Contextualised task 33

Crossing the River Severn

Teaching Notes

This task focuses on the finances of the Severn River Crossings and should help students to understand the issues behind what has become a controversial topic. Contrary to what they may hear in the media, this data suggests that the charges are sensible and appropriate, even if unpopular.

Task A: Income

Outline
Students are presented with information in a variety of forms, including text, tables and charts. They use the information to estimate the annual income generated by operating the Severn Crossings.

You will need:
- Teachers' script
- PowerPoint
- Question sheet
- Task A: Road Traffic Estimates
- Task A: Severn Crossing charges
- Mark scheme

Task B: The handover target

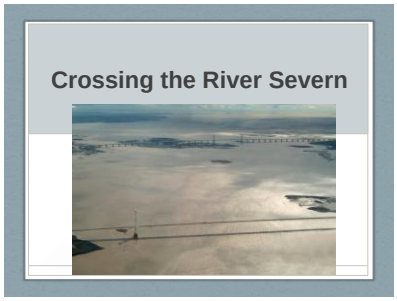
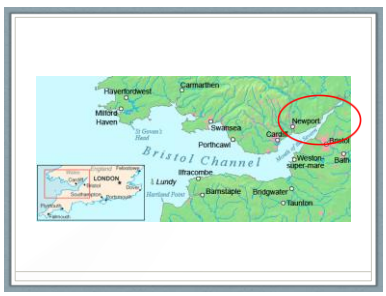
Outline
Students consider how inflation has affected the amount of money that needs to be raised in order to cover construction costs. They calculate a time series of this value, and then compare it to the time series of the cumulative total raised so far. Students construct a graph of the data to produce a striking image of the data.

You will need:
- Question sheet
- Task B: Twenty years of data
- Task B: Twenty years of data (version 2) (optional)
- Spreadsheet (optional)
- Mark scheme

The cumulative total raised up to 2015 is provided in **Task B: Twenty years of data**. However, students can be challenged to calculate this value themselves. This involves complex calculations with many variables to consider. **Version 2** should be used in this case, and the spreadsheet could also be provided.

Task A: Teachers' script for PowerPoint presentation

The text in the right-hand boxes provides a possible script to be read to students. However, it is probably preferable to use your own words and elaboration. When questions are asked, time for discussion in pairs / groups should be provided. Ensure that students are given opportunity to explain their reasoning in response to these questions. All students need to understand the concepts in order to make progress with the task.

Slide 1		*Keep this slide on the screen until you are ready to start the presentation*
Slide 2		The source of the River Severn is on the mountain of Pumlumon, near Llanidloes in Powys. It flows for 220 miles before reaching the Bristol Channel. The Severn is the longest river in the UK. *https://en.wikipedia.org/wiki/River_Severn#/media/File:SevernSource06.JPG*
Slide 3		There are 107 bridges across the River Severn. Some are very significant and distinctive structures. One is even a UNESCO World Heritage Site. What is the average distance between two bridges on the River Severn? *(2.056… miles)* *en.wikipedia.org/wiki/List_of_crossings_of_the_River_Severn* *Pont droed yng Nghoedwig Hafren © OLU* *Ironbridge © Keith Havercroft* *Pont Gymraeg, Amwythig © David Dixon* *Ail Bont Hafren © Sarah Charlesworth*
Slide 4		As the River Severn approaches Bristol it becomes a mile wide. *Advance one click* In 1886 a railway tunnel was opened. For over 100 years – until the Channel Tunnel opened – it was the longest railway tunnel in the UK. It still carries trains under the river between England and Wales today.

Slide 5		There might be over 100 bridges across the Severn, but **THE** Severn Bridge was opened on 8th September 1966. *Advance one click* The Second Severn Crossing opened thirty years later in 1996. *Advance one click* It cost £380 million to construct. *Advance one click* The same company runs both bridges. There is still £60 million outstanding debt on the first bridge too. Vehicles pay a toll to cross the bridges. When the company has raised a total of £440 million to cover their costs, the bridges will be handed back to the government. But inflation makes a big difference. *Advance one click* The agreement is that the £440 million would be linked to prices in 1989. Between 1989 and 2015, inflation has been nearly 140%. How could you find the value of the £440 million today? *(e.g. £440,000,000 × 2.4 = £1,056,000,000)* Over £1 billion!

Task A: Question sheet

Here are some facts about traffic on Britain's roads, and the Severn Bridges.

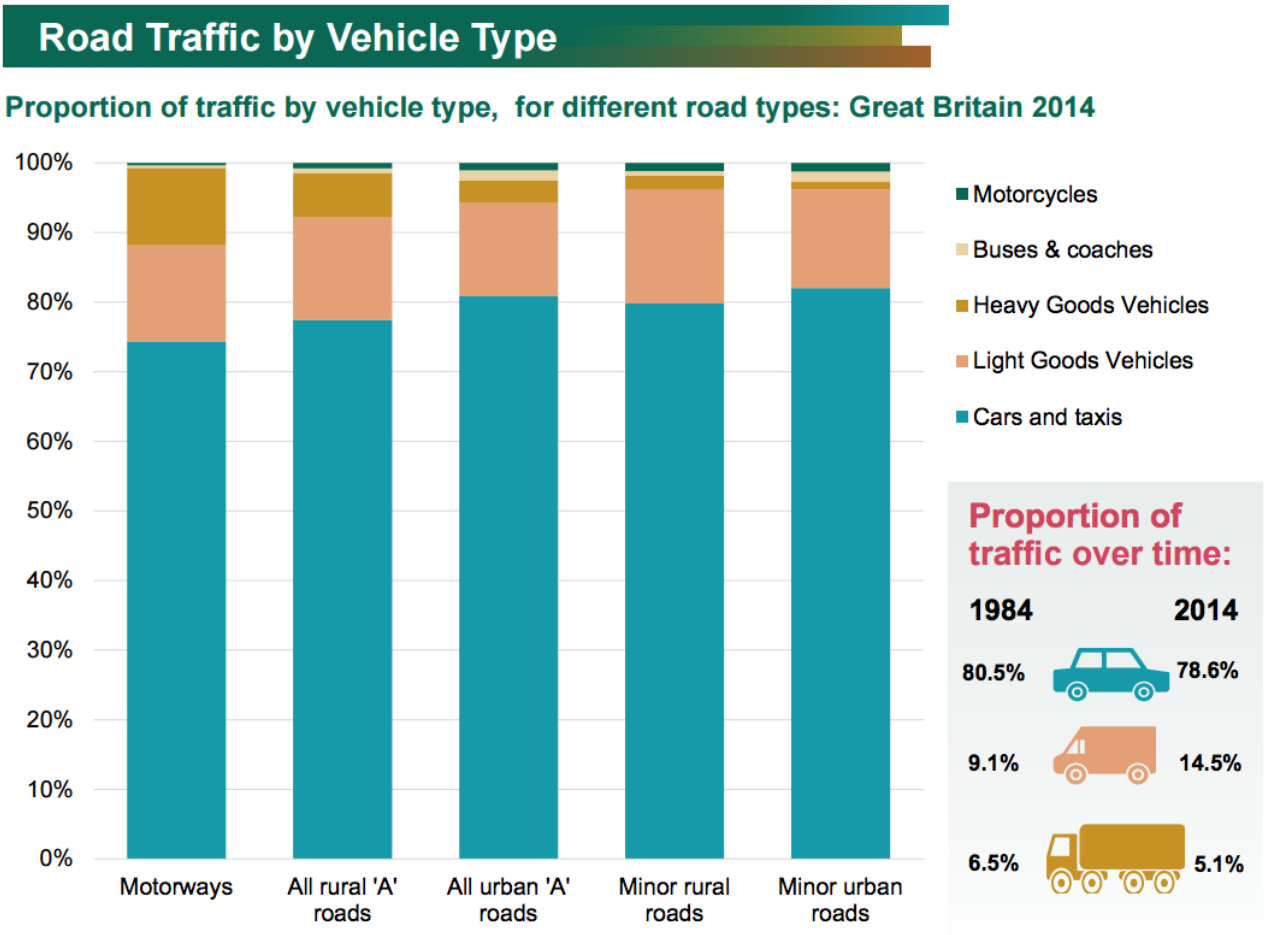
- The Severn Bridge carries the M48 motorway.
- The Second Severn Crossing carries the M4 motorway.
- The toll is only charged in one direction. Motorists pay the charge when travelling towards Wales.
- About 62,000 vehicles use the Second Severn Crossing every day.
- About 18,000 vehicles use the Severn Bridge every day.
- An average of 80,000 vehicles use the Severn Bridges each day.
- Motorcycles do not have to pay to cross either of the Severn Crossings.
- £440 million in 1989 is equivalent to £1056 million in 2015.
- A 'Light Goods Vehicle' is a van up to 3.5 tonnes.
- A 'Heavy Goods Vehicle' is over 3.5 tonnes.

Estimate the amount raised by operating the two Severn Crossings. State and justify the assumptions that you make.

You need the information on two further sheets:

- Road Traffic Estimates
- Severn Crossing charges

Task A: Road Traffic Estimates



Proportion of traffic by vehicle type

Since the 1980s, cars have accounted for around 80 per cent of all motor vehicle traffic and continue to be the main contributor to changes in the volume of overall motor vehicle traffic.

However, LGVs have become more important recently, accounting for 14.5 per cent of all motor vehicle traffic in 2014 compared to 9 per cent in 1984.

The contribution of different vehicles to total traffic varied with road type: in 2014, HGVs made up 11 per cent of traffic on motorways, but only 1.4 per cent on minor roads. This may reflect that HGV journeys tend to be longer than the average for other vehicle types; longer journeys tend to use motorways for a greater proportion of the distance.

Statistical release: Road Traffic Estimates, Great Britain 2014, DfE, 21 May 2015

Task A: Severn Crossing charges

Current charges

Toll category	Description	2015 charge
Category 1	Cars and minibuses with up to 9 seats	£6.50
Category 2	Small buses with up to 17 seats Vans up to 3.5 tonnes	£13.10
Category 3	Buses with more than 17 seats Goods vehicles weighing 3.5 tonnes or more	£19.60

Historical charges

Date	Category 1	Category 2	Category 3
5 June 1996	£3.80	£7.70	£11.50
1 January 1997	£3.90	£7.80	£11.70
1 January 1998	£4.00	£8.10	£12.10
1 January 1999	£4.20	£8.40	£12.50
1 January 2000	£4.20	£8.50	£12.70
1 January 2001	£4.40	£8.70	£13.10
1 January 2002	£4.40	£8.90	£13.30
1 January 2003	£4.50	£9.00	£13.50
1 January 2004	£4.60	£9.30	£13.90
1 January 2005	£4.80	£9.60	£14.30
1 January 2006	£4.90	£9.80	£14.70
1 January 2007	£5.10	£10.20	£15.30
1 January 2008	£5.30	£10.60	£15.90
1 January 2009	£5.40	£10.90	£16.30
1 January 2010	£5.50	£10.90	£16.40
1 January 2011	£5.70	£11.50	£17.20
1 January 2012	£6.00	£12.10	£18.10
1 January 2013	£6.20	£12.40	£18.60
1 January 2014	£6.40	£12.80	£19.20
1 January 2015	£6.50	£13.10	£19.60

source: https://en.wikipedia.org/wiki/Second_Severn_Crossing

Task A: Mark scheme

The information below is intended as a guide only

Full credit

Produces a logical and fully justified estimate; e.g.

80,000 × 365 = 29,200,000 vehicles a year use the Severn Crossings

From the chart,
74% of the vehicles on motorways are cars (accept 73%)
14% of the vehicles on motorways are LGVs (accept 13% to 15%)
11% of the vehicles on motorways are HGVs (this is stated in the text)
0.5% of the vehicles on motorways are coaches (accept 1%)

Assume that these percentages apply to the Severn Crossings as both are motorway bridges.

Assume that half the crossings result in a toll being charged since the toll is only paid in one direction. 29,200,00 ÷ 2 = 14,600,000

Category 1 (Cars)
74% of 14,600,000 = 10,804,000
10,804,000 × £6.50 = £70,226,000

Category 2 (LGVs)
14% of 14,600,000 = 2,044,000
2,044,000 × £13.10 = £26,776,400

Category 3 (HGVs and coaches)
11.5% of 14,600,000 = 1,679,000
1,679,000 × £19.60 = £32,908,400

Total: £129,910,800

Partial credit

A fully justified solution that does not use the correct percentages as stated above

OR

A fully justified solution that does not take into account the fact that the toll is only charged in one direction

OR

Uses the number of vehicles a day instead of the number of vehicles a year

OR

Makes no more than two arithmetical errors in an otherwise correct and justified solution

Limited credit

Provides evidence of at least three of the following:

- Identifies that not all of the 80000 vehicles pay a toll as it is only paid in one direction
- Establishes an estimate of the number of vehicles crossing the bridge every year
- Identifies the need to work out percentage of vehicle types from the chart provided
- Identifies the need to work out an estimate of the number of each vehicle type crossing the bridge each year (unless scaling up the corresponding result for one day)
- Estimates the amount raised by each vehicle type in a year (or day)
- Find the total amount raised

No credit

Any other response

Task B: Question sheet

The company that operates the Severn Crossings is called 'Severn River Crossing plc'.

When Severn River Crossing plc has raised enough money to cover the cost of building and running the bridges, they will be handed over to the British government.

You have already seen that this cost is £1,056,000,000 in 2015. It will continue to rise with inflation.

In the meantime, not all money raised can be put towards this bill. There are three big costs to the company:

- The toll includes VAT. The money raised has to be paid to the government. The VAT rate is 20% in 2015.
- The company has to spend money operating and maintaining the bridge, and paying interest on money owed. This is about £10,000,000 in 2015.
- Every company has to pay corporation tax on their profit made. Corporation tax is also 20% in 2015.

1. Use your estimate in part 1 of this task. Estimate the profit made by operating the Severn Crossings. State your calculations clearly and justify each one.

2. The table on the resource sheet **Task B: Twenty years of data** gives information about how the estimated profit has built up since 1996. This is based on:

   - The fact that vehicle numbers have increased at a rate of 1.8% per year
   - The increases in the toll every year as shown on sheet **Task A: Severn Crossing charges**
   - The assumption that the rate of corporation tax and VAT have stayed the same*
   - The assumption that the proportion of types of vehicle has stayed the same

   a) The target to raise by Severn River Crossing plc was £440 million in 1989. Show that this figure had increased to £614 million by the time the Second Severn Crossing opened in 1996.

   b) Calculate what the target to raise had increased to in each year from 1997 to 2014.

   c) Plot a graph of the 'cumulative profit' time series. On the same graph, plot the 'target to raise' time series.

   d) Comment on your graph.

* *they haven't – but it makes the mathematics simpler*

Task B: Twenty years of data

Year	Inflation since 1989 (%)	Number of vehicles (millions)	Cumulative profit (£million)	Target to raise (£million)
1996	39.59	10.6	17	
1997	42.94	21.6	51	
1998	47.37	22	87	
1999	52.38	22.4	126	
2000	54.66	22.8	165	
2001	59.3	23.2	207	
2002	62.17	23.6	249	
2003	64.93	24	294	
2004	69.71	24.4	340	
2005	74.8	24.8	388	
2006	79.7	25.2	439	
2007	85.45	25.6	493	
2008	93.42	26	549	
2009	101.16	26.4	608	
2010	100.15	26.8	668	
2011	109.36	27.2	731	
2012	120.24	27.6	799	
2013	127.29	28	870	
2014	134.11	28.6	945	
2015	139.73	29.2	1023	1055

Task B: Twenty years of data (version 2)

Year	Inflation since 1989 (%)	Number of vehicles (millions)	Cumulative profit (£million)	Target to raise (£million)
1996	39.59	10.6		
1997	42.94	21.6		
1998	47.37	22		
1999	52.38	22.4		
2000	54.66	22.8		
2001	59.3	23.2		
2002	62.17	23.6		
2003	64.93	24		
2004	69.71	24.4		
2005	74.8	24.8	388	
2006	79.7	25.2		
2007	85.45	25.6		
2008	93.42	26		
2009	101.16	26.4		
2010	100.15	26.8		
2011	109.36	27.2		
2012	120.24	27.6		
2013	127.29	28		
2014	134.11	28.6		
2015	139.73	29.2		1055

Task B: Mark scheme

The information below is intended as a guide only

Full credit

A fully justified estimate in question 1; e.g.

£129,910,800 ÷ 1.2 = £108,259,000 (the amount remaining after the VAT bill)
£108,259,000 – £10,000,000 = £98,259,000 (subtract costs)
£98,259,000 × 0.8 = £78,607,200 (the amount remaining after corporation tax)

Note that the order of these things is important:

- VAT must be accounted for first as it is just money raised on behalf of the government
- Corporation tax will be charged on the profit and must be applied after costs have been subtracted

AND

Shows that a 39.59% increase on £440 million is £614,196,000; e.g. 440 × 1.3935 = 614.196

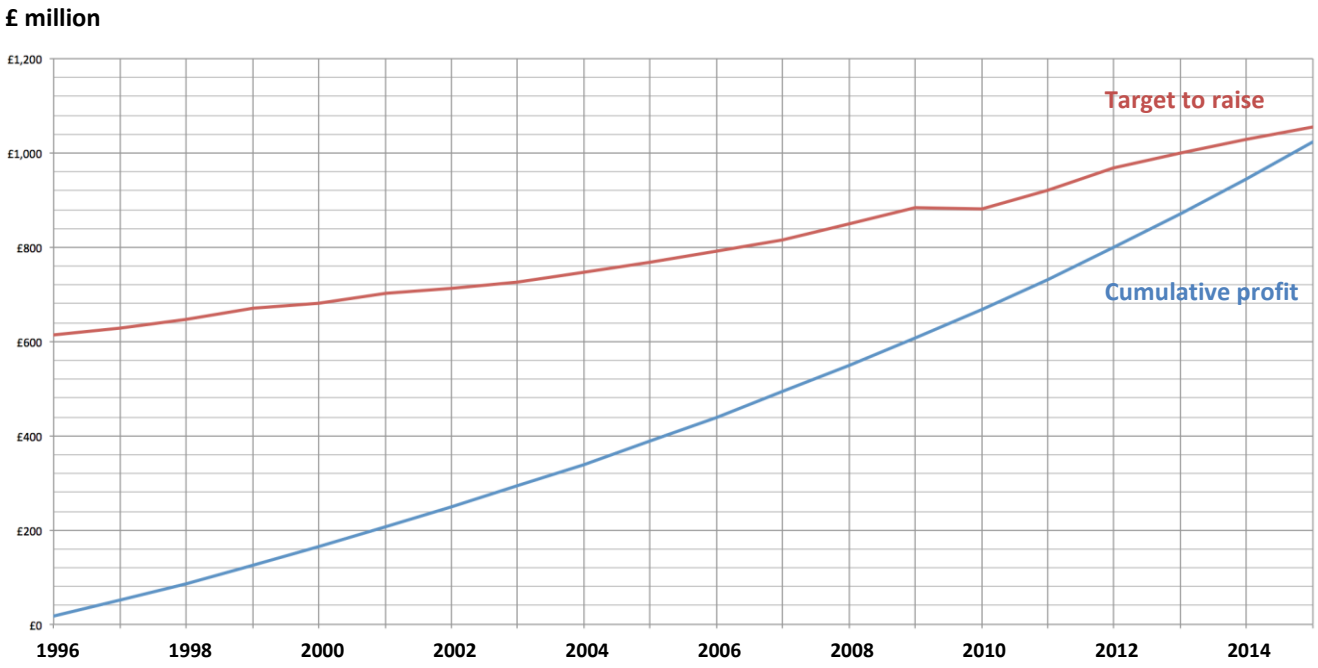
AND

Finds the 'target to raise' figure for each year

Year	Inflation since 1989 (%)	Number of vehicles (millions)	Cumulative profit (£million)	Target to raise (£million)
1996	39.59	10.6	17	614.196
1997	42.94	21.6	51	628.936
1998	47.37	22	87	648.428
1999	52.38	22.4	126	670.472
2000	54.66	22.8	165	680.504
2001	59.3	23.2	207	700.920
2002	62.17	23.6	249	713.548
2003	64.93	24	294	725.692
2004	69.71	24.4	340	746.724
2005	74.8	24.8	388	769.120
2006	79.7	25.2	439	790.680
2007	85.45	25.6	493	815.980
2008	93.42	26	549	851.048
2009	101.16	26.4	608	885.104
2010	100.15	26.8	668	880.660
2011	109.36	27.2	731	921.184
2012	120.24	27.6	799	969.056
2013	127.29	28	870	1000.076
2014	134.11	28.6	945	1030.084
2015	139.73	29.2	1023	1054.812

AND

Plots a correct time series graph of the data



AND

Comments on the graph; e.g. Severn River Crossing plc have nearly raised the amount that was first agreed

Partial credit

A fully justified estimate for question 1

AND

Shows that a 39.59% increase on £440 million is £614,196,000; e.g. 440 × 1.3935 = 614.196

AND

Finds the 'target to raise' figure for each year

OR

Completes all parts of question 1 and 2 but does not justify calculations

OR

Completes all parts of question 1 and 2 with up to three arithmetical errors

Limited credit

Provides evidence of at least three of the following:

- Interpreting the subtraction of VAT as an original value problem
- Understanding the correct order of deductions from revenue generated
- Understanding how to use the inflation figure to calculate the amount of money to be raised in any given year
- Knowing how to construct a time series graph

No credit

Any other response

Progression in reasoning			
Identify processes and connections • identify, measure or obtain required information to complete the task	Read through the information given, and identify what might be useful information to gather next. Identify how this information might be obtained. *e.g. identifies what information given in the list (Task A) is necessary*	Identify all the information that is needed to solve a problem, and how this information might be obtained. *e.g. identifies that the proportion of each vehicle type is needed and recognises that the statistical release is the source of this information*	As information is gathered, review its usefulness, and whether further information or different information is required. *e.g. evaluates the usefulness of the information in the statistical release, recognises that the text provides some accurate data but that some estimates also need to be drawn from the chart*
Represent and communicate • interpret graphs that describe real-life situations, including those used in the media, recognising that some graphs may be misleading	*e.g. can extract the proportion of cars from the compound bar chart*	*e.g. can extract the proportion of any vehicle type from the compound bar chart*	*e.g. can interpret the comparative time series charts, commenting on rates of change*
Review • draw conclusions from data and recognise that some conclusions may be misleading or uncertain	*e.g. recognises that assumptions in Task A affect the estimate of the amount raised*	*e.g. recognises that calculations for the annual profit are based on an estimate and therefore that the figure is not certain*	*e.g. realises that the final part of the task involves a number of assumptions and that there is a significant degree of uncertainty in the results which could amount to several millions of pounds*

GCSE Content	
GCSE Mathematics – Numeracy and GCSE Mathematics	**GCSE Mathematics only**
Understanding number and place value • Reading and writing whole numbers of any magnitude expressed in figures or words.	
Understanding number relationships and methods of calculation • Using the facilities of a calculator, including the constant function, memory and brackets, to plan a calculation and evaluate expressions. • Using addition, subtraction, multiplication, division, square, square root, power, root, constant, memory, brackets and appropriate statistical functions. • Using calculators effectively and efficiently. • Understanding and using number operations and the relationships between them, including inverse operations and the hierarchy of operations. • Finding a fraction or percentage of a quantity. • Calculating fractional and percentage changes (increase and decrease), including the use of multipliers. • Repeated proportional changes; appreciation and depreciation.	
Solving numerical problems • Interpretation and use of mathematical information presented in written or visual form when solving problems. • Money: VAT, taxation. • Profit and loss. • Finding the original quantity given the result of a proportional change. • Carrying out calculations relating to enterprise, saving and borrowing, investing, appreciation and depreciation. • Giving solutions in the context of a problem, selecting an appropriate degree of accuracy, interpreting the display on a calculator, and recognising limitations on the accuracy of data and measurements. • Rounding an answer to a reasonable degree of accuracy in the light of the context.	
Processing, representing and interpreting data • Constructing line graphs for the values of a variable at different points in time; understanding that intermediate values in a line graph may or may not have meaning.	
Discussing results • Recognising that graphs may be misleading. Looking at data to find patterns and exceptions. • Drawing inferences and conclusions from summary measures and data representations, relating results back to the original problem.	

Key
Foundation tier content is in standard text.
Intermediate tier content which is in addition to foundation tier content is in underlined text.
Higher tier content which is in addition to intermediate tier content is in **bold text**.