# SM Travel

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## Executive Summary

The SM Travel project aims to consolidate and model the processes of a travel office (call center) to be located in the U.S., in which requests are handled over the phone for a twelve hour period per day. The model evaluates the current design and proposes a configuration that minimizes operating costs while achieving the desired customer-service levels. The current model prioritizes cardholder customers (gold or silver) over regular customers, minimizes the number of busy signals received and decreases process and wait-times within the system. This report proceeds to evaluate various recommendations on the number of trunk lines, reserved lines, number of operators and shift patterns and methods of estimating the expected wait times by customers. Based on a cost-effective system configuration, the proposed final model utilizes 50 trunk lines with 3 reserved lines for cardholders, implements a customized eight hour schedule for staffing levels, with a total of 204 hours of work per day at a cost of $4,832. The performance criteria is met with regular customers waiting for 9.28 minutes, silver customers waiting for 50 seconds, and gold customers waiting for 20 seconds on average to seize an operator. Additionally less than 2% cardholders and 20% regular customers receive busy signals upon entering the system.

## Process Modeling and Data

Various types of data are used to model the call center, with scheduled operator numbers and trunk lines utilized being the two main variables acting as controls. We aim to minimize these two control variables to ensure customer satisfaction criteria is met while conducting a cost-efficient operation. Other types of data utilized in creating this model include client, call and operator types; service and waiting times, among others. The minimum performance criteria is specified below:

- 98% of all gold-card customers should have a wait or queue time of 90 seconds or less.
- 95% of all silver-card customers should have a wait or queue time of 3 minutes or less.
- 85% of all regular customers should have a wait or queue time of 15 minutes or less.
- No more than 2% of cardholder customers should receive a busy signal
- No more than 20% of regular customers should receive a busy signal

Client Type and Priority

The model initiates with customers arriving into the system. There are two predominant customer types: regular and cardholders customers. Cardholders are the more valuable customers and therefore get priority over regular customers. The cardholder client type further breaks down into gold and silver, with silver being the majority (68%). Cardholder type allows for priority in seizing trunk lines, with a small proportion being reserved for their use. The hourly rates of arrival for each customer type were input into the model through Arena's 'Schedule' module, which is outlined in Appendix A and C.

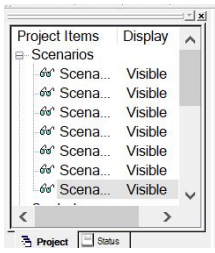
Upon arrival, if a trunk line is not available, customers will exit the system, otherwise they proceed to seize one and wait until an operator becomes available. Gold customers get priority service and can be served by any of the gold, silver, or regular operators, while silver customers can only be served by silver or regular operators, and regular customers can only be served by a regular operator. Each type of customer has their own distributions on the maximum amount of time they are willing to wait for an operator. The tolerance for cardholders is UNIF (8,17) and

for regular customers is UNIF (12,30) in minutes. If the wait time exceeds their tolerance, they will leave the system, and if not they will wait until they seize an operator.

Trunk Lines

Upon customer arrival, trunk lines are being seized if the number of ‘current scheduled lines’ is greater than ‘current busy lines’, implying at least one trunk line is available for use. If a trunk line is not available at that time, the call will be rejected and the customer may call back at another time. To enforce a priority system for cardholder customers, a small proportion of trunk lines are reserved. When trunk lines are being congested, this restricts regular customers from seizing a trunk line, while allowing cardholders to seize the reserved lines. The baseline for the number of total trunk lines is 50, obtained at a fixed cost. Addition of an extra trunk line beyond 50 is associated with a cost of $170 per day, purchased in bundles of five.

‘Number of trunk lines’ and ‘reserved trunk lines’ are two of the major control variables within this model. Various combinations of these two variables were tested through the model using the Process Analyzer tool to see how response variables such as utilization, cost and performance would be affected at different values. An example of trials with different trunk line values are shown in figure below.




| | | Scenario Properties | | | Controls | | Responses | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | Name | Program File | Reps | Trunk Lines | ReservedTrunkLines | Gold Cardholder.NumberIn | MoreThan1.5 Mins | Silver Cardholder.NumberIn | MoreThan3Mins | Regular Customer.NumberIn | MoreThan15 Mins |
| 1 | | Scenario 1 | 25 : Final-Project.p | 1 | 50.0000 | 3.0000 | 699.000 | 0 | 1434.000 | 13 | 414.000 | 61 |
| 2 | | Scenario 2 | 25 : Final-Project.p | 1 | 50.0000 | 4.0000 | 746.000 | 1 | 1360.000 | 5 | 297.000 | 61 |
| 3 | | Scenario 3 | 25 : Final-Project.p | 1 | 51.0000 | 5.0000 | 721.000 | 0 | 1559.000 | 9 | 288.000 | 57 |
| 4 | | Scenario 4 | 25 : Final-Project.p | 1 | 51.0000 | 3.0000 | 686.000 | 0 | 1379.000 | 4 | 386.000 | 61 |
| 5 | | Scenario 5 | 25 : Final-Project.p | 1 | 51.0000 | 5.0000 | 721.000 | 0 | 1559.000 | 9 | 288.000 | 57 |
| 6 | | Scenario 6 | 25 : Final-Project.p | 1 | 52.0000 | 3.0000 | 668.000 | 2 | 1410.000 | 2 | 443.000 | 63 |
| 7 | | Scenario 7 | 25 : Final-Project.p | 1 | 51.0000 | 4.0000 | 677.000 | 1 | 1448.000 | 2 | 293.000 | 57 |

*Figure 1: Process Analyzer Results*

Operator Scheduling and Service Times

Along with trunk lines, number of operators and scheduling serves as the two variable resources that act as control variables. The number of operators per hour and the scheduling pattern has a significant impact on the model’s response variables such as wait times, busy line signals and

overall cost. This section illustrates how operational data is integrated to the model using Arena modules

There are three types of operators, gold, silver and regular, and each type serves their respective set of customers as mentioned in section above. Gold customers can get served by any operator, silver customers served by either silver or regular operators and regular customers getting served by regular operators. Within each of the three operator types (gold, silver and regular), there are five different types of shifts distributed over the 12 hour day. This allows for 15 different staffing levels being implemented in the model.

| Customer Type | Served by Operators | Total Operators Available |
|---|---|---|
| Gold | ✓ Gold<br>✓ Silver<br>✓ Regular | 15 |
| Silver | ✓ Silver<br>✓ Regular | 10 |
| Regular | ✓ Regular | 5 |

*Table 1: Set of Operators Serving each Customer Type*

In implementing this in Arena, the ‘Set’ module was utilized to create sets of operators: ‘Gold Customer Operators’, ‘ Silver Customer Operators’ and ‘Regular Customer Operators’ with each set containing its respective operators, as outlined in Table 1. The set was created following the criteria of ‘Preferred Order’ of serving, with gold customers preferring gold operators, silver operators preferring silver customers and so on. Refer to Appendix B for the full table on staffing levels, and figures on implementation of operator schedule in Arena using ‘Resources’, ‘Sets’ and ‘Scheduling’ modules.

The service times of operators vary with operator types: gold, silver or regular, in addition to varying with the call types. The three types of calls are as follows: information, reservations and changes, with calls regarding reservations being majority (76%), information (16%) and changes (8%) taking minority. In addition to service times, after customers exit the system, operators continue to do ‘after call work’, after which operators move on to the next customer. The service

times for each call type, for regular operator type are provided below. Service and after call work times for silver and gold operators are reduced by 5% and 12% respectively. Refer to Appendix C for full figures.

| Call Type | Service | After Call Work |
|---|---|---|
| Information | 1.2 , 2.05 , 3.75 | 0.05 , 0.10 |
| Reservations | 2.25 , 2.95 , 8.6 | 0.5 , 0.8 |
| Changes | 1.2, 1.9 , 5.8 | 0.4 , 0.6 |

*Figure 2: Call Types and Service Times for Regular Operators*

Availability of operators are determined through a Decision module, which forwards customers to an operator if an operator in its respective set is available. If not, the customer is moved to a queue to wait for an operator to be available. The section on ‘Queuing and Wait Times’ will further address the model’s queuing process. All operator types are able to serve all call types. Upon availability of an operator, the customers’ call type is specified and an operator is ‘seized and delayed’ until the customer's request is complete. The customer exits the system and releases the trunk line, but the operator is delayed further for their after call work, after which they are released to serve another customer.

Queuing and Wait Times

The queuing process is an integral part of the call center model as it dictates wait times for customers and therefore abandoned call rates. In this model customers are required to queue when all operators qualified to serve them are occupied. This generates three queues, one for each customer type. Just as customers are moved to the queue, an Assign module is used to start recording their waiting time (‘StartWaitingTime’). The queue is dictated using a Hold module, which holds the customer in the queue until an operator is available.

The queuing system is modeled in favor of gold customers, followed by silver and then finally regular customers. While waiting in the queue, if any operator becomes available, gold customers are given priority to seize the operator. Secondly, if an operator is available (silver of regular operator) and no gold customers are in the gold queue, silver customers are given priority to seize the operator. Finally if a regular operator is available and there is no one in the

silver or gold waiting queue, then regulars go ahead and seize the operator. The figure below outlines a series of events in the event that a regular operator is available.

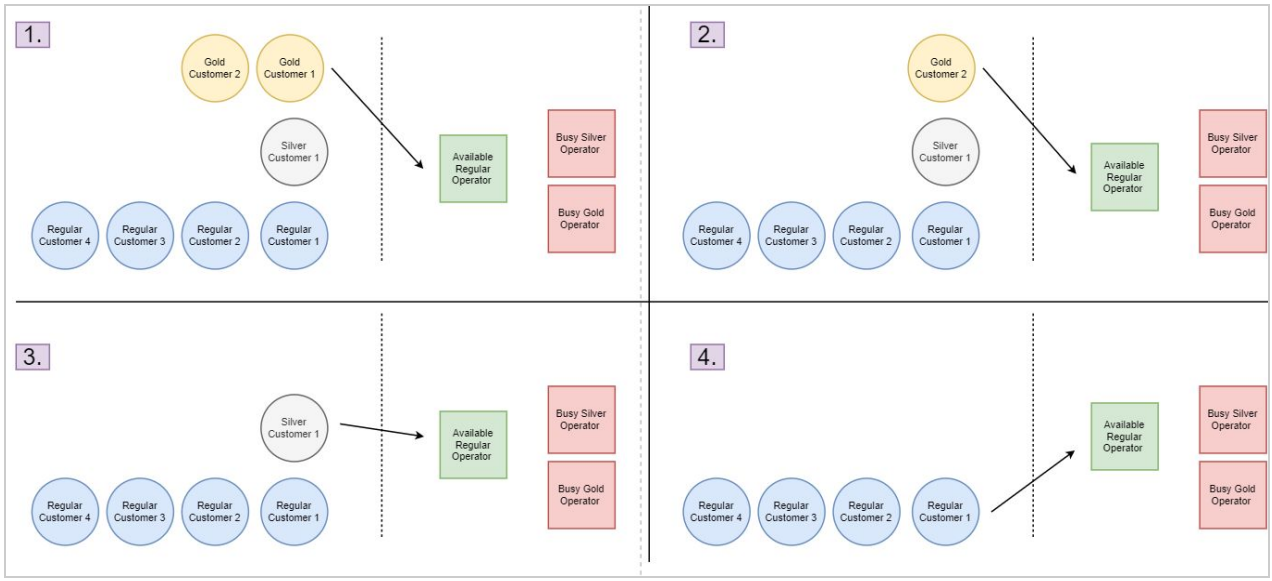



*Figure 3: Example on nature of the priority system implemented in queuing system*

As the customer seizes an operator, their total time waited is calculated using an Assign module (TNOW - StartWaitingTime). Customers whose wait time exceeds their tolerance exits the system, while those within their tolerance continue on to seize the operator, declare their call type and leave the system once complete.

## Baseline Model

As the process analyzer does not allow using a schedule-based approach for handling operator staffing patterns, a control variable in the model, multiple versions of the model were created. First, a model was created as a baseline with fixed capacity of operators instead of scheduled operators to reach cost and work efficiency. These results were later adapted to our Final Model with the original operator scheduling intended for the call center.

To get a general idea of the optimal total working hour of the operator for each pool, we experimented running the model with a fixed schedule for every operator. In other words, we took the shift pattern out of consideration and made the assumption that all three operator types (gold, silver and regular) will work for 12 constant hours, since the process analyzer does not allow using a schedule-based approach for resources. After multiple trials, we managed to generate the following information which we believe to be most attainable and cost-effective:

**Total Operating Cost/Day: $3924**

| **Operators Types** | **Number of operators (Working 12 Hours/Day)** | **Equivalent Number of operators (Working 8 Hours/Day)** | |
|---|---|---|---|
| Gold | 5 | 7.5 (7 Full-time and 1 Part-time) | |
| Silver | 5 | 7.5 (7 Full-time and 1 Part-time) | |
| Regular | 7 | 10.5 (10 Full-time and 1 Part-Time) | |
| **Customers Type** | **% Waits Less than (1.5/ 3/ 15 mins)** | **% Receives Busy Signal** | **% Have no wait time** |
| Gold | 100% | 0% | 77.43% |
| Silver | 98.4% | 0% | 20% |
| Regular | 91.42% | 8.08% | 26.27% |
| **Trunk lines** | **Numbers** | | |
| Total | 50 | | |
| Reserved | 4 | | |

*Table 2: Baseline Model Result*

Using MS Excel Solver, we took a further step by estimating the number of optimal workers for each operation hour based on the customer arrival rates (Refer to appendix F for details).

Based on results, the optimum solution is to maintain 5 operators in the system for the gold and silver pool, and 7 operators for the regular pool at every operational hour. In this case, resource scheduling based on customer arrival rates does not yield any significant improvement. This could be due to the system being constantly overloaded with customers, with a heavy priority placed on the cardholders.

Although all the criteria are met at a very efficient operating cost, this model was not further pursued since the staffing pattern is realistically unattainable. Specifically, a staffing pattern with each operator working for non-consecutive hours throughout the day is highly infeasible (Refer to appendix F). However, this model will be a good alternative should the company consider flexible working hour options and take on many part-time employees rather than sticking to a 8 hour shift scheduling. For now, the model is solely used as a baseline to arrive at the recommended model in the next section.

## Final Model

Based on results from the baseline model, the optimum number of hours per day for each operator type and optimum number of trunk lines and reserved trunk lines were taken into consideration to create a model integrating 8-hour-shift scheduling. Keeping the optimum numbers in mind, various schedules and trunk line numbers were trialed to reduce operational cost and meet the minimum performance criteria. Through trial and error, two models that satisfy the performance criteria were obtained as below:

Trial 1:

**Total Operating Cost/Day: $4832**

| Operators | Hours/ Day | % Waits Less than (1.5/ 3/ 15 mins) | % Receives Busy Signal | % Have no wait time |
|---|---|---|---|---|
| Gold | 64 | 100% | 0% | 92% |
| Silver | 72 | 99% | 0% | 65% |
| Regular | 120 | 85% | 7% | 52% |
| **Trunk Lines** | **Numbers** | | | |
| Total | 50 | | | |
| Reserved | 3 | | | |

*Table 3: Final Model Trial 1 Results*

Trial 2:

**Operating Cost/Day: $5100**

| Operator Type | Hours/ Day | % Waits Less than (1.5/ 3/ 15 mins) | % Receives Busy Signal | % Have no wait time |
|---|---|---|---|---|
| Gold | 72 | 100% | 0% | 97% |
| Silver | 72 | 100% | 0% | 69% |
| Regular | 104 | 86% | 10% | 39% |
| **Trunk Lines** | **Numbers** | | | |
| Total | 52 | | | |
| Reserved | 3 | | | |

*Table 4: Final Model Trial 2 Results*

While both trials meet the minimum performance criteria, the cost of operation varies. Taking into consideration the need for cost minimization, and that trunk lines can only be purchased in bundles of 5, Trial 1 is chosen as the best overall model, as it meets both the cost minimization and performance criteria.

## Results and Analysis

Having finalized the best model, this section provides an in-depth analysis of its statistics. Through this model 2,972 cardholder customers arrived into the system, and a total of 2,133 silver and gold customers seized a trunk line, where 839 were turned away and could call back at another time. Similarly, 2,748 regular customers arrived into the system but only 414 were able to seize a trunk line due to the priority that cardholder customers receive. A total of 2,547 customers that seized a trunk line.

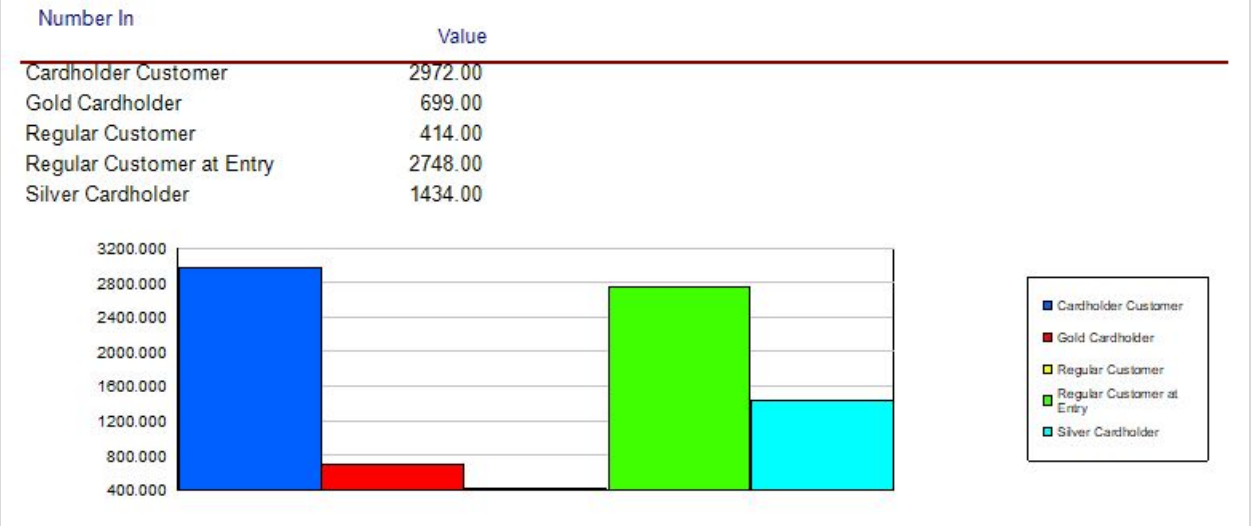



*Figure 4: Customer Arrival Numbers by Type*

Customer Wait Times

Through multiple trials using the Process Analyzer, a configuration that achieved all three maximum wait-time requirements was found. At 50 trunk lines with 3 lines reserved, all the criteria were met based on assumptions made, as illustrated by the table below. All 699 Gold customers that came into the system waited 90 seconds or less. 1,421 of 1,434 Silver customers waited 3 minutes or less, for a rate of 99%. 353 of 414 Regular customers waited 15 minutes or less, or a rate of 85.3%.

| Customer Type | Wait Time Tolerance | Expected Performance | Actual Performance |
|---|---|---|---|
| Gold | 1.5 minutes | 98% | **100%** |
| Silver | 3 minutes | 95% | **99.0%** |
| Regular | 15 minutes | 85% | **85.3%** |

*Table 5: Customer Wait Time Comparison*

Busy Signals

The first decision was to determine how to quantify the number of customers that receive the busy signal. We made the assumption that 'Busy Signal' would refer to customers seizing a trunk line and being put on hold until their wait-time tolerance is exceeded, where they abandon the call. Given the current system limitations and experimental results, achieving the given criteria goals while defining 'busy signal' as being unable to seize a trunk line was seen as incredibly difficult to achieve. Instead we redefined it to quantify another meaningful measure that describes the performance of the system well. Having made this assumption and determining what constituted a busy signal, we looked into our actual performance numbers.

| Customer Type | Busy Signal Threshold | Actual Performance |
|---|---|---|
| Cardholder | No more than 2% | **0%** |
| Regular | No more than 20% | **7%** |

*Table 6: Busy Signal Comparison*

Estimated Wait Times

The expected waiting times differed by customer type, as cardholders are served much faster than a regular customer. The figure below highlights the average expected waiting time for each customer by type. GoldCustomerQueue refers to the average waiting time for a Gold Customer which is approximately 0.33 minutes, or 20 seconds. Similarly, SilverCustomerQueue, the amount of time a Silver Customer waits, averages to 0.83 minutes, or 50 seconds. Finally, RegularCustomerQueue refers to the wait time of a Regular customer, which averages to 9.23 minutes.

**Time**

| Waiting Time | Average | Half Width | Minimum Value | Maximum Value |
|---|---|---|---|---|
| GoldCustomerQueue | 0.3383 | (Insufficient) | 0.00318847 | 1.3985 |
| Process Gold Change.Queue | 0.00 | (Insufficient) | 0.00 | 0.00 |
| Process Gold Info.Queue | 0.00242042 | (Insufficient) | 0.00 | 0.2493 |
| Process Gold Res.Queue | 0.00 | 0.000000000 | 0.00 | 0.00 |
| Process Reg Change.Queue | 0.00 | (Insufficient) | 0.00 | 0.00 |
| Process Reg Info.Queue | 0.03406235 | (Insufficient) | 0.00 | 2.2481 |
| Process Reg Res.Queue | 0.03726304 | (Insufficient) | 0.00 | 2.6357 |
| Process Silv Change.Queue | 0.00 | (Insufficient) | 0.00 | 0.00 |
| Process Silv Info.Queue | 0.00 | (Insufficient) | 0.00 | 0.00 |
| Process Silv Reserve.Queue | 0.00032625 | (Correlated) | 0.00 | 0.3595 |
| RegularCustomerQueue | 9.2778 | (Insufficient) | 0.01477588 | 26.5337 |
| Seize Trunk Line 2.Queue | 0.00 | 0.000000000 | 0.00 | 0.00 |
| Seize Trunk Line.Queue | 0.00 | 0.000000000 | 0.00 | 0.00 |
| SilverCustomerQueue | 0.8294 | (Correlated) | 0.00279815 | 6.8377 |

*Figure 5: Average Customer Waiting Times by Type*

## Recommendations

The most cost-effective system configuration that we would recommend SM Travel to use is 50 trunk lines, with 3 reserved for cardholder customers. This configuration gives the most cost-effective solution, while achieving performance level goals set out by SM Travel based on assumptions made.

To create the staffing patterns needed we created an initial schedule with each of the 15 operators. As each operator is required to work 8 hours a day, eight five-hour shifts were created, one for each operator per customer type. Since the wages differ between operators, this was taken into account when determining the optimum staffing levels. When running our model, we discovered that regular customers were getting served at a significantly low rate. For this reason a more fluctuated schedule with differing levels of operators was created. The maximum number of regular operators at one time is 15, silver operators is 9, and gold operators is 8. Overall we would have 64 working hours per day assigned to gold operators, 72 hours for silver and 120 hours for regular operators for a total of 204 working hours per day at a cost of $4,832, with no additional trunk lines used. This optimized the staffing schedule to give the model the best results.The following outlines the optimum operator schedule with number of operators per each shift.

| ***Operator*** | ***Gold*** | | | | | ***Silver*** | | | | | ***Regular*** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Shift*** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** |
| ***Num.*** | *3* | *1* | *1* | *1* | *2* | *3* | *1* | *1* | *1* | *3* | *4* | *2* | *1* | *2* | *4* |
| ***Total Operator*** | *8* | | | | | *9* | | | | | *15* | | | | |
| ***Total Hours*** | *64* | | | | | *72* | | | | | *120* | | | | |
| ***Total Cost*** | *(64) x (23) = 1472* | | | | | *(72) x (20) = 1440* | | | | | *(120) x (16) = 1920* | | | | |

*Table 7: Optimum Operator Schedule*

## Limitations

A major limitation we faced in building this model was using the Student version of Arena. As we could not access the full version, we were limited in the number of modules, variables and entities that can be used. Due to this we were unable to model and record certain aspects of our model. For example, the majority of the results of response variables were calculated manually since we were unable to use additional Record modules. The model was simplified by deleting comparatively insignificant modules, which caused us to prioritize certain performance levels over others. Had we had access to the full version in the future, a more in-depth and accurate model could have been developed.

Another limitation was being unable to easily run and record various trials with the process analyzer as it did not allow for the change of schedule-based resources. As we were unable to incorporate a schedule into the process analyzer, an additional baseline model was created. Based on the results from the baseline model, various potential operator schedules were created and were manually tested, which led to a tedious and inefficient trial and error process. Due to the limitation in the system capabilities and our knowledge, we were unable to fully experiment the model with additional trunk lines beyond 50. A few configurations with 52 trunk lines were tested, but our experiments did not go any further due to the majority of our trials

being manual computation. With the restriction of obtaining trunk lines in bundles of five rather than individually, further discouraged trials as it would introduce a multitude of possible scenarios that could not be accounted for through manual trial and error. For this reason, the focus was on optimizing the trunk line set-up using only the 50 lines provided, to reduce costs and improve the efficiency of the current set-up.

## Conclusion

In conclusion, we were able to successfully build and simulate a model that achieves a list of customer-performance levels set out by SM Travel based on assumptions made. While limited by the student version of Arena Simulation, we were able to create a model that SM Travel can use to optimize their staffing and resource levels to decrease operational cost and increase efficiency. This simulation project allowed for using various Arena based modules and utilizing the process analyzer to run scenarios with varying control variables to achieve desired responses.

**Appendix A: Customer Arrival Schedule**

| Time Period | Regular Arrival Rates | Cardholder Arrival Rates |
|---|---|---|
| 7 AM – 8 AM | 87 | 89 |
| 8 AM – 9 AM | 165 | 243 |
| 9 AM – 10 AM | 236 | 221 |
| 10 AM – 11 AM | 323 | 180 |
| 11 AM – NOON | 277 | 301 |
| NOON – 1 PM | 440 | 490 |
| 1 PM – 2 PM | 269 | 394 |
| 2 PM – 3 PM | 342 | 347 |
| 3 PM – 4 PM | 175 | 240 |
| 4 PM – 5 PM | 273 | 269 |
| 5 PM – 6 PM | 115 | 145 |
| 6 PM – 7 PM | 56 | 69 |

Figure: Hourly arrival rates of cardholder and regular customers

## Appendix B: Service Times and After Call Work

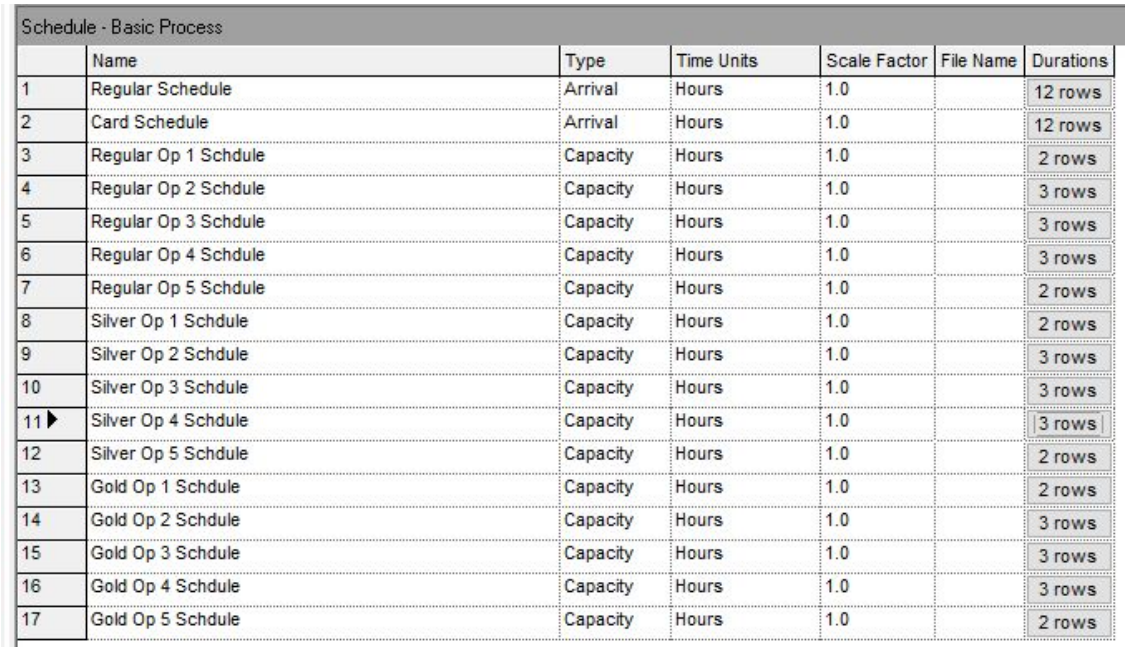
| | Call Type | Service Time | Service Time | Service Time | After Call Work | After Call Work |
|---|---|---|---|---|---|---|
| **Regular** | Information | 1.2 | 2.05 | 3.75 | 0.05 | 0.1 |
| | Reservations | 2.25 | 2.95 | 8.6 | 0.5 | 0.8 |
| | Changes | 1.2 | 1.9 | 5.8 | 0.4 | 0.6 |
| | | | | | | |
| | | | | | | |
| | **Call Type** | **Service Time** | **Service Time** | **Service Time** | **After Call Work** | **After Call Work** |
| **Silver** | Information | 1.14 | 1.9475 | 3.5625 | 0.0475 | 0.095 |
| | Reservations | 2.1375 | 2.8025 | 8.17 | 0.475 | 0.76 |
| | Changes | 1.14 | 1.805 | 5.51 | 0.38 | 0.57 |
| | | | | | | |
| | | | | | | |
| | **Call Type** | **Service Time** | **Service Time** | **Service Time** | **After Call Work** | **After Call Work** |
| **Gold** | Information | 1.056 | 1.804 | 3.3 | 0.044 | 0.088 |
| | Reservations | 1.98 | 2.596 | 7.568 | 0.44 | 0.704 |
| | Changes | 1.056 | 1.672 | 5.104 | 0.352 | 0.528 |

Figure: Service times and after call work times

**Appendix C: Operator Scheduling**

| Operator Type | Shift Time |
|---|---|
| Operator 1 | 7 AM - 3 PM |
| Operator 2 | 8 AM - 4 PM |
| Operator 3 | 9 AM - 5 PM |
| Operator 4 | 10 AM - 6 PM |
| Operator 5 | 11 AM - 7 AM |

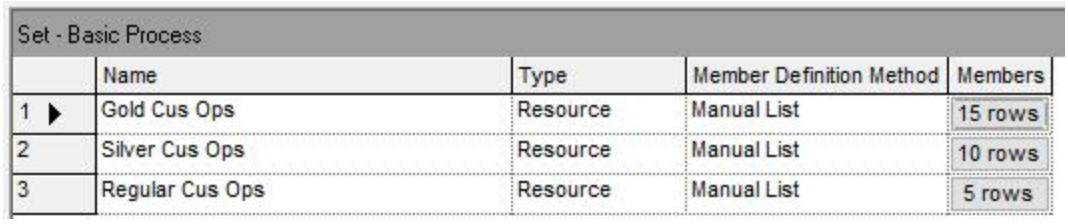
Table: Five shifts and times for each operator type (gold, silver, regular)



Schedule - Basic Process

| | Name | Type | Time Units | Scale Factor | File Name | Durations |
|---|---|---|---|---|---|---|
| 1 | Regular Schedule | Arrival | Hours | 1.0 | | 12 rows |
| 2 | Card Schedule | Arrival | Hours | 1.0 | | 12 rows |
| 3 | Regular Op 1 Schdule | Capacity | Hours | 1.0 | | 2 rows |
| 4 | Regular Op 2 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 5 | Regular Op 3 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 6 | Regular Op 4 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 7 | Regular Op 5 Schdule | Capacity | Hours | 1.0 | | 2 rows |
| 8 | Silver Op 1 Schdule | Capacity | Hours | 1.0 | | 2 rows |
| 9 | Silver Op 2 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 10 | Silver Op 3 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 11 | Silver Op 4 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 12 | Silver Op 5 Schdule | Capacity | Hours | 1.0 | | 2 rows |
| 13 | Gold Op 1 Schdule | Capacity | Hours | 1.0 | | 2 rows |
| 14 | Gold Op 2 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 15 | Gold Op 3 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 16 | Gold Op 4 Schdule | Capacity | Hours | 1.0 | | 3 rows |
| 17 | Gold Op 5 Schdule | Capacity | Hours | 1.0 | | 2 rows |

Figure: Modeling operator schedule with Arena Schedule module



Set - Basic Process

| | Name | Type | Member Definition Method | Members |
|---|---|---|---|---|
| 1 | Gold Cus Ops | Resource | Manual List | 15 rows |
| 2 | Silver Cus Ops | Resource | Manual List | 10 rows |
| 3 | Regular Cus Ops | Resource | Manual List | 5 rows |

Figure: Creating sets of operators for customer types in the preferred order

## Appendix D: Resources (Trunk Lines and Operators)

Variable - Basic Process

| | Name | Comment | Rows | Columns | Data Type | Clear Option | File Name | Initial Values | Report Statistics |
|---|---|---|---|---|---|---|---|---|---|
| 1 ▶ | ReservedTrunkLines | | | | Real | System | | 1 rows | ☐ |

Figure: Variable ‘Reserved Time Lines’

Resource - Basic Process

| | Name | Type | Capacity | Schedule Name | Schedule Rule | Busy / Hour | Idle / Hour | Per Use | StateSet Name | Failures | Report Statistics |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 ▶ | Trunk Lines | Fixed Capacity | 50 | 50 | Wait | 0.0 | 0.0 | 0.0 | | 0 rows | ☑ |
| 2 | Regular Op 1 | Based on Schedule | Regular Op 1 Schdule | Regular Op 1 Schdule | Ignore | 16 | 16 | 0.0 | | 0 rows | ☑ |
| 3 | Regular Op 2 | Based on Schedule | Regular Op 2 Schdule | Regular Op 2 Schdule | Ignore | 16 | 16 | 0.0 | | 0 rows | ☑ |
| 4 | Regular Op 3 | Based on Schedule | Regular Op 3 Schdule | Regular Op 3 Schdule | Ignore | 16 | 16 | 0.0 | | 0 rows | ☑ |
| 5 | Regular Op 4 | Based on Schedule | Regular Op 4 Schdule | Regular Op 4 Schdule | Ignore | 16 | 16 | 0.0 | | 0 rows | ☑ |
| 6 | Regular Op 5 | Based on Schedule | Regular Op 5 Schdule | Regular Op 5 Schdule | Ignore | 16 | 16 | 0.0 | | 0 rows | ☑ |
| 7 | Silver Op 1 | Based on Schedule | Silver Op 1 Schdule | Silver Op 1 Schdule | Ignore | 20 | 20 | 0.0 | | 0 rows | ☑ |
| 8 | Silver Op 2 | Based on Schedule | Silver Op 2 Schdule | Silver Op 2 Schdule | Ignore | 20 | 20 | 0.0 | | 0 rows | ☑ |
| 9 | Silver Op 3 | Based on Schedule | Silver Op 3 Schdule | Silver Op 3 Schdule | Ignore | 20 | 20 | 0.0 | | 0 rows | ☑ |
| 10 | Silver Op 4 | Based on Schedule | Silver Op 4 Schdule | Silver Op 4 Schdule | Ignore | 20 | 20 | 0.0 | | 0 rows | ☑ |
| 11 | Silver Op 5 | Based on Schedule | Silver Op 5 Schdule | Silver Op 5 Schdule | Ignore | 20 | 20 | 0.0 | | 0 rows | ☑ |
| 12 | Gold Op 1 | Based on Schedule | Gold Op 1 Schdule | Gold Op 1 Schdule | Ignore | 23 | 23 | 0.0 | | 0 rows | ☑ |
| 13 | Gold Op 2 | Based on Schedule | Gold Op 2 Schdule | Gold Op 2 Schdule | Ignore | 23 | 23 | 0.0 | | 0 rows | ☑ |
| 14 | Gold Op 3 | Based on Schedule | Gold Op 3 Schdule | Gold Op 3 Schdule | Ignore | 23 | 23 | 0.0 | | 0 rows | ☑ |
| 15 | Gold Op 4 | Based on Schedule | Gold Op 4 Schdule | Gold Op 4 Schdule | Ignore | 23 | 23 | 0.0 | | 0 rows | ☑ |
| 16 | Gold Op 5 | Based on Schedule | Gold Op 5 Schdule | Gold Op 5 Schdule | Ignore | 23 | 23 | 0.0 | | 0 rows | ☑ |

Figure: Resource ‘Trunk Line’ in resource module

Appendix E: Cost Report

7:59:47PM **Category Overview** April 6, 2020

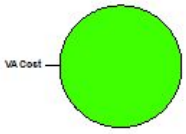
## Unnamed Project

Replications: 1 Time Units: Minutes

### Key Performance Indicators

**All Entities**

| | Average |
|---|---|
| Non-Value Added Cost | 0 |
| Other Cost | 0 |
| Transfer Cost | 0 |
| Value Added Cost | 3,441 |
| Wait Cost | 0 |
| Total Cost | 3,441 |




**All Resources**

| | Average |
|---|---|
| Busy Cost | 3,441 * |
| Idle Cost | 1,400 |
| Usage Cost | 0 |
| Total Cost | 4,841 |


* *these costs are included in Entity Costs above.*

**System**

| | Average |
|---|---|
| Total Cost | 4,841 |
| Number Out | 5,702 |

## Appendix F: Fixed Schedule Model - Staffing Pattern for Operators

| | Operators | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operation Hours | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | TOTAL |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 7 |
| 2 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 7 |
| 3 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 7 |
| 4 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 7 |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 7 |
| 6 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 7 |
| 7 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 7 |
| 8 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 7 |
| 9 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 7 |
| 10 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 7 |
| 11 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 7 |
| 12 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 7 |
| TOTAL | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 4 | 84 |
| Consecutive Hours | 8 | 3 | 3 | 8 | 5 | 6 | 4 | 3 | 3 | 5 | 2 | |

Figure: Shift Pattern for Regular Operators

| | Opertators | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Operation Hours | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 5 |
| 2 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 5 |
| 3 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 5 |
| 4 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 5 |
| 5 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 5 |
| 6 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 5 |
| 7 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 5 |
| 8 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 5 |
| 9 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 5 |
| 10 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 5 |
| 11 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 5 |
| 12 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 5 |
| TOTAL | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 4 | 60 |
| Consecutive Hours | 4 | 8 | 8 | 7 | 6 | 3 | 4 | 2 | |

Figure: Shift Pattern for Silver & Gold Operators