

**Module 4D16 2018/19**

**CONSTRUCTION MANAGEMENT**

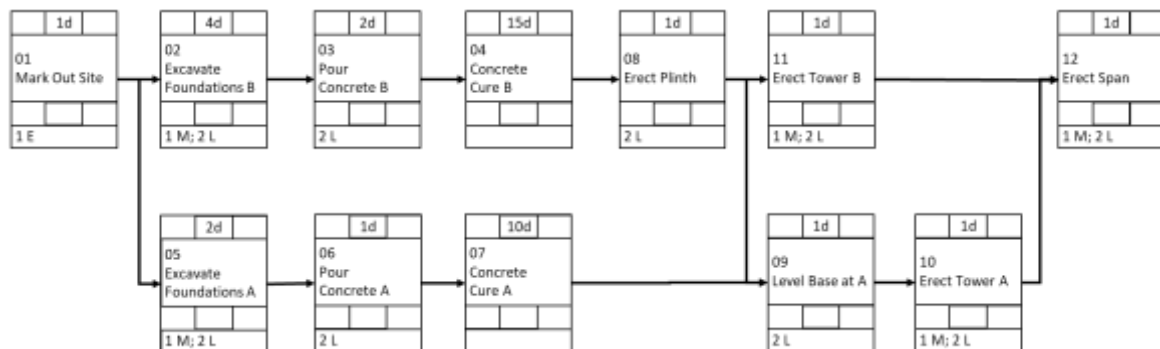
**Exam Crib**

1 (a) The results of the Time Analysis are as follows:

ID	Description	Days	Pred	Labour	ES	EF	LS	LF	Total Float	Free Float
01	Mark Out Site	1		1E	00	01	00	01	00	00
02	Excavate Foundations at A and B	6	01	1M, 2L	01	07	01	07	00	00
03	Pour Concrete Foundations at A and B	3	02	2L	07	10	07	10	00	00
04	Allow Concrete to Cure	15	03		10	25	10	25	00	00
05	Erect Plinth	1	04	2L	25	26	25	26	00	00
06	Level Base at A	1	04,05	2L	26	27	26	27	00	00
07	Erect Tower at A	1	06	1M, 2L	27	28	27	28	00	00
08	Erect Tower at B	1	05	1M, 2L	26	27	27	28	01	01
09	Erect Span	1	07,08	1M, 2L	28	29	28	29	00	00

The critical path runs through activities 01,02,03,04,05,06,07,09

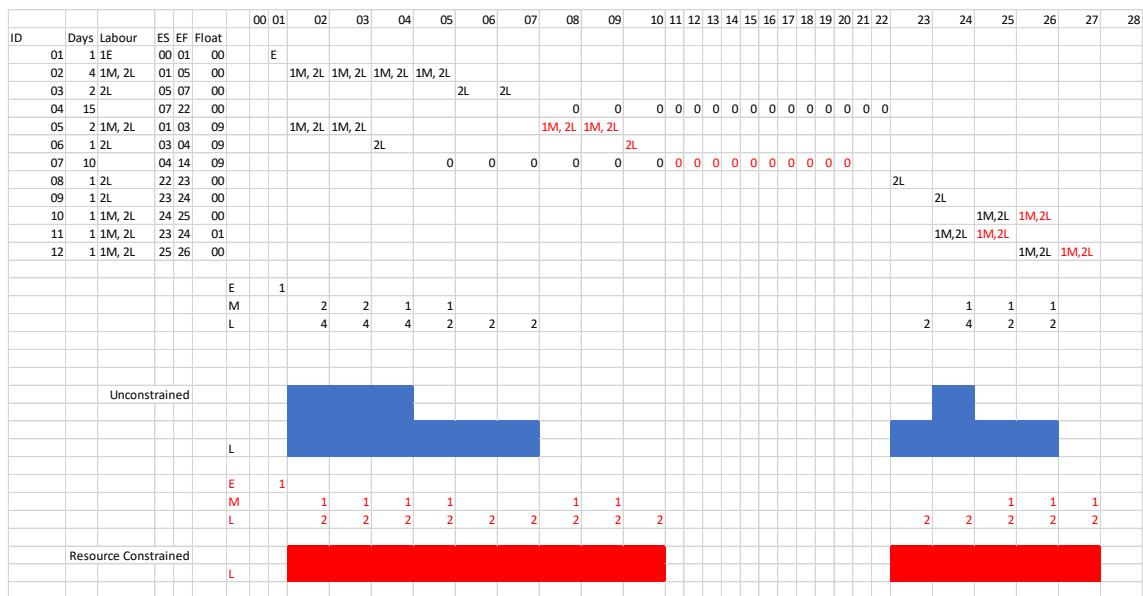
(b) The excavation, concrete pour and cure activities for bases A and B are not logically connected. The network diagram can be revised as follows:



This reduces the critical path by 3 days as shown in the revised Time Analysis below:

ID	Description	Days	Pred	Labour	ES	EF	LS	LF	Total Float	Free Float
01	Mark Out Site	1		1E	00	01	00	01	00	00
02	Excavate Foundations at B	4	01	1M, 2L	01	05	01	05	00	00
03	Pour Concrete at B	2	02	2L	05	07	05	07	00	00
04	Allow Concrete to Cure at B	15	03		07	22	07	22	00	00
05	Excavate Foundations at A	2	01	1M, 2L	01	03	10	12	09	00
06	Pour Concrete at A	1	05	2L	03	04	12	13	09	00
07	Allow Concrete to Cure at A	10	06		04	14	13	23	09	09
08	Erect Plinth	1	04	2L	22	23	22	23	00	00
09	Level Base at A	1	07,08	2L	23	24	23	24	00	00
10	Erect Tower at A	1	09	1M, 2L	24	25	24	25	00	00
11	Erect Tower at B	1	08	1M, 2L	23	24	24	25	01	01
12	Erect Span	1	10,11	1M, 2L	25	26	25	26	00	00

(c) (i) The plot is shown below – the histograms are not required of students. The red section relates to part (ii).



(ii) Due to the float on activities 05,06,07 the base activities for “Tower A” can be slipped until after those of “Tower B”. Although there is also float on activity 11, each of the 4 activities following activity 08 requires 2 labourers and they must be carried out sequentially. The preferred sequencing of activity 11 with activities 09 and 10 in this scenario would depend on convenience – it might be sensible to position the machine in preparation for activity 11 while activity 09 is underway, for example. The resource constraint of 2 labourers can only be met by extending the overall duration by one day, to 27 days. The revised resource plot is shown in the figure above. The red text in the activity section shows the revised schedule, where relevant.

**Assessor's Report 2019 - Question 1**

26 students (41%) attempted this question. Answers were either very good or poor, with little centre-ground. Errors typically involved misinterpretation of the information provided in figures 1 and 2, particularly the logical link between the installation of the plinth for column B and the levelling of the base for column A. Other errors involved careless mistakes and failure to adopt a systematic approach. A number of students ignored the last part of (c)(ii) and did not discuss float.

2 (a) (i) The CDM Regulations 2015 are enacted under the Health and Safety at Work etc. Act, 1974.

(ii) The Regulations aim to protect the health and safety of those carrying out or affected by construction work, those using a structure designed as a workplace, and those who maintain or clean a structure.

Construction is defined under the Regulations as “the carrying out of any building, civil engineering or engineering construction work”. This includes all work associated with the construction, alteration, conversion, fitting out, commissioning, renovation, repair, upkeep, redecoration or other maintenance, decommissioning, demolition or dismantling of a structure.

(b) (i) Under the Regulations, the Client is required to ensure that the construction project is set up so that it is carried out from start to finish in a way that adequately controls the risks to the health and safety of those who may be affected. Their duties include:

- Ensuring that construction work is carried out, so far as reasonably practicable, without risk to the health and safety of workers.
- Ensuring that adequate welfare facilities are provided in respect of any person carrying out Construction Work, and that health and safety arrangements are maintained and reviewed throughout the Project.
- Notification of Project (Form F10), where appropriate.
- Appointing the Principal Designer and Principal Contractor, ensuring that they have the necessary skills knowledge and experience, and that they comply with their duties.
- Providing Pre-Construction Information to other Duty Holders and ensuring that the Construction Phase Plan and Health and Safety File are produced at the appropriate times.

(ii) **The Health and Safety File** is a document containing relevant health and safety information to be taken into account during any subsequent maintenance, cleaning, refurbishment and demolition. It is compiled by the Principal Designer, and typically contains:

- A brief description of the work carried out.
- Residual hazards within the structure.
- Key structural principles.
- Hazardous materials used.

- Information on removal or dismantling of plant and equipment.
- Health and safety information about maintenance equipment.
- The nature, location and markings of significant services.
- As-built drawings of the structure, its plant and equipment.

**Pre-Construction Information** is information about, or relevant to, the project which is already in the Client's possession, or available to the Client. The Client is responsible for providing pre-construction information in the first instance but may be assisted by the Principal Designer. The contents will depend upon the nature of the construction work to be carried out but will typically contain:

- Information about the project, such as the client brief and key dates of the construction phase.
- Any relevant information in existing Health and Safety Files.
- Environmental restrictions and health or safety hazards on the site, including design and construction hazards and how they will be addressed.
- Arrangements for the planning and management of the project, such as the resources and time being allocated to each stage of the project and the arrangements to ensure there is co-operation and coordination between duty holders.

The pre-construction information will usually be updated during the design process to inform the Construction Phase Plan.

The **Construction Phase Plan** is a document that records how health and safety will be managed for the construction phase of a project. It is produced by the Principal Contractor, assisted by the Principal Designer, and is the basis for communicating to all those involved in the construction phase of the project. Its contents typically include:

- A description of the project, such as key dates and details of key members of the project team.
- Arrangements for the management of the work.
- Provisions for the control of any of the specific site risks relevant to the work involved.

(iii) If the Client fails to appoint a Principal Designer and Principal Contractor.

**Assessor's Report 2019 - Question 2**

32 students (50%) attempted this question. Some answers were very good, but some suggested that the answer was based on very little preparatory work. Common errors included: listing the principles of the CDM regulations, rather than their purpose; not recognising the full scope of construction work, as defined in the regulations; misunderstanding the purpose of the documents, and the duty holders primarily responsible for producing them; and failing to understand that the Health and Safety File principally relates to the structure rather than the project.

3 (a) There are three main types of business of particular relevance to the Construction industry: Sole Traders, Partnerships and Limited Companies. *Additional marks should be given for students who differentiate between sub-types: Partnerships and Limited Partnerships, and Limited Companies and Public Limited Companies.*

Sole Traders are the simplest form of business. The owner owns the business as an individual, provides the initial capital and hence keeps all the profits, after paying tax. They can employ staff (“sole” refers to responsibility for the business rather than the number of staff). The owner is personally liable for losses, and the liability is unlimited. Taxation is in the form of income tax, based on the owner’s self-assessment return. This form of business is most likely to be found among very small contractors or sub-contractors.

Partnerships are the simplest form of jointly-owned business. The law of partnership is based on agency, with each partner becoming an agent of the others. The partners must agree to run a business for their joint benefit, with the intention of making a profit. Each partner is an agent of the firm and is therefore entitled to make commitments on behalf of the firm. The owners provide the initial capital, own the business as individuals and hence keep all the business profits after paying tax. Like sole trader businesses, partnerships do not have a legal personality. The owners are jointly liable for debts and losses, and the liability is unlimited. Taxation is in the form of income tax, based on the partnership tax return and the owners’ self-assessment returns. Due to the level of trust required among partners, this type of business is usually only suitable for small numbers of partners, though they may employ significant numbers of staff. It is most likely to be found in the construction industry among small professional services firms.

A development of simple partnerships, Limited Liability Partnerships (LLP) apply many of the provisions of the companies act to a partnership. The principal differences between LLPs and other partnerships are: that the firm has a legal personality, so partners are not jointly and severally liable for the actions of other partners; and the liability of members is limited to the amount of capital they contributed to the LLP. The main cost of these benefits is an increase in administration and reporting requirements. LLPs are most likely to be found among professional services firms.

Limited Companies exist in three forms, the two most common being private limited companies limited by shares, and public limited companies limited by shares (PLC). A limited company is an organisation set up to run a business. Every limited company has shareholders who own shares in the company. The company has a legal personality of its own and can own property and other assets in its own right. Directors are responsible for

running the company, and often own shares, but they do not have to. The company is liable without limit for its own debts, but the liability of shareholders is limited to the full nominal value of their shares. The shares of private limited companies are not traded publicly, but those of a PLC are traded on a market, such as the London Stock Exchange. The main benefit of a private limited company is its separate legal identity, the main disadvantages are the additional administration and reporting requirements (compared with a sole trader or simple partnership). The purpose of the PLC is to raise capital from the public to run the enterprise, but it too has a separate legal entity. Due to its public listing, the disclosure rules for a PLC are much more stringent than those for other limited companies.

Private limited companies are common among small and medium-sized contractors and professional services firms. Large contractors and professional services firms are often Public Limited Companies.

(b) A PLC has two main sources of finance: internal revenues, and external funders. External funds can be in the form of debt or equity.

Internal retained revenues are funds generated by the firm's operations and, as such are available to be used as the directors see fit. This makes reserves a relatively low-cost form of finance. The chief drawback is that for most companies the amount available is limited.

Debt may be in the form of bank loans (including overdrafts), bonds, or current liabilities. Current liabilities are not usually regarded as a meaningful source of investment funding, but they can be quite significant for a large General Contractor. Bank loans and bonds both involve borrowing money at an agreed interest rate and repayment schedule. Since interest payments are an expense, from a tax perspective debt is cheaper than equity. However, it can result in cash flow problems because the debt must be serviced regardless of the success of the business or project.

Equity funding involves obtaining finance by selling a part of the business. The purchaser effectively takes on some of the risk of the business because the value of their shareholding will fluctuate with the success of the firm. This reduces the cash flow risk, but results in dilution of share ownership and earnings, and possibly some control of the business.

The choice of source is likely to be influenced by various factors, such as the scale of funding sought, the timescales over which it is required, and the purpose for which it is intended. Since the firm is a PLC, the equity markets are likely to be the favoured option



for large sources of funds for business development. Other sources are unlikely to be sufficient, other than for short-term funding to cover operational demands.

(c) The financial status of a potential client is always a serious consideration when choosing whether to bid for a contract. The contract is of little value if the client does not have the money to pay. Credit ratings and financial reports are available for limited companies, particularly PLCs, and industry trade groups and other contractors may be able to provide additional information.

However, financial health data may not be available for a subsidiary which may, in any case, have very limited assets of its own, most being vested in the parent. In these circumstances it is usual to obtain parent company guarantees.

**Assessor's Report 2019 - Question 3**

34 students (53%) attempted this question. Most answers were reasonably good, with some very good. The best answers addressed the whole of the question and provided explanations and rationales for their recommendations. Common shortcomings included: Omitting references to the separate legal identity of limited companies and limited liability partnerships, and its implications; confusing corporate and project financing arrangements; misunderstanding the reporting and governance differences between public and private limited companies; providing poor examples of firms likely to be found under the various business types; and omitting a reference to the use of parent company guarantees when agreeing contracts with subsidiaries.

4 You have recently taken over the project depicted in Figure 3, which has been underway for 12 weeks. The previous construction manager departed at short notice, and it was not possible to arrange a handover. Your Project Director has asked for your evaluation of the current cost and programme status of the project, and your plans to ensure that the project is delivered on time.

(a) (i) (ii) (iii)

Activities	BCWS	BCWP	CV	SV	CPI	SPI
A	£ 200,000	£ 200,000	-£ 50,000	£ -	0.800	1.000
B	£ 400,000	£ 400,000	-£ 100,000	£ -	0.800	1.000
C	£ 400,000	£ 300,000	-£ 100,000	-£ 100,000	0.750	0.750
D	£ 200,000			-£ 200,000		
E	£ 200,000			-£ 200,000		
F						
G						
H						
I						
J						
Total	£ 1,400,000	£ 900,000	-£ 250,000	-£ 500,000	0.783	0.643

[Note BCWS for D of £198,000 (0.33\*£600,000) is acceptable, resulting in SV (D) = -£198,000, total SV = -£498,000 and total SPI = 0.644]

(b) Despite the delay, the critical path remains ABCDGIJ. The remaining duration for activities CDGIJ is 5+30+30+10+10=85. The total projected duration for the project, assuming future activities are completed within their Normal Duration, is elapsed duration to date (12 weeks = 60 days) plus the remaining duration of the critical path (85 days), which is 145 days, or 29 weeks, in total.

The total project cost may be estimated as follows:

Total cost to date = £1,150,000  
 Provision to complete activity C = £100,000/CPI = £133,000  
 Total budget activities D-J = £2,700,000

**Total Projected Cost= £3,983,000.00**

(c) To recover the programme, the critical path must be reduced by 15 days. Only activities D and G are on the critical path with the possibility of crashing their durations. Activity D has the earliest late finish date and crashing reduces the critical path by 10 days, at a cost of £150,000. Activity G can also be reduced by 10 days at a cost of £150,000. For the purposes of this exercise, it is assumed that it is not possible to take only part of the duration reduction. This is the most conservative assumption, and with limited information the correct basis on which to make a commitment. In the real world, this assumption could be tested later because it depends on the nature of the task, and, if it proved possible, a partial reduction could be more cost-effective.

The total reduction in the project duration is 20 days at a cost of £300,000. The revised projected project duration is 125 days and the total projected cost is £4,283,000.

(d) Both the CPI and SPI are indicators of project performance to date and can bring to light serious problems. However, it is not appropriate to use a simple extrapolation for the following reasons [*Not all expected from students*]:

- The delay and additional cost to date may well relate to particular features of the activities undertaken so far. Groundworks, for example, occur in the early stages of a project and frequently encounter unexpected problems.
- The cost and programme issues could be due to poor subcontractor performance, but the firms involved may have completed their work on the project.
- If the problems are due to poor management of the project, it is to be expected that this progress report will attract senior management attention and remedial action.
- Various other factors such as accelerated mobilisation and late variations to the specification could also lead to poor performance in the early stages of a project.
- The project team must not be complacent, and it may take some time for remedial actions to have an effect on the project. Project performance should continue to be monitored closely to allow further action to be taken at the earliest opportunity.

**Assessor's Report 2019 - Question 4**

This was the most popular question with 55 attempts (86%). The question was mostly answered very well. Common errors included: Assuming that the remaining portion of activity C would be completed to budget; assuming that activity G could be partially crashed (without more information it is safer to assume that it cannot); and not providing adequate explanations, with examples, for part (d).

5 (a) [*Expect range of responses including some of those outlined below. The main issues highlighted should be: limited scope for standardisation and process optimisation; constraints on sharing learning; price competition leading to low levels of investment (associated with the lack of a pipeline of work), including in training; and difficulty in applying design for construction.*]

The challenge of improving construction productivity has long been recognised, and considerable improvements have been achieved in some areas. However, features of the industry which serve to constrain improvements in productivity include:

- Designs are rarely replicated, which limits the scope for standardisation (including off-site) and for product and process optimisation
- Client engagement with the design process is typically greater in construction than elsewhere, which can lead to late design freeze, and change requests, which in turn lead to a sub-optimal construction process
- Clients frequently promote price competition in both design and construction, potentially reducing the scope for investment in process and product improvement
- Design is usually undertaken by multiple organisations, constraining shared learning and standardisation
- In traditional procurement arrangements, constructors are typically engaged late in the design process, making it difficult for them to contribute their expertise to the design, and to optimise the design for construction.
- Construction is usually undertaken in-situ, which means that a new site is established for each project, with its own unique constraints. This leads to start-up and initialisation issues on every project, and limits the scope for process optimisation
- The arrangements of the site, and the working conditions usually change frequently during construction, again, reducing the scope for optimisation
- Many elements of the construction process are sub-contracted, with different configurations of suppliers on each project. This means that learning is frequently not readily shared or applied.
- Design undertaken by multiple organisations => learning not readily shared or employed

(b) [*Expect students to describe some of those listed below. Some may list all of them, but an adequate answer would include at least one sampling method and one questionnaire method. The important insight, is the need for mixed methods to investigate*

*thoroughly – which might be satisfied by, e.g. the Craftsman Questionnaire Sampling method.]*

Review existing cost reporting and control system records to ascertain input and output figures.

#### Advantages

- Usually already available, and easy to understand
- Historical information can show trends and provides benchmarking against other sites
- Information can be used to evaluate field performance and rates for forecasting

#### Disadvantages

- Reporting cycle often not suitable to provide timely information, particularly on works of shorter duration
- Data collected and reported is usually designed to meet corporate or contractual reporting requirements
- Aggregation makes it difficult to pinpoint the root of problems
- Collection methods may involve human error in estimating input & output

Activity Sampling, which can include field ratings and productivity ratings, provides a measure of how much of the workers' time is spent on useful work.

#### Advantages

- Provides specific measures and comparative ratios (e.g. waiting/total)
- Information can be used to monitor trends of repetitive ongoing activities
- Easy to administer and relatively low-cost
- Can identify areas for further investigation

#### Disadvantages

- Indirect measure of productivity – measures activity rather than outputs
- Observation can influence behaviour - Workers may seek to mislead observer
- Human errors can be a problem, particularly with complex operations or congested sites.

Craftsmen Questionnaires must be carefully designed and sensitively administered to obtain useful information and to avoid antagonising the workforce. They seek to draw on the knowledge and experience of the workers themselves.

#### Advantages

- Effective in collecting information for management regarding support and administration problems
- Can be a motivational tool, engaging with workers and listening to their views
- Can surface problems quickly and relatively inexpensively
- If designed well, can test assumptions and identify new issues

#### Disadvantages

- Lacks evidence of statistical validity due to data collection method
- Can be time consuming to collect data. It interrupts workers, initially introducing another source of unproductive activity.
- Open-ended questions can be difficult to analyse quantitatively

Foreman Delay Surveys are undertaken periodically and are intended to identify the prevalence of factors that affect the productivity of their teams. Again, must be carefully designed to focus on issues not directly within the foreman's responsibility, to avoid "blame" and dishonest responses.

#### Advantages

- Current information; Easy to administer, analyse and summarise
- Inexpensive; Can cover complete jobs, or discrete elements.
- Promotes two-way communication between management and foreman
- Directs management's attention to problem areas

#### Disadvantages

- Unlikely to list delays indicating that it is the foreman's fault
- Can be difficult to convince foremen to keep such records on a regular basis
- Can claim to be too busy; May fear retaliation if report shows senior management issues
- No information on work method used or quality of work force

Craftsman Questionnaire Sampling combines activity sampling with a craftsman questionnaire to provide statistically validated performance data, and information on related activities and issues.

#### Advantages

- Operatives fill it out in the field, recalling activities completed very recently
- Consists of a simple one-page survey



- Because sampling is random, the theory of Binomial Distribution can be applied
- Relatively easy to analyse statistically, but still provides descriptive insights
- Provides access to crafts people’s knowledge, and engages them in the process

Disadvantages

- Interrupts operatives in the field (potentially an additional element of non-productive time)
- Indirect measure of productivity – measures activity rather than outputs

Ideally, a mixed method approach should be adopted to gather both measures of productivity and the underlying factors affecting it. Existing reports, including cost and schedule performance reports, may highlight particular areas for attention, in which case productivity can be assessed by a sampling method before undertaking questionnaire-based investigations to identify specific causes and opportunities for improvement. If no existing reports are available, a foreman survey could be used to identify problem areas, which could then be sampled to obtain measures and further investigated with targeted craftsmen questionnaires.

(c) (i)

	Operative 1	Operative 2	Operative 3	Averages
%Effective	40%	50%	50%	46.7%
% Contributory	30%	20%	30%	26.7%
% Ineffective	30%	30%	20%	26.7%

$$\text{Labour Utilisation Factor} = \frac{\text{effective\_work} + \frac{1}{4} \text{essential\_contributory\_work}}{\text{total\_observed}}$$

	Operative 1	Operative 2	Operative 3	Total
Effective	4	5	5	14
Contributory	3	2	3	8
Ineffective	3	3	2	8

$$\text{Labour Utilisation Factor} = \frac{14 + \frac{8}{4}}{30} = 53.3\%$$

The Labour Utilisation Factor is 53.3%, which appears low, though benchmarks should be consulted because typical Utilisation Factors vary depending on trade and other

features. Further investigation is required to explore what can be done to improve productivity. Although Operative 1 appears to be less productive than the other two, all three are engaged on a single task, so the effectiveness of each cannot be considered in isolation. With only 30 samples, the result is not likely to be reliable, and the first step should be to repeat the exercise with considerably more samples.

(ii) 384

A 95% confidence limit means that there is a 95% chance that the results calculated from the sample are representative of the population sampled. A +/-5% limit of error means that the percentage calculated from the sample lies within +/-5% of the true percentage in the population, with, in this case, a confidence level of 95%. The sample size of 384 is a conservative one, assuming the worst-case category proportion of 50%, that is, the percentage result which results in the largest standard deviation, based on no prior estimate of the likely outcome.

**Assessor's Report 2019 - Question 5**

45 students (70%) attempted this question. The quality of answers was quite variable, but most students attempted to engage with the elements that required judgement or explanation. There were a number of common errors: In part (a), addressing factors affecting productivity in general, rather than constraints on productivity improvement; in part (b), failing to make a recommendation, or ignoring the value of multiple methods; and in part (c)(i), omitting the discussion of significance and validity. Part (c)(iii) was generally not answered well, and there were very few references to the population, or the mean.