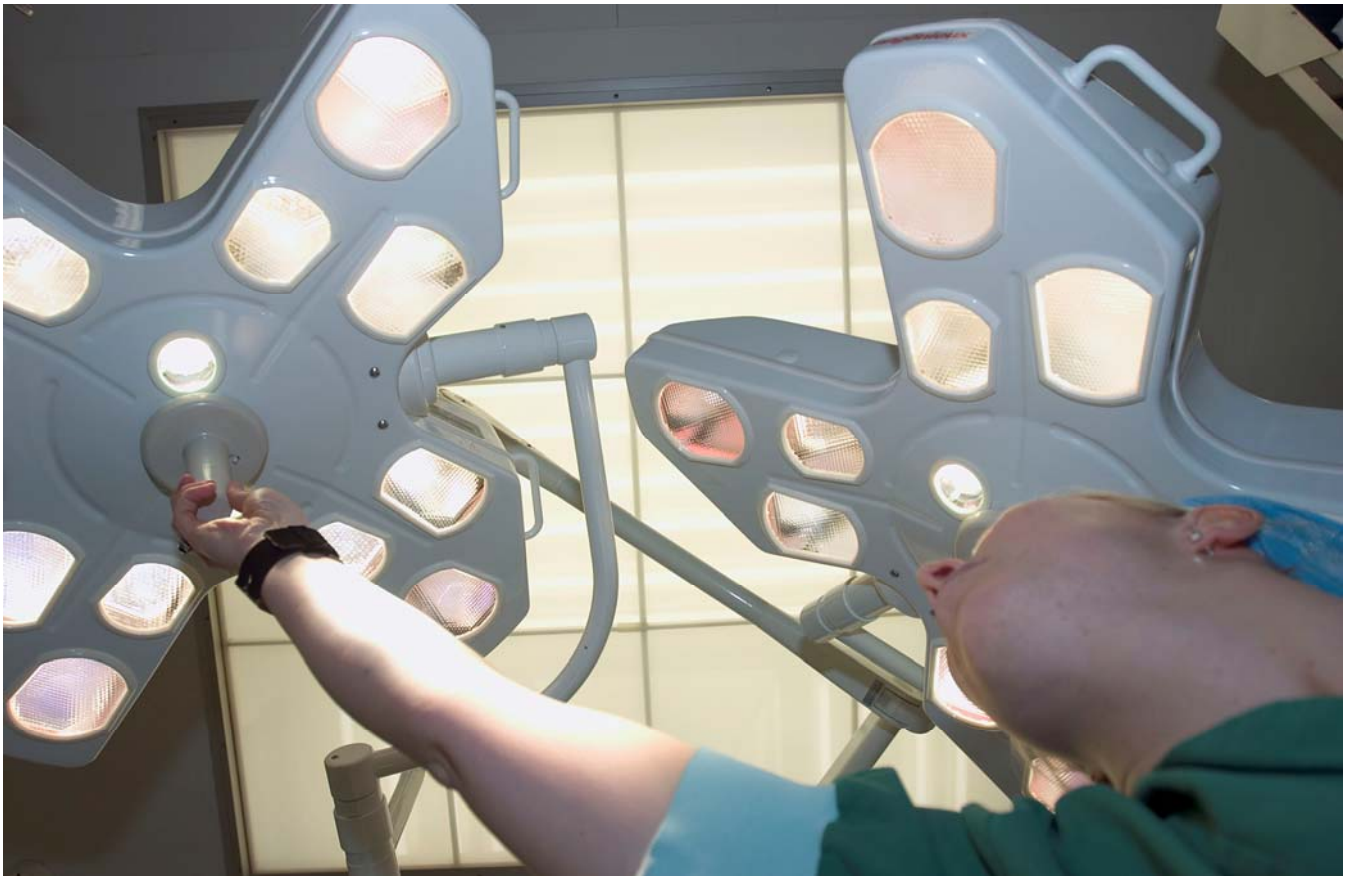
LNMB ORHC
Assignment 1

by:

Erwin Hans, MSc, PhD

e.w.hans@utwente.nl
tel. 053-4893523
Center for Healthcare Operations Improvement & Research
http://www.choir.utwente.nl
University of Twente, the Netherlands



Introduction

Background

One may say that the operating room (OR) department of a hospital forms the heart of the organization. Like blood passing through the human heart, the majority of the patients pass through the OR. If its availability is insufficient, the consequences are felt in the entire hospital, and even in society.

An OR departments is a complex organization, with multiple stakeholders acting with conflicting interests, high interdependency with other hospital departments, high labor and resource dependency and intensity, as well facing continuous public pressure for high quality care and cost effectiveness. As OR-departments grow in absolute or relative terms, such as increased case mix surgery variety (Wullink *et al.*, 2005) or the number of specialties served, the management of an OR becomes more complex. OR-managers are challenged to deal with this complexity, while facing multiple management objectives: addressing the quality of care, the quality of labor of OR personnel, and the efficiency of the OR-processes (van Houdenhoven *et al.*, 2005).

Aside from the complexities stemming from human resource management and materials management, OR surgical scheduling is one of the most challenging issues of OR management. Schedules form a basis for communication and coordination between the various internal and external players (Davenport and Beck, 2000). Within an OR department, internal players include OR-personnel, surgeons, anesthetists, wards, suppliers and, naturally, the external players; patients, their families and tax payers. One of the reasons OR surgical scheduling is complex is the inherent uncertainty associated with its operations: the occurrence, timing and duration of OR-events are often uncertain. For example urgent surgery occurs, surgeries are cancelled at the last minute, the timing of the arrival of surgeons and materials is often erratic, as are surgery durations.

In this assignment, you are responsible for providing the specialties with fully functional operating rooms. This, however, encompasses a number of complex tasks. The volume of elective patients that must be treated in the OR-department is given by the agreement between the hospital board, and health insurers. In addition, an unknown number of emergency patients will have to be treated. To make an operating room available for surgery, necessary equipment must be installed, materials must be made available, and supporting personnel like surgical and anesthesia assistants, and anesthetists must be hired. Of course the budget is limited, so you must decide on how many operating rooms to open, and how to divide them in a fair way over all specialties. Some extra capacity is required to deal with the variability inherent to surgery.

In many hospitals, inpatient and outpatient operating rooms are divided into separate departments. Consider whether this traditional inpatient/outpatient organization is a logical one from a financial and logistical point of view.

Aside from the aforementioned strategic choices, you are also responsible for the tactical planning. This encompasses dividing the OR-capacity over the specialties and determining an OR-program that specifies when specialties/doctors may perform their surgeries. We consider the OR-program during regular time, i.e., from Monday to Friday, during regular working time (8:00-15:30).

Assignment

At the annual meeting between the hospital board and the health insurers an agreement has been rendered about the case mix that is to be performed at the hospital. The case mix prescribes the (inpatient and outpatient) patient volumes per specialty, and a rough estimation of the number of emergency cases, based on historical data. The total expected number of *elective* (so excluding emergency) patients is 17000. Table 1 shows the division of these patients by specialty. For example, 11.5% of all surgeries are eye surgeries.

Table 1 Division of patients over the specialties[1]

Specialty	*Relative part of total patient volume*
1. General surgery	0.181
2. Gynecological surgery	0.094
3. Oral surgery	0.073
4. ENT surgery	0.155
5. Pulmonary surgery	0.018
6. Neurosurgery	0.056
7. Eye surgery	0.115
8. Orthopedic surgery	0.088
9. Plastic surgery	0.109
10. Urological surgery	0.111
Total	1.000

The hospital performs elective surgeries 52 weeks a year, 5 days a week.
Table 2 shows the detailed elective surgery characteristics. For each specialty, the surgeries are divided into a number of categories. For each category, a relative frequency is given (i.e., the percentage of all the specialties' surgeries that fall within the category), the expected surgery duration, and the standard deviation of surgery duration. For example for "General Surgery" (Specialty nr. 1) there are 9 categories of surgeries. Twenty three percent of the surgeries (category 1) have an expected duration of 50.53 minutes, with a standard deviation of 10.32 minutes. Surgery durations are lognormal distributed, but OR-planners often assume the total surgery duration is normal distributed. For each specialty, the first patient category considers the *outpatient* patients (patients that undergo surgery, and go home the same day), and all other categories the *inpatient* patients (patients that stay at the hospital for at least for one night after surgery, and that usually are in a hospital bed before surgery). Of all outpatient patients, approximately 10% do not show up on the day of surgery. These are the so-called "no shows".

Surgery planning impacts various other hospital resources, such as IC-beds, and wards. The availability of these resources influences the processes at the OR. For example, before a surgery starts on a patient that is expected to require intensive care, the availability of an IC-bed has to be guaranteed. If an IC-bed cannot be guaranteed, the surgery is cancelled. Of all inpatient surgeries, approximately 5% have to be cancelled on the day of surgery for this reason, or other reasons beyond control: for example the anesthetist may decide that a patient is unfit for surgery.

In addition to outpatient and inpatient patients there are the so-called *emergency* patients. Emergency patients turn up unexpectedly, and have to be helped as quickly as possible. The average number of emergency surgeries performed during the day in regular time is displayed in Figure 1 (including the 95% confidence interval *of the mean*):

[1] In Dutch: Oral surgery = kaakchirurgie, ENT surgery = KNO (Keel Neus Oor)

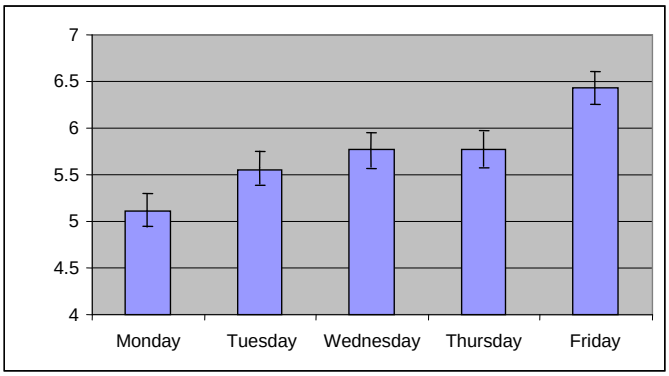


Figure 1 Average number of emergency surgeries

The average duration of an emergency surgery during the day in regular time (in minutes) is displayed in Figure 2 (including the 95% confidence interval *of the mean*):

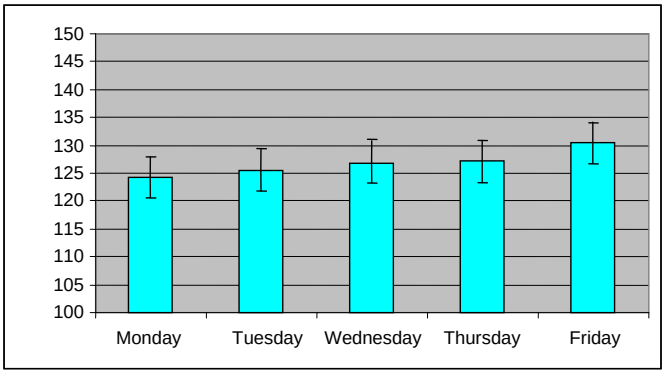


Figure 2 Average emergency surgery duration (in minutes)

During the performance of a surgery several professionals are present in an OR. We distinguish five different types of professionals:

- *Surgeons* perform surgery on patients
- *Anesthetists* are responsible for the process of anesthesia and the stability of a patients' vital organs
- *Anesthesia Assistants* record the condition of vital organs and assist the anesthetist
- *Surgery Assistants* directly assist the surgeon in his/her work (first assistant, or: "instrumenterende"), or collect and give materials required for the surgery to the first assistant (second assistant, or: "omloop")
- *Holding and Recovery staff* is personnel at the holding who prepare the patient at the holding until a surgery can be performed. Afterwards, personnel at the recovery take care of the patients' recovery from the surgery. An anesthetist discharges patients from the recovery.

In the OR-department there are 25 operating rooms that can potentially be prepared for use. For this purpose, a dedicated/generic inpatient operating room requires at least 0.5 anesthetists ("0.5" means that there must be at least 1 anesthetist per 2 ORs), at least 2.4 surgery assistants, and at least 1.1 anesthesia assistants. For an emergency room dedicated solely to emergency surgeries the resource allotment is equivalent. An outpatient operating room requires at least 0.25 anesthetists, at least 1 surgery assistant and at least 1 anesthesia assistant. If, for example, you open 3 inpatient ORs, 1 emergency, and 1 outpatient ORs, you need: $\lceil 2.25 \rceil = 3$ anesthetists, $\lceil 10.6 \rceil = 11$ surgery assistants, and $\lceil 5.4 \rceil = 6$ anesthesia assistants. Anesthetists, anesthesia assistants, and surgery assistants are a common resource: they can be used by any surgeon/specialty.

Table 2 General elective surgery duration characteristics

Specialty nr.	*Category nr.*	*Relative frequency*	*Expected surgery duration (min.)*	*Surgery duration standard dev. (min.)*
1	1	0.23	50.53	10.32
1	2	0.17	50.53	93.69
1	3	0.04	67.21	31.23
1	4	0.07	99.6	43.61
1	5	0.07	134.59	52.45
1	6	0.08	150.2	89.04
1	7	0.14	170.82	63.3
1	8	0.05	212.74	88.82
1	9	0.15	261.99	87.49
2	1	0.22	40.38	9.33
2	2	0.04	79.7	64.81
2	3	0.12	52.37	19.19
2	4	0.14	73.3	43.22
2	5	0.18	98.12	31.68
2	6	0.22	124.52	43.1
2	7	0.02	155.58	40.56
2	8	0.06	212.57	82.42
3	1	0.17	44.26	16.34
3	2	0.09	97	57.06
3	3	0.28	86.77	28.51
3	4	0.35	129.66	42.67
3	5	0.11	237.74	86.92
4	1	0.23	21.22	12.7
4	2	0.04	102.41	124.6
4	3	0.23	40.04	17.46
4	4	0.13	65.24	54.48
4	5	0.12	102.37	34.82
4	6	0.1	127.01	32.33
4	7	0.08	181.68	65.34
4	8	0.04	254.1	74.59
4	9	0.03	549.22	202.98
5	1	0.12	33.76	8.97
5	2	0.03	72.25	9.82
5	3	0.14	63.67	33.54
5	4	0.62	76.51	33.13
5	5	0.09	81.67	23.54
6	1	0.02	39.21	12.02
6	2	0.08	192.22	164.98
6	3	0.17	112.77	40.62
6	4	0.14	171.37	61.83
6	5	0.28	255.15	62.29
6	6	0.12	324.2	73.3
6	7	0.19	491.64	176.52
7	1	0.16	50.43	13.13
7	2	0.02	83.41	46.27
7	3	0.29	46.32	14.32
7	4	0.33	60.01	21.54
7	5	0.15	94.59	29.96
7	6	0.05	127.29	34.19
8	1	0.18	60.17	21.46
8	2	0.05	107.12	58.16
8	3	0.1	61.37	23.01
8	4	0.13	83.07	29.7
8	5	0.21	108.66	38.29
8	6	0.17	160.08	42.55
8	7	0.11	198.83	45.33
8	8	0.05	291.44	102.18
9	1	0.26	45.01	12.88
9	2	0.04	118.62	46.97
9	3	0.09	62.7	22.08
9	4	0.11	82.27	28.15
9	5	0.13	112.14	35.79
9	6	0.18	139.19	38.84
9	7	0.09	186.64	117.45
9	8	0.1	312.34	180.76
10	1	0.12	37.44	10.69
10	2	0.03	120.78	68.28
10	3	0.06	59.37	50.48
10	4	0.26	73.78	25.74
10	5	0.13	101.92	48.81
10	6	0.15	152.01	48.81
10	7	0.17	229.91	67.82
10	8	0.08	384.65	123.27

Table 3 displays the annual "all in" personnel and fixed operating room costs. Surgeons are employed and paid by the specialties, so their costs do not have to be accounted for. Fixed operating room costs include materials, instruments, equipment, holding and recovery staff, management, and real estate costs.

Table 3 Fixed annual personnel and OR costs

Subject	*Annual costs (€)*
1 anesthesia assistant	60.000
1 anesthetist	170.000
1 surgery assistant	60.000
1 generic inpatient OR	500.000
1 dedicated inpatient OR	400.000
1 emergency OR	400.000
1 outpatient OR	350.000

Generally each OR contains specialized equipment, such as microscopes, mobile C-arms (used for making scans). In practice, this equipment is generally assigned to specific operating rooms. We make the following assumptions. Outpatient and emergency ORs are generic (i.e., available to all specialties). Inpatient ORs, however, can either be made generic (i.e., available to all specialties), or can be dedicated to a particular specialty. If you choose to divide the dedicated inpatient-ORs over the specialties, this means that an OR assigned to a specialty may not be used by another specialty. While appealing from a specialty's point of view, it also simplifies elective surgery scheduling. Dedicated inpatient ORs are cheaper than generic inpatient ORs (Table 3), because they require less specialized equipment. They may be assigned to a different specialty every day.

In this assignment you will decide how many operating rooms to open per patient type (inpatient, emergency, and outpatient). If you decide to open an emergency OR, this OR (including personnel!) will be solely dedicated to emergency surgeries. If you decide to open an outpatient OR, this OR (including personnel!) is also solely dedicated to outpatient surgeries. As a result, opening emergency ORs is optional: you can use inpatient ORs (but no outpatient ORs) to deal with emergency surgeries during the regular (elective) program. Opening outpatient ORs is also optional, since you can perform these surgeries in an inpatient OR. However, if you use an inpatient OR for outpatient surgeries (i.e. you mix inpatient surgeries with outpatient surgeries), the personnel occupation (and costs) and the annual fixed OR-costs are the same as for an inpatient OR. It is not possible to perform inpatient surgeries in an outpatient OR. Table 4 is an overview of where surgeries can be performed. *Note that, if you decide to use outpatient (resp. emergency) ORs, you must deal with all outpatient (resp. emergency) patients in the outpatient (resp. emergency) ORs.*

Table 4 Overview of where surgeries can be performed

	Can be performed in (type of OR):			
Type of surgery:	Generic Inpatient OR	Dedicated Inpatient OR	Outpatient OR	Emergency OR
Inpatient surgery	YES	YES	NO	NO
Outpatient surgery	YES[1]	YES[1,3]	YES	NO
Emergency surgery	YES[2]	YES[2]	NO	YES

[1.] Unless you have outpatient ORs.
[2.] Unless you have emergency ORs.
[3.] Only if the OR is dedicated to the corresponding specialty.

Each operating room operates for precisely 450 minutes (7.5 hours) per day in so-called "regular time". Overtime is costly and restricted by law. At the same time, as
Table 2 demonstrates, the variability in surgery durations can be very high. If the 450 minutes of regular capacity would be filled entirely with surgeries, the surgery duration variability will surely cause overtime. In fact, if a surgery is about to start, and more than 20% of the expected duration of the surgery lies in overtime, the surgery is cancelled. Obviously, this is something you will want to avoid as much as possible. In order to avoid overtime, and patient cancellations, we will enforce a 70% probability that all surgeries are completed within regular time (450 minutes).

Erasmus MC in Rotterdam uses the following method to approximately attain this probability. Suppose S (with elements *i*) is the set of surgeries planned in an operating room. Suppose that μ_i and σ_i are the expected duration and standard deviation of surgery *i*. Suppose that X is the stochastic variable that represents the total surgery duration of all the surgeries in S. Suppose we assume that X is normally distributed, then we know from statistical theory that:

$$P\left(X \le \sum_{i \in S} \mu_i + 0.5 \cdot \sqrt{\sum_{i \in S} \sigma_i^2} \right) \approx 69.15\%$$

In other words, if half of the standard deviation of the total surgery duration is used as slack time, the probability of overtime is 30.85%.

This is illustrated by Figure 3 (in which $\mu = \sum_{i \in S} \mu_i$, and $\sigma = \sqrt{\sum_{i \in S} \sigma_i^2}$):

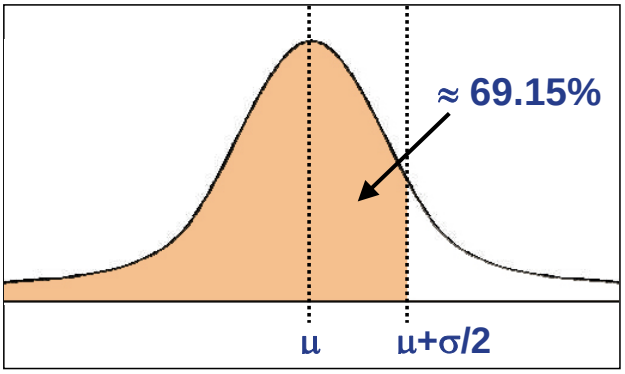


Figure 3 Normal distribution

The "0.5" in the formula is referred to as the "slack factor". Table 5 shows how a slack factor 0.50 yields a probability of 69.15%. You may choose to enforce an even lower probability of overtime, or even use another capacity reservation approach to attain the 70% probability that the program finishes within the 450 minutes.

Note: some surgery types have an expected duration of more than 450 minutes. The operating rooms where these surgery types are planned do not have to comply with the 70% rule.

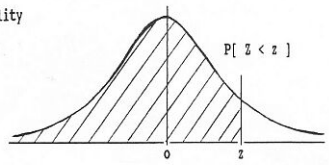
Table 5 Cumulative probabilities of the standard normal distribution

STANDARD STATISTICAL TABLES

1. Areas under the Normal Distribution

The table gives the cumulative probability up to the standardised normal value z

i.e. $P[\,Z < z\,] = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} \exp(-\frac{1}{2}Z^2)\, dZ$



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5159	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7854
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8804	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9773	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9865	0.9868	0.9871	0.9874	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9924	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9980	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
z	3.00	3.10	3.20	3.30	3.40	3.50	3.60	3.70	3.80	3.90
P	0.9986	0.9990	0.9993	0.9995	0.9997	0.9998	0.9998	0.9999	0.9999	1.0000

Since the surgeons are employed by the specialties, and not by the OR-department, they do not have to be taken into account in your financial analysis. However, the number of surgeons available per specialty restricts the number of parallel ORs that a specialty can work in simultaneously. Table 6 gives the number of surgeons available per specialty. For emergency surgeries, specialized trauma surgeons are always available, so you do not have to account for the surgeons used in emergency surgeries.

Table 6 Number of surgeons available per specialty

Specialty	*Number of available surgeons*
1. General surgery	6
2. Gynecological surgery	3
3. Oral surgery	3
4. ENT surgery	4
5. Pulmonary surgery	1
6. Neurosurgery	4
7. Eye surgery	3
8. Orthopedic surgery	4
9. Plastic surgery	4
10. Urological surgery	4

The assignment is as follows. Based on the aforementioned information, determine:

i) How many operating rooms to open of each category (generic inpatient, dedicated inpatient, emergency, outpatient). Note: when calculating the number of required ORs do not forget to account for the slack you must reserve in every OR, in correspondence with your slack factor.

ii) If you have dedicated inpatient ORs, clearly indicate (per dedicated OR, per day) to which specialty they are assigned. Note: this division will be the same for all weeks of the year. Also note that an OR can not be "dedicated" on one day, and "generic" on the other.

iii) Your slack factor or other capacity reservation approach to attain the 70% probability that the program finishes within the 450 minutes.

iv) Calculate how much your OR-department costs per year (fixed annual OR and personnel costs).

Write a proposal (an MS Word document "Assignment1 (your name).doc", max. 1500 words) in which you state your decisions clearly (give an overview of how each OR is used, for every day of the week), and motivate them (outline your analysis, calculations, and argue your decisions). Discuss what performance indicators you find important, and how your strategic decisions align with these. Hand in all calculations that you may have done (e.g. an MS Excel worksheet with some explanation). Write your contact data on your work so that we may contact you if we have any questions regarding your work.

Hand in your work by email to:
e.w.hans@utwente.nl
With subject: LNMB Assignment 1 – your name

Important:
Make sure that your analysis in this assignment is not solely based on financial data, but results in an OR-department that strives to perform optimally on all relevant performance indicators (e.g. productivity/efficiency, quality of care measures, etc.). For example, some decisions may not be favorable from a financial point of view, but they give more flexibility when planning the patients in the operating rooms, and thus yield a higher OR-utilization; or maybe decisions may reduce expected emergency patient waiting time.