INSTITUTE AND FACULTY OF ACTUARIES

EXAMINATION

4 October 2019 (am)

Subject CP2 – Modelling Practice
Core Practices

Paper Two

Time allowed: Three hours and fifteen minutes

INSTRUCTIONS TO THE CANDIDATE

1. *You are given this question paper and the Excel file.*

2. *Mark allocations are shown in brackets.*

3. *Attempt all questions. Questions are to be answered as per "exam requirements".*

If you encounter any issues during the examination, please contact the Examinations Team at
T. +44 (0) 1865 268 255

© Institute and Faculty of Actuaries

Exam requirements

1 Read the background document, which describes the scenarios that have been modelled and documented for this project.

2 Read the audit trail which has been written by your colleague, another actuarial student, for the calculations that they performed. This will assist you in following and understanding the calculations performed in the Excel model provided.

You are not required to add to or amend the audit trail.

You should assume that your colleague's calculations have been checked and are correct.

3 Expand the spreadsheet model to produce the required calculations for the additional scenarios. You should ensure that the additional work you undertake on the spreadsheet contains appropriate self-checks. The model should include the following:

(i) The effect on the initial projections if ABC increases the number of parcels to be delivered to 650 per day. [4]

(ii) The impact of having the same fixed price paid per driver per delivery. This price needs to earn the target profit 100% of the time on the original number of deliveries (determined for the 'most deliveries' allocation option only). [5]

[Total 9]

4 Construct, for each of the following, a suitable chart (or charts) to illustrate:

(i) for both allocation options in Scenario 1, the range of profit outcomes for each simulation versus ABC's target profit

(ii) a comparison of the amounts paid per parcel for each of the drivers under Scenario 1 and Scenario 4.

[8]

[Sub-total 17]

5 Prepare a summary document of around five to seven pages, capturing the main features and results of the work completed by you and your colleague. You can assume that the summary is being prepared for your boss, a senior actuary, who will present the work to the Chief Executive Officer (CEO) of ABC Parcel Delivery Company.

Your summary should include the following:

- purpose of the project, data, assumptions and method used by you and your colleague
- results, including charts
- commentary on the results
- key conclusions
- suggested next steps.

Commentary on the results should cover, but not be limited to:

- analytical comments on each stage of the results, including explaining patterns in the results and any unusual features
- an explanation of the differences between the results under the various scenarios modelled.

Next steps need to be specific to the project, with some mention of why each step is valid.

The summary should cover the full scope of the project, including the scenarios which were modelled in the spreadsheet provided.

Marks available for the summary:

Methodology (including purpose, data, assumptions and method)	[25]
Results, including charts	[5]
Commentary on results and conclusions	[23]
Next steps	[20]
Drafting	[10]

[Sub-total 83]

[Total 100]

Background

ABC Parcel Delivery Company (ABC) is looking to set itself up as a competitive and profitable parcel delivery company.

ABC currently employs four drivers to deliver parcels. Each driver can deliver a different maximum number of parcels per day and receives a different fixed payment per parcel delivered. If the proposed allocation of parcels for a driver on a given day is less than the driver's minimum, then no parcels are allocated to that driver for that day.

An extra driver is available to pick up any surplus parcels not allocated to the other drivers – this driver has no minimum or maximum allocation.

The payment amounts per parcel, and the expected maximum and minimum parcels that can be delivered for each driver are:

Driver	*Amount paid per parcel ($)*	*Minimum number of parcels*	*Maximum number of parcels*
I	2.25	40	50
II	1.25	100	500
III	3.5	75	200
IV	3	100	700
V (only if any surplus parcels)	3	N/A	N/A

Customers pay ABC $5 for each parcel delivered. ABC expects to deliver 550 parcels each day.

ABC has a target profit, per day, of $1,450.

The CEO of ABC has contacted your boss to assess ABC's target profitability in various scenarios.

The CEO of ABC has expressed a concern that there is some uncertainty over the maximum number of parcels that a driver can deliver in a day. The maximum number of parcels that can be delivered can be adversely affected by a range of outside factors such as road traffic levels, roadworks, driver sickness etc. The CEO of ABC would like the assessment of whether ABC can reach its target profit to allow for the uncertainty of the maximum number of parcels which can be delivered by each driver.

Your boss has suggested using a random number generator to help assess the uncertainty in the maximum number of parcels that can be delivered by each driver. These random numbers are assumed to have a Uniform (0,1) distribution. 100 simulations should be modelled, whereby the adjusted maximum number of parcels that can be delivered in a simulation is determined by taking a random number and multiplying it by the maximum number of parcels for each driver each day, with the minimum number of parcels applied as a minimum. Your boss has asked that you project the potential range of earnings per day based on 100 simulations for each driver (I to V) for the various scenarios to be assessed.

The CEO of ABC has asked that the following scenarios are assessed:

Scenario 1

Two allocation options have been considered by ABC:

(a) Allocate parcels to the cheapest drivers first from drivers I to IV in order of which driver has the lowest cost per parcel, with any remaining parcels going to Driver V.
(b) Allocate parcels to the drivers I to IV in order of who has the highest maximum number of parcels, with any remaining parcels going to Driver V.

Scenario 2

For both allocation options in Scenario 1, assume Drivers I and II both have problems with their vehicles and so are only able to make half the expected maximum number of deliveries. (For this scenario also assume that the minimum number of parcel deliveries for Drivers I and II also halves.)

Scenario 3

For both allocation options in Scenario 1, assume an increase in the total number of parcels per day from 550 to 650. Assume all other parameters are as in Scenario 1.

Scenario 4

For allocation option (b) in Scenario 1, assume all drivers are paid the same amount for each parcel delivered. Your boss has suggested that this should be calculated by determining the maximum amount that could be paid per driver per delivery to ensure that ABC reach their target profit 100% of the time (based on the fixed random numbers provided).

Modelling requested

To provide the information for the CEO of ABC, your boss asked your colleague to produce a model to determine the following:

(i) For Scenario 1, determine the number of simulations for which the ABC target profit is reached assuming the parcels are allocated to the cheapest driver first (i.e. 'cheapest driver' Scenario 1(a)).
(ii) For Scenario 1, determine the number of simulations for which the target profit is reached assuming the parcels are allocated to the driver who has the highest maximum first (i.e. 'most deliveries' Scenario 1(b)).
(iii) For Scenario 2, repeat the calculations carried out for (i) and (ii) assuming both Drivers I and II have problems with their vehicles (i.e. Scenarios 2(a) and (b)).
(iv) For Scenario 3, repeat the calculations carried out for (i) and (ii) assuming the number of parcels to be delivered increases from 550 to 650 (i.e. Scenario 3(a) and (b)).
(v) For Scenario 4, repeat the calculations carried out for (ii) but determine (using goal seek) the fixed payment per delivery for all five drivers in order for ABC to reach their target profit 100% of the time (i.e. Scenario 4).

Unfortunately, your colleague has been taken ill before being able to complete the modelling required. They have developed a spreadsheet covering steps (i)–(iii) above, and produced a first draft of an audit trail for the calculations which have been completed. Your boss has asked you to complete the outstanding work, using the existing model as your starting point.

Your boss would also like you to construct, for each of the following, a suitable chart or charts that illustrate:

(i) the profits for each simulation compared to ABC's target profitability for Scenarios 1(a) and (b)

(ii) the amount paid per driver per parcel in Scenario 1 compared to the fixed amount for all drivers that was determined in Scenario 4.

Finally, your boss needs you to prepare a summary document covering all elements of the work (both the original work your colleague completed and the additional modelling you are undertaking).

Your summary should include the following:

- purpose of the project, data, assumptions and method used by you and your colleague
- results, including charts
- commentary on the results and key conclusions
- suggested next steps.

You are not expected to add to or amend the audit trail, but a description of the method for both the existing and your additional modelling and results should be included in the summary.

Audit trail

The following audit trail should be read alongside the model provided.

Objective

ABC Parcel Delivery Company is a newly established company offering parcel deliveries within their local area.

The CEO of ABC would like to understand whether, given their current charging structure and expectations on number of parcels to be delivered, they will reach their target daily profit.

The purpose of the spreadsheet is to project the profit under 100 simulations, for four scenarios.

Note: highlighted cells do not copy across.

"Parameters" worksheet

This worksheet details the inputs used in the scenarios.

The CEO of ABC provided the following information:

- the minimum number of deliveries per driver, as well as the maximum allocation per day – shown in the table below
- the price paid to each driver per parcel delivered – shown in the table below
- total number of parcels to be delivered per day – 550
- price ABC charges to deliver each parcel – $5.

Driver	*Price paid per parcel ($)*	*Minimum number of parcels*	*Maximum number of parcels*
I	2.25	40	50
II	1.25	100	500
III	3.5	75	200
IV	3	100	700
V (only if any surplus parcels)	3	No minimum	No maximum

The statistics department within the actuarial firm provided 400 random numbers, four sets of 100 numbers for each driver.

A check on the random numbers has been completed by drawing a graph to ensure that they are all in the range 0 to 1.

Assumptions

- Data provided by ABC is correct and accurate for modelling purposes.
- Number of parcels are rounded down to next lowest integer.
- 100 simulations is sufficient to provide a good indication of possible options to draw conclusions on profitability of the company.

"Number of parcels delivered" worksheet

This worksheet is used to determine the number of parcels each driver could potentially deliver under each simulation.

Columns A to H show the number of parcels to be delivered by each driver under each of the simulations.

For each driver the number of parcels delivered is calculated as the greater of that driver's minimum number of parcels and the relevant random number multiplied by the maximum number of parcels that driver would deliver. Note that only full numbers of parcels can be delivered so all numbers are rounded down.

The total number of parcels to be delivered is calculated in column F as the sum of the four drivers' amounts in each row.

Checks are completed in columns G and H, column G checks that the total number of parcels is greater than or equal to 0. Column H checks that the total number of parcels is not greater than the sum of all four drivers' maximum parcel delivery.

Columns J to Q calculate the number of parcels under Scenario 2, where Drivers I and II have vehicle problems so the number of parcels is reduced to half those in columns B and C. Columns M and N (the number of parcels for Drivers III and IV) are the same as columns D and E.

This sheet does not limit the number of parcels to 550, as these allocations are completed in the next sections.

"Cheapest driver first" worksheet

This worksheet is used to determine the profit under each simulation based on allocating the parcels to the drivers in order of price paid per parcel.

Columns A to G determine the number of parcels allocated to each driver.

As Drivers I and II are the cheapest, allocate them the full amounts of parcels from the "number of parcels delivered" worksheet. We know both drivers will need to be used because the sum of the maximum for these drivers is equal to 550 based on the initial table, which is the total number of parcels to be allocated.

Column E calculates the number of parcels for Driver IV – this is calculated as:

- the minimum of the number of parcels to be allocated to the driver from "number of parcels delivered" worksheet; and
- the possible maximum parcels remaining from that available to what has already been allocated, i.e. 550 less number of parcels allocated to Drivers I and II.

Column D does a similar calculation for Driver III, but allowing for any allocation to Driver IV as well as I and II.

Column F calculates the total number of parcels allocated to the four drivers by summing the amounts in the row.

Column G allocates any remaining parcels to Driver V as the total number of possible parcels (550) less the total in column F.

Columns J to T determine the profit that ABC will earn for each simulation.

Column K calculates the Income earned as the total number of parcels (550) × $5 per parcel – these are taken from the parameters sheet.

Columns L to P then calculate the amounts to be paid to each driver based on the number of parcels they deliver. This is calculated by taking the number of parcels from columns B–E and G multiplied by the relevant price per driver from the parameters sheet.

Column Q calculates the total amount paid to the drivers as the sum of columns L to P.

Column R calculates the profit as income – expense, this being column K less column Q.

Column S then flags if the profit is greater than the target profit amount.

Columns V to X contain some summary information on the simulation results. Maximum profit is calculated in cell W4 as the maximum of the results in column R. Cell X4 uses the MATCH function to highlight which simulation this was from. Similarly, in W5 the minimum of the results in column R is shown using the MIN function. Cell X5 uses MATCH to show the simulation which generates this figure. Cell W6 shows the average profit amount – using the AVERAGE function.

Cell W12 shows the number of simulations where the profit achieved is greater than the target, using the COUNTIF function.

Cell W13 converts this into a percentage based on the number of simulations.

"Most deliveries" worksheet

This worksheet shows the profit calculations for 100 simulations assuming the parcels are allocated to the drivers who could deliver the most parcels first (before "uncertainty adjustment"), i.e. allocated to Driver IV, then II, then III and finally I.

Columns B to E (containing the formulae allocating parcels to drivers) have been changed from the previous worksheet.

Column E calculates the allocation to Driver IV as the minimum of the total number of parcels available to deliver (i.e. 550) and the number generated within column E of the "number of parcels delivered" worksheet.

Column C calculates the number of parcels for Driver II as either the lower of the remainder of the parcels to be delivered and the number calculated within column C of the "number of parcels delivered" worksheet, or zero if this is below the minimum delivery quantity.

Column D calculates in a similar manner to column C but also allowing for any parcels allocated to Driver II.

Column B finally allocates any remaining parcels to Driver I.

Any surplus parcels are allocated to Driver V in column G.

All remaining calculations in this worksheet are as per the "Cheapest driver first" worksheet.

"Cheapest driver (car issues)" worksheet

This worksheet calculates the impact on results if both Drivers I and II experience difficulties and are only able to deliver half their original potential.

This worksheet is a copy of the "cheapest driver first" worksheet – the only difference is that the lookups from the "number of parcels delivered" sheet looks at the second table in columns K to N.

"Most deliveries (car issues)" worksheet

This worksheet calculates the impact on results if both Drivers I and II experience difficulties and are only able to deliver half their original potential.

This worksheet is a copy of the "most deliveries" worksheet – the only difference is that the lookups from the "number of parcels delivered" sheet looks at the second table in columns K to N.

END OF PAPER