10

Worked example – Paper 1

0   Introduction

This chapter contains an example project for CP2 Paper 1. It consists of the project specification and instructions, followed by a detailed solution.

The solutions are presented as a running commentary of the thought process that a well-prepared student might go through when working through this project. Extracts from the student's work are interspersed.

The complete audit trail is shown in Section 3.

The student's plan for the project is on page 9.

1   Example project – Paper 1

Exam requirements

1.   Read the background document, which describes the scenarios that need to be modelled and documented for this project.

2.   Construct a spreadsheet model that produces the following calculations and charts. You should ensure that your spreadsheet contains appropriate self-checks and that you have performed and documented robust reasonableness checks at each stage of your calculations.

   (i)   Carry out appropriate checks on the annuity factors provided.   [4]

   (ii)   Carry out the pension projections for the individuals shown in the table under each of the three scenarios.   [8]

   (iii)   Use your spreadsheet to extend the table given to show the following information:

   - age now

   - fund now

   - salary

   - the pension in the first year, expressed as a percentage of final salary, under each arrangement (annuity / drawdown) for each scenario.   [8]

   (iv)   Produce a graph showing a comparison of the pension percentages for the individuals in the table under each arrangement based on Scenario 2.   [5]

Note: All scenarios outlined above should be modelled separately within your spreadsheet. The user should not need to change the parameters to see the results.

Marks available for spreadsheet model and checks:

Accurate completion of above modelling steps   [25]
Demonstration of good modelling technique and practice   [7]
Checks (both automatic and reasonableness)   [8]

[Sub-total 40]

3.   Produce an audit trail for your spreadsheet model that includes the following aspects:

•   purpose of the model

•   data and assumptions used

•   methodology, *ie* a description of how each calculation stage in the model has been produced

•   explanation of the checks performed.

You should ensure that your audit trail is suitable for both a senior actuary, who has been asked to approve your work, and a fellow student, who has been asked to peer review and correct your model, or to continue work on it, or to use it again for a similar purpose in the future.

Marks available for audit trail:

Audit approach

Fellow student can review and check methods used in the model   **[8]**
Senior actuary can scrutinise and understand what has been done   **[8]**
Written in clear English   **[5]**
Written in logical order   **[4]**

Audit content

All steps clearly explained   **[10]**
Clear signposting included throughout   **[5]**
Statement of assumptions made   **[5]**
All model steps accurately covered   **[15]**

                                                                            [Sub-total 60]

                                                                            [Total 100]

Background

You have been approached by *LongerLives*, a company that provides advice on retirement options to employees who are contributing to personal pension plans.

In the past they have advised most of their clients when they reach retirement age to take out an index-linked annuity. Under this arrangement, the employee's entire fund built up by retirement is used to buy a pension for the remainder of their life, which will increase each year in line with inflation.

They are now offering a 'drawdown' option where the fund remains invested after retirement and the pensioner withdraws an amount directly from this fund at the start of each year to provide an income.

An analysis has produced the following table showing the typical profile of their clients. 'Fund now' indicates the fund the employee has already built up by the age indicated.

Age	Fund now (£K)	Salary (£K)
20	0	20
30	10	25
40	25	30
50	50	35
60	100	40

You have been asked to assist with a series of calculations to compare the projected pensions (expressed as a percentage of the client's salary at retirement) under each arrangement (annuity and drawdown) for the individuals in the table.

Under both arrangements, you should assume that retirement takes place at age 65 and the pension payments increase each year in line with inflation.

Technical notes

You have been provided with the following table of annuity factors. These are used to calculate the cost of buying a pension of £1 per annum under the annuity arrangement. The interest rate to use when using this table is the rate of inflation plus 1%.

	ANNUITY FACTORS (k +1%)			
AGE	2%	3%	4%	5%
55	22.4	20.5	18.7	16.9
60	20.6	19.0	17.3	15.6
65	18.9	17.4	17.3	14.3
70	17.2	15.8	14.4	13.0
75	15.5	14.2	13.0	11.7

Drawdown calculations are carried out on the assumption that everybody lives to exactly age 90.

It is assumed that all employees will contribute 15% of their salary between now and retirement.

The calculations are to be carried out on three different bases, as show in the table below. In each case, the values of these variables are assumed to remain constant in the future.

	SCENARIO		
VARIABLE	Scenario 1	Scenario 2	Scenario 3
Investment return (i)	4%	6%	8%
Salary increases (j)	3%	4%	5%
Inflation (k)	1%	2%	3%

Additional guidance sheet A – Illustration / formulae

The illustration below shows a breakdown of the calculations required to carry out the pension projections for Scenario 1 (working in £000s).

The formulae used here are as follows:

x = Current age

R = Retirement age

M = Maximum age (for drawdown)

i = Investment returns

j = Salary increases

k = Inflation

$$Factor 1 = (1+i)^{R-x}$$

$$Factor 2 = (1+i)^{R-x} + (1+j)(1+i)^{R-x-1} + \cdots + (1+j)^{R-x-1}(1+i)$$

$$= (1+i)\left[\frac{(1+i)^{R-x} - (1+j)^{R-x}}{i-j} \right]$$

$$Factor 3 = (1+i)\left[\frac{1 - \{(1+i)/(1+k)\}^{R-M}}{i-k} \right]$$

Illustration

Client details: Age now = 40, Fund now = 25, Salary now = 30

$Factor 1 = 2.67$, $Factor 2 = 59.49$, $Factor 3 = 17.99$

Salary at retirement (age 65) $= 30 \times 1.03^{25} = 63$
Projected fund at retirement $= 25 \times 2.67 + 15\% \times 30 \times 59.49 = 334$

Pension (annuity arrangement) $= 334/18.9 = 18$, *ie* 28%
Pension (drawdown arrangement) $= 334/17.99 = 19$, *ie* 30%

Additional guidance sheet B – Excel hints

You should treat the table of annuity factors as the data for this project.

2 Student's commentary

2.1 Getting started

Right, then. I've downloaded and printed out the instructions for the project.

I'll start by reading through the instructions carefully to make sure I understand what I have to do.

It's about personal pensions. I don't work in pensions, but I don't expect it will require any specialist knowledge of pensions and I can see that they've given a page of formulae to help with the calculations.

They're asking me to compare two types of pension arrangement – annuities and drawdown. I remember reading something about that in Subject CP1. I think they changed the rules on annuities a few years ago but I can't remember the details.

They've also given three scenarios in the table. So that will be similar to the other CP2 projects I've looked at.

2.2 Planning the project

OK, that gives me a good idea of what's going to be involved. I'll spend the next quarter of an hour doing a handwritten plan to map out how I'm going to set up the worksheets in my spreadsheet. I'll also include some checks I can apply and make a note of any issues I need to mention in my audit trail.
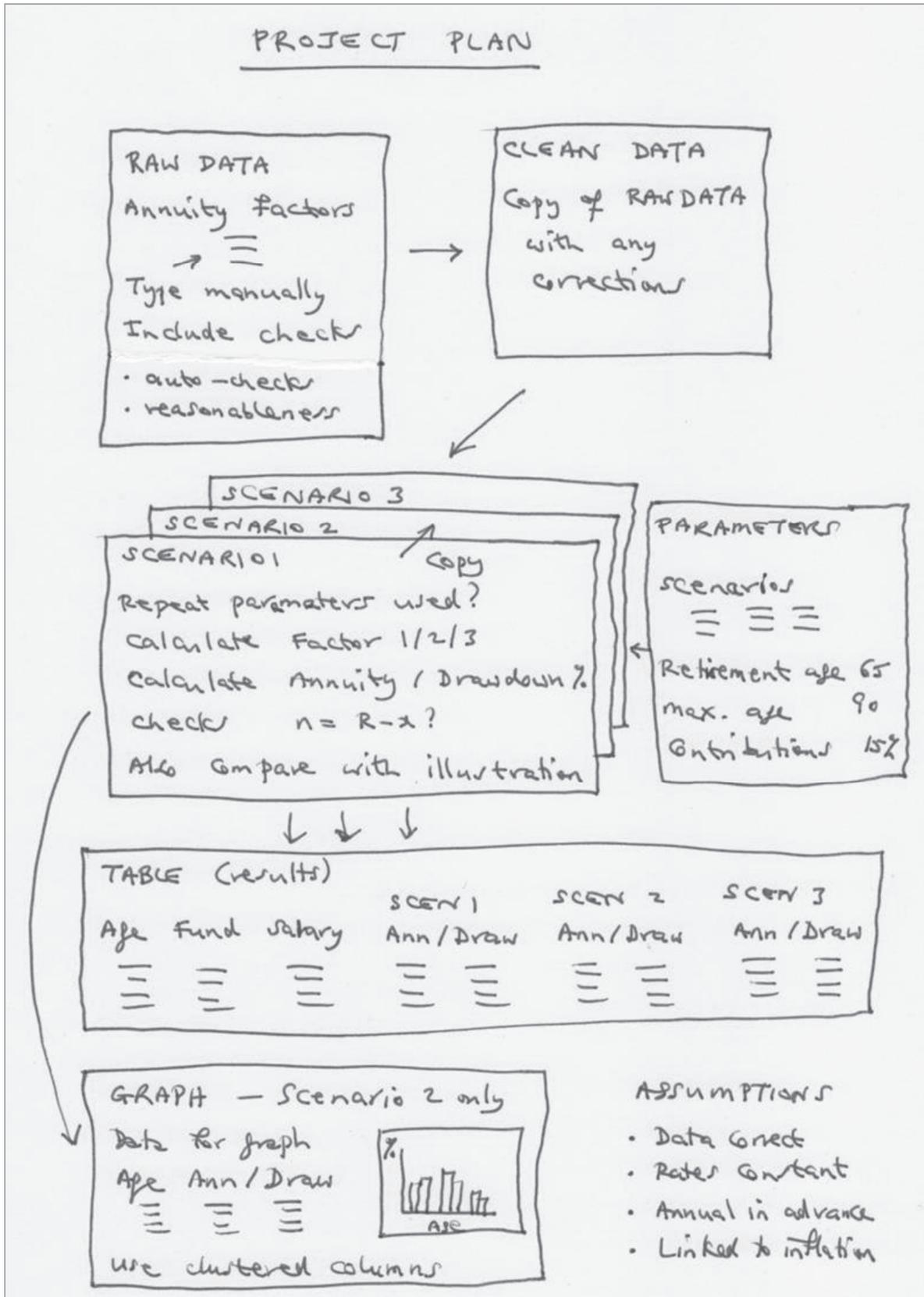
My tutor on the Preparation Day said that some people like to start their spreadsheet with an Overview tab with the basic information for the project and a list of the worksheets, but that this was an 'optional extra'. So I'll leave this till the end and not worry if I don't have time to do it.

[See **Project Plan** on the next page]

Next comes the data. Hmm. The instructions give quite a few tables of information, but I wouldn't really call those data. We don't have a list of employees with their dates of birth, or anything like that. Maybe the data is the small table with the client profile on the first page. I'm not sure.

Ah! I see it says in the Excel hints at the end that we should treat the table of annuity factors as the data. Part (i) also asks us to check the annuity factors. So I suppose that makes sense. They probably came from an insurance company or a table off the internet. So I'll make the annuity factors my data and apply some checks to the numbers.

2.3 Project plan

PROJECT PLAN

RAW DATA
Annuity factors
Type manually
Include checks
- auto –checks
- reasonableness

CLEAN DATA
Copy of RAW DATA
with any
corrections

SCENARIO 3
SCENARIO 2
SCENARIO 1   Copy
Repeat parameters used?
Calculate Factor 1/2/3
Calculate Annuity / Drawdown %
check   n = R–x?
Also compare with illustration

PARAMETERS
scenarios
Retirement age 65
max. age   90
Contributions   15%

TABLE (results)

Age	Fund	Salary	SCEN 1 Ann/Draw	SCEN 2 Ann/Draw	SCEN 3 Ann/Draw

GRAPH — Scenario 2 only
Data for graph
Age Ann/Draw
use clustered columns

ASSUMPTIONS
- Data correct
- Rates constant
- Annual in advance
- Linked to inflation

*Then there's the parameters. I can treat the information in the other tables as parameters.
There's the client profile table and the percentages in the table of scenarios. There's also the three
numbers – the retirement age (65), the drawdown that goes up to age 90 and the 15%
contribution rate. These should be parameters because they will feed into the calculations and
they might need to be changed later.*

*There are three scenarios and the calculations look quite complicated. So I'll set up 3 separate
worksheets for these. I'll use the illustration they've given to help me understand the calculations
when I get to that stage. And I can use the illustration to check my answers. For the moment I'll
just make a note that this is where I'll calculate the 3 calculation factors they've used in the
illustration.*

*After that I'll add a Results worksheet that brings together the key numbers they've asked for in
the table in part (iii). I'll write down all the column headings for that, so that I know what exactly
I'm aiming for.*

*And then my final table will be for the graph. As usual, I'll pick out the data I need for the graph
and include it on the same sheet as the graph itself.*

*Well, 15 minutes has gone already. It says that there are only 25+5+10=40 marks for the
spreadsheet, but 60 marks for the audit trail. So I need to make sure I allocate enough time to the
audit trail and don't spend too long doing the spreadsheet.*

2.4   Setting up the audit trail

*In fact I'll set up my audit trail now. I prefer to do my audit trails in Word, rather than trying to
squeeze things into columns in Excel. So let's create a new Word document ... double-click on the
Microsoft Word icon on the desktop ... and let's give the new file a name ...* **File** > **Save** *... I'll give it
the name I've been told to use with my ARN number in … and I'll make a note of which folder I've
put it in, so that I can find it again later.*

*I'll start by typing an introduction describing the background to the project. I'm going to update
the rest of the audit trail as I go along, after I've done each section of my spreadsheet.*

[If you want to refer to the student's finished **Audit Trail** as you're reading through, you can find it
in Section 3 on page 18.]

2.5   Setting up the spreadsheet (student's commentary)

*We haven't been given any data on a spreadsheet to work with, so I'll just set up a new
spreadsheet by double-clicking the Excel icon on the desktop.*

Note

In the printed book the colours used by the student show as shades of grey, but the student has
used actual colours in his spreadsheet. If you want to see the actual spreadsheet, you can
download it from the ActEd website. (Go to **www.acted.co.uk** and follow the links.)

Data

I'll start with the data. So, if I double-click on the tab name 'Sheet1', I can then change the name to 'RawData'.

Since I've only be given a hard copy of the data (the annuity factors), I'll have to type these in myself. I'll type in a table of annuity factors exactly as they appear in the instructions. I'll use very simple formatting, just changing the 'bits round the edge' to bold to distinguish them from the values in the middle of the table. Excel doesn't show the 0 when you type 19.0, which makes the numbers look inconsistent. So I'll also set all the numbers to show 1 decimal.

Hmm … I must have made a mistake. I've typed the number 17.3 twice. Actually, it looks like there's a mistake in the table we've been given. One of those 17.3's is wrong. Actually, that's good because I can include some automated checks on the numbers, which should earn me some marks.

How can I check these numbers? These numbers represent the cost of a pension of £1 a year, so they must basically be values of a_x – or probably $\ddot{a}_x$ – since it says that the drawdown pensions are paid at the start of the year. I know from the other actuarial subjects that these should go down as the person gets older and they should also go down as the interest rate increases. To check that they go down I'll type the formula **=IF(AND(B5>B6,B6>B7,B7>B8,B8>B9),"OK","Error!")** *in cell B10. I can now copy this formula across to the other columns. Good! It's picked up the error in the 4% column.*

I can do something similar for the rows. In cell F5 I'll type the formula **=IF(AND(B5>C5,C5>D5,D5>E5),"OK","Error!")** *and then copy it down the column. These are all ok this time – no new errors.*

	A	B	C	D	E	F
1	RAW DATA					
2						
3			ANNUITY FACTORS			
4	AGE	2%	3%	4%	5%	CHECKS
5	55	22.4	20.5	18.7	16.9	OK
6	60	20.6	19.0	17.3	15.6	OK
7	65	18.9	17.4	17.3	14.3	OK
8	70	17.2	15.8	14.4	13.0	OK
9	75	15.5	14.2	13.0	11.7	OK
10	CHECKS	OK	OK	Error!	OK	

Screenshot 1 – RawData worksheet

It doesn't really make sense here to do the usual kinds of summary statistics. Calculating the average etc doesn't make much sense. So I'll leave it at that.

*I'll now set up a new tab for the corrected data I'll use for the later calculations. I'll call it 'CleanData'. I can do this quickly by right-clicking on the RawData tab name and then selecting 'Move or copy sheet' and ticking the 'Create a copy' box. I then need to link the entries by formula to the original data. So I click in cell B5 in the CleanData tab and then start typing = and then click over to the RawData tab, pick out cell B5 and press **Enter**. Excel enters the formula =**RawData!B5**. I can then copy this formula to the whole table. Now, if anyone makes any corrections to the raw data later, these will follow through automatically.*

	A	B	C	D	E	F
1	CLEAN DATA					
2						
3			ANNUITY FACTORS			
4	AGE	2%	3%	4%	5%	CHECKS
5	55	22.4	20.5	18.7	16.9	OK
6	60	20.6	19.0	17.3	15.6	OK
7	65	18.9	17.4	15.85	14.3	OK
8	70	17.2	15.8	14.4	13.0	OK
9	75	15.5	14.2	13.0	11.7	OK
10	CHECKS	OK	OK	OK	OK	

Screenshot 2 – CleanData worksheet

I now need to amend the incorrect value. It's the 17.3 in the middle of the 4% column. It looks as though someone has copied this from the number above. But what value should I use? They haven't told us what mortality table these numbers are based on, so I can't just look it up. And anyway, these probably come from an insurance company and they will have adjusted the rates to allow for expenses and profits. I wonder if the illustration uses this number. It says the illustration is for Scenario 1 and that you look up 'inflation rate + 1%' in this table. So that would be 2% for Scenario 1. Yes, they've use the 18.9 figure for 2% and age 65 in the illustration. So that doesn't help me.

The numbers seem to progress fairly steadily in the table. So I can probably just average the ones either side for the moment and make a note in the audit trail that the correct number needs to be established. If I average above and below I get 15.85, the same as if I average either side. So I'll use that number. In fact, I can say that I've averaged the four surrounding numbers, which sounds a bit more scientific. I'll use dark shading for that cell to show that it's a correction and I'll change it to 2 decimal places so that I can see the exact value I've used. And I'll make a note in the audit trail to say that I've used manual intervention here.

Another very simple reasonableness check I could mention is to say that with a low rate of interest such as 2%, the discounting will have very little effect, so the annuity factors should be just a little smaller than the life expectancy at that age. So 75-year-olds will live to 90-something, which seems right.

Which reminds me … I need to type up the description of the data preparation in the audit trail before I forget.

Right. I think I've written enough about the data preparation for anyone looking at my spreadsheet to see what I've done. I'd better press on ...

Parameters

I'll set up a new tab for the parameters. I'll arrange the rates for the three scenarios in a table, as in the instructions. I can put the other parameters separately below. I'll add the letters used for these in the calculations (R and M) for reference.

	A	B	C	D
1	**PARAMETERS**			
2				
3			**SCENARIOS**	
4		**Scenario 1**	**Scenario 2**	**Scenario 3**
5	**Investment return (i)**	4%	6%	8%
6	**Salary increases (j)**	3%	4%	5%
7	**Inflation (k)**	1%	2%	3%
8				
9				
10	**OTHER PARAMETERS**			
11	Retirement age (R)	65		
12	Maximum age (M)	90		
13	Contribution rate	15%		

Screenshot 3 – Parameters worksheet

Scenario calculations

I'll spend a minute studying the calculations in the illustration. The details are the same as for the 40-year old in the table based on Scenario 1. So I can use this as an independent check.

OK, I think I can see now where all the numbers come from.

The formulae in the calculations look quite complicated, but basically:

- *R, M and the contribution rate are constant throughout*

- *i, j and k, as well as the annuity factor and Factor3, are constant within each scenario*

- *x is different for each row.*

Before I forget, I'll make a note that some of these could be included as assumptions.

The number of years to retirement (R – x) appears in Factor1 and Factor2 and in the calculation of the salary at retirement. So I'll break down the calculations by adding a separate column (called n) for this.

*It'll also make it easier to check if I show the parameters specific to each scenario at the top. This will also stop the Excel formulae containing lots of references to the Parameters tab (like **Parameters!$B$11**, which I'll have for R) and becoming really long and unreadable. I suppose I could set these up as named ranges but I don't think I need to here.*

	A	B	C	D	E	F	G	H	I	J	K	L
1	**SCENARIO 1**											
2												
3	**VARIABLES**											
4	Investment return		4%									
5	Salary increases		3%									
6	Inflation		1%									
7												
8	**FACTORS**											
9	Annuity factor		18.9									
10	Factor 3 (drawdown)		17.99									
11												
12	Age	Fund Now	Salary	n	Factor1	Factor2	Final Sal	Final Fund	Annuity	%	Drawdown	%
13	20	0	20	45	5.84	214.20	75.63	643	34	45%	36	47%
14	30	10	25	35	3.95	117.75	70.35	481	25	36%	27	38%
15	40	25	30	25	2.67	59.49	62.81	334	18	28%	19	30%
16	50	50	35	15	1.80	25.27	54.53	223	12	22%	12	23%
17	60	100	40	5	1.22	5.97	46.37	157	8	18%	9	19%
18												
19			CHECKS	OK	OK	OK						

Screenshot 4 – Scenario1 worksheet

The final formulae used in row 13 are as follows:

Cell	Heading	Formula
A13	Age	=Parameters!F5 *(originally typed manually)*
B13	Fund now	=Parameters!G5 *(originally typed manually)*
C13	Salary	=Parameters!H5 *(originally typed manually)*
D13	N	=Parameters!$B$11–$A13
E13	Factor 1	=(1+$C$4)^$D13
F13	Factor 2	=(1+$C$4)*((1+$C$4)^$D13–(1+$C$5)^$D13)/($C$4–$C$5)
G13	Final sal	=$C13*(1+$C$5)^$D13
H13	Final fund	=$B13*$E13+Parameters!$B$13*$C13*$F13
I13	Annuity	=H13/$C$9
J13	%	=I13/$G13
K13	Drawdown	=H13/$C$10
L13	%	=K13/$G13

I'll set up the Scenario1 tab first. I can then just copy it and make the necessary changes to create Scenario2 and Scenario3.

The three percentages at the top are easy. I just need to link these to the correct parameter values for Scenario 1. So in cell C4 I need **=Parameters!B5**. *It doesn't really matter whether I put $ signs with this. I'm not going to copy this cell anywhere. And when I create the sheets for the other scenarios it will be a different formula anyway. So I'll ignore the dollars to make it easier to read.*

I'll need to get the annuity factor from the table in the Data tab. I expect I can use some kind of look-up function for that. For the time being I'll just type it in manually and make a note to come back and automate it in a minute. I want to focus on getting answers for everything first. Here the inflation rate is 1%, so I need to use the figure for age 65 and 2%, which is 18.9.

Next, I'll type in the first three columns of the table with Age, Fund now and Salary, as in the question. Hmm. I suppose that would be a form of hard-coding. We're supposed to avoid typing in numbers directly into cells unless they're parameters. Actually, that's a tricky one. The ages etc aren't really parameters or data. We only really need them to complete the table. But they are used for the calculations in each of the scenarios. So I think it's best to treat them as parameters. If I include these in the parameters worksheet, I can link the scenario calculations and the table to them.

F	G	H	I
	EMPLOYEE PROFILES		
Age	**Fund now (£K)**	**Salary (£K)**	
20	0	20	
30	10	25	
40	25	30	
50	50	35	
60	100	40	

Screenshot 5 – Parameters worksheet (part)

[5 minutes later]

Ok, I've typed in all the formulae. Let's check whether my numbers agree with the illustration. I should get 28% and 30% for the two percentages for the middle row. Uh-oh! The 28% is right, but I've got a negative answer for the second one! That's the one that uses Factor3. Actually, Factor3 is negative too – which I should have spotted earlier. So the mistake must be in the formula. Let's check it carefully against the formula they've given. Ah, yes. I've got one of the left brackets in the wrong place. I can easily edit that. Yes, Factor3 is now 17.47 and the final answer is 30%. Great!

The formula for Factor3 in cell C10 now reads **=(1+$C$6)*(1–((1+$C$4)/(1+$C$6))^ (Parameters!$B$11–Parameters!$B$12))/($C$4–$C$6)**

Ok, let's go back and put in a proper formula for the annuity factor, which is done manually at the moment. The annuity factor is based on the inflation rate in cell C6 plus 1%. I need to look across row 6 in the CleanData tab (which is the 4th row, counting the interest rates as the 1st) to find the entry corresponding to. So I think I need **=HLOOKUP(C6+1%,CleanData!$B$4:$E$7,4,FALSE)**. *Yes, that's giving the right answer. This formula assumes the retirement age is 65. I can't think how to make it look down the column as well. Can you put an HLOOKUP inside a VLOOKUP?! I'll leave it like this and make a note about it in the audit trail.*

I really need to put in some automated checks here. Hmm. I suppose I could check that the average of the values of n in the table is consistent with the average of the ages. The average values should add up to the retirement age R. Also, Factor1 and Factor 2 appear to be decreasing as you move down the table. This makes sense because you are approaching retirement.

So I'll add an extra row with those checks in. I'll have to use a few AND functions to check Factor1, but I can then just copy the same formula across for Factor2.

I can set up the other two scenarios now. The only things I need to change are the formulae for the 3 variables at the top, to make sure they link to the correct scenarios.

Time to update the audit trail.

The Parameters tab is easy to document but for the scenario calculations I need to remember to explain all the formulae in words.

[15 minutes later]

Assumptions

I need to make a list of the assumptions made in this model. I already made a note of some of these when I did my initial plan. I'll put these near the beginning of my audit trail.

Results table

The results table is easy to create. I just need to set up a separate Table tab and pick out the entries listed in the instructions.

Ah, yes! I was going to link the ages etc in the Scenario tabs to the ages here. I'll do that now.

|	A	B	C	D	E	F	G	H	I
1	TABLE								
2									
3				SCENARIO 1		SCENARIO 2		SCENARIO 3	
4	Age	Fund now (£K)	Salary (£K)	Annuity	Drawdown	Annuity	Drawdown	Annuity	Drawdown
5	20	0	20	45%	47%	62%	66%	87%	92%
6	30	10	25	36%	38%	48%	51%	64%	68%
7	40	25	30	28%	30%	36%	38%	45%	48%
8	50	50	35	22%	23%	26%	28%	32%	33%
9	60	100	40	18%	19%	20%	22%	23%	25%

Screenshot 6 – Table worksheet

Graph

Finally, I need to set up a tab for the graph. I'll include a 'Data for graph' section with the numbers I need to use. It says to base the graph on Scenario 2, so I need to link to these values.

*A good type of chart to use for comparisons like this is a 'clustered column chart'. I think it will do it automatically if I just highlight my complete table of data (cells B4 to C9, including the headings) and then select **Insert**, click **Column** and pick the first chart type (2D clustered column). Yes, there we go. And red and blue are sensible colours to use.*

*To get the ages appearing on the x axis, I right-click on the graph, choose **Select data**, move to the right hand panel, click **Edit** and then highlight the range of cell containing the ages (cells A5 to A9). Then press **OK**.*
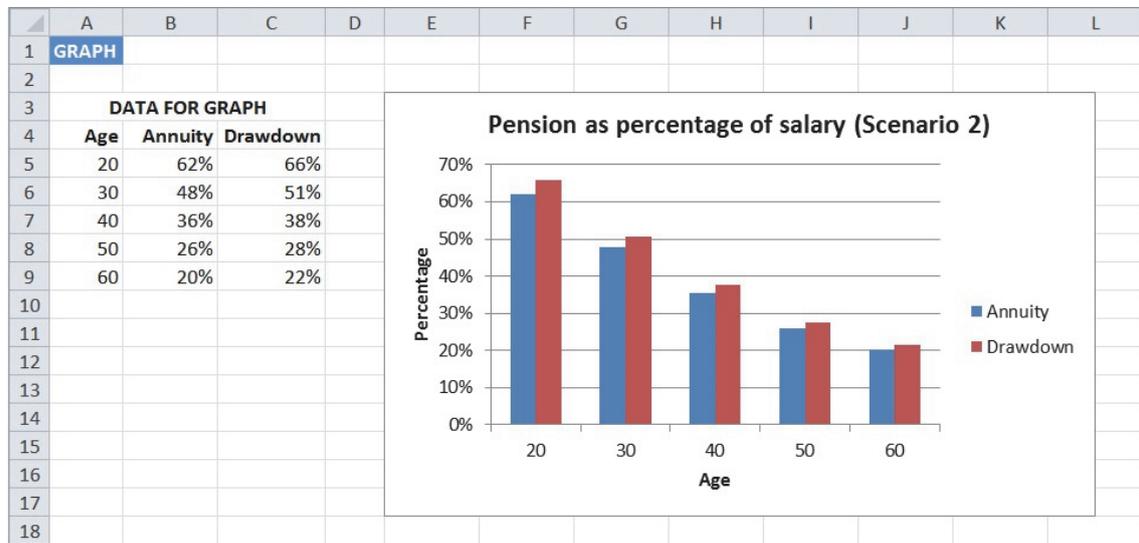
Screenshot 7 – Graph worksheet

*I just need to add a title and to label the axes. To do these I need to highlight the graph, then select the **Layout** menu at the top. I can now use the **Chart Titles** and **Axis Titles** features. For the title I usually use the 'Above chart' option and for the vertical axis I usually use the **Rotated title** option, which makes it write 'sideways'.*

I've been going for 2½ hours now. Let's finish off the audit trail now.

3   Audit trail

This audit trail relates to the spreadsheet **Worked Example Project (Paper 1).xls**.

It was last updated on 1 September 2018 by A. Student.

Background

We have been asked by *LongerLives* to carry out a comparison of two pension arrangements for employees with person pension plans – annuities and drawdown.

The accompanying spreadsheet calculates the projected pension amounts for the annuity and drawdown options under three different economic scenarios and a graph comparing the two arrangements for one of the scenarios.

Detailed descriptions of each worksheet are set out below.

The following colour conventions have been used:

- Pale shading indicate input cells that can be changed by the user

- Dark shading indicates corrected data

- Checks are shown in red.

No macros or user-defined functions have been used.

Assumptions

The spreadsheet model makes a number of assumptions:

- The annuity factors provided are correct (after any adjustments have been made).

- The retirement age and the maximum age are assumed to be fixed.

- The rates of investment return, salary increases and inflation assumed in each scenario will remain constant in the future.

- The value assumed for the maximum age is appropriate.

- Pensions are paid annually in advance and are index-linked to inflation.

- Employees will be able to draw down their pensions in the future without any restrictions being introduced.

Data (annuity factors)

We have been provided with a table of annuity factors (provided by the client) for a selection of retirement ages and interest rates.

These have been entered manually in the **RawData** worksheet. Checks have been included to ensure that these factors decrease with both the age and the interest rate, as would be expected. These revealed an error in one of the values.

Other summary statistics, such as average, max, min were not considered useful here.

The **CleanData** worksheet contains the annuity factors that will be used for the subsequent calculations. These are linked by formula to the values in RawData. As the values appear to progress smoothly, the incorrect value has been manually overwritten as a temporary measure with the average of the four surrounding numbers. **The correct value needs to be established and entered in the RawData tab.** The formula from the cell above the incorrect value in CleanData can then be copied down.

As another reasonableness check, the annuity factors at the lowest interest rate appear to be consistent with life expectancies for the various ages.

Note that, if more data values need to be added to the table (*eg* more interest rates), the formulae on the CleanData tab will need to be copied across the worksheet and references elsewhere to this range of cells will need to be adjusted.

Parameters

The following parameters can be set here by the user:

- the investment return (i), salary increase rate (j) and inflation rate (k) for each scenario

- the retirement age (R), maximum age (M) for drawdown and contribution rate

- the employee profiles (age, fund now and salary) to be used in the calculations.

Note, however, that the annuity factors currently assume a fixed retirement age of 65, irrespective of the parameter value shown here.

Scenario calculations

The worksheets **Scenario1**, **Scenario2** and **Scenario3** carry out the pension projections for each of the three scenarios.

The three economic variables at the top are linked to the corresponding parameter values. These are the only inputs that differ between the scenarios.

The annuity factor is extracted from the annuity table in CleanData using an HLOOKUP function. The value is based on the inflation rate plus 1%. (As stated above, this version of the spreadsheet always uses a retirement age of 65.)

Factor3 is an actuarial factor used to calculate the amount of pension that can be taken in the first year using drawdown under the economic assumptions of this scenario. The projected fund is divided by this factor to calculate the pension amount. The formula used assumes that all pensioners will live to the same maximum age M and they will drawdown their entire fund by that age. The formula has the form of an annuity factor calculated at the real rate of interest (*ie* the interest rate net of inflation).

For reference, the actual formula is $(1+i)/(i–k)*[1-\{(1+i)/ (1+k)\}^{\wedge}(R–M)]$.

The first three columns of the table are linked by formulae to the values in the Parameters tab. **Age** is the employee's current age. **Fund Now** is the amount currently in the employee's pension fund and **Salary** is the employee's current annual salary.

Column n is the number of years to retirement, calculated as $R - x$, where R is the retirement age and x is the current age. This has been added to simplify the calculations, as this is used in several of the later formulae.

Factor1 is the compound interest factor $(1+i)^n$, which is used to accumulate the existing fund up to retirement age at the rate of investment return (i).

Factor2 is used to accumulate the future contributions up to retirement age, allowing for future salary increases and future investment returns. It is derived as the sum of a geometric series with terms corresponding to each future year, which leads to the formula $(1+i)/(1-j)*[(1+i)^n-(1+j)^n]$.

The **Final Sal** column shows final salary, which is calculated by rolling up the current salary to retirement age (for a period of n years) at the rate of salary increases (j).

The **Final Fund** column gives the projected fund the employee will have at retirement age. It is calculated by applying Factor1 to Fund Now by multiplying them and applying Factor2 to this year's pension contribution (the contribution rate times current salary) by multiplying them, and then calculating the total of these two components.

Annuity is the projected annual pension amount for the first year under the annuity arrangement. It is calculated by dividing the Final Fund by the annuity factor.

This is then expressed as a percentage of the employee's salary at retirement.

Drawdown is the projected annual pension amount for the first year under the drawdown arrangement. It is calculated by dividing the Final Fund by the Factor3.

This is then expressed as a percentage of the employee's salary at retirement.

CHECKS

- The check below the values of n ensures that the average age in the table and the average value of n sums to the retirement age R.

- The checks below the Factor1 and Factor 2 columns use a combination of AND functions to ensure that the values of the factors decrease down the column, *ie* with increasing age.

Table

The **Table** worksheet summarises the results in the form of a table.

The entries in the first three columns of the table are linked to the employee profiles in the **Parameters** worksheet.

The other entries are linked directly to the two corresponding columns in the Scenario tabs (headed '%').

Graph

The **Graph** worksheet produces a graph comparing the pension percentage amounts under the two arrangements.

The input values for the graph are linked directly to the columns with the same names in the worksheets for Scenario 2.

A clustered column chart has been used here, as this makes it easy to compare the results for the different scenarios.

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