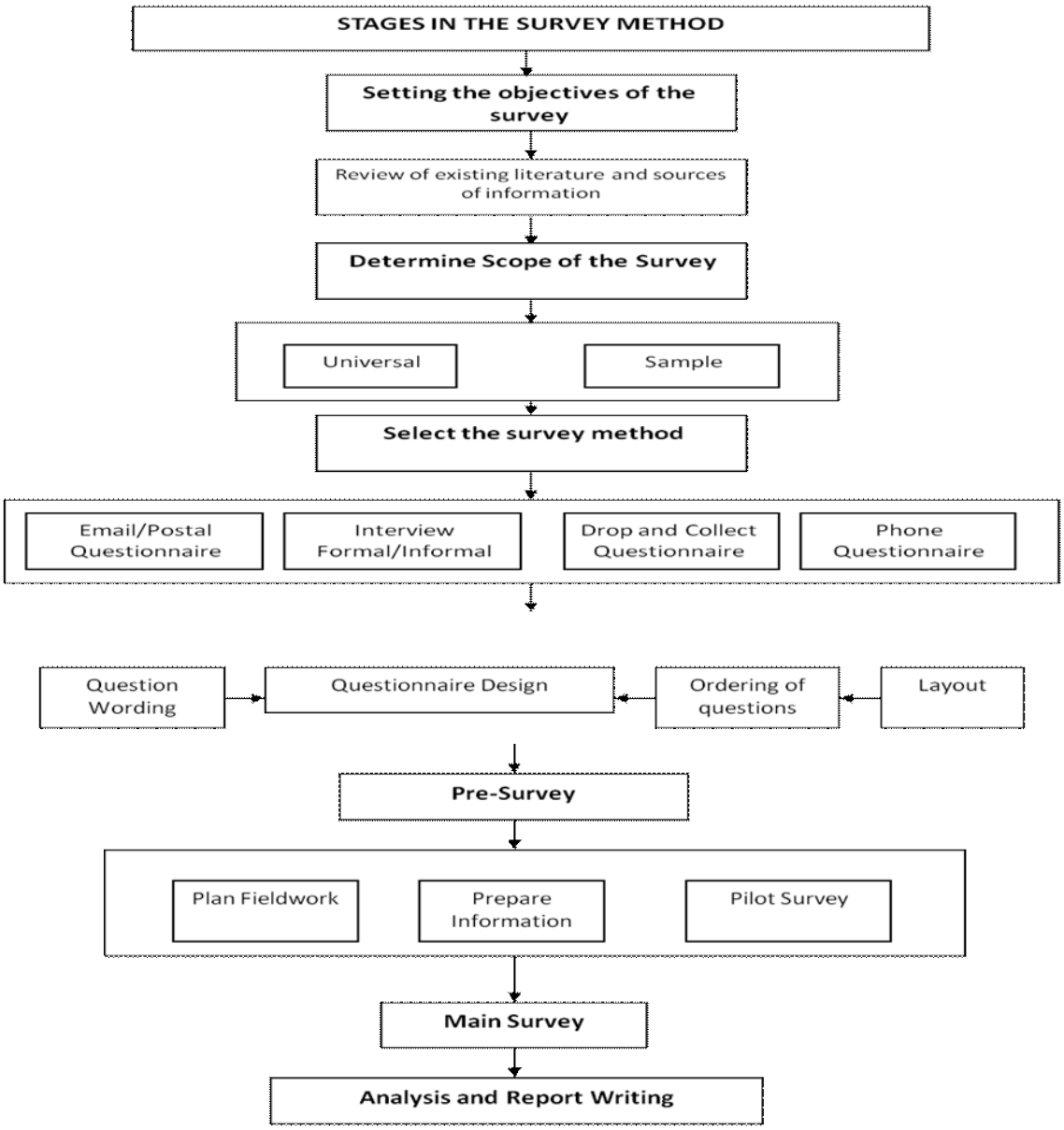


Fig 3.1 Stages in survey method (Source: William Hynes, 2011)

3.3.2 Objectives of the Survey

The first step in compiling a survey or questionnaire is a review of existing literature, information sources and the proposal. This allows the researcher to determine that their question(s), objectives or hypothesis have firstly, not been previously answered, and secondly it raises awareness of any gaps that may be found in the literature. Naoum (2007), states that the questionnaire will usually emanate from the proposal or literature review. After a comprehensive review of the literature applicable to the subject area, the author has identified four main objectives that will form the basis of the study, namely;

1. The software used by Irish QS firms.
2. Their willingness to adopt new technologies/software.
3. The current industry awareness of CAM and BIM.
4. Factors that may prohibit QS firms implementing CAM and BIM applications.

3.3.3 Scope of the Survey

The selection of the participants was carried out by the use of the random sampling technique. A random sample is a subset of individuals that are randomly selected from a group or population. Naoum (2007) identified two steps that need to be undertaken in order to draw a random sample;

1. Identify the population from which the sample is drawn.
2. Obtain a sample that is representative of the larger population.

In respect of the first step, the author obtained a list of QS firms from various sources such as the Society of Chartered Surveyors Ireland (SCS) website, work experience and the authors own personal contacts made via LinkedIn. The second step is dictated by the size of the list of QS firms. If the list is small, all the firms identified can be asked to complete the questionnaire, whereas if the list is large, a system of random selection must be devised to ensure each firm has the same prospect of selection. For the purposes of this study, the questionnaire survey was distributed to all 42 QS Firms identified, as the list was small.

3.3.4 Survey Method

The method chosen for this survey was that of an online questionnaire compiled by the use of an internet software package. The software allowed the questionnaire survey to be circulated to a chosen list of quantity surveying firms by email. The email contained a brief description of the survey and contained a link that directed the participants to the survey. Following on from the experience of Moore (2009), a preliminary email was initially sent to the list of QS firms asking firstly for their co-operation in completing the survey and secondly, to provide the contact details for the individual(s) within the company who will be best suited to responding to the survey. This was done to potentially gain a higher response rate.

3.3.5 Questionnaire Design

When designing the survey-, the author used a four-step process;

1. Ensure correct wording of the questions
2. Keep the questions in a logical order
3. Determine the type of questions to ask
4. Categorize the questions in line with the objectives

The author designed the questions to be both short and comprehensive. The questions were developed to ensure avoidance of using leading, double or hypothetical questions. They were then structured in a logical order to ensure that the standard of the overall questionnaire was satisfactory.

"Questionnaires are classified into two types: the 'open' form or unrestricted type, and the 'closed' form or restricted type" (Naoum, 2007. p 68). Open-ended questions are used to outline the participant's opinions, whereas closed questions lend themselves to short responses such as Yes/No, Agree/Disagree etcetera. For the purpose of this questionnaire, the majority of the questions asked were closed type questions, however in two instances the author asked for the respondent's opinions through open type questions.

The survey was categorized in line with the stated objectives outlined earlier in the chapter.

- Questions 1 and 2 were 'General Information' questions about the respondent and the size of the QS firm in which he/she worked.

- Questions 3 and 4 sought to determine how QS firms measured quantities during the production of the BOQ, what (if any) software was used and how the firms output their quantities when the measurement is complete.

- Questions 5, 6 and 7 establish if CAM software has either improved or reduced both the time taken and the accuracy whilst performing a quantity take-off. The respondents are also asked to outline factors that have prohibited their firms implementing CAM software if it the company's measure quantities using the traditional method of quantity take-off.

- Finally, questions 8, 9 and 10 aims to determine the current awareness of BIM applications within QS firms in Ireland and access their willingness to adopt new technologies such as BIM.

3.3.6 Pilot Survey

The final step prior to sending out the finished questionnaire is to complete a pilot study. According to Bell (1996) cited in Naoum (2007), a pilot study "gets the bugs" out of the questionnaire, allowing the respondents in the main study to complete the questionnaire without much difficulty. The feedback from the study, such as the length of time it took, identifying any unclear questions or elements that may have been missed, could provide valuable information in order to compile an adequate survey. For the pilot study, the author sent the questionnaire to five QS's currently practicing in the Dublin area and requested feedback as mentioned above. Four out of the five Qs's responded, which helped the author improve the overall standard of the questionnaire.

3.4 Primary Research: Participant Observation Case Study

Bowen (2011a) citing Stake (1995) notes that a case study gathers qualitative information about the particularity and complicity of the case study been investigated. Participant observation *"involves participating in a situation, while, at the same time, recording what is being observed. Hence, participant observation has been associated with qualitative methods, as the data collected by this technique tend to be predominantly qualitative"* (Iacono et al. 2009).

For the purpose of this thesis the author performed a self-observation case study which evaluated how the three differing quantity take-off techniques of traditional, on-screen takeoff and BIM and their respective tools compared with one another when used to produce two elements of a BOQ.

A case study method was adopted because it allowed the collection of qualitative data through self-observation. Furthermore, Yin (2009) claims the choice to use a case study is dependent on the researcher's aims and objectives. As the author wishes to discover firstly, 'if' and secondly 'why' measurement using a BIM tool is more efficient and accurate than that of traditional and on-screen takeoff methods, the case study method is relevant. It is then the author's intention to highlight the results to Irish QS firms, as the author believes that this study is extremely relevant to them, as the ever-increasing ability of computer software to automate the measurement process can have significant benefits, such as increased productivity and competitive advantage, in a currently depressed Irish construction industry. Within Chapter 4, the author details the stages and process involved in carrying out the case study and analyzes the findings. The author has chosen a small industrial building to use for the case study.

3.5 Secondary Research: Literature Review

The literature review sought to describe the evolution of construction measurement from traditional or manual practices to the current utilization of sophisticated computer software packages designed for the construction industry, that allow the generation of automated quantities with a BIM model. It also evaluates how this programs can dramatically improve the efficiency and to a lesser extent accuracy, of one of the core QS tasks; taking-off quantities in the preparation of a BOQ. In order to achieve this, various applications were contrasted and there capabilities assessed. Consideration was also given to the current barriers to implementing these tools and outlines their limitations of use in respect of quantity surveyors. Various sources of information were reviewed during this process, including;

- Textbooks
- Web-based literature
- Journals
- Past Theses

The information gained in the literature review allowed the author to form their own opinions and hypotheses. It also formed the basis of the research methodology that sought to meet the aims and objectives of the study. The different aspects of BIM and CAM discovered in the literature review dictated the type of questions asked in the survey, while also allowing the author to better understand the various applications and the potential efficiency and accuracy benefits that could be investigated.

3.6 Summary

This chapter appraised the use of research strategies and concluded that the most appropriate choice was that of a mixed-method approach. The aim of combining both the primary research methods and secondary research was to provide creditable findings that can be highlighted by the author to Irish QS firms that show both the actual benefits and limitations of using BIM tools for quantity takeoff. The results of the survey in conjunction with the conclusions outlined in Chapter Five, provided the author with sufficient information to analyse his hypothesis and determine if the aims and objectives of the study were accomplished.

CHAPTER 4: PARTICIPANT OBSERVATION CASE STUDY

CHAPTER 4 PARTICIPANT OBSERVATION CASE STUDY

4.1 Introduction

For this study, the author will perform an experiment between the use of BIM, CAM and the traditional method of taking off quantities for a small industrial building. This chapter outlines the process involved, and how the study was executed.

This study is limited to the comparison of two software programs used in Ireland for taking-off quantities, BTOS and CostX. The author has also limited the size of the experiment, owing to time pressures, to Elements (23) Floors and (21) External walls.

4.2 Preparing for the Study

Following the decision to undertake the study, the author proceeded to take a number of steps in order to prepare for the study;

- Step 1

  The first step was to identify a suitable building to use as the focus of the study. Following a meeting with Dr. Alan Hore (Assistant Head of School of Real estate and construction economics), a small industrial building he suggested was selected. Dr. Hore then provided me with three different forms of electronic documents to use carrying out the study.

- Step 2

  The second step was the analysis of the chosen buildings drawings in order to determine which elements were to be quantified during the study. The period of time to complete the study was relatively short. Therefore it was unrealistic to attempt to produce a full bill of quantities for the three measurement techniques. To overcome this, the author decided to complete element (23)-floors and element (21)-external walls, as per the national standard building elements.

- Step 3

  The next step was to identify, through research and discussions with my tutor's, the measurement software tools to utilize during the course of the study. Each tool was evaluated in order to satisfy the criteria set out by the author, namely;

    1. Ease of use and familiarity of the application.

2. It is used in the Irish construction industry.

3. Access to the software can be gained.

After evaluating the options available, the author elected to use the following software packages to complete the study: Microsoft Excel, Buildsoft Takeoff system (BTOS), Exactal CostX and Autodesk Revit Architecture.

- Step 4

Once the software programs were chosen, the author then proceeded to gain access to them. This was achieved through applying directly to the software vendors for educational licenses, which allowed me to download their software directly to my computer. Firstly, the author was granted a six-month license by Exactal for their CostX program. The author then become a member of the Autodesk Education Community, this membership allows the download of any of Autodesk's vast array of products for a period of 36 months free of charge. Lastly, BTOS and Microsoft Excel were available for use in Dublin Institute of Technology (DIT), Bolton Street.

- Step 5

The last step in preparation for the study was to become familiar with each of the programs in order to correctly perform the exercise. This was accomplished by sourcing the various software user manuals, performing "trial" projects and attending various training courses and seminars both inside and outside DIT. The following table 4.1 outlines the training received;

Course	Location	Duration/Seminars Attended	Trainer
Autodesk Student Expert Program and Revit Essentials	Blackrock, Co. Cork	3 Days	Ger O'Sullivan (Datech)
CostX	Bolton St. DIT	3 (2 hour) Seminars	Dermot Kehily (Lecturer, DIT)
CostX	Bolton St. DIT	1 (60 minute) tutorial	Trevor Woods (constructit.ie)
BTOS	Bolton St. DIT	Seminar	Dermot Kehily (Lecturer, DIT)

Table 4.1 Software training

4.3 Study Part 1: Manual Take-off

The manual or "traditional" part of the study took place on Monday, 19th March, 2012, in room 325 of Dublin Institute of Technology, Bolton Street. In preparation for the manual takeoff, the author took the following measures;

1. The building was illustrated on ten architectural drawings, which were given to the author by Dr. Alan Hore. These drawings were in an electronic format (JPEG) as shown in figure 4.1, and therefore were required to be printed out in hardcopy to perform the task. The drawings where printed on size A3 paper.

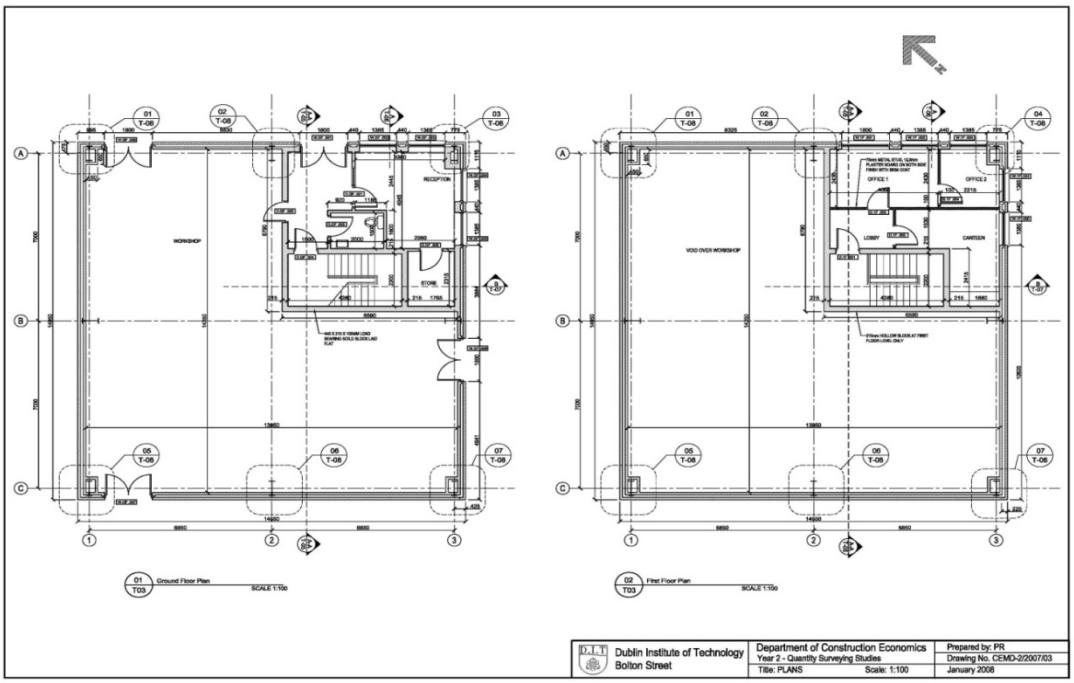


Fig 4.1 Example of electronic drawings received (JPEG)

2. An Excel spreadsheet was formatted and prepared for presenting the finished elements as detailed in Figure 4.2. As alluded to earlier, the Excel program was selected as the final output as few if any QS's practicing in Ireland continue to use dimension sheets or billing paper. The Excel spreadsheet was structured in accordance with the current SMM used in Ireland, the ARM4.

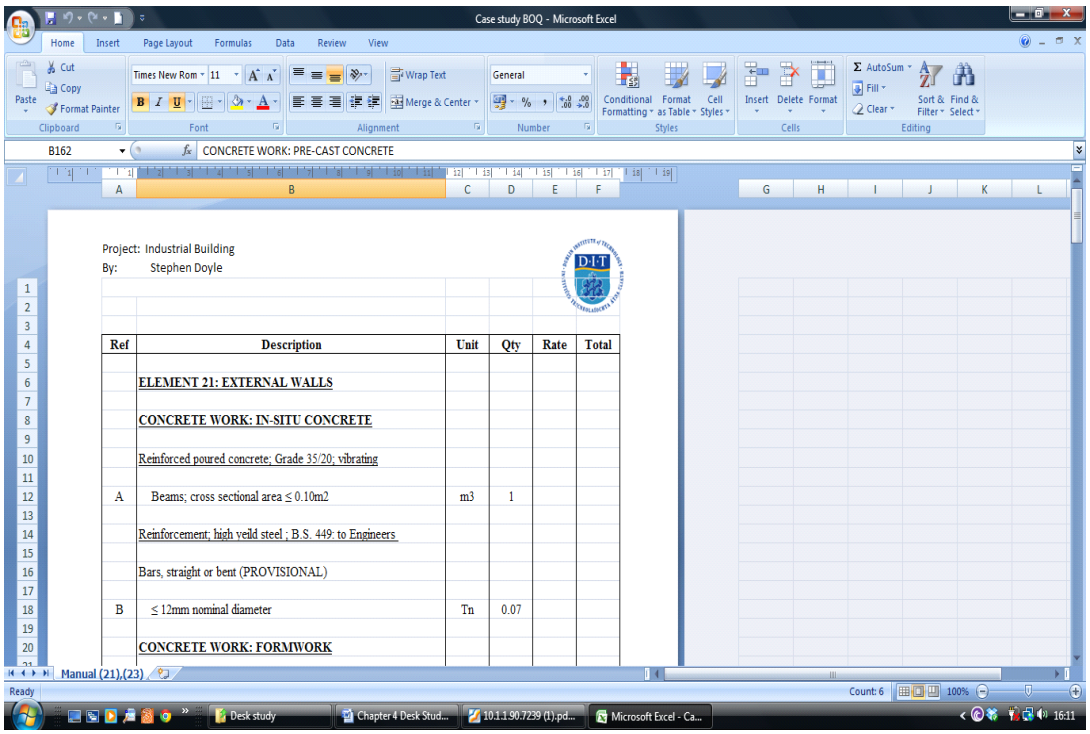


Fig 4.2 Formatted Excel spreadsheet in line with ARM4

3. In order for this study to be considered reliable, the author requested that a fellow construction economics and management student - Shane Carolan, to supervise the takeoff and time this part of the study using a stopwatch.

The Takeoff

Following completion of the preparations, the author commenced with the takeoff. A combination of a scale ruler and the dimensions stated on the drawings were used to complete element (21) - external walls and element (23) – floors. All calculations required to produce the quantities were hand-written on a notepad. These quantities were then manually input into the Excel spreadsheet to complete the process and can be seen in (Appendix C).

4.4 Study Part 2: CAM Take-off

The CAM or on-screen takeoff part of the study took place on Tuesday, 20th March 2012, in room 325 of Dublin Institute of Technology, Bolton street. The CAM takeoff tool used in this study was the Buildsoft takeoff system (BTOS). Dermot Kehily, a lecturer at DIT, recommended this software to the author. In preparation for the on-screen takeoff, the author took the following measures;

1. The first step for this portion of the study was to create a new "job" in Buildsoft once the program was opened. For the purposes of this study it was named "CAM Takeoff". As described in Chapter Two, the program has three distinct layers or sheets, the first been the job summary sheet which allowed the author to note the elements (21 and 23) been measured.

2. Following this, the author then typed out the required material descriptions in accordance with ARM4 on the "trade breakup" sheet.

3. The final step was to activate the BTOS on-screen takeoff tool via clicking the following icon on the toolbar. Once opened, the author loaded the drawings (JPEG files as described above) to the system and set each drawing individually to the required scale.

4. Similar to part one, for this study to be considered reliable, the author requested that a fellow construction economics and management student, Shane Carolan, to supervise the takeoff and time this part of the study using a stopwatch.

The Takeoff

The author then proceeded with the takeoff. The procedure for measuring from drawings once BTOS has been activated is outlined in Chapter Two. The on-screen takeoff tool can be activated from two areas within the traditional Buildsoft program, each producing different results. A single result (m, m2, m3, Nr or Tn figure) will be returned by placing the cursor in a QTY cell of the "trade breakup" sheet and initiating the takeoff tool. For the purposes of this study however, the author activated the tool via the QTY cell in the "calculation" sheet as shown in figure 4.3, which returned a more detailed description and breakdown of each quantity (length, width, height etc). The

author found this option more desirable as it documents how the user generated his final quantity if the figures are called into question.

Openings such as windows and doors were deducted by inputting their dimensions into a schedule. Once complete, individual openings can be selected from the schedule and subtracted from the quantity been measured. This process was then repeated for each quantity until both elements were completed. The finished elements are shown in Appendix C. There was however, some limitations to using this takeoff tool. Although the software is relatively easy to master, the author found it frustrating at times as you must activate and exit the on-screen takeoff tool for each measurement. Furthermore, it also requires some manual measurement for quantities such as tonne weight of steel reinforcement.

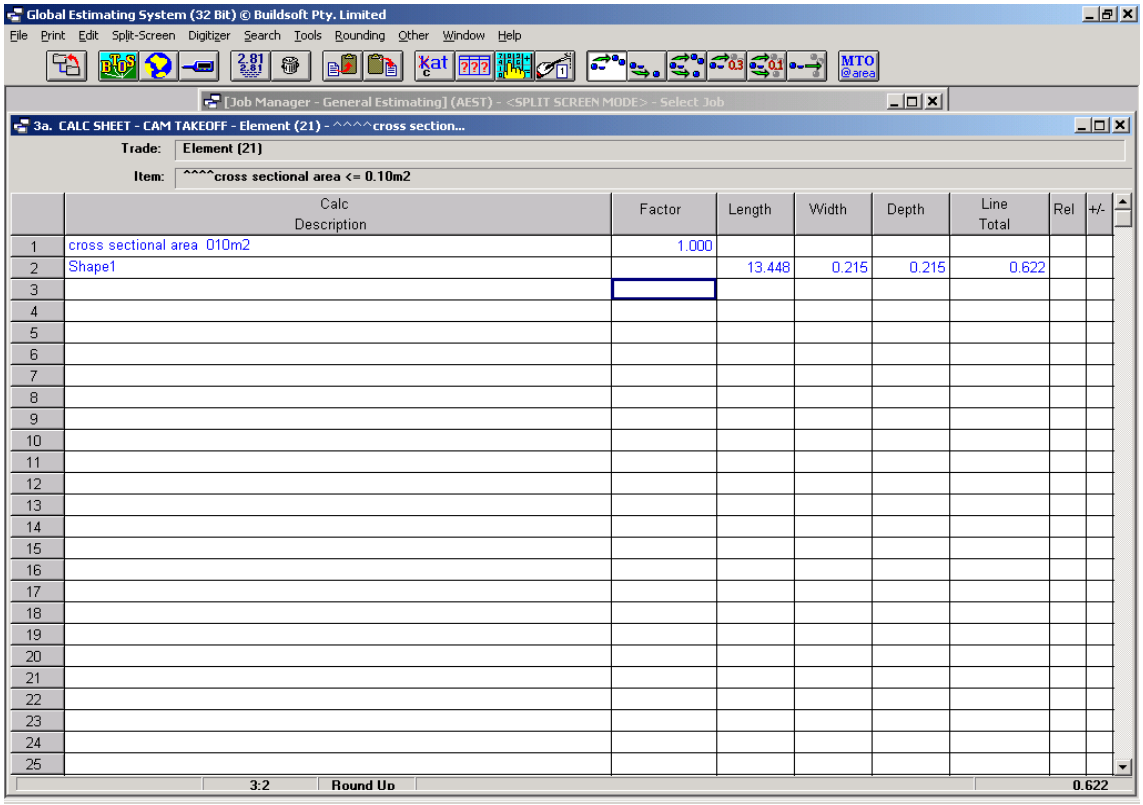


Figure 4.3 Activating BTOS via the "calculation sheet"

4.5 Study Part 3: BIM Take-off

The BIM quantity takeoff part of the study took place on Friday, 23th March, 2012, in room 325 of Dublin Institute of Technology, Bolton Street. The BIM takeoff tool used in this study is Exactal's CostX, version 3.30. This software was recommended to the author by Trevor Woods of Construct-IT. In preparation for the BIM takeoff, the author took the following measures;

1. The model used in this section of the study was produced using Autodesk's Revit Architecture software program, and was given to the researcher by Dr. Alan Hore. However, credit must be given to Gary Bowen who assisted in producing the model. In order to make the model compatible with CostX, it was necessary to convert the model from Revits own file format (.rvt), to either a DWFx or IFC file format to enable CostX to read the file. Figure 4.4 below illustrates how this is achieved.

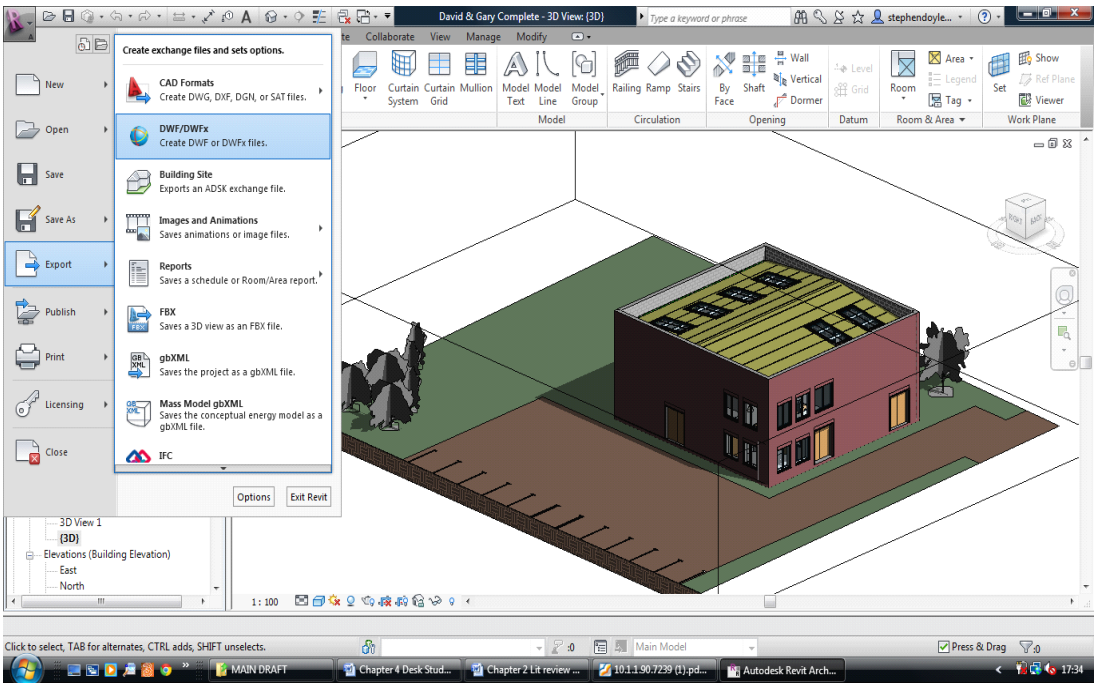


Fig 4.4 Creating a DWFx file in Autodesk Revit

2. The next step was to create a "project" in CostX, which for the purposes of this study was named "BIM takeoff". Firstly, you simply import the above-mentioned DWFx file into the dimension view of the CostX software. Secondly, you "add" a workbook in the costing view. This workbook is a spreadsheet built into the software that allows you to format numerous styles of reports, BOQ's or cost plans. Similar to the first two parts of the study,

the author modified the workbook to satisfy the layout required by ARM4 as shown in figure 4.5.

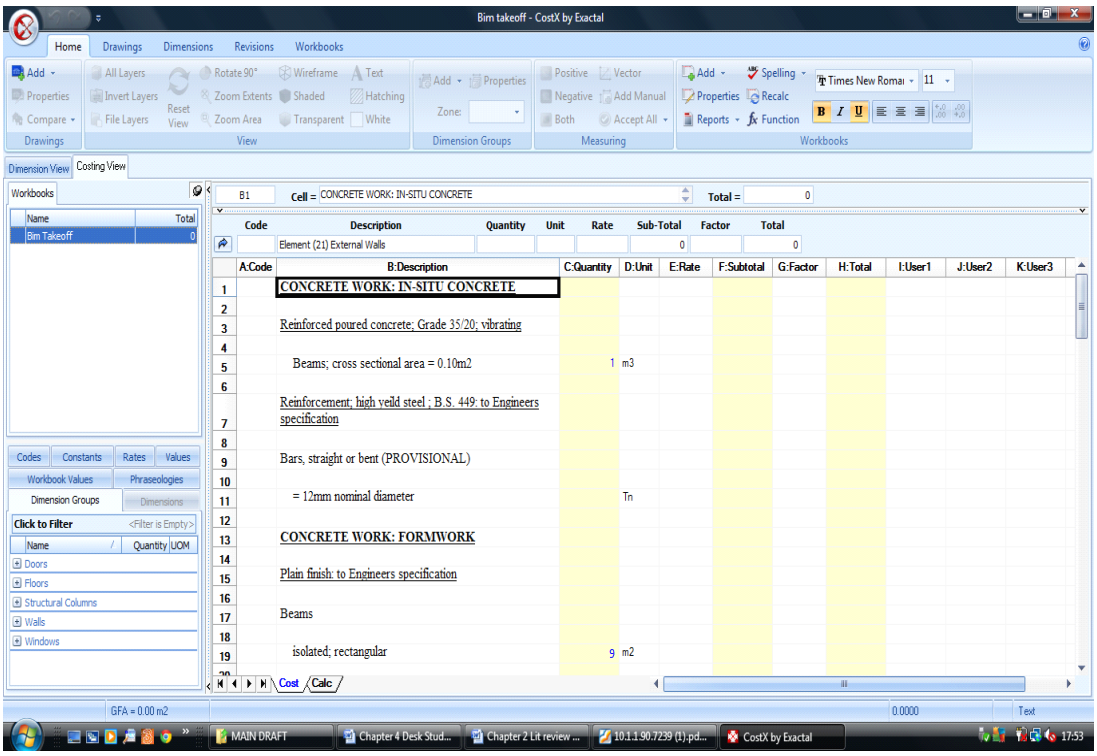


Fig 4.5 Formatted CostX spreadsheet in line with ARM4

3. Again, in order for this study to be considered reliable, the author requested that a fellow construction economics and management student, Shane Carolan, to supervise the takeoff and time this part of the study using a stopwatch.

The Takeoff

Following the preparation stage, the author commenced with the takeoff. As described in Chapter Two, there are three options a user can take to perform the takeoff using a BIM model in CostX. The option used in this study was “option 2- Import Dimensions from BIM Properties” which displays all model object quantities using a standard CostX BIM template.

This extracts all quantities contained in the model and separates the quantities into “dimension groups”. A dimension group lists all similar building components under a single heading or “family”. For example, figure 4.6 shows all the different types of windows under the windows dimension group.

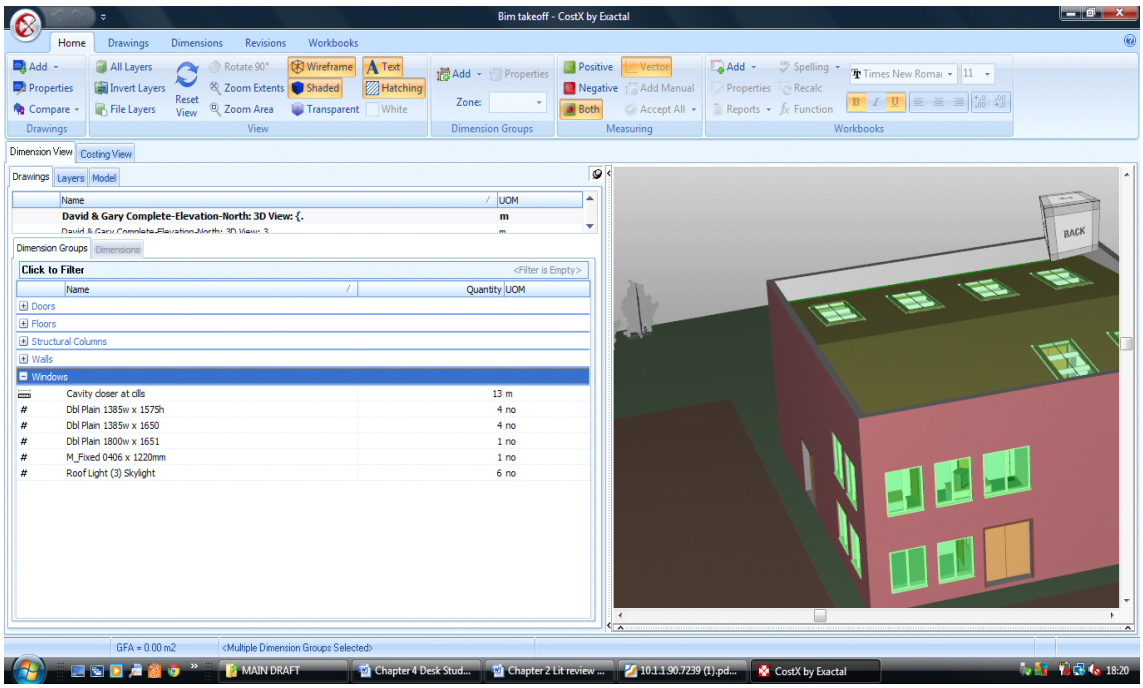


Fig 4.6 Window dimension group (highlighted in blue)

However, owing to the small scale of the quantity takeoff been performed which required the measurement of only two elements- (21) and (23); it was not necessary to extract “all quantities” from the model. To access the quantities needed, you can isolate any components/materials within the model by either switching off multiple “layers” as in AutoCAD or by right clicking on a component in the model and select the “show only objects in” option. Figure 4.7 is a example of how all walls in the model were isolated.

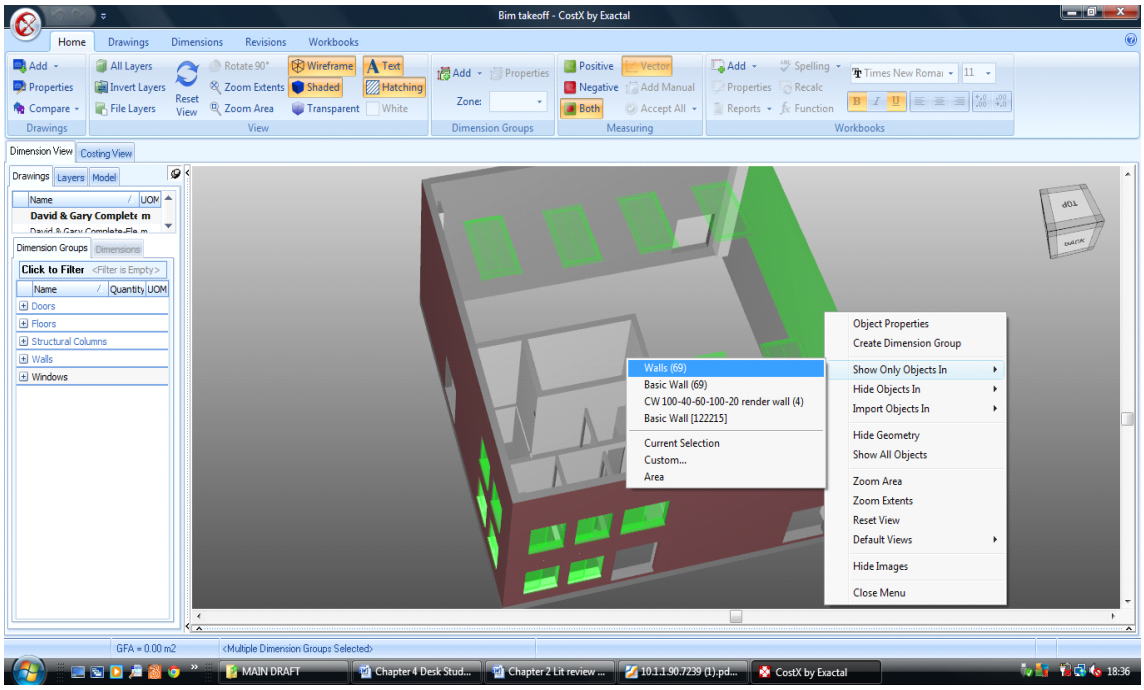


Fig 4.7 Isolating walls in BIM model

Once a component was isolated, which in this case was walls, the author then performed the takeoff by way of "option 2" described above. This quantifies only the isolated items that then populate the dimension group tab, showing all wall types and dimensions. The author found this method easier as it was quick and easy to perform without cluttering up the dimension groups. This method is shown in figure 4.8.

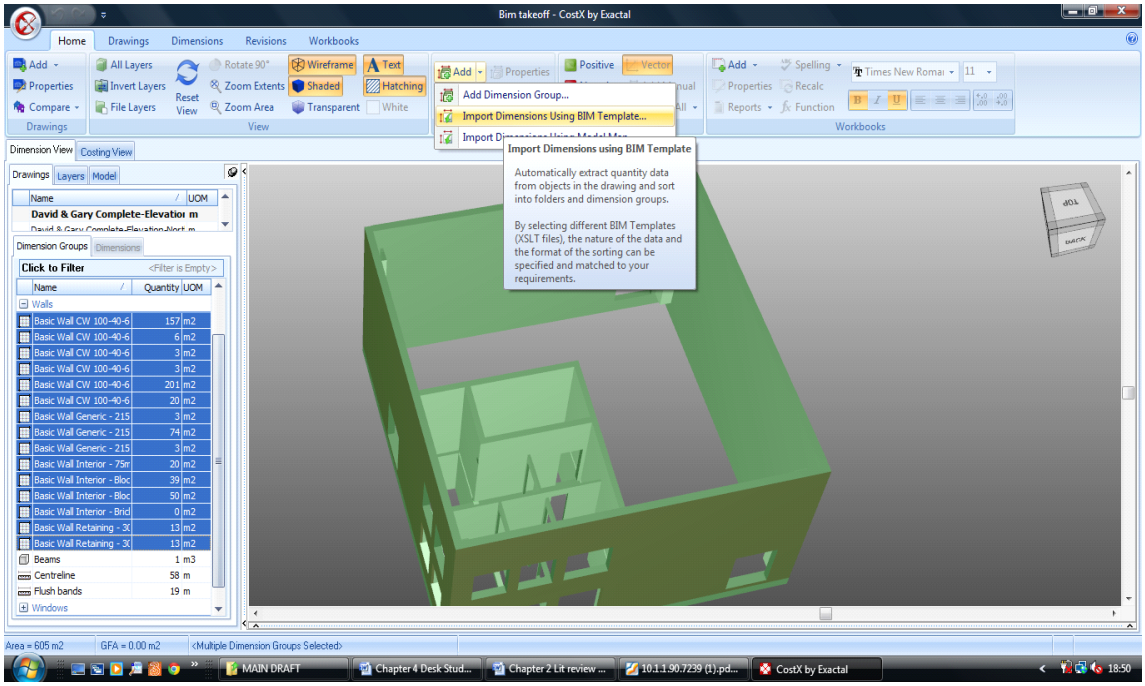


Figure 4.8 Automatic takeoff of isolated components

This step was repeated to obtain all the quantities, lengths, areas and volumes of the various components needed in order to complete the takeoff.

There were however, limitations to the BIM takeoff with respect to gathering certain quantities. For example, in order to produce quantities that are required under certain headings in the ARM4, some on-screen CAM and manual measurement was needed, as no template exists at present that can extract the required information in line with ARM4. Furthermore, unless the model is produced in the first instance by collaborating with QS's, certain components could be missing. The author experienced these difficulties when it came to measuring concrete formwork, damp proof courses, and steel reinforcement.

The next step in the BIM takeoff process was to transfer the extracted quantities from the dimension groups to the workbook. This can be accomplished in two ways, namely;

- **Generate the workbook from the dimension groups automatically.** This will instantly transfer all quantities taken from the model into the workbook and

create “live links” which are explained in Chapter 2. However, it was not used in this instance as the workbook is not then arranged in line with the measurement rules in ARM4.

- **Drag and drop into the workbook from the dimension groups.** The method was used as the author could place the quantities directly into the pre-prepared workbook that satisfied the measurement rules as shown in figure 4.9.

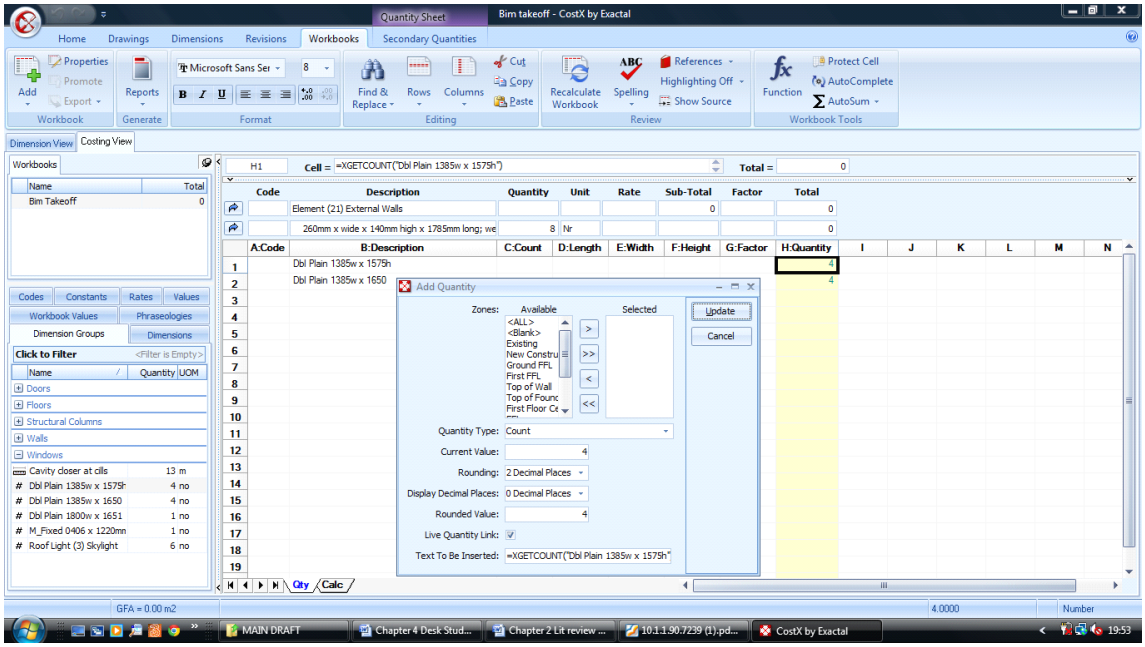


Fig 4.9 Adding quantities by the “drag and drop” method

Finally, once the takeoff was complete, a bill of quantities can be generated and printed from the software program. Figure 4.10 illustrates this process. See Appendix C for the completed elements (21) external walls and (23) floors.

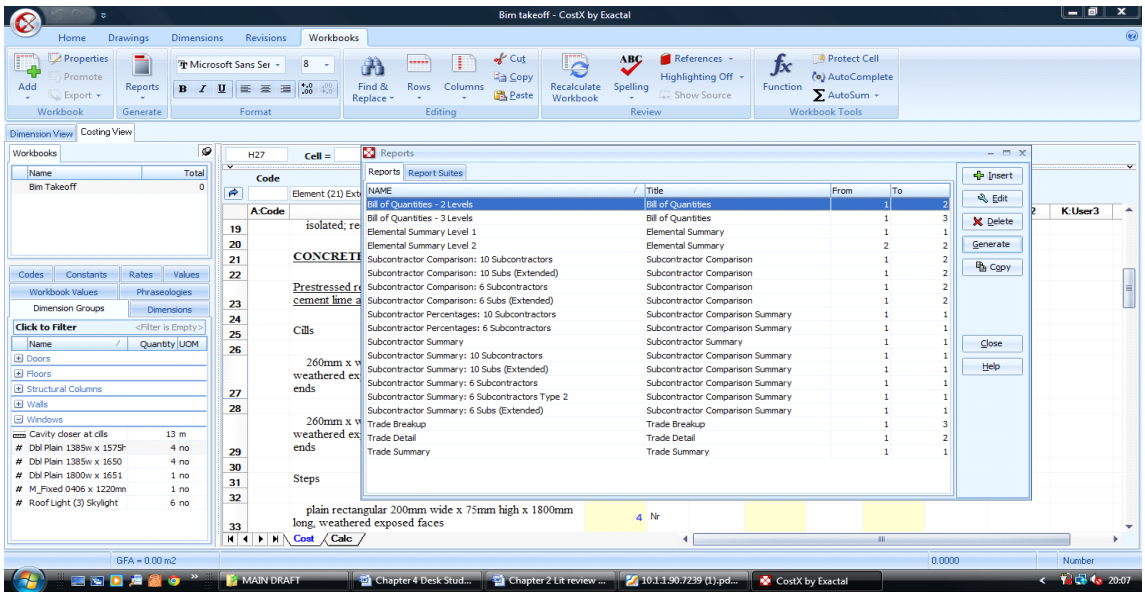


Fig 4.10 Generating a BOQ in CostX

CHAPTER 5:RESEARCH FINDINGS AND DISCUSSION

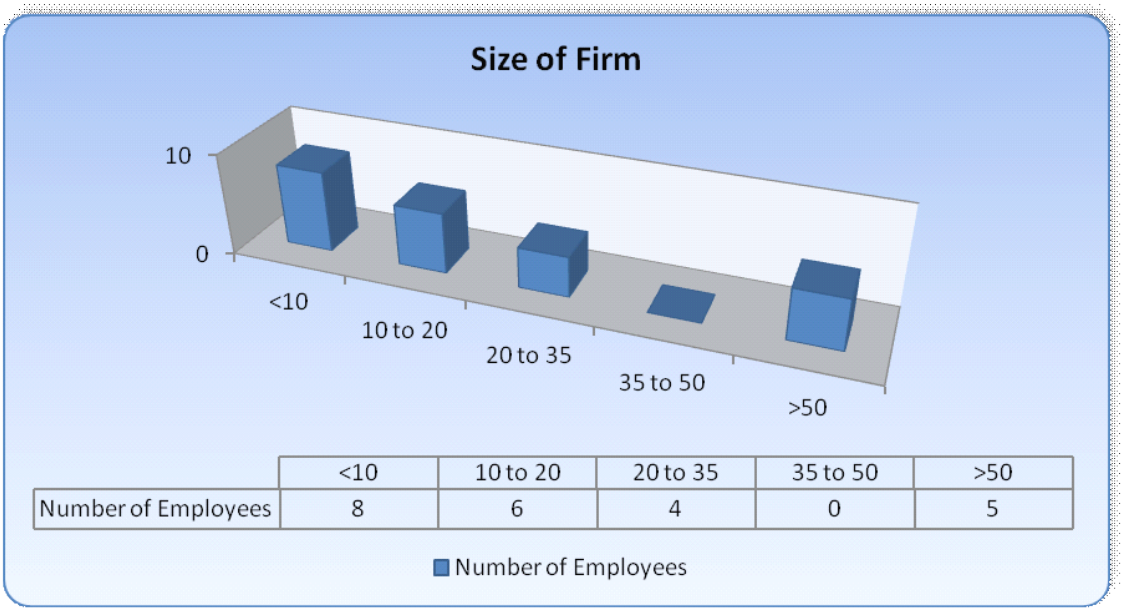
CHAPTER 5 RESEARCH FINDINGS AND DISCUSSION

5.1 Survey Results

As noted in Chapter Three, the survey was distributed to 42 quantity surveying practices across the country. By the time the deadline of the survey expired, a total of 23 firms of the initial 42 requested responded to the questionnaire. This equated to a response rate of 55%, which the author considers satisfactory.

General Information (Q1-2)

Of those that responded to the survey, the vast majority totaling 83% are employed as a consultant QS. This result was somewhat expected due to the direct e-mailing to SCS members who predominately are with consultancies rather than contractors. The remainder of the responses collected were from contractors QS's and a designer (Arch/Eng), with response percentages of 13 and 4 respectively. Q2 was asked to determine the size of the firms the respondents were employed by. The results shows that 78% of the respondents work in firms employing less than 35 people, while the remaining 22% were from firms who employed over fifty people, as shown in figure 5.1.



	<10	10 to 20	20 to 35	35 to 50	>50
Number of Employees	8	6	4	0	5

Fig 5.1 Size of firm respondents employed in

Measuring Quantities (Q3-4)

The third question asked how the respondents and their firms performed the core QS task of taking-off quantities. As outlined in Chapter two, there are a number of separate ways and tools which can be utilized to complete this task, from the traditional manual method using a scale ruler to any of the various software packages available today designed to assist the measurement process. The question listed a range of tools and programs for the respondent to select, whilst also affording the opportunity to specify alternative tools or programs which were not listed.

The results as shown in figure 5.2 conclude that manual measurement through the use of a scale ruler and hardcopy drawings is still the most prevalent within Irish QS firms, accounting for 73.9%. The remainder of the respondents used various CAM tools with Buildsoft's BTOS, Exactal's CostX and surprisingly in the opinion of the author Adobe professional, each having an equal 8.7% share of popularity. It should also be noted that two respondents, one who primarily uses Adobe and the second who uses the manual approach, pointed out that on occasion, they use a digitizer and CADMeasure respectfully, as a secondary tool to assist with the takeoff.

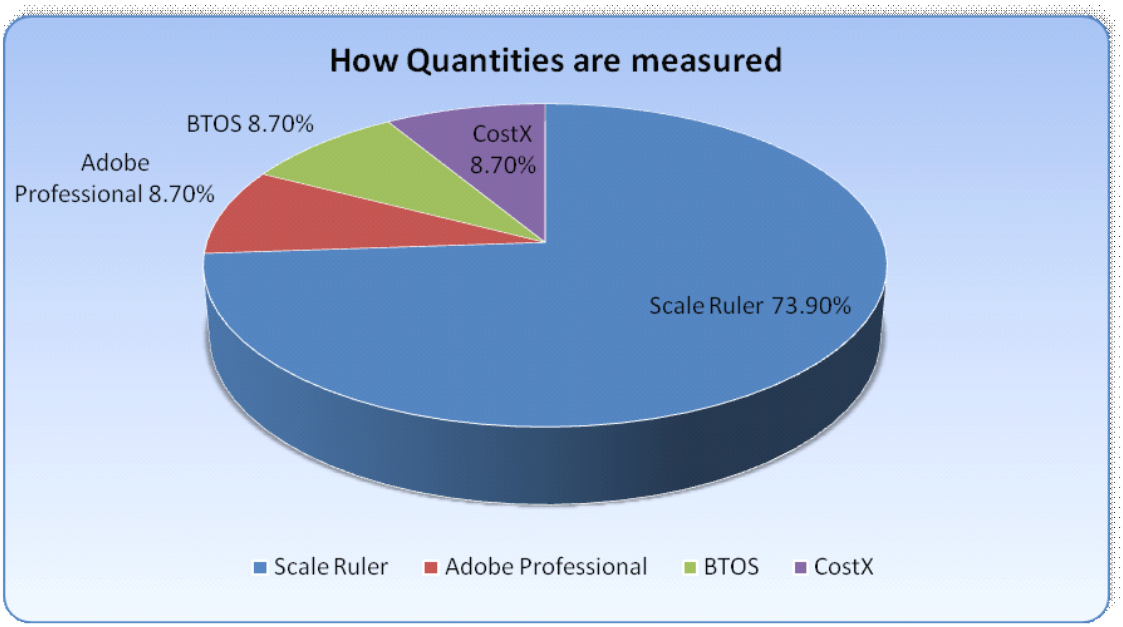


Fig 5.2 How Irish QS firms takeoff quantities

Similar to quantity takeoff tools, there are also various software packages designed for assisting in the production of priced documents and BOQ's. Question four sought to identify which software's were favored, again in the form of a multiple choice question which listed popular programs. Respondents could choose more than one software if

they so wished. Of those surveyed, 100% use some form of computer software in the process of completing a BOQ, which suggests there is a heavy reliance on computers by QS's for managing, sorting and presenting data. It is evident that although the majority of respondents measure quantities in the traditional manner, producing a BOQ using a combination of dimension sheets and billing paper is outdated.

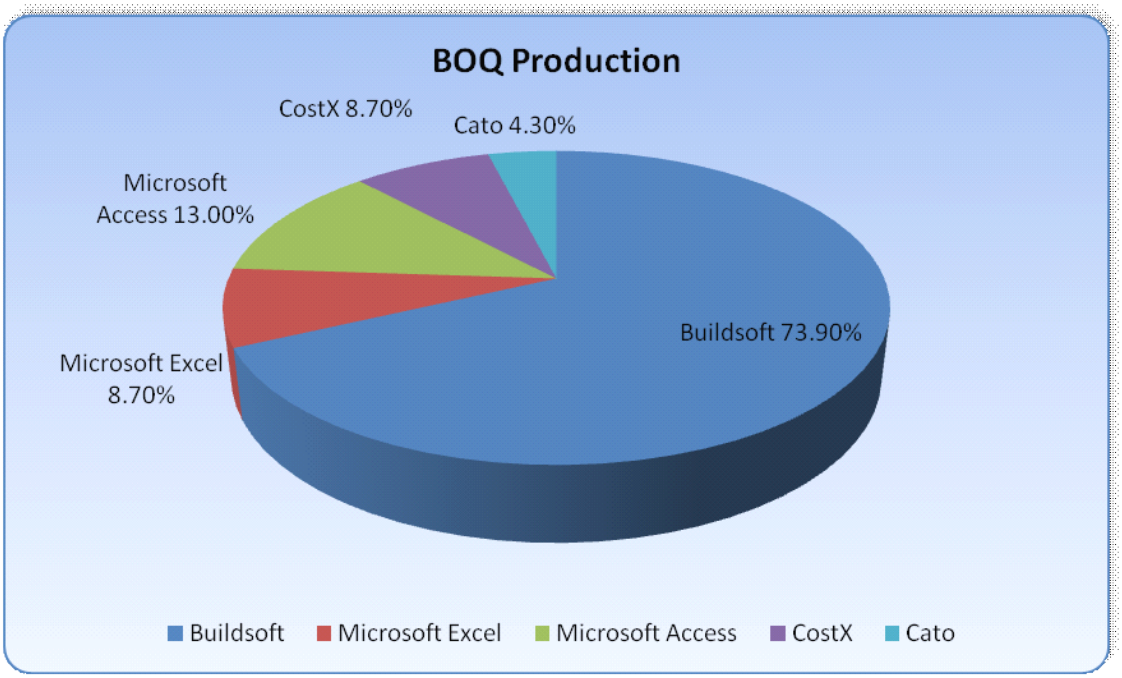


Fig 5.3 Software used to produce a BOQ

As figure 5.3 suggests, the Buildsoft estimating package is the most widely used method of BOQ production with 73.9% of respondents utilizing this program. The results also suggest that there is a direct correlation between manual scale rule measurement and the use of Buildsoft, both having identical percentages. Three of the respondents who use Buildsoft as their primary BOQ production tool also noted that at times they employ secondary programs, them been: Cato (2) and Microsoft Excel (1).

Computer-Aided Measurement (Q5-7)

Question five and six where asked to determine if those respondents who use CAM software, have realized any gains in their measurement accuracy and efficiency.

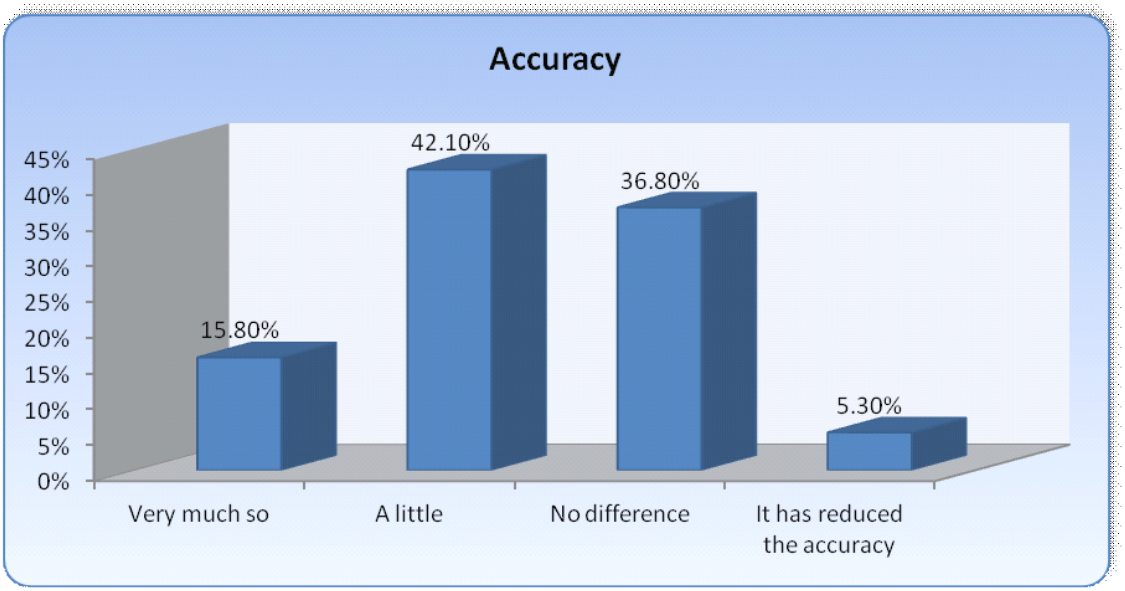


Fig 5.4 Effect of using CAM software on accuracy

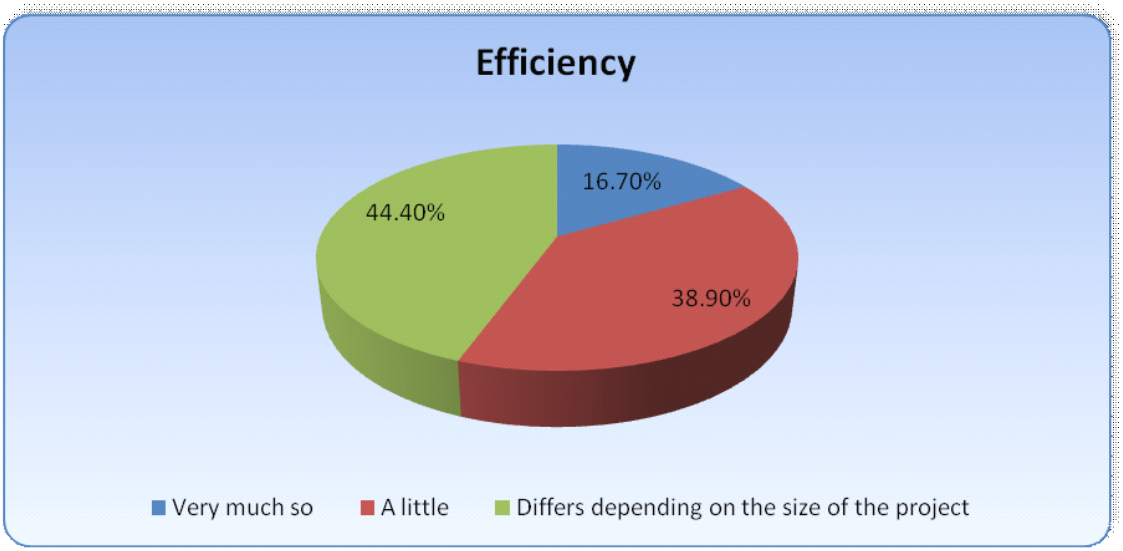


Fig 5.5 Effect of using CAM software on accuracy

The results as illustrated in figures 5.4 and 5.5, conclude that in terms of accuracy gains, 79% of the respondents have either realized small improvements or experienced similar results in accuracy compared to measurement by hand. With respect to efficiency gains, 44.4% of respondents pointed out that a lot would depend on the size of the project been worked on. These results compliment the findings of the *"CITAX Project Module 5 – Computer-aided Measurement"* study as outlined in Chapter two, where the study reported in detail the ideal environment in which accuracy and efficiency gains can be maximized by utilizing CAM.

An opportunity, in the form of an open-ended question, was provided in question seven to those respondents who do not use CAM for taking-off quantities. They were requested to indicate if they would be willing to implement CAM software and what factors have prohibited them from doing so already. 76% of respondents indicated that they would be willing to implement CAM software. The overwhelming reason that has prohibited them from doing so was cost, both the initial investment in purchasing the software, license fees and staff training costs. Time and change of work practices were also put forward as prohibiting factors.

There was a total of 18% that were unsure if they would implement CAM. Reasons for their uncertainty were primarily a lack of knowledge and understanding of the software or process. Other respondents cited that the benefits of adopting CAM software would need be highlighted to them before a decision could be made. Finally, 6% indicated that they would not implement CAM software. Reasons given for this stance were skepticism regarding efficiency and productivity gains. CAM was not considered value for money when efficiency was compared to cost. One respondent also quoted trust issues, pointing out that he has found "glitches" and "corruption of data" an all too common occurrence with estimating software.

Building Information Modelling (BIM) (Q8-10)

The questionnaire concluded with three questions designed to assess Irish QS's awareness of BIM and gather their opinions on how BIM software and processes could potentially increase measurement efficiency and accuracy. The final question asked the respondents what they feel are the main barriers to implementing BIM into Irish QS firms.

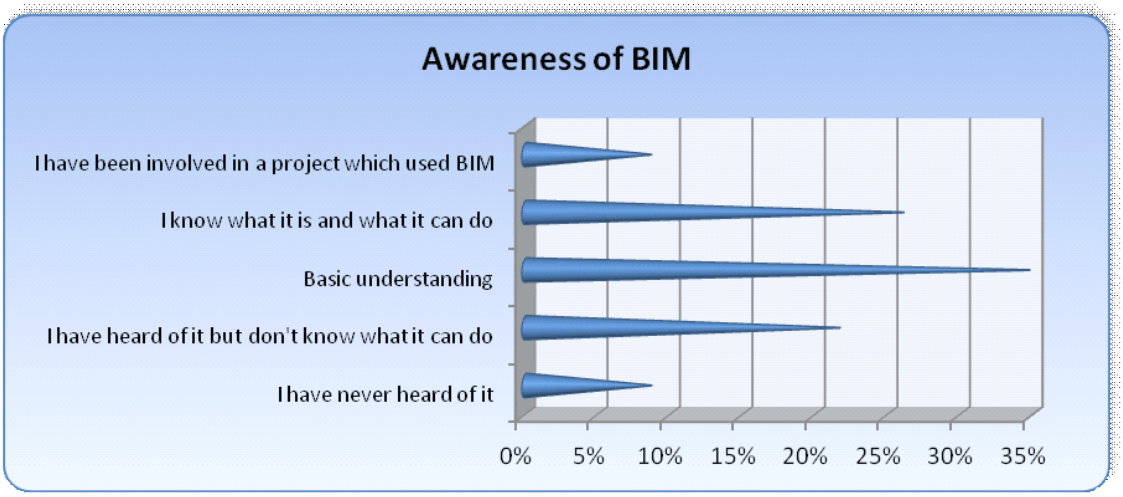


Fig 5.6 Respondents awareness of BIM

92% of those surveyed are aware of the existence of BIM albeit with a varying degree of knowledge and understanding of what BIM processes and software are capable of, as shown in figure 5.6. These results highlight that although Irish QS's are gradually becoming more educated on the subject, there is significant room for improvement. It is in the authors opinion, essential that Irish QS's become accustomed to BIM not only to improve productivity but also to expand the services we can offer potential clients and compete for business internationally, as governments including the US, Canada and the UK are now insisting BIM but used on public construction projects.

Question nine was an open-ended question which gauged the respondents opinions about how within the next five years, they think BIM processes and software will increase the efficiency and accuracy of quantity takeoffs. The most common points of view noted included:

- BIM will allow less labour intensive measurement.
- It will lead to a vast reduction in time and resources to produce BOQ's.
- Better design input from QS's will lead to increased accuracy.

Individual respondents also suggested that the introduction of BIM and advances in software will free up time to allow QS's to focus on other important aspects of their role such as pricing, identifying risks and client relations. Furthermore, it was also suggested that QS's could only realize BIM's full potential in respect of measurement, if SMM's were either altered to compliment automated takeoff or "done away with altogether".

Question ten was a multiple-choice question which asked respondents what barriers existed that they felt would prohibit QS firms from implementing a BIM software application. The respondents were able to choose several or all responses if they so wished. The question responses where developed from the research the author performed in Chapter Two, where the most common barriers to implementation were identified. There was a total of 65% of those surveyed that cited the initial set-up cost was the biggest barrier. Individual or network licenses for BIM software can cost approximately €1,000 to €8,000 each. Autodesk Revit for example can cost approximately €5,500 per license with annual maintenance costs of €800, while Autodesk Quantity Takeoff can cost €2,000 per license. (Bowen, 2011a)

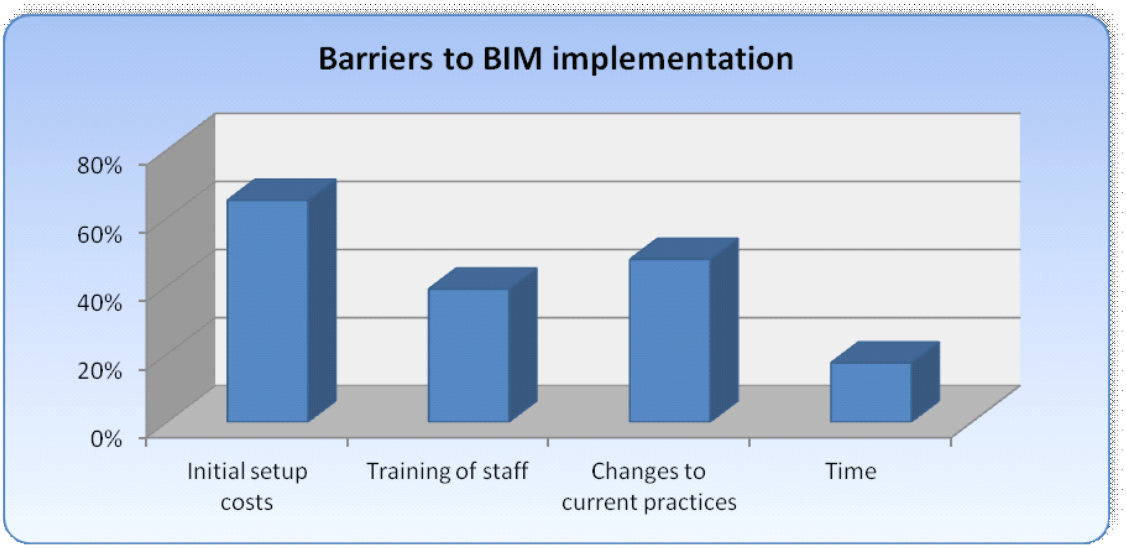


Fig 5.7 Barriers to Implementing BIM applications

As shown in figure 5.7, a high percentage of respondents also felt both staff training and changes to current practices would have a negative effect to Irish QS firms implementing BIM applications.

5.2 Case Study Findings

The three quantity takeoffs carried out in this study, as described in Chapter Four, were then analyzed. These construction measurement techniques were assessed by comparing the results of two KPI's, them been;

1. Time taken to perform the quantity takeoff
2. The accuracy of the measurements

Table 5.1 documents the time taken for each method.

Takeoff Method	Traditional/Manual	Computer-aided measurement (CAM)	Building information modelling (BIM)
Time Taken	1hr 28mins	1hr 16mins	39mins

Table 5.1 Time taken for each takeoff method

The overall values above show that the takeoff performed using the BIM method recorded a significant reduction in the time compared to both the manual and CAM methods which proves the hypothesis of the study to be correct in respect of efficiency.

However, a more efficient quantity takeoff is of no value if the accuracy of the final output is reduced. Therefore each takeoff must be evaluated for accuracy against the

results obtained by a suitably qualified third party who performed an identical quantity takeoff or "quantity template". For the purposes of this study the third party was Dermot Kehily, a lecturer at DIT.

It was found that the authors manual and CAM takeoff quantities matched those produced by Dermot Kehily, with the exception of very slight variances in quantities which can be attributed to rounding. This suggests that the takeoff's performed were accurate. However, there were two instances in element (21) of the BIM takeoff where the quantities returned contradicted the results in the template.

Material Quantified	102.5mm Brickwork	100mm Blockwork
% Difference	5% decrease	1% increase

Table 5.2 Instances where quantities differ in the BIM model

As Table 5.2 illustrates, the BIM model returned a 5% decrease in brickwork and a 1% increase in blockwork compared to the quantity template. The reason for the discrepancy in the quantity of brickwork can primarily be attributed to the area of the brick "flush bands" above the windows and doors not been accounted for in the BIM model, whereas in the manual takeoff the area was included. The 1% increase in blockwork could in the author's opinion, be as a result of a modelling error.

Notwithstanding this, the quantities generated from the BIM model were consistent with the manual and CAM takeoffs. Therefore, the theory of BIM *improving* the accuracy of the material quantities as stated in the hypothesis was proven to be in-correct, effectively they were the same. Therefore in practice, the quality and accuracy of the information taken from a BIM model is largely dependent on the quality and accuracy of information put into it, if quantity accuracy is to be improved. In order for QS's to get the full benefits of BIM, they must either become capable of manipulating a model to extract the correct quantities or have a greater input at design stage when the model is been produced. This would then ensure it contains the required information to produce accurate and efficient quantity takeoffs.

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CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

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6.1 Conclusions

The aim of this thesis was to compare the use of BIM to the current measurement practices used in QS firms in Ireland. The criteria under which this was examined were the KPI's of efficiency and accuracy. The hypothesis, as set out in Chapter One concluded that, the successful implementation of BIM for the purposes of measurement would increase efficiency but accuracy will remain consistent with manual and CAM methods. This section of the thesis reviews what has been examined earlier in order to form relevant conclusions and discuss how the objectives of the thesis have been achieved and how these were combined to meet the overall aim of the thesis.

The first objective set out by the author in Chapter One was to investigate and document "the evolution of measurement and measurement software". The literature review identified how the core QS task of quantification has evolved from the age-old traditional practice of using pencil and paper to the gradual introduction and increasing popularity of I.T. systems and software such as spreadsheet based programs and CAM. Furthermore, the potential BIM offers professional QS firms is discussed in detail. The drivers of this change were primarily shown to be as a result of QS firms seeking to reduce errors and omissions in quantity takeoffs and increasing productivity with more efficient work practices. By examining the characteristics and evaluating the attributes of various construction software programs, it was demonstrated how these factors among others could potentially be improved by implementing them, particularly a BIM system.

The second objective was to "identify the software used by QS firms in Ireland and to ascertain their willingness to adopt new technologies such as CAM/BIM". The view of Irish QS firms was determined from an industry survey. The results of the survey revealed that although the majority of QS firms still obtain quantities utilizing traditional or manual methods, 100% of respondents currently use spreadsheet based software for manipulating and presenting data, representing a general shift to the use of I.T. in QS firms. It also revealed that the consensus amongst respondents was that CAM and BIM processes and software would be more widely adopted in the future. The reasons why Irish QS firms have largely avoided the adoption of both CAM and BIM to date were investigated, with the majority of respondents listing the cost of software and

training, lack of knowledge of the processes and unwillingness to change current practices as major deterrents.

The third and primary objective was to "compare traditional and CAM practices to the use of BIM in quantity take-off". This was met through the undertaking of a self-observation case study performed by the author of a small industrial building. Each of the three methods were assessed and compared under the criteria headings of time and accuracy. The results of the study illustrated that substantial efficiency gains are achievable for QS firms by automating quantity takeoffs via a BIM model, without compromising the accuracy of the quantities.

The author believes this study provided a new insight of the potential benefits that could be realized by Irish QS firms adopting more advanced I.T. systems. However, it has also outlined and evaluated the limitations of measuring quantities using the three methods, with particular reference to the significant complications that will need to be overcome using a BIM model for quantity takeoff.

Finally, the fourth objective of the study was "to highlight the findings of the desk study to QS firms in Ireland under 2 main key performance indicators (KPI's)", namely;

- Will my quantities be accurate?
- Will I save time?

This objective was met by affording the respondents of the industry survey the opportunity to be sent a copy of the results of the self-observation case study performed by the author. Prior to asking QS firms to complete the survey, as a gratuity, the author agreed to email the results of the study to each respondent upon receipt of their preferred email address. Furthermore, the author intends to upload a summary of the results to the various construction industry groups as listed below via the social media website, www.LinkedIn.com. (Member numbers correct as of 9/04/2012)

- Society of Chartered Surveyors Ireland (713 members)
- Construction Ireland (2,932)
- CITA SME EIN (128 members)
- Dublin Institute of Technology – Graduate Network (5,870)

Following the findings in this study, the authors attendance at various seminars/workshops and the reading of various articles on the subject of BIM, the author has concluded that BIM is the future of the construction industry not only in Ireland but also around the world. BIM offers the most realistic opportunity for the construction industry to achieve the "holy grail" of any building project; completed quicker at a lower cost and finished to a higher standard. Various countries have already actively embraced this relatively new concept, including our near neighbours the UK. Ireland however, has been slow to adopt this new way of working and thinking.

It is therefore, an opportune time for research into BIM's potential and in particular for Irish QS firms. Moving from conventional practices to BIM has been shown in this study to increase efficiency in quantity takeoff. It promises the automation of the labour intensive QS task of measurement to free up time to concentrate on the now more diverse range of tasks performed by QS's such as risk management, life-cycle costing and pricing. It also offers users and clients alike, increased project visualization, design information and collaboration. Furthermore, as client's demand more for less in today's depressed industry, BIM offer QS firms who implement it, the opportunity to differentiate themselves from their competitors. It will enable them to offer client's more accurate BOQ's and cost plans in a shorter timeframe, while also been capable of bidding for increasingly larger and more complicated projects.

However, BIM is more than just a software program; it is a process that will require systematic changes to work practices and substantial initial investment by all disciplines in the industry. In addition, there are legal and contractual considerations and these major hurdles will need to be overcome before the Irish industry fully embraces BIM.

6.2 Recommendations

Educating students in BIM

The addition of BIM processes and software modules to current taught courses in third level colleges such as construction economics and management could provide both current and future students with the ability and knowledge to manipulate BIM models in order to extract material quantities for use in BOQ's and cost plans.

Making BIM mandatory on large projects

Currently, the Irish government is the largest client within the Irish construction industry. Therefore, the Government should follow the UK Government's lead as discussed earlier in Chapter Two, and make the use of BIM mandatory on all public projects over a certain cost. The knock on effect would be that all industry discipline's including QS's having to implement BIM in order to compete for public contracts.

Review SMM/Standards

BIM should underpin, rather than complicate, existing measurement rules and standards. Models should be developed according to measurement and estimating processes rather than be limited to the material information models currently contain. Industry wide standards should be developed to act as a framework for BIM models to be produced, that allows QS's to extract information from a model without having to sort vast amounts of data according to trades or elements, which can be complicated and time-consuming in BIM.

Subsidize BIM software/training

Cost of software and training is the biggest deterrent to firms who wish to implement BIM into their practices. As pointed out in Chapter Five, certain software licenses can cost thousands per license. This in conjunction with possible I.T. upgrades and staff training costs would require significant initial capital investment. One possible remedy would be to ask either Government bodies or industry bodies (or a combination of both) to subsidize QS firms willing to implement a BIM system.

The promotion of BIM by construction organizations

A lack of knowledge of BIM is also a much cited reason for its failure to be adopted into Irish QS firms. Although there have been great strides in BIM promotion, mainly through the efforts of CITA and their commitment to running 10 workshops in 2012 alone, there is still an enormous information gap in the industry. National organizations with greater influence such as the SCS, CIOB and CIF should investigate BIM use in Ireland and report on the findings to raise awareness to its members.

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APPENDIX A: SURVEY QUESTIONNAIRE

Q1. What is your Profession?

- ☐ Consultant QS
- ☐ Contractor QS
- ☐ Sub-Contractor QS
- ☐ Designer (Arch/Eng)

Other (please specify)

Q2. How many employee's are in your company?

- ☐ <10
- ☐ 10-20
- ☐ 20-35
- ☐ 35-50
- ☐ >50

Q3. How does your company primarily measure quantities from construction drawings?

- ☐ Traditional Method (scale ruler)
- ☐ Adobe Professional
- ☐ Btos
- ☐ CadMeasure
- ☐ CostX
- ☐ Autodesk Revit/QTO

Other (please specify)

Q4. When you have measured your quantities, what software do you use to complete your Bill of Quantities?

- ☐ Buildsoft
- ☐ Microsoft Excel
- ☐ Microsoft Access
- ☐ CostX
- ☐ Cato

Other (please specify)

Q5. Has Computer Aided Measurement (CAM) improved the accuracy of your quantities?

- ☐ Very much so
- ☐ A little
- ☐ Not sure
- ☐ It has reduced the accuracy

Q6. Has Computer Aided Measurement (CAM) reduced the time it takes you to measure quantities?

- ☐ Very much so
- ☐ A little
- ☐ Differs depending on the size of the project
- ☐ It has increased the time it takes

Q7. If your company currently measures quantities using the traditional method, would they be willing to implement Computer Aided Measurement (CAM) software and what factors have prohibited them from doing so already?

Q8. Please identify your awareness of Building Information Modelling (BIM)?

- ☐ I have never heard of it
- ☐ I have heard of it but don't know what it can do
- ☐ Basic understanding
- ☐ I know what it is and what it can do
- ☐ I have been involved in a project which used BIM

Q9. Within the next few years, what new ways do you see that BIM processes and software will increase efficiency and accuracy within a quantity surveyors firm?

Q10. What do you feel are the main barriers to implementing a BIM application into quantity surveying practices?

- ☐ Initial setup costs
- ☐ Training of staff
- ☐ Changes to current practices
- ☐ Time

Other (please specify)

APPENDIX B: RESEARCH PROPOSAL

SCHOOL OF REAL ESTATE AND CONSTRUCTION ECONOMICS

CONSTRUCTION ECONOMICS AND MANAGEMENT DEGREE

DT111 AND DT155

THESIS PROPOSAL FORM

2011/2012

THESIS PROPOSALS MUST ONLY BE SUBMITTED IN THIS FORMAT. THIS PROPOSAL CAN BE ACCESSED ON THE MAIN COMPUTER UNDER THE NAME OF :

SUBMISSION DATE: Please fill this form and submit it WEDNESDAY 2nd NOVEMBER 12 NOON. The form is intended to help you formulate your proposal. Your attention is drawn to the Regulations for Construction Economics and Management Degree course thesis guidelines.

STUDENT'S NAME: STEPHEN DOYLE

PROGRAMME: DT 111/4 **STUDENT MOBILE NO:** 087 2409172

Student Outside Email: stephendoyle1983@gmail.com

Student DIT email: C08882860@mydit.ie

1. WORKING TITLE OF THESIS

"Comparing time and accuracy of Building Information Modelling to current Measurement practices used in QS firms in Ireland"

2 OBJECTIVES

1. Investigation into the evolution of measurement and measurement software.
2. To identify the software used by QS's in Ireland and to ascertain their willingness to adopt new technologies such as CAM/BIM.
3. To undertake a case study comparing traditional or CAM practices to the use of BIM in quantity take-off.
4. Highlight the findings of the case study to QS firms in Ireland under 2 Main headings;
   (1) Will my quantities be correct?
   (2) Will I save time?

3. PRELIMINARY CHAPTER HEADINGS

1. Introduction

- Background
- Scope of research
- Aims & Objectives
- Research Methodology
- Outline of Chapters

2. Evolution of Measurement by the use of Advanced Technologies (Lit. Review)

- Introduction
- Traditional Construction Measurement Practice (Paper based take off)
- Advancements in Construction Measurement (Buildsoft, excel)
- The use of Computer Aided Measurement by (CadMeasure, Costx, Btos)
- Future Development : BIM Estimating Software (QTO, Vico, Synchro, CostX)
- Conclusion/Discussion

3. Industry Practice Review (Survey)

- Introduction
- Survey (A questionnaire will be posted on the website http://www.linkedin.com)
- Questions (Who is using CAM?, What software? If not, would they implement it? Why haven't they done so already?, Identify awareness of BIM? Would they implement it?..etc)
- Pilot Survey
- Results
- Conclusion/Discussion

4. The use of BIM in Quantity Take-off (Desk Study)

- In this chapter I intend to complete a desk study using BIM technology. I am to attend a training course in Cork run by John Bennett to learn how to use Revit and QTO 2010. I will then pick a simple project and complete a traditional paper based or 2D PDF take off and then the same project using Revit & QTO2010.
- Results
- Conclusion/Discussion

5. Conclusion

- Discussion on case study (adv & disadv. of BIM based take off, elemental differences)
- Recommendations
- Future research

4. LIST THE DATE AND OTHER INFORMATION SOURCES, AND ORGAN-ISATIONS/INDIVIDUALS WHO YOU INTEND TO CONSULT IN THE COURSE OF YOUR RESEARCH

Individuals (Dec – Feb)

- Gary Bowen (via Skype), BSc (Surv.), MSc, PQS, MSCS, MRICS
  Cost Consultant, Cost Consulting & Project Management, Altus Group
  333 11th Avenue SW, Suite 1200, Calgary, AB T2R 1L9 Canada
- Trevor Woods, Construction IT Consultant at Construct IT
- John Bennett, Datech, Cork, Ireland
- Ralph Montague, BArch MRIAI, Managing Partner, ArcDox
- Kerrigan Sheanon Newman (KSN)
- BruceShaw
- Keogh McConnell Spence (KMCS)

Forums (www.linkedin.com)

- BIM Ireland (199 members)
- CITA Bim group (400 members)
- DIT Graduate Network (4495 members)
- Society of Chartered Surveyors Irealnd (349 members)
- Revit Users Ireland (427 members)

5. RESEARCH METHODOLOGY.

Which of the following methods do you intend to incorporate in your study:

		Please Tick
*	Documentary Research	___
*	Interviews	___
*	Questionnaire Survey(s)	✔
*	Case Study(s)	✔
*	Other (Specify)	___

Please state why you consider this/these method(s) to be appropriate.

(Students may choose more than one method.)

6. PRELIMINARY REFERENCES INCLUDING TEXTBOOKS, LIBRARY CATALOGUES, JOURNALS, DATABASES, PREVIOUS THESES

Websites/Articles

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- http://au.autodesk.com/
- http://www.bsssoftware.com/
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- Byrne. E. *"The role of building information modelling in the production of construction cost estimation"*, Dublin Institute of Technology. (2008)
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Training Course

- 3 Day Revit training course (Datech, Cork) December.

APPENDIX C: CASE STUDY TAKEOFFS