

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

$w \in Weeks$: set of weeks

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

$week_d$ is the week number of day d in set $d \in Days$

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

$minDemRatio$ 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

$newPntBfCovid_{f,sl,ss,io,ms,d}$ is the new patients admitted without COVID-19 test constraints at the facility f , service line sl , sub-service ss , for inpatient/outpatient indicator io , and medical/surgical indicator ms on day d

$fixOpenFlag_{f,sl,ss}$ is a flag and is set to 1 if the facility f , service line sl , sub-service ss is open, 0 otherwise.

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 .

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

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,

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

Objective Functions

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

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

Constraints

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

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

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 the weekly demand of f, sl, ss .

$$\sum_{\substack{io, ms, d \text{ and} \\ week_d = w}} NewPatients_{f, sl, ss, io, ms, d} \geq minDemRatio \sum_{\substack{io, ms, d \text{ and} \\ week_d = w}} newPntBfCovid_{f, sl, ss, io, ms, d} OpenFlg_{f, sl, ss, d} \quad \forall f, sl, ss, w \quad (3)$$

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.

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

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 .

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

Sub-service open constraint: If a sub-service ss is open at f, sl on day d then it should be open for the remainder of the horizon.

$$OpenFlg_{f, sl, ss, d+1} \geq OpenFlg_{f, sl, ss, d} \quad \forall f, sl, ss, d \text{ and } d1 \in d \quad (6)$$

Sub-service already opened constraint: If a sub-service ss is already opened at f, sl then we set $OpenFlg$ variable as 1 for the entire planning horizon.

$$OpenFlg_{f, sl, ss, d} = 1 \quad \forall f, sl, ss, d \text{ and } d = minday \text{ and } fixOpenFlag_{f, sl, ss} = 1 \quad (7)$$