Using Large Data Sets Workbook – AQA (Cars) version

This booklet uses Excel and Desmos

This workbook explores the different types of activities that students and teachers might undertake with a Large Data Set so that it can be used effectively to support the learning of statistical concepts. You will need the AQA dataset for 2019-2020 which can be downloaded at *https://www.aqa.org.uk/subjects/mathematics/as-and-a-level/mathematics-7357/assessment-resources*

Key Skills

- Understand the dataset and its context
- Cleanse a dataset and know how to deal with outliers
- Sort and Filter the dataset
- Produce summary statistics
- Draw frequency charts and box plots for a set of data
- Draw graphs of several datasets side by side for comparison
- Draw scatterplots and plot lines and curves of best fit
- Use technology to calculate correlation coefficients and equations of regression lines
- Take a random sample from a dataset

Software Used

- A spreadsheet (in this case Excel)
- Graphing and statistical software (in this case Desmos).

1 Becoming familiar with the dataset

Open the "AQA-AS-A-MATHS-LDS-2019-2020" file which contains the dataset. The first sheet in the spreadsheet files explains the origin of the data and the third sheet contains a glossary of terms. The fourth sheet contains a key to the codes used. The data itself is in the second sheet.

Students are required to understand the context of the data so that it important that they read these sheets whilst looking through the dataset. Some questions you might like to consider are:

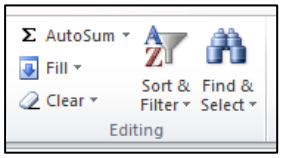
- What is the source of the data and how up to date is it?
- Who collected it and how was it collected?
- Why are there only 5 makes of car and how were these chosen? What other restrictions were applied to the dataset?
- There are some missing data items. How should you treat these items when analysing the data?

Students need to understand each of the fields. Some of them might warrant further discussion. Students should be encouraged to research further so that they fully understand the concepts. Further information can be found at *https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01* and *https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01*

2 Sorting and filtering the dataset in Excel

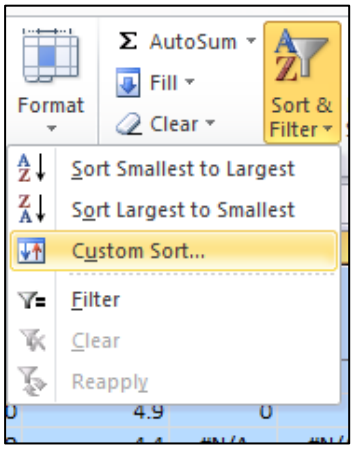
Further familiarity with the dataset can be gained by sorting and filtering the data within Excel. This can help identify any possible outliers or rogue values.

These functions can be found at the far end of the top toolbar:

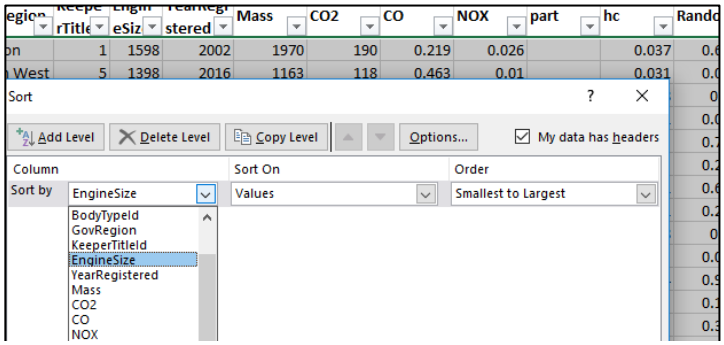


Suppose you want to sort the data according to Engine Size. Use Crtl-A to select all the data.

Select the custom sort option:



When the dialogue box appears select the field that you want to sort on and specify the order, smallest to largest. Also make sure that the 'My data has headers' box is checked otherwise your column headings will get sorted as well.

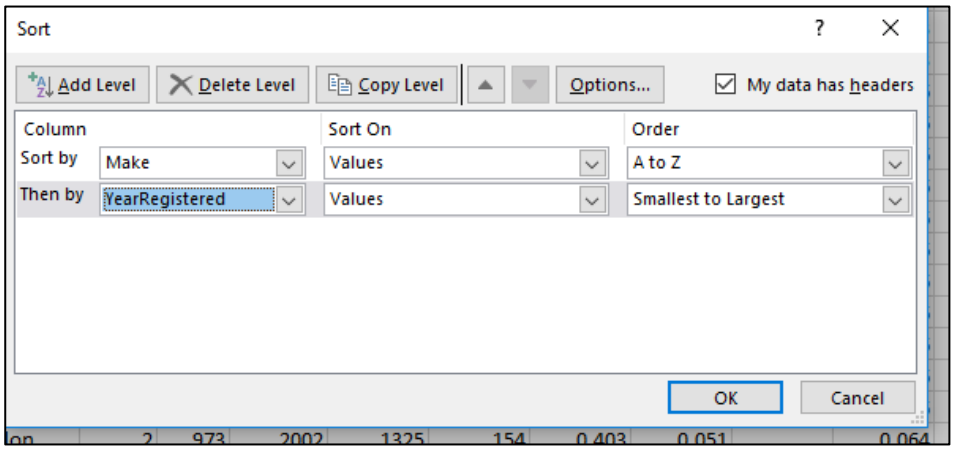


The data is now sorted in order of engine size:

A	B	C	D	E	F	G	H	I	J	K	L
eferenceNu	Make	Propulsio nTypeId	BodyTyp eId	GovRegion	Keepe rTitle	Engin eSiz	YearRegi stered	Mass	CO2	CO	NOX
3645	BMW	3	14	South West	2	0	2016	1270	0		
3530	BMW	8	14	South West	1	647	2016	1390	13	0.053	0.002
3495	BMW	8	14	South West	1	647	2016	1390	13	0.053	0.002
3025	BMW	8	14	North West	2	647	2016	1390	13	0.053	0.002
974	VAUXHALL	1	13	North West	2	973	2002	1430	135	0.342	0.048
505	VAUXHALL	1	13	South West	1	973	2002	1430	135	0.342	0.048
519	VAUXHALL	1	13	North West	1	973	2002	1430	135	0.342	0.048
337	VAUXHALL	1	13	London	2	973	2002	1430	135	0.342	0.048
503	VAUXHALL	1	14	London	1	973	2002	1430	135	0.342	0.048
1017	VAUXHALL	1	13	London	1	973	2002	1405	135	0.342	0.048

What problem has been identified here? How would you deal with this?

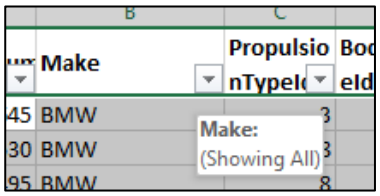
It is possible to sort the data using several fields using the ‘add level button



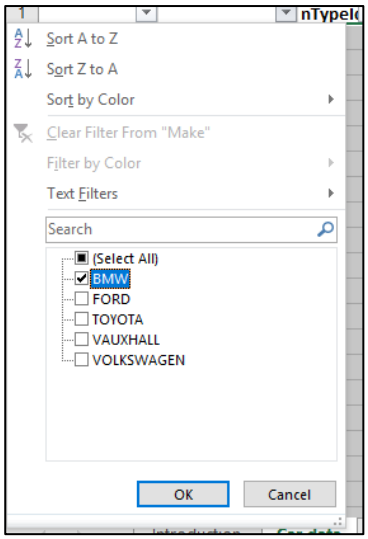
Try the above sort (remember to select all the data first using Ctrl-A). It should give you the data in order of make and the year.

An alternative approach if you just want to focus on a subset of the data is to use filters. The dataset comes with filters already set up. These are the arrows next to each heading.

Suppose you wish to just look at BMWs. Then click on the arrow next to make:



And then scroll down and uncheck the box for everything except BMW



Now you should have only BMWs:

ReferenceNu	Make	Propulsion Type	BodyType Id	GovRegion	KeeperTitle	EngineSize	YearRegistered	Mass	CO2
3645	BMW	3	14	South West	2	0	2016	1270	0
3530	BMW	8	14	South West	1	647	2016	1390	13
3495	BMW	8	14	South West	1	647	2016	1390	13
3025	BMW	8	14	North West	2	647	2016	1390	13
2335	BMW	2	14	London	5	1496	2016	1395	106
3606	BMW	2	14	North West	2	1496	2016	1395	103
2719	BMW	2	14	South West	5	1496	2016	1425	96
1947	BMW	2	13	London	5	1496	2016	1425	103
3309	BMW	2	14	South West	5	1496	2016	1395	89
2612	BMW	2	14	London	5	1496	2016	1395	94

To turn the filters off click on the filter button again.

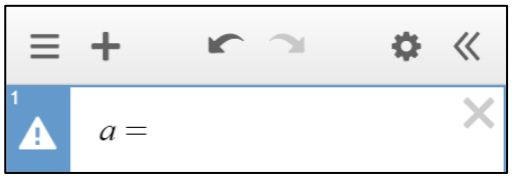
Exercise: Sort the data by Carbon Dioxide emissions. Do the newer cars generally have lower emissions? Are there any exceptions?

3 Producing summary statistics

Using the dataset, select the 2nd sheet and highlight column J (Carbon Dioxide emissions) and copy it (Ctrl-C).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Referenc	Make	Propulsio nTypeI	BodyTyp eId	GovRegion	Keepe rTitle	Engin eSiz	YearRegi stered	Mass	CO2	CO	NOX	part	hc	Random nu
2	440	VAUXHALL	1	96	London	1	1598	2002	1970	190	0.219	0.026		0.037	0.090257
3	1465	VAUXHALL	1	14	South West	5	1398	2016	1163	118	0.463	0.01		0.031	0.421968
4	3434	VOLKSWAGEI	1	14	South West	2	1395	2016	1316	113	0.242	0.033		0.048	0.530683
5	1801	VAUXHALL	1	14	South West	4	1598	2016	1355	159	0.809	0.012		0.051	0.846909
6	2330	BMW	2	13	South West	5	1995	2016	1445	114	0.18	0.023			0.793613
7	2216	FORD	2	6	South West	5	1499	2016	1425	98	0.354	0.074			0.453814
8	1323	VAUXHALL	1	14	South West	5	1398	2016	1163	118	0.463	0.01		0.031	0.319890
9	1396	VAUXHALL	1	14	South West	5	1398	2016	1163	118	0.463	0.01		0.031	0.670311
10	264	TOYOTA	1	14	London	4	1998	2002	1440	212	0.76	0.04		0.08	0.721762
11	2971	VOLKSWAGEI	2	6	South West	5	2967	2016	2185	174	0.138	0.039			0.458509
12	1846	VAUXHALL	1	14	London	2	1398	2016	1199	137	0.645	0.008		0.044	0.35932
13	2707	FORD	2	14	North West	5	1499	2016	1399	98	0.354	0.074			0.507777
14	2419	VAUXHALL	2	6	South West	5	1598	2016	1393	89	0.268	0.047			0.524543
15	3809	FORD	2	14	South West	5	1997	2016	1681	122	0.145	0.059	0.001		0.901670
16	1720	VAUXHALL	1	14	North West	2	1598	2016	1355	159	0.809	0.012		0.051	0.611480

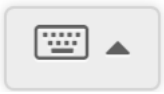
Go to a new input bar in Desmos and type:



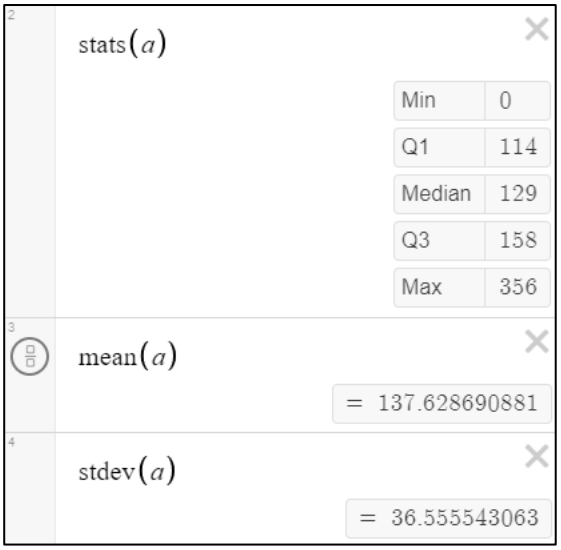
Then press Ctrl-V to paste the data:

This should create the list (called a). You can now refer to the list in other commands.

The following commands can be found in functions > Stats from the onscreen keypad:



- stats(a)
- mean(a)
- stdev(a)



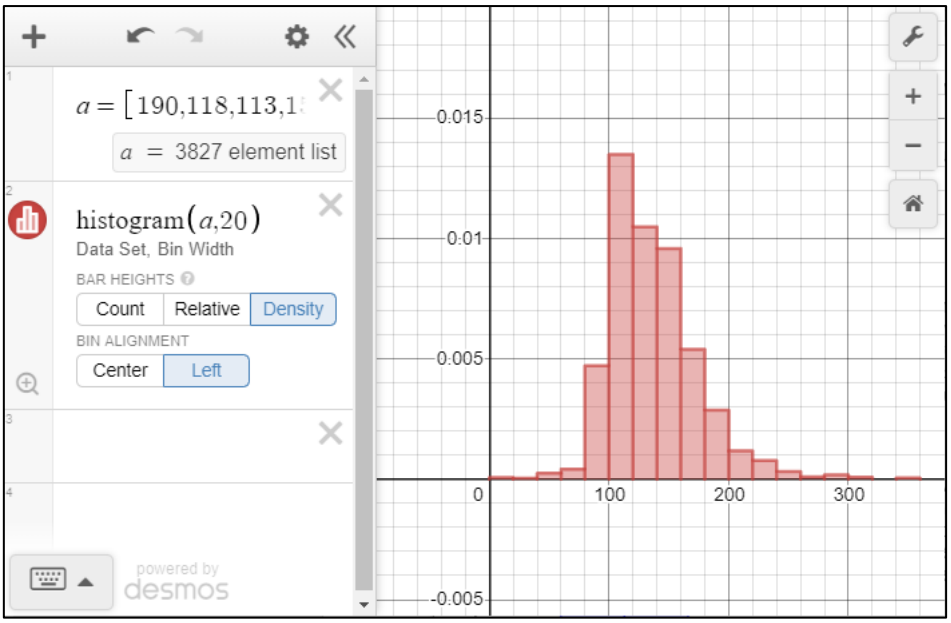
Exercise: Produce these statistics for NOX emissions for the different makes of cars. What similarities or differences do these statistics show you? How does Desmos treat the blank entries?

4 Drawing frequency charts and box plots

Desmos can display a range of graphs and charts. You can use the previous steps for copying the data into Desmos and then select a visualization from: $\text{functions} > \text{Dist}$

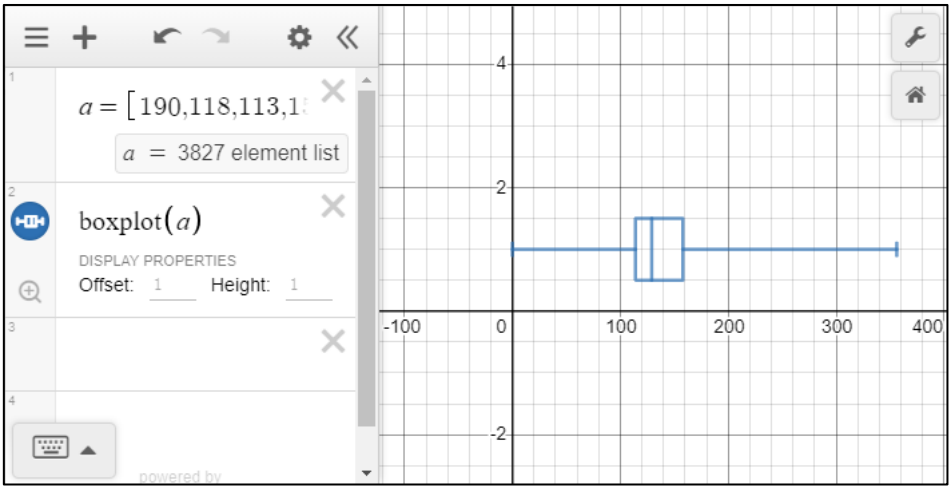
Desmos includes both histograms and boxplots.

For a histogram you should enter the data set and the bin width.



Setting the bar heights to Density is consistent with the UK definition of a histogram. The magnifying glass icon in the input row can be used to auto-scale. Setting the bin alignment to Left is often more useful. For bins of width 20 the first bin will contain values of x where $0 \leq x < 20$.

For a boxplot enter the data set.



What picture of the data does the box plot give?

5 Drawing Graphs side by side for comparison

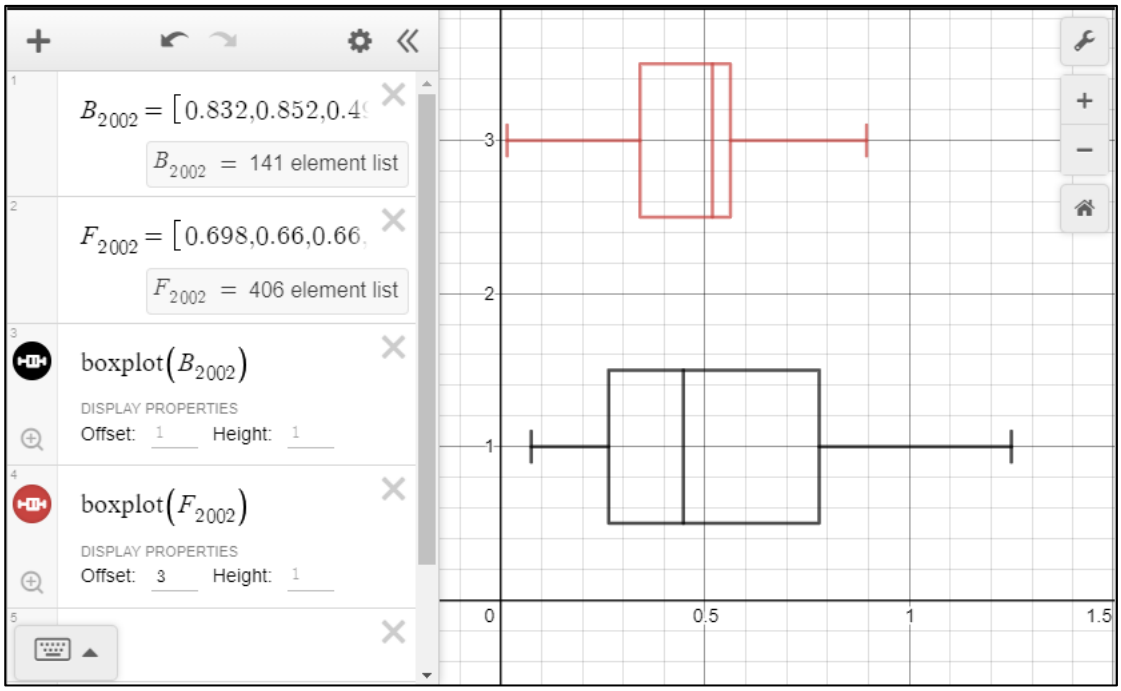
The following example compares the CO emissions for different makes and different years.

Going back to the original excel spreadsheet, **sort** the data by year and then by make:

A	B	C	D	E	F	G	H	I	J	K	L
Referenc	Make	Propulsion Type	BodyType Id	GovRegion	Keeper Title	Engine Size	YearRegistered	Mass	CO2	CO	NOX
321	BMW	1	2	South West	1	2171	2002	1600	237	0.832	0.005
886	BMW	1	2	North West	2	1995	2002	1395	175	0.852	0.05
420	BMW	1	4	South West	1	2494	2002	1615	230	0.494	0.017
588	BMW	1	3	London	1	2979	2002	0	230	0.447	
737	BMW	2	13	North West	1	1995	2002	1505	185	0.203	0.375
921	BMW	1	2	London	1	2171	2002	1600	237	0.832	0.005
1021	BMW	1	6	North West	1	4619	2002	2180	356	1.231	0.068
250	BMW	1	5	South West	1	2979	2002	1505	218	0.269	0.009
484	BMW	1	6	London	1	2979	2002	2095	310	0.582	0.015
920	BMW	2	2	North West	2	1995	2002	1490	148	0.101	0.377
278	BMW	1	4	South West	2	2171	2002	1355	222	1.02	0.037
805	BMW	1	5	North West	1	2171	2002	1500	226	0.498	0.014

Each group will need to be copied as a new list into Desmos. Data items K2 to K142 correspond to CO emission from BMWs manufactured in 2002. Data items K143 to K549 to the CO emissions of 2002 Fords.

Copying each group across into Desmos (NB just type B2002 to obtain the variable name with the subscript):



Exercise: Draw the boxplots for the CO emissions for other makes. What conclusions can be reached by comparing these plots?

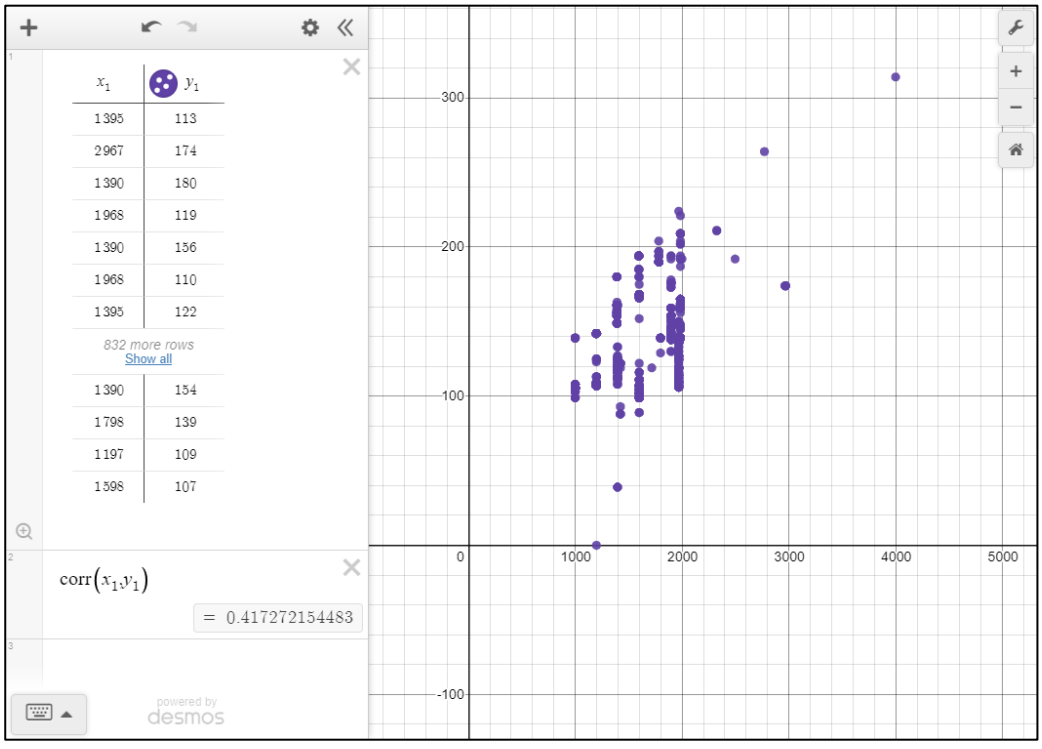
6 Drawing Scatterplots

You can investigate whether there is a relationship between two variables, regarding the data as bivariate data, by copying and pasting two columns of data from Excel into Desmos.

Desmos has a maximum of 1000 data pairs for a bivariate data so you will need to work with a subset of the full data set. In the following example the data has been filtered to show only Volkswagen cars and the columns for Engine Size and CO2 have been copied by selecting column G then pressing Ctrl and selecting column J. These have been copied into a new blank spreadsheet and then these two columns have been copied and pasted into Desmos.

	A	B	C	D	E	F	G	H	I	J	K
1	Reference	Make	PropulsionTypeId	BodyTypeId	GovRegion	KeeperTitleI	EngineSize	YearRegistered	Mass	CO2	CO
4	3434	VOLKSWAGEN	1	14	South West	2	1395	2016	1316	113	0.242
11	2971	VOLKSWAGEN	2	6	South West	5	2967	2016	2185	174	0.138
19	371	VOLKSWAGEN	1	14	London	1	1390	2002	1220	180	0.096
26	1929	VOLKSWAGEN	2	14	London	2	1968	2016	1394	119	0.079
37	1156	VOLKSWAGEN	1	14	London	2	1390	2002	1181	156	0.165
49	2274	VOLKSWAGEN	2	6	South West	5	1968	2016	1503	110	0.137
52	3446	VOLKSWAGEN	1	14	South West	2	1395	2016	1247	122	0.158
55	3331	VOLKSWAGEN	1	6	London	5	1984	2016	1574	162	0.609
59	3523	VOLKSWAGEN	1	14	South West	2	1197	2016	1107	107	0.157
86	2622	VOLKSWAGEN	1	13	London	1	999	2016	1055	106	0.407
99	3348	VOLKSWAGEN	1	14	London	2	1395	2016	1247	120	0.158
108	3500	VOLKSWAGEN	1	14	South West	2	1197	2016	1229	113	0.236
109	2196	VOLKSWAGEN	1	14	South West	2	1197	2016	1107	107	0.157
113	3647	VOLKSWAGEN	2	5	South West	1	1968	2016	1375	109	0.212
120	3305	VOLKSWAGEN	2	96	London	5	1968	2016	1843	136	0.052
122	53	VOLKSWAGEN	1	13	London	1	1596	2002	1285	185	0.53
123	2130	VOLKSWAGEN	1	13	North West	2	1984	2016	1382	139	0.341

	A	B
1	EngineSize	CO2
2	1395	113
3	2967	174
4	1390	180
5	1968	119
6	1390	156
7	1968	110
8	1395	122
9	1984	162
10	1197	107
11	999	106
12	1395	120
13	1197	113
14	1197	107
15	1968	109
16	1968	136
17	1596	185
18	1984	139



The Scatterplot shows some positive correlation between the two variables. This can be confirmed by calculating: $\text{corr}(x_1, y_1)$

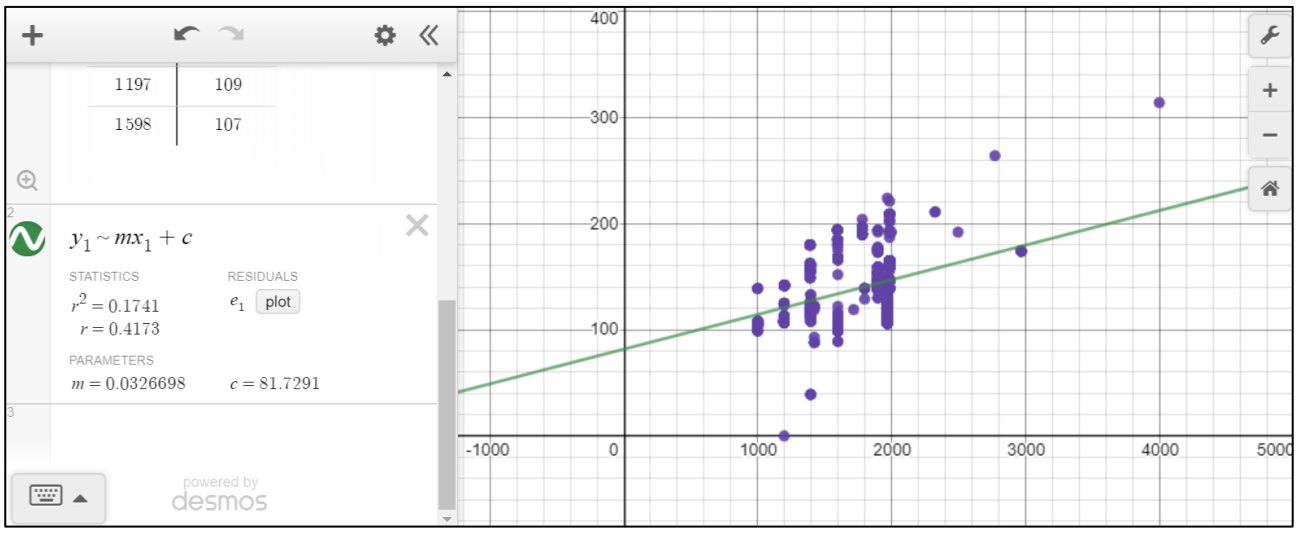
NB for subscripts typing $x1$ will automatically be updated to x_1.

7 Regression models

Desmos allows for any regression model that can be defined as a generalised function. In practice students will mainly use a linear model: $y = mx + c$.

Bivariate data can be copied into Desmos as described in section 6.

The regression model is defined using the tilde symbol, ~, e.g. $y_1 \sim mx_1 + c$.



Students are expected to use (but not derive) non-linear models for data. For example you might consider a log model instead.

The residual sum of squares (RSS), also known as the sum of squared errors of prediction (SSE) gives a guide to how good a fit the model will be. The residuals can be plotted using the plot button.

Exercise: Find the amount of correlation between engine size and mass. There are a number of cars whose mass is recorded as zero. Can you exclude these to get a better picture?

8 Random Sampling

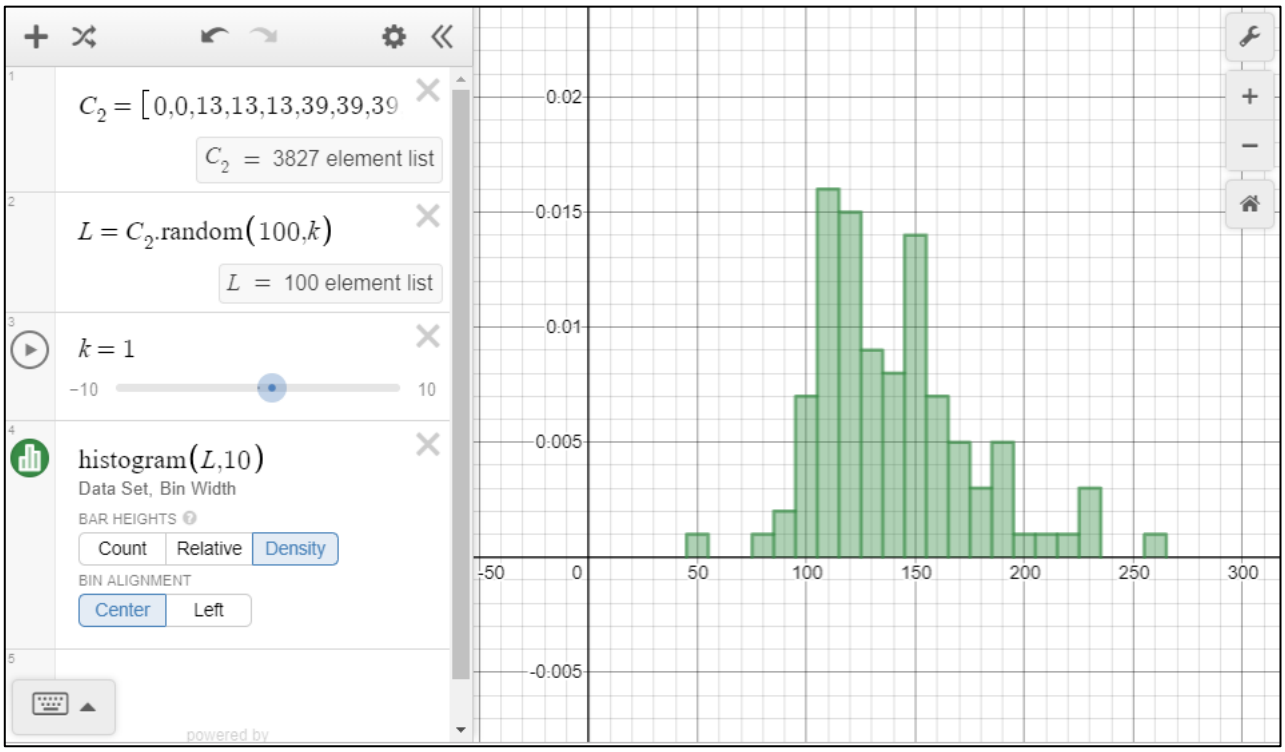
You can use the random function to select a random sample from a list of values. In the following example a random sample of size 20 will be selected from the CO_2 data.

Enter a new variable of C_2 and copy the full list into Desmos.

To create a random sample of size 100 type: $L = C_2.\text{random}(100)$

This can be plotted using $\text{histogram}(L, 10)$ and setting the bar heights to density.

To generate different samples change the list to $L = C_2.\text{random}(100, k)$. k is a "seed" for the random sample and changing this will generate a new sample.



One application of this method is in selecting several samples of the same size and comparing statistics such as the mean or the standard deviation with their true values in the whole dataset. This illustrates the idea of statistical variation. The sample size can then be changed to see how that affects the variation.

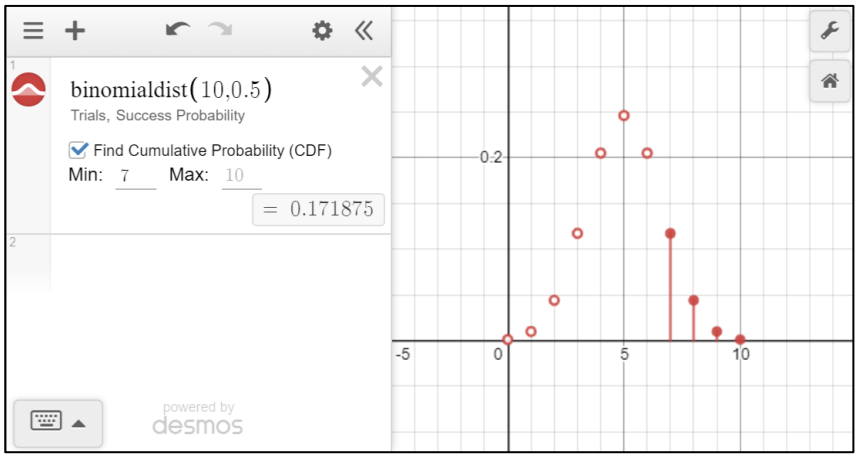
Appendix 1: Ideas for investigations

- Are there any differences in emissions between different makes of cars?
- Are the emissions for cars registered in 2002 worse than for the cars registered in 2016?
- Is there a correlation between mass and emissions?
- Is there a correlation between engine size and emissions?
- Is there a correlation between the CO2 and NOX emissions?
- Is there a link between the engine type and the emissions?
- Are any particular makes of cars more likely to be owned by companies?
- Do different genders have different sized cars?

Appendix 2: Using Desmos for distributions

Binomial distribution

- Select: functions > Dist > binomialdist
- Enter the number of trials and probability of success.
- To calculate the probability of a range select CDF and set the limits.



Normal distribution

- Select: functions > Dist > normaldist
- Enter the mean and standard deviation.
- To calculate the probability of a range select CDF and set the limits.