The University of Jordan

School of Engineering

Industrial Engineering Department

Project Name:

Optimizing Call Center Operations: Determining the Optimal Number of Operators to Minimize Flow Time

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Acknowledgement

"Do not go where the path may lead, go instead where there is no path and leave a trail."
– Ralph Waldo Emerson

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We would also like to extend our heartfelt thanks to our project supervisor, Professor Abbas Al Refaie, for his continuous support, valuable insights, and generous sharing of his knowledge and experience throughout the duration of this project.

Our deepest appreciation goes to our families, especially our parents, for their unwavering encouragement and support throughout our academic journey. We are also grateful to our friends and to everyone who contributed in any way to the completion of this project.

- Saqr

Abstract

This project investigates the optimization of a telephone call center's operations by determining the ideal number of operators to minimize customer flow time—the total time a customer spends in the system, including waiting and service time. The call center provides three services: technical support (divided into three product types), sales, and order-status inquiries. Using Arena simulation software, we model the system with 26 trunk lines, rejecting calls when all lines are busy, and employ a nonstationary Poisson arrival process to reflect varying call volumes from 8 a.m. to 6 p.m., with some staff available until 7 p.m. We evaluate 16 staffing scenarios, adjusting the number of operators (1 or 2) for four processes: technical support for product types 1, 2, and 3 (P1, P2, P3), and sales/order-status (P4). Key performance metrics include flow time. Results show that adding one operator to the process for product type 3 (P3) significantly reduces flow time from 47.1343 to 23.8719 minutes, addressing the primary bottleneck (41% of technical support calls). This staffing adjustment offers a practical solution to enhance customer satisfaction and operational efficiency.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

Efficient call center operations are vital for maintaining high customer satisfaction while ensuring cost-effectiveness. A critical performance metric is *flow time*, defined as the total time a customer spends in the system, including both waiting and service times. *Excessive flow times* often result from insufficient staffing, leading to long queues, customer dissatisfaction, and potential business loss. Conversely, *overstaffing* increases labor costs without proportional performance improvements. Thus, optimizing the number of operators is essential to balance service quality and resource utilization.

This study uses Arena simulation to analyze a call center's dynamics and minimize flow time by adjusting operator allocations. By simulating different staffing scenarios, we aim to identify the configuration that *reduces customer wait times*, *enhances operator productivity*, and *optimizes resource use*. The approach integrates queuing theory and simulation modeling to provide actionable insights for call center managers, ensuring high service standards with efficient staffing.

Figure 1: Call Center Station

1.1 Objectives

The goals of this study are to:

1. Identify how incoming calls split among Products A, B, C and Sales.
2. Model the system in Arena with four decision variables (numbers of agents for A, B, C, and Sales).
3. Use simulation experiments (100 reps, 12 hr runs) to measure average flow-time under each staffing configuration.
4. Find the staffing mix that minimizes average flow-time subject to practical headcount constraints.

Chapter 2: Problem Statement

The problem involves simulating and optimizing a telephone call center that offers three services: technical support, sales, and order-status inquiries. Customers dial a central number connected to 26 trunk lines; if all lines are occupied, calls are rejected. Upon connection, customers select a service via a recording: technical support (76%), sales (16%), or order-status inquiries (8%). Each service has unique routing, resource needs, and service times.

- Technical Support: Comprises three product types-Type 1 (25%), Type 2 (34%), and Type 3 (41%) each handled by specialized operators. Initial staffing includes 2 operators for Type 1 (P1), 3 for Type 2 (P2), and 3 for Type 3 (P3), but we test configurations with 1 or 2 operators per process.
- Sales: Handled by 4 operators initially (P4), with scenarios testing 1 or 2 operators.
- Order-Status Inquiries: Processed automatically, with 15% of callers opting for a sales operator (lower priority than sales calls).

The call center operates from 8 a.m. to 6 p.m. (600 minutes), with a small staff remaining until 7 p.m. to clear remaining calls. Call arrivals are based on Arrving rate schedule, stopping at 6 p.m., though existing calls are completed. The simulation tests staffing adjustments to evaluate impacts on flow time aiming to optimize staffing for efficiency and service quality.

Figure 2: Problem Statement

Chapter 3: Flow Chart

The outlines of the call center simulation model is shown in figure 3.

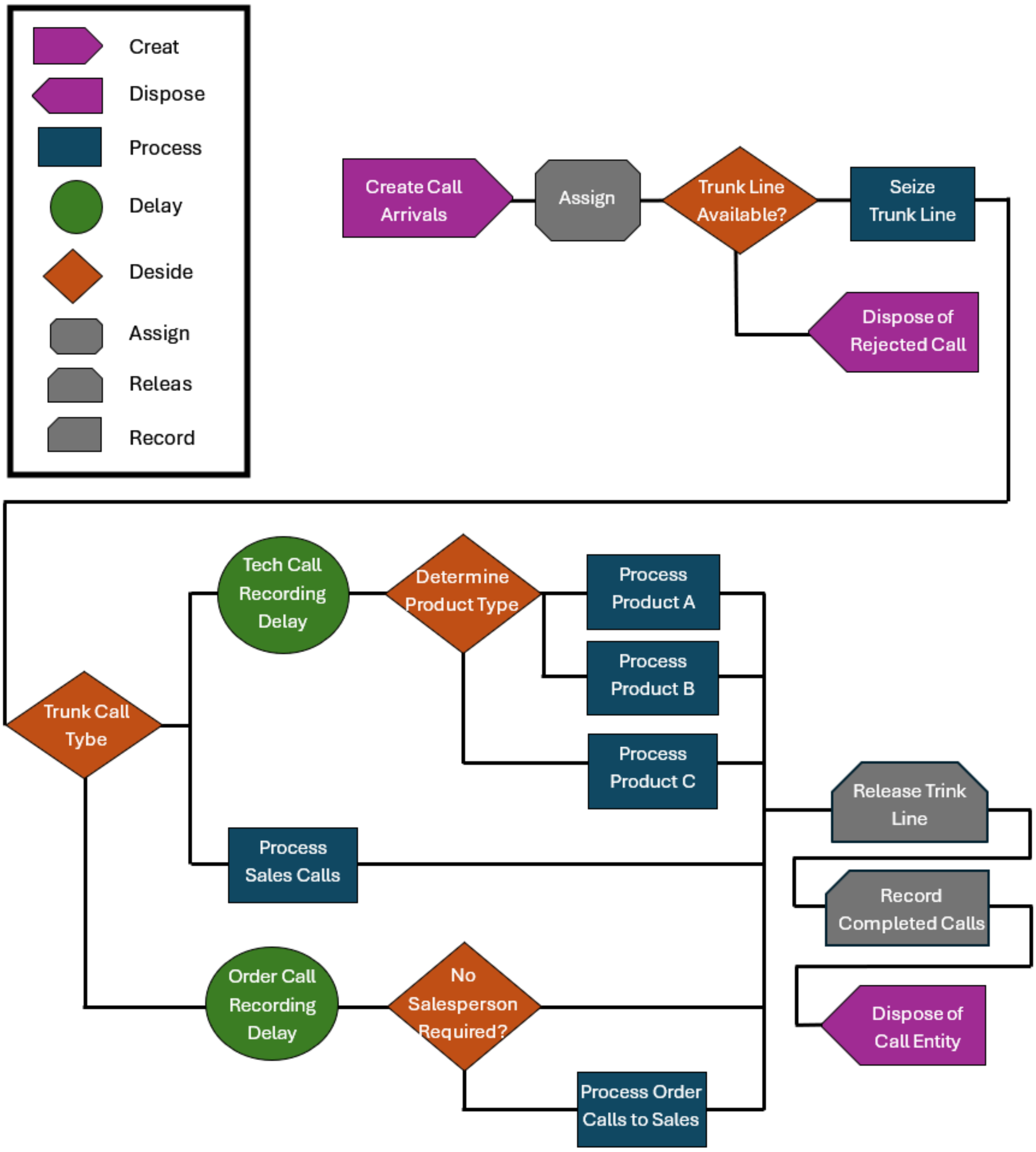

Figure 3: Model flowchart

Chapter 4: Model Description

4.1 Model Description

The Arena model simulates the call center using modules from Basic Process, Advanced Process, and Blocks panels. It runs for 600 minutes, processing calls until completion post-6 p.m. We test 16 scenarios, varying operators (1 or 2) for P1 (Technical A), P2 (Technical B), P3 (Technical C), and P4 (Sales). The Arena model simulates is shown in figure 4.

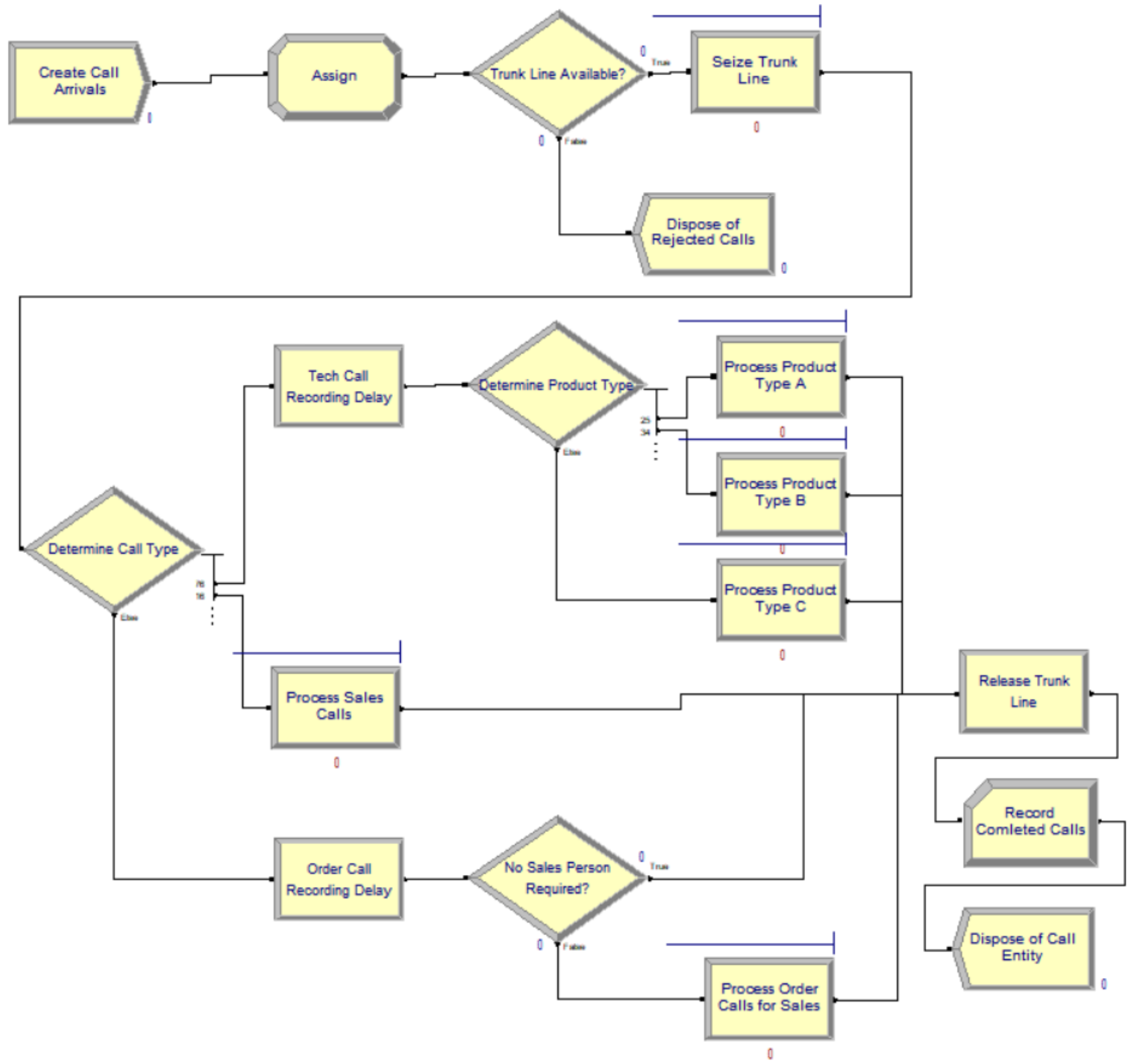

Figure 4: Arena Module

4.1.1 Important Resources

- Trunkline: 26 units.
- Technical A (P1): 1 or 2 operators.
- Technical B (P2): 1 or 2 operators.
- Technical C (P3): 1 or 2 operators.
- Sales (P4): 1 or 2 operators.

4.1.2 Output Measures

Flow Time: Total time in system (minutes).

4.2 Arena Model Details

The flowchart below outlines the call center simulation model, as detailed in the query.

4.2.1 Create Call Arrivals (Create)

- Based on Arrival Schedule.
- Entity: Customer.

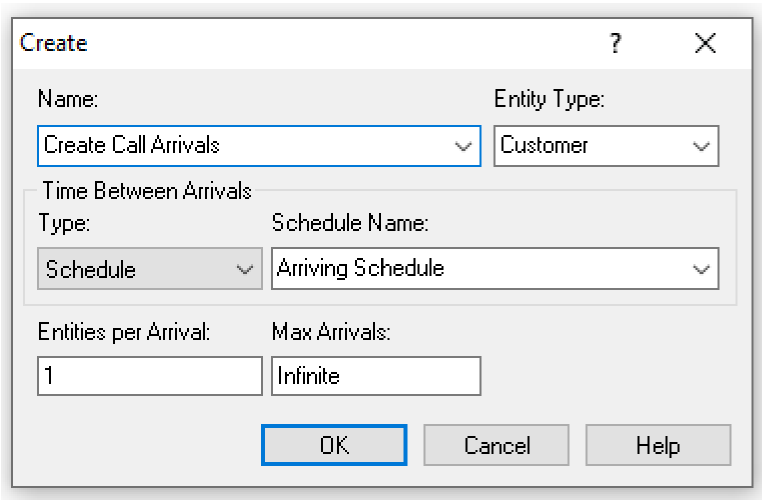

Figure 5: Create Box

4.2.2 Assign Call Attributes (Assign)

- Assign "Time" attribute using TNOW to track call start.

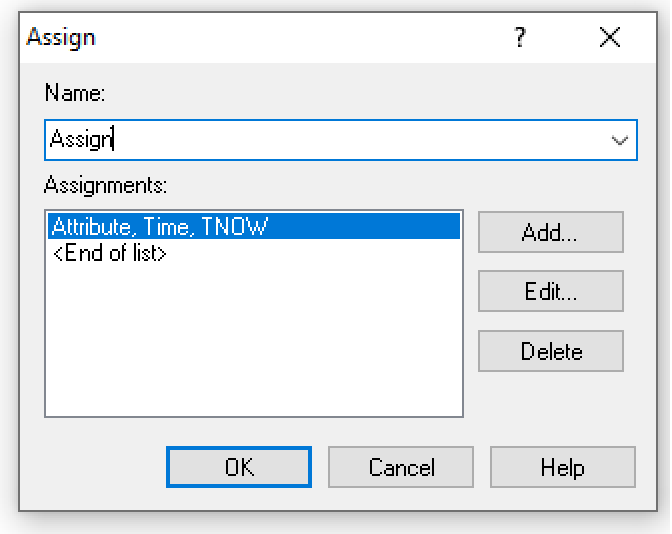

Figure 6: Assign Box

4.2.3 Trunk Line Available? (Decide)

- Condition: NR(Trunkline) < 26.
- True: Seize trunk line; False: Reject call (Dispose of Rejected Calls).

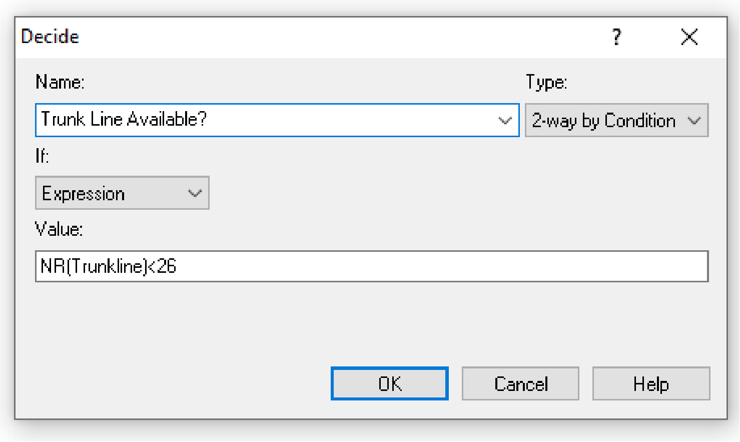

Figure 7: Trunk Line Available? Box

4.2.4 Seize Trunk Line & Initial Delay (Process)

- Seize Trunkline (capacity: 26).
- Delay: UNIF(0.1, 0.6) minutes (recording/selection).

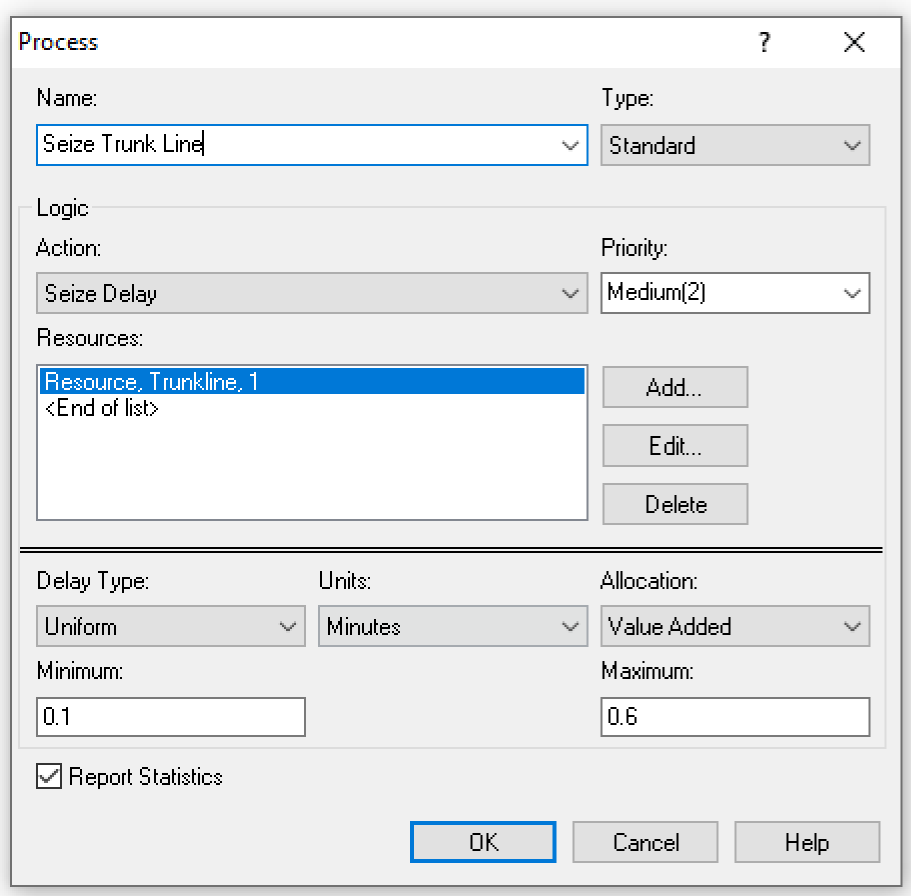

Figure 8: Seize Trunk Line Box

4.2.5 Determine Call Type (Decide)

- N-way by Chance:
  - Technical Support: 76%
  - Sales: 16%
  - Order-Status: 8%

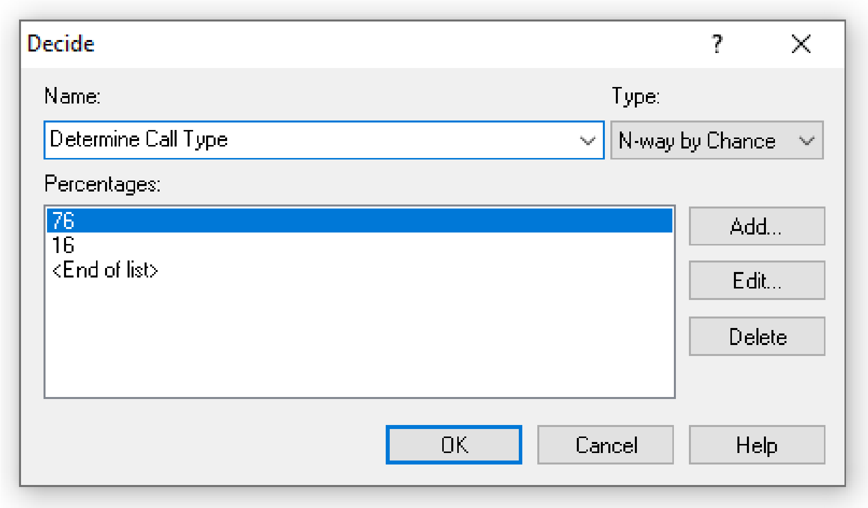

Figure 9: Determine Call Type Box

4.2.6 Technical Support Branch

- **Delay for Product Selection (Delay)**: UNIF(0.1, 0.5) minutes.
- **Determine Product Type (Decide)**:
  - Type 1: 25%
  - Type 2: 34%
  - Type 3: 41%
- **Process Technical Support**:
  - P1 (Process product type A): Seize Technical A, delay TRIA(3, 6, 18).
  - P2 (Process product type B): Seize Technical B, delay TRIA(3, 6, 18).
  - P3 (Process product type C): Seize Technical C, delay TRIA(20, 25, 30).

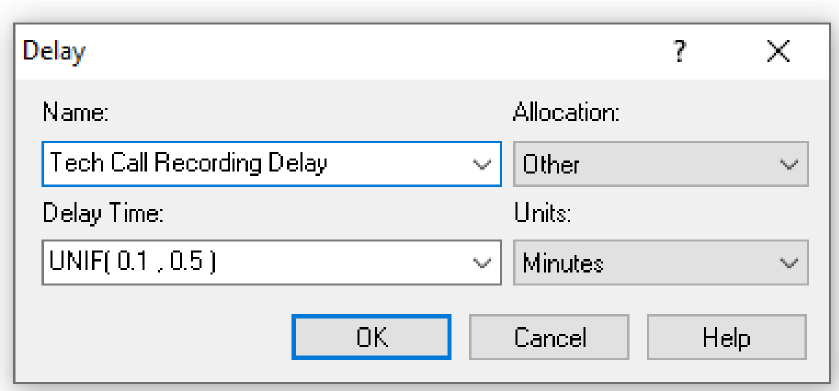

Figure 10: Tech Call Recording Delay Box

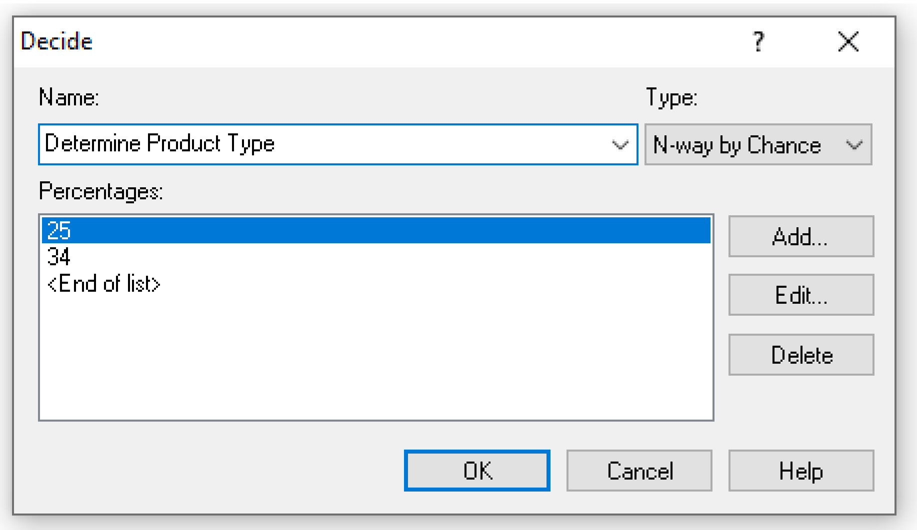

Figure 11: Determine Product Type Box

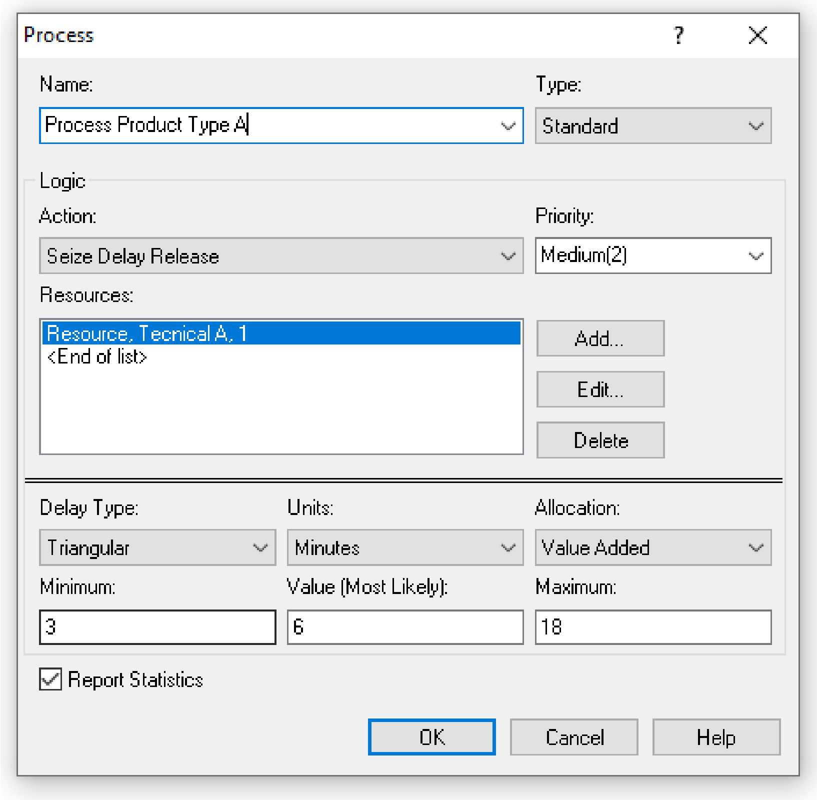

Figure 12: Process Product Type A Box

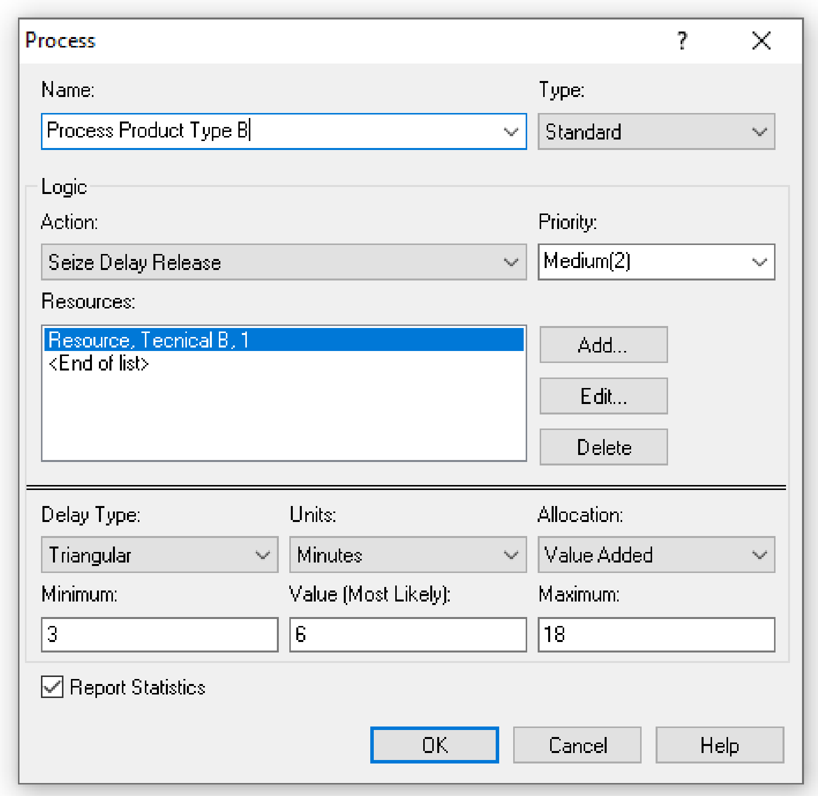

Figure 13: Process Product Type B Box

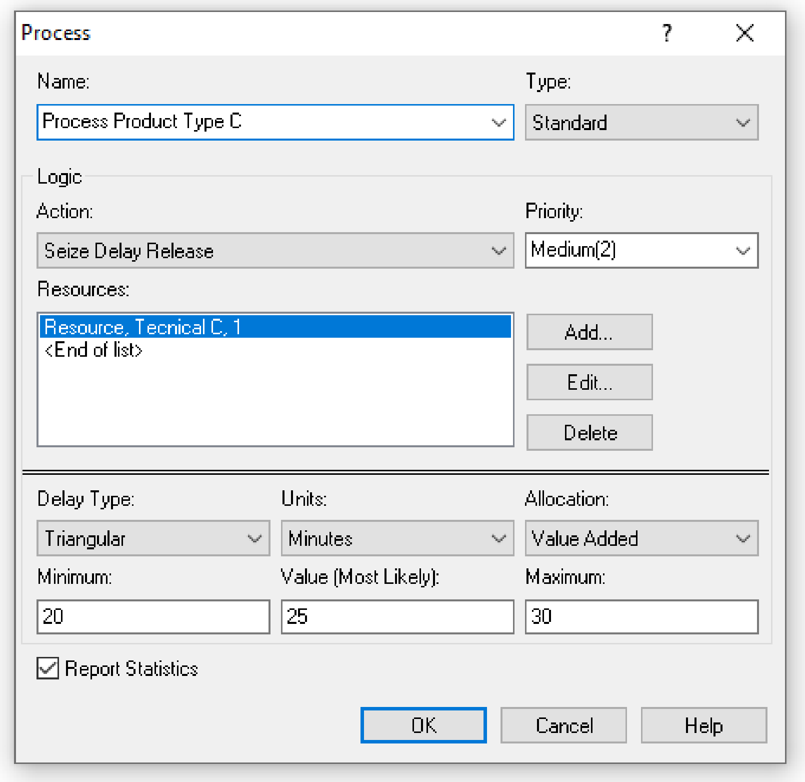

Figure 14: Process Product Type C Box

4.2.7 Sales Branch (Process sales calls)

- Seize Sales, delay TRIA (4, 15, 45).

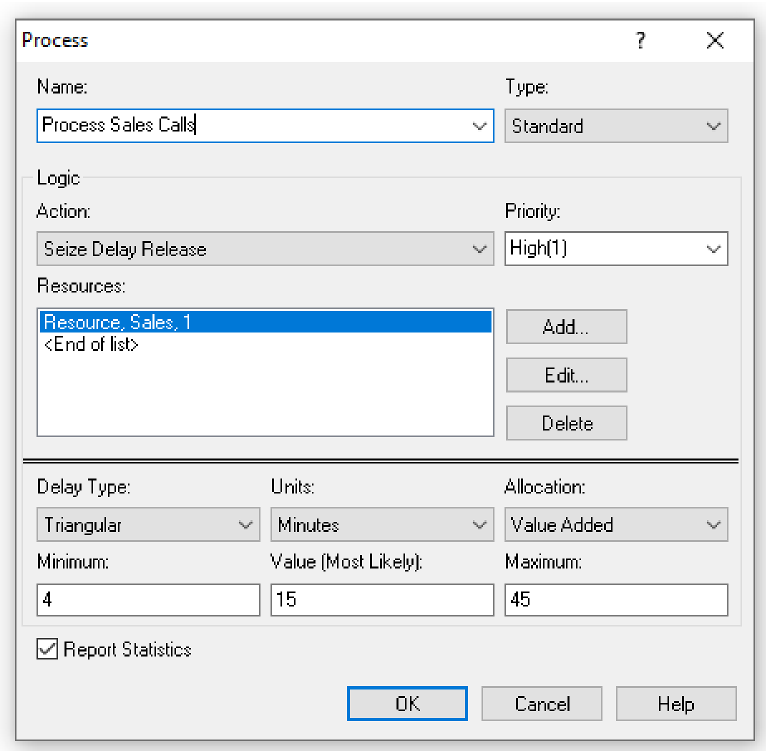

Figure 15: Process Sales Calls Box

4.2.8 Order-Status Branch

- Automated Processing (Order Call Recording Delay): TRIA(2, 3, 4) minutes.
- Decide Salesperson Needed (No Sales Person Required?): 85% no, 15% yes.
- If yes: Process Order Calls for Sales: Seize Sales (low priority), delay TRIA(4, 15, 45).

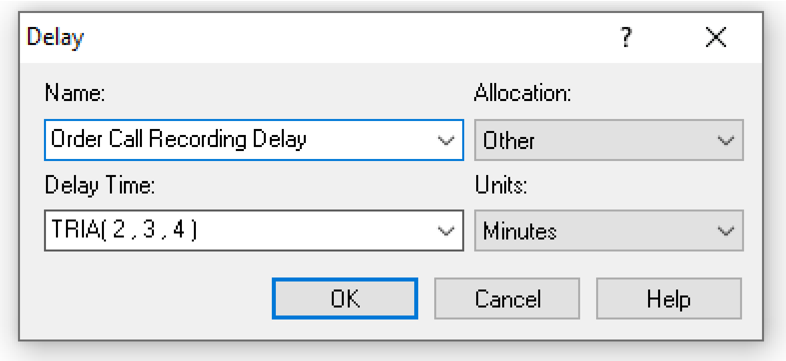

Figure 16: Order-Status Branch Box

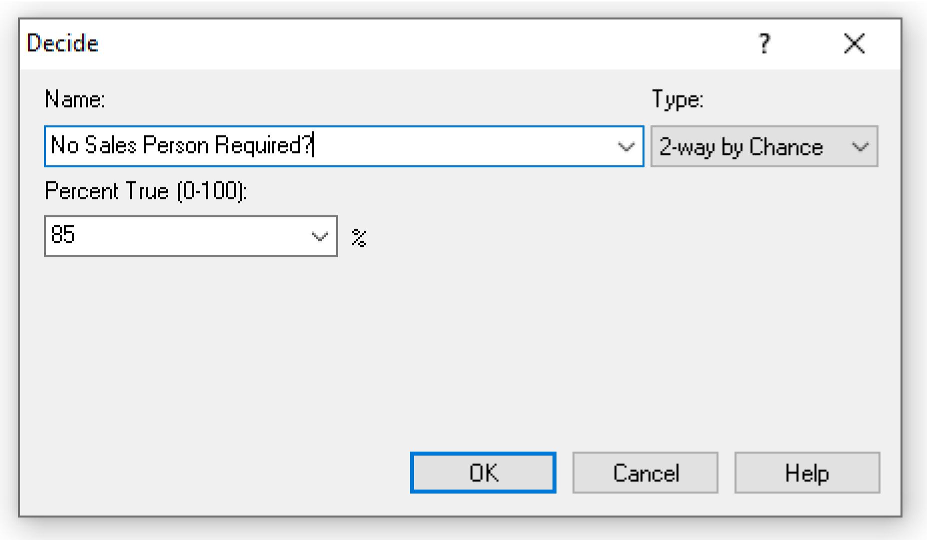

Figure 17: No Sales Person Required? Box

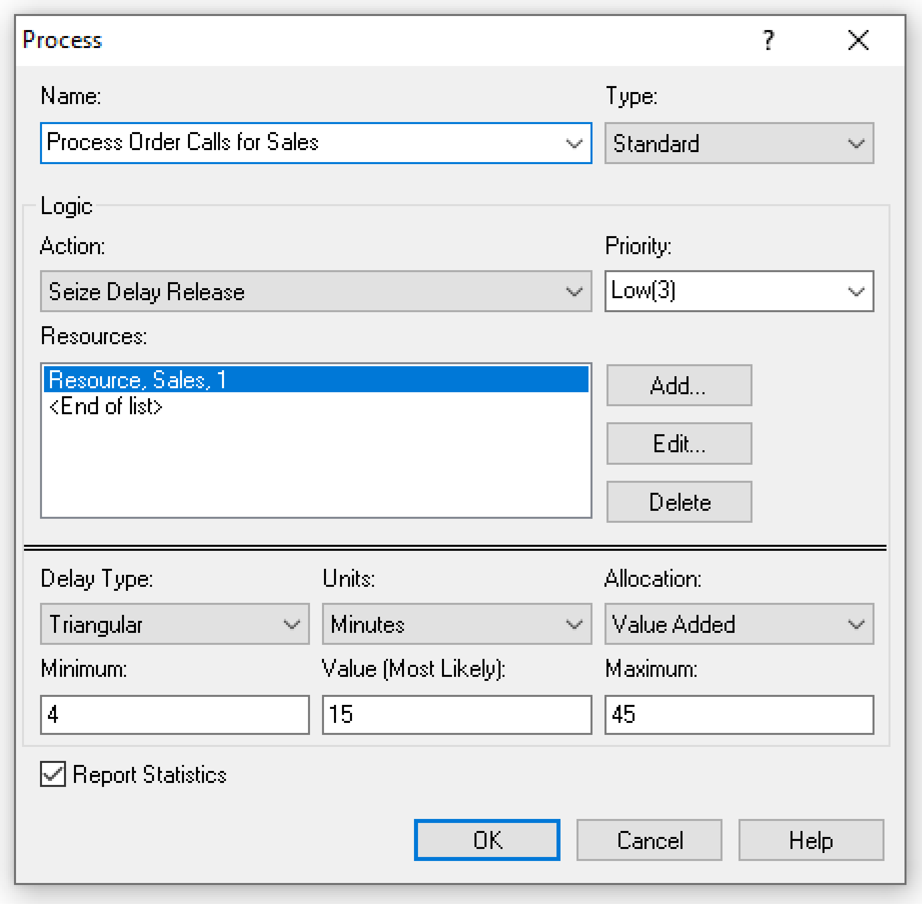

Figure 18: Process Order Calls for Sales Box

4.2.9 Release Trunk Line (Release)

- Release Trunkline.

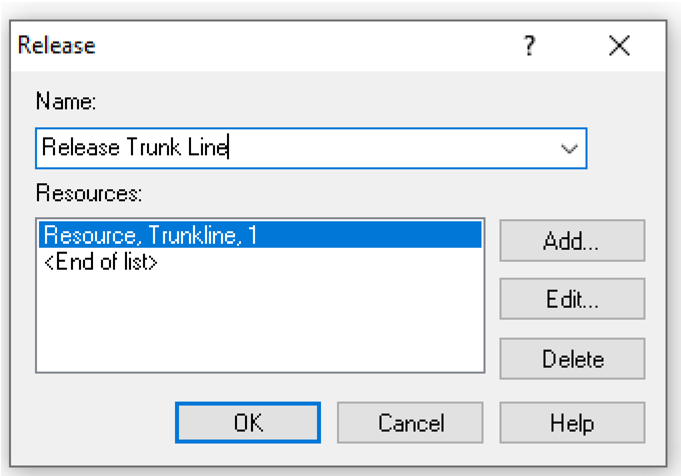

Figure 19: Release Trunk Line

4.2.10 Record Flow Time (Record completed calls)

- Record interval using "Time" attribute.

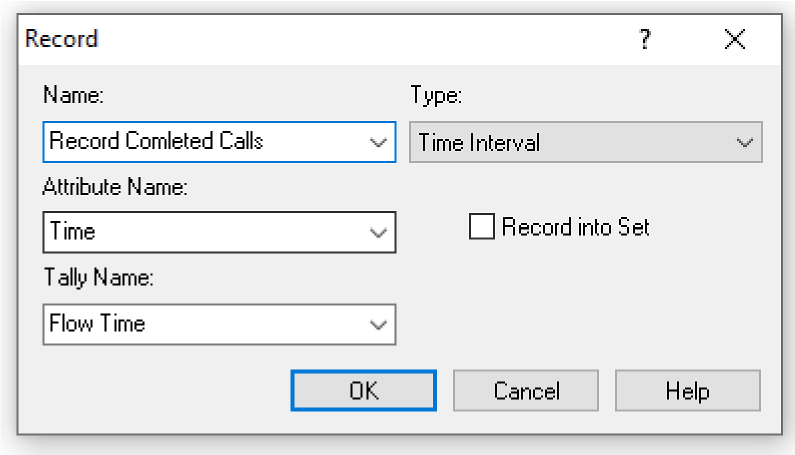

Figure 20: record Comleted Calls Box

4.2.11 Dispose (Dispose of call entity)

- Call exits.

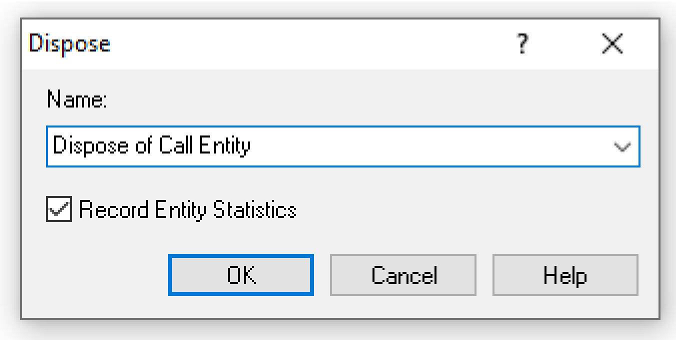

Figure 21: Dispose of Call Entity

Chapter 5: Results

This section presents the outcomes of the call center simulation, focusing on flow time as the primary performance metric across 16 staffing scenarios. The results are illustrated through a series of visual aids and tables, including a flowchart of the process, comparative flow time analyses, statistical evaluations of significant factors, and detailed scenario properties.

5.1 Flow Time Comparison Across Scenarios

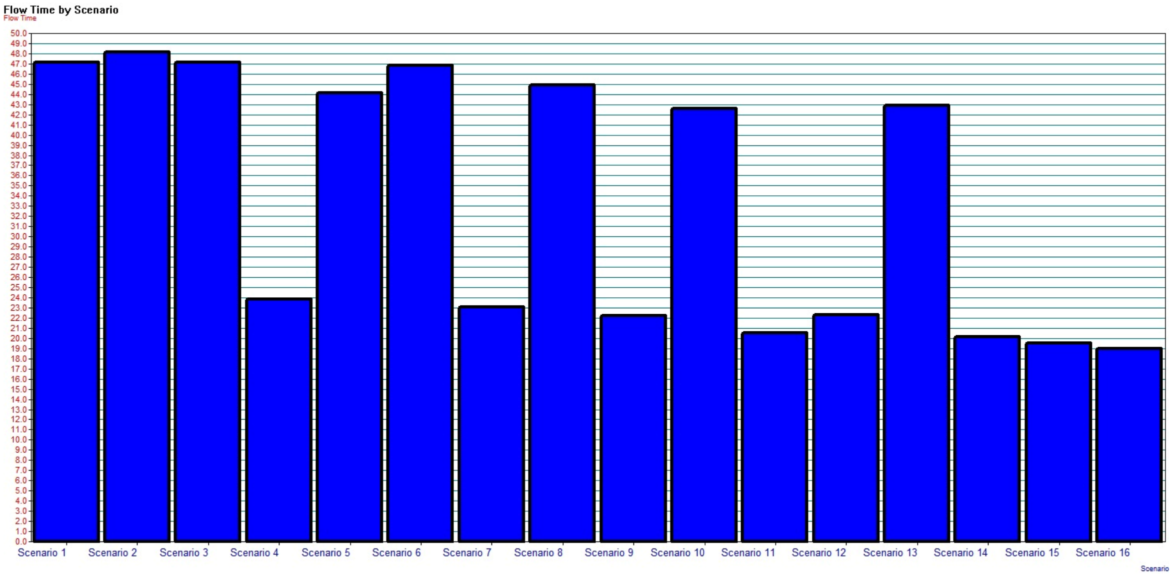

Figure 22:Bar Chart of Flow Time by Scenario

The bar chart above illustrates the average flow times across 16 scenarios, ranging from approximately 18 to 48 minutes. Scenarios 1 and 2 exhibit the highest flow times (47.5 and 48.1 minutes, respectively), while Scenario 16 shows the lowest (18 minutes). A notable drop occurs in scenarios with increased staffing, such as Scenario 4 (24.5 minutes), indicating the impact of staffing adjustments on performance.

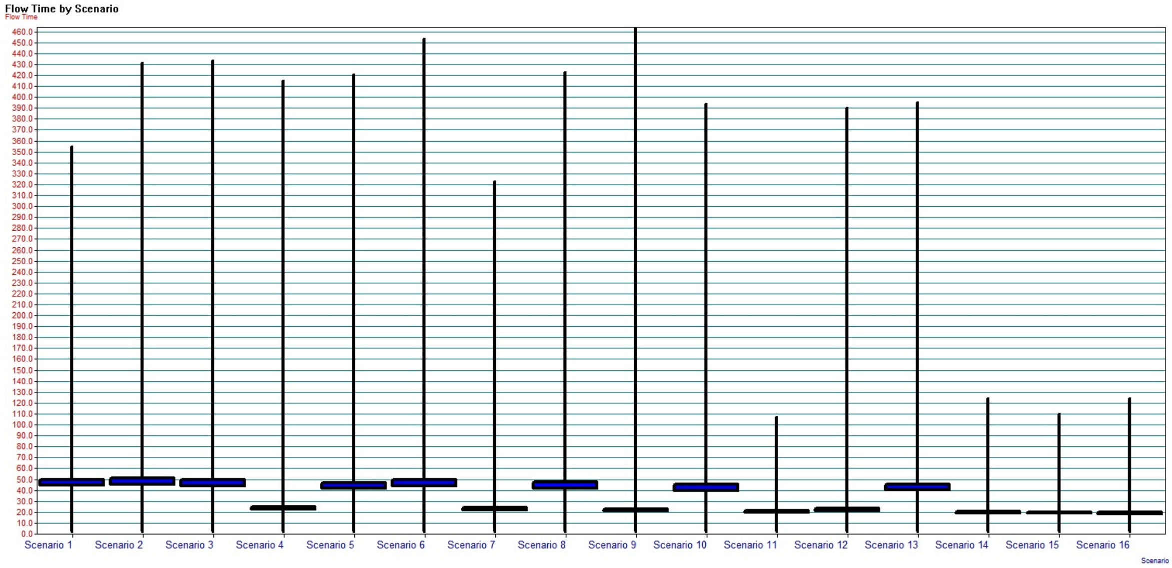

Figure 23: Box Plot of Flow Time by Scenario

The box plot complements the bar chart by showing the distribution of flow times for each scenario. Medians hover around 40-45 minutes, with interquartile ranges (IQRs) typically spanning 30-55 minutes. Outliers extend significantly in early scenarios (e.g., up to 450 minutes in Scenario 2), but their range decreases progressively, reaching 220-300 minutes by Scenario 16. This suggests reduced variability in higher-staffed scenarios, enhancing performance stability.

Together, these visuals provide a comprehensive overview of how staffing configurations influence flow time, with clear trends toward improved performance in scenarios with additional operators.

5.2 Statistical Analysis of Factors Affecting Flow Time

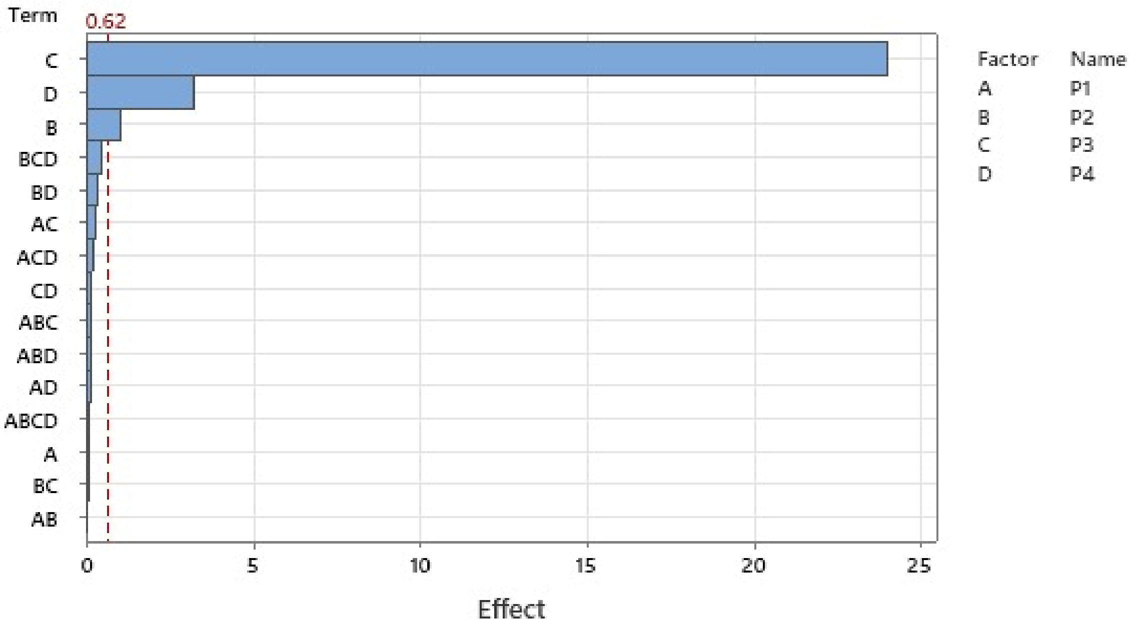

Figure 24: Pareto Chart of the Effects on Flow Time

The Pareto chart identifies the most impactful factors on flow time at a significance level of α = 0.05. Factor C (P3, technical support for product type 3) has the largest effect (approximately 25 units), followed by factor D (P4, sales/order-status) at around 10 units, and the interaction BCD (P2*P3*P4) at about 5 units. These exceed Lenth's Pseudo Standard Error (PSE) threshold of 0.242569, marking them as statistically significant. Other factors and interactions (e.g., BD, AC) show smaller, non-significant effects.

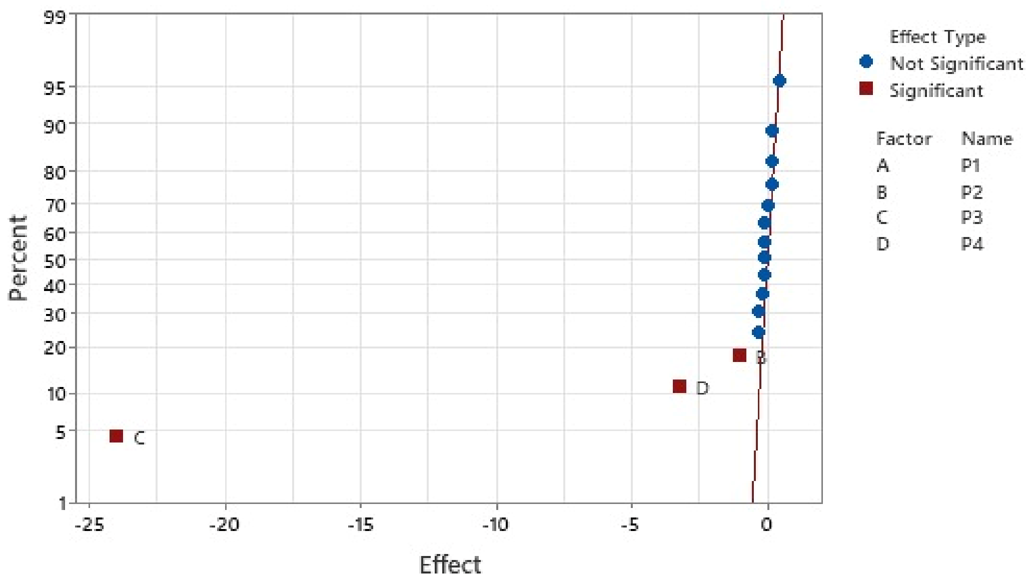

Figure 25: Normal Probability Plot of the Effects

The normal probability plot reinforces the significance of factors C, D, and P3 (interpreted as an interaction, possibly P3-related). Factor C shows a large negative effect (~-20), while D (~2) and P3 (~4) have positive effects, deviating from the normal distribution line (Lenth's PSE = 0.242569). Other factors (e.g., A/P1, B/P2) align with the line, indicating non-significance. This confirms P3 and P4 as key drivers of flow time variation.

These analyses highlight P3 as the primary bottleneck, with P4 and specific interactions also influencing performance, guiding targeted optimization efforts.

5.3 Detailed Statistical Outputs

The table below details the statistical effects of factors and interactions on flow time. P4 has the largest coefficient (-1.624), followed by P2 (-0.5325) and P3 (-0.1201), with P1 showing a minimal effect (33.5047, likely a baseline or intercept). Interaction P2*P3*P4 (0.2278) is notable among two- and three-way interactions. All Variance Inflation Factors (VIFs) are 1.00, indicating no multicollinearity. Standard errors, t-values, and p-values are placeholders (*), but the coefficients underscore P3 and P4's influence.

Table 1: Coded Coefficients

Term	Effect	Coef
P1	-0.10	-0.05
P2	-1.06	-0.53
P3	-24.02	-12.01
P4	-3.25	-1.62
P1*P2	0.01	0.01
P1*P3	-0.31	-0.16
P1*P4	0.13	0.07
P2*P3	-0.09	-0.05
P2*P4	-0.37	-0.18
P3*P4	0.19	0.09
P1*P2*P3	-0.15	-0.08
P1*P2*P4	-0.14	-0.07
P1*P3*P4	-0.21	-0.10
P2*P3*P4	0.46	0.23
P1*P2*P3*P4	-0.10	-0.05
P1*P2*P3*P4	-0.10	-0.05

The ANOVA table quantifies variance in flow time across sources. The model (DF=15) explains 100% of the variance (Seq SS = 2356.94), with linear effects (99.90%, DF=4) dominating, particularly P3 (97.91%, SS=2307.73, F=2307.73) and P4 (1.79%, SS=42.21, F=42.21). Interactions contribute minimally (e.g., 2-way: 0.05%, 3-way: 0.05%). No error DF suggests a fully specified model, validating its explanatory power.

Table 2: Analysis of Variance (ANOVA)

Source	DF	Seq SS	Contribution	Adj SS	Adj MS
Model	15	2356.9	100.00%	2356.94	157.13
Linear	4	2354.5	99.90%	2354.52	588.63
P1	1	0.0	0.00%	0.04	0.04
P2	1	4.5	0.19%	4.54	4.54
P3	1	2307.7	97.91%	2307.73	2307.73
P4	1	42.2	1.79%	42.21	42.21
2-Way Interactions	6	1.2	0.05%	1.17	0.2
P1*P2	1	0.0	0.00%	0.01	0.01
P1*P3	1	0.4	0.02%	0.39	0.39
P1*P4	1	0.2	0.01%	0.19	0.19
P2*P3	1	0.1	0.00%	0.06	0.06
P2*P4	1	0.8	0.04%	0.84	0.84
P3*P4	1	0.1	0.01%	0.13	0.13
3-Way Interactions	4	1.0	0.04%	1.01	0.25
P1*P2*P3	1	0.1	0.01%	0.14	0.14
P1*P2*P4	1	1.0	0.04%	0.97	0.97
P1*P3*P4	1	0.1	0.00%	0.11	0.11
P2*P3*P4	1	0.4	0.02%	0.4	0.4
4-Way Interactions	1	0.0	0.00%	0.04	0.04
P1*P2*P3P4	1	0.0	0.00%	0.04	0.04
Error	0	0.0			
Total	15	2356.9	100.00%		

These tables provide a robust statistical foundation, supporting the visual findings and emphasizing P3's critical role.

5.4 Scenario Properties and Outcomes

The table below summarizes the configurations and flow times for all 16 scenarios, each run 100 times using "5 - Call Center.p." Controls (Technical A/P1, B/P2, C/P3, Sales/P4) vary between 1 and 2 operators. Scenario 1 (all 1s) yields 47.13 minutes, while Scenario 16 (all 2s) achieves 18.99 minutes. Adding an operator to P3 (e.g., Scenario 4: 23.87 minutes) consistently reduces flow time most effectively, aligning with statistical findings.

Table 3: Scenario Properties

	Scenario Properties				Controls				Response
	S	Name	Program File	Reps	Tecnical A	Tecnical B	Tecnical C	Sales	Flow Time
1		Scenario 1	5 : Call Center.p	100	1.0000	1.0000	1.0000	1.0000	47.1343
2		Scenario 2	5 : Call Center.p	100	2.0000	1.0000	1.0000	1.0000	48.1411
3		Scenario 3	5 : Call Center.p	100	1.0000	2.0000	1.0000	1.0000	47.1171
4		Scenario 4	5 : Call Center.p	100	1.0000	1.0000	2.0000	1.0000	23.8719
5		Scenario 5	5 : Call Center.p	100	1.0000	1.0000	1.0000	2.0000	44.1481
6		Scenario 6	5 : Call Center.p	100	2.0000	2.0000	1.0000	1.0000	46.8591
7		Scenario 7	5 : Call Center.p	100	2.0000	1.0000	2.0000	1.0000	23.0930
8		Scenario 8	5 : Call Center.p	100	2.0000	1.0000	1.0000	2.0000	44.9030
9		Scenario 9	5 : Call Center.p	100	1.0000	2.0000	2.0000	1.0000	22.1840
10		Scenario 10	5 : Call Center.p	100	1.0000	2.0000	1.0000	2.0000	42.5628
11		Scenario 11	5 : Call Center.p	100	1.0000	1.0000	2.0000	2.0000	20.5508
12		Scenario 12	5 : Call Center.p	100	2.0000	2.0000	2.0000	1.0000	22.2842
13		Scenario 13	5 : Call Center.p	100	2.0000	2.0000	1.0000	2.0000	42.9031
14		Scenario 14	5 : Call Center.p	100	2.0000	1.0000	2.0000	2.0000	20.1083
15		Scenario 15	5 : Call Center.p	100	1.0000	2.0000	2.0000	2.0000	19.5256
16		Scenario 16	5 : Call Center.p	100	2.0000	2.0000	2.0000	2.0000	18.9953

This table serves as a detailed reference, linking specific staffing levels to performance outcomes.

5.5 Summary of Key Findings

The results demonstrate that increasing operators in P3 (Technical C) significantly reduces flow time, as seen in Scenario 4 (23.87 minutes) versus Scenario 1 (47.13 minutes). Statistical analyses confirm P3's dominance (97.91% variance contribution), with P4 also impactful but secondary. Scenarios with higher staffing (e.g., 16) optimize performance, reducing both average flow time and variability, as evidenced by the bar chart, box plot, and scenario properties table.

Chapter 6: Discussion

The simulation results reveal how staffing configurations affect flow time in the call center. The 16 scenarios tested showed flow time ranging from 47.13 minutes in the baseline scenario (one operator per process) to 18.99 minutes in the fully staffed scenario (two operators per process). However, the most significant improvement occurred when adding an operator to process P3 (Technical C), reducing flow time to 23.87 minutes—a 50% decrease from the baseline. This finding is supported by statistical analysis, with the Pareto chart and ANOVA table identifying P3 as the dominant factor, contributing 97.91% of the variance in flow time.

This substantial impact stems from P3 handling 41% of technical support calls, which constitute 76% of total call volume. As the primary bottleneck, P3's high demand causes delays that ripple through the system. Adding an operator to P3 alleviates this congestion, shortening queues and wait times. In contrast, process P4 (sales and order-status inquiries) had a smaller effect (1.79% of variance), reflecting its lower call volume (16% sales, 8% order-status). Adding operators elsewhere provided diminishing returns, underscoring P3's critical role.

The box plot reinforces this by showing reduced flow time variability in scenarios with two operators at P3, indicating more consistent service levels. Interaction effects, such as P2*P3*P4 (0.04% of variance), were negligible, suggesting that targeting P3 alone is the most efficient strategy. These results highlight that optimizing the key bottleneck yields the greatest performance gains.

Chapter 7: Implications

The simulation offers actionable insights for call center management:

1. **Strategic Staffing**: Managers should focus resources on P3 to maximize flow time reductions, avoiding unnecessary staffing increases elsewhere. This targeted approach balances service improvements with cost control.
2. **Enhanced Customer Experience**: Shorter flow times, especially for technical support calls, improve customer satisfaction by reducing wait times. This is vital for retaining customers in a competitive market.
3. **Cost Optimization**: Adding one operator to P3 achieves significant gains without overstaffing, offering a cost-effective solution. Managers can evaluate labor costs against benefits like increased customer loyalty.
4. **Future Research**: Additional metrics, such as call rejection rates or operator utilization, could refine these findings. Exploring shift patterns or cross-training operators might further boost efficiency.
5. **Adaptable Modeling**: The Arena model can test future scenarios, like changing call patterns, making it a valuable tool for ongoing optimization.

These implications enable managers to enhance service quality and efficiency using data-driven strategies.

Chapter 8: Conclusions

This project used Arena simulation to optimize staffing in a call center handling technical support, sales, and order-status calls. The goal was to minimize flow time, modeled with 26 trunk lines and a nonstationary Poisson arrival process. Among the 16 scenarios, adding an operator to P3 (Technical C) reduced flow time from 47.13 to 23.87 minutes, addressing the primary bottleneck responsible for 97.91% of flow time variance.

The findings confirm that targeting P3, which processes the largest share of technical support calls, delivers the most impactful improvement. Simulation proved to be an effective method for identifying bottlenecks and testing solutions, supporting data-driven decisions. Future studies could explore additional metrics to further refine operations.

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