CAA GLOBAL

EXAMINATION

18 October 2023 (am)

Module 5: Models and Audit Trails

Time allowed: Three hours and fifteen minutes

INSTRUCTIONS TO THE CANDIDATE

1. You are given this question paper and an 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 Assessment Team on T. 0044 (0) 1865 268 873.

Background

A researcher at a university is performing a mortality study on a group of insects. The researcher has asked you to help create a model that performs some useful analysis. They have already started to produce life tables for the insects and have provided the number living (l_x) for ages $0 \leq x \leq 25$ where x is measured in days. For both tables the starting value (or radix), l_0, is 10,000. There are separate tables for males and females. They have also provided details of the current population of insects being studied. The current population consists of 30 insects.

The researcher would first like you to expand the life tables by adding columns for d_x, q_x and p_x (see actuarial notation definitions under 'Additional guidance'). They would also like you to produce a calculation sheet that can be used by their students. The calculation sheet should calculate ${}_{n|m}q_x$, i.e. the probability that an insect aged x will survive for n days but die during the subsequent m days. The calculator should use inputs that the student can vary for x, n, m and the sex of the insect.

Using the population data, the researcher would like you to produce a chart that illustrates the demographic mix (i.e. the number of insects split by 5 day age group and sex). They would also like the model to calculate the approximate expectation of life for each insect in the population.

Finally, the researcher thinks that by increasing the temperature of the insects' tank their mortality could be reduced. They estimate a reduction factor of 20% for males and 15% for females, which would be applied as follows:

For $0 \leq x < 25$, $q_x^{\text{reduced}} = (1 - \text{reduction factor}) \times q_x$

For $x = 25$, $q_x^{\text{reduced}} = q_x$.

They would like you to create a new life table reflecting this reduced mortality. The life tables should use the same starting value as the original tables, i.e. $l_0 = 10{,}000$ for both males and females.

Additional information

When performing the calculations you should assume the following:

- Population ages are exact.
- Insects are either male (M) or female (F).

PART 1

(i) Construct a spreadsheet model. Include separate worksheets for data, data checks, parameters, life tables, q_x chart, calculator, demographic mix chart, expectation of life, adjusted life tables and any other worksheets as required. [2]

(ii) Carry out a range of checks on the data provided and comment on whether the data appears to be sensible, given the information that has been provided. You are NOT required to make any alterations to the data. [4]

(iii) Identify and set out the parameters for the model you are going to use in the 'parameters' worksheet. [2]

(iv) Create two life tables, one for male insects and one for female insects, which have columns for l_x, d_x, q_x and p_x for ages $0 \leq x \leq 25$ in the 'life tables' worksheet. [4]

(v) Plot a single chart showing q_x separately for male insects and female insects for ages $0 \leq x \leq 25$ in the 'qx chart' worksheet. [3]

(vi) Create a calculator sheet that calculates ${}_n|m q_x$ (i.e. the probability that an insect aged x will survive for n days but die during the subsequent m days) using user inputs for x, n, m and the sex of the insect.

[**Note:** See 'Additional guidance'.]

[5]

(vii) Plot a single chart showing the number of insects in each 5 day age group (i.e. 0–5, 6–10, 11–15, 16–20 and 21–25) separately for male insects and female insects in the 'demographic mix chart' worksheet. [5]

(viii) Calculate approximately the complete expectation of life for each insect in the population in the 'expectation of life' worksheet.

[**Note:** See 'Additional guidance'.]

[5]

(ix) Create a life table for male insects that has columns for l_x, d_x, q_x and p_x for ages $0 \leq x \leq 25$, and reflects the reduced mortality resulting from increasing the temperature of the tank in the 'adjusted life tables' worksheet. [5]

(x) Create a life table for female insects that has columns for l_x, d_x, q_x and p_x for ages $0 \leq x \leq 25$, and reflects the reduced mortality resulting from increasing the temperature of the tank in the 'adjusted life tables' worksheet. [2]

Marks available for spreadsheet model:

Model accuracy, completeness and good modelling techniques and data validation of initial data (part (ii)). [37]

Reasonableness and automated checks, other than in part (ii). [5]

[Sub-total 42]

PART 2

You need to document all your work in an audit trail so that a fellow analyst student (with similar experience to yourself) could:

- peer review and check your model.
- continue to work on your model.
- run your model on different assumptions or extend your model to allow for extra data fields or scenarios.

Your audit trail should include the following aspects:

- The purpose of the model
- A description of the data used
- Any assumptions you have made
- Any limitations of your assumptions or of the model
- Your methodology, i.e. a description of what you have done to calculate the required values, and how and where in the model you have done it
- An explanation of all the checks you have performed
- Your key results
- A description of the charts you have produced.

The audit trail should be in a separate Word document.

Marks available for audit trail:

Audit approach

- Fellow analyst student can review, check and modify the model. [8]
- Written in clear English. [4]
- Written in a logical order. [3]

Audit content

- All model steps accurately included. [21]
- All checks clearly recorded. [8]
- All steps clearly explained. [8]
- Clear signposting and labelling. [6]

[Sub-total 58]

[Total 100]

Additional guidance

Notation

l_x	the number of insects who attain age x according to the mortality table.
$d_x = l_x - l_x + 1$	the number of insects who die between ages x and $x + 1$ according to the mortality table.
p_x	the probability that an insect aged x will live 1 year.
$q_x = 1 - p_x$	the probability that an insect aged x will die within 1 year.
e_x	the curtate expectation of life of an insect aged x.
${}_np_x$	the probability that an insect aged x will live n years.
$\mathring{e}_x$	the complete expectation of life of an insect aged x.
${}_{n\|m}q_x$	the probability that an insect aged x will survive for n years but die during the subsequent m years.

Useful formulae

$$e_x = \sum_{k=1}^{25-x} {}_kp_x$$

$$\mathring{e}_x \cong e_x + {}^1/_2$$

$${}_{n|m}q_x = \frac{l_{x+n} - l_{x+n+m}}{l_x}$$

END OF PAPER