On the Optimal Staffing of Surgeons and Efficient Scheduling of Surgeries at a High-Volume Eye Hospital

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Abstract

It is well-known that the demand for services at many if not all hospitals is variable over a given year such that the demand is significantly higher in some months compared to the rest of the months in any given year. This is especially true for surgical departments at many hospitals. Therefore, it is a challenge to staff the surgical departments in such a way that the demand for surgeries throughout a year is met without creating significant over- or under-staffing at any point in a given year. In other words, an optimal level of staffing is sought so that the staff is not significantly over- or under- utilized at any point in a given year. In this paper, we consider an algorithmic approach of arriving at such an optimal level of staffing given some practical constraints. We apply this approach to the surgery department of the paying section of the Aravind Eye Hospital in Madurai, India.

1. Introduction:

Surgery departments of many hospitals experience highly variable demand for surgical services. For example, we consider the Aravind Eye Hospital (AEH) in Madurai, India. This hospital has a paying section (PAEH) where patients pay for the services demanded, and a free section where surgeries are performed free of charge. The free section only performs cataract surgeries, whereas surgeries at PAEH fall into one of the six groups: Cataract, Cornea, Glaucoma, Orbit/Oculoplasty, Paediatrics, and Retina. Figures 1 through 6 display the monthly demand experienced by the six surgery groups of PAEH in the years 2002, 2003, and 2004. The figures clearly demonstrate that the demand experienced by each group is highly variable over any given year. The challenge, then, is to propose a scientific and quantitative method of arriving at an optimal level of staffing for each of the six groups. We propose a methodology below which achieves this optimal level. The rest of the paper confines itself to PAEH, but we emphasize that the logic underlying the proposed method can easily be generalized to any hospital which performs surgeries, ophthalmic or non-ophthalmic.

2. Constraints:

Any practical optimization problem has to be solved given one or more constraints. In the context of PAEH, the constraints are: cost, time, rank level of a surgeon (senior or junior), multitasking, and specialized training of junior surgeons. The cost constraint implies that there is a ceiling under which the staffing is cost-effective, and above which it is not cost-effective. The time constraint implies that a surgeon should not operate beyond a pre-specified number of hours on any given day in order to prevent burn-out and to minimize the risk of complications. Surgeons are also typically required to multi-task by spending time in the out-patient departments (OPD), and to conduct research and teaching since PAEH has a training program for doctors wishing to specialize in one of the six surgery groups. An informal survey of doctors at PAEH revealed that on any given day, a surgeon should ideally perform surgeries for no more than 8 hours. An equitable distribution of surgical and OPD workload implies the equality of the number of days a surgeon performs surgery and the number of days he/she is in OPD. We assume that for each group there is at least one senior and one junior in each group's staff. This assumption is valid for any high-volume hospital which provides surgical training to junior doctors.. Furthermore, junior and senior surgeons should be given an equal chance to perform surgeries. In particular, we propose that a junior surgeon should always work side-by-side a senior surgeon. This implies that if the total number of surgeons in a group is even, the numbers of senior and junior surgeons will be equal. If the total number is odd, there will be one extra senior surgeon since a junior surgeon should not work unsupervised. We assume that operating tables come in pairs, so that one table is used for performing surgery, whereas the second one is used for getting the next patient ready so that there is no loss of time between patients. Last but not least, we are restricting ourselves to the staffing of surgeons, since the number of staff which assist surgeons in an operating theatre is a function of the number of surgeons. In the rest of the paper, staff will refer to the total number of senior and junior surgeons in each group.

3. Methodology:

Since the demand for surgeries is variable over a given year, we first calculate the optimal staff for each month before proposing an optimal number of staff that would serve throughout a given year. Since there is a time constraint, we have to account for how long a surgery takes to be finished by a senior and by a junior. After looking at the distribution of surgeries in each group in the year 2004, modes were identified to determine the most frequently occurring surgeries. Infrequent surgeries were lumped in a miscellaneous category. Tables 1 through 6 display the surgery times for each group by type of surgery and by rank level of a surgeon. One caveat is that the Cornea surgeries in the miscellaneous group are performed only by a senior Cornea surgeon. Also note that in the algorithm proposed below, we used 55 minutes as the time taken by a senior Cornea surgeon to perform a surgery in the miscellaneous category. Similarly, we used 1.5 and

2.5 hours as the times taken by a senior and a junior Retina surgeon, respectively, to perform a surgery in the Vitrectomy class. Also, it is noteworthy that all surgeons in all the six groups can perform cataract surgeries, whereas surgeries of the non-Cataract type can only be performed by a group specializing in that type.

We now propose a step-wise iterative and a bottom-up algorithm to determine staffing for each month. At the outset, we emphasize that for any given day, the algorithm outputs the allotment of surgeries for each surgeon *before* surgery begins. Moreover, since surgeries of the non-Cataract type can only be performed by the group specializing in that type, the allotments for surgeries of the non-Cataract types are first worked out. Only then, the allotment of cataract surgeries is worked out. The algorithm starts with the minimum infrastructure, that is, one senior and one junior surgeon for each group. Each group's list is first randomly shuffled to ensure that seniors and juniors are equally likely to be allotted any given surgery, the exception being the miscellaneous type of Cornea surgeries, which are distributed only among seniors. For each surgeon, the algorithm keeps track of their accumulated surgery time. The actual allotment of surgeries is then done as follows. In the beginning, each surgeon has accumulated no surgery time. So the first surgery is assigned randomly. The next surgery is assigned to the surgeon with the least accumulated surgery time, and so on. Ties of accumulated times are broken randomly. Once the surgery assignments are complete, the total surgery time accumulated by each surgeon is computed. This procedure is repeated for the entire month. The algorithm keeps count of how many times each surgeon worked beyond 8 hours in a given month. It also computes the average daily operating time in that month. Note that the random shuffling of surgeries implies a distribution of the number of times a surgeon exceeds 8 hours, and also a distribution of the average daily operating time. Thus, for a given month, the entire procedure above is repeated 100 times. Then we calculate the mean (over 100 simulations) of the numbers of times a surgeon exceeds 8 hours. We also calculate the mean (over 100 simulations) of the average daily operating time for each surgeon. Among the groups which include at least one surgeon who on average exceeds the 8-hour time limit at least 1 day of the month, the group which includes a surgeon whose mean of the average operating times is the highest among all groups is assigned one more table pair and one more surgeon. This surgeon is senior if the number of the current staff for that group is even, and junior if the number is odd.

The entire incremental process above is repeated until the average number of times any surgeon in any group exceeds 8 hours over a 100 simulations is below 1 for all surgeons in all groups.

4: Results

The output of the algorithm is the minimum number of surgeons needed by rank level for each month. This number is doubled to create a staff of two teams of surgeons for each group so that each team operates on three working days, and is in OPD on the remaining three working days. On a given working day and for a given operating team in any group, there is one table pair per surgeon. Tables 7 through 12 display the minimum staff required for each month of the year 2004, and also the number of table pairs required by each group in each month.

Note that there is no variation in the number of staff required for each month for the Cataract, Cornea, Glaucoma and the Paediatrics groups. The Orbit/Oculoplasty group required 3 table pairs for all months except for the months of February, May and September, for which it required 4 table pairs. The Retina group required 3 table pairs for all months except August, for which it required 4 table pairs. Thus there are two options. Option1 is to have 2 table pairs for each month for the Cataract, Cornea, Glaucoma and Paediatrics groups; and 3 table pairs for all months for the Orbit/Oculoplasty and Retina groups. Option 2 is the same as above, except that we require 4 table pairs for each month for the Orbit/Oculoplasty and Retina groups. The staffing levels suggested by the two options are given in Table 13.

One way to decide between the two options is to choose the option which minimizes the disparity among the average daily operating hours among all groups. That is, for each option, we calculate the difference between the maximum mean daily operating time among all groups and surgeons and the minimum mean daily operating time among all groups and surgeons. Here the mean refers to that of average daily operating times calculated for 100 simulations.

Tables 14 and 15 display these mean times for the year 2004 for each group for both options. The maximum disparity using option 1 is 1.77 hours, which reduces to 1.4 hours if we use option 2, thus yielding a reduction only by about 21 %. It is also illustrative to look at the mean number of days on which a surgeon exceeds 8 hours. These means yielded by both options are given in Tables 16 and 17. These may suggest that not much is gained by using Option 2. However, a final conclusion is only possible by doing a cost-benefit analysis of Option 2.

Last but not least, it is important to look at the current staffing levels at PAEH to determine if they are close to the optimal levels suggested in Table 13. Table 18 suggests that all groups except Orbit/Oculoplasty are overstaffed. In addition to the staffing level, one may also want to determine how many operating theatres are needed. Assuming that at most two table pairs are allowed in an operating theatre (OT), Table 19 displays the number of OT's suggested by Options 1 & 2, and also the current number of OT's at PAEH. For all groups except Orbit/Oculoplasty, the current number of OT's at PAEH suffice. Our results suggest that the Orbit/Oculoplasty group may need another OT.

7. Conclusions and Future Directions:

Hospitals, like many other businesses, face variable demands for their services. In this article, we presented a quantitative, statistical approach of arriving at an optimal level of staffing of surgeons at an eye hospital given several practical constraints as well as variable demands.. Though this methodology was illustrated using the surgery department of an eye hospital, it is general enough in its logic to be applied to other businesses. As far as hospitals are concerned, our methodology underscores the need and importance of keeping detailed records of durations of surgeries as performed by both junior and senior surgeons. This would make the results of our methodology more accurate, although the logic of the approach used would not change. A mathematical proof that our methodology arrives at an optimal solution is beyond the scope of this paper, but shall be taken up by the author in a future article.

Figure 1: Cataract

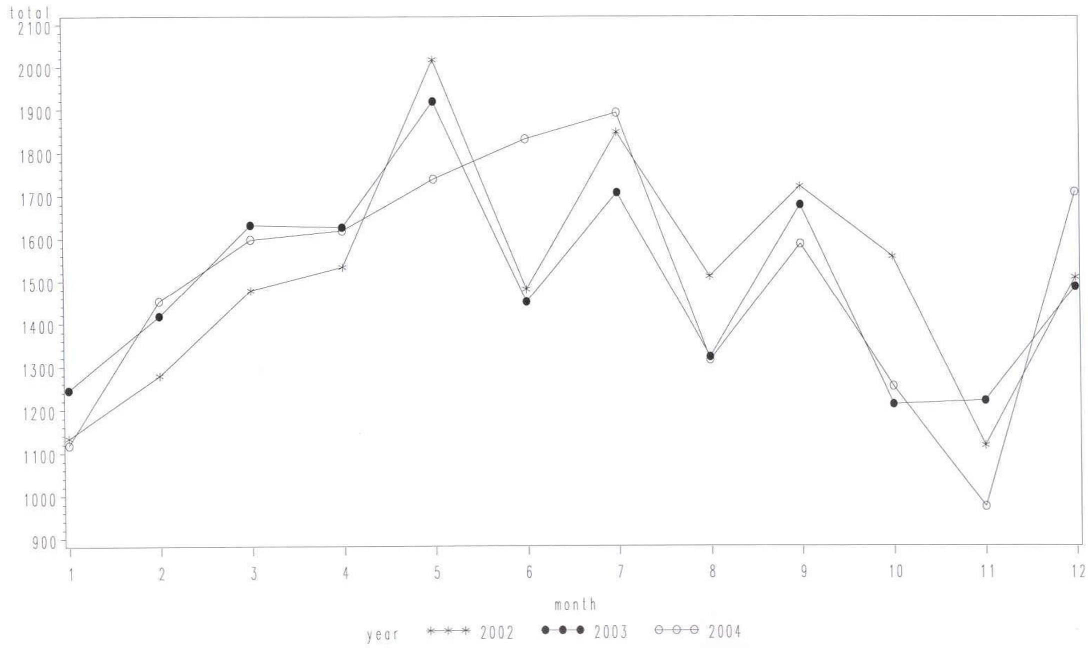

Figure 2: Cornea

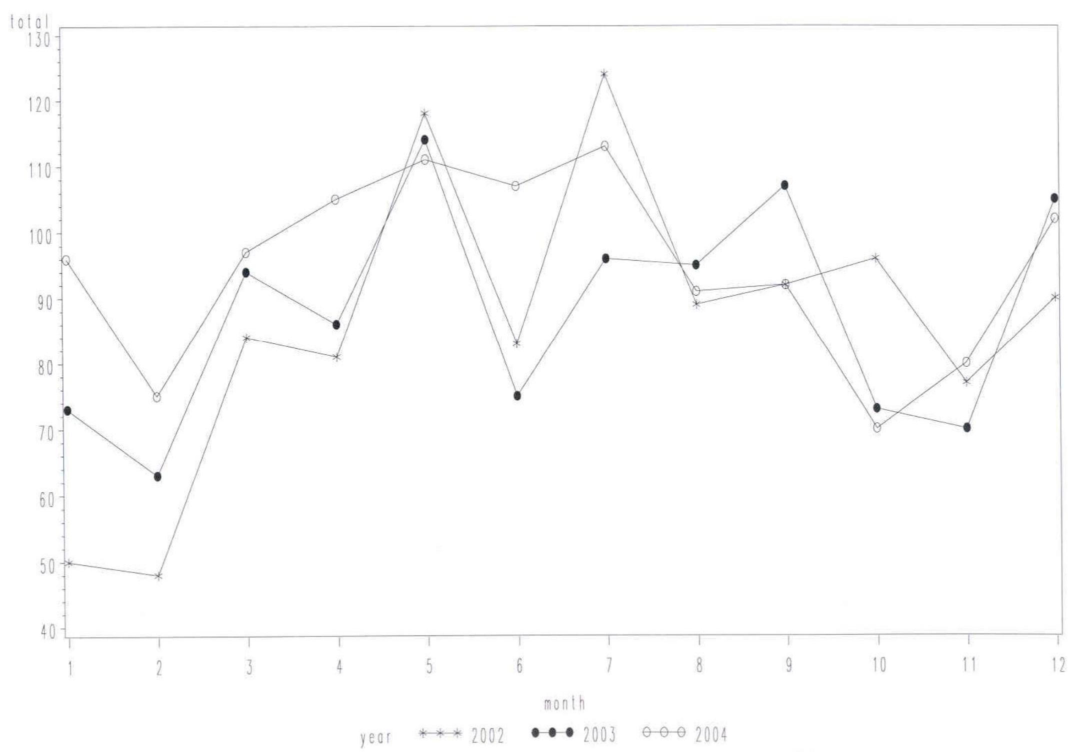

Figure 3: Glaucoma

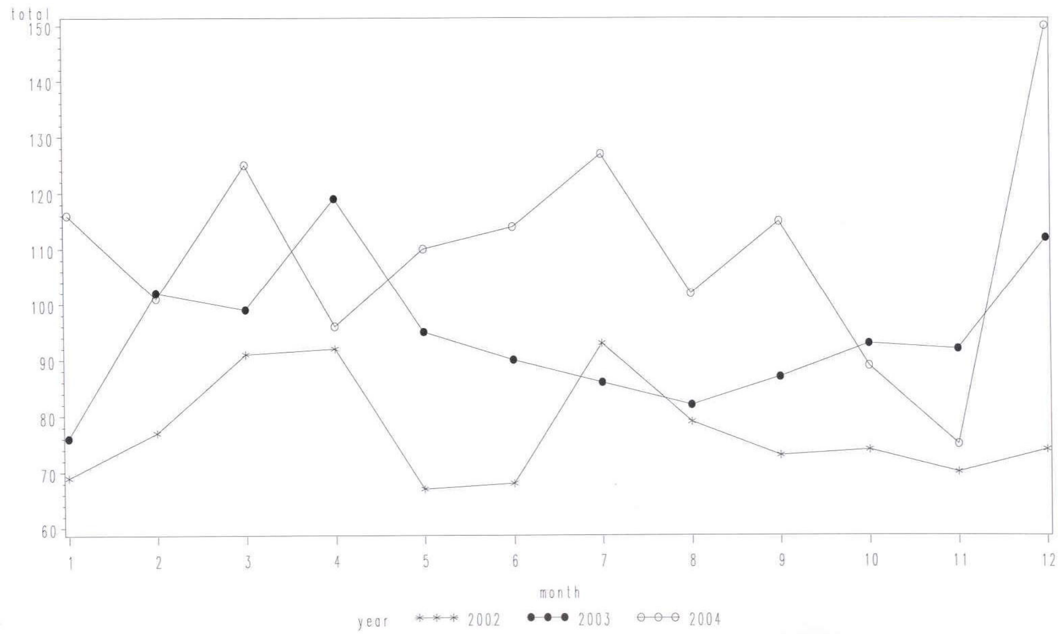

Figure 4: Orbit/Oculoplasty

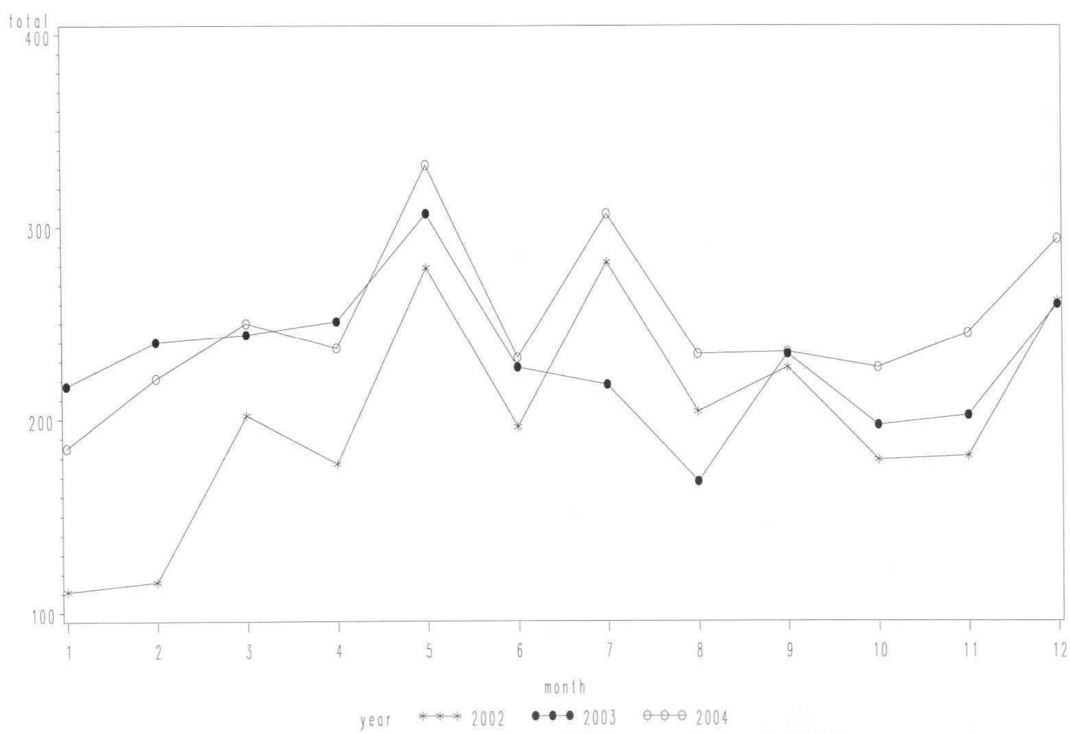

Figure 5: Paediatrics

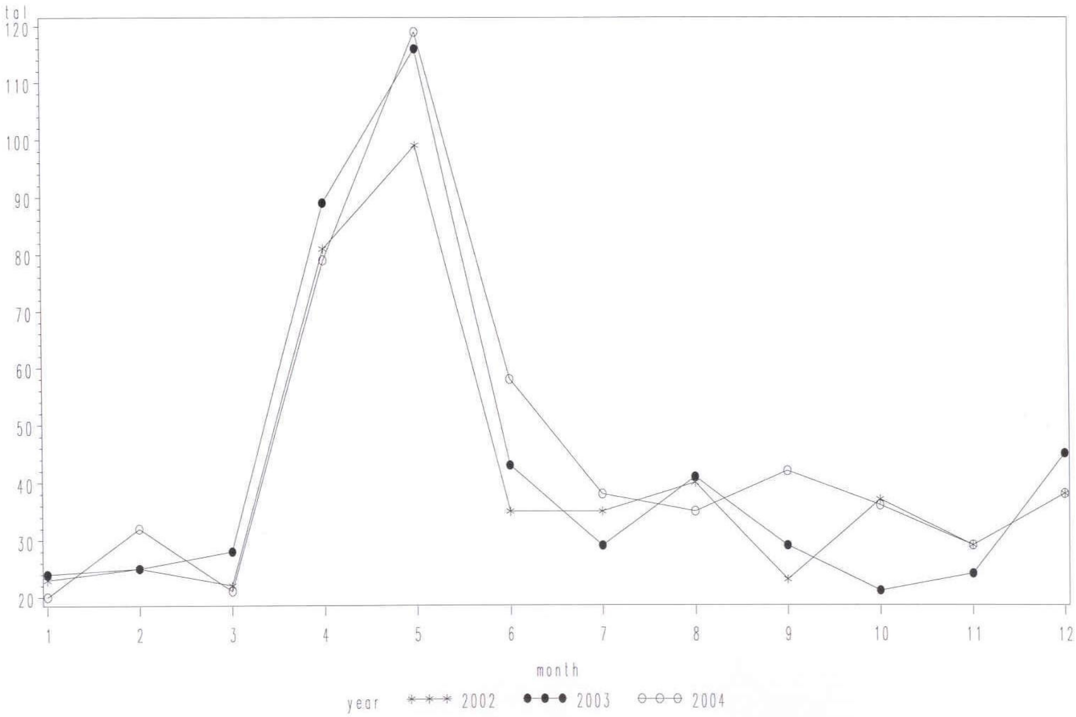

Figure 6: Retina

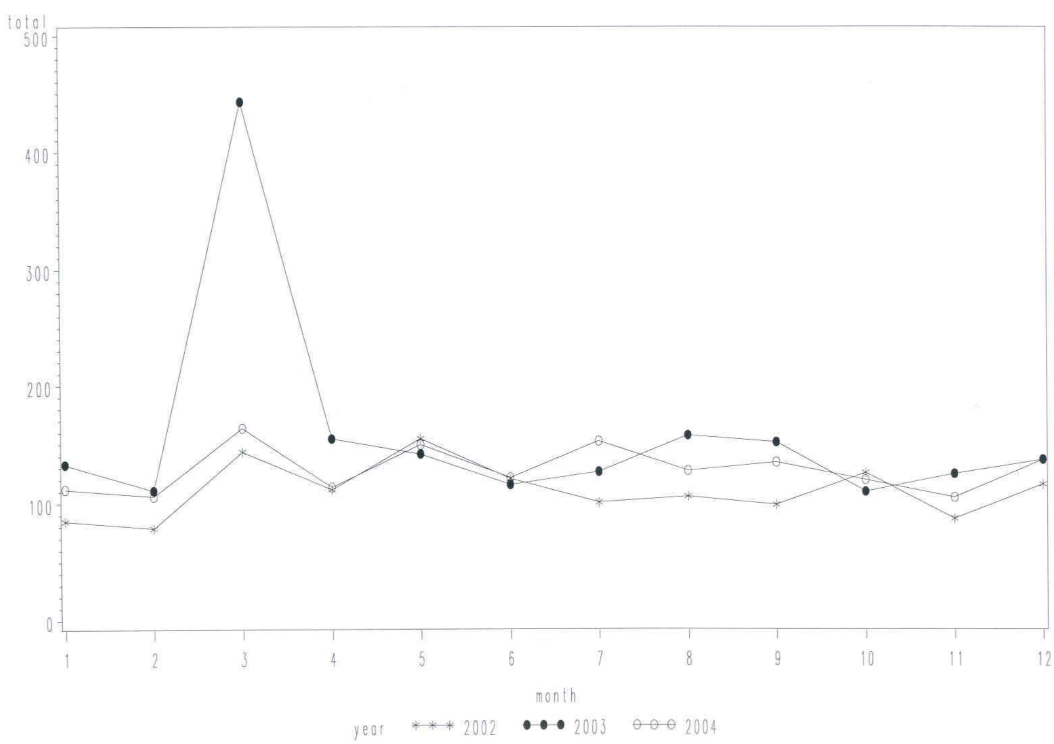

Table 1: Cataract Times in Hours		
Type	Senior	Junior
Cataract	1/6	1/3

Table 2: Cornea Times in Hours		
Type	Senior	Junior
Pterygium With Conjunctual Transplantation	1/4	1/2
P.K.P With IOL	2/3	5/4
Keratoplasty	1/2	1
Therapeutic Graft	1/2	1
Lamellor Graft	1/2	1
Therapeutic Keratoplasty	1/2	1
T.P.K With IOL	2/3	5/4
Regrafting (P.K.P)	1/2	1
Misc.	[1/3, 1.5]	NA

Table 3: Glaucoma Times in Hours		
Type	Senior	Junior
RPT Trabeculectomy	1/3	5/12
Trabeculectomy	1/3	5/12
Trabuculotomy	1/3	5/12
Combined (Surgery (Phaco)	1/3	5/12
Combined Surgery	1/3	5/12
Glaucoma Triple Procedure-IOL	1/3	5/12
Glaucoma Triple Procedure (Phaco)	1/3	5/12
G.T.P. (Phaco) + CTR	1/3	5/12
G.T.P (M. Phaco)	1/3	5/12
Misc.	1/4	1/4

Table 4: Orbit/Oculoplasty Times in Hours		
Type	Senior	Junior
Excision Biopsy	1/4	1/2
Chalazion	1/6	1/6
Frontalis Sling	1/4	3/4
Tarsorraphy	1/6	1/3
Probing	1/6	1/3
DCT	1/4	3/4
DCR	1/3	1
Misc	1.5	2

Table 5: Paediatric Times in Hours		
Type	Senior	Junior
Squint Correction	0.5	1
Squint With Cataract	0.75	1.5
Squint With Phaco	0.75	1.5
Globe Fixation	1.5	NA
Squint With IOL	0.75	1.5

Table 6: Retina Times in Hours		
Type	Senior	Junior
SB+SRFD	1	2
Silicon Oil Removal	3/4	3/4
Vitrectomy Class	[1,2]	[2,3]
Misc.	1	1

Table 7: Total number of surgeons and table pairs needed for the Cataract group			
Month	Senior	Junior	Table pairs
January	2	2	2
February	2	2	2
March	2	2	2
April	2	2	2
May	2	2	2
June	2	2	2
July	2	2	2
August	2	2	2
September	2	2	2
October	2	2	2
November	2	2	2
December	2	2	2

Table 8: Total number of surgeons and table pairs needed for the Cornea group			
Month	Senior	Junior	Table pairs
January	2	2	2
February	2	2	2
March	2	2	2
April	2	2	2
May	2	2	2
June	2	2	2
July	2	2	2
August	2	2	2
September	2	2	2
October	2	2	2
November	2	2	2
December	2	2	2

Table 9: Total number of surgeons and table pairs needed for the Glaucoma group			
Month	Senior	Junior	Table pairs
January	2	2	2
February	2	2	2
March	2	2	2
April	2	2	2
May	2	2	2
June	2	2	2
July	2	2	2
August	2	2	2
September	2	2	2
October	2	2	2
November	2	2	2
December	2	2	2

Table 10: Total number of surgeons and table pairs needed for the Orbit/Oculoplasty group			
Month	Senior	Junior	Table pairs
January	4	2	3
February	4	4	4
March	4	2	3
April	4	2	3
May	4	4	4
June	4	2	3
July	4	2	3
August	4	2	3
September	4	4	4
October	4	2	3
November	4	2	3
December	4	2	3

Table 11: Total number of surgeons and table pairs needed for the Paediatrics group			
Month	Senior	Junior	Table pairs
January	2	2	2
February	2	2	2
March	2	2	2
April	2	2	2
May	2	2	2
June	2	2	2
July	2	2	2
August	2	2	2
September	2	2	2
October	2	2	2
November	2	2	2
December	2	2	2

Table 12: Total number of surgeons and table pairs needed for the Retina group			
Month	Senior	Junior	Table pairs
January	4	2	3
February	4	2	3
March	4	2	3
April	4	2	3
May	4	2	3
June	4	2	3
July	4	2	3
August	4	4	4
September	4	2	3
October	4	2	3
November	4	2	3
December	4	2	3

Table 13: Staffing levels suggested by Options 1 and 2				
Group	Option 1: Seniors	Option 1: Juniors	Option 2: Seniors	Option 2: Juniors
Cataract	2	2	2	2
Cornea	2	2	2	2
Glaucoma	2	2	2	2
Orbit/Oculoplasty	4	2	4	4
Paediatrics	2	2	2	2
Retina	4	2	4	4

Table 14: Mean daily operating times in hours for Option 1			
Group	Senior 1	Senior 2	Junior
Cataract	2.13		2.20
Cornea	3.08		2.34
Glaucoma	2.14		2.19
Orbit/Oculoplasty	3.75	3.71	3.90
Paediatrics	2.13		2.20
Retina	3.30	3.27	3.58

Table 15: Mean daily operating times in hours for Option 2				
Group	Senior 1	Senior 2	Junior 1	Junior 2
Cataract	2.07		2.14	
Cornea	3.43		2.29	
Glaucoma	2.08		2.13	
Orbit/Oculoplasty	3.30	3.26	3.47	3.47
Paediatrics	2.07		2.14	
Retina	3.09	2.99	3.33	3.27

Table 16: Mean number of days when operating time exceeds 8 using Option 1			
Group	Senior 1	Senior 2	Junior
Cataract	0		0
Cornea	6.13		0
Glaucoma	0		0
Orbit/Oculoplasty	7.06	6.64	8.91
Paediatrics	0		0
Retina	1.33	1.19	1.79

Table 17: Mean number of days when operating time exceeds 8 using Option 2				
Group	Senior 1	Senior 2	Junior 1	Junior 2
Cataract	0		0	
Cornea	8.07		0	
Glaucoma	0		0	
Orbit/Oculoplasty	1.81	1.58	2.52	2.51
Paediatrics	0	0	0	0
Retina	1.12	1.11	1.28	1.24

Table 18: Current staffing levels at PAEH		
Group	Seniors	Juniors
Cataract	4	17
Cornea	3	3
Glaucoma	4	4
Orbit/Oculoplasty	2	3
Paediatrics	3	3
Retina	7	8

Table 19: Number of operating theatres			
Group	Option 1	Option 2	PAEH
Cataract	1	1	1
Cornea	1	1	1
Glaucoma	1	1	1
Orbit/Oculoplasty	2	2	1
Paediatrics	1	1	1
Retina	2	2	2