Unit 10: Surveying in Construction

Delivery guidance

This unit gives learners a great opportunity to get out of the lecture room and into the field to undertake practical surveying tasks, before then developing their skills in the production of accurate survey drawings. Through the high percentage of fieldwork and drawing in this unit, learners will be engaged by the practical application of the theoretical elements they must master.

Approaching the unit

Practical demonstrations that allow learners to get hands on with surveying equipment will offer the best means of delivery. Learners will also need plenty of opportunity to use the equipment in practice tasks, which will build up their understanding of the booking of information and how to record this correctly.

Accuracy is a skill that learners will develop as they learn to read and interpret measurements. Calculations will need to be presented and demonstrated in class, accompanied by set tasks for learners to test and reinforce their learning with tutor support. Such exercises should always apply to the survey, so learners understand what they are doing in a site engineering and design context.

You will need to source a safe site or location within your country that will offer areas that can be used for linear, levelling and angular surveys. Sloping topography is ideal for such situations, as it adds to the degree of complexity required at this level. You must ensure the location chosen should be free from any hazards or risks associated with undertaking practical surveying activities.

You will find group work essential for the practical fieldwork, due to the nature of the surveys that are to be undertaken. Learners will therefore need to annotate their initials against any measurements they take within group work and evidence of learning can be reinforced by witness or observation records.

Access to a range of surveying equipment – tape measures, ranging poles, automatic levels and theodolites, for example – needs to be considered regarding access, calibration and currency.

Delivering the learning aims

Learning aim A

Learning aim A covers the theoretical knowledge that learners will require before undertaking any practical fieldwork exercises. Learners have to understand the methods used for surveying techniques. This can best be delivered through your demonstration of the theoretical techniques that underpin linear, levelling and angular measurement. Working through these topics in order will allow learners to progressively learn how to correctly read a tape measure, then use a level and finally a theodolite, which may be a less familiar item to them. Learners will require access to a range of surveying equipment and resources. This equipment and resources could be hired in for the duration of the unit.

Many different delivery methods could be used for this – for example, simple classroom-based exercises to explain the methods used for a linear survey; an explanation of the Height of Collimation methods for topographical surveying; and, finally, setting up a theodolite over a coin within the classroom for angular surveying. The methods of booking the survey for each will need to be detailed during these classroom sessions. Simple annotated drawings will explain much of the theoretical knowledge required in this learning aim.

Learners should be encouraged to research instructional videos online – of which there are many. You could also arrange for a site engineer to come as a guest speaker to explain current industry practices. Learners would value this insight, and it may also enable further employer engagement and support such as providing opportunities for site visits for learners to observe site engineering activities.

Learning aim B

Learning aim B is the main practical element of the unit. This is delivered using an appropriate plot of land that will contain enough topography for linear, levelling and traverse surveys. You will need to select this so that all three areas can be accommodated without having to transport equipment too far and without any risk to learners' health and safety.

The first practical is a linear survey. Learners could produce a scaled map of an area that should contain sufficient detail to survey. This detail could be trees, bushes, footpaths, services, kerb edges, buildings and other structures. Placing the survey stations is the key to achieving this so each survey line picks up sufficient detail. There are no systematic checks required on equipment as standard tape measures are used.

Learners will then need to carry out a levelling survey in an area that has a suitable range of topography so differences in levels can be obtained. A slope would be ideal for this so learners could survey down a grid line pegged out for them, then across the slope for a long section.

Learners will be booking levels in the correct position in order to calculate reduced levels accurately, so the development of mathematical skills and interpretation of processes is essential here. The ability to read a staff accurately is also essential. Learners will need to be shown how to book levels using the rise and fall and the Height of Collimation methods.

Finally, learners will move on to practise the use of a theodolite and develop the skills required to read angles. The prerequisite to this is learners' understanding of the use of degrees, minutes and seconds in the measurement of horizontal angles. You will need to demonstrate this technique and also the 360 degree horizontal scale on a theodolite. This is because the scale often measures past zero, which means the measured angle will need to be calculated from the before and after readings. A simple demonstration of the DMS button on a calculator will show this function. The set up on site of a suitable traverse network that has at least five stations will be required here.

Learning aim C

The final learning aim covers the production of the drawings resulting from the fieldwork surveys. This has links with *Unit 7: Graphical Detailing*. The use of conventions that are employed in your country for the production of survey drawings can be illustrated by providing examples for learners to view and use for their drawing production. You will need to guide learners on the appropriate scales to use, dependent on the size of the practical exercises undertaken. You will also need to decide the size of media to use (A3 or A2) and which would be most suitable for the large sections and drawing contours. The use of computer-aided design (CAD) software can also be considered for the production of some of the drawing elements for those learners who have sufficient prior experience in its use and application to surveying. The production of contouring will require some mathematical skills to be taught so learners know how to plot the position of a contour on a grid line. Examples on overlays will enable learners to understand this process and apply it to a grid of levels taken in the field.

Assessment model

Learning aim	Key content areas	Assessment approach
A Understand the methods and technologies that underpin surveys	**A1** Linear, levelling and angular measurement **A2** Equipment used to perform fieldwork surveys **A3** Sources of systematic errors	A report on the techniques and instruments used to record survey data, including potential sources of systematic errors and their minimisation to produce accurate data for plan and section details production
B Undertake fieldwork surveys to collect data for drawings	**B1** Linear surveys **B2** Levelling surveys **B3** Read and record horizontal angles of a closed transverse **B4** Basic arithmetic operations **B5** Application of applied mathematical techniques	Linear survey and level booking sheets to demonstrate accurate recording of surveying measurements. Teacher observation sheets confirming individual understanding and contribution to the practical tasks carried out during fieldwork tasks with others. A report: • evaluating the methods used to take levelling and angular measurements in terms of accuracy • including linear survey and level booking sheets of reduced levels and check calculations including coordinates, calculations and corrections. A series of plan and section scaled detail drawings, to include a: • linear survey line plotted accurately to scale • contoured plan of a surveyed area of land • long section detail of one surveyed line
C Develop drawings from completed fieldwork surveys	**C1** Conventions used in survey drawings **C2** Production of survey drawings **C3** Corrected closed traverse drawing	

		• indicating rise and fall of ground between survey stations • plot of a corrected closed traverse. The drawings/details can be produced using manual or computer-aided design (CAD) drawing techniques.

Assessment guidance

The assessment needs to be split into two assignments. The first would cover learning aim A and the theoretical knowledge that learners require to undertake the practical tasks. The format for this assessment for learning could be a formal report that explains the techniques, equipment and processes to record linear, levelling and angular surveys. Extensions can be added to explain how errors occur within each survey; the evaluation needs to outline the advantages and disadvantages of each method, process and technology used for each survey. A table within the report would be an ideal vehicle to achieve this.

The second assignment would be a practical assessment that will cover learning aims B and C assessment criteria. Observation records should be used to evidence performance on equipment checks and adjustments. A survey book could be given to record all three surveys within one document, witnessed by you.

The production of drawings will require graphical detailing resources for the three surveys, which will need to be drawn on paper in accordance with appropriate national and international standards – for example, a border, scale and title block.

Getting started

This provides you with a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 10: Surveying in Construction

Introduction

This is a very hands-on unit and, from the outset, you should get learners to hold, handle and experiment with the surveying equipment. This can be done effectively by:

- demonstration by you
- practice sessions by learners and feedback from you
- assessment sessions.

Following this sequence will develop learners' independent skills and prepare them to undertake a variety of surveys used in construction. Time will be needed for learners to start reading a staff or theodolite and record accurately the measurements taken. This skill takes practice!

Learning aim A - Understand the methods and technologies that underpin surveys

Learning aim A1, A2 and A3

- This learning aim is focused on introducing learners to the theoretical principles fundamental to the surveys to be studied. It is recommended that you approach the theory in the three distinct areas, taught in succession: linear, levelling and angular knowledge. Throughout delivery, you will find the use of textbook resources a good way for learners to absorb this knowledge, findings from which can then be shared in group discussion.
- An interactive, hands-on approach with the instruments will be of great value for learners as you demonstrate the set up and correct operation of equipment. Opportunities to engage equipment suppliers could be explored for demonstrations of the current range of surveying equipment. Demonstrate, then allow learners to practise using a level and taking staff readings.
- Providing a temporary benchmark with a known height will enable small levelling exercises to be set where learners can work independently and where you will be able to check accuracy against the TBM. This will teach learners about accuracy and calculation errors.
- You will also need to ensure learners are aware of what constitutes an 'acceptable error' in the use of the equipment. This may be a local country-recognised standard – for example, 15mm on concrete finished levels for wearing surfaces is permitted in Bahrain. Learners can conduct independent research activities to investigate this and you may wish to direct them to a number of civil engineering websites that give detailed

explanations of the errors that occur in surveys. Your feedback and analysis of the practice surveys that learners undertake can reinforce this.

Linear Surveying

- To introduce linear measurement, you could begin with horizontal distances, the practice of 'chainage' and the use of perpendicular offsets. Give a demonstration of slope and horizontal lengths, along with a simple three-sided triangle survey, which would give a good starting point for learners. They can then begin their own linear survey, working in small groups. Teach the standard symbols used within your country – e.g. trees, kerbs, fence lines and so on.
- You will need to teach how a linear survey is recorded using tramlines down the centre of a survey paper. Begin by demonstrating this down one survey line then get learners to practise on the other two survey lines.
- Once learners have learned how to record a linear survey, they can then independently undertake the assessment survey and fully record this for drawing production.

Levelling survey

- To introduce linear measurement, you could begin with horizontal distances, the practice of 'chainage' and the use of perpendicular offsets. Give a demonstration of slope and horizontal lengths, along with a simple three-sided triangle survey, which would give a good starting point for learners. They can then begin their own linear survey, working in small groups. Teach the standard symbols used within your country – e.g. trees, kerbs, fence lines and so on.
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- Once learners have learned how to record a linear survey, they can then independently undertake the assessment survey and fully record this for drawing production.

Angular surveying

- Learners should now be ready to cover angular measurement using a theodolite. You will, of course, need to explain degrees, minutes and seconds within a lecture, as these are the units the instrument is calibrated within.
- The first major task is to get learners to set up over a known point. Start with a coin on a level non-slip surface and demonstrate how to get the optical plumb of the theodolite over the centre of the coin.
- The next stage is to move outside and use a 50 × 50 peg with a round head nail in the top, to act as a 'station point'. Once learners have mastered this, move onto three stations forming a triangle. The sum of the three internal angles is 180 degrees, so learners need to be shown how to measure an angle using face left and right. Demonstrate this for one angle, then get them to survey the other two and collate

readings.

- Learners should also be introduced to modern technology and practices in surveying and would benefit from a discussion on how technology may change working practice, or could be of benefit (e.g. through improved accuracy or reduced cost) – for example, digital theodolites, digital imagery, use of drones, aerial photography in topographic surveying, using GNSS systems.

Learning aim B – Undertake fieldwork surveys to collect data for drawings

Learning aim B1

- The surveying principles now understood, learners can progress to the practical application of this knowledge. Typical areas that could be surveyed safely could include:
    - open spaces or parkland with sufficient details
    - land available at your centre
    - a building plot.

Make sure the area to be surveyed is safe and free from any hazards, and that you have permission to use this resource from the landowner.

Linear survey

- For the linear survey, learners will need to set up trilateration for an area using survey stations such as pegs, ranging poles or survey arrows. You will also need to hand out clipboards and plain A4 paper (with tramlines down the centre) for the recording of the linear survey. Other resources required would be two 30m reel tape measures and a 5m steel tape measure.
- As an initial task, ask learners to sketch the position of the stations and tape the three sides of the triangle so they can plot these lines for the drawing. In addition, encourage learners to use their smartphone cameras to record each survey line so that they have a photograph to refer back to when they are drawing the survey as part of learning aim C content delivery.
- Accurate surveying requires appropriate selection of equipment and learners will need to demonstrate this understanding. This could be accomplished by giving learners a range of equipment to choose from. They could then write out their justification as to why they have selected the particular piece chosen. Evaluation could be directed through tutor feedback at the end of the linear survey, where discussions are held on what went well, what did not and how learners would improve next time.

Learning aim B2

Levelling survey

- You can then move on to the levelling survey. The required outcome of this practical task

is for learners to produce plans of land and section detail drawings. There is no requirement to produce a contoured plan, only some cross-sections, long sections and spot height drawings for the assessment in learning aim C. The sections will require an area of topography that has a slope that can be surveyed using horizontal distances and vertical levels. For example:

  - a slope cross-section, 30m long with a 3m rise in height
  - a cross-section of an access road to detail camber, kerbs and footpaths
  - an access ramp to a building
  - a long section across a slope.

- This could be achieved by a site visit for half a day to an area that has a range of topography that could be used to produce a set of cross-sections. Equipment needed would be just one automatic level per cross-section, which can be set up at the top of the section. If a 5m staff is used and the slope drop does not extend past this, then no movement of the level is required.
- Alternatively you could produce a grid of levels across the area of land and then plot cross sections and long sections from this grid.
- You will need to establish at your location a benchmark point that all learners can reference to. This could be a temporary bench mark (TBM) or a known fixed benchmark. This needs clearly highlighting as the point of reference for all survey work and a reduced level applied to this 'known' point.

Learning aim B3

Angular survey

- Finally, the angular survey needs to be carried out. Practice is required for learners to set up a theodolite over a station marker so they can accomplish this with some speed and accuracy. This can be achieved indoors using a coin on the floor with learners setting up correctly on the centre of the coin. The variation in theodolites – from string plumb lines, optical plummets and laser plummets – must also be considered. You may wish to hire the latest technology available to assist with this practical task.
- The angular survey should be set up in the form of a traverse network encompassing angles and distances that can be plotted onto media, e.g.:
  - a building and surrounding boundaries
  - a plot of land and boundaries
  - a car park and boundaries
  - a park with sufficient details to survey.
- The traverse needs to contain at least five stations so the angles and coordinates can be corrected using a Bowditch method. You will need to give coordinates for one of the points.

- A standard template for recording dimensions can be used. Learners will need to capture face left and face right angles and average these.

Learning aim B4 and B5

- B4 and B5 require that mathematical techniques are applied to the following levelling booking methods:
    - Height of Collimation checks
    - rise and fall method checks
    - Bowditch correction method.
- All of the above will need preparation of exemplar calculations that can be worked through with learners so they gain the knowledge to apply these to their practical measurements. The Bowditch method is especially complex and you may like to consider the use of a spread sheet to perform such calculations accurately.

Learning aim C – Examine superstructure design and construction

- This final learning aim covers the production of drawings from each of the surveys. Manual drawing techniques should be used that have been learned from Unit 7: Graphical Detailing. The drawings need to be a size that enables sufficient detail to be produced. A3 drawing paper should be suitable for the plotting of the linear survey to scale. Note that if Unit 7 is not going to be taken (i.e. if you are delivering the Foundation Diploma where it is not mandatory), additional time will have to be spent introducing and practising graphical detailing for this learning aim. Where learners are taking both units, this presents an opportunity for holistic delivery.
- A useful preparation for this activity could be a tracing plot of the three stations to be given to learners. This would make it easier for learners to start the plot, rather than having to use a compass with an extension bar to scribe the stations from a base line. Pin pricks could then transfer the three stations onto the paper. Ensure that peg annotation is correctly applied – e.g. A, B and C match those used in the survey.
- Learners should be encouraged to reference north and to orientate their drawing accordingly. This will link the survey with any planning permission requirements for location and block plan drawings.
- The cross-sections of the levelling topography need to be drawn to a suitable scale so the cross-section is clearly defined and of a suitable size. Vertical and horizontal scales can be exaggerated for this purpose. Learners should plot at least two cross-sections on the one drawing to demonstrate competent assessment skills.
- All of the drawings produced will need to conform to a recognised national or international drawing standard, such as BSI, EN ISO 19650-2.2018. Drawings will need a title block completing for each that details the drawing type, learner name, scale and reference.

- Presentation skills can be delivered by providing exemplars of survey plots so learners can understand the standards required for a pass or merit in the assessment criteria.
- The evaluation of the final drawing could be assessed using an interview technique that is recorded where a professional discussion with the learner is undertaken. Questions could draw out the following:
    - the quality of learners' work and how it could be improved
    - what areas did not work well
    - how errors occurred
    - how they could minimise these
    - what techniques could be improved
    - the advantages of each technique
    - the disadvantages of each technique.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

- Unit 6: Construction Mathematics
- Unit 7: Graphical Detailing
- Unit 13: Site Engineering in Construction

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Internationals in Construction and the Built Environment. Check the Pearson website at http://qualifications.pearson.com/endorsed-resources for more information as titles achieve endorsement.

Textbooks

BSI, *EN ISO 19650-2.*2018, British Standards Institute, IBSN 9780580924675 – organisation and digitisation of information about buildings and civil engineering works, including building information modelling (BIM); information management using building information modelling

Huth M, *Understanding Construction Drawings with Drawings* (6th edition), Delmar Cengage Learning, 2013, ISBN 9781285061023 – this book has examples of both domestic and commercial projects and deals with the subject presented in a hands-on manner

Irvine W, *Surveying for Construction* (fifth edition), McGraw Hill Education, 2005, ISBN 9780077111144 – a well-known textbook that covers all aspects of surveying

Bannister A and Raymond S, *Surveying*, Prentice Hall, 1998, ISBN 9780582302495 – a well-known textbook that covers all aspects of surveying

Topliss, S, *BTEC Level 3 National Construction and the Built Environment Student Book*, Pearson, 2010, ISBN 9781846906565

Journal

Construction Manager (The Chartered Institute of Building) – this journal contains updates on construction projects, methods and materials

Journal of Green Building (College Publishing) – the journal addresses sustainability, new materials and modern methods of construction

Videos

'OTENBuildingCourses – this Australian surveying organisation produces detailed videos demonstrating basic surveying methods

Websites

Civil projects online – a forum website that contains detailed site surveying issues

Designing Buildings Wiki - land surveying site for information on aspects of land surveying with links to other articles on the website regarding different types of surveys

Royal Institute of Chartered Surveyors – the professional body for surveyors in the UK, which has worldwide membership; the site offers some free educational guides and agreed standards of operation

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling learners to access them through the school/college intranet.