

Operations strategy A2

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Last checked 5 October 2026

Read first: [Inventory management](#), [Capacity utilisation and outsourcing](#), [Quality management](#)

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What you need to know

By the end of this topic you should be able to:

1. **Explain how the people, the market knowledge and the money a business has shape its operations decisions:** the skills of its workforce (human resources), what its marketing tells it about customers, and the finance it can raise.
2. **Explain how Information Technology (IT) and Artificial Intelligence (AI) are changing the work of operations managers.**
3. **Explain why operations need to be flexible** in three ways: in the quantity produced (volume), in how fast orders reach customers (delivery time) and in what each product is like (specification).
4. **Explain process innovation:** what it is, with examples, and what it can gain or cost a business.
5. **Describe the main features of an enterprise resource planning (ERP) programme.**
6. **Explain how ERP can make a business more efficient** in six areas: inventory control, costing and pricing, capacity utilisation, responses to change, workforce flexibility, and management information.
7. **Explain the aims and purposes of lean production.**
8. **Explain six operational strategies used to achieve lean production:** Kaizen, quality circles, simultaneous engineering, cell production, JIT manufacturing and waste management.
9. **Explain the limitations** of those strategies.
10. **Explain how lean production links to** inventory control, quality, the roles of employees, capacity management and efficiency.
11. **Explain why operations need to be planned.**
12. **Use network diagrams to plan operations**, and know their parts: activities, dummy activities and nodes.
13. **Carry out critical path analysis (CPA) on a network:** find the minimum project duration and the critical path, calculate total float and free float, interpret the results, and explain how managers can use the minimum duration and the floats to run a project.
14. **Evaluate CPA as a management tool:** its benefits and its limitations.

Some neighbouring ideas belong to other topics: buffer inventory and JIT as a way of managing inventory are in inventory management, calculating capacity utilisation is in capacity utilisation and outsourcing, TQM is in quality management, and ARR and payback, which often sit next to an ERP question, are in investment appraisal.

Understand it

Operations never decide alone

Imagine a furniture maker that could switch to computer-controlled cutting machines. The operations manager may be sure it would work, but three other parts of the business decide whether it can happen.

- **Human resources.** Does anyone know how to set up, program and repair the machines? Can staff be retrained, or must specialists be hired, and are they available locally? A workforce that has done the same job for twenty years may resist; a young, adaptable one may welcome the change. Even the experience of the manager in charge matters.
- **Marketing.** How many units will customers want next year, and how varied? Market research decides how much capacity is worth buying and whether the business needs one standard product or many versions. What the marketing department promises customers (next-day delivery, a choice of colours) becomes a target that operations has to hit.
- **Finance.** Machines, buildings and software cost money up front. A business with little cash, falling profits or heavy borrowing may have to lease instead of buy, introduce the change in stages, outsource the work, or pick a cheaper method.

A good operations answer always asks: **can this business staff it, sell what it makes, and pay for it?**

IT and AI in operations

For a long time computers in a business were mainly **filing cabinets**: they stored sales records, stock lists and wage details. Now they also **control the work itself**. Designers draw products on screen (computer-aided design, CAD), the drawings are passed straight to machines that cut or shape the parts (computer-aided manufacture, CAM), barcodes and sensors show where every item is, and online orders flow directly into the production schedule.

AI goes a step further: a system that finds patterns in large amounts of data and uses them to forecast or to decide. Examples: forecasting how many sandwiches each shop will sell tomorrow from the weather and last year's sales; working out the shortest delivery routes; warning that a machine bearing is wearing out before it breaks; using cameras to reject faulty items on the line; answering simple customer questions by chatbot. The operations manager's job moves from **reacting** to what has happened towards **anticipating** what will happen, while the computer takes over many routine decisions.

Gains	Drawbacks
Fewer staff hours per unit, so unit costs fall	Large initial cost and the finance it needs
Consistent work: machines do not get tired or careless	Staff need training, and output may dip while they learn
Production can run around the clock	Jobs may go: redundancy payments, worried staff, damage to the firm's image
Problems are spotted and answered faster	A system failure or cyber-attack can halt the whole operation

Gains

Decisions rest on up-to-date data

Drawbacks

Poor data gives poor forecasts, and managers may trust the system too much

Some customers prefer dealing with a person

Flexibility

Each kind of flexibility answers a different worry.

Flexibility	The worry	How a business provides it
Volume	Demand rises or falls sharply, by season or by surprise	Temporary, part-time or multi-skilled staff; overtime; machinery that is not fully used; outsourcing the extra
Delivery time	Customers want their order quickly, or want it sooner than planned	Suppliers who deliver at short notice; stocks of key parts; scheduling software
Specification	Customers want something slightly different from the standard	Machines that can be reset quickly; CAD/CAM; products built from standard modules; mass customisation , where a product made on an efficient production line is still varied for each buyer

Why it matters: tastes now change quickly, many buyers expect products made for them and delivered fast, and a business that cannot offer this loses sales to one that can. Being able to follow demand also means less stock has to be held "in case". But flexibility has a cost: adaptable machines are dearer than single-purpose ones, multi-skilled staff need training, temporary staff may be less loyal, and capacity kept for peaks raises average costs in quiet months.

Process innovation

Process innovation is an improvement to the *route* by which a business turns its inputs into what it sells: the method, the equipment or the system. What the customer receives stays much the same; what changes is how it is made, delivered or handled behind the scenes. A test: if the customer is buying something new, that is product innovation; if they are buying the same thing that has reached them a new way, that is process innovation.

Examples: a dairy that fills bottles with a robot instead of by hand; a restaurant where diners order on a tablet at the table; a builders' merchant whose customers book deliveries through an app; a factory changing from a long production line to teams; an insurer that uses AI to assess claims.

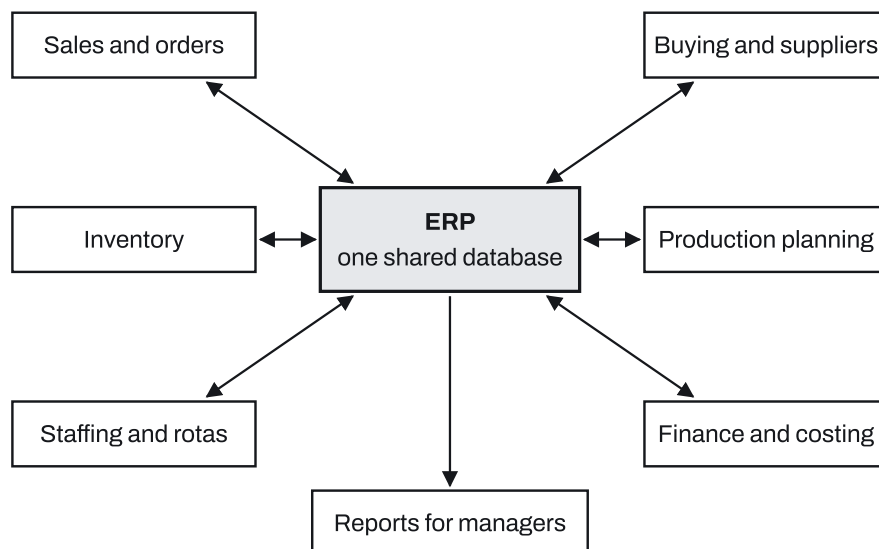
- **Possible benefits:** lower unit costs; faster output and shorter waiting times; more consistent quality; more capacity from the same building; information shared quickly between departments; customers paying sooner; an advantage over rivals.

- **Possible drawbacks:** the cost of the change and the problem of financing it; the other projects that must wait (the **opportunity cost**); disruption while it is installed; training; staff who fear for their jobs or dislike new methods, and redundancy costs if jobs go; breakdowns and early faults; the loss of a "hand-made" appeal; spare capacity if demand does not grow.

Enterprise resource planning (ERP)

Picture a business where every department keeps its own records. Sales has a spreadsheet of customers, the buyer has a stock program, the workshop plans on a whiteboard and finance uses accounts software. One order is typed in three times, the copies disagree, and no one can see the whole picture.

ERP replaces those separate records with **one shared database that every department works from**. Each department uses its own **module** (selling, buying, stock, production planning, staffing, accounts), but all the modules read and update the same data. A sale entered by the sales team immediately changes the stock figures, the production plan and the accounts.



Main features of an ERP programme:

- one database with a **module for each department**;
- **live tracking** of orders, stock, work in progress and deliveries;
- **automated routine tasks**, such as raising an order with a supplier when stock falls to a set level, sending invoices or drawing up staff rotas, increasingly with AI forecasting built in;
- **reports and analysis** that combine figures from every department;
- links to the systems of major suppliers and customers.

How ERP makes a business more efficient (more output from the same inputs, or the same output from fewer):

Area	What ERP does	What it saves
Inventory control	Works out from confirmed orders which materials are needed and when, and orders them	Less money tied up in stock, fewer shortages; makes JIT possible
Costing and pricing	Records the actual materials, hours and overheads used on each job	Accurate unit costs, quick quotes, prices that can differ by customer or order size
Capacity utilisation	Spreads the full order book across machines and shifts	Fewer idle and overloaded periods; fixed costs spread over more output
Responses to change	Re-plans buying, production and staffing together when an order or forecast changes	Changes handled in hours, not days
Workforce flexibility	Shows which skills are needed on which days	Rotas that match the work; less overtime and idle time
Management information	Puts current figures from every department in one place	Faster, better-informed decisions

Drawbacks: a high purchase and set-up cost, plus yearly licence fees; training; disruption while the old data is moved across; settings that are wrong (for example a re-order level that is too low) make the system take wrong decisions automatically; a single failure affects every department; dependence on the software company; staff may resent rotas set by a computer. When ERP disappoints, ask whether the software is at fault, or the way it was set up, the suppliers, or the managers using it.

Lean production

Lean production sets out to make a product or provide a service with the **smallest possible amount of every input** (materials, labour hours, floor space, stock, energy, time) while keeping or raising quality. Its purposes are lower unit costs, fewer faults, and faster, more reliable responses to customers. Anything that uses resources without making the product better is treated as waste: making more than has been ordered, people or machines waiting, moving goods or walking about more than necessary, doing extra work on a product, stock sitting on shelves, faulty items, and ideas that staff have but nobody asks for.

The six strategies the syllabus lists:

Strategy	How it works	Example
Kaizen	Improvement is part of everyone's job, every week, in many small steps rather than an occasional big investment	A packer moves the label printer next to her bench and saves ten seconds on every box; across all staff and all year, hundreds of such changes add up

Strategy	How it works	Example
Quality circles	A suggestion box run as a team: a handful of staff from one area are given time away from their jobs every week or two, choose a fault they keep running into, test what causes it and present their fix to managers	Five drivers at a bus depot look into why buses leave late on Monday mornings and propose a new cleaning schedule
Simultaneous engineering	When a new product is developed, design, engineering, buying and marketing work on it side by side from the start instead of one after another	A phone case's shape is checked by the factory and the buyer while it is still being drawn, so problems are found early and the launch comes sooner
Cell production	The production line is split into teams; each team (a cell) makes a whole product or a complete section of one, organises its own work and checks its own output	Six workers in one corner build complete office chairs, swapping jobs between them
JIT manufacturing	Nothing is made until a later stage, and in the end a customer, has asked for it; materials arrive just before they are used	A sandwich bar makes each sandwich when it is ordered, with bread delivered every morning
Waste management	Going through every step of the process to find and remove each kind of waste, and reducing, reusing and recycling materials and energy	A printer cuts paper offcuts by changing sheet sizes and sells the rest for recycling

Limitations:

- Every method needs training, which costs money and time, and output may fall while staff adjust.
- Managers must let staff take decisions, and staff must accept more responsibility. Some will not, some feel extra pressure, and stress and labour turnover may rise.
- JIT depends on suppliers who are close, reliable and able to deliver small amounts often, and on accurate demand forecasts. With little stock, one late delivery stops production and a sudden rise in orders cannot be met.
- Kaizen's gains are small and may dry up once the obvious changes are made; much of what was learned leaves with experienced staff.
- Circle meetings take time away from production, are hard to arrange for part-time or shift workers, and staff may expect to be paid extra.
- Simultaneous engineering needs close teamwork across departments; cells need multi-skilled staff and a new layout.
- Lean suits steady demand better than demand that swings unpredictably.

Links to other areas:

- **Inventory control:** JIT keeps stock low, so holding costs fall and inventory turnover rises, but there is no cushion if supplies fail.

- **Quality:** a faulty item is waste, so lean aims to get it right first time, with each worker checking their own work; it fits naturally with TQM.
- **Employees' roles:** workers move from one repeated task to being multi-skilled members of teams that are responsible for quality and improvement. Many find this more motivating; all find it more demanding.
- **Capacity management:** making only what is ordered prevents overproduction; space and time freed up add capacity; teams that can switch tasks let output follow demand.
- **Efficiency:** fewer inputs are used for each unit of output, so unit costs fall.

Why operations need planning

A project such as opening a new branch, installing new machinery or launching a computer system is made up of many tasks, and some cannot start until others have finished. Without a plan, workers turn up before the materials, materials arrive (and are paid for) weeks before anyone can use them, and nobody knows when the project will end. **Operations planning** decides the order of the tasks, when each can start, when each resource is needed and when the whole project will be complete.

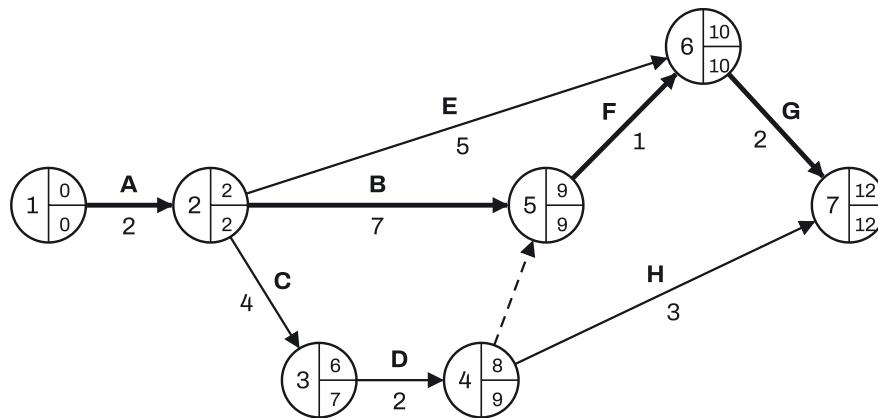
Network diagrams

A **network diagram** draws the plan.

- An **activity** is a task that takes time and uses resources. It is drawn as an arrow from left to right, labelled with its letter and its duration.
- A **node** is a circle where one or more activities end and others begin. The left half holds the node's number. The right half holds two times: the **earliest start time (EST)** at the top and the **latest finish time (LFT)** at the bottom.
- A **dummy activity** is a dashed arrow that takes no time and uses no resources. It shows that one activity must wait for another when no real arrow can show it without creating a false link.

Harbourside Dental is turning a storeroom into an X-ray room. Times are in weeks.

Activity	Task	Must wait for	Weeks
A	Plan the room and choose the equipment	–	2
B	Order the scanner and wait for delivery	A	7
C	Building work, including lead-lined walls	A	4
D	Electrics and decorating	C	2
E	Recruit a radiographer	A	5
F	Install the scanner	B, D	1
G	Train staff and test the scanner	E, F	2
H	Tell patients and take bookings	D	3



Why the dummy? Installing the scanner (F) needs both the scanner (B) and the finished room (D). Telling patients (H) needs only the finished room. If B and D ended at the same node, H would start from it and would wrongly wait for the scanner as well. So D ends at its own node 4, H leaves from node 4, and the dummy from node 4 to node 5 carries the message "D must be finished" to F.

Forward pass: the ESTs, working left to right. Node 1 is 0. For every other node, work out (EST of the node an arrow comes from + that arrow's duration) for **each** arrow coming in, and take the **largest**: the next activities cannot begin until the slowest arrival. A dummy adds 0.

- Node 2: $0 + 2 = 2$. Node 3: $2 + 4 = 6$. Node 4: $6 + 2 = 8$.
- Node 5: B gives $2 + 7 = 9$; the dummy gives $8 + 0 = 8$. Largest: 9.
- Node 6: F gives $9 + 1 = 10$; E gives $2 + 5 = 7$. Largest: 10.
- Node 7: G gives $10 + 2 = 12$; H gives $8 + 3 = 11$. Largest: 12.

Backward pass: the LFTs, working right to left. The final node's LFT equals its EST. For every other node, work out (LFT of the node an arrow goes to – that arrow's duration) for **each** arrow going out, and take the **smallest**: the node must be reached in time for the most urgent activity leaving it.

- Node 7: 12. Node 6: $12 - 2 = 10$. Node 5: $10 - 1 = 9$.
- Node 4: H gives $12 - 3 = 9$; the dummy gives $9 - 0 = 9$. Smallest: 9. Node 3: $9 - 2 = 7$.
- Node 2: B gives $9 - 7 = 2$; C gives $7 - 4 = 3$; E gives $10 - 5 = 5$. Smallest: 2. Node 1: $2 - 2 = 0$.

The **critical path** is the chain of activities with no spare time: **A, B, F, G**. Every node on it has $EST = LFT$, and each of its activities exactly fills the gap between its two nodes. Its durations add up to the **minimum project duration**: $2 + 7 + 1 + 2 = 12$ weeks, the same as the final node's EST. A delay to any critical activity delays the opening by the same amount.

Float

Every activity has a **time window**. It opens at the EST of the node where the activity starts. For **total float**, it closes at the LFT of the node where the activity ends: the last moment it can finish without the project's finish moving. The window minus the activity's own duration is the slack it has:

$$\text{total float} = \text{LFT of end node} - \text{duration} - \text{EST of start node}$$

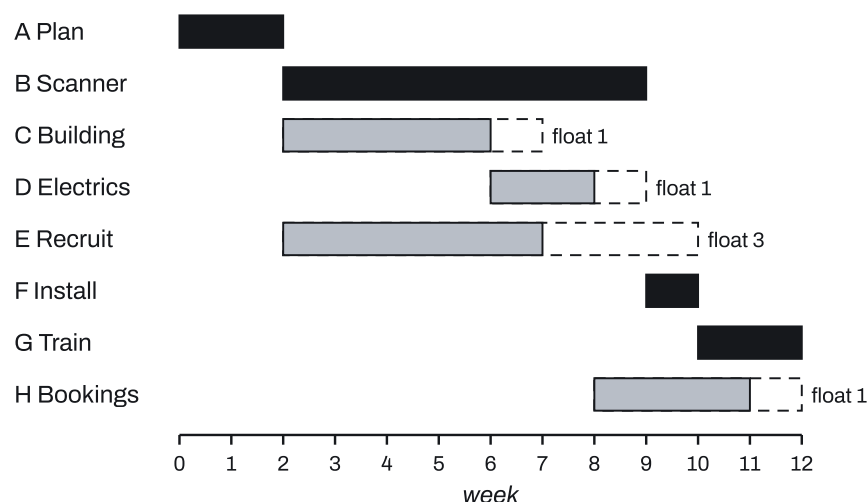
For **free float**, the window closes earlier, at the **EST** of the node where the activity ends: the moment the next activities would like to begin. Slack measured against that is the delay that does not disturb anything else:

$$\text{free float} = \text{EST of end node} - \text{duration} - \text{EST of start node}$$

So free float is never more than total float, and every critical activity has a total float of 0.

Activity	Total float	Free float	What it means
E Recruit	$10 - 5 - 2 = 3$	$10 - 5 - 2 = 3$	The radiographer can arrive up to 3 weeks late without affecting anything
C Building	$7 - 4 - 2 = 1$	$6 - 4 - 2 = 0$	Any delay pushes back the decorating, but 1 week does not move the opening
D Electrics	$9 - 2 - 6 = 1$	$8 - 2 - 6 = 0$	Any delay pushes back the bookings campaign, but 1 week does not move the opening
H Bookings	$12 - 3 - 8 = 1$	$12 - 3 - 8 = 1$	Up to 1 week late affects nothing

C, D and H lie on one chain and **share** a single spare week: if the building work uses it, the decorating and bookings have none left. That is why total float can be "used up" by an earlier activity, while free float belongs to the activity alone.



Using the results to run the project

- **Ordering and hiring at the right time.** ESTs show when each resource is first needed. The staff training (G) cannot start before week 10, so the trainer is booked for week 10, not week 2, and the dentist pays later, which helps cash flow.
- **Knowing where to look.** A week lost on a critical activity is a week lost on the opening; a week lost within float is not. Managers chase the scanner delivery (B) much harder than the recruitment (E).
- **Moving people.** Staff working on an activity with float can be lent to a critical activity that has fallen behind, or a floating activity can be started later to even out the workload.

- **Checking progress.** Each LFT is a deadline. Comparing progress with it each week shows at once whether a delay threatens the finish.
- **Setting dates.** The minimum duration shows whether a target date is realistic and what date to give patients, customers or investors. If it is too long, extra resources on critical activities, or splitting them so parts run at the same time, can shorten it.

Benefits of CPA as a management tool: it makes managers think through every task and the order they must come in; it gives the shortest possible project time and a start and finish date for every task; it shows which tasks have slack and which have none, so resources go where they matter; it gives deadlines to monitor against and shows how serious any delay is; it gives a reliable date to people outside the business.

Limitations: every answer depends on the time estimates, and for a project the business has never done before there is no past experience to estimate from; estimates from suppliers or contractors may be optimistic because they want the work; events outside the business (late shipments, bad weather, strikes, permits) can upset any plan; drawing and updating a network takes time and money; it is a plan, not management, so the project still needs people to run it; it assumes staff and equipment can be moved between tasks, which is not always so; a plan with no spare time fails at the first delay; it says nothing about cost, quality or whether the project is worth doing at all.

Key facts and formulas

There is no formula sheet for this subject, so every row below has to be learned.

Formula	Status
EST of a node = the largest value of (EST of the node an arrow comes from + that arrow's duration); the first node's EST is 0	Learn it
LFT of a node = the smallest value of (LFT of the node an arrow goes to – that arrow's duration); the final node's LFT equals its EST	Learn it
Total float of an activity = LFT of its end node – its duration – EST of its start node	Learn it
Free float of an activity = EST of its end node – its duration – EST of its start node	Learn it
Minimum project duration = EST of the final node = the sum of the durations of the activities on the critical path	Learn it
Critical path: the activities with zero total float, through nodes where EST = LFT	Learn it
Dummy activity: a dashed arrow, with no duration and no resources, that shows a dependency	Learn it
Three kinds of operational flexibility: volume, delivery time, specification	Learn it

Formula	Status
Process innovation changes how a product is made or a service delivered; product innovation changes what is sold	Learn it
ERP: one shared database used by every department through its own module	Learn it
Lean production: making the product with the least possible amount of every input by removing all kinds of waste	Learn it

How to do it

We have tagged 30 questions on this topic (2021–2025), on Papers 1 to 4. 6 of them mix two types (network calculations followed by an evaluation of CPA), so the counts add up to 36.

Question type	Questions
Evaluate the usefulness or importance of CPA	7
Calculate from a network diagram	6
Analyse or evaluate process innovation	6
Evaluate or advise on a whole operations strategy	5
Evaluate or analyse lean production, JIT or Kaizen	4
Evaluate whether to invest in ERP	3
Analyse or evaluate how ERP improves efficiency	3
Discuss the importance of operational flexibility	2

The marks are for four skills: **K** (knowledge: a correct term, definition or point), **App** (application: using this business's facts and your own calculated figures), **An** (analysis: a chain of causes and consequences with two or more links) and **Eval** (evaluation: a supported judgement). In the examples, (K), (App), (An) and (Eval) after a sentence show the mark it earns.

1. Evaluate the usefulness or importance of CPA (7 questions)

Paper 3, [12], nearly always straight after calculations on the same network. It is worded in several ways: how useful CPA is as a management tool, its importance to the success of a project, its role in a project, whether it will make sure an objective is met, or whether a manager is right to be confident of a deadline. Since 2023 the marks are 2 K, 2 App, 2 An and 6 Eval; earlier papers split them 2, 2, 4 and 4.

1. **K**: say what CPA is (a network showing the order of activities, from which the critical path, the floats and the minimum duration are found) **and** at least one thing it does for managers or one limitation. A definition on its own is only limited knowledge.

2. **App:** use your answers from part (a): the minimum duration against the target date, the named critical activities, the float on a named activity. Add who supplied the estimates, whether the business has done such a project before, and which activities depend on outsiders.
3. **An** on both sides, for example:
 - an activity found to have no slack → managers check it every week → a slip is noticed while it can still be recovered → the opening date holds;
 - each activity's EST known → equipment and staff booked for that week, not earlier → no wages paid for waiting and no bills paid early → better cash flow;
 - float found on an activity → its workers can help a late critical activity → time recovered without hiring extra staff;
 - against: a supplier's delivery estimate is too short → the true critical path differs from the drawn one → the deadline is missed even though the plan looked safe.
4. **Eval:** answer the exact question for this business. Weigh how much CPA matters here (many linked tasks, little time to spare, a costly penalty for lateness) against what it cannot do, and say what its value depends on: how accurate the estimates are and who made them, the manager's experience, how much is in outside hands, whether progress is checked against the plan, and whether the money, equipment and people are in place. For "will it ensure..." the honest answer is "it helps, but it cannot guarantee", with reasons from the case.

Write about **CPA**, not about whether the project itself is a good idea.

2. Calculate from a network diagram (6 questions)

Short Paper 3 parts before the evaluation. Show the formula, the numbers put into it and the answer.

- **Complete a node [2]:** one mark for each number. EST by the forward pass (largest), LFT by the backward pass (smallest), counting a dummy as 0. Write the numbers in the node printed on the diagram; do not add new nodes.
- **EST of an activity:** the EST of the node it starts from. Check every route into that node, including dummies.
- **Minimum project duration [1]:** the final node's EST, which equals the total of the critical path's durations.
- **Critical path:** list its activities in order (a dummy is not named). Every node on it has $EST = LFT$.
- **Total float, usually [3]:** 1 for the formula or a correct description, 2 for the correct numbers substituted, 3 for the answer. When it is [2]: 1 for the correct numbers substituted, 2 for the answer; the formula alone earns 1 only if nothing else can be credited.
- **Free float:** the same patterns, with the EST of the end node in place of its LFT.

Units are not required, but a wrong unit (days for weeks) can cost a mark. If an earlier answer is wrong but used correctly later, the later method marks are still given.

3. Analyse or evaluate process innovation (6 questions)

- **Analyse two benefits, or two disadvantages, of a process innovation [8]**, on Paper 2 or Paper 3: 2 K, 2 App, 4 An. A definition of process innovation earns at most 1 K; the other K comes from naming the benefit or disadvantage. One App per point. Only the direction asked for is rewarded, and if you give more than two points only the best two count; one fully developed point alone can reach 3 An.
 - **Evaluate the impact, importance or sufficiency of process innovation [11–16]**: for example the effect of automation, how far product and process innovation matter to profit, or whether modernising a factory will be enough to raise efficiency. Paper 3 [12] is 2 K, 2 App, 2 An, 6 Eval.
1. **Points to choose from**: drawbacks are the cost and its financing (cash flow), the opportunity cost, training, staff resistance and redundancies, disruption while it is installed, technical failure, losing a hand-made image; benefits are lower unit costs, time saved, shared and up-to-date information, faster payment, more consistent quality and more capacity.
 2. **App**: what the innovation is in this case, how many staff it affects, how strong the business's finances are, and what else it is planning to spend on.
 3. **An**: at least two links each, ending at costs, sales, cash flow or profit. For example: *the old and new systems must run side by side for several weeks → staff enter every order twice → overtime costs rise just as cash is needed to pay for the system.*
 4. **Eval** (only when asked): is the innovation enough on its own, or are training, extra capacity, marketing or other changes also needed? It depends on the demand forecast, the reliability of the technology, how staff and any union respond, and the state of the economy.

4. Evaluate or advise on a whole operations strategy (5 questions)

Paper 4, [20]: 3 K, 2 App, 8 An, 7 Eval, on a long case with a timeline and appendices. Either "evaluate how effective X's operations strategy was" (or how far it led to success or failure) between two dates, or "advise X on an operations strategy".

1. **K (3)**: one operations term fully explained (term plus two points of explanation), or two terms each partly explained. **Without a K mark, no other marks can be given**, so define a term early. Any idea from this topic or earlier operations topics counts: JIT, Kaizen, quality circles, cells, simultaneous engineering, waste management, ERP, IT and AI, flexibility, process innovation, CPA, the influence of HR, marketing and finance, capacity, quality.
2. **App (2)**: the case's dates, decisions and appendix figures (capacity utilisation, lead times, sales, costs, delays).
3. **An (8)**: take one element of the strategy, give a developed chain to costs, sales or profit, then counterbalance it with a chain the other way. Do this for **two** elements to reach the full 8.
4. **Eval (7)**: judge each element; say which worked best and which worst; consider other causes (a manager's inexperience, skills shortages, marketing, finance, government policy, competitors, suppliers); end with an overall judgement that answers the question and says what it depends on.

For **advise**: a joined-up strategy that fits the case's problems (not a list of every method), two or three elements analysed with their drawbacks, then which to do first and why, what it costs, and what success depends on. SWOT, PEST, Ansoff and the Boston matrix are tools for analysis, not operations strategies.

5. Evaluate or analyse lean production, JIT or Kaizen (4 questions)

- **Evaluate whether lean production (or JIT, or lean techniques) will be sufficient** to meet objectives, raise efficiency or solve inventory problems [12–16]: since 2023, 2 K, 2 App, 2 An, 6 Eval for [12].
 - **Analyse two benefits of introducing Kaizen [10]**: K, App and An only. Show you know Kaizen itself (small, constant improvements suggested by all staff), not lean production or training in general, and do not just copy the case's description.
1. **K**: lean as using the least of every input by removing waste; name the methods that suit the case; define any ratio the question uses.
 2. **App**: each objective or problem with its figure (defect rate, inventory turnover from your part (b), workforce size, deadlines); the product (does it spoil? is it bulky?); where the suppliers are; the workforce's attitude and any union agreement; the finances.
 3. **An**: match a method to each problem and chain it to the objective. For instance: deliveries each morning in place of a month's supply → a smaller store and less cash sitting in stock → inventory turnover rises towards the target. Workers given a say in fixing faults on their own line → the true causes are found → fewer items rejected, so less material and time wasted per good unit. Counter-chains: staff used to fixed jobs take months to learn new ones → output falls during the change; a supplier abroad cannot deliver little and often → JIT leaves the line idle → orders missed.
 4. **Eval**: "sufficient" means asking **what else** is needed: new machinery or ERP, better management, new suppliers, marketing. Say what success depends on, then decide.

6. Evaluate whether to invest in ERP (3 questions)

Paper 3, [12], after an ARR or payback calculation (the calculation is in investment appraisal): 2 K, 2 App, 2 An, 6 Eval from 2023.

1. **K**: ERP as one shared database used by every department, plus its effects in the six areas, and its costs.
2. **App**: your ARR against the business's return on capital employed or the interest rate; payback against the system's expected life; the cost against profit, cash and gearing; the case's problems ERP would solve (stock-outs, waste, perishable stock, slow quotes).
3. **An**: for, one chain from an ERP area to cost, revenue or profit; against, one chain from cost, training, disruption, redundancies, or reliance on suppliers.
4. **Eval**: decide, and give the deciding factor: return against risk, whether finance is available given the gearing, how trustworthy the savings estimates are (a software seller's figures may be optimistic), how long the system takes to work fully, whether discounting would change the picture, and what else the money could do.

7. Analyse or evaluate how ERP improves efficiency (3 questions)

- **Analyse two ways ERP could improve efficiency, or its advantages [8–10]**, Paper 3: for [8], 2 K, 2 App, 4 An. A definition of ERP or of efficiency earns at most 1 K; the other comes from naming a way. One App per way; only the best two ways count.
- **How significant was ERP to the strategy [20]**, Paper 4: marked like type 4.
 1. Pick the two areas from the table in "Understand it" that fit the case's problems best.
 2. **App**: the case's symptom for each (stock-outs, slow quotes, idle and overloaded weeks, mismatched rotas, departments not sharing data).
 3. **An**: what ERP changes → what that saves or earns → the effect on unit costs, sales or profit.
 4. For the [20] version: judge area by area (which ERP functions worked, which failed), ask whether failures came from the software or from its settings, the suppliers or the managers, and reach an overall verdict.

8. Discuss the importance of operational flexibility (2 questions)

Paper 1 essays, [12], about a named kind of business (a toy maker, a car maker), with no case, marked by levels.

1. Define flexibility through its **three kinds** with real methods (mass customisation, machines that can be reset quickly, multi-skilled or temporary staff); if innovation is named, define it and separate product from process.
2. Apply to the named industry: how much its demand swings, how much its buyers want different versions, how fast rivals change.
3. Analyse: matching output and design to what buyers want this season → orders not lost to rivals → more sales and profit; counter: flexible equipment and research cost more, and temporary staff may be less committed.
4. Evaluate: how much it matters depends on how fast the market changes, the firm's size and finance, and whether price, brand or marketing matter more; reach a clear judgement.

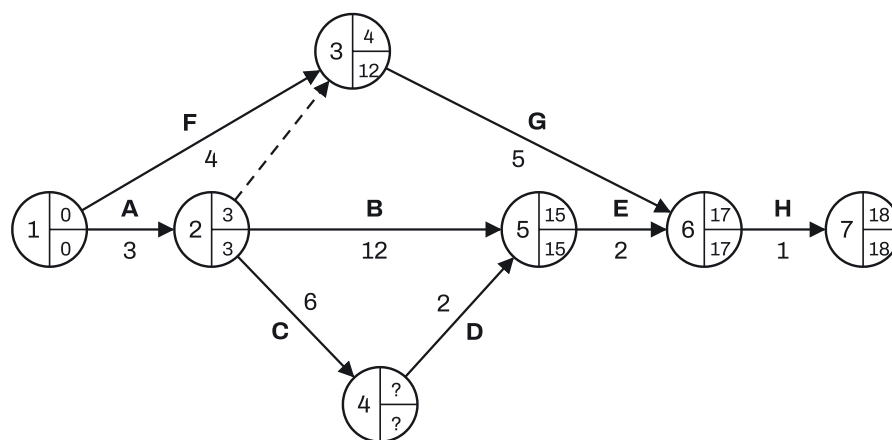
Worked examples

Example 1

Riverbend Brewery (RB) is adding a canning line so that it can sell beer in cans as well as kegs. Times are in weeks.

Activity	Task	Must wait for	Weeks
A	Choose the machine supplier	–	3
B	Machine built and shipped by the supplier	A	12

Activity	Task	Must wait for	Weeks
C	Extend the building	A	6
D	Fit drains and power	C	2
E	Install the canning line	B, D	2
F	Design the can artwork	–	4
G	Order printed cans (needs the artwork, and the can size from the chosen supplier)	A, F	5
H	Trial run	E, G	1



(a) Fill in the earliest start time and the latest finish time at node 4. **[2]**

(b) State the shortest time in which the canning line can be ready. **[1]**

(c) Calculate the total float of the can order (G). **[3]**

(d) Calculate the free float of the artwork design (F), and explain what your answer means for RB. **[4]**

(a) EST: node 2 is at 3 and C takes 6, so $3 + 6 = 9$ (1). LFT: only D leaves node 4, and node 5's LFT is 15, so $15 - 2 = 13$ (1).

(b) The final node's EST: 18 weeks (1). Check: the critical path A, B, E, H gives $3 + 12 + 2 + 1 = 18$.

(c) Total float = LFT of end node – duration – EST of start node (1) = $17 - 5 - 4$ (2) = 8 weeks (3).

(d) Free float = EST of end node – duration – EST of start node (1) = $4 - 4 - 0$ (2) = 0 weeks (3).

What it means: if the artwork (F) is even one week late, ordering the cans (G) has to start late too (1). But F's total float is $12 - 4 - 0 = 8$ weeks, so the trial run, and the whole project, is not delayed unless the artwork and the can order between them lose more than 8 weeks.

Example 2

Tidewater Tents (TT) makes two standard designs of tent on a single production line, with 40 permanent staff. The line can make 1,200 tents a month. From October to March orders average 300 tents a month, so staff spend much of their time making tents for storage. From May to August orders reach 2,100 a month; staff work overtime at time and a half, and shops still run out. Last year TT turned down three orders from music festivals, worth a total of 54,000 dollars, because the festivals wanted their own logo printed on every tent and TT's line can only make its two designs.

Analyse how TT could increase its flexibility of volume and of specification. [8]

Volume: a mix of staff contracts. Volume flexibility means being able to raise or cut output as demand changes (K). TT's orders swing from 300 a month in winter to 2,100 in summer, but its line can make only 1,200 and every one of its 40 staff is permanent (App). TT could keep a smaller permanent core and take on seasonal workers for a second summer shift, so that in winter it pays for fewer hours that only produce tents for the warehouse, and in summer it adds capacity without paying time and a half (An). Wage costs then rise and fall with sales; fewer tents sit in storage over the winter, and in summer the extra shift means shops are restocked instead of losing sales to rivals, so profit rises in both seasons (An).

Specification: digital printing. Specification flexibility means being able to change a product's features to suit the buyer (K). TT lost 54,000 dollars of festival orders because its line makes only two fixed designs (App). If TT adds a computer-controlled fabric printer at the end of the line, a logo designed on screen can be printed on to the standard tent, so each festival gets its own tents while the line itself carries on making the same two designs (An). TT can then accept orders like these, charge a higher price for personalised tents, and spread its fixed costs over more output, so revenue and profit rise (An).

$2K + 2App + 4An$ (a developed chain on each kind) = 8. No judgement is needed.

Example 3

Use RB's network from Example 1. A supermarket chain has agreed to stock RB's canned beer from week 20. RB's head brewer drew the network; RB has never installed a canning line before. The 12 weeks for B is the overseas machine supplier's own estimate, which includes six weeks at sea. A local builder, who has done two earlier jobs for RB and finished both on time, gave the 6 weeks for C. The artwork (F) will be done by RB's own marketing assistant.

To what extent will critical path analysis (CPA) reduce the risk that RB misses its week-20 start with the supermarket? [12]

Knowledge. CPA draws all the activities of a project in their order on a network, so that managers can see which activities have no slack (the critical path), how much spare time the others have, and the shortest time the project can take (K). This lets managers decide where a delay would matter and when each task should start (K).

Application. The shortest time is 18 weeks against the supermarket's week 20, so RB has 2 weeks in hand (App). The machine (B, 12 weeks) is on the critical path, while the can order (G) has 8 weeks of total float and the building work (C) has $13 - 6 - 3 = 4$ (App).

For. CPA shows RB that the machine's 12 weeks matter more than anything else, so RB can ask the supplier for a fixed shipping date and weekly updates; if the ship is delayed, RB hears about it while there are still 2 spare weeks and time to pay for faster freight, so the supermarket start is kept (An). It also shows that the can order cannot start before week 4 and can start as late as week 12 without delaying the trial, so RB can pay the can printer later and keep its cash for the machine (An).

Against. The most important number on the network is an estimate from outside RB. Six weeks at sea can easily stretch by two or more, and RB, which has never done this before, has no past job to check the 2-week installation and the 1-week trial against; if the shipping, installation and trial overrun by more than the 2 spare weeks between them, the line misses week 20 even though the network said 18 (An).

Judgement. CPA does reduce the risk, and by more than for a routine job, because RB has only 2 weeks to spare and the network shows exactly which activities would use them up: the machine, its installation and the trial, not the building work or the cans (Eval). It cannot remove the risk, because the biggest single threat is a shipping delay that RB does not control, and the installation and trial times are the guesses of a brewer with no experience of canning lines (Eval). How much CPA helps depends on whether RB acts on it: checking the supplier's progress each week, agreeing a back-up such as air freight in advance, and asking the machine supplier's engineers to help with the installation so that E is less likely to overrun. The builder's good record and the 4 weeks of float on C mean RB should spend its attention on B, E and H (Eval).

The marks: 2 K, 2 App, 2 An, and 6 Eval for a judgement about RB that weighs what CPA shows against what it cannot control, and says what its value depends on.

Example 4

Fernhill Kitchens (FK) makes fitted kitchen units to order: about 4,000 units a year. Customers wait 9 weeks for delivery; FK's two main rivals deliver in 5. FK holds 240,000 dollars of boards and fittings, about four months' supply, because each long production line makes large batches of one unit type. 7% of units are found faulty at the end of the line and must be rebuilt, at an average cost of 90 dollars each. Each order is written on a paper job sheet for the workshop and also entered in the sales office's spreadsheet; last month two customers changed their measurements by phone, the spreadsheet was changed but the job sheets were not, and both kitchens had to be rebuilt. FK has 100,000 dollars of cash; its gearing is already 55%. Its directors can afford only one of two plans this year.

- **Plan 1: ERP.** Cost 150,000 dollars, plus a licence of 20,000 dollars a year. The software seller estimates savings of 60,000 dollars a year.
- **Plan 2: lean production.** Reorganise the workshop into cells, train staff, start quality circles, and buy boards just in time from a supplier 20 km away that delivers twice a week. Cost 45,000 dollars; FK's own estimate of savings is 30,000 dollars a year. FK expects board stock to fall to 80,000 dollars.

Evaluate which of the two plans FK should carry out first. [12]

Knowledge. ERP gives every department one shared database, so an order entered once updates the stock, the production plan and the accounts at the same time (K). Lean production aims to use the least possible amount of every input; here it would use cells, quality circles and JIT deliveries (K).

Application. Plan 1 saves $60000 - 20000 = 40000$ dollars a year on the seller's figures, so it pays back in $150000 \div 40000 = 3.75$ years; Plan 2 pays back in $45000 \div 30000 = 1.5$ years (App). FK rebuilds $4000 \times 0.07 = 280$ units a year, costing $280 \times 90 = 25200$ dollars, and Plan 2 would cut stock by $240000 - 80000 = 160000$ dollars (App).

For Plan 1. With one database, a change taken by the sales office reaches the workshop at once, so kitchens are no longer made to the wrong size; the cost of rebuilding them and the damage to FK's name both disappear (An).

For Plan 2. Teams that build whole units and check their own work see their faults straight away, and circles can find out why 7% are rebuilt; each unit avoided saves 90 dollars and frees time to build new orders, which helps cut the 9-week wait (An). Twice-weekly deliveries replace four months of stock, releasing cash and floor space (An).

Judgement. FK should start with Plan 2. It tackles the problems customers notice most, the 9-week wait and the faults, and it is affordable: it costs 45,000 dollars of FK's 100,000 dollars, while Plan 1's 150,000 dollars would mean more borrowing on top of 55% gearing (Eval). Plan 2 also prepares the way for Plan 1: if stock really falls by 160,000 dollars, FK will have about $100000 - 45000 + 160000 = 215000$ dollars of cash, enough to buy the ERP next year without borrowing, and JIT is easier to run once ERP orders boards automatically (Eval). The risks are that the 30,000-dollar saving is FK's own estimate, that staff used to long lines may take months to work in cells, and that JIT depends on the local supplier's reliability; meanwhile, until ERP arrives, FK should fix the wrong-measurement problem cheaply by making one person responsible for changing the job sheet whenever a customer changes an order (Eval).

The marks: 2 K, 2 App, 2 An, and 6 Eval for a decision in FK's context that compares the two plans on cost, finance and the problems they solve, and says what the choice depends on.

Common mistakes

- **EST and LFT in the wrong places, or the same number in both** (March 2022). The EST goes at the top right of the node and the LFT at the bottom right; they come from two different passes, so they are only equal on the critical path.
- **Random numbers, or extra nodes** (March 2025). Some answers drew a new node or put guesses in the nodes. Fill in the printed node, using the forward pass for the EST and the backward pass for the LFT.
- **Forgetting the dummy.** Many could not find the critical path, or the EST of a node, because a dummy carried a dependency they missed (March 2022, November 2022). Treat every dummy as an activity of length 0 in both passes.
- **The wrong route to an EST** (June 2021). Many gave an EST from the wrong chain of activities. Check every arrow into the node and take the largest total.

- **A float with no working** (June 2021). A wrong answer with no working scores nothing, while the formula alone earns a mark. Write the formula, then the numbers, then the answer.
- **Right formula, wrong numbers** (March 2025). The LFT (or, for free float, the EST) comes from the node at the **end** of the activity's arrow; the other EST comes from the node at its **start**.
- **Writing about the project instead of CPA** (June 2021). Some answers judged whether the new machines would help the business, not how CPA helps install them. Weak answers also only defined CPA and repeated the diagram's numbers; name specific activities and floats and say what managers would do with them (March 2025).
- **A limitation that would fit any business** (June 2021). "CPA cannot guarantee success" is weak; "the network was drawn by a manager with no experience of such a project" is strong.
- **Not knowing what ERP is** (June 2021). Many answers quoted the case or thought ERP was a person (an "ERP specialist"). Say it is software that links every department's data in one place.
- **Using ARR as the only application** (March 2023). Compare the ARR with the business's return on capital employed, add payback, and tie the decision to finance and gearing.
- **Writing about product innovation when the question says process** (June 2022). Process innovation is about how the product is made or delivered.
- **Giving advantages when only disadvantages were asked for** (June 2021). They earn nothing.
- **Ignoring your own calculation in a lean question** (March 2021). Use the inventory turnover or defect figure you worked out, and remember the downside: JIT cannot cope with a sudden jump in orders without close, reliable suppliers.
- **Treating "operational flexibility" as flexibility between departments** (March 2022). Use volume, delivery time and specification, with examples such as mass customisation.
- **Offering SWOT or PEST as an operations strategy** (June 2023). They are ways to analyse a situation; an operations strategy is about methods such as lean production, ERP, CPA and process innovation.

How to get the marks

- **Command words.** *Calculate*: formula, working, answer. *State* or *identify*: the answer alone is enough. *Analyse*: the number of points asked for, each with a chain of two or more links to costs, revenue or profit, and no judgement. *Evaluate*, *Assess*, *Discuss*, *To what extent*, *Advise*: both sides, then a decision for this business with reasons and what it depends on.
- **Calculations**: each step usually earns a mark, and later method marks follow your own earlier answers.
- **[8] analyse two**: 2 K (a definition earns at most one), 2 App (one per point), 4 An (a developed chain on each point). One paragraph per point; extra points are not rewarded.
- **[12] evaluate on Paper 3**: 2 K, 2 App, 2 An, 6 Eval. The top level needs a judgement **in context**, using the case's facts and your own calculated figures; a conclusion that could be written about any business stays below it.
- **[20] on Paper 4**: 3 K, 2 App, 8 An, 7 Eval. Explain one term fully first, since nothing else counts without a K mark; analyse two elements on both sides; finish by weighing the elements, other causes and what the result depends on.

- **Precise terms in your own words:** ERP as one shared database for all departments; lean as using the least of every input; Kaizen as small improvements by everyone, all the time; process innovation as a change in how, not in what; total float against the finish date, free float against the next activity.
- **Use the case's numbers:** the gap between the minimum duration and the deadline, the float on a named activity, a defect rate, inventory turnover, ARR against the return on capital employed.
- **"Sufficient", "ensure" and "which first"** all need a comparison: what else is needed, and why the method alone cannot guarantee the result.

Quick check

1. A project has five activities (days): P 3 (no predecessor), Q 5 (after P), R 2 (after P), S 4 (after R), T 1 (after Q and S). Find the minimum project duration and the critical path, and calculate the total float and the free float of Q.
2. Volume, delivery time or specification? (a) A bike shop promises repairs within 24 hours. (b) A sportswear brand lets buyers choose the colour of every part of a trainer online. (c) An ice-cream maker takes on 30 extra staff each summer.
3. Name the lean strategy: (a) a toy maker's designers, engineers and buyers work together on a new toy from the first day; (b) orders for wedding flowers are made up only after the couple confirms, with flowers delivered that morning; (c) six assemblers build complete lawnmowers in one area and test each one themselves; (d) cleaners at a hotel meet every two weeks to decide why rooms are being finished late, and suggest a new trolley layout.
4. Which ERP efficiency area does each problem call for? (a) A printer's quotes take three days because nobody knows the cost of each job. (b) A factory's machines are idle on Mondays and overloaded on Fridays. (c) A café keeps running out of milk while other items go out of date.
5. Product or process innovation? (a) A cinema replaces its ticket desk with online booking and tickets scanned from phones. (b) A drinks maker launches a sparkling tea. (c) A courier uses AI to plan its vans' routes.

Answers

1. ESTs: P ends at 3; Q ends at $3 + 5 = 8$; R ends at $3 + 2 = 5$; S ends at $5 + 4 = 9$; T can start at the larger of 8 and 9, which is 9, and ends at 10. Minimum duration: 10 days; critical path P, R, S, T ($3 + 2 + 4 + 1 = 10$). Q runs from the node with EST 3 to the node where T starts (EST 9, LFT $10 - 1 = 9$). Total float of Q $= 9 - 5 - 3 = 1$ day; free float $= 9 - 5 - 3 = 1$ day.
2. (a) Delivery time. (b) Specification. (c) Volume.
3. (a) Simultaneous engineering. (b) JIT manufacturing. (c) Cell production. (d) Quality circle.
4. (a) Costing and pricing. (b) Capacity utilisation. (c) Inventory control.
5. (a) Process: viewers see the same films, but buy and show their tickets a new way. (b) Product: the drink itself is new. (c) Process: the delivery service is the same, but it is planned a new way.

Past questions to try

- 9609/32/F/M/25 Q4: complete two nodes and a total float, then the benefit of CPA as a management tool.
- 9609/31/O/N/23 Q3: minimum duration and a total float, then whether CPA will meet an objective.
- 9609/32/F/M/23 Q4: ARR on an ERP system, then whether to invest in it.
- 9609/42/F/M/24 Q2: advise a business on an operations strategy for survival and growth.