

# Cleveland Clinic - Medical Resource Optimization Mathematical Formulation

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## Dimensions

$r \in Resources$  : set of resources

$f \in Facilities$  : set of facilities

$sl \in Servicelines$  : set of service lines

$ss \in Sub - services$  : set of sub-services

$io \in Inpatient/Outpatient$  : set of Inpatient/Outpatient indicator

$ms \in Medical/Surgical$  : set of Medical/Surgical indicator

$d \in Days$  : set of days

## Data Parameters: Model Coefficients

$capacity_{f,sl,ss,r}$  is the capacity of resource  $r$  at facility  $f$ , service line  $sl$ , sub-service  $ss$

$utilization_{f,sl,ss,io,ms,r}$  is the usage of resource  $r$  per patient per day at facility  $f$ , service line  $sl$ , sub-service  $ss$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$revenue_{f,sl,ss,io,ms}$  is the revenue per patient at facility  $f$ , service line  $sl$ , sub-service  $ss$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$margin_{f,sl,ss,io,ms}$  is the margin per patient at facility  $f$ , service line  $sl$ , sub-service  $ss$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$demand_{f,sl,ss,io,ms,d}$  is the maximum demand of facility  $f$ , service line  $sl$ , sub-service  $ss$ , and day  $d$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$losMean_{f,sl,ss,io,ms}$  is the mean hospitalization time of facility  $f$ , service line  $sl$ , sub-service  $ss$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$minday$  is the minimum day among the set  $d \in Days$ ,  $\min_{d \in Days} d$

$maxday$  is the maximum day among the set  $d \in Days$ ,  $\max_{d \in Days} d$

$dlyRapidTest_d$  is the total daily rapid tests available across all facility  $f$ , service line  $sl$ , sub-service  $ss$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$dlyNonRapidTest_d$  is the total daily non-rapid tests for COVID-19 available across all facility  $f$ , service line  $sl$ , sub-service  $ss$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$daysBeforeSurgAdm$  is the number of days before which a surgery patient should be tested for COVID-19 (using a non-rapid test kit)

$minDemandRatio$  is the minimum proportion of demand that must be satisfied at a sub-service  $ss$  if its is open at a facility  $f$ , service line  $sl$

## Decision Variables

$NewPatients_{f,sl,ss,io,ms,d} \geq 0$  is the number of patients accepted in facility  $f$ , service line  $sl$ , sub-service  $ss$ , on day  $d$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$

$OpenFlg_{f,sl,ss} \in \{0,1\}$  is the binary variable indicating if facility  $f$ , service line  $sl$ , sub-service  $ss$  is open

## Variables

$TotalPatients_{f,sl,ss,io,ms,d}$  is the total number of patients accepted in facility  $f$ , service line  $sl$ , subservice  $ss$ , cumulative for day  $d$ , for inpatient/outpatient indicator  $io$ , and medical/surgical indicator  $ms$  where,

$$TotalPatients_{f,sl,ss,io,ms,d} = \sum_{\substack{d1 \in d \text{ and} \\ \max\{[d - losMean_{f,sl,ss,io,ms} + 1], \\ minday\} \leq d1 \leq d}} NewPatients_{f,sl,ss,io,ms,d1} \quad \forall f, sl, ss, io, ms, d$$

$NumNonRapidTestAvl_d$  is the number of non-rapid tests available on day  $d$ , after using it on new patients who will be admitted for surgery after ' $daysBeforeSurgAdm$ ' days, where,

$$NumNonRapidTestAvl_d = dlyNonRapidTest_d - \sum_{\substack{f,sl,ss,io,ms \text{ and } d1 \in d \text{ and} \\ \min\{[d + \\ daysBeforeSurgAdm], \\ maxday\} \\ \text{and } ms = 'SURG'}}$$

## Objective Functions

$$\max \quad TotalRevenue = \sum_{f,sl,ss,io,ms,d} NewPatients_{f,sl,ss,io,ms,d} revenue_{f,sl,ss,io,ms}$$

$$\max \quad TotalMargin = \sum_{f,sl,ss,io,ms,d} NewPatients_{f,sl,ss,io,ms,d} margin_{f,sl,ss,io,ms}$$

## Constraints

Maximum demand constraint: Number of patients accepted for  $f, sl, ss, io, ms$  should be less than the maximum demand for day  $d$ .

$$NewPatients_{f,sl,ss,io,ms,d} \leq demand_{f,sl,ss,io,ms,d} OpenFlg_{f,sl,ss} \quad \forall f, sl, ss, io, ms, d \quad (1)$$

Capacity constraint: Resources used for the total number of patients for  $f, sl, ss$  on day  $d$  should be less than equal to available capacity of resource  $r$  for  $f, sl, ss$ .

$$\sum_{io,ms} utilization_{f,sl,ss,io,ms,r} TotalPatients_{f,sl,ss,d} \leq capacity_{f,sl,ss,r} \quad \forall f, sl, ss, d, r \quad (2)$$

Minimum proportion of demand constraint: If a sub-service  $ss$  is open at  $f, sl$  then, we should at the least satisfy a minimum proportion of demand of  $f, sl, ss$ .

$$\sum_{io, ms} NewPatients_{f, sl, ss, io, ms, d} \geq minDemandRatio \sum_{io, ms} demand_{f, sl, ss, io, ms, d} OpenFlg_{f, sl, ss} \quad \forall f, sl, ss, d, r \quad (3)$$

COVID-19 inpatient tests constraint: Total number of inpatients accepted for  $f, sl, ss, ms$  in day  $d$  should be less than the total available non-rapid test for the day and daily rapid test available.

$$\sum_{\substack{f, sl, ss, io, ms \\ \text{and } io='I'}} NewPatients_{f, sl, ss, io, ms, d} - NumNonRapidTestAvl_d \leq dlyRapidTest_d \quad \forall d \quad (4)$$

COVID-19 surgery patient tests constraint: Total number of surgery patients who will be admitted for surgery after ' $daysBeforeSurgAdm$ ' days for  $f, sl, ss, io$  in day  $d$  should be less than the the total non-rapid test available for the day  $d$ .

$$\sum_{\substack{f, sl, ss, io, ms \text{ and } d1 \in d \text{ and} \\ \min\{[d + \\ daysBeforeSurgAdm], \\ maxday\} \\ \text{and } ms='SURG'}} NewPatients_{f, sl, ss, io, ms, d1} \leq dlyNonRapidTest_d \quad \forall d \quad (5)$$