# Chapter 3
# Measurement Conventions

*"The quantity surveyor should always use a pen to enter dimensions – use of a pencil and eraser shows a lack of moral fibre."*

These were the words of my measurement lecturer back in the 1960s – and quite right too!

The essence of his message was that taking off quantities is meant to be a thorough and precise process which, if followed correctly, should give the measurer the confidence to enter dimensions in ink and not in pencil.

The process starts with a close scrutiny of the drawings, the preparation of a 'take-off list' and the careful consideration of what is to be measured and how it should be set down on the page. This includes paying particular attention to how side-cast calculations are to be set out, making sure that there is plenty of room between item descriptions and ensuring that, when mistakes are made, they are corrected in the proper manner using established and accepted practice.

Taking-off is also done in conjunction with a specification that informs the description of items to be measured and establishes either the standard of materials and workmanship required (prescriptive specification) or the end result required from the work to be carried out (performance specification).

## 3.1 Traditional conventions

Edexcel Level 3 Unit 9: *Measuring, Estimating and Tendering Processes in Construction and the Built Environment* dated January 2010 includes 'traditional' and 'cut and shuffle' bill production methods in the unit content.

This reflects the *raison d'être* of measurement as a means of producing quantities of construction work, fixed in place, so that bills of quantities can be produced, thereby enabling tenders to be invited from interested contractors.

Whilst the RICS has indicated a significant decline in the use of formal bills of quantities since 1987, 24.5% of all projects (18.8% by value) nevertheless seem to be procured in the traditional way, and, therefore, traditional quantity surveying services are still in demand (Davis Langdon (AECOM), 2011). However, with the marked increase in the popularity of design and build/design and construct and drawings and specification methods of procurement,

informal bills of quantities are commonly prepared by contractors and/or subcontractors for tendering purposes and for work package procurement.

Consequently, measurement still figures strongly in the activities of the industry, and it makes sense, therefore, to embrace all that modern computer software can offer to practitioners involved in producing and/or using quantities.

### 3.1.1    Taking off quantities

Measurement (aka taking-off, quantity take-off) is the process of obtaining dimensions and calculating quantities from drawings; this may be done physically on-site, from paper-based drawings or from digital drawings, images or models.

In the construction industry, the process of measurement is mainly associated with quantity surveyors who, over the years, have developed conventions, or methods of working, that bring order, consistency, clarity and auditability to the measurement process.

Quantity surveying conventions are well described in traditional textbooks such as Willis and Seeley, but it bears repeating here that the conventions for entering dimensions are equally applicable to on-screen measurement as paper-based take-off.

The essential discipline for competent measurement is following the correct order for entering the **dimensions** so that it is easy to revisit the dim sheet to see where the quantities have come from. For this reason, it is important to enter length, followed by width followed by depth. On paper, it is important that the dimensions are entered vertically on the correct paper; otherwise, the measurer will quickly end up in a mess. On-screen, it doesn't matter whether this is done vertically or horizontally, as the software will dictate how the dims are entered. Some software give a choice of vertical or horizontal dimension entry; some don't.

The dimension sheet is laid out as illustrated in Table 3.1 where it can be seen that dimensions are entered in a strict order, on specially ruled paper, according to convention. Also illustrated is a typical item description with side-cast (or waste) calculations that make up the principal dimension entered in the dimension column. This is to be contrasted with an on-screen equivalent which shows the same conventional build-up of a side cast but with a different method of presentation.

Traditional conventions also include a means of multiplying a set of dimensions by another number. In Table 3.2, it can be seen that there are 3 nr items possessing the same dimensions and that **times-ing** is a way of reducing repetition in the take-off. The on-screen version is identical.

Often, in a take-off, items are measured which possess the same dimensions as an item previously measured but which has already been 'times-ed'. A way of adding an additional number to the calculation is by the convention of **dotting-on**. This is illustrated in Table 3.3 where it can be seen that the on-screen version is a close representation of the traditional method except that the 'dot' is replaced by a 'D'.

It will be noted that the **incorrect dimensions** shown in Table 3.4 are deleted correctly as per my old lecturer's instructions!

Dotting-on and times-ing are relevant in the context of computer software packages, which provide the facility to do the calculation but have a different way of entering the figures (e.g. in CATO 3 dot-on 5 is entered 3D5, as the computer would take a full stop as a decimal point).

Table 3.5 shows grouped dimensions relating to the same item with a bracket keeping them together.

This is not necessary in CATO or QSPro because the dimensions relating to individual items are retained in their individual dim sheet.

The **anding**-on of one set of dimensions to another item description shown in Table 3.5 is replicated in the QS software, but CATO and QSPro achieve this in slightly different ways. In effect, though, the dims are copied and pasted from one dim sheet to another.

**Table 3.1**  Dimension sheet.

## Dimensions

The dimension paper is laid out in two equal columns each identical to the example shown. These are numbered as 'pages' Each of the pages is subdivided into four columns:

1. One column for times-ing
2. One for dimensions
3. One for squaring
4. A final column for the item description and any waste or side-cast calculations

| X-ing | Dims | Squaring | Description | Sidecast |
|---|---|---|---|---|
| **ENTERING DIMENSIONS** | | | | |
| | 3.00 | | Cube | |
| | 2.00 | | | |
| | 4.00 | | | |
| | | 24.00 | | |
| | 3.00 | | Superficial | |
| | 2.00 | | | |
| | | 6.00 | | |
| | 3.00 | | Linear | |
| | | 3.00 | | |
| | 4 | | Number | |
| | Item | | Item | |

## Item descriptions and side casts

| X-ing | Dims | Squaring | Description | Sidecast |
|---|---|---|---|---|
| **DIMENSION SHEET** | | | | |
| | 162.95 | | Half brick thick facings (P.C. £900/1000); cement mortar (1:4); in skin of hollow wall; pointed one side | Centre line |
| | 4.66 | | | 2/49.60    99.200 |
| | | 759.36 | | 2/32.10    64.200 |
| | | | | 163.400 |
| | | | | less 4/.112    0.448 |
| | | | | 162.952 |

Causeway TOA8 – Project: 111 (SMM7)

File  Settings  Descriptions  Measurement  Locate  Options  Anding On  Edit  Help

Measurements and Descriptions for 111  Dim File BBB - Superstructure (Bill Order)

Dim Sheet  000001                                    Factor: 1.000                    Side Calc  Code

Times    Dimension    Result         Signpost                        E  MASONRY
         162.952                                     (A1)             F10 BRICK/BLOCK WALLING
           4.660
         ==========   759.366         centre line

SideCalc & Signpost

SideCalc:
Variables:            Functions:            Verify
(A1)      A1   centre line

Sidecalc Variables      Save as a New Variable
(A1)

Signpost:
centre line

**Table 3.2**  Times-ing.

| 'Traditional' times-ing | | | | | On-screen version |
|---|---|---|---|---|---|



**Table 3.3**  Dotting-on.

**Dotting-on**



Dotting-on is a means of adding two or more times-ings together in order to multiply a set of dimensions by the factor desired

In the above example, it can be seen that the dimensions $3.00 \times 2.00 \times 4.00 = 24$ are multiplied by 8 ($=5+3$ or 5 dot-on 3) giving a total of 192

Dotting-on to a times-ing on-screen:

- $2 + $ (or dot-on) $2 \times 5 = 20$
- $20 \times 12 \times 0.35 \times 0.5 = 42.00$

**Table 3.4**  Incorrect dimensions.

| X-ing | Dims | Squaring | Description | Side cast |
|---|---|---|---|---|
| ALTERATIONS | | | | |
| 15 | 3.00 2.00 4.00 | 360.00 | | |

Whilst there is undoubtedly still a role for traditional taking-off using dimension paper, or site 'dim books', measurement has moved on significantly since the 1980s, and computer soft-ware for measurement now plays a significant role in the quantity surveyor's work.

However, there are occasions when written down dimensions are preferable to computer-generated dims, physical measurement on-site being a prime example. It is also

**Table 3.5**   Grouping and anding-on dimensions.

| X-ing | Dims | Squaring | Description | Sidecast |
|---|---|---|---|---|
| | GROUPING DIMENSIONS | | | |
| | 12.00 | | | |
| | 9.00 | | | |
| | 4.50 | 486.00 | | |
| | 10.00 | | | |
| | 4.80 | | | |
| | 3.20 | 153.60 | | |
| | | 639.60 | | |
| 2 | −3.00 | | | |
| | −1.50 | | | |
| | −1.00 | −9.00 | | |
| | | 630.60 | | |
| | ANDING ON | | | |
| | | | & | |
| | | 621.60 | | |

probable that many small subcontractors prefer to write dimensions down as they feel that they cannot justify the expense of measurement software or the time to learn how to use it (they would be wrong on both counts!).

Nonetheless, the decline in the use of formal bills of quantities and the increased use of drawings and specification procurement are key drivers for investing in some sort of software in order to ensure that quantities can be taken off quickly and efficiency in order to meet the demands of the tendering process.

Top-end measurement packages are admittedly pricey, but some software systems such as QSPro are very reasonably priced. Microsoft Excel© offers a 'cheap and cheerful' alternative, but a great deal of repetitive typing and entering of formulae is necessary. This is not 'smart' for significant measurement tasks.

### 3.1.2   Cut and shuffle

'Cut and shuffle' was developed in the early 1960s and, by the 1970s, was perhaps the most popular and widely used method of bill production in QS practices. It was a form of pre-computer age 'automation' for the take-off and billing process. In common with the 'traditional' method of taking-off, there is no empirical evidence that cut and shuffle is still used to any great extent, but, equally, there is no reason why it shouldn't be.

Unlike the traditional method, there is no standardised paper or rulings for the cut and shuffle system, and according to Spain (1995), some professional offices even used different sorts of paper for different purposes.

The system uses a specially coated or 'sensitised' two-sheet paper that produces a copy of the dimensions which are then 'squared' and totalled. At this stage, the 'top' copy of the take-off is 'cut' (some QSs used specially perforated paper) and 'shuffled' into BQ order. All sheets of the same item are pinned together and brought to a total for billing. The 'bottom' copy is filed.

Cut and shuffle pages are laid out in A4 landscape and are split into four or five sections, each section representing a dimension page. Each cut and shuffle 'parent slip' contains only one item description, and any subsequent 'children' slips or pages contain only dimensions or side-cast calculations relating to that item. All pages are numerated and referenced back to the 'parent' item containing the item description. Once the slips are in BQ order, further slips may be introduced for headings, collections and summary pages as necessary.

The principal characteristics of cut and shuffle are:

- It is supposedly quicker than the 'traditional' method.
- It avoids separate abstracting and billing.
- Descriptions are written only once.
- Mistakes are avoided because there is no need to transfer squared dimensions to an abstract sheet.
- Taking-off may well be more time consuming due to the need for extensive referencing of the slips.
- The system is seemingly less useful for post-contract control purposes as measured items have to be searched for in all the take-off slips.

### 3.1.3  Direct billing

Direct billing is a neat and practical alternative to the traditional 'take-off, abstract and bill' system where dimensions, waste calculations, item descriptions, quantities and pricing columns are provided on the same page.

The system is particularly useful for contractors and subcontractors who simply require an 'internal' quantity take-off and pricing arrangement that is not intended for publication as a formal tender document.

Depending on the size and complexity of the project in question, direct billing can have a number of disadvantages:

- There is no means of collecting dimensions for similar items together unless like items are measured at the same time.
- Deductions for openings must be taken with the relevant item which can result in a great deal of repetition, for example:
  - Deductions for doors and windows must be taken with the appropriate masonry, plastering and painting items and cannot be 'anded-on'.
- The eventual bill of quantities can be 'bitty' because like items are not kept together as a consequence of not measuring in a strict 'take-off list' order.
- The direct bill of quantities will be much longer and bulkier than a traditional paper-based BQ.

Direct billing is particularly advantageous for taking off quantities for 'composite' items in bills of quantities, for example:

- Excavations where earthwork support and working space is included in the item coverage.
- Concreting items where formwork and reinforcement items are not measured separately.
- Underground drainage for manholes and gullies.

The modern equivalent of 'direct billing' is direct-entry or on-screen measurement software, but the big advantage of the software is that like items can be collected together and a professional-looking bill of quantities can be printed.

### 3.1.4   Item descriptions

Most standard textbooks on measurement rely on 2D paper drawings and traditional dimension paper in order to illustrate the basic principles of measurement, and it is probable that most quantity surveyors learn this way. It is a good way to develop an understanding of QS conventions and to gain confidence and the ability to 'read' drawings – presupposing, of course, a sound knowledge of construction technology and a basic grounding in arithmetic and geometry.

Perhaps the most difficult aspect of measurement is developing the ability to write clear item descriptions, and this is confirmed by Lee et al. (2014) who explain the need for long experience and the ability to write clearly yet briefly so as to avoid verbose and misleading descriptions.

The item description is the key to helping the contractor's estimator to understand the measured item and to subsequently price the item accurately and competitively. In the absence of a clear and precise description, there will always be a doubt as to the true meaning of the work described, and it is likely that each competing contractor will interpret the item in a different way. This leads to inconsistency in pricing, tenders that are not 'like for like' and the potential for arguments and claims once the project gets underway.

### 3.1.5   Standard phraseology

Of considerable help with regard to writing BQ item descriptions was the publication in 1965 of the Fletcher–Moore (Fletcher and Moore, 1965) system of standard phraseology. The system consisted of paper-based reference manuals which were referred to by the QS in order to build up suitable item descriptions. Effectively, the Fletcher–Moore library was a database of item descriptions taken from the prevailing standard method of measurement.

Some estimators at the time felt that the Fletcher–Moore item descriptions were somewhat 'clipped' in that they were very brief and lacked the personality of item descriptions phrased by experienced quantity surveyors, who had the skill to both comply with the rules of the standard method of measurement and to add nuances of information that helped the estimator to price the job.

### 3.1.6   2D paper-based drawings

There are two ways of producing quantities using measurement software in conjunction with paper-based drawings:

- Using figured dimensions or by scaling from the drawings using a traditional scale rule.
- Using a digitiser or graphics tablet which enables data to be captured electronically:
  - By tracing lines manually.
  - By plotting the corners of linear polylines[1] or shapes.

### 3.1.7   Figured dimensions/scaling

Using dimensions shown on the drawings is the traditional way of taking dimensions for quantities; it is still used in the industry and perhaps will always have a role to play especially for small take-offs, or where the quantities required are simple, or for measuring variations.

The main problem with this method is that drawings are never fully dimensioned and therefore some scaling is inevitable. When dimensions have to be scaled, accuracy is always questionable, and even when drawings are full scale (i.e. not reduced or photocopied), there are always inaccuracies built in by the drawing reproduction/printing process, and there is always a bit of

guesswork involved when using a scale rule. Straight lines are not so bad, but curves represent a degree of difficulty both in scaling and with regard to accuracy.

A further issue that often crops up is that figured dimensions can sometimes be stated incorrectly (yes, even architects and engineers make mistakes!), and an overall total figured dimension may not equate to the figured dimensions that make it up.

Anecdotal evidence would suggest that there is a certain degree of indiscipline amongst practitioners when using paper-based taking-off. Non-QS-trained personnel invariably write down dimensions horizontally on non-QS paper, as opposed to vertically on dimension paper as a QS would; the dimensions are usually haphazardly organised with no audit trail as to where dimensions have come from or how a composite measurement (such as a centre line girth) has been calculated.

This leads to problems of clarity, accuracy and difficulties (often some time later) when dimensions have to be referred to (e.g. where there has been a variation or where the work has to be remeasured). Happily, using measurement software helps to overcome some of these problems.

### 3.1.8   Digitised measurement

Digitising tablets may be corded or uncorded, and they come in a variety of sizes; some are solid stand-alone work stations (like an architect's drawing board on a stand), some are solid but smaller for use on the desktop, and some are of the 'roll-up' variety for better portability. The data is digitised using either a stylus (a bit like a pen) or a puck; this is like a computer mouse but with an optical viewer and for precise targeting of points on the drawing.

**Useful Website**
http://www.visualprecision.co.uk
Measurement by digitiser has certain advantages compared to using traditional scale rules:

- Data capture is quicker and more 'fun'.
- Accuracy is significantly better.
- Drawings that have been reduced or are otherwise not to scale can be accommodated.
- Photocopied drawings can also be measured accurately.

Out of scale drawings can be measured by simply calibrating the drawing. This is done by clicking on the end points of a line of known dimension (it could be a figured dimension on the drawing or the scale indicator itself), and the software will work out the scale automatically.

Telling the software that a particular line represents (say) 10.34 m enables it to calibrate the scale of the drawing which is then applied to other digitised lines. It is a good idea to calibrate two lines as a double check.

## 3.2   Modern conventions

Modern quantity surveying conventions, whilst respecting their traditional heritage, are very much determined by the computer software that many quantity surveyors now use. Dimension entry, side casts and other protocols are still part of the quantity surveyor's work, but they may be done differently due to the way that the software is designed and operated. Different ways of working are now necessary too, as QSs frequently work in a variety of media such as 2D and 3D CAD, PDF files, 3D models and BIM models.

Ashworth (2010) notes that computers were first used for processing bills of quantities back in the 1960s, but the computers and associated software were a far cry from their modern-day

equivalents. Masterbill Micro Systems Ltd claim to have developed the world's first bill production software for the personal computer in 1981, and now their Masterbill Elite© and Masterbill QSCad© are widely recognised as two of the leading software packages available.

There are, however, a number of well-known – and some not so well-known – software packages available to the quantity surveyor or subcontractor, with origins both in the United Kingdom and in other countries. The QS software used in this book is CATO and QSPro from the United Kingdom and the excellent Australian product, Buildsoft Cubit.

Computer-based measurement systems have taken the Fletcher–Moore idea of a library or database of standard item descriptions to a new level, so much so that some of the measurement software packages available provide several databases within the same software package. Consequently, some software houses provide a CESMM3/4, MMHW4 database as well as SMM7/NRM/ARM4 which enables users to switch database seamlessly according to whether the project is building, civil engineering or highway work.

### 3.2.1   Measurement software

There are basically three types of measurement software packages:

- SMM-based packages.
- Non-SMM-based packages.
- Hybrid packages.

#### SMM-based packages

SMM-based packages rely on a database of item descriptions for building up complete bills of quantities. Some software systems include a number of databases in the software package that can be accessed depending upon the type of work being measured.

Common SMM databases include:

*United Kingdom*
- The RICS New Rules of Measurement – NRM2.
- The Civil Engineering Standard Method of Measurement – CESMM4.
- The Method of Measurement for Highway Works – MMHW4.

*Republic of Ireland*
- The Agreed Rules of Measurement – ARM4.

*Australia*
- Australian Standard Method of Measurement of Building Works 5th Edition.

*Republic of South Africa*
- Standard System of Measuring Building Work 6th Edition.
- The Civil Engineering Standard Method of Measurement (South African Edition) – CESMM3.

*International*
- Principles of Measurement (International) – POM(I).

Examples of SMM-based software are Causeway CATO Take-Off and Bills, QSPro for Windows and Vector by Snape Software. Each of these has extensive libraries of a variety of standard methods of measurement including SMM7, NRM1 and 2, CESMM and MMHW, etc. CATO and Vector also have the POM(I) library.

All SMM-based software works in much the same way by selecting item descriptions from the library and then entering dimensions, either manually or from digital drawings. The features that distinguish software packages one from another – flexibility, multiple sorting capability,
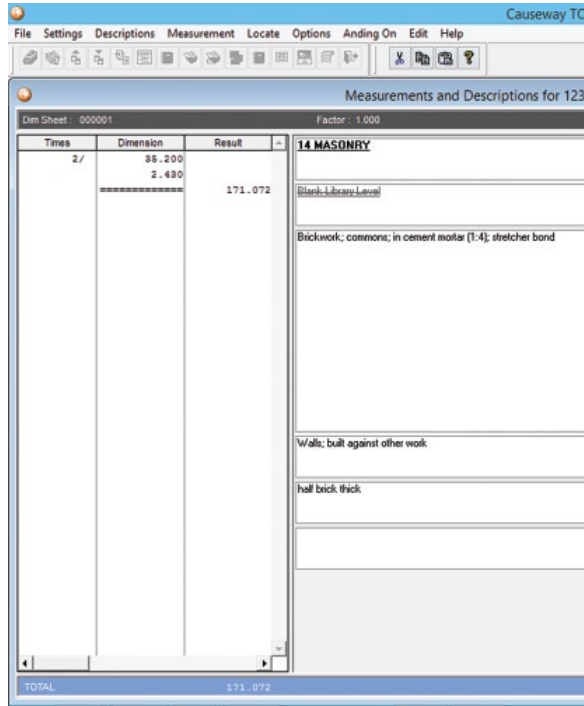
**Figure 3.1**    CATO dim sheets.

ease of use, library availability, estimating and cost planning facility, report functionality, afford-ability, etc. – must be assessed by the individual user.

CATO is based on a system of traditional 'dim sheets' which the user may group together conveniently (e.g. into elements such as substructure, superstructure, finishes and so on). Item descriptions are chosen from the library, edited as necessary, and dimensions are entered into the dim sheet as illustrated in Figure 3.1.

This is a comparable system to traditional quantity take-off on dimension paper.

QSPro similarly relies on a comprehensive library of item descriptions, but this is accessed differently than CATO.

As illustrated in Figure 3.2, the window for building the item descriptions is split, with the library in the lower pane (NRM2) and the item description above. Quantities are entered directly into the quantity 'box' or built up, with side casts and 'anding-on' if required, in a sepa-rate window as shown.

QSPro is flexible enough to offer two-dimensional layouts, a horizontal display as illustrated in Figure 3.2 and the traditional vertical method as shown in Figure 3.3.

### Non-SMM-based packages

Non-SMM-based packages, such as Buildsoft Cubit, require item descriptions to be developed by the compiler.

Buildsoft Cubit enables bills, or schedules, of quantities to be produced, either for a single trade or for an entire project. This may be done:

- From scratch.
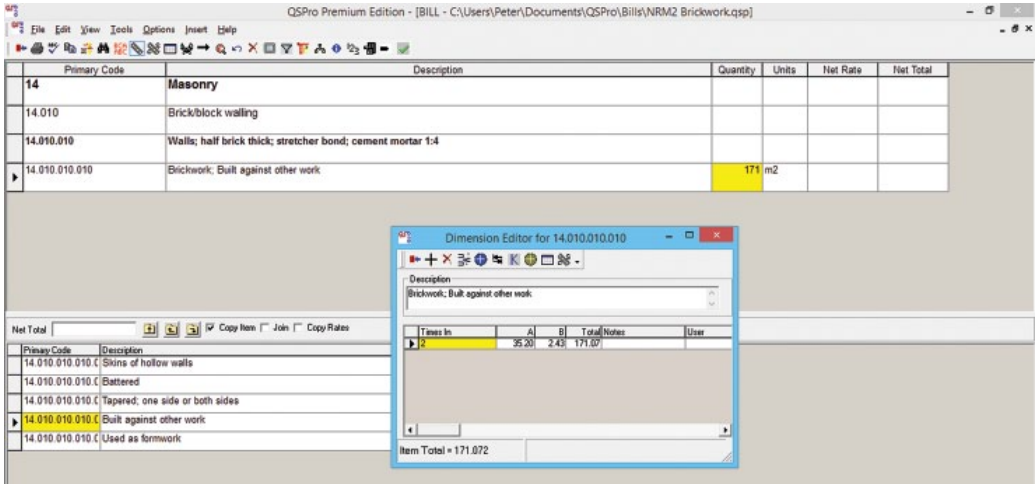- From a previous project imported into the current project.
- From a 'template'.

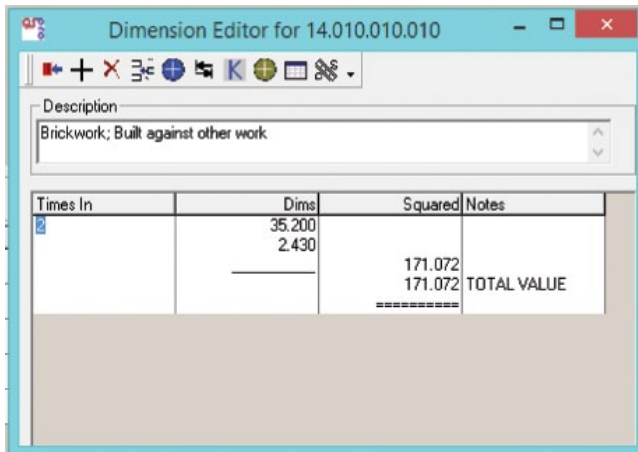Part 1



**Figure 3.2**   QSPro dim sheet.



**Figure 3.3**   QSPro – vertical dimensions.

Templates may be developed very easily in Buildsoft Cubit by nominating a previous project and naming it as a 'template'. The software saves the item descriptions, units and all the formatting but does not save quantities or the drawings that the quantities were based on. The template is then ready to work on in the new project.

Projects are split up into 'jobs' which is where the quantities for individual parts of a project reside. 'Jobs' are user defined which can be elemental, work section, trade or any other classification.

Quantities are entered either manually or by on-screen measurement in Buildsoft Cubit, and on-screen take-off is aided by a 2D to 3D toggle which enable walls, columns, beams, etc. to be viewed in three dimensions rather than simply on plan. This is especially useful in that deductions for doors and windows can be clearly seen and walls of different heights and configurations can be viewed in perspective.

Items are created in the left-hand 'estimate' sheet, with the detailed calculations, including deductions, that make up the quantities being performed in the lower left 'calculation' sheet.
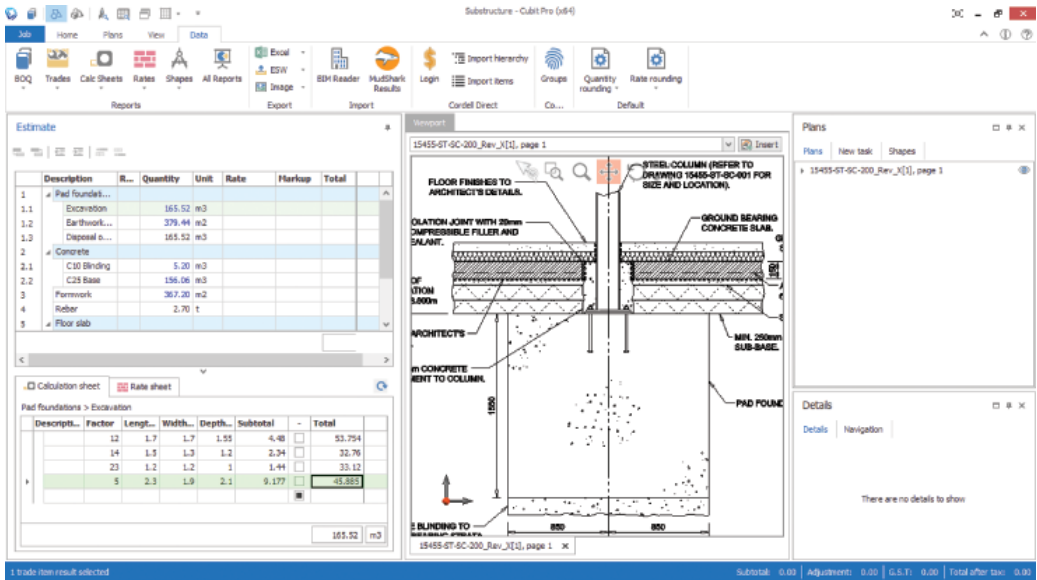
**Figure 3.4**   Buildsoft Cubit.

| | Description | R... | Quantity | Unit | Rate | Markup | Total |
|---|---|---|---|---|---|---|---|
| 1 | Pad foundations | | | | | | |
| 1.1 | Excavation | | 165.52 | m3 | | | |
| 1.2 | Earthwork support | | 379.44 | m2 | | | |
| 1.3 | Disposal off site | | 165.52 | m3 | | | |
| 2 | Concrete | | | | | | |
| 2.1 | C10 Blinding | | 5.20 | m3 | | | |
| 2.2 | C25 Base | | 156.06 | m3 | | | |
| 3 | Formwork | | 367.20 | m2 | | | |
| 4 | Rebar | | 2.70 | t | | | |
| 5 | Floor slab | | | | | | |
| 5.1 | Sub-base | | 148.50 | m3 | | | |
| 5.2 | Sand blinding | | 29.70 | m3 | | | |
| 5.3 | A193 Mesh | | 594.00 | m2 | | | |
| 5.4 | C30 Concrete slab | | 118.80 | m3 | | | |

**Figure 3.5**   Buildsoft Cubit hierarchy.

Drawings are imported into the central 'Viewport', and it is in this pane that on-screen measurement is performed. To do this, an item is created, a unit is chosen, and the drawing is then measured by mouse clicking from point to point.

Some of the functionality of Buildsoft Cubit is illustrated in Figure 3.4.

In Figure 3.5, it can be seen that Buildsoft Cubit can easily produce a hierarchical schedule of quantities with non-SMM-based item descriptions which can then be printed as a trade report, or bill of quantities, within Cubit or exported to MS Excel.

Other non-SMM-based measurement software includes Autodesk Quantity Take-off, Exactal CostX, Swiftplan and Trimble VICO.

### Hybrid packages

Some software packages offer the best of both worlds – a choice of SMM-based standard libraries and the option to create bespoke libraries. The latter might be based loosely on a specific standard method of measurement, or the item descriptions might be drafted 'in-house'.

For example, at the time of writing (November 2014), the additional functionality of an NRM2 Library is in its latter stages of development which will effectively make Buildsoft Cubit a 'hybrid' software package.

This is an important development because the addition of a standard library of descriptions to an essentially non-SMM-based package is attractive. Some QS practices use two software packages – one SMM based and the other not, as it is then possible to measure and bill items that do not appear in the standard libraries, such as partial contractor design elements and provisional sums that would normally have to be word processed.

Use of non-SMM-based software for BQ preparation is a matter of risk perception.

When a standard method of measurement is used, everyone understands (or should understand):

- What is to be included in the rate for an item and what is not.
- The balance of risk in the employer–contractor or contractor–subcontractor relationship.
- The legal situation should there be a deviation from the SMM (e.g. as regards unfair contract terms).

This is not the case with bills of quantities containing non-SMM item descriptions, and this can lead to difficulties, even disputes, about what is included and excluded from the item coverage.

However, there can also be significant advantages in using non-SMM item descriptions:

- Item descriptions can be kept brief.
- A bill of quantities can be produced quickly.
- Less attention need be paid to measuring minor items.
- Any configuration of BQ/schedule is possible.
- Activity schedules, price lists and contract sum analyses can be produced.
- The estimator can price the tender far quicker provided the item coverage is clearly understood.

### Microsoft excel

Strictly speaking, Excel is not a type of measurement software, but, to all intents and purposes, it can be classified as such because of its widespread use for measurement and related tasks particularly by site-based quantity surveyors and measurement engineers.

The big disadvantage of Excel compared with library-based software is that there is no database of standard descriptions readily available. This can be developed 'in-house', but a great deal of time and effort is required to set up the database in the first instance. Another difficulty with Excel is that each calculation requires an individual formula, whereas measurement software packages perform all calculations automatically.

Remembering that there are a number of standard methods of measurement for different types of construction work, Excel can only realistically be used for creating builders' quantities for individual projects where the number of item descriptions is limited or for subcontracts or for site remeasures and for the measurement of variations and extra work.

A major advantage of Excel is that some measurement software packages, and 2D and 3D CAD systems, can link directly to Excel enabling quantities to be automatically generated. As most subcontractors will not own a specialist measurement package, this enables bills of quantities/schedules to be prepared for trade and subcontract enquiries, and exported electronically, in a language that most businesses have on their desktop. An Excel export from QSPro is shown in Figure 3.6 where it can be seen that the full formatting of the bill of quantities is retained within the Excel spreadsheet environment. The full functionality of Excel is also retained.

**Figure 3.6**   QSPro export to MS Excel.

## 3.2.2   Electronic communications

It is now commonplace in the construction industry for drawings to be transmitted electronically. This can be done is several ways:

- PDF.
- Web interface, for example, Eleco BIMCloud.
- Online file-transferring platform, for example, WeTransfer Plus.
- File hosting service, cloud storage service and online file storage provider, for example, Dropbox Business.
- Web-based portals such as DocElite, which have access restricted by user name and password.

Whether communicating between design team members, or to contractors or by main contractors to subcontractors, drawings frequently arrive by email attachment for review, measurement, tendering or subcontract quotations. The days of a pile of folded paper drawings in a brown envelope landing on the door mat are pretty well over!

Most people working in construction, however, are used to reading paper-based drawings and, therefore, the temptation when receiving drawings that have been produced electronically is to print off a hard copy.

This may well be fine for some purposes but can be problematic from a measurement perspective. The paper printout from a desktop printer is unlikely to be to a true scale, and frequently printouts are A4 or A3 at best and are too small to read comfortably.

Even with the time and expense of a true to scale printout, the paper drawings so produced will not be completely reliable due to processing inaccuracies. More importantly, printing a hard copy will limit the extent to which measurement software can be used unless it is intended to measure using a digitiser. The whole point about electronic drawings is to make the most of the speed, accuracy and efficiency of computerised taking-off.

Quantities can be extracted from Vector or Raster plans and drawings.

Raster plans are single-layer, flattened images such as PDF, JPG, BMP, PNG and TIFF. They require a drawn scale and pixelate when zoomed in. This may be contrasted with Vector plans which possess 'layer' data and more accurate lines for taking-off. The 'layer' data in Vector plans includes outlines, walls, room names and text which can be selected with suitable software, such as Exactal CostX, Buildsoft Cubit, CATO and Snape Vector, and used to create schedules or bills of quantities. Layer data can be turned off or on.

Whether taking-off quantities using measurement software or manually, the starting point for all measurement is the information provided by the designer in the shape of project drawings, schedules and standard details.

This design information forms the basis of the eventual bills of quantities which depends for its completeness on the stage that has been reached in the development of the design. Irrespective as to who receives this information – be it PQS, contractor or subcontractor – the information may arrive in several forms, including 2D paper-based drawings, as described in Section 3.1.6. Modern convention, however, is to transmit design information electronically, either with drawings or digital images.

### 3.2.3   2D or 3D CAD drawings

Electronically produced drawings and other documents may arrive in one or more file formats which are signified by the file ending. Just as a Microsoft Word document may have a file ending of (*.doc) or (*.docx), for example, so a CAD drawing file will have its own file ending. There are lots of file types used in computer-aided design and for document exchange, but some of the most commonly encountered ones are:

- *.dwg – **DraWinG**
- *.dgn – **DesiGN**
- *.dwf – **D**esign **W**eb **F**ormat
- *.dxf – **D**rawing e**X**change **F**ormat
- *.pdf – **P**ortable **D**ocument **F**ormat

#### DWG files

*.dwg is an intelligent file source and is the native format for several CAD packages. Autodesk products, such as AutoCAD and Autodesk Revit, use DWG files for storing 2D and 3D design data, and it is reputedly the most popular file format for CAD drawings. Plans with *.dwg file endings are Vector plans.

DWG technology facilitates a variety of methods for navigating around drawings including zooming in/out and panning and also enables 'layers' of the drawing to be turned on/off. This is a great feature for measurement because the complexities of reading a paper-based drawing can be overcome by selecting a particular layer to view (e.g. partitions, windows, plumbing appliances). As well as a variety of design and annotation capabilities, DWG files facilitate simple measurement.

The DWG file format is the native format for some other CAD packages as well, such as IntelliCAD and Caddie, and DWG files are also supported non-natively by other CAD applications.

**Useful Website**
http://www.autodesk.co.uk/

### DGN files

DGN is the native CAD file format supported by Bentley Systems. Bentley CAD software products, such as MicroStation, are used on a wide variety of construction projects for both 2D and 3D design and drafting. The DGN file format is not as widely used as the DWG format preferred by Autodesk.

DGN files display similar functionality to DWG files.

### DWF files

The DWF file format was developed by Autodesk to facilitate the exchange of data-rich design files between design team members in order that they may be viewed, reviewed or printed. The highly compressed nature of DWF files means that they are smaller and faster to transmit than design files, and, because of their functionality, they can be used to transmit complex CAD drawings in a single file as well as 3D models from most Autodesk Design applications.

DWF files are not intended to replace AutoCAD drawings (DWG) or other native CAD formats but may be converted into DWG files with a suitable DWF–DWG converter. Files other than Autodesk Design Web Format files may use the DWF file extension.

### DXF files

DXF is a CAD data file format, developed by Autodesk, which facilitates data transfer (interoperability) between AutoCAD and other software programs. AutoCAD and some other CAD software programs are capable of creating, opening and editing DWF files. The Autodesk Design Review program can view, print and mark up DWF files. Files with *.dxf endings contain Vector plans that have the capability of 'layer' access that can be readily enabled/disabled.

### PDF files

Drawings are frequently transmitted in the PDF file format – especially to contractors and subcontractors for tendering purpose – as the files are easy to open. PDF files – both drawings and other documents – do not rely on specific application software, computer operating systems or computer hardware. All that is required to view a PDF file is a suitable 'reader' such as Adobe Acrobat Reader or Nitro PDF Reader which are available online as free downloads.

PDF is the most commonly used file type. They can be flat Raster plans (i.e. a scanned image) or a smart layered Vector plan produced from CAD. Unlike CAD plans, which have the correct scale embedded in the file, PDF plans need to be scaled because they can be up to 3% out of scale. This can be simply overcome by calibrating the drawing as described in Section 3.2.6.

### 3.2.4    Digital images

Images taken with a digital camera, or mobile phone, can be measured using appropriate software such as PhotoModeler.

The software extracts 3D measurements and models from photographs taken with an ordinary camera and can produce accurate lengths, areas, volumes and cross sections from almost any photograph.
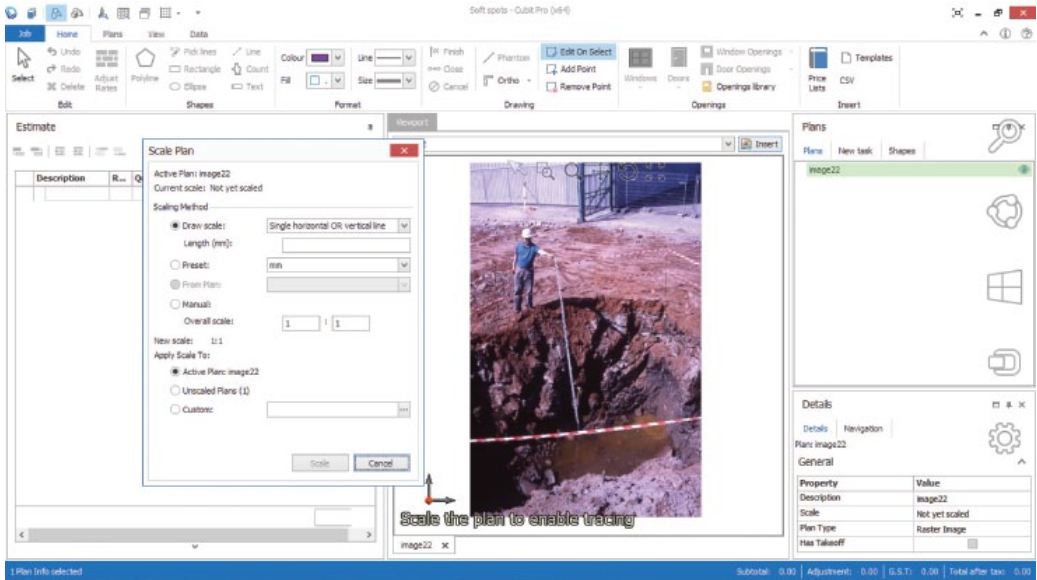
**Figure 3.7**    Scaling soft spot excavation.

Measurement may also be done from image files using proprietary measurement software such CATO or Buildsoft Cubit.

The image must be in a file type that the software can read, and there must be a dimension, or an object representing a dimension (e.g. measuring staff) in the image, which is capable of being scaled.

Figures 3.7 and 3.8 show Buildsoft Cubit goes about the measurement of a soft spot from a site photograph.

A JPEG image is first imported into the Viewport, and the software asks for the image to be scaled (see Figure 3.7). Note the measuring staff acting as the scale.

The excavation can then be measured on-screen using the polyline tool, and a volume for the item is calculated in the Estimate window as shown in Figure 3.8.

### 3.2.5    Viewing electronic files

Appropriate software is needed to be able to read electronic files, but it is not necessary to have a CAD package on your computer to be able to view CAD files.

Bentley Systems offer a free viewer download called Bentley View into which a variety of file formats can be imported and then viewed. A large number of file formats are supported by the viewer including DGN, DWG and DXF, but PDF is not a recognised format.

**Useful Website**
http://www.bentley.com/bentleyview

Alternatively, Autodesk's AutoCAD® WS is a free cloud-based web and mobile app that facilitates viewing, editing and sharing DWG files. The software works in a web browser or on a smart phone or other mobile device. AutoCAD® WS converts to PDF and DWF and allows DWG, DWF and DXF files to be opened directly from an email.
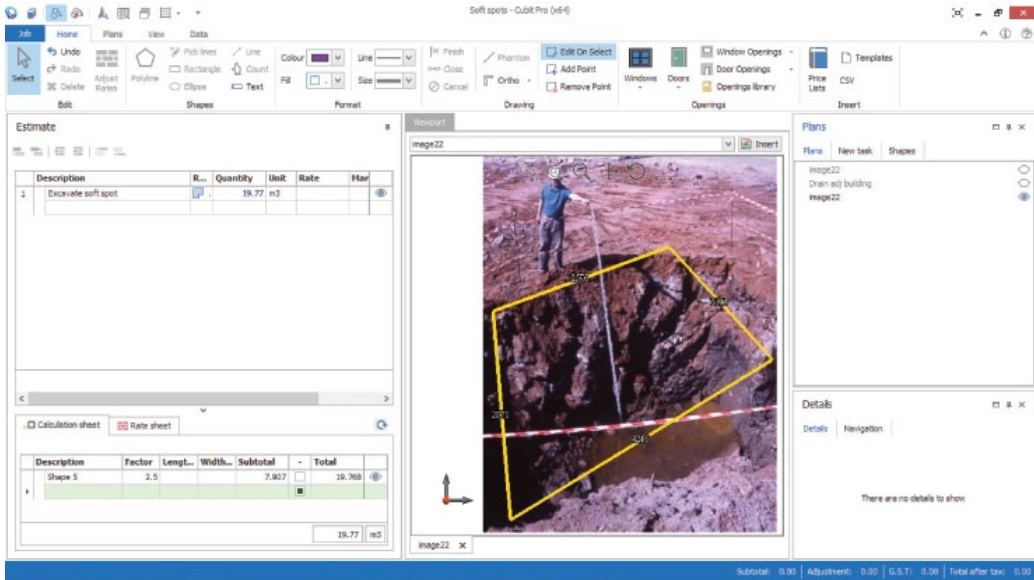
**Useful Website**
https://www.autocadws.com/web

**Figure 3.8**    Calculating the soft spot volume.

Autodesk® DWG TrueView™ is a free file viewing and conversion software that enables DWG and DXF files to be opened as they would be in AutoCAD. Also from Autodesk, the free Autodesk® Design Review software download enables DWG files to be opened, viewed and printed, and changes to Autodesk 2D and 3D design files can also be tracked. All this is possible without the original design software.

**Useful Website**
http://www.autodesk.co.uk/designreview

If you have access to measurement software, it is important to verify which file types the software package is capable of reading in order to be able to access the drawing or other information. Should the software be unable to read certain file types, it is possible to download a file converter from the Internet. File converters can convert several file types including:

- DWG files to DXF or DWF
- DWG files to PDF
- PDF to DXF
- DWG files to an image file such as JPG/TIF/BMP

Acquiring a file converter may necessitate a purchase, but some file converter software is available on a free trial.

**Useful Websites**
http://www.autodwg.com/
http://www.teklabimsight.com/

### 3.2.6   Calibrating electronic drawings

CAD files may be imported into on-screen measurement software without calibration, but good practice suggests that they should, nevertheless, be checked before taking off quantities. Care has to be taken with PDF drawings, however, to make sure that the scale is true and any measurements taken will be accurate. To do this:
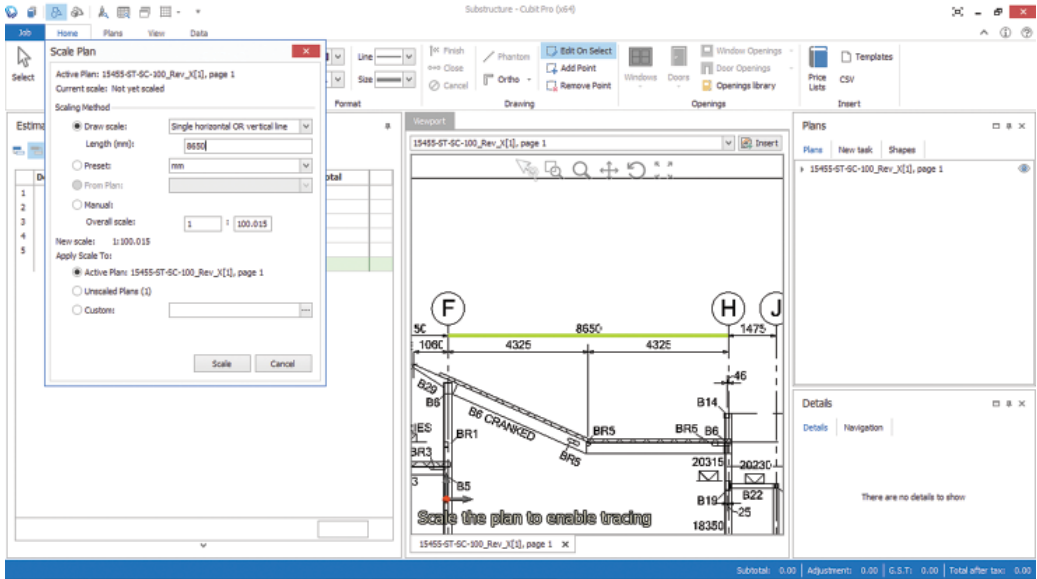
**Figure 3.9**    Calibrating PDF in Buildsoft Cubit.

1. Open the file in the measurement software.
2. On the horizontal x-axis, click on each end of a line with a known dimension.
3. Type the dimension into the pop-up box.
4. Press the 'enter' key.
5. The drawing is now calibrated.
6. Repeat the process on the y-axis as a double check.

Good practice when calibrating the scale of a drawing is to use the largest known line on the drawing and then to check another known length. Calibration is a common process with all on-screen measurement packages, and this is illustrated in Figure 3.9 using Buildsoft Cubit.

## 3.3  BIM conventions

BIM models are a completely different proposition compared to 2D and 3D CAD. CAD drawings are based on lines and polylines, whereas BIM models consist of parametric objects that carry technical, geometric and other data. BIM models are 'intelligent', whereas CAD drawings are 'dumb' in the sense that the lines that make them up do not carry any such data.

Consequently, the components in a BIM model may (but not always) possess measurement data that can be extracted and imported into a variety of software packages for quantity take-off, estimating and project management purposes. Take-offs, counts and measurements can be generated directly from the underlying model.

However, the nature and content of BIM models is different to 2D and 3D CAD, and their use requires a different mindset and different protocols compared with traditional quantity surveying conventions or their modern interpretations to date. The quantity surveyor's workflow is different to that demanded by traditional or even modern conventions, because it is the model that generates the quantities and not the quantity surveyor.

This doesn't mean that the quantity surveyor is redundant in the 'BIM-space' environment – far from it – it just means that the same analytical and critical skills, allied to professional judgement,

knowledge of construction processes and procurement methods and the ability to ferret out detail, must be applied in a different way.

### 3.3.1   BIM models

BIM is object-based modelling where designs are derived by selecting objects from a library, as opposed to drawing lines. A window, for example, is a component that will have its own properties, but it also understands and can interact with other components in the model. This means that a window can be introduced into an external wall, and the wall object reacts by creating a suitable opening.

The properties possessed by the objects in a model may include quantities that can be extracted very quickly and may then be imported into measurement or estimating software for manipulation as required. This data can be used for a variety of purposes, including cost planning and detailed estimating, using the dimensions associated with the various object types contained within the design model.

This sounds like a perfect world for designers where quantity surveyors are no longer needed and bills or schedules of quantities may be obtained from the model at the push of a button. This can be done, but the problem is that the quantities will not be in an intelligible form, and they will invariably be wrong. The cryptic descriptions attached to model components are often not clear, and this makes it difficult to identify just what particular components are.

Additionally, the quantities generated from models will not be complete because BIM models do not model everything. A door may be modelled, but the architraves and door stops won't be.

### 3.3.2   BIM quantities

Quantities can be extracted from BIM models – they are embedded in the various components or objects that make up the model. However, unless a designer understands the quantity surveyor's way of thinking, inaccuracies can be quickly accumulated because, for instance, Revit default settings are set to zero decimal places, and considerable rounding errors could occur on a large contract. IFC files do not generate quantities by default, and this has to be accommodated by checking the 'include base quantities' box.

Models can also be used to derive quantities. In this case, model components, such as reinforced concrete columns, can be used to calculate the quantities of associated items that are not modelled, such as formwork and rebar.

Other quantities may have to be generated from 2D representations of the model. Therefore, expansion joints in a concrete floor slab will have to be measured by scaling from paper printouts or by on-screen measurement once their positioning and specification have been determined.

The quantity surveyor's skill is expressed by following traditional conventions in a modern context, and the 'art' of the profession is in validating the content of the model to establish what has been modelled and what has not.

### 3.3.3   Quantity extraction

Because reliable quantities cannot be generated automatically by BIM models, quantities have to be extracted using a suitable tool so that the data can then be manipulated as required. Software such as CATO, Buildsoft Cubit and Exactal CostX can do this, but it is only feasible to import the data into a spreadsheet-type workbook or Excel file. These are non-SMM-based media, and, therefore, further manipulation is needed to import the data into a BQ production package.
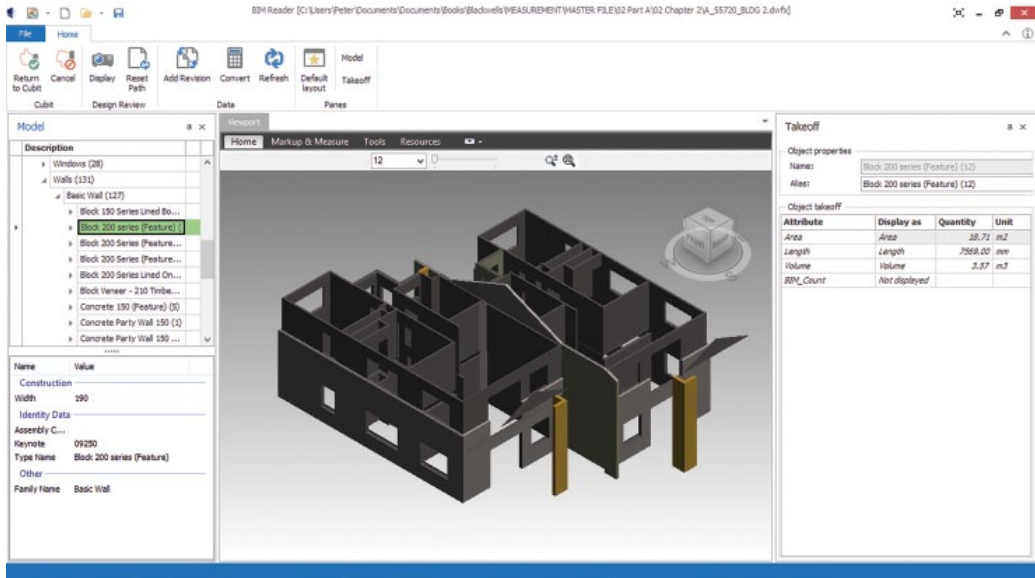
**Figure 3.10**   BIM component 'standouts'. Reproduced by kind permission of Building Software Services (BSS).

Care must be exercised when extracting quantities from a model because objects that appear to be fully detailed may only have reached an early stage of design resolution. Rendered models are impressive, and it is beguiling to imagine that the level of design development is consistent with a fully rendered level of design detail. This is unlikely to be the case in some instances, and the degree of reliability of the quantity data must be established by interrogating the model and talking to designers.

The beauty of BIM models, however, is their transparency. As one architect recounted, "there is no hiding place with BIM", and models can be interrogated to see whether a particular connection, joint, fitting or connecting plate has been designed or not. Designers cannot get away with inserting a 'cloud' to represent an unresolved design issue as they would do on a CAD drawing.

Depending on the software, quantities can be extracted from a model in several ways:

- From the model description window on the left which lists the contents of the model and the number count of each component.
- From the take-off (or properties) window on the right which displays the attributes or properties of the selected component.
- By dragging and dropping component data into an integrated spreadsheet direct from the model on-screen.
- By scheduling quantities in the integrated spreadsheet by dragging and dropping from the properties window.

In Figure 3.10, also from Buildsoft Cubit, the walls have been made to standout by hiding other components – this makes it easier to read the model and extract the desired information. It can be seen that the walls are hierarchically categorised in the model contents window and that 'Block 200 series' walls are displayed in the take-off panel together with the properties of this category of wall. The attributes displayed give the area, length and volume of the 'Block 200 series' walls which can then be extracted to the conventional Cubit take-off via the Return to Cubit menu button (top left).

### 3.3.4   Validation of quantities

Quantity surveyors, contractors and subcontractors, who are used to producing quantities traditionally or using on-screen measurement, need to adopt different protocols or conventions when extracting and using quantities from BIM models.

Of primary concern is to find out what has been modelled and what has not and whether further detail has been added by the designer in 2D or 3D CAD. Several sources of design information need to be looked at in order to get to all the quantities, and 2D drawings may be required to see whether there has been any duplication of quantities in the model because of overlapping components.

It is also important to understand how quantities in a model have been calculated because this will not have been done as a QS would do it. Pipe fittings are objects, and therefore, the quantities given for pipe runs (drainage, plumbing, etc.) are measured from fitting to fitting (there is no convention of 'extra over' in BIM). It may not be clear whether model quantities are given net of deductions for openings or pile caps in ground floor slabs, and there may be some degree of unreliability when it comes to the quantification of irregular areas in models.

Architectural models do not contain all the detail needed to produce a complete bill of quantities, and even structural engineers' models contain only the principal structural elements. Details of fittings and connections would only be derived from the fabricator's model, and thus, a number of different models would have to be interrogated to determine a complete 'picture'.

### 3.3.5   Reading BIM files

BIM modelling platforms are clearly commercial software systems. They come with their own highly developed libraries of parametric objects, and the output files carry native file extensions such as *.RVT (Autodesk Revit) and *.DB1 (Tekla Structures). If you do not possess a legitimate copy of the software, the files cannot be read in their native form.

BIM models can, nevertheless, be 'read' with a variety of free downloadable BIM investigation and review tools such as Autodesk Design Review, Solibri Model Checker and Tekla BIMSight. This software is fine for interrogating models to see what is there and what isn't modelled, but they have little or no capacity to extract quantities.

BIM models can be exported from their original platforms into DWF or DWFx file formats, but these are not native files. They can, nonetheless, be read by some measurement software via an integrated BIM reader. The non-native BIM file is imported into the reader, and the software can extract the desired properties – that is, quantities – from the model. BIM models can also be exported to IFC format which, being non-proprietary, can also be read by BIM Readers.

Figure 3.11 illustrates a DWFx file (BIM model) that has been imported into the Viewport of Buildsoft Cubit BIM Reader. It can be seen that the model has 12 nr columns, 26 nr floors and 5 nr Roofs.

### 3.3.6   BIM model output

It will be observed that the quantities provided by the model illustrated, whilst in recognisable units, are not expressed as a quantity surveyor would express them:

- They are not in SMM format.
- They are not in a loosely framed descriptive language that a contractor would be able to price.

They are, however:

- Presented in a hierarchical breakdown structure.
- Capable of being exported to other software that can add the descriptive and other details that are lacking.
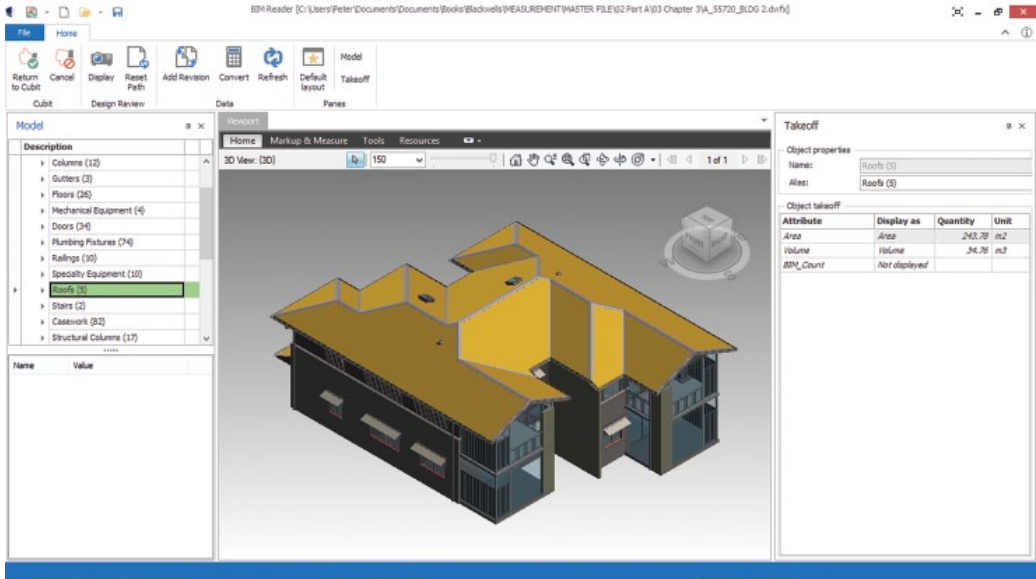
**Figure 3.11**   BIM model. Reproduced by kind permission of Building Software Services (BSS).

BIM quantities must be treated with caution. Where the quantities come from, who created them, how have they been calculated and their accuracy or reliability are doubts that a quantity surveyor may have, until persuaded otherwise.

It is quite clear that 5D BIM is not fully developed at the moment, and there are a number of interoperability and other issues to resolve before it can be considered established practice. There are no agreed rules of measurement as yet, there are no conventions as there are in 'ortho-dox' measurement, and there is no certainty that traditional practice will translate well into the BIM world of construction measurement.

If there is one BIM measurement convention that is paramount, it is the validation of quantities through thorough and meticulous detective work.

## Note

1.   A group of interconnecting lines or curves in two or three dimensions; also called polygonal chain.

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Part 1