Dynamic Customer Flow Optimization at Sprouts Grocery Store

Faculty Mentor

Dr. Paritosh Ramanan

Team Member:

Mittapally Mahendhar

Srujanth Reddy Gangidi

Table of Contents

ACKNOWLEDGMENTS

We wish to express our profound gratitude to **Dr. Paritosh Ramanan**, whose expertise and guidance have been indispensable throughout the course of this research. His insightful feedback and unwavering support greatly enhanced the quality and depth of our study.

We are also immensely grateful to **Mr. Dave,** the manager at Sprouts Farmers Market, for his generous cooperation and assistance. His willingness to provide the necessary data and insights significantly contributed to the success of our project.

Their contributions were not only instrumental in conducting this research but also enriched our learning experience. Thank you for your invaluable support.

1. INTRODUCTION

In the competitive landscape of retail, customer satisfaction is paramount and often hinges on the efficiency and effectiveness of in-store processes. One of the most critical aspects influencing consumer satisfaction in grocery stores is the checkout experience. Lengthy checkout times can lead to customer dissatisfaction, reduced loyalty, and ultimately, lost revenue. Sprouts, like many retail environments, experiences variable customer flow throughout the day, which can challenge the traditional fixed configuration of checkout counters and staff allocation. In response to this challenge, there is a growing interest in employing advanced simulation tools to optimize store layouts and operations dynamically.

2. PROBLEM STATEMENT

Sprouts Grocery Store is grappling with significant operational challenges stemming from fluctuating customer traffic patterns, impacting its ability to manage customer flow efficiently. The primary concern lies in the time-varying ingress and egress of customers, which leads to overcrowding during peak hours and underutilization during quieter times. These peak periods often see the store's facilities overwhelmed, with customers facing long wait times at checkout counters, difficulty navigating congested aisles, and a general sense of discomfort due to the crowded environment. Such conditions not only disrupt the shopping experience but also strain the store’s operational capabilities, making it challenging to maintain an efficient service delivery.

Conversely, during off-peak hours, the apparent underutilization of resources such as staffing and space results in economic inefficiencies, where the expenditure does not correspond with optimal revenue generation. The bottleneck at checkout counters, particularly evident during busy hours, further exemplifies the store's struggles with managing customer throughput effectively. This leads to extended waiting times, customer dissatisfaction, and potentially lost sales as shoppers may decide against purchases or even visiting during peak times.

Figure 2.1 - Customer waiting in line for checkout.

The overarching impact of these issues is a decrease in customer satisfaction, which is critical for customer retention and the store's long-term profitability. Operational inefficiencies not only affect the store's financial performance but also risk damaging its reputation among consumers. To address these challenges, Sprouts Grocery Store needs a comprehensive strategy aimed at smoothing customer traffic throughout the day, enhancing the shopping experience, and optimizing operational efficiency across all hours of operation.

2.1 MAIN OBJECTIVE (PROPOSED SOLUTION)

The primary goal of this project is to develop a comprehensive Simio simulation model to represent accurately the customer flow within Sprouts grocery stores. The model aims to analyze the impact of varying patterns of customer arrivals and departures on the store's operations throughout the day. By simulating different scenarios, the project seeks to identify the optimal configurations of checkout counters and the allocation of attendants to align with observed customer flow patterns. The ultimate objective is to reduce checkout times and enhance customer satisfaction by ensuring a smoother and more efficient shopping experience. This endeavor not only aims to improve customer satisfaction but also seeks to provide actionable insights that can be applied to optimize daily operations and resource management in retail settings.

3. DATA COLLECTION

The data collection process for this project was primarily conducted through direct collaboration with the store manager called **Dave**, who provided crucial operational data from Sprouts grocery store. This collaboration ensured access to accurate and relevant data, tailored specifically to the daily operations and customer flow patterns of the store.

3.1 DATA OVERVIEW:

The data provided includes detailed records of customer arrivals and the number of checkout counters operational during different times of the day. Key metrics collected are as follows:

Daily Customer Arrivals: Approximately 1000 customers visit the store each day.

Peak Hours: Identified as between 10 AM and 2 PM, during which approximately 40% of daily customers arrive, translating to around 400 customers during these four hours.

Non-peak hours are designated from 7:00 AM to 9:00 AM in the morning and from 3:00 PM to 10:00 PM in the afternoon. During these periods, the remaining 600 customers are expected to visit the store.

Counter Operation: During peak hours, the store operates between 3 to 5 checkout counters, while during non-peak hours, the number of open counters reduces to 2 to 3.

Operational Hours: The store is open 15 hours a day, from 7 AM to 10 PM, seven days a week, allowing for a broad analysis of customer flow across various times.

Table 3.1.1 - Input data provided by Manager.

Category	**Data**
Daily Customer Arrivals	1000 customers per Day
Peak Hours	10 AM to 2 PM (approx. 400 customers)
Non-Peak Hours	7:00 AM to 9:00 AM and 3:00 PM to 10:00 PM (approx. 600 customers)
Counter Operation	Peak Hours: 3 to 5 counters; Non-Peak Hours: 2 to 3 counters
Operational Hours	15 hours a day, from 7 AM to 10 PM, 7 days a week

Data Usage: The collected data forms the basis for the Simio simulation model. The model uses these metrics to replicate the current customer flow and checkout operations. The specific focus on the number of counters available during peak and non-peak hours provides a direct link to analyzing potential bottlenecks and operational inefficiencies.

4. DATA ANALYSIS:

Analysis of Interarrival Times:

The analysis began by calculating the average interarrival times for customers during peak and non-peak hours, identified as 0.6 minutes and 1.1 minutes per customer, respectively. This calculation is based on 400 customers arriving during the 4 peak hours and 600 during the 11 non-peak hours. These metrics are crucial for setting up the simulation model, as they define the frequency of customer entries. So, for the above interarrival rate inserted the customer arrivals in rate table to manage the ingress according to the time.

Weighted Distribution Method:

This method involves assigning a weight to each hour based on expected customer traffic, which is reflective of typical daily patterns seen in retail environments. The weight represents the relative number of customers expected during each hour.

Steps Used in the Weighted Distribution:

Assign Weights to Each Hour:

- Hours that are expected to have higher customer traffic (like midday hours) were assigned higher weights.
- Early morning and late evening hours, which typically have lower customer traffic, were assigned lower weights.
- The table provides a detailed list of the weights assigned.

Customers per Hour:

- For each hour, the number of customers is calculated by taking the weight for that hour, dividing it by the total weight, and then multiplying by the total number of customers expected in a day.

$$\text{Customers per Hour} = \left(\text{Weight of Hour}/\text{Total Weight}\right) \times \text{Total Customer}$$

Result:

- This calculation gives a proportional distribution of customers based on the weight of each hour, aligning customer arrival patterns with realistic shopping behavior.

Table 4.1 - Numbers of customers arrive at each hour.

Time	Weight	Customers
7 AM	2	24
8 AM	3	35
9 AM	5	59
10 AM	8	94
11 AM	10	118
12 PM	10	118
1 PM	10	118
2 PM	8	94
3 PM	7	82

4 PM	6	71
5 PM	5	59
6 PM	4	47
7 PM	3	35
8 PM	2	24
9 PM	2	24

Why Use This weight distribution Method?

The weighted distribution method is particularly useful in scenarios like retail operations where customer traffic is not uniform throughout the day. It allows for a more nuanced model that reflects peak times during which more staff might be needed, and quieter times when fewer resources can be allocated. This method is effective in helping businesses plan resource allocation, staffing, and operational strategies based on predicted customer flows.

By using this method, we can create a histogram-like distribution that starts low, peaks around midday, and then decreases, which mirrors the natural ebb and flow of customer visits to a store like Sprouts throughout the day. This approach provides a more accurate and useful simulation input or business planning tool compared to a flat rate distribution across all hours.

4.1 RATE TABLE IMPLEMENTATION:

A rate table was developed to guide the simulation of customer arrivals based on the established interarrival times. This table is integral to the simulation model, dictating how customer entities are generated over time, corresponding with both peak and non-peak periods.

Properties: CustomerArrival (Rate Table)

Basic Logic	
Interval Size	1
Number of Intervals	15
General	
Name	CustomerArrival
Description	

Figure 4.1.1 - Customer arrival properties rate table

Starting Offset	Ending Offset	Rate (events per hour)
Day 1, 00:00:00	Day 1, 01:00:00	24
Day 1, 01:00:00	Day 1, 02:00:00	35
Day 1, 02:00:00	Day 1, 03:00:00	59
Day 1, 03:00:00	Day 1, 04:00:00	94
Day 1, 04:00:00	Day 1, 05:00:00	118
Day 1, 05:00:00	Day 1, 06:00:00	118
Day 1, 06:00:00	Day 1, 07:00:00	118
Day 1, 07:00:00	Day 1, 08:00:00	94
Day 1, 08:00:00	Day 1, 09:00:00	82
Day 1, 09:00:00	Day 1, 10:00:00	71
Day 1, 10:00:00	Day 1, 11:00:00	49
Day 1, 11:00:00	Day 1, 12:00:00	47
Day 1, 12:00:00	Day 1, 13:00:00	35
Day 1, 13:00:00	Day 1, 14:00:00	24
Day 1, 14:00:00	Day 1, 15:00:00	24

Figure 4.1.2 - Rate of arrivals per hour

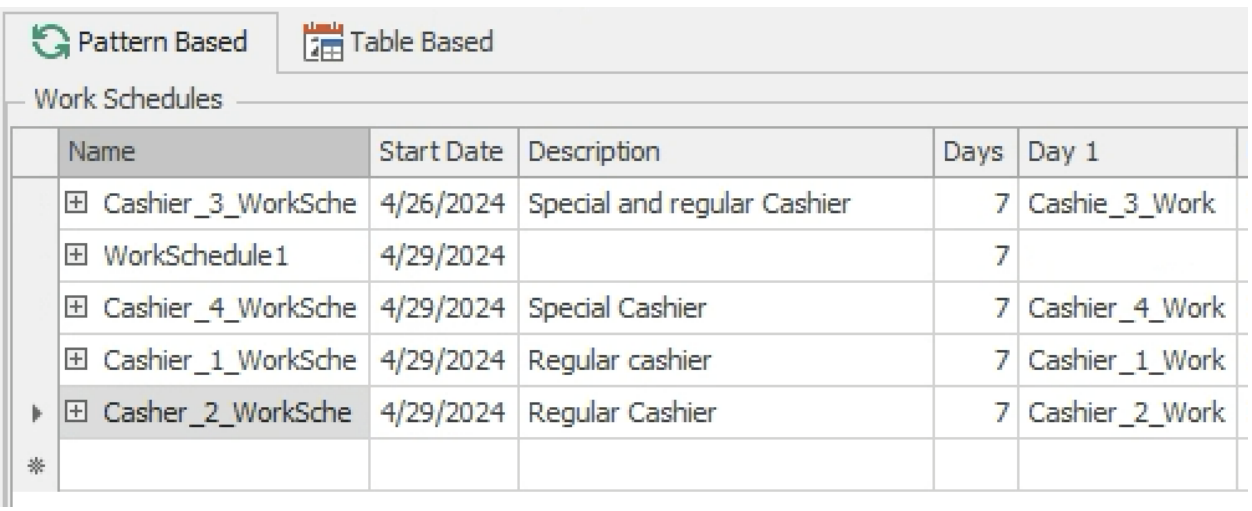
4.2 WORK SCHEDULES FOR CHECKOUT COUNTERS:

The simulation also incorporated specific work schedules for checkout counters, which vary between peak and non-peak hours. These schedules ensure that the model can dynamically adjust the number of open counters based on the volume of customer arrivals, mimicking real-world operational adjustments.

In the work schedules, there are 4 attended checkout counters. However, during peak hours, between 3-5 counters are operational, whereas during non-peak hours, the number ranges from 2-3. The self-checkout stations are available for use throughout the entire day.

To reduce the dependency on the attendants we have introduced to implement the self-checkouts. It reduces the work force and reduction in wait time of customers in queue.

Cashier 1 and Cashier 2 are on duty for the entire day, working extended hours from 7 AM to 10 PM.



Pattern Based | Table Based

Work Schedules

Name	Start Date	Description	Days	Day 1
Cashier_3_WorkSche	4/26/2024	Special and regular Cashier	7	Cashie_3_Work
WorkSchedule1	4/29/2024		7	
Cashier_4_WorkSche	4/29/2024	Special Cashier	7	Cashier_4_Work
Cashier_1_WorkSche	4/29/2024	Regular cashier	7	Cashier_1_Work
Casher_2_WorkSche	4/29/2024	Regular Cashier	7	Cashier_2_Work

***Figure 4.2.1- Pattern based cashier work schedules*.**

Cashier 3 and Cashier 4 serve as special cashiers who are specifically deployed during peak hours to handle increased customer traffic. Occasionally, one of these special cashiers may also be assigned full-time duties as needed.

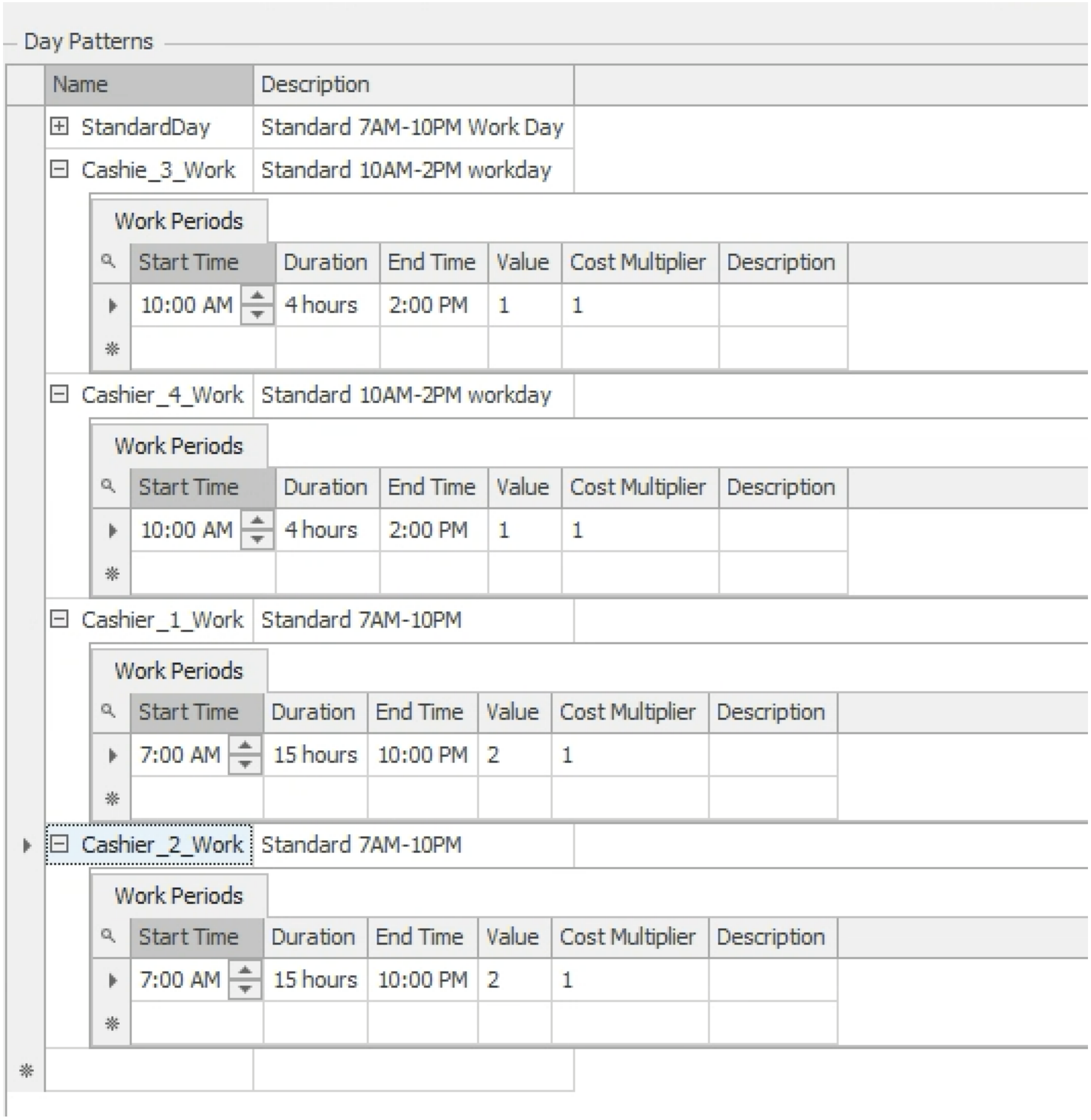


Figure 4.2.2 - Day patterns timings of cashier

Additionally, self-checkout stations have been implemented to enhance customer convenience. At these stations, customers can independently handle all aspects of the checkout process—from scanning items and packing them into bags to making card payments. This self-service option helps streamline operations and reduce wait times during busy periods.

5. SIMULATION MODEL

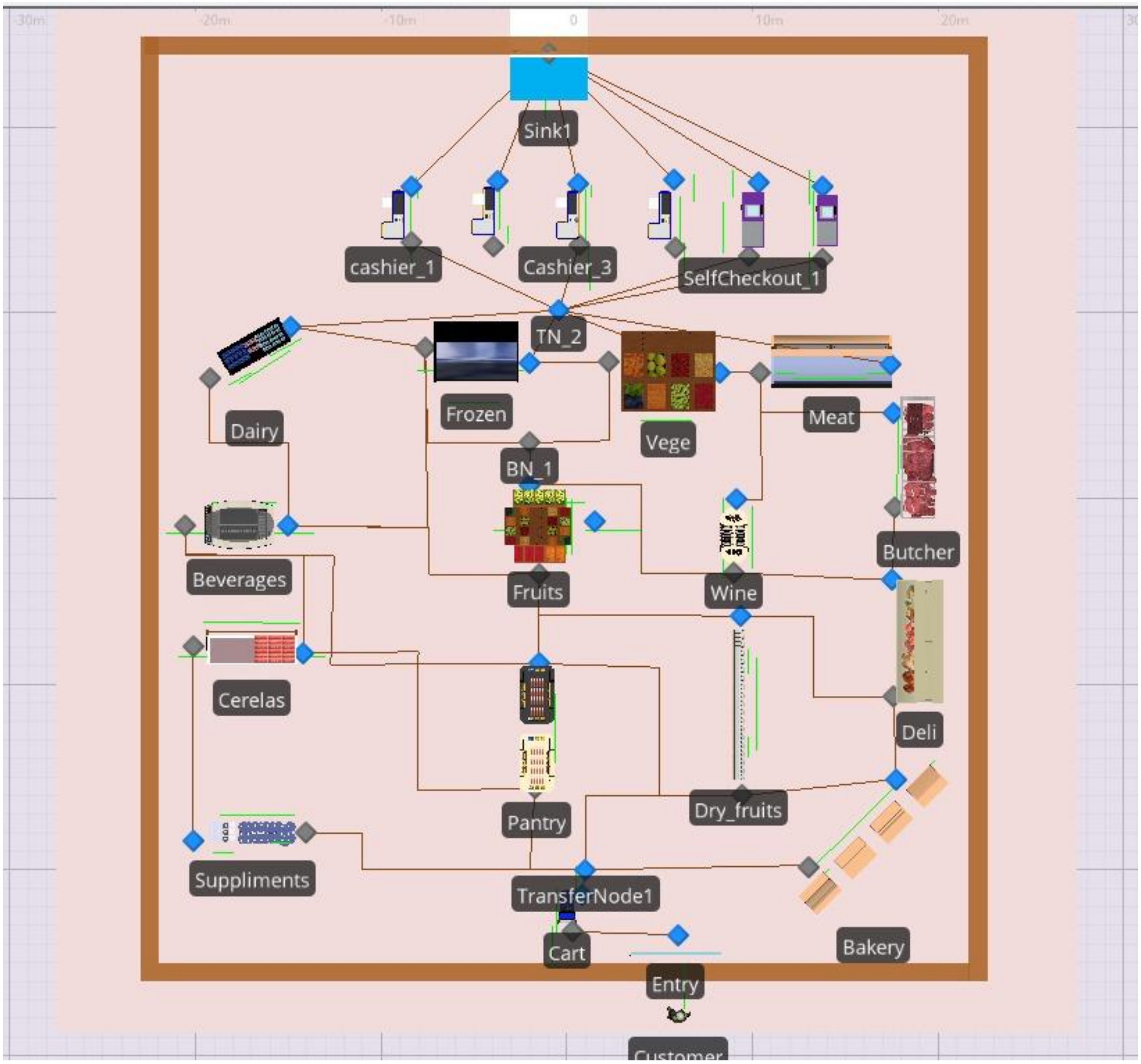


Figure 5.1- Outline simulation model of sprouts market

The above *figure-5.1* shows simulation model of a Sprouts grocery store intricately maps out the customer journey from entry to exit, encompassing a variety of product sections and checkout options. As customers enter, they can grab a cart and navigate through different departments—ranging from Dairy, Beverages, and Cereals on the left, to Fruits, Vegetables, and Dry Goods in the center, and specialized sections like Meat, Deli, and Bakery towards the right. The layout is designed to guide customers efficiently through the store, ensuring easy access to all sections.

At the checkout, the model includes several counters to accommodate varying customer needs and traffic volumes: Cashier-1 and Cashier-2 operate all day for general purchases, while Cashier-3 and cashier_4 is reserved for peak times to alleviate congestion. Additionally, a self-checkout option offers convenience for those preferring a quick, self-service exit. After purchases are made, customers exit through the designated point, completing their shopping experience.

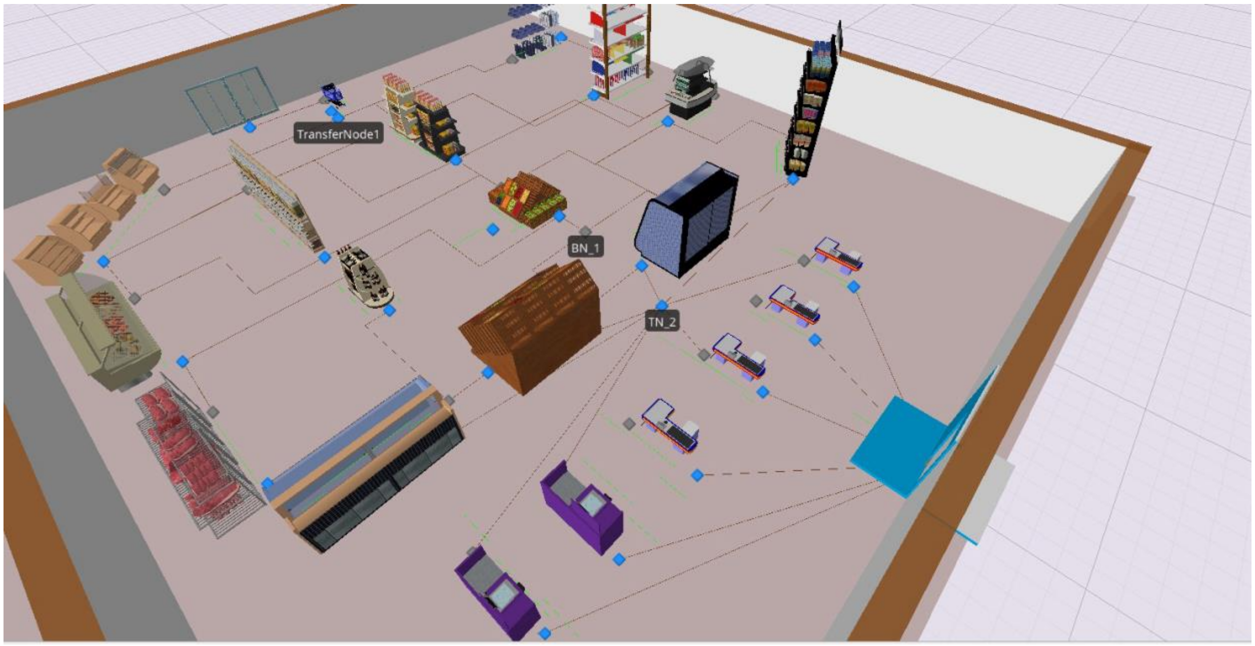
5.1 TABLE OF SERVERS WITH DISTRIBUTION:

The below service time distribution is assumed no data was provided by the Manager.

Table 5.1.1 - Service time distribution of servers

Servers	Service Time Distribution
Supplements	Random. Triangular (0.5, 1, 1.5)
Cereals	Random.Triangular(0.5, 1, 1.5)
Beverages	Random.Triangular(0.5, 1, 1.5)
Dairy	Random.Triangular(0.5, 1, 1.5)
Pantry	Random.Triangular(0.5, 1, 1.5)
Fruits	Random.Triangular(0.5, 1, 1.5)
Frozen	Random.Triangular(0.5, 1, 1.5)
Dry Fruits	Random.Triangular(0.5, 1, 1.5)
Bakery	Random.Triangular(0.5, 1, 1.5)
Vegetables	Random.Triangular(1, 2, 3)
Deli	Random.Triangular(2, 4, 6)
Butcher	Random.Triangular(1.5, 3, 5)
Meat	Random.Triangular(1, 2, 3)
Cashier_1, Cashier_2, Cashier_3, Cashier_4	Random.Triangular(1, 2, 3)
Self-checkout_1, Self-checkout_2	Random.Triangular(1.5, 3, 5)

5.1.2 - Frontside top view of sprouts market



5.1.3 - Checkout station's top view of sprouts market

6. OUTPUT ANALYSIS:

The report critically evaluates the experimental results obtained under various cashier configurations in a retail environment. This analysis methodically dissects the data to understand the effectiveness and efficiency of each scenario in managing customer flow and optimizing cashier utilization. Key metrics such as average customer entries and exits, utilization percentages, and wait times are compared to derive actionable insights that could inform operational strategies to enhance the shopping experience and operational throughput.

The focus of the analysis is on assessing how different configurations—ranging from traditional cashier setups to combinations including special and self-checkout options—affect the dynamics of customer service. This includes evaluating how each scenario contributes to or detracts from the store's ability to handle peak load times and streamline customer transactions.

This Analysis aims to provide a comprehensive analysis that not only interprets the data but also recommends refined strategies for deployment in similar retail settings, ensuring that the conclusions drawn are both statistically sound and practically viable.

6.1 SCENARIO'S

Normal Scenario:

There are two normal cashiers handling the customers. This scenario records an average of 1020 customers entering and 1017 leaving the store. The utilization rates for the cashiers are 57% and 59%, with average waiting times in the queue of 2.29 and 2.11 minutes, respectively.

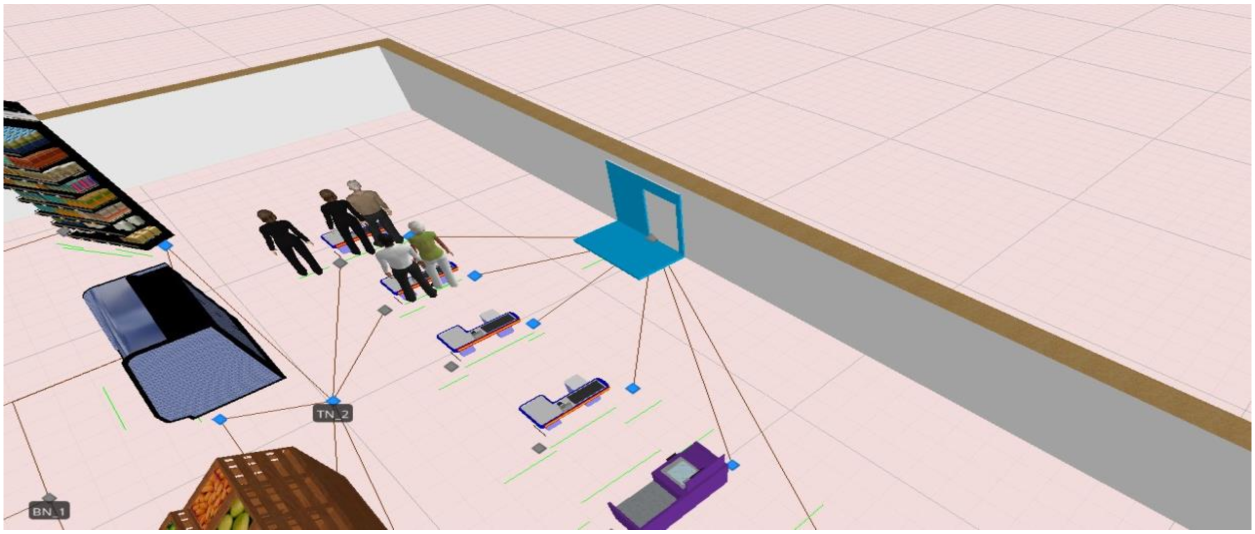


Figure 6.1.1 - Normal Scenario

<u>Scenario 1</u> :

Introduces a more complex setup with 2 normal cashiers, 2 special cashiers (operating between 10 AM and 2 PM), and 1 self-checkout. This leads to a slight decrease in the average number of customers entering (978) and leaving (931) the store. The utilization rates drop significantly for the normal cashiers to 25.12% and 26.81%, with much shorter waiting times of about 0.116 and 0.12 minutes. The special cashiers show a 52% utilization with a 1.2-minute wait, and the self-checkout sees a 58% utilization with a 1-minute wait.

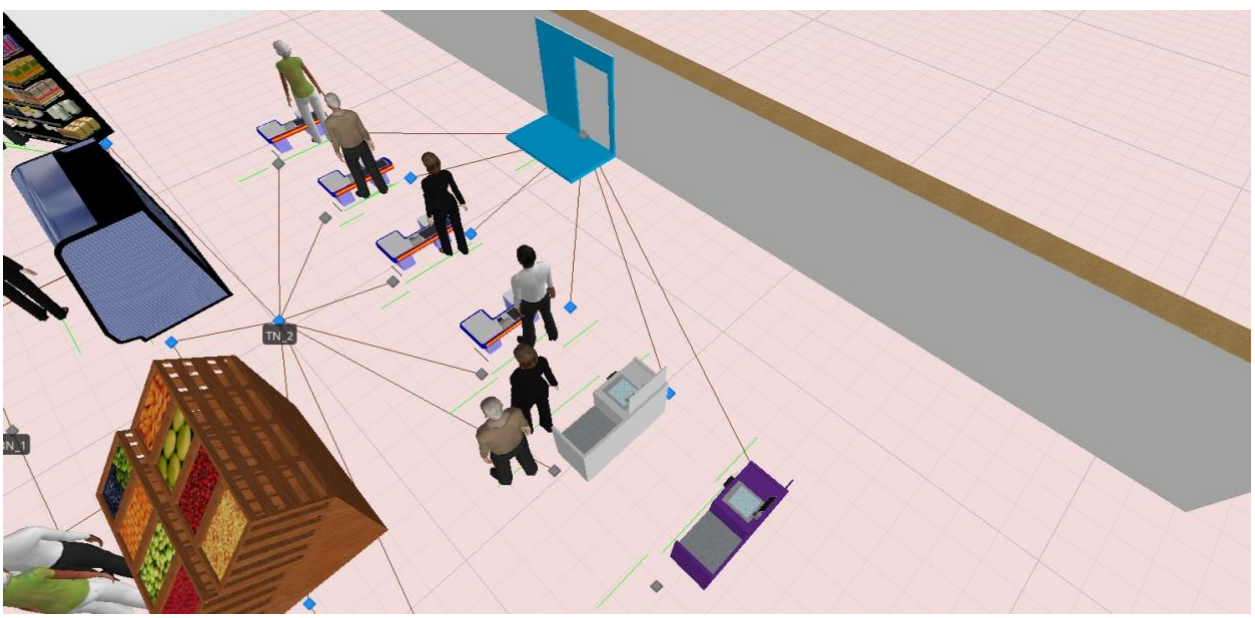


Figure 6.1.2 - Scenario_1

Scenario 2 :

comprises 3 normal cashiers and 1 special cashier. The customer numbers slightly decrease again, with 976 entering and 866 leaving. The utilization rates are somewhat evenly distributed among the normal cashiers (around 28% to 29%), with very low waiting times (0.16 to 0.18 minutes). The special cashier has a higher utilization of 99.6% with a notably lower wait time of 0.42 minutes compared to Scenario 1

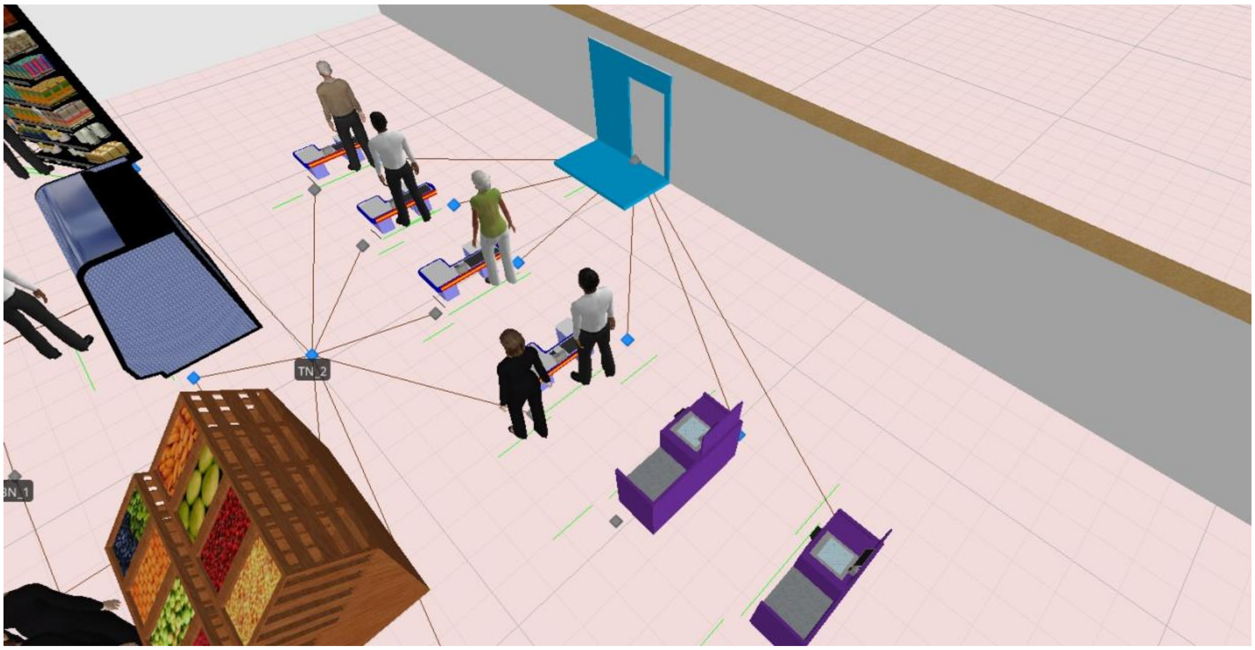


Figure 6.1.3 - Scenario_2

Scenario 3 :

simplifies the arrangement to 2 normal cashiers and 1 self-checkout. This setup sees 943 customers entering and 940 leaving, indicating efficient throughput. The normal cashiers have utilization rates of 32% and 39%, with waiting times between 0.25 and 0.38 minutes. The self-checkout is utilized by 65% of the customers, resulting in a 1-minute average wait.

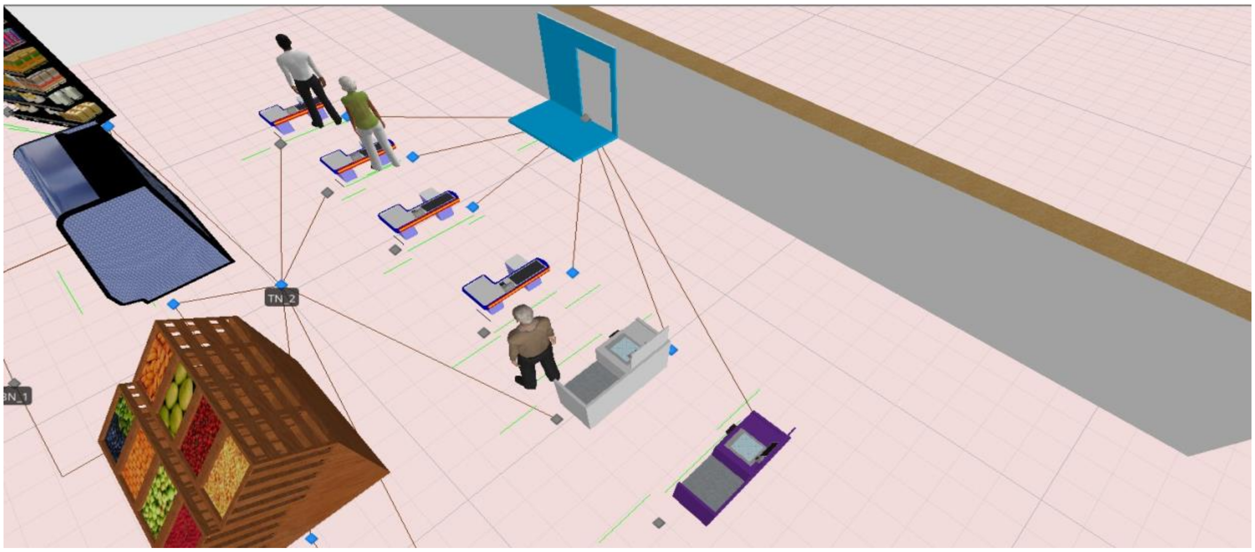


Figure 6.1.4 - Scenario_3

Scenario 4 :

the configuration changes to 1 normal cashier, 1 special cashier, and 2 self-checkouts. This scenario has the highest entry count at 995 but a lower departure of 831 customers. The normal cashier's utilization drops to 27% with a minimal 0.15-minute wait. However, the special cashier is heavily utilized at 93% with a 0.6-minute wait, and the self-checkouts have slightly increased waits of 0.89 and 0.90 minutes at utilizations of 58% and 56%.

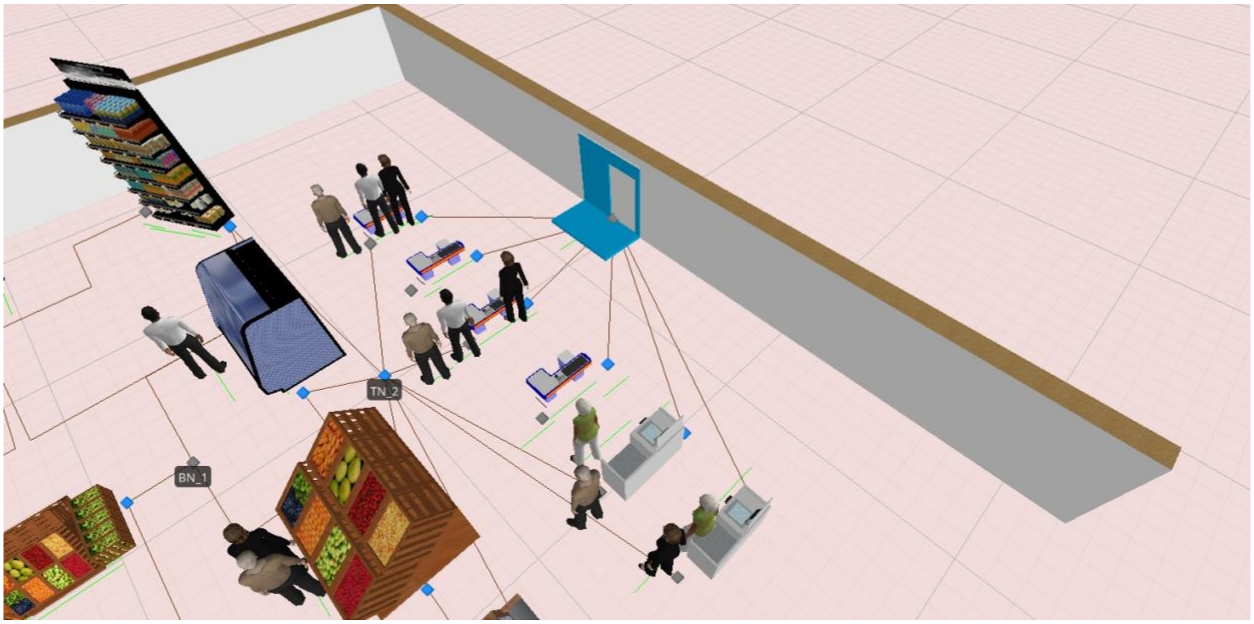


Figure 6.1.5 - Scenario_4

6.2 EXPERIMENTAL RESULTS

From the table we can conclude that Scenario 2 stands out as the optimal configuration due to its effective balance of resource utilization and customer service metrics. This setup, involving three normal cashiers and one special cashier, leads to high utilization rates for all cashiers and notably low waiting times for customers. The high utilization of cashiers indicates that the workforce is being used efficiently, minimizing idleness that could otherwise increase operational costs. Concurrently, the low wait times enhance customer.

Table 6.2.1- Experiments results according to the scenarios.

	Normal situation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	2 Normal Cashiers	**2 Normal Cashier + 2 Special cashiers + 1 Self checkout**	**3 Normal Cashier + 1 Special cashiers**	**2 Normal Cashier + 1 Self Checkouts**	**1 Normal Cashier +1 Special Cashier + 2 Self Checkouts**
Average Number of Customer Entering the store	1020	978	976	943	995
Average Number of Customer Leaving the store	1017	931	866	940	831
Cashier 1					
Cashier 1 Utilization	57	25.12	28	32	27
time of waiting in queue for Checkout	2.29 min.	0.116 min.	0.16 min.	0.25 min.	0.15 min.
Cashier 2					
Cashier 2 Utilization	59	26.81	29	39	
time of waiting in queue for Checkout	2.11 min	0.12 min.	0.18 min.	0.38 min.	
Cashier 3		Special	Special		Special
Cashier 3 Utilization		52	99.6		93
time of waiting in queue for Checkout		1.2 min	0.42 min		0.6 min.
Cashier 4		Special			
Cashier 4 Utilization		57	25		
time of waiting in queue for Checkout		1.12 min	0.32 min.		
Self Checkout 1					
Cashier 1 Utilization		58		65	58
time of waiting in queue for Checkout		1 min.		1 min.	0.89 min.
Self Checkout 2					
Cashier 1 Utilization					56
time of waiting in queue for Checkout					0.90 min.

satisfaction by reducing the time customers spend in queues, which can also increase the likelihood of repeat visits. The effective matching of cashier numbers to customer flow minimizes wait times without underutilizing staff resources, establishing Scenario 2 as the ideal model for maximizing both customer satisfaction and operational efficiency.

In comparison, Scenario 4 also presents itself as a viable option due to its benefits in reducing wait times, which can improve customer satisfaction. However, it falls short of Scenario 2 in achieving the same level of efficiency in resource utilization. Despite this, Scenario 4 is still considered a strong alternative for environments where reducing direct labor costs is a priority. This makes Scenario 2 the superior choice for balancing customer service and operational effectiveness, while Scenario 4 serves as a secondary option where cost considerations may slightly outweigh the efficiency of resource use.

7. FUTURE SCOPE AND RESEARCH

The evaluation of different cashier configurations provides a solid foundation for further enhancements in retail operations management. Here are a few potential areas for future exploration:

Evaluating the Impact of Self-Checkout Stations and Mobile Payment Options:

Research could investigate the effects of introducing self-checkout stations and mobile payments on transaction times and labor costs. This would involve assessing changes in customer throughput and satisfaction levels, potentially providing a more seamless shopping experience.

Developing a dynamic staffing model that adjusts based on real-time customer flow could optimize resource allocation. By predicting customer inflows and adjusting staff levels accordingly, retailers could enhance service during peak times and reduce unnecessary labor costs during slower periods.

Recommendations for Store Layout Changes:

Exploring structural changes to store layouts to improve customer flow could significantly enhance the shopping experience. This research would analyze how different layouts impact customer navigation and interaction with cashier zones, aiming to reduce bottlenecks and streamline the checkout process.

8. CONCLUSION:

This study analyzed various configurations of checkout counters and staffing patterns to optimize customer ingress and egress in a retail setting. The results clearly show that Scenario 2, which involves a balanced combination of normal and special cashiers, provides the most efficient solution, effectively enhancing operational efficiency and significantly minimizing customer wait times. The reduction in wait times proved critical, not only improving overall customer satisfaction but also increasing the probability of customers returning.

This configuration demonstrated its superiority in facilitating a streamlined checkout process, which is essential for maintaining a competitive edge in the retail market. As retailers continue to adapt to changing consumer behaviors, the insights gained from Scenario 2 offer a valuable blueprint for future optimizations in similar retail environments.

9. REFERANCES

- Mykoniatis, K., Angelopoulou, A., & Nichols, S. S. (2021). Society 5.0: a simulation optimisation study of dynamic scheduling for a grocery store. *International Journal of Simulation and Process Modelling*, *17*(2-3), 178-186.

- Hema, V., & Herman, T. (2023). OPTIMIZING GROCERY STORE PROCESSES AND REDUCING WAIT TIME: A DISCRETE EVENT SIMULATION STUDY. *International Journal of Management Communication*, *1*(1), 1-13.