# Use Case 1: Medical Resource Optimization

## **High-Level Description**

SAS will develop and propose a mathematical model-based solution for reopening clinical facilities, their services, and their corresponding sub-services, considering the capacity limitations on manpower, equipment, test kits etc. Optimally computing re-opening plan for clinical facilities, their services, and their corresponding sub-services, across various locations is challenging with constraints on several resource capacities, particularly on the COVID-19 tests. For instance, the requirement of COVID-19 testing *x* days before any surgery admission increases the complexity in decision making. SAS will build a bi-criteria mathematical model to maximize total revenue and maximize total margin across all facilities over the planning horizon.

## **2. Functionality Description**

The problem will be modeled as a bi-criteria Mixed Integer Linear Programming (MILP) mathematical model. Detailed mathematical model is provided in the Appendix. The functionalities of the model are described in the following sections.

### Optimization goal

The model has two objectives; Objective 1 is to maximize the total revenue across all the clinical facilities, their services, and their corresponding sub-services. Objective 2 is to maximize the total margin across all the clinical facilities, their services, and their corresponding sub-services. Revenue and margins are a function of the number of patients accepted over the planning horizon, subject to resource availability and resource usage by the accepted patients provided by the customer (resource constraints), COVID-19 test requirements and availability (COVID-19 rapid and non-rapid test kit constraints), and the forecasted demand.

### Business Rules

The re-opening of clinical facilities and number of patients accepted will adhere to the following rules:

* Capacity of each resource at a facility, their services, and their corresponding sub-services cannot be exceeded.
* Utilization of ICU resources at a facility cannot exceed the maximum utilization allowed.
* The number of patients accepted at a facility, their services, and their corresponding sub-services cannot exceed the maximum forecasted demand.
* The number of rescheduled patients across all days in a facility, service line, and sub service cannot exceed the maximum patients allowed for rescheduling. Also, rescheduling of patients is allowed only if the sub-service is open.
* If a sub-service is open at a facility / service-line, we should at the least satisfy a minimum proportion of weekly acceptable patients at the facility, service-line, and sub-service. The minimum proportion is defined by customer. The acceptable patients at the facility, service-line, and sub-service is computed dynamically within the optimization model by removing the COVID-19 test constraints.
* Total number of emergency surgery and inpatients accepted across all facilities (excluding inpatient-surgery patients), their services, and sub-services, in service categories Medical/Surgery, in a day should be less than the total daily rapid test available.
* Total number of surgery patients who will be admitted *x* days later (excluding the emergency surgery patients) across all facilities, their services, and sub-services, in service categories IP/OP, in a day should be less than the total available non-rapid test for the day.
* If a sub-service is open at a facility / service-line on a day, it should remain open for the remainder of the horizon.
* Consider a sub-service open for the entire horizon if it is already open at a facility / service-line.
* The sub-service can only be open on the first day or on the start of a phase.

### Demand Generation

SAS will analyze the historical patient services data for each facility, their services, and their corresponding sub-services, by service categories (IP/OP and Medical/Surgery). Utilizing the historical data, a time series forecasting model will be proposed to forecast demand for the planning horizon for each facility, their services, and their corresponding sub-services, by service categories (IP/OP and Medical/Surgery). The demand is given as an input to the optimization model.

### 2.4 Optimization Recommendations

SAS will give recommendations on which facility, services, sub-services to reopen, which maximizes our optimization objectives to attain optimization goal (as discussed in section 2.1) while respecting business rules (detailed in section 2.2). Medical resource capacity sharing across facilities is not considered. However, COVID-19 test kits (rapid and non-rapid) are shared across all facilities. The availability of resources stays constant over the planning horizon. Revenue and margins do not change over the planning horizon. The recommendations are based on the forecasted demand.

## **3. Input and Output Data Description**

The following section describes the required inputs at high level. Detailed data model is provided in the Appendix.

### Input Data Description

* **Utilization of the resources data**: This table contains the utilization of each resource per patient per day, by service categories (IP/OP and Medical/Surgery), at each facility, their services, and its corresponding sub-services.
* **Capacity of the resources data**: This table contains the capacity available for each resource (normalized per patient) at each facility, their services, and its corresponding sub-services.
* **Financial data:** This table gives data on the revenue and margin per patient, by service categories (IP/OP and Medical/Surgery), andat each facility, their services, and its corresponding sub-services
* **Service-related data:** This tables provides data on mean/variance of length of stay, number of caregivers, cancelled services, and rescheduled percentage of cancelled services, by service categories (IP/OP and Medical/Surgery), and at each facility, their services, and its corresponding sub-services.
* **Demand data:** This table gives us the maximum forecasted demand for the planning horizon, by service categories (IP/OP and Medical/Surgery), and at each facility, their services, and its corresponding sub-services.
* **Optimization parameters input data.** These are optimization parameters that the users will be able to control when submitting optimization jobs. Examples include COVID-19 test kits availability and phase dates for test kit availability. The users can create use these optimization parameters to create scenarios. The users can select to modify some or sub-set of these parameters for running the optimization model.

### Optimization Parameters

The following table describes the optimization parameters you can modify in the input table called INPUT\_OPT\_PARAMETERS.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter Name (Level)** | **Description** | **Default Value** | **Acceptable Values** |
| PLANNING\_HORIZON (Global) | Defines the planning horizon (in weeks) for the forecasting and optimization model. | 12 | >1 |
| OPTIMIZATION\_START\_DATE (Global) | Defines the start date for the optimization model. Three different options are available: phase 1 start date (PHASE\_1\_DATE), tomorrow (TODAY\_PLUS\_1), or day after last date in the demand data file (HISTORY\_PLUS\_1). | PHASE\_1\_DATE | PHASE\_1\_DATE TODAY\_PLUS\_1 HISTORY\_PLUS\_1 |
| RUN\_INPUT\_DEMAND\_FCST (Global) | Specifies whether to run the forecast model to generate demand forecast or to use the external demand forecast file. If this parameter is set to YES, the run the demand forecast model using the historical demand data. If this is set to NO, use the externally provided demand forecast file. | YES | YES / NO |
| FORECAST\_MODEL (Global) | Defines the model used for forecasting demand. Two different forecasting methods are available: TSMDL uses time series method and YOY uses year-over-year method. | TSMDL | TSMDL YOY |
| FILTER\_SERV\_NOT\_USING\_RESOURCES (Global) | Flag to filter out sub-services that do not use any resources, and sub-services whose only resources utilizations are not defined in the capacity table. | NO | YES / NO |
| LOS\_ROUNDING\_THRESHOLD (Global) | Length of stay threshold is used to round up or round down the *length\_stay\_mean* (*los*) variable. If the fractional portion of the *los* variable is less than the parameter value, we round down the *los* variable value. If the fractional portion of the *los* variable is greater than the parameter value, we round up the *los* variable value. | 0.5 | 0 to 1 |
| DATE\_PHASE\_\* (Scenario) | Start date of the phase \*. | NA | Date String  in the format MM/DD/YYYY |
| RAPID\_TESTS\_PHASE\_\* (Scenario) | Number of daily rapid tests available beginning on the corresponding phase date (i.e., DATE\_PHASE\_\*) | 0 | Integer |
| NOT\_RAPID\_TESTS\_PHASE\_\* (Scenario) | Number of daily not-rapid tests available beginning on the corresponding phase date (i.e., DATE\_PHASE\_\*) | 0 | Integer |
| TEST\_DAYS\_BA (Scenario) | Defines the number of days before admittance that each non-emergency surgery patient must be tested for COVID-19 (using a non-rapid test kit). | 0 | > 0 and < number of days in the PLANNING\_ HORIZON |
| RAPID\_TEST\_DA (Scenario) | Fraction of inpatients (including emergency surgical patients) that should be tested for COVID-19 on the day of admission (using a rapid test kit). | 0 | 0 or  1 to 100 |
| HOLD\_RAPID\_COVID\_TESTS (Scenario) | Defines the number of rapid tests put aside on hold for each day. The parameter value is subtracted from the daily available rapid tests. If this number is larger than the number of available rapid test kits, we will hold aside all the rapid test kits. | 0 | Integer |
| HOLD\_NOT\_RAPID\_COVID\_TESTS (Scenario) | Defines the number of non-rapid tests put aside on hold for each day. The parameter value is subtracted from the daily available not-rapid tests. If this number is larger than the number of available not-rapid test kits, we will hold aside all the not-rapid test kits. | 0 | Integer |
| TEST\_FREQ\_DAYS (Scenario) | Defines the frequency (in days) in which the admitted patients should be tested for COVID-19. Note that this parameter is currently not being used. | 0 | Integer |
| TEST\_VISITORS (Scenario) | Defines whether the visitors should be tested for COVID-19 or not. If this parameter is set to YES, then the visitors should be tested for COVID-19. Note that this parameter is currently not being used. | NO | YES / NO |
| ALLOW\_OPENING\_ONLY\_ON\_PHASE (Scenario) | Limits opening of sub-services only on phase start dates. If this parameter value is YES, the sub-services can open only on phase start dates. If this parameter value is NO, the sub-services can open on any day in the planning horizon. | NO | YES / NO |
| SECONDARY\_OBJECTIVE\_TOLERANCE (Scenario) | Defines the fraction of the *Revenue* (primary objective value) which must be achieved when solving the model for maximizing *Margins* (secondary objective). Say *R* is the objective value of the model when solving for the Revenue. A value of 95 for the SECONDARY\_OBJECTIVE\_TOLERANCE parameter denotes that the *Revenue* should be at least 95% \* *R*, when solving the model for maximizing margin (secondary objective). | 99 | 1 to 100 |
| TREAT\_MIN\_DEMAND\_AS\_AGGREGATE (Scenario) | Specifies whether an ‘ALL’ value in any level of the hierarchy for MIN\_DEMAND\_RATIO is used to apply the minimum demand constraint across each sub-service individually, or across all subservices in aggregate. | NO | YES / NO |
| REMOVE\_DEMAND\_CONSTRAINTS (Scenario) | Specifies whether all demand constraints are removed from the optimization model. If this parameter is set to YES, the optimization model will run without maximum and minimum demand constraints. | NO | YES / NO |
| REMOVE\_COVID\_CONSTRAINTS (Scenario) | Specifies whether the COVID-19 test constraints are removed from the optimization model. If this parameter is set to YES, the optimization model will run without the COVID-19 test constraints. | NO | YES / NO |
| USE\_DECOMP (Scenario) | Specifies whether to use the decomposition algorithm to solve the optimization problem. | NO | YES / NO |
| ICU\_MAX\_UTILIZATION (Scenario / Facility) | Fraction of ICU Beds capacity that is available to the optimization model; the remaining ICU Beds capacity will be reserved for COVID-19 surge events. | 100 | 0 or  1 to 100 |
| ALREADY\_OPEN (Scenario / Facility / Service / Sub-service) | Indicates whether a facility/service line/sub-service is already open. If this parameter is set to YES, the optimization model will fix the opening date for this sub-service to be the first date of the optimization, instead of recommending an opening date for this sub-service. | NO | YES / NO |
| MIN\_DEMAND\_RATIO (Scenario / Facility / Service / Sub-service) | Minimum proportion of the weekly demand that must be satisfied when a facility/service line/sub-service is open. This parameter can be defined at any combination of the facility/service line/sub-service hierarchy. Depending on the value of TREAT\_MIN\_DEMAND\_AS\_AGGREGATE, it applies either to each individual open sub-service within the specified hierarchy, or to the aggregate demand across all open sub-services within the specified hierarchy. | 0 | 0 or 1 to 100 |
| EMER\_SURGICAL\_PTS\_RATIO (Scenario / Facility / Service / Sub-service) | Defines the proportion of emergency surgical patients at a facility, service line, and sub-service. | 0 | 0 or 1 to 100 |
| OPEN\_FULLY (Scenario / Facility / Service) | Specifies whether the service line must fully open. A value of YES means the service line must fully open, and a value of NO means the service line can partially open. Note that this parameter is currently not being used. | NO | YES / NO |

### 3.3 Configuration of Scenarios

The INPUT\_OPT\_PARAMETERS table also contains a column called SCENARIO\_NAME that can be used to configure different optimization scenarios that will run in parallel. You can use a distinct value of a scenario name to indicate that the specified optimization parameter should be applied only to that particular scenario, or you can use the value of ALL as the scenario name to indicate that the specified optimization parameter should be used in all of the scenarios.

Only the optimization-specific parameters are permitted to have different values for different scenarios. Some of the parameters affect the input data processing and forecasting steps instead of the optimization step, and these parameters must have the same value for all scenarios. The following is a list of parameters that are required to have the same value for all scenarios. We recommend that you use scenario\_name=‘ALL’ for these parameters so that you only need to specify them one time in INPUT\_OPT\_PARAMETERS:

• PLANNING\_HORIZON

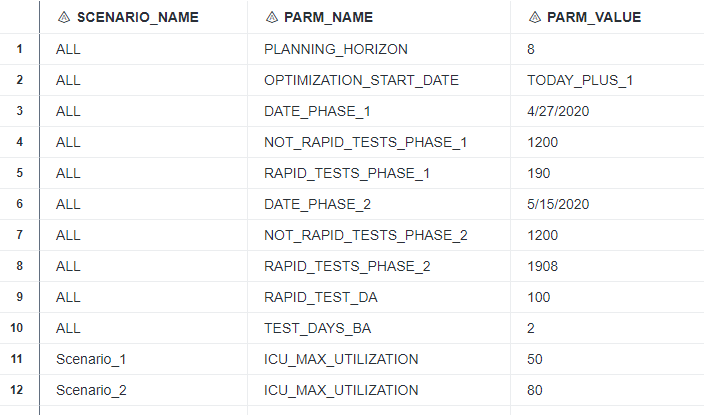
• FORECAST\_MODEL

• OPTIMIZATION\_START\_DATE

• FILTER\_SERV\_NOT\_USING\_RESOURCES

• LOS\_ROUNDING\_THRESHOLD

The following example shows a portion of the INPUT\_OPT\_PARAMETERS table for two scenarios, where the scenarios use common optimization parameters for everything except the ICU\_MAX\_UTILIZATION. Scenario\_1 uses 50% max ICU utilization, and Scenario\_2 uses 80% max ICU utilization. The other columns in this table (FACILITY, SERVICE\_LINE, SUB\_SERVICE, IP\_OP\_INDICATOR, and MED\_SURG\_INDICATOR) are hidden for display purposes, but in this example these columns all have values of ‘ALL’ for every row, because the parameters used in this example are not specific to individual levels of the hierarchy.



### 3.4 Output Data Description

* **Optimization output data**. Shows the recommended reopening plan for the clinical facilities, their services, and their corresponding sub-services.

## **4. Deliverables**

Deliverables of this phase of the project will consist of a set of output results produced for a specific scenario.

# APPENDIX

The .tex file for the mathematical formulation can be accesses from the mro\_documentation folder.

The input and output data model can be accessed from the mro\_documentation folder.