<u>Decision and Discreet Coursework</u>

Aim:
To investigate whether or not my local petrol station would benefit, in the way of cutting waiting times, from having more fuel pumps open.

By doing this I hope to be able to simulate opening enough pumps in order t o create waiting times less than 1 minute, what I would be willing to wait at a petrol station for petrol.

The way in which I will do this is by collecting sufficient data from my local garage that would enable me to simulate 20 cars using the petrol station. The data of which I will **need** to collect to complete a simple simulation is:

Arrival Time of Each Car:
This will allow me to calculate an inter arrival time of which is needed to simulate the time in between cars arriving at my garage.

Arrival Time of Car n+1 – Arrival Time of Car n = Inter Arrival Time

n = number of car in order of arrival

This will be done for all of the cars of which I have collected data for. I will then group these figures in sensible ranges, of which I can refine later, to calculate the probability of each inter arrival event range occurring.

Length of Service of Each Car:
I have decided that the most accurate way of calculating length of service will be to record the time in between the customer exiting his/her vehicle and re-entering it.

Time Customer Re-enters Car – Time Customer Exits Car = Length of Service

This length of time will be the length of service. By doing this for a sensible amount of time I will be again be able to group the figures of which I obtain for this data type and put them into necessary ranges to calculate the probability for each length of service event range occurring.

Probabilities:
To produce my simulation I had to show the probability of each likely event happening it terms of inter arrival times and length of service. I did this by for both groups of data splitting them into equal groups. To begin they were not to be very big, as that would not give me enough events able to occur, which would make the simulation not very accurate.

The data I collected for **inter arrival** times ranged from 144 seconds to that of 12seconds. To begin with I used ranges of 20 seconds to group the data, of which could give 8 different events. The time shown as the event would be that of the mid point for its group.

e.g 0-19 range, mid point = 9.5 seconds

I manually tallied each range up with the amount of data I had collected specifying that range. From the tallied ranges I could now work out the probability of each range/event occurring. I did this using the formula for each range as:

*Car Tally of Range / Total Number of Cars * 100*

		I.A Lookup	
Range	% Decimal	R.N >	Event
0 to 19	0.043478	0	9.5
20 to 39	0.086957	0.043478	29.5
40 to 59	0.217391	0.130435	49.5
60 to 79	0.217391	0.347825	69.5
80 to 99	0.217391	0.565215	89.5
100 to 119	0.130435	0.782605	109.5
120 to 139	0.043478	0.913035	129.5
140 to 159	0.043478	0.956513	149.5

By turning these percentages into decimals, I am able to generate a random number to determine what event will happen. Here to the left is the lookup table generated for inter arrival times and the raw data needed to produce it. (R.N = Random Number and I.A = Inter Arrival). The random number generated in the spreadsheet is looked up in this table and returns the statement in the 'Event' column for the one of which it is greater than solely in the 'R.N >' column. The 'R.N >' column was made by adding up the percentage for each event starting from 0 as the first event then adding Event 1's percentage to it to get Event 2's R.N and so on.

The same method was used for the **Service Length** lookup table, although service length data ranged this time from 34 – 315. So this time I used ranges of 50 for each group, of which created 7 events possible of occurring. Again the midpoint of each range was used as the event time.

e.g 0-49 range, midpoint = 24.5

See data sheets for all lookups.

The Simulaitons:

Simulation 1

Simulation 1 shows what the probable event would be for a petrol station with only one fuel pump, able to be used by just one customer at a time, as 20 cars pass through the station during a period of time. This is the simplest way the petrol station could be constructed. As you can see from Simulation 1's 'Average Mean Wait Time', the amount of time that can the customer can be expected to wait is 896.13 seconds (14:46:13). The mean waiting times in this simulation range from 517.00 seconds to 1464.50 second both of which are unacceptable amounts of time to have to wait to receive petrol.

Simulation 2

Simulation 2 adds another fuel pump to simulations 1's basic design. Instead of just having one pump to choose from, the customer can choose to go to whichever fuel pump that will be vacant first. This obviously should dramatically cut waiting times by half or more, as there are two pumps able to serve two customers at once, halving waiting times. As you can see by simulation 2's 'Average Mean Wait Time', this is so, as it has dropped to only 125.28 seconds (02:05:28). Although a minimum of 6.55

seconds is the least anyone had to wait it ranges to a massive 348.45 seconds (05:48:45) during this simulation, waiting for this length of time during a busy rush day could still be frustrating for the customer.

Despite simulation 2's inadequate waiting time, it can be seen how the solution of adding extra pumps efficiently reduces waiting times.

Simulation 3

It can be seen from this simulation that the best way in which to cut waiting times at this petrol station would be to add 2 extra pumps. Again by adding the third pump it had significantly reduced the average mean waiting time to 13.16 seconds. Although at the end of the day no waiting time would be the best result, 13.16 seconds is near enough. From the table of Mean Waiting times it can be seen how waiting times range from 0.00 seconds to 53.50seconds – both of which less than my overall aim.

By adding extra pumps to this station, it can be seen how this would efficiently reduce waiting times from the original simulation 1's average mean wait time of 893.16 seconds to simulation 3's 13.16 seconds, just by adding 2 more pumps.

Simulation 4

Simulation 4 extends upon simulation 3's 3 pump system by both adding an extra pump, to make the total 4, thus creating to separate stations both of which have 2 pumps. Further, each station is positioned in a way so that they have a pump on both the left side and the right. Taking this into account, I have also collected data revealing the probability of the side of the car the petrol cap is on, therefore suggesting which side of the fuel station the car would go to. (N.B If the car has a petrol cap on the left side, it would go to the right side of the fuel station to fill, for convenience).

I calculated probabilities of **petrol cap side** by collecting data showing during the passing of 40 consecutive cars 26 had caps on the left side and 14 had caps on the right. I then calculated the probabilities of each event, left/right, occurring using the formula:

*Number of Cars With m Side cap / Number of Cars * 100*

m= side of car (left/right)

In the same way as was done with inter arrival times and service lengths I created a lookup table that was to be used in my simulations. No ranges needed to be created, as there were only two outcomes possible, left or right.

See data sheets for all lookups.

Simulation 4 now takes into account what side of the car the pump is on and then assigns it to the pump that is earliest free out of the necessary side.

As it can be seen from simulation 4, although there are more pumps than that of simulation 3, the average mean waiting time has increased. The mean waiting times range from 1.75 seconds to 102.73 seconds. The increase is due to the fact that I have failed to include an unless statement to shape the way in which 'although naturally the customer would go to its necessary pump side, coinciding with the side of which the petrol cap is on, if both these pumps are being used, to go to the next pump available or is without a customer, even if it is on the opposing side'. Although this would cause inconvenience for the customer (in stretching the pump hose across his/her car), many still do this.

Assumptions:
During my simulations I have had to assume such things to be able to generate a simulation. Although if I were to collect my data again, it would be possible to overcome these assumptions, it would take far to long.

- Everyone using the petrol station is using it only for petrol.
- A customer starts his/her service as soon as the previous customer has finished; there is no time delay.
- Whenever there is more than one pump available, the customer will use the pump that has the lowest number
- Each pump works without maintenance and serves each type of petrol.
- Each customer knows in advance when the customers in front will fish their service, thus choosing the one that will be next free.
- For simulation 4, customers would only go to the pump which would best suit the side of the car their petrol cap is on (i.e. left side petrol cap, right side pump).

Range of Adaptability:
Simulations 1-3 are very adaptable for use with any form of queuing system. Supermarket, shops and banks could all use the same simulation as none go into further detail of what actually happens at the checkout. Simulation 4 could not be used at any of these as it takes into account what side of the car the petrol cap is, of which humans do not need to reflect upon. However it could be used for a motorway pay booth, however, instead of referring to what side of the car the petrol cap is on, you would take into account what side of the car you wish to pay out of, whether it be the passenger seats or the drivers window.

Limitations:
I collected my data between 1:00pm to 2:00pm on Wednesday February 25th at my local garage situated on a B road just off the main A69 route from Carlisle to Newcastle. As I was unable to time by myself more than one form of data, I had to first record inter arrival times and then service lengths of which were both 30 minutes long. Obviously the fact that both sets were collected for just 30 minutes means that there would not have been a wide enough range of data to gain sufficient probabilities. (The reasons for such short times were because I could only collect data for 1 hour due to the stations restrictions). Also this problem would mean that the car inter arrival times were not the cars of which service time I have collected.

During collecting data I was told from workers there that the busiest time for them is on Saturday mornings, this is mainly due to weekend days out needing petrol for the car. During the working week (mon-fri) the busiest time is between the early morning, lunchtime and evening rushes of which commuters are at there busiest transportation times. As my data was collected at this time (any other was deemed inappropriate, due to congestion), my data lacks considerably, the rush hours. If I was to collect my data again, I would go at each contrasting time and gain a mean of both inter arrival time and service length. From this I would have the most accurate data I could possibly gain.

Other limitations which would inevitably have effected my data are that of it was a school holiday, meaning more cars were out than normal during this time for family trips etc, fluctuations in petrol prices at this particular garage could lead to ranging customers, road works in the area could have lead to less people using the area and natural events like the weather. The only way to overcome these limitations would be to collect data over a larger period of time.

Refinements:
In an attempt to produce the best simulation possible I have decided to refine simulation 3, as it was the best simulation for low wait times. To refine it I a have produced new ranges for the inter arrival and service time lookups by halving the ranges thus creating more possible events for each case. Again, the new lookups are shown within my data sheets. What you notice form these more accurate ranges is that due to the short time of which I collected these results, some ranges would not have had a car occupy them. These ones have been made larger to fit with the original lookup range size.

Simulation 5
As a refinement of simulation 3 I predicted that the average mean wait time for this simulation would be around about the same as for that of simulation 3. Indeed, it even compliments this. The actual average mean wait time for this simulation is 5.33 seconds. The reason it is smaller is due to the fact that there are more events that are possible and more accurate measurements of ranges. This means that due to more precise probabilities of ranges the simulation is a lot more reliable.

Conclusion:
My aim to begin with at the start was to produce through simulating a petrol station, an appropriate number of petrol pumps, which would dramatically cut waiting times at my local garage. By simulating a refined 3 pump station, it is clear that in order to cut waiting times they would see it necessary to add an extra pump to there present 2 pump system. It is also clear that they would be able to open a 2 station, 4 pump system, in which customers could choose which side pump to go to, of which they would benefit from. However, as money plays a major role in development, a 3 pump station would do the optimal job and therefore I can conclude, in order to decrease customer waiting times to less than 1 minute, my local petrol station would have o have 3 petrol pumps.

Evaluation:
My simulations worked very well in the fact that they 1,2, 3 and 4 produce results, which with little assumption would benefit customer satisfaction. Although I was unable to collect sufficient data to properly design simulation 4, the idea works. If I was able to generate a calculation that would outline its defaults then I am sure it would decrease waiting times from that of simulation 4's. If I had enough time, I would also refine each simulation as it could possibly bring the simulation of a 2 pumps stations mean waiting times under 1 minute. Each simulation is not bias as I

have used random numbers using spreadsheet software which means to human tinkering could have changed these random numbers, this can be seen as each random number cell has the formula ‘RAND()’, showing the computer has done it itself. To make it more sensitive, I would have to measure times to decimal seconds in order to produce even further accurate results. The way in which I have kept all random numbers to 6 decimal places has also kept it fair. So from this evaluation I can say I have successfully created a simulation able to predict the optimal number of pumps needed to satisfy customers and staff at my local garage.

Data Sheets:
Raw Data
Lookups
Simulations 1,2,3,4 and 5
Simulations 1,2,3,4 and 5 Average Mean Wait Times
Simulations 1,2,3/5 and 4 Annotated Formula