Discrete Event Simulation: A comparative study using Empirical Modelling as a new approach.

0301941

Abstract

This study introduces Empirical Modelling as a new approach to create Discrete Event Simulations based on an example model of Lush, a high street cosmetics retailer. The model is designed as a business optimisation tool, allowing the store manager to select the optimal amount of staff for any given trading day. Moreover the model should be seen as an educational tool, allowing managers to see the effect of altering their staffing levels.

1 Introduction

Discrete Event Simulation is a technique used to examine a scenario sequence of events and determine how the situation would work in real life. A basic example of a Discrete Event Simulation is a queuing system in a bank whereby all customers join a queue to wait for the next available teller. Using a simulation, the bank can experiment with different scenarios, such as introducing an extra teller, or by having a 'quick deposit only' queue. The bank can then use this information to see how this will affect the average queuing time for customers. By creating a model of the scenario, the bank does not run the risk of reducing performance by conducting the experiments on real customers. Modelling in this way also allows the bank to show how much the available resources are being utilised, which could lead to a decision to drop a particular resource in order to make the system more efficient.

The models are simple and ignore the finer details such as the exact movements of individual customers and instead take a more general view focusing on the number of people in a queue, or the number of people performing an activity. The models also include entry and exit points where the subjects enter and exit the system. The length of an activity as well as the number of subjects entering the system can be fixed or variable based on various mathematical distributions.

Central to the discipline of Empirical Modelling is the ability to interact with the modelling environment to make real time changes. The Empirical Model should show advancement on the existing approaches by allowing the modeller to interactively manage the model of the store and dynamically allocate staff to work the shift when demand calls. It would also allow the manager to determine which activity any given member of staff should be performing at a particular time.

2 Problem Description

Lush is a brand name given to a chain of stores selling 'Fresh Handmade Cosmetics'. The business operates nearly 90 stores in the UK as well as over 500 stores worldwide. The company prides themselves in offering all of their customers a personalised shopping experience, with interactive demonstrations and thorough consultations. The range of products extends from bath ballistics, shower jellies to a selection of fresh skin care products.

Although all of the UK stores are given assistance from the Lush Head Office, each of the stores is very different and will have different requirements in terms of staff and resources. As a consequence, each of the stores are encouraged to be as individual as possible and the UK support team encourage each of their shop managers to run the shop as if it were their own.

Due to the great variation in size and location of the shops it is difficult to apply a generic trading pattern to all of the shops worldwide. One of the main problems faced by managers is employing the correct number of staff at any given time. During peak trading hours it is essential to have enough staff to man the many demonstration areas and offer advice to customers, as well as being able to process payment. As store managers are also responsible for managing their budget, having too many staff work-

ing at a particular time can result in an inefficient use of resources and can result in un-necessary expenditure which will reduce their profit margin. Alternatively if there are not enough members of staff to assist the customers then it is likely that the customers will have to endure long queuing periods, which could eventually result in them leaving the store without making a purchase.

Lush use various Key Performance Indicators (known internally as 'Business Drivers'), to monitor the performance of each of their stores. Each of the stores are fitted with a door counter which counts the number of visitors to the shop in each trading day. Using their till systems they are also able to monitor the number of transactions processed each day and using both bits of information they can calculate the percentage of visitors that were converted into customers. This is known as 'Customer Conversion' and is the main business driver the company monitors, as it shows how effective the staff are at making a sale. The company also considers the average number of items purchased as well as the average value of each transaction. For this model we will restrict ourselves to examining Customer Conversion.

It is hoped that the use of Discrete Event Simulation will allow the management staff in Lush branches to have more of an understanding as to how their staffing levels will affect their store performance and Business Drivers. The interactivity afforded to Empirical Modelling in conjunction with this discipline could also aid with the training of new managers.

3 Comparison of Tools

There are many commercial off the shelf products available to create Discrete Event Simulations, including packages such as Simul8 and Witness. All of these tools are designed to help create and experiment with models as easily as possible. For this project we consider the model in 0301941 (2007) which was created using Simul8.

3.1 Simul8

Simul8 is designed to create realistic models for real-life scenarios (Simul8, 2008). Creating the initial model is a very visual task and the modeller is simply able to drag and drop the various work centres, queues, entry and exit point to the screen. The dependencies between these activities are then set by clicking on the parent activity and dragging an arrow to the proceeding activity. Some work centres can require a resource to be present for the activity to complete and as such recources can be created and linked to any number of work centres.
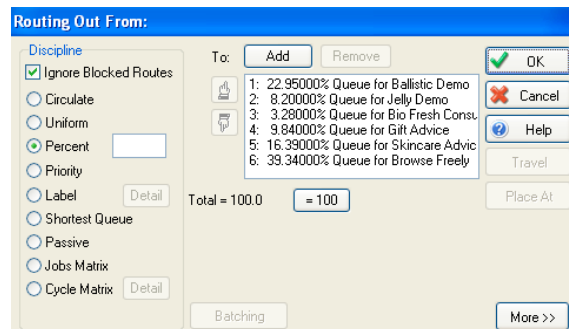

Figure 1: Graphical Routing Out in Simul8

Any links between activities can be set using a simple interface (figure 1) and routing can be dependent on many options including percentages and queue lengths and for more advanced requirements visual logic may be used.

After the basic model has been created the modeller can perform a run of the model. After every run of the model, each of the activities will have recorded data including the average queuing time, the resource utilisation and the efficiency of a work centre. This data can then be examined and any bottlenecks in the system can be identified. The experimental conditions, such as the number of available resources, can then be changed and the experiment re-run.

A lot of emphasis is given to the inclusion of various random mathematical distributions to ensure realistic generation of data. An example of this would be modelling people arriving in a bank. It is very unlikely that people would arrive at a constant rate throughout the day and more likely that there is some random element to the arrival pattern. Simul8 uses a selection of distributions to estimate these arrival times. Similar distributions can be used to determine other factors such as the length of time of an activity.

When the optimal experimental conditions are set, the model can then be subject to an automated process of multiple runs. The software will automatically perform the simulation any number of times and will report the average, minimum and maximum statistics.

The main issue to date is the inability for a user to interact with the model during a run. Simul8 will take charge of assigning resources to the various work centres as and when a resource is available. For a Lush store manager it is important that they have the flexibility to assign their resources (or in this case members of staff) to the activity they think is most vital. Consequently one of the major short

falls of the Simul8 tool is the inability to dynamically interact with the model at run time.

3.2 Eden, DoNaLD and SCOUT

We have attempted to create a similar model to the Simul8 model in 0301941 (2007) using the tools available in the Eden interpreter. Eden is the Engine for Definitive Notations and is the primary software tool used in Empirical Modelling. One of the fundamental concepts behind the Eden language is formula definitions (Yung, 1989). If a variable is defined by other variables (e.g. x is $y + z$) it is known as a formula variable. In a traditional programming language this variable 'x' may be assigned the value of 'y + z' at any given time and it will keep this value until such a time as 'x' is re-defined, regardless of any changes to the values of y and z. Using a formula definition, 'x' will be defined as 'y + z' and any changes to the variables 'y' or 'z' will result in the update of variable 'x'. As such the value 'x' is determined by the values of 'y' and 'z' and this is known as a dependency. The Eden interpreter maintains these dependencies and as such lends itself nicely to uses such as Discrete Event Simulation where each of the activities is dependent on the state of another. For example the state of a queue for an activity is dependent upon the state of the activity, as the queue may only release a work unit to the activity when the activity is available.

Another fundamental concept in Eden is action specifications. An Eden procedure (or proc) will be executed each time a specified variable is updated or touched (Yung, 1989). The procedure includes a set of statements that will be executed sequentially when the procedure is activated. In the case of the shop simulation, updating a variable, such as the availability of staff, will execute a procedure to allow more staff to be assigned to the various activities.

DoNaLD is implemented in the Eden interpreter and is a notation for 2D line drawing and includes data types such as points, lines and shapes. In the case of this model, DoNaLD has been used to create the visual plan of the shop. This notation has been vital in implementing the shop model as the graphical layout of the model is key to any simulation, especially when the model is to be visually interpreted and used as an educational tool.

Finally SCOUT is a definitive notation for screen layouts. It has been used to create controls that affect the working of the model, as well as providing the user feedback via the Graphical User Interface (GUI).

Creating a model using the Eden interpreter is not as simple as creating the same model in Simul8, nor is it intended to be. Simul8 is a tool designed exclusively for developing Discrete Event Simulations, whereas Eden can be used for any number of different modelling approaches. As such, creating the model involves comprehension of the three notations, but does result in a model that is more suitable to our original goal in that it allows dynamic interaction during the running of the model.

The dependency maintenance provided by Eden allows us to update the situation during the run of a simulation. For example, a customer moving to the ballistic queue will mean that a ballistic demonstration can now take place, providing a member of staff has been allocated to the ballistic demonstration unit. In this example, the demonstration taking place is dependent upon the availability of staff and the location of the customer. Dynamically assigning a member of staff to the ballistic unit with a queue will result in an immediate demonstration.

4 Description of Model

The model has been designed to demonstrate a real life sequence of events that a visitor to a Lush shop may encounter. The sequence of events can be seen in figure 2. For the model, the visitors are generated just outside the front door of the shop. The visitors will remain here until such a time as the front door of the shop is opened. The visitors then go to a location in the middle of the shop where they decide which activity choose. The activities are selected at random with varying probabilities. For example, 40% of the time a visitor is selected at random for a ballistic demonstration. This is identical to the function performed by the 'routing out' in Simul8 as seen in figure 1. It is the case that the queues for each activity are assigned a particular size and if the queue is full the visitor will select a different activity. Again this is implemented in Simul8 by selecting the 'ignore blocked routes' option in Simul8.

From this point, each of the customers will join a queue for their chosen activity. Each of the activities requires a member of staff (a resource in modelling terms) for the activity to take place. Any available staff can be assigned to an activity dynamically at runtime. The modeller can monitor the size of each of the queues and assign staff as appropriate.

Finally, after performing the activity, the visitor will then decide whether to pay or to leave without making a purchase. In this model, this is determined by the size of the queue at the till area. If the queue is
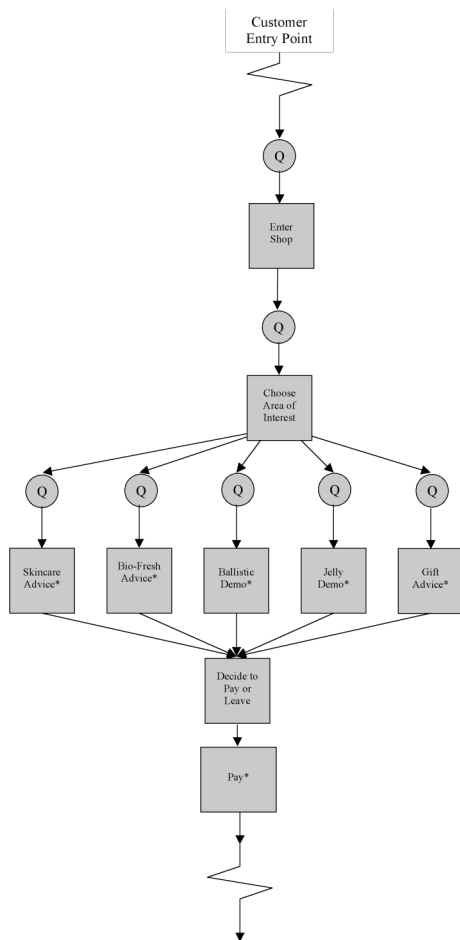
Figure 2: The Flow of Events on Entering the Shop

more than seven people in length, any visitors will simply leave the store without making a purchase.

4.1 Graphical Representation

A graphical representation of the shop layout has been created using DoNaLD. The visualisation of the shop allows the modeller to have an overall view of the activities taking place in the shop at any given point and will allow the modeller to make any decisions regarding the allocation of staff.

The dependencies in this 2D representation are also maintained by the Eden interpreter and as such results in the layout updating dynamically. For example, when a consultation is in progress, a label is generated to this extent and the shop layout is updated accordingly.

The view of the shop is incorporated in the final window design which is managed by the SCOUT interpreter. The window also includes the various option buttons and statistical feedback from the model. The buttons give the user the option to as-

sign staff to the various activities, open and close the door, increase the total available staff and change the number of minutes between the arrival of each customer. Again the dependency maintenance and procedures in Eden allow the text in each button to update automatically when clicked.

4.2 Scenario Variance

Each trading day will vary to the next in terms of the number of visitors to the store. The model includes the ability to vary the time between successive customer arrivals as well as the number of available staff. This allows the modeller to experiment using different scenarios, such as a busy day with few staff, a busy day with many staff or a quiet day with many staff etc. The findings from this experimentation can then be used to apply the correct number of staff to a real working day in a real shop.

4.3 Model Limitations

Although the model is designed to be a representation of a real-life scenario, it is not always realistic. In practice there are many other factors affecting the running of the shop and the performance of the activities. For example, one member of staff may be quicker than average at performing a ballistic demonstration or another member of staff may be working slower than usual due to contracting a virus from a friend. These other factors are numerous and cannot be included in the computer model. It is often the case that factors such as this can be generalised and in this instance, both of these can be accounted for by considering a random variation in the time taken to perform each activity.

5 Practical Uses

The model was originally designed for two different purposes; to act as an educational tool for management staff and to aid with the optimisation of running a store. Both of these are considered here.

5.1 Education

Creating the model in Eden gives the huge benefit of being able to dynamically interact with the model whilst the simulation is in progress. Whereas Simul8 does allow the modeller to make changes to the levels of staff before the simulation is run, it does not allow any subsequent interaction. The Simul8 tool can be useful in terms of planning staff numbers in advance, but offers little real-time feedback to the modeller and as such is not the best tool for educational purposes.

With the graphical layout and intractability afforded by Eden, the resulting model is far more suitable for educational purposes. Potential managers can use the tool to instantly see how the allocation, number of staff and the volume of visitors affect the stores Customer Conversion percentage. Using a tool like this should allow them to take this information back to the shop floor and implement it in real-life.

5.2 Optimisation

In terms of business optimisation, Simul8 provides extensive statistical analysis tools. Including all the advanced features of Simul8, such as the option to perform instant repeated runs would require extensive implementation in Eden and as such Simul8 would provide the easiest option to perform a simulation for optimisation purposes.

For simplicity, each of the activities in the Eden model takes a uniform time to complete and visitors arrive at the store at a uniform rate. Although this is unrealistic, it simplifies the model to a degree that is suitable for educational purposes. In order to create a more realistic model, various random mathematical distributions (such as the normal distribution) should be used to generate customers at varying intervals and to determine the length of each of the activities.

Finally, for any simulation to be truly accurate, it must be based on valid observed data. Simul8 integrates with other tools such as Stat::Fit (Stat::Fit, 2008) to generate mathematical distributions based on real data. For example, observing customer arrival intervals to the shop could be used to generate a distribution suitable for realistic modelling purposes.

6 HCI and Usability

One major concern for the use of this model as a training tool is that it should be fairly easy to use. The ease of use of a system is often referred to as the Usability of a system. It is important that when using a tool such as our shop simulation, the user should be concentrating more on the real life effect of the model, rather than how to interact with the model. As such, all the main functionality of the model can be manipulated via the user interface through various buttons. To make the button use easier, the colour of the button changes when clicked, along with the descriptive text. For example, when the user clicks on the blue 'assign staff to ballistics' button, this then changes to a green 'remove staff from ballistics' button. This provides feedback to the user so that they know their action has been successful.

The model also makes it clear when an option is not available by changing the button text from black to grey. This may occur when all of the available staff are assigned elsewhere, or still performing an activity. There are other limitations with regards the number of available staff as this number may not be greater than six (the total number of activities) and no less than the current number of assigned staff. The arrival rate of customers is also limited to no more than one customer per minute.

7 Future Improvements

The Lush store model is still limited in terms of its functionality and realism. In order to make the simulation more realistic, it is possible to implement various random distributions to vary the arrival rate of customers, as well as the length of each activity. The current model is also limited so that each of the work centres can only provide one consultation at a time. In Simul8 it is possible to define how many work centres are available at each activity, for example the till area could now have two work centres (two tills).

Along with these changes, another SCOUT window could be implemented so that the user of the model can graphically change each of these options to suit the situation and the observed data.

8 Conclusion

This paper has examined the suitability of Empirical Modelling to the discipline of Discrete Event Simulation. It has shown that the dependency maintenance and the action procedures in Eden provide a good basis on which to create a simulation.

Although slightly more simplified than the existing Simul8 model (0301931, 2007), the Eden model gave the benefit of direct interaction during run-time and as such provided a valuable educational tool.

Adapting the Eden model to be more realistic is possible and would enhance the existing model. This would be far more complicated than it would be using the Simul8 tool.

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