PART A:

1. INTRODUCTION

The STJ Coffee Shop – which is the study case in this report – owned by three close friends Samantha, Tom, and Jane is a local coffee shop located in the centre of Edinburgh within the vicinity of the University of Edinburgh. The coffee shop is what we can term a "small business", and challenges that these small businesses have faced during the COVID-19 pandemic (which includes drops in revenue leading to bankruptcy amongst other issues), makes this simulation even more pertinent in mitigating the effects of the pandemic on revenue loss or customer dissatisfaction; loses that can be attributed to operational inefficiencies. Small businesses, as we have come to realise, are essential to any economy in that they provide opportunities for entrepreneurs and create meaningful jobs with greater satisfaction than some positions with larger, traditional companies. Additionally, they foster the local economies, keeping money close to home and supporting neighbourhoods and communities. It could be said that they are the livelihood of many economies around the world. The STJ coffee shop employs three full-time workers (Sam, Tom, and Jane) who work based on some level of agreed rotation, and two part-time workers (who also work different hours). The shop mainly provides drinks (coffees, tea, and soft drinks) as well as food items (such as cakes, fruits etcetera). Part time workers such as David and the other members of staff are employed to accommodate busy periods.

2. PROJECT FOCUS AREA AND GENERAL ASSUMPTIONS

This study seeks to analyse the daily process at the STJ Coffee Shop. Although there are several compartments of the coffee shop (such as the restroom, the kitchen etcetera), this project focuses on the operational process of the coffee shop and does not consider activities that could be deemed extra-curricular (such as the use of bathrooms). As such, this project envelopes only processes such as customer arrival patterns, till operations, order preparation, table preparation etcetera while factoring in the behavioural patterns of the customers. The arrival pattern for example is based on our behavioural observation of the customers such as the inter-arrival times, the waiting-times and even behaviours towards queue length.

A goal of this study is to better understand the importance of data collection as it would in effect make the simulation or any other form of analysis easier in the future even for the coffee shop. Given this, the data used in the analysis includes those based on justifiable assumptions and observations. For example, the data for customer arrival was collected over a week during outside teaching term times. The implication of this is that many students were not visiting the campus and as such, the customer arrival is lower at this point and might not be a true reflection of the arrival pattern of customers to the coffee shop. To model the customer arrival rate, the observed data is ***multiplied by***

three for each arrival interval period based on the assumption that arrivals are estimated to be three times larger when the school is in full session during teaching terms.

Another assumption of the model is that different customers do not share the same table. If we take the two-seater table as an example, what this assumption means is that, while an individual customer makes use of a two-seater table, the second seat cannot be occupied by another individual customer. This is based on the idea that customers do not like to share tables with strangers. As Expected, this assumption does not hold when the table in use is the long table (if purchased) that can sit up to ten (10) individuals. Finally, we assume that negligible time is used in the processing of certain activities such as the cleaning of tables just before a customer makes use of the table. The same assumption holds with the preparation time for fruits, cakes etcetera (this in part because the foods are homemade and already prepared down and because whatever time it takes to serve the food item is factored into the time taken to prepare the drinks).

3. STATEMENT OF THE PROBLEM

The three shop owners are concerned with increased queue lines at the Till and would like to improve the operational process to reduce waiting times and possibly increase revenue.

4. OBJECTIVES OF THE STUDY AND RESEARCH QUESTIONS

The foremost objective of the study is to understand the operational process and operational times of processes in the STJ coffee shop. After such understanding, the next step objective is to identify sources of inefficiency leading up to long waiting times in the coffee shop as well as processes causing long queues. In summary, the set of objectives will greatly benefit the operations of STJ Coffee Shop, and it includes analysis of data to provide recommendation for improvement in:

a. Processes: Can we identify sources of inefficiencies/long queues and manage them accordingly?
b. Resource and Personnel Allocation: What is the optimal combination of resource and personnel Allocation?
c. Scheduling and time utilization.

Finally, and as stated in the introduction, another important goal of this project is to encourage the continued use of data analysis by STJ Coffee Shop. The data collection and analysis that occurred because of this simulation is something not normally done by the coffee shop as we had to collect certain data ourselves through a five-day observation (which was during a time when most students were not having lectures). It is without doubt that if data were collected over a longer period, the project would yield better results.

5. METHODOLOGY

The processes of the coffee shop were simulated based on certain assumptions and using the software "Arena Simulation". This tool is a simulator that allows us to identify system constraints and limitations and the reasons behind specific system conditions. Different combinations of inputs and the expected outcomes were also analysed using the Process Analyzer tool (such as when one of the owners takes a day off). The results are further elaborated in the next section. In summary, the simulation was done based on our observation of the rate at which customers arrive at the coffee shop, coupled with the availability of resources (such as trays, tables, baristas etcetera), observed customer behaviour and the expected processing time of certain activities (such as the preparation of the orders or the collection of orders). By combining all these factors and by simulating (virtual imitation of the processes) these activities, we can derive certain outcomes that can be analysed to improve the operations of the coffee shop.

To assess the impact of different strategies, and to recommend rational resource levels, we take the following into consideration:

a. The Average rate at which customers enter the shop over different hours of the day.
b. The time required by a Barista to collect orders at the till.
c. The time required by a barista to process and serve each of the different order types, and the amount and type of variations in these times.
d. Shift staffing options (when does David arrive? How many hours does he work? Etcetera).
e. Limiting factors and resources such as the amount of tables, trays etcetera that are available at the coffee shop.

In this study, primary data was collected and extensively used in the analysis. The tools used are Arena, Process Analyzer, OptQuest, and Excel.

6. ANALYSIS OF RESULT AND RECOMMENDATION

To understand the difficulties faced by the Coffee Shop, we first simulated a scenario where all observations and resources are kept at their current levels. The result is depicted in the figure 1 and 2 below for the different schedules of Sam, Tom, and Jane (i.e., one for when everyone is around and the second for when just any two of the founders are around). Figure 2 shows the number of customers that came into the shop, the number that were fully attended to, and the number of customers that left the coffee shop due to the size of the queue at the till while figure 1 shows the hourly utilization rate of Baristas under the two schedules (Where "Day Off" signifies when either of Sam, Tom or Jane is not around, "Day On" signifies when all three are around).

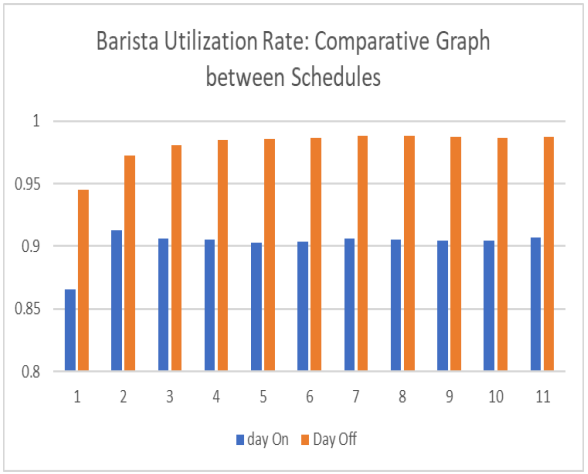

Figure 1 Comparative Statistics: Barista Hourly Utilization Rate

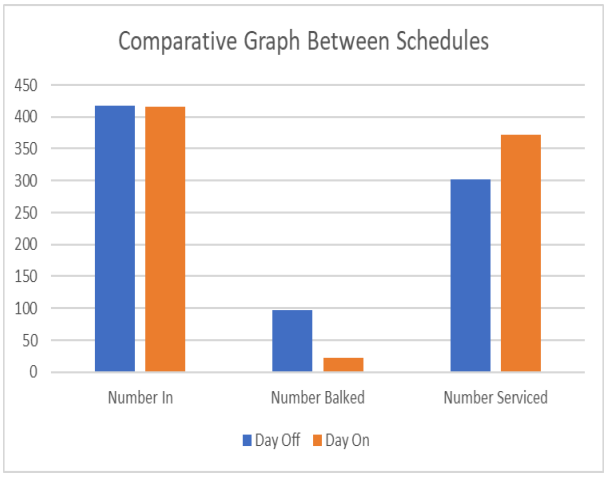

Figure 2: Comparative Statistics on Balk rate.

As expected, the utilization rate of customers and the total number of balked customers is relatively higher on days when either one of the three founders takes a day off. Unsurprisingly, the utilization of the Baristas is way higher on days when one of the owners is not on ground. By understanding the hourly utilization rate of the Baristas, we can better plan on when to probably hire more help or manage resources better. For Example, when all three owners are around coupled with the part-time workers, the second hour seems to be the time when the Baristas are most busy. From this, we can understand that hiring a part worker to cover this shift could significantly reduce the workload of the shop workers and possibly reduce the balk rate.

It would of course be inefficient and wasteful to get a full-time staff if customers are not balking at all given intervals. As such, we took a closer look at balking patterns per hour to have a better understanding of when customers leave the coffee shop due to the size of the queue. The result is presented in figure 4 below:

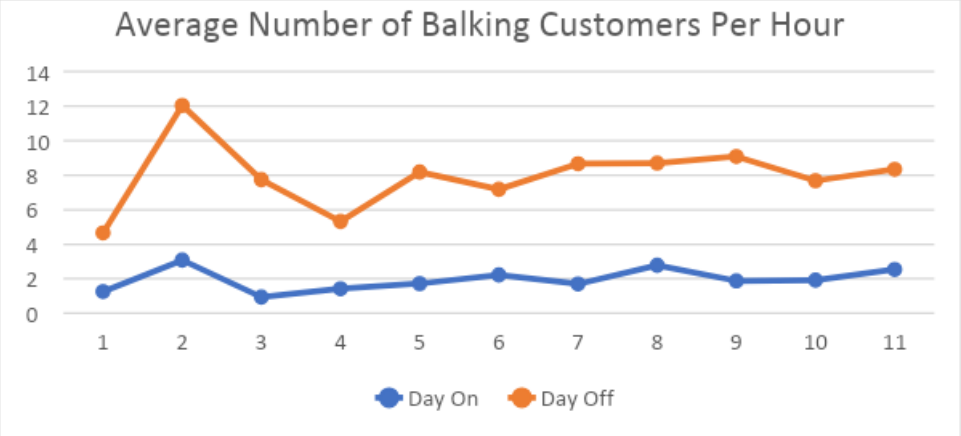

Figure 3 Hourly Balk Rate of Customers

Surprisingly, the second hour seems to be the time with the highest balk rate both for when Sam, Tom and Jane are working and when one of them takes a day off. A viable solution for STJ Coffee Shop could be to employ a part-time staff to cover these shifts that record spikes in balking as opposed to hiring full time staff to cover for them.

An important field in Analytics is Optimization which quite simply is the process of making the most effective use of resources available. To this end, this analysis goes a step ahead in proposing the best combination of resources to prevent/reduce the balking of customers from the coffee shop as well as maximizing revenue for the coffee shop. Based on the available choices in increasing resources, numerous combinations of the resources that could significantly reduce the balking rate. As such, the choice of inputs should be dependent on the associated cost of increasing such resources. For example, an approach that aims to minimise the number of employed baristas while keeping the balking at low levels might be to employ two additional part-time baristas when all the owners are on duty (that is, Sam, Tom and Jane are working), and three when either of them takes a day off. This information coupled with the hourly balk rate can be combined to plan on the time shifts of the new additions. A comprehensive combination of resources that could minimise balking rate is attached in the appendix of this report as table 8.

Another concern for STJ coffee shops especially in these times of uncertainty is the ability of the coffee shop to maximize revenue. As such, an additional perspective was given towards revenue maximization for the coffee shop. The results are particularly interesting as the combination of resources that maximize the most revenue includes increasing the Baristas at the coffee shop by four (4) whilst reducing the number of two-seaters to one and the number of trays to 3. The employment of additional baristas could be informed based on the balk rate depicted in figure 3. This strategy

involved here includes reducing the number of sit-in customers. Five possible revenue optimizing combinations of resources are included in the appendix as table 9**.**

6.1. RECOMMENDATION

One particularly interesting result of the optimization – specifically, the maximization of revenue – shows that by reducing the number of tables available for sit-ins, revenue could be increased and by extension the total number of balking customers could be reduced. This is because, if fewer tables are available, more customers are inclined to become "Take-Out" customers even though they might have originally come into the coffee shop with the intention of sitting in. Additionally, if fewer seats are available for sit-in, it could reduce the pressure on the workers/baristas in terms of the time taken to clean the tables. This time could be better spent attending to other activities in the coffee shop. It also provides a cheaper alternative to renting space from "QRmill Estate" and the procurement of additional tables and chairs that would be needed in the new rented space.

PART B: APPENDIX

TECHNICAL COMPONENTS OF THE STUDY

This section expatiates on the technical components of the simulation and the implementation of assumptions, distributions, and data collected in the Arena Simulation Software for the STJ Coffee Shop. It gives an overview of how the study was implemented in Arena. Given this, this section is divided into different sun-sections such as selected details in Arena (such as arrivals, attributes, processes, etcetera), relevant elements of the design of the experiment, and analysis technique used.

A. ELEMENTS OF THE DESIGN AND SELECTED DETAILS:

1. ARRIVALS

The customers to the coffee shop were modelled based on inter-arrival times given in the table below. Considering the time of the collection of the data (which was over a five-day period when students were hardly in the campus), the data collected was factored by three to represent a more realistic depiction of the arrival patterns in the coffee shop. This also highlights the importance of data collection because if data were collected more frequently by STJ coffee shop, the inter-arrival times could possibly paint a different picture from our observation and assumption.

Customer Arrival Pattern/ Inter Arrival Times					
Period	8am to 10am	10am to 12pm	12pm to 4pm	4pm to 6pm	6pm to 8pm
Expected Arrivals	30	24	36	45	36

Table 1 CUSTOMER INTER-ARRIVAL RATE

In Arena, arrival schedules provide one method of defining the arrival pattern of entities to the system and this was implemented in the software.

2. MODELLING CUSTOMER ATTRIBUTES (CHARACTERISTICS)

It was also noted that customers have different attributes upon arriving at the coffee shop. For example, when customers arrive at the coffee shop, they could arrive as individuals, pairs/couples, or in groups of three or four. Another example of the customers attribute in the simulation study is the type of customer that has arrived. From the analysis, the customer could come into the coffee-shop with the intention of sitting in or with the intention of taking-out. Therefore, upon arrival at the coffee shot, the attributes are assigned to the customer. The collection of data found that customers arriving as individuals accounted for 30% of total customers, pairs/couples accounted for 40% of customers, groups of threes accounted for 15% of arrivals, and groups of four accounted for 15% of arrivals. It was also noted that upon arrival at the coffee shop, about 40% of customers come into the STJ coffee shop with the intention of sitting in, while 60% come with the intention of being take-out customers. These two attributes (customer size and customer type) were modelled with a discrete

probability distribution. Another important attribute assigned to each arriving customer is the time of arrival.

3. RESOURCES

The resources used in the simulation include those observed in the coffee shop and those noted in conversations with the three owners. These include four trays, two two-seater tables, four trays and the working schedules of the owners, David, and the additional part-time barista. It should be noted that in the base model of the analysis, we started with the staffing schedules when one of the three owners takes a day off and by using "Process Analyzer", determined the results when all three owners are scheduled to work together as opposed to having different arena models.

4. COFFEE SHOP SECTIONS

While modelling in Arena, the coffee shop and in fact the model is divided into three sections. The first section comprises customer arrivals into the STJ coffee shop as well as the customers' behaviours. Here the customers are assigned their attributes upon arrival based on a discrete probability function. The time of arrival into the coffee shop is also captured for all customer arrivals. A key component to this stage is the modelling of customer behaviour towards the size of the queue. We know that customers balk upon seeing that the queue size at the till is more than 10. We also know customers arriving in groups tend to queue up together thereby forming a part of the queue (that is, if a group of three customers arrive, they are assumed to take up three spaces in the queue while they talk) although only one makes the order. Upon arrival, and as opposed to splitting the customers to their sizes, we let the customer proceed to the till. However, in deciding as to whether to join the queue or not, we include a decision module that looks at the sum of attributes in the queue and decides whether to proceed or balk. In essence, if there are distinct four customers already on the queue, when a customer arrives at the coffee shop, Arena evaluates the "***Sum of attributes (customer size) currently in the till queue***". If the sum of this attribute is greater than 10, the arriving customer balks and leaves the coffee shop. This represents an easier way of modelling customer behaviours towards queue size as opposed to splitting and batching or using the "blocks and elements module". Upon Making the order, we know that customers move to another queue to receive their orders. Considering that this is a discrete event simulation, we clone the entities into two and route the duplicates to the second station (the order receiving and table section of the coffee shop) for them to wait for their orders. The orders then proceed to the preparation stage where they are split into the customer size (since the orders by the customers could be different with varying preparation times). These orders are also then batched into one and sent to the second station where they are batched with the customers that placed the order. At this stage, take-out customers collect their orders and leave the coffee shop. The Sit in customers continue in the coffee

shop and a series of decisions are made based on the dynamics of events taking place in the coffee shop.

Statistics on hourly utilization and hourly balk rate are also collected over fifty replications.

5. DISTRIBUTIONS IN THE STUDY

This sub-section gives an overview of the time taken for certain activities as modelled in Arena.

Drink Type	Percentage	Distribution	Minimum	Mean	Maximum
Coffee	50%	Uniform	2 minutes	-	4 minutes
Tea	20%	Triangular	1 minute	2 minutes	3 minutes
Soft Drink	30%	Exponential	-	30 seconds	-

Table 2 DRINK DISTRIBUTION AND TIME TAKEN

As stated in the project overview, it is assumed that negligible time is taken for preparation of food items as they are already made as well as cleaning of tables. Each table stay at the STJ coffee shop was estimated from observation to take an exponential distribution with a mean of 30 minutes.

B. ANALYSIS TECHNIQUES USED:

The modelling and simulation were run using Arena Simulation. Process Analyzer was used to compare the performance of different parameters in our simulation model. Considering that the Process Analyzer is agnostic to whether a schedule was used or not, especially regarding the scheduling of staff, a variable was created, and this study uses the “Variables” module within the duration field to modify the schedule in Arena. The staff schedule was then set as a function of this variable. By modifying the variable in Process analyzer, we can easily compare results for when all three owners are around and when one takes a day off. For example, the default schedule is when one of the owners takes a day off. For example, if the variable was set to 10, the amount of baristas available within a particular period becomes a function of the variable that was created. This then enables us to increase the variable value by one in process analyzer to signify that all staff are present. Statistics are also collected using the read/write module.

Having compared the results for different scheduling options in the Process Analyzer, we optimized the operations of the STJ Coffee Shop to understand the combination of inputs that could generate the best output. This analysis focused on two objectives. The first being the minimization of the balk rate while the second being the maximization of revenue. This optimization was done using another tool extension in Arena called “OptQuest”. It should be noted that the variable created and used as a function for the availability of staff was set as a control variable for both OptQuest and Process Analyzer. Finally, the results generated by Arena, Process Analyzer, and OptQuest were analysed

using Excel. Data used was primary data that includes data from observation, and interaction with the coffee shop owners.

PART C: APPENDIX

CONCEPTUAL MODEL

The conceptual model can be defined as the specific description of the imitation of the process to be modelled by describing the objectives, inputs, outputs, content, assumptions, and simplifications of the model. Given this, the contextual model is divided into two subsections: the scope of the model, and the level of detail of the model.

SCOPE OF THE MODEL:

1. STATEMENT OF THE PROBLEM AND OBJECTIVE OF THE STUDY

The owners at STJ Coffee Shop have noticed for some time now the increasing balk rate of customers and customers at the queue at the till. The owners are worried about the effects these problems could cause to the coffee shop and are looking for ways to optimize operational efficiency to reduce balk rate while simultaneously increasing/maximizing revenue.

Given the above statement of the problem, the objective of the simulation study is to improve the operational efficiency of the STJ Coffee Shop to avert loss of customers, while maximizing revenue. The study aims to imitate the operating environment of the STJ coffee shop to give meaning insight into managerial considerations that could improve their processes.

To begin with, we give a simple graphical illustration/representation of the coffee shop in the diagram below:

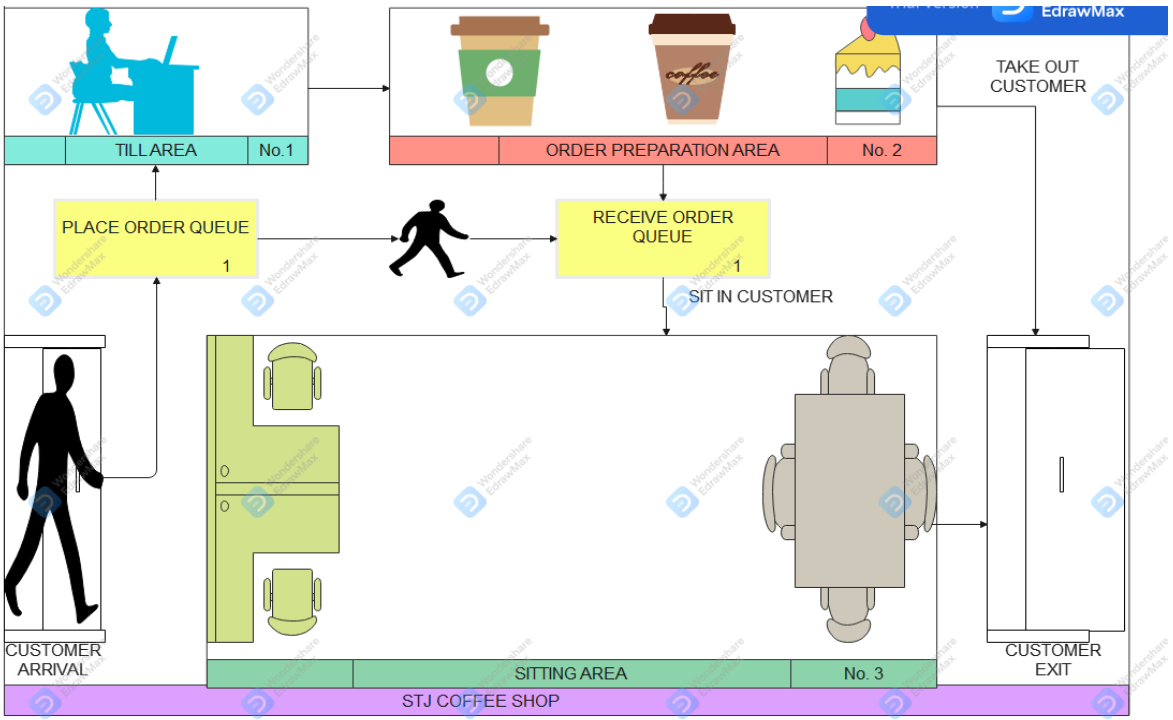

Figure 4 Graphical Illustration of The STJ Coffee Shop

The process in simple terms involves customers arriving at the coffee shop, placing their orders at the till if the queue size at the till is favourable, waiting for their orders, deciding whether to sit in or take out, and finally exiting the coffee shop.

2. EXPECTED BENEFITS OF THE SIMULATION TO STJ COFFEE SHOP

There are numerous benefits of the simulation project to the STJ Coffee shop. Simulation helps us imitate a real system without the headaches and costs that might be associated with implementing real life changes that might not yield expected results. In the STJ Coffee Shop scenario for example, one could simply employ more staff and expect that the problem might not persist. This could work, but at the same time, the results might not be desirable. The ability to compare different scenarios by imitating the processes and behavioural patterns of individuals in that system provides a more efficient method of analysing which changes might be desirable or not desirable. Given the above, the benefits of the simulation to the STJ Coffee Shop can be summarised below:

- **Cost Effectiveness:** Computational imitation of different combinations of inputs in a real-life system are in most cases going to be a lot cheaper than making real-life experiments. In the case of the STJ Coffee Shop, it would be quite expensive and inefficient to alter daily activities daily to ascertain the best combination of inputs or managerial decisions that ensure that the objective is met. Simulation provides an easier alternative for the owners.

- **Variability:** Computational imitation of a real-life system ensures that variables such as inputs can be easily varied to ascertain its effect on outcomes. As expected, this is much more efficient than varying inputs in real -life systems.
- **Time Efficiency:** Experimenting with the STJ Coffee Shop would be time consuming as it may take long periods of time (maybe weeks, or even months) to get a true reflection of the system and an optimal combination of resources/inputs to achieve the desirable goal. The contrary is the case with computational simulations as a simulation can run many times faster than real time. Consequently, results on system performance can be obtained in a matter of minutes, maybe hours if computer simulation is applied. This also has the advantage that results can be obtained over a very long-time frame, maybe years of operation, if required. Faster experimentation also enables many ideas to be explored in a short time frame, abilities which might prove impossible or time inefficient in real-world scenarios.
- **Ability to Control Conditions in the Simulation:** When comparing alternatives in the STJ Coffee Shop, it is useful to control the conditions under which the experiments are performed so direct comparisons can be made. This is difficult when experimenting with the coffee shop itself. For instance, it is not possible to control the arrival of customers at the coffee shop. With a computational imitation of the system, the conditions under which a trial is performed can be repeated many times. In our case, the same pattern of customer arrival can be performed time and time again.

3. THE EXPERIMENTAL FACTORS AND RESPONSES

To design the conceptual model of the STJ Coffee Shop, there is the need to understand the inputs (experimental factors) and outputs (Responses) used in the analysis. These inputs and outputs are represented in the table below:

Experimental Factors ● The STJ Staff Schedule ● The Trays ● The Four-Seat Table ● Two-Seater Tables ● Long Tables (possible Addition) *Responses to Determine Success of Objective* ● Hourly Balking of Customers *Responses to Identify reasons for Balk Rate:* ● Time Series showing Hourly Balking of Customers ● Time Series Showing Hourly Utilization Rate of Baristas

Table 3 EXPERIMENTAL AND RESPONSE FACTORS

4. **ASSUMPTIONS OF THE ANALYSIS**

The Assumptions in the model as relating to customer inter-arrival times, processing times, etcetera are given as thus:

- Assumptions on Inter-arrival Rate is based on data collected over a five-day average. Due to the time the data was collected and the fact that many students are not on campus during this time, the numbers were factored by three to present a truer representation of the arrival patterns. The new arrival rates are given as:

Customer Arrival Pattern/ Inter Arrival Times					
Period	8am to 10am	10am to 12pm	12pm to 4pm	4pm to 6pm	6pm to 8pm
Expected Arrivals	30	24	36	45	36

Table 4 INTER ARRIVAL RATES

- Based on interaction with the owners, the preparation time of orders are given below:
  - Coffee: Minimum of 2 minutes and maximum of 4 minutes.
  - Tea: minimum of 1 minute, maximum of 3 minutes and average of 2 minutes
  - Soft Drink: usually 30 seconds.
  - Time taken to prepare the food items such as cakes and fruits is factored into the processing time of the drinks.
- The number of workers can vary and as such different schedules are compared.
- Customer arrivals can vary. Customers can arrive as individuals or in groups of up to four. Consideration is not made for groups exceeding four since STJ Coffee seldom have these sorts of arrivals. From observation, the distribution of arrivals is depicted in the table below:

Customer Arrival Size Distribution				
Arrival Size	1 (Individuals)	2 (Pairs/Couples)	3 (Group of Threes)	4 (Group of Fours)
Percentage of total Arrivals	30%	24%	36%	45%

Table 5 DISTRIBUTION OF CUSTOMER ARRIVALS BY SIZE

- In terms of customer orders at the coffee shop, observation and interaction with the coffee shop owners revealed the following:
  - All customers order a minimum of a drink (For this we assume that no customer orders more than a drink). From observation, the order of drinks can be represented below:

Customer Drink Order Type			
Order Type	Coffee	Tea	Soft Drink
Percentage of total Arrivals	50%	30%	20%

Table 6 DISTRIBUTION OF DRINK ORDER BY TYPE

- Not all customers order side food. Customers that ordered a side food can be represented below:

Customer Side Order Type			
Order Type	Cakes	Fruits	Others
Percentage of total Arrivals	37%	25%	28%

Table 7 DISTRIBUTION OF SIDE ORDERS BY TYPE

5. SCOPE OF THE ANALYSIS

The analysis would only cover events for weekdays. This is because students have started to use the University Library somewhat less over weekends, plus all Schools and Departments have just moved to a “100% doors-shut over weekends” policy, so the main university campus tends to be not as busy on Saturdays and Sundays and by extension, STJ coffee shop is usually not busy on weekends.

6. BPMN REPRESENTATION OF THE STJ COFFEE SHOP

The logic flow of the various principles in the coffee shop is depicted in the diagram below:

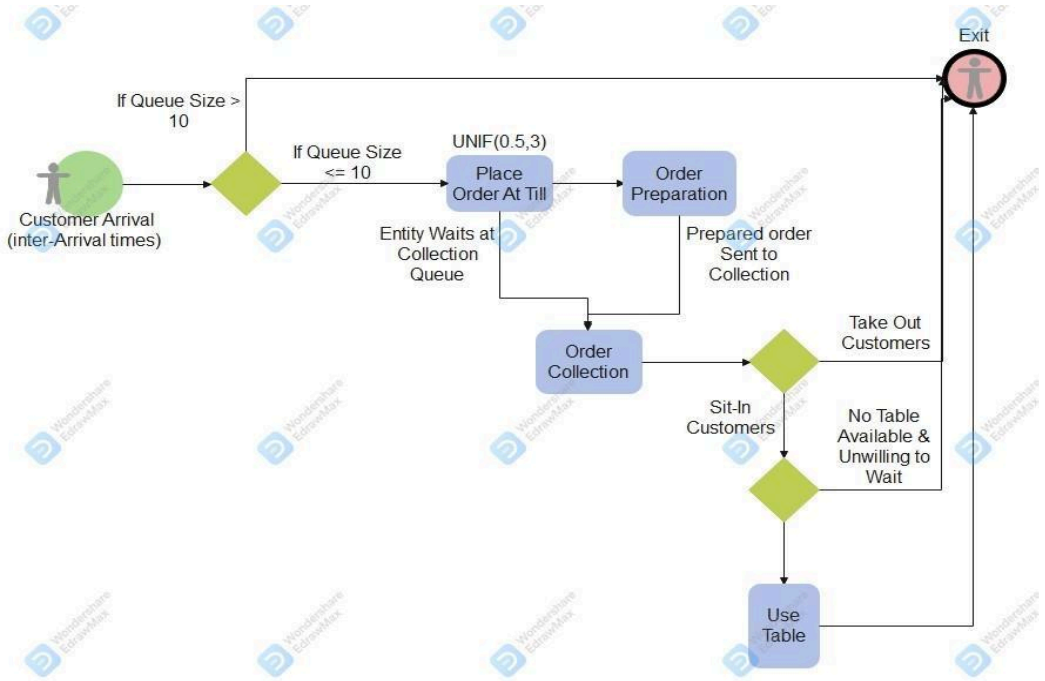

Figure 5 BPMN REPRESENTATION OF EVENTS IN THE COFFEE SHOP

Number of Balked Customers	Barista Increase	Number of Long Tables Needed	Trays	Two-Seater Tables Needed
2	4	2	4	7
2	4	2	4	6
2	4	1	4	7
2	4	1	4	6
2	4	1	4	5
2	4	1	4	4
2	4	1	4	3
2	3	2	4	6
2	3	2	4	7
2	3	1	4	6
2	3	2	4	5
2	3	1	4	5
2	3	1	4	4
2	3	1	4	3
3	**2**	**2**	**4**	**5**
3	4	0	5	6
3	4	0	5	4
4	3	0	5	6
4	4	0	5	3
4	4	1	4	2
4	3	1	4	2
5	3	0	5	3
5	3	0	3	2
6	4	0	4	3
6	4	1	5	7

Table 8 COMBINATION OF RESOURCES TO REDUCE BALKING OF CUSTOMERS

Revenue	Baristas Addition to Full Schedule	Long Table	Trays	Two-Seater Tables
3055.4	4	10	7	5
3037.03	4	0	3	1
3034.6	4	11	3	2
2993.37	3	1	5	2
2981.73	3	1	5	3
2973.7	4	0	4	3

Table 9 COMBINATION OF RESOURCES TO MAXIMIZE REVENUE