Simulation Modeling Project

United Dairy Farmers
3325 Clifton Ave, Cincinnati, OH 45220

Submitted by: -
Rahul Bhasin (M13255512)
MS – Business Analytics'20
University of Cincinnati

Abstract

United Dairy Farmers is a chain of stores offering dairy products and retail items. The Company manufactures and retails dairy products like ice creams, yogurt, powder, milkshakes, hand-dipped cones, juices, and milk products, etc. UDF serves customers throughout the States of Ohio, Kentucky, and Indiana. Customers from Clifton and adjacent areas visit the UDF store at Clifton Ave, Cincinnati for their dairy products need. Thus, it is very much important for the UDF Store to carefully design their operations to offer the best service to their customers.

During peak hours, customers usually find long queues at the billing counter and milkshake counter, causing them inconvenience. In fact, many of the customers prefer to buy their dairy products from other stores nearby to avoid long queues at UDF, resulting in loss of revenue for the UDF store. This project aims to understand and optimize customer service operations at UDF.

TABLE OF CONTENTS

1. Introduction

1.1 Current Process

The United Dairy Farmers store at Clifton Avenue remains open for 24 hours 7 days a week. It typically witnesses the rush around 9:00 PM to 11:00 PM every day. The UDF store offers dairy products to the customers which they can look around and put in their baskets to shop. The store had a self-service beverage counter for coffee, soft drinks and hot chocolate. The UDF store also offers Milkshakes to its customers, for which they have a dedicated Milkshake Maker staff member at the milkshake counter. Post selecting the dairy products, beverage or milkshake, the customers move to the billing counter to pay their bills where 2 cashiers serve them with payment.

We can observe in the Google Maps results below that the peak hours of the United Dairy Farmers store at Clifton Avenue are 9 PM to 12 AM.
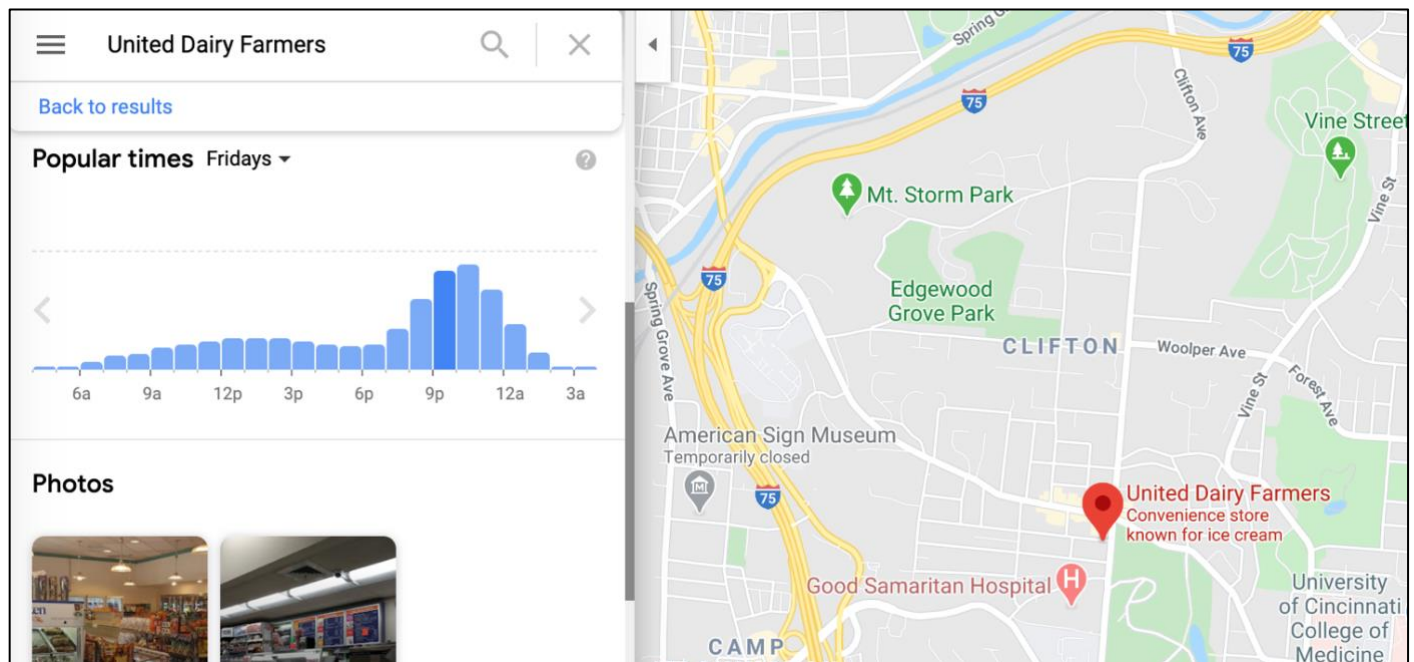
1.2 Objectives

The purpose of this project is to develop a simulation model of United Dairy Farmers store at Clifton Ave, Cincinnati using the Arena Software. The objective of building this project is to understand and optimize the following things: -

- Wait time in queue for the customers at the billing counter
- Wait time in queue for the customers at the Milk Shake counter
- Utilization of UDF Staff performing different tasks
- Factors resulting in delay of customer service

1.3   Problem Statement

As per the staff at UDF and Google Maps results, the UDF store at Clifton Avenue typically witnesses the rush around 9:00 PM to 11:00 PM every day. Because of the rush, the average waiting time of customers in queues at the billing counter and milkshake counter increases considerably. Moreover, many of the customers leave the outlet and prefer to buy their dairy products, beverage and milkshakes from other stores nearby to avoid long queues at UDF, resulting in loss of potential revenue for the UDF store. This project aims to improve customer service operations at UDF by minimizing the customer waiting times and optimizing the utilizations of UDF staff members.

1.4   Model Assumptions

Because of the limitations of simulating a system in real world, following assumptions have been made in this project: -

1) There are no breaks during work hours of UDF staff.
2) Only 1 customer is served by 1 UDF staff at any given time.
3) Customers come to UDF store individually or in a batch size of 2. If they arrive in batch of 2, they purchase similar items.
4) The milkshake counter and billing counter are adjacent to each other.
5) Beverage counter has enough machines/ logistics for customer's self-service, so queue does not line up over there.
6) Each customer who enters buy something.
7) When a customer collects his/her order, he or she leaves the system.

All these assumptions hold true all the time when the model is running.

2. Component Details

The simulation model comprises of following components: -

i)   Entities:
- Customers arriving to UDF store individually or in a batch size of 2

Entity - Basic Process

	Entity Type	Initial Picture	Holding Cost / Hour	Initial VA Cost	Initial NVA Cost	Initial Waiting Cost	Initial Tran Cost	Initial Other Cost	Report Statistics
1 ▶	Customer ▼	Picture.Person	0.0	0.0	0.0	0.0	0.0	0.0	☑

ii)   Resources:
- 2 Cashiers who are only skilled at handling operations at billing counter
- 1 Milkshake Maker staff member who is only skilled at making milkshakes at milkshake counter

Resource - Basic Process

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics
1 ▶	Cashier ▼	Fixed Capacity	2	0.0	0.0	0.0		0 rows	☑
2	MilkShake_Maker	Fixed Capacity	1	0.0	0.0	0.0		0 rows	☑

iii)   Queues:
- Billing Counter Queue: FIFO with unlimited length; this is the queue where customers lineup to make payment to casher.
- Milkshake Counter Queue: FIFO with unlimited length; this is the queue where the UDF Milkshake Maker staff member serves the customers by making fresh Milkshake for them.

Queue - Basic Process

	Name	Type	Shared	Report Statistics
1 ▶	Billing Counter.Queue ▼	First In First Out	☐	☑
2	Staff making Milk Shake.Queue	First In First Out	☐	☑

3. About Data

3.1   Data Collection

The data for this simulation study was collected during peak hours 9:00 PM to 11:00 PM at UDF store, Clifton Avenue. Customer's arrival time wait time at beverage counter and wait time at milkshake counter were noted.

Important observations from collected dataset: -
- i)   75% of the total customers arrive individually
- ii)   79% of the total customers buy dairy products
- iii)   35% of the total customers purchase beverage
- iv)   10% of the total customers buy milkshake

3.2   Fitting data using Input Analyzer

With the help of Input Analyzer in Arena, we analyzed the distribution of various data points we collected. Arena' Input Analyzer finds the best fit distribution to any input data. It plots the fitted function to the dataset on the existing histogram. It also adds statistical information about the distribution selected, and test statistics for Chi-Square Goodness of Fit and Kolmogorov-Smirnov tests.

Below are some of results obtained from the Input Analyzer in Arena for various data points collected.

i)   Customer inter arrival time:
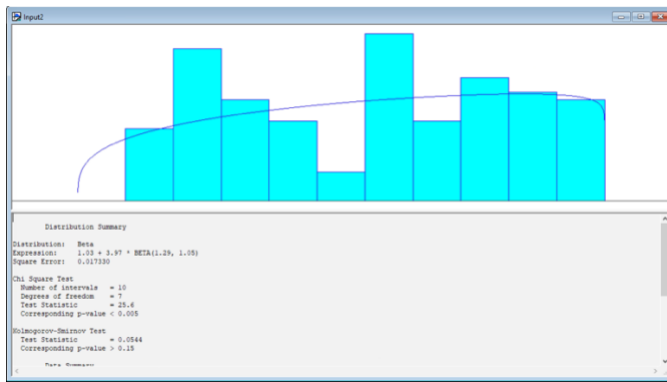- -   A normal distribution followed
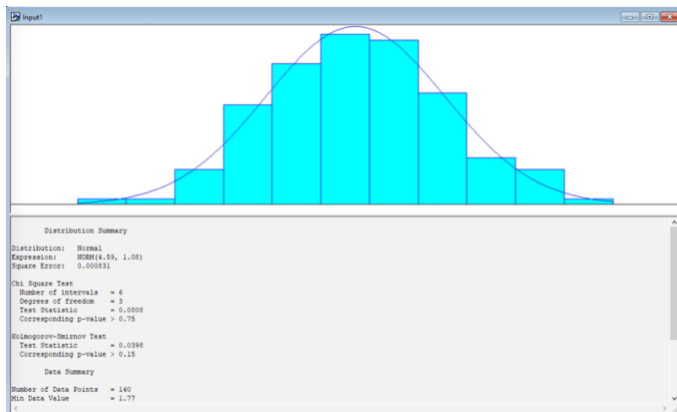
ii)   Time taken to buy Grocery Items:
- -   Input Analyzer not used
- -   Distribution followed: TRIA (4,16,24)

iii)   Time taken at beverage self-service counter:
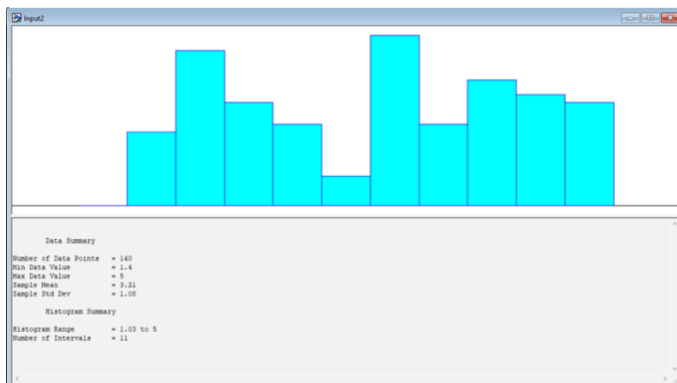- -   A binomial distribution followed

iv) **Time taken at milkshake counter:**
- Input Analyzer not used
- Distribution followed: TRIA (4,6,9)

v) **Billing Time:**
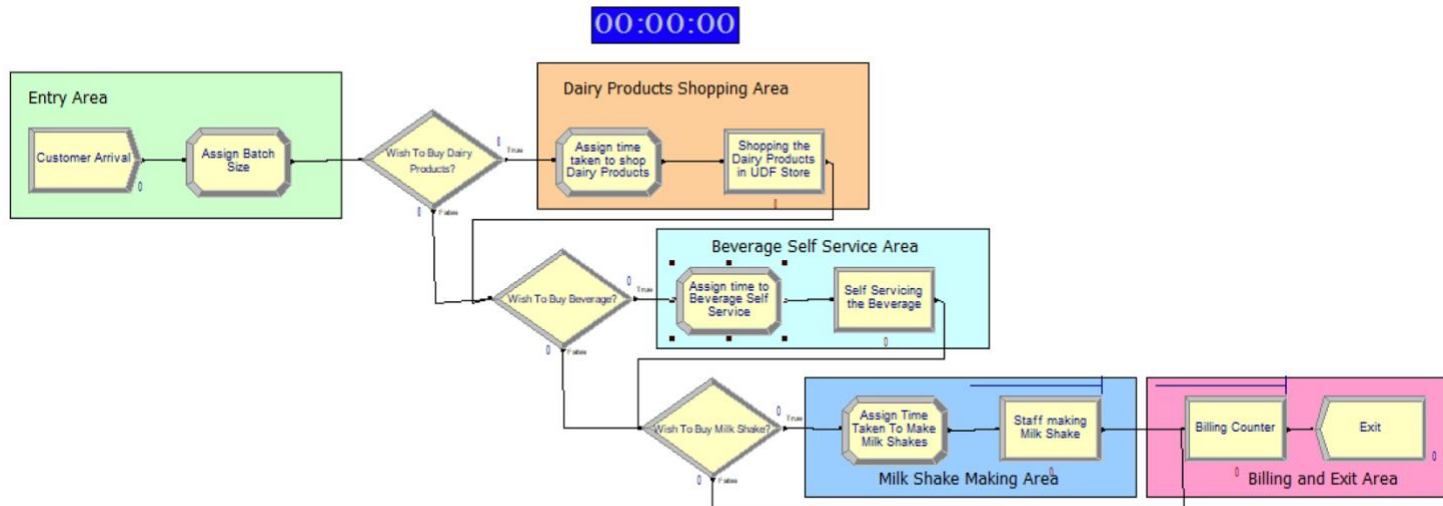- A binomial distribution followed

4. Arena Model

4.1   Modeling the system

Below is the model in Arena which we used to model customer orders at UDF:

We will be discussing each of the component of our model one by one in detail.

i.   **Entrance Area:** This is the area where the customers arrive. In this area we assign the batch size to customer based on whether is arrived individually or in a group of two. Also, the arrival of customers follows a normal distribution.
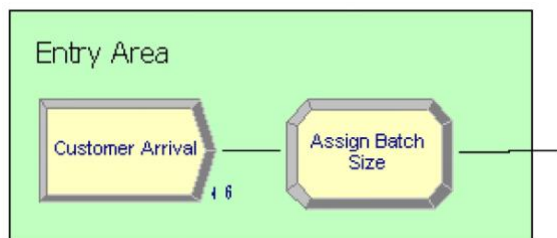
**ii.** **Dairy Products Shopping Area:** In this area customers spend time in deciding and selecting the dairy products they wish to purchase. Here we assign customers 'Item_decide_time' value which follows a triangular distribution. 'Item_decide_time' value is doubled if batch size is equal to 2 and 79% of the total customers arrive at this area.
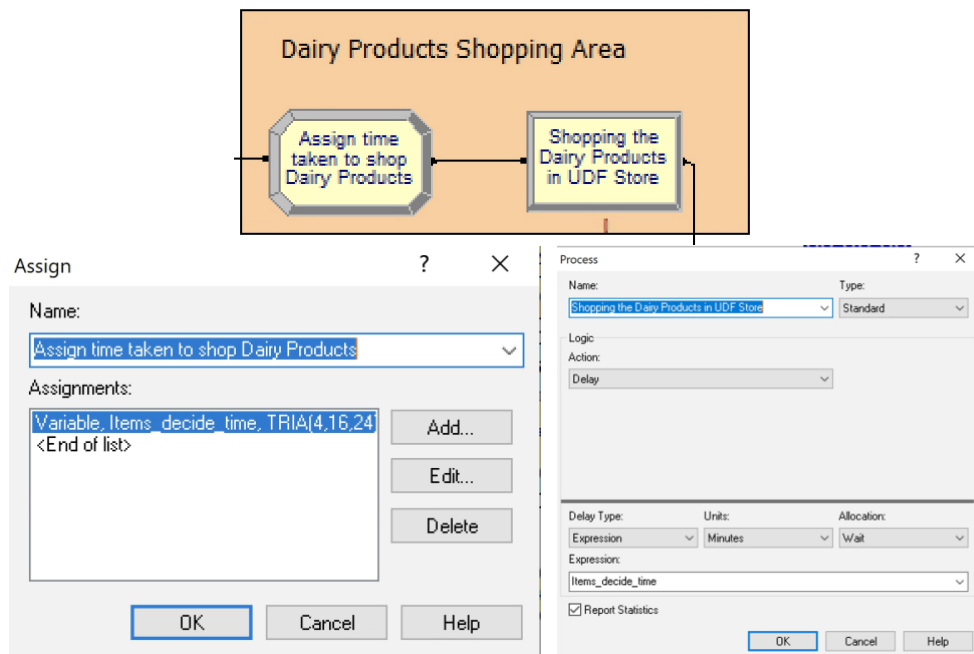
iii. **Beverage Self Service Area:** This is the area where customers spend time at a self-service beverage counter to get their coffee, soft drinks or hot chocolate. In this area we assign customers 'Beverage_Fill_Time' value which follows a binomial distribution. Beverage_Fill_Time is doubled if batch size is equal to 2 and 35% of the total customers use this area.
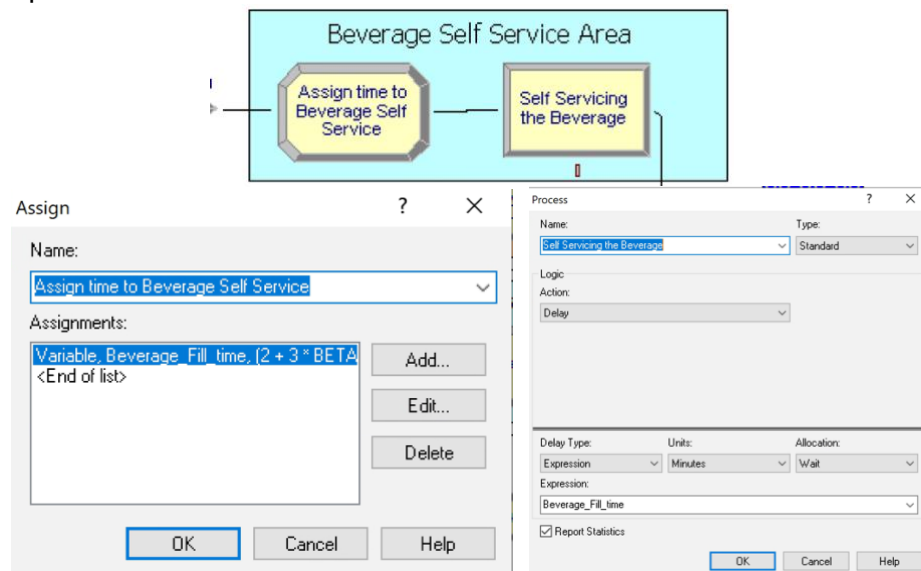
iv. **Milkshake Making Area:** In this area a dedicated Milkshake Maker staff member makes milkshake for the customers at the counter. Here we assign customers 'MilkShake_Time' value which follows a triangular distribution. Processing time is doubled if batch size is equal to 2 and only 10% of the total customers use this area.
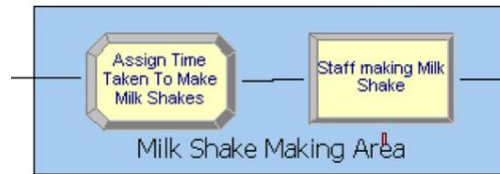
Milk Shake Making Area

v. Billing and Exit Area: Post selecting the dairy products, beverage or milkshake, the customers move to the billing counter to pay their bills where 2 cashiers serve them with payment. The wait time at billing counter follows a binomial distribution. Wait time is doubled if batch size is equal to 2.
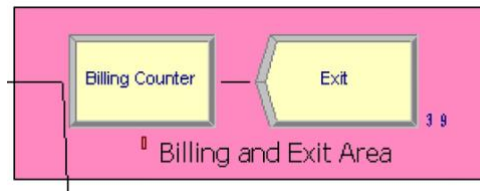
Billing and Exit Area

vi. Decision Points: Apart from the areas mentioned above, there are 3 decision points in our system based on which a customer decides where he/she wish to purchase dairy product, beverage or/and milkshake. The 3 decision points are as follows:
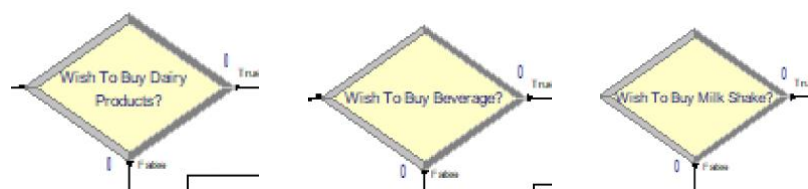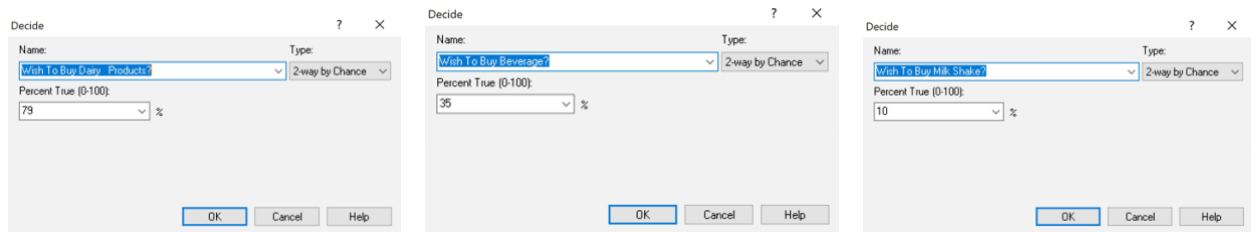
4.2   Simulating the System

Simulation Model with above configurations was run for 2 hours window as Replication Length was set equal to 2 and for 50 replications.
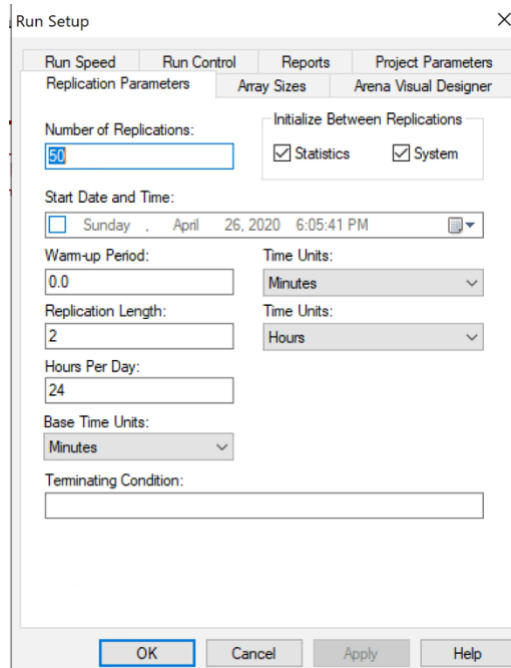
5.Simulation Results

The Arena Software produces detailed report of Simulation Model results by Entity, Queue and Resources etc. We ran our simulation model for 2 hours window by setting up Replication Length equal to 2 for 50 replications.

Below is the snapshot of our model at the end of simulation. We can observe that a long queue of customers is standing at the billing counter, 2 hours after the beginning of our simulation.

5.1   Results by Entity: -

Below results show that our model served 39 customers out of 46 customers who entered the UDF Store. On an average a customer stayed in store 21.9 minutes and the average waiting time was 19.53 minutes.

Entity Detail Summary
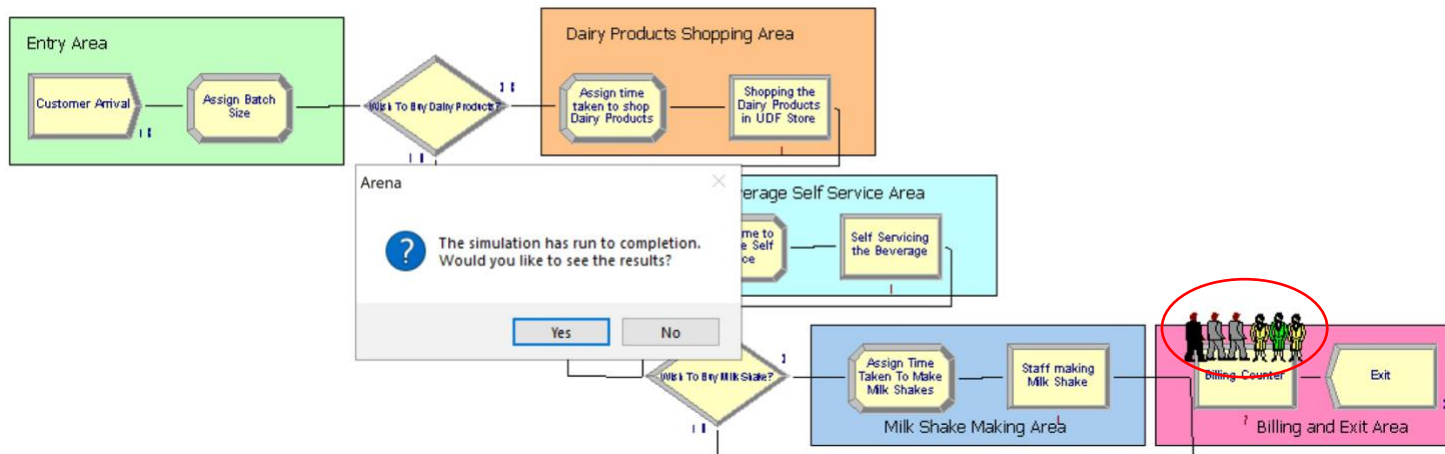
Time

	NVA Time	Other Time	Total Time	Transfer Time	VA Time
Customer	0.00	0.00	21.89	0.00	2.36
Total	0.00	0.00	21.89	0.00	2.36

Other

	Number In	Number Out
Customer	46	39
Total	46	39

Customer

Time	Average	Half Width	Minimum	Maximum
Total Time	21.8923	(Insufficient)	1.4866	61.
Wait Time	19.5337	(Insufficient)	0.00	58.
VA Time	2.3586	(Insufficient)	1.2519	3.
Transfer Time	0.00	(Insufficient)	0.00	
Other Time	0.00	(Insufficient)	0.00	
NVA Time	0.00	(Insufficient)	0.00	

5.2   Results by Queue: -

Results based on queue show that for Billing Counter Queue average waiting time was 5.78 minutes.

Queue Detail Summary

Time

	Waiting Time
Billing Counter.Queue	5.78

5.3   Results by Resources: -

Arena's resource detail summary reveals that the cashiers' utilization was 71% and Milkshake Maker staff's utilization was 18%.

Resource Detail Summary

Usage

|	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
Cashier	0.71	1.41	2.00	72.00	0.71
MilkShake_M	0.18	0.18	1.00	3.00	0.18

6. Improving the System

As we can observe from the Arena Results of our original model that the resource utilization of Milkshake Maker staff (18%) is significantly less from the resource utilization of cashier (71%). Also, the average waiting time of customer is considerably high. Our aim is to reduce the wait time of customers in current scenario without adding any additional financial burden for UDF store.

One of the suggestions is **to cross train the Milkshake Maker staff member at UDF store**. Currently, this resource is only dedicated for making milkshakes for customers at the milkshake counter and remains idle most of the time which we observed from the above resource utilization results. We can train this staff members with the skills required at billing counter so that during peak hours when there are long queues at billing counter, then if available, the Milkshake Maker staff member can temporality perform duties of a cashier in between to reduce billing queue's wait time. The only add-on we would require is an additional billing/ payment machine at the billing counter.

To incorporate the suggested changes in our original simulation model, we added an additional resource, which is Milkshake Maker staff member to the billing counter, as shown below.
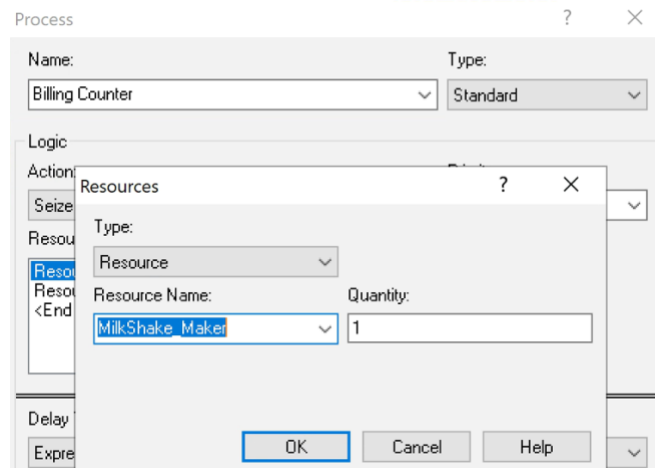
Below is the snapshot of our improved model at the end of simulation. We can observe that there is no longer any queue of customers at the billing counter, 2 hours after the beginning of our simulation.
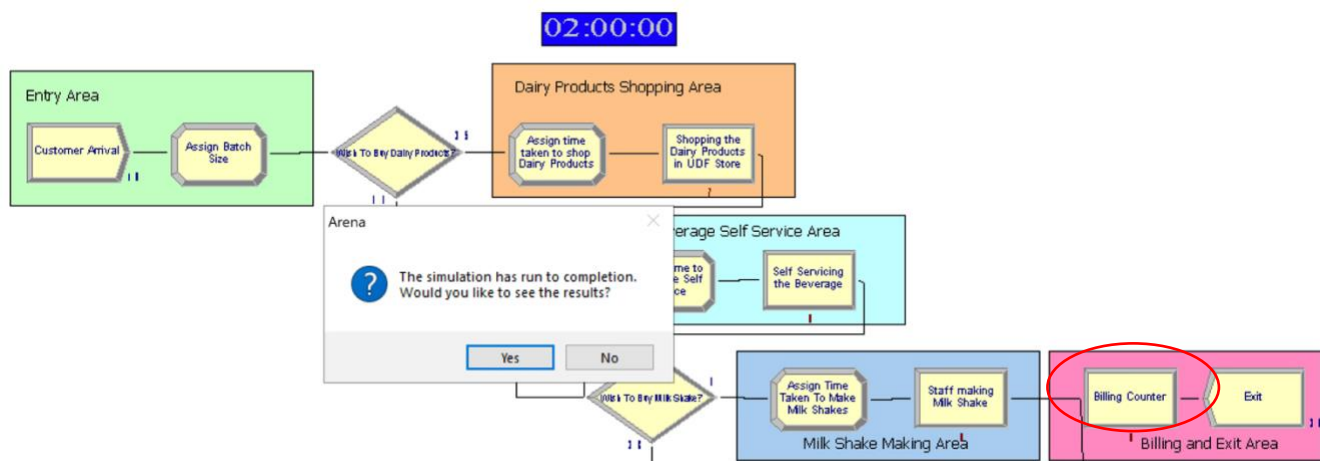
6.1   Improved Results by Entity: -

Below results show that the average waiting time of our updated model got improved from 19.53 minutes to 17.94 minutes, thus improvement by reduce of 1.59 minutes of waiting time.

Also, the average time a customer stayed in store reduced from 21.9 minutes to 20.36 minutes.

Entity Detail Summary

Time

	NVA Time	Other Time	Total Time	Transfer Time	VA Time
Customer	0.00	0.00	20.36	0.00	2.40
Total	0.00	0.00	20.36	0.00	2.40

Other

	Number In	Number Out
Customer	48	35
Total	48	35

Customer

Time	Average	Half Width	Minimum	Maximum
Total Time	20.3624	(Insufficient)	1.4866	54.
Wait Time	17.9644	(Insufficient)	0.00	52.
VA Time	2.3979	(Insufficient)	1.2519	3.
Transfer Time	0.00	(Insufficient)	0.00	
Other Time	0.00	(Insufficient)	0.00	
NVA Time	0.00	(Insufficient)	0.00	

6.2   Improved Results by Queue: -

Results based on queue show that for Billing Counter Queue average waiting time improved from 5.78 minutes earlier to just 2.36 minutes now.

Queue Detail Summary

Time

	Waiting Time
Billing Counter.Queue	2.36
Staff making Milk Shake.Queue	0.00

6.3   Improved Results by Resources: -

Arena's resource detail summary reveals that the Milkshake Maker staff's utilization jumped from 18% in previous model to 82% in updated model.

Resource Detail Summary

Usage

	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
Cashier	0.77	1.53	2.00	78.00	0.77
MilkShake_M	0.82	0.82	1.00	40.00	0.82

7.Conclusion

In this project, we developed and simulated a model for the United Dairy Farmers store located at Clifton Avenue, Cincinnati. We collected 2-hour window UDF data during peak interval and based on certain assumptions we developed a simulation model in Arena software. We simulated and analyzed the Arena results of our model. To achieve our goal of reducing the wait time of customers in current scenario, we made a few changes in our original model for improvements. We observed that by cross training the Milkshake Maker staff member at UDF store, we can reduce the average wait time by 1.59 minutes. With the improved model we can also improve the resource utilization of the store and reduce inconvenience being caused to customers during peak hours.