**Assessment submission form:**

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| **Assessment title** | Discrete Event Simulation of the local newsagents Clarks |
| **Module code** | MIS41100 |
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**Signed: Robert Tuke** **Date: 22/08/2021**

**Code containing the details of the simulation in python as well as excel files containing details simulation data have been provided with this submission.**

**Abstract**

In this paper I perform a discrete event simulation of a typical weekday in a local newsagents situated in Dublin called “Clarks” with a goal of making decisions such that they minimise the waiting times of the customers in line and the degree of congestion when moving around in the shop. By eliminating congestion we aim to maximise the overall revenue, Clarks can accumulate through processing customers as quickly as possible and preventing them from going elsewhere.

With this view in mind in this paper I simulated three alternative scenarios Clarks could adopt in order to improve its efficiency, 100 simulations were run on the initial formulation and each of these scenarios. The confidence intervals and mean Revenue gained from these simulations were used to compare the 3 alternative scenarios and the initial formulation against each other. Scenario 3 created the greatest improvement overall, in which the shop is rearranged in such a way as to allow the employment of a third till at the cost of reducing the max capacity of the line to 5.

**Intro and problem formulation**

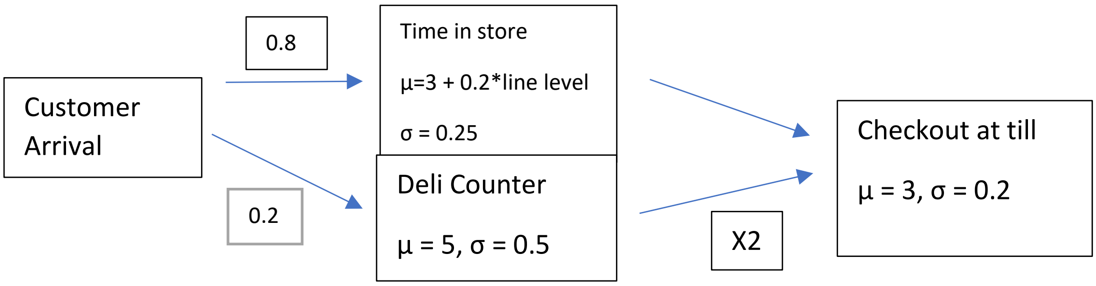
“Clarks” is in a very high competition space as there are many competing shops on the same street and the ability of the shop to minimise the waiting times of its customers is highly important as there are a variety of options open for potential customers to choose from if there are too many people in the shop or waiting in line.

Our goal in this paper is to maximise revenue by improving the overall efficiency of Clarks and keeping the number of customers below the maximum capacity of the checkout line which in the initial formulation is set to 10, the max capacity of the shop which is also set to 10 and the maximum capacity of the line for the deli counter which is set to 5. Beyond these upper bounds no new customers will arrive and will instead go to a competing shop, therefore our overall goal in this simulation is to find the ideal scenario that prevents these three items to exceed capacity.

The total time of the simulation, employee pay and the max capacities of the line, shop and deli counter were modelled deterministically, all other variables within this simulation were modelled as stochastic random variables following a normal distribution.

The specific problem formulation and value of certain variables such as average checkout time or average amount of customers arriving at specific times of the day were chosen after consulting with the owners of the shop. This problem was formulated as a discrete event simulation and was coded in python using the package Simpy, greater detail on the problem formulation can be found within the python files enclosed with this submission. Detailed results for each of the simulations as well as additional data visualisations can be found on the excel files provided.

**Initial formulation**




Our problem was formulated following a timetable corresponding with Clarks weekday opening hours which operate from 7am – 7pm on in which the amount of customers arriving at any one time is dictated by whether we are in prime business hours where 1 customer arrives every minute or we are in regular business hours in which 1 customer arrives on average every 4 minutes.

**Timetable for new customers arriving to the shop**

| | |
|---|---|
| 07:00 – 08:00 | μ = 4, σ = 1, (Regular) |
| 08:00 – 09:00 | μ = 1, σ = 0.2, (Prime) |
| 09:00 – 12:00 | μ = 4, σ = 1, (Regular) |
| 12:00 – 13:00 | μ = 1, σ = 0.2, (Prime) |
| 13:00 – 16:00 | μ = 4, σ = 1, (Regular) |
| 16:00 – 17:00 | μ = 1, σ = 0.2, (Prime) |
| 17:00 – 19:00 | μ = 4, σ = 1, (Regular) |

Regular hours = 1 customer every 4 minutes with standard deviation of 1 following a Gaussian distribution

Prime = 1 customer every 1 minute with standard deviation of 0.2 following a Gaussian distribution

Roughly 20% of all customers that arrive go to the deli counter and takes around 5 minutes for the customers to make their order and to have their food made and wrapped up. The remaining 80% of customers pick and choose the items that they want to buy, it is important to note that this process is not done in parallel due to the extreme constraints on space given the small size of Clarks and customers are asked to wait outside of the shop. A customer takes on average 3 minutes to do this in addition to an extra 0.2 minutes for every customer that is within the checkout line as the bigger the line the less freely the customer can move quickly throughout the shop to choose their products.

Both the deli counter customers and the regular customers use the same checkout line, however deli counter customers are counted twice as they spend roughly twice as much and on average take twice as long to process on the tills as the till operator must manually put in what the customer ordered as the deli counter food, in contrast to the other products, does not have a barcode.

Two owners of the shop operate the till in different shifts throughout the day and checkout customers at the same speed with an average checkout time of 3 minutes per customer and 6 minutes for the deli counter customers. Regular customers pay on average 5 euro each while deli counter customers pay on average 10 euro each. With our initial formulation we managed to earn 1229 euro in revenue with a 95% confidence interval between 1158 and 1300, however our shop and our checkout line exceeded their max capacity over 17 times and 51 times respectively. This means that we lost a significant amount of customers due to congestion within our shop and we lost on average 883 euro from all customers combined, this means there is a lot of room for improvement in how Clarks can be operated and that our primary bottleneck is our checkout line capacity.

**Scenario 1: Replacing deli counter with new selection shelves**

In our first scenario we try to solve our checkout line bottleneck by getting rid of our deli counter and replacing it with shelves that provide greater selection to the regular customer, this change will increase the capacity of our checkout line to 15. Due to the fact that deli counter customers are no longer provided for we expect customers to be more willing to wait for service due to shorter time in lines and will keep shop capacity at 10 even as checkout line capacity rises to 15.

We estimate to increase our earnings from our regular customer to 6 due to the greater selection of products and that all of the customers who would have bought something from the deli counter will instead go to a different shop.

In this scenario our checkout line never exceeded it max capacity but our shop did reach max capacity 19 times on average, what was most striking about this scenario is the amount of revenue that was lost. On average 62 deli counter customers went elsewhere, which alone represents 620 euro in lost revenue, despite the improvements in the checkout line bottleneck we earned on average of 1184 euro which is lower than our initial formulation score of 1229.

**Scenario 2: Add another till**

In this second scenario we hire employees to rotate on an extra till within the shop, each employee is paid 11 euro per hour in wages so in total, this extra till will cost 132 euro per day. These new employees are not as well trained as the owners, in addition being employees and not owners, they are understandably less psychologically invested in the business than the owners are and therefore these employees are expected to take 50% longer to checkout new customers on the tills.

This scenario represents a significant improvement as our average total revenue minus the additional cost of the new employees comes to 1379 euro, despite this the lower bound of our 95% confidence interval is at 1288 which is within the range of our initial formulation. This improvement is likely due to an improvement in our ability to quickly process customers at the checkout line bottleneck most importantly our ability to quickly process the individuals on the deli counter. While the checkout line bottleneck was reduced, this scenario had on average 18.6 instances where shop capacity was exceeded which is nearly identical to the 18.8 instances in our initial formulation.

**Scenario 3: Rearrange shop to reduce line and create a new till**

In our final scenario we attempt to rearrange the shop in such a way that the max capacity of the line is reduced making space for a third till, in this scenario we will employ two extra tills operated by newly hired employees. Given that the line has been reduced to 5 and there are now 3 tills we predict that customers will be more willing to wait in the shop and predict that shop capacity will increase to 15 overall.

This scenario provided the most efficient results overall by achieving an average revenue of 1427, this was including the 264 spent on employee wages. In addition the lower bound of the confidence interval for this scenario was greater than the higher bound for the same interval on our initial formulation meaning we can be sure to greater than 95% level of confidence that this scenario will outperform our initial formulation. 212 euro on average was lost from this scenario compared to 883 from our initial formulation and there were extremely few instances where max capacity for either the line or the shop was exceeded.

**Conclusion**

**Final Results Summary**

| | Mean Revenue | 95% CI interval Revenue |
|---|---|---|
| Initial Formulation | 1229 | [1158, 1300] |
| Decision 1 | 1184 | [1126, 1242] |
| Decision 2 | 1379 | [1288, 1471] |
| Decision 3 | 1437 | [1352, 1522] |

In this paper we formulated a typical weekday of a local newsagents as a discrete event simulation problem where most of the variables were stochastic subject to a normal distribution. We compared the initial formulation with 3 alternative scenarios of how the owners could alter the strategy of the shop based primarily on the mean revenue and confidence interval gained from 100 test simulations on each strategy. Our most successful strategy and our recommendation going forward for the owners of Clarks is to adopt alternative scenario 3 in which the shop is rearranged to allow for a three tills that can be operated by new hires.

However, there are certain limitations to this paper, one consideration is that perhaps new customers who value the personal touch will be less likely to buy from Clarks if new hires arrive and who have less of a connection with the customer as compared to the owners or alternatively perhaps there are additional as yet unknown benefits to replacing the deli counter. While I have attempted to model as many variables as possible certain hidden items such as these have not been accounted for and although simulations of this kind are much better representations of reality compared to deterministic models there is still a great information loss that occurs when turning a problem from the real world into a mathematical formulation.