Development of a Lexicographic Multi-Objective Optimization Model for OT Master Allocation Schedule

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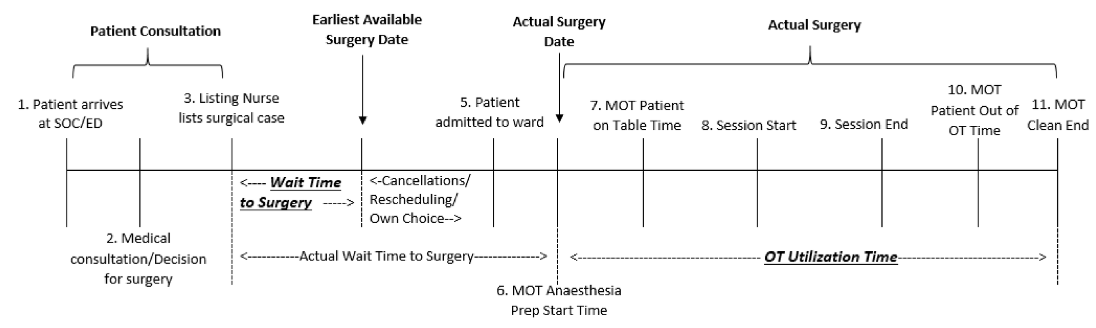
Megan Zi Ying, Quek[1];Boon Yew, Ang[2];Qi Qi, Wang[3];
Shuangchi, He[1]; ; Shao Wei Sean Lam[2];

[1]National University of Singapore; [2]SingHealth; [3]Singapore General Hospital;

Background

Operating Theatres (OTs) are essential facilities that allow surgical cases to be performed safely and effectively. Performing surgical cases involves the coordination of several resources, making the scheduling of such surgical cases a complex process.

A Master Surgical Schedule (MSS) is a cyclic schedule generated to dictate the allocation of different OTs to different surgical disciplines for each day of the week. The aim of this study is to develop a holistic and efficient OT Master Allocation Schedule (MAS) that maximizes OT utilization rates (OTU) and reduces patients' waiting times to surgery (WTS).

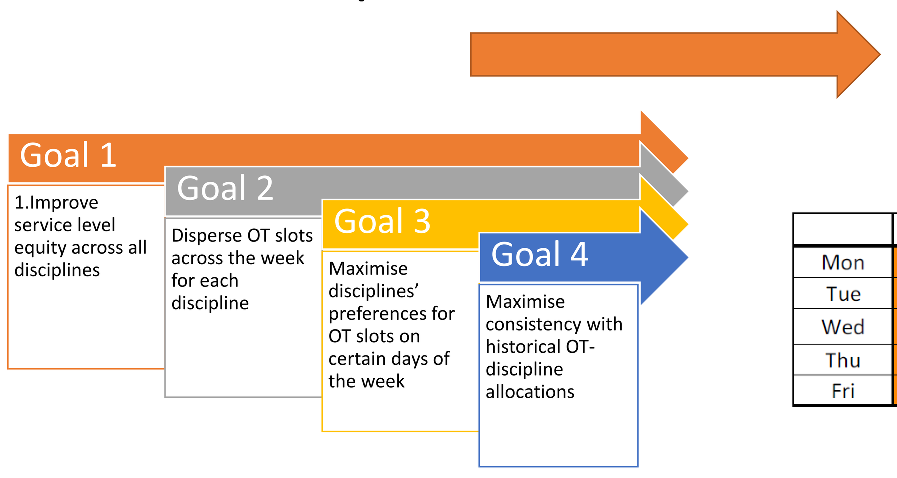


	OT1	OT2	OT3	OT4	OT5
Mon	OTO	OTO	O&G	O&G	O&G
Tue	OTO	OTO	ENT	Cardiac	O&G
Wed	OTO	OTO	OTO	O&G	O&G
Thu	OTO	OTO	ENT	Cardiac	O&G
Fri	OTO	OTO	ENT	Cardiac	O&G

Methodology

A multi-objective linear programming (MOLP) model was developed based on Singapore General Hospital (SGH) Major Operating Theatres (MOTs) scheduling processes, comprising of 18 surgical disciplines that share 23 elective OTs and 2 emergency OTs in order to improve the effectiveness of the MSS. The constraints of the model factors in OT-discipline compatibilities and surgeon availability. The model is solved using the lexicographic method.

Goals are optimized sequentially before moving to the next goal in order to develop the final schedule



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Tue	OTO	OTO	ENT	Cardiac	O&G
Wed	OTO	OTO	OTO	O&G	O&G
Thu	OTO	OTO	ENT	Cardiac	O&G
Fri	OTO	OTO	ENT	Cardiac	O&G

The model produces a solution to achieve the following four objectives in decreasing order of priority:

<u>Objective 1:</u> Maximise minimum service level met across all disciplines

$$Max\ z_t \quad (1)$$

	Demand in hours (D_{jt})	Allocated ($\sum_k a_{jkt}$)	Service level (sl_{jt})
OTO	120	99	0.83
O&G	90	72	0.80
Cardiac	30	27	0.90
ENT	35	27	0.77

<u>Objective 2:</u> Maximise the number of days a week for which each discipline can operate

$$Max \sum_k \sum_j n_{jkt} \quad (2)$$

	Demand (D_{jt})	Max no. of operable days ($\sum_k n_{jkt}$)
OTO	120	5
O&G	90	5
Cardiac	30	3
ENT	35	3

<u>Objective 3:</u> Maximise disciplines' preferences for OT slots on certain days of the week

$$Max \sum_k \sum_j R_{jk} a_{jkt} \quad (3)$$

R_{jk}	Mon	Tue	Wed	Thu	Fri
OTO	1	1	1	1	1
O&G	2	2	2	1	1
Cardiac	0	2	0	2	2
ENT	0	2	0	2	2

Ranking scale: 2 - favourable, 0 - netural, 1 - unfavourable

<u>Objective 4:</u> Maximise the allocation of OT slots based on relative frequency of past OT-discipline usage.

$$Max \sum_k \sum_j \sum_{i \in S_t} F_{ij} x_{ijk} \quad (4)$$

F_{ij}	OT1	OT2	OT3	OT4	OT5
OTO	0.9528	1.0000	0.6043	0.0038	0.0008
O&G	0.0008	0.0015	0.1811	0.9110	0.9361
Cardiac	0.0015	0.1613	0.0076	0.4307	0.0015
ENT	0.0011	0.0005	0.6043	0.0015	0.0023

<u>Constraints</u>:

(5), (7): Total allocated hours does not exceed available OT hours

(6): Surgical disciplines are only allocated to compatible OTs

(8), (9): Minimum service level is met by all disciplines for OTs for the same type

(10), (11): Binary modelling constraint for n_{jkt}

(12), (13): Minimum and maximum hours to allocate to each discipline depending on surgeon availability.

(14): Binary modelling constraint for both decision variables x_{ijk} and n_{jkt}

$$\sum_j (x_{ijk} \times T) \leq H \qquad \forall i \in S_t, \forall k \qquad (5)$$

$$x_{ijk} \leq c_{ij} \qquad \forall i \in S_t, \forall j, k \qquad (6)$$

$$a_{jkt} = \sum_{i \in S_t} x_{ijk} \times T \qquad \forall j, k \qquad (7)$$

$$sl_{jt} = \frac{\sum_k a_{jkt}}{D_{jt}} \qquad \forall j \qquad (8)$$

$$sl_{jt} \geq z_t \qquad \forall j \qquad (9)$$

$$a_{jkt} \leq M \times n_{jkt} \qquad \forall j, k \qquad (10)$$

$$a_{jkt} \geq n_{jkt} \qquad \forall j, k \qquad (11)$$

$$a_{jkt} \geq A_{jkt}^{min} \qquad \forall j, k \qquad (12)$$

$$a_{jkt} \leq A_{jkt}^{max} \qquad \forall j, k \qquad (13)$$

$$x_{ijk}, n_{jkt} \in \{0, 1\} \qquad \forall i \in S_t, \forall k \qquad (14)$$

Results & Discussion

The MOLP model developed provides an improved MSS based on the following quantitative metrics used to evaluate the effectiveness of the model:

1. Service level met for each discipline
2. Number of slots allocated to each discipline on each day
3. Percentage of favourable and unfavourable slots allocated to each discipline

	Service level met
OTO	0.83
O&G	0.80
Cardiac	0.90
ENT	0.77

(i)

No. of slots allocated	Mon	Tue	Wed	Thu	Fri
OTO	2	2	3	2	2
O&G	3	1	2	1	1
Cardiac	0	1	0	1	1
ENT	0	1	0	1	1

(ii)

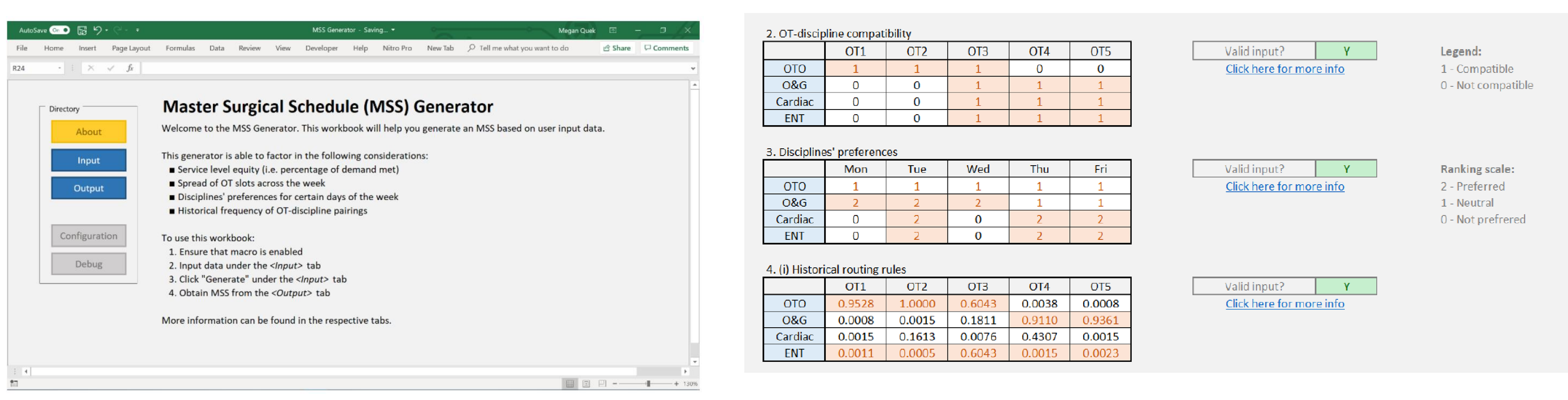
	No. of slots assigned to		
	Favourable	Neutral	Unfavourable
OTO	0	11	0
O&G	6	2	0
Cardiac	3	0	0
ENT	3	0	0
Total (#)	12	13	0
(%)	48%	52%	0%

(iii)

The development of this MOLP model allows for the operator to systematically generate an MSS based on data of each disciplines' demand, preferences and past OT assignments . The model also introduces a quick and accurate way of generating the MSS and may potentially help to improve OTU and the surgeons' perception of slot allocation equity.

<u>User Interface</u>

The model was built and solved in Microsoft Excel using the OpenSolver add-in and includes user guidance to providing user inputs, such as OT slot preferences and viewing the final schedule output given by the model.



Conclusion

The MOLP model helps to improve OT slot allocation equity of the MAS while systematically factoring in the disciplines' preferences, past OT-discipline allocations, OT-discipline compatibilities and surgeon availability constraints. This would aid in improving the overall objectives of maximising OTU and reducing patients' WTS.