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Bart van Eekelen, Ivo Adan and Jan Vissers

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Bart van Eekelen, Ivo Adan and Jan Vissers
Eindhoven University of Technology

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Contents

List of Tables

1 Introduction

In the current situation hospitals try to use the resources they have to the maximum. The purpose of this project is to explore and compare new policies for hospital production control. We are going to explore three concept-policies and compare these with the current policy. We talk about "concept"-policies, because it may very well be that the best policy will be a mix of several concept-policies.
The first policy we will consider is Zero Waiting Time, which aims (obviously) at no waiting time for patients. The other two policies are somewhat similar to each other. They both are concerned with the uncertainty of patients about their waiting times. Therefore, when using one of these policies doctors immediately give patients an appointment. In the first of these two policies (Booked Admissions Without Coordination) the doctor is only concerned with his own agenda. A patient is booked the first day the doctor is able to operate him. In the other policy (Booked Admissions With Coordination) a patient is booked based on not only the ability to operate, but also based on the availability of the other resources of the hospital.
The current policy will be called Maximum Resource Use.

2 Case description

In this section we give a description of the hospital used in our simulation. More specifically we will list the different types of resources and the amounts of those resources the hospital has. Also descriptions of the different policies used in our simulations are given. These descriptions make use of assumptions which we will make more specific and explain in sections 3.1 and 3.2.

2.1 Hospital and resources

In the simulation we will consider a simple hospital with only one specialty and one type of patients, namely *gall bladder*-patients. The resources of the hospital can be divided into five categories. First there are regular hospital beds (denoted by *beds*). Apart from the regular hospital beds there are beds used in the Intensive Care (denoted by *IC-beds*). The third category are the Operation Theaters (denoted by *OT*'s). The nurses in the hospital are represented not in terms of the number of full-time equivalents, but in points a day. What one nursing point stands for is explained in the subsection about the patients and their needs. Fifth and last category of resources are the specialists working in the hospital. The number of normal beds, IC-beds, OT's, nursing points and specialists are all parameters which we can modify in the simulations. For the OT's we can modify the amount of hours they are available each day (the same is possible regarding the specialists). The total amount of 'OT-time' is the number of OT's times the hours (minutes in the simulation) they are available each day (this is also valid for total specialist time). All the types of resources are summarized in table 1. The way we

Resource	Unit of expression	Capacity
Beds	# beds	190
IC-beds	# beds	6
Nurses	# nursing capacity points	662
Specialists	minutes per day	3100
OT	minutes per day	1200

Table 1: Categories of resources

determined the capacities will be shown in appendix A.

2.2 Patients

As was said in the previous paragraph the hospital only treats gall bladder patients. The hospital makes a distinction between two types of patients. First we have the *urgent* patients. Urgent patients need immediate treatment. If an urgent patient arrives and at that time there aren't enough resources at hand to treat the patient he is rejected. The urgent patient then will be moved to an other hospital. Apart from the urgent patients there are patients who do not need immediate treatment. Those patients are said to be *elective*. When an elective patient arrives and there are not enough resources to treat him, the patient will be put on a waiting list. The patient will wait until the hospital is able to admit him. Elective patients do not leave without being treated. We now describe the proces of treatment an elective patient goes through, also regarding the resources that a patient requires each day.
The first day an elective patient is only admitted, nothing else is done. The first day an elective patient requires an bed. He also requires 10 minutes specialist time and 3 nursing points. The second day the patient is operated. Of course he still requires a bed. After the operation he might require an IC-bed (25% of all patients require an IC-bed after operation). If so, the regular bed remains reserved and cannot be used by an other patient. A patient that is operated requires extra care from the nurses during that day, so he 'consumes' 5 nursing points. The use of the OT is 60 minutes (fixed operation time) and during the operation a specialist is required. Adding up the 10 minutes a specialist spends per patient per day makes that a patient requires 70 minutes specialist time the second day. The third day is the day after the operation. This day the IC-bed (if used the day before) becomes available for other patients again. The patient still requires a bed, 5 nursing points (extra care on the day after operation) and 10 minutes specialist time (standard). The amount of days that a patient stays in the hospital after the third day is stochastic. This length of stay is distributed with a mean of 7 days and a standard deviation of 2 days. During this stochastic staying time the patient requires a bed. He also requires 3 nursing points and 10 minutes specialist time per day.

Urgent patients require exactly the same resources. The only difference between elective and urgent patients (apart from the fact that an urgent patient can't be put on the waiting list) is that urgent patients are operated the same day they are admitted. The stochastic staying time is also distributed with mean 7 days and standard deviation 2 days.

Table 2 summarizes the needs of the elective patients.

resource \ day	1: admission	2: operation	3: day after oper	4, 5, ...
Hospital beds	1	1	1	1
IC-beds	0	1, if needed	0	0
OT	0	60	0	0
nursing points	3	5	5	3
specialist time	10	70	10	10

Table 2: Resource requirements elective patient

In the simulation we have made certain assumptions about the arrival of patients. Important is the mean number of patients arriving per day. Our hospital is supposed to treat about 6500 patients every year. This corresponds with a mean number of $\frac{6500}{365} = 17,8$ patients per day. That is why the mean number of patients will be set on 18.
The arrival of patients is Poisson-distributed, with mean $\lambda = 18$. The probability of k arrivals on a certain day is $P(k\ arrivals) = e^{-\lambda}\frac{\lambda^k}{k!}$. One of the properties of the Poisson-distribution is that we can split it up in three separate processes with separate means λ_1, λ_2 and λ_3 (with $\lambda_1 + \lambda_2 + \lambda_3 = \lambda$). In our simulation we use the three means $\lambda_1 = \lambda_e$, $\lambda_2 = \lambda_u^d$ and $\lambda_3 = \lambda_u^n$. The process with mean λ_e is used for the arrival of elective patients. Because urgent patients can arrive 24 hours a day, we need two processes to simulate their arrivals. One for the arrivals during the day (λ_u^d) and one for the arrivals during the night (λ_u^n). We assume that every 24 hour consists of 8 hours 'day' and 16 hours 'night'. Out of all the arrivals 50% is urgent and the other 50% is elective. From this it follows that $\lambda_e = \frac{\lambda}{2} = 9$, $\lambda_u^d = \frac{1}{3}\frac{\lambda}{2} = \frac{\lambda}{6} = 3$ and $\lambda_u^n = \frac{2}{3}\frac{\lambda}{2} = \frac{\lambda}{3} = 6$. However, the precise value of these three parameters can be changed in our simulation. All the changes can be made individually, perhaps changing the mutual proportions while making those changes. In our simulation we will use different settings of these parameters but the settings as explained above are the 'standard' settings.

2.3 Policies

In our simulation we compare four different policies. These policy differences mostly concern the way the patients on the waiting list are handled. We next give a description of the different policies.

2.3.1 Maximum Resource Use (MRU)

The policy MRU is concerned with using the available resources to the maximum. This policy describes the current way of handling patients.

First we determine a certain percentage of the resources to be reserved for urgent patients. This means that a certain percentage of the beds, IC-beds, OT-time, nursing points and specialist time can not be used by elective patients. This percentage is the same for all types of resources. Next we try to admit as much elective patients in the hospital as possible using the remaining capacity of the resources. To do this, every day we decide how much and which elective patients we plan to admit in N days, with N a parameter which can be changed in our simulation. How this is done will be explained in paragraph 3.2.1. It is easy to see that a small N is what the hospital aims for, because the smaller the N, the more accurate the available resources in N days can be estimated (and filled). From the patients view, a small N often means a sudden 'admission-call' from the hospital, which means that the patients should always be prepared to be admitted. For example, going on a holiday is risking a missed call from the hospital. This inconvenience is gone when using a large N. On the other hand though, we expect that a large N means a greater probability of a cancellation, for there will be more uncertainty about the available resources on the day of admission.

2.3.2 Zero Waiting Time (ZWT)

The three policies MRU, BAWOC, BAWC are all three more or less similar to each other. ZWT on the other hand is fundamentally different. ZWT considers all patients equally. In other words, all patients are considered to be urgent. Two big differences between 'real' urgent patients and 'pseudo' urgent patients (elective patients) remain. First we have the fact that elective patients don't get operated on the day of their admission. Second difference is that urgent patients are moved to an other hospital if they can't be admitted to the hospital immediately. Elective patients can still be put on a 'waiting list'. For an elective patient, this means that they return to the hospital the next morning to see if they can be admitted. Because the elective patients can be put on the waiting list urgent patients have priority, but once a elective patient is admitted he can not be cancelled anymore.

2.3.3 Booked Admissions Without Coordination (BAWOC)

When using the policy BAWOC we first determine a certain percentage of the resources to be reserved for urgent patients the same way as we did using MRU. Based on the remaining capacities we determine a maximum on the total number of patients that can be admitted each day. Important to say is that the only resources used to calculate the maximum are OT time. Also important is the fact that such a 'quota' is determined only once and is based on the amount of OT time reserved for urgent patients. Planning the arriving patients is easy using this policy. For every patient we simply determine the first day on which there is still room for admitting patients. We plan that patient to be admitted that day. Important difference with MRU is the fact that with BAWOC the number of planned admissions is (nearly) the same every day. Nearly, because it could happen that there are not enough patients to 'fill' the day. An advantage of BAWOC is that arriving patients immediately hear when they will be admitted. A disadvantage is that when a patient is cancelled all patients that arrived later are already planned, so the cancelled patient has to be put back to the end of the waiting list. The just cancelled patient can't be given priority over the other patients.

2.3.4 Booked Admissions With Coordination (BAWC)

BAWC is the same as BAWOC with the difference that this policy does look at all resources when the next admission date for a patient is determined. Important is that for every patient the next available admission date is determined individually. The next available admission date is calculated using the expected remaining staying time of the patients that are already in the hospital and the expected process for all patients planned to be admitted before the patient considered. Again, we reserve a certain percentage for urgent patients.

3 Model

Before we can compare the different policies, we first have to turn reality into a mathematical model, which can be simulated. This mathematical model should reflect reality as good as possible, without getting to complicated to simulate. This means that we have to simplify reality. In our mathematical model we make several assumptions which simplify reality. Some of these assumption are hardly a violation of reality, while other really do make a difference. We now list all the assumptions we made and try to justify our choice for these assumptions.

3.1 General assumptions

We first list the general assumptions, which are valid for all policies. After that, we list for each policy their individual assumptions.

1. When there are not enough resources available at the time of the admission a patient will be cancelled;
2. Urgent patients leave the system when they are cancelled;
3. Elective patients stay on the waiting list when they are cancelled;
4. We do not take weekends into account;
5. Every patient (elective or urgent) has the same fixed duration of their operation;
6. By the time a patient is admitted it is known whether the patient needs an IC-bed after the operation;
7. Urgent patients arrive during the day as well as during the night;
8. Elective patients can only be admitted during the day;
9. An OT is only available during the day for the operation of an elective patient.

Ad 1. Every time a patient is about to be admitted, the available resources are checked. If any of the resources does not suffice, the patient will be cancelled. Important is to note that for elective patients the use of some of the resources is more the second day than the first day. The OT for example is not used the first day, because an elective patient is operated on the second day. So, if an elective patient is about to be admitted today, also the expected available resources for tomorrow are checked.

Ad 2. As said before urgent patients require immediate treatment. They therefore can not wait for resources to become available. A rejected urgent patient moves to an other hospital. For the simulation this means that he leaves the system and has to be considered as lost.

Ad 3. In contrast with urgent patients an elective patient does not have to be treated immediately. They can (and will) stay on a waiting list when they are cancelled. We assume an elective patient to be patient. He does not leave the waiting list for any other reason than admission. Patients don't leave the system without being treated.

Ad 4. In our simulation we consider an average day during the week. In reality we should take into account that in the weekend only urgent patients are being treated. In reality elective patients are only operated during the week. Not taking the weekend into account obviously does violate reality. However, since our aim is comparing the different policies, it is our opinion that leaving the weekends out of the simulation does affect all policies in a similar manner. So, the policy that would be the best in reality will still be the best in our simulation. Another argument for neglecting the weekends is that maybe in the (nearby) future hospitals will decide to treat weekends as just two more days in a week.

Ad 5. A consequence of the assumption that every patient has the same operation duration is that each day a fixed number of patients can be operated. This assumption prevent the situation in which the maximum OT-time is exceeded in the middle of an operation. Without this assumption we would take the probability that this occurs into account while we are planning and admitting patients. We don't think it to be a serious violation of reality since in reality no strict boundaries exist. For example, a specialist would not quit in the middle of an operation just because his working hours are over.

Ad 6. Because sometimes the possibility of admission depends on whether a patient needs an IC-bed, we assume that we already know if a patient does indeed need an IC-bed. The total number of days that a patient will spend in the hospital is not known. In our simulation we do know this length of stay but we don't use this knowledge in the planning, because in reality the staying time is not known.

Ad 7. Accidents can happen 24 hours a day. Therefore urgent patients can also arrive 24 hours a day.

Ad 8. Since elective patients don't need immediate treatment, they can only arrive (and be admitted) during office hours.

Ad 9. Out of office hours the OT can only be used for emergency operations. Elective patients can only be operated during office hours. A consequence of this assumption is a maximum for the total number of elective patients that can be operated in a day. This maximum says that the mean number of arrivals of elective patients should be less than 8 times the number of available OT's, since every operation costs an hour and a day has 8 office hours (assuming office hours being 9 am. until 5 pm.).

3.2 Policy assumptions

Beside general assumptions we have assumptions specific for a certain policy. Assumptions about, for example, rules for handling the people on the waiting list.

3.2.1 Maximum Resource Use

- Each day we plan which patients we will admit N days later.
  This interval is called the notification period. In our simulation the value of N can be changed. The standard value of N is 3. This value is reasonable for both hospital and patients. Patients have enough time to prepare for admission and the hospital can give a fairly good prediction of available resources.
  This planning is based on the expected available resources in the hospital.
  Since we plan a patient to be admitted in N days, we calculate the expected available resources in the hospital in N days. We take into account both the patients already in the hospital and the patients planned to be admitted before the patient considered.
  Since an elective patient has different needs on the second day of his stay (more nursing points, OT time and specialist time and perhaps an

IC), we also calculate the expected acailable resources in the hospital in $N+1$ days.
If the available resources are sufficient for the patient on both the day of admission and the day of operation, the patient will be planned.
Note that the required resources are largest on the day of operation, so we don't have to check the available resources on the days after the operation.

- When selecting patients from the waiting list to be admitted, we look for the patients that arrived first.
This means that we give priority to patients that have been cancelled for admission, which is only logical. In more detail, this does not mean that we simply select the last patient that has been cancelled, since there can be another patient that has been cancelled the same day and originally arrived earlier.

3.2.2 Zero Waiting Time

- Elective patients that can not be admitted one day, return the next day to see if there are available resources for them that day.
This means that they don't wait for the hospital to call them. This results in a 'waiting list' that becomes empty every morning for the short time that is needed to see whether or not the patients can be admitted. The patients that can not be admitted return to the waiting list.

3.2.3 Booked Admissions Without Coordination

- Elective patients which are cancelled return to the waiting list. The same day they get a new admission date.
Because all the other patients on the waiting list already have an admission date, cancelled patients return to the back of the 'queue'.

- The maximum number of elective patients that can be admitted each day is different for every different setting of the parameters.
This maximum is determined by the operating capacity. In our hospital we have 1200 minutes Operation Theatre time so the maximum number of elective patients that can be admitted is $\frac{1200}{60} = 20$ (this in case no resources are reserved for urgent patients). If there is indeed some

percentage, say p, of the resources reserved for urgent patients, the 'Quota' is set on $Q = \lfloor \frac{p}{100} \times 20 \rfloor$.

- The planning of the patients is done regarding only the OT.
  Before admission however, the availability of the other resources is checked. If there is a resource which lacks sufficient available capacity, the patient will be put back on the waiting list.

3.2.4 Booked Admissions With Coordination

- Similar to the policy BAWOC, cancelled patients make a new appointment with their specialists.

- When determining the next available admission date, we take into consideration both the expected remaining staying time of the patients that are already admitted and expected resources that will be used by the patients that are planned to be admitted between this day and the next admission date.
  The way this is done is similar to the method we used with MRU. The only difference here is that we plan as much days ahead as is necessary to plan all the waiting patients.

3.3 Procedure

In the simulation every day is built up as the same sequence of events. We will list the events that occur every day in chronological order. We first list the events when we use the one of the three policies MRU, BAWOC or BAWC. The list of events using ZWT is slightly different.

1. Leaving patients.
   First we release all the patients that are discharged. Beds and other resources they used become available again for other patients.

2. Urgent patients daytime.
   After releasing the discharged patients we consider the urgent patients that arrive during daytime. For each patient we check if there are enough resources to admit him. We do this in order of arrival, which prohibits us to 'plan' the urgent patients. For example, it could be that the number of urgent patients that arrive is twice the amount the hospital can admit. Because in general it is not important which patients

are treated, but how much, we would prefer to admit a patient which does not need an IC-bed over one that does. Admitting the 'IC-less' patient would leave an IC-bed for other patients.
First we check the available resources. We then check for each urgent patient that has arrived if there are enough resources for admission. If so, the urgent patient will be admitted. If not, the urgent patient will be rejected.
At this point we update the performance measures concerning the urgent patients arriving during the day.

3. Arriving elective patients.
When we use one of the three policies MRU, BAWOC or BAWC the earliest day elective patients can be admitted is the next morning. So it would make no difference if we simulate those elective patients to arrive after the urgent patients that arrive during the night rather then after the 'urgent patients daytime'. However, when we use ZWT, elective patients CAN be admitted the same day they arrive. So, when we use ZWT, it is important that the elective patients arrive before the urgent patients in the night do. In order to be able to compare the different policies we must be able to re-create the same stream of patients. To make the streams exactly the same the order of arrival of different types of patients should be the same.
So, the simulation puts the arrived elective patients on the waiting list for the time-being.

4. Elective patients scheduled for admission.
Next event during a day is the admission of elective patients. Again, we first check which amount of resources is still available now that the new urgent patients have arrived. Knowing the available resources the elective patients on the waiting list scheduled for admission are admitted one at the time, each time updating the available resources. When one of the resources dries out, the rest of the elective patients are cancelled for admission. There is one exception, which are the IC-beds. When there are no more IC-beds available it might still be possible to admit an elective patient without the need for an IC-bed.
At this time the performance measures concerning elective patients are updated.

5. Urgent patients nighttime.
   After admitting the elective patients we consider the urgent patients that arrive during the night. This part is almost the same as the part regarding the urgent patients that arrive during the day. Difference is that for urgent patients during the night OT-time is not a restriction. If necessary, patients operated during the day can be moved from their IC's, so at the start of the night all IC's are virtually available. So there are only three resources that can cause a urgent patient to be rejected, namely beds, nursing points and specialist time. An urgent patient during the night however only requires 10 minutes specialist time, since the operation time required is scheduled as extra time.
   At this point we update the performance measures concerning the urgent patients arriving during the night.

6. Planning elective patients.
   Next thing we do is planning the elective patients on the waiting list that do not have a date of planned admission yet (or not anymore). The way the planning is done is different for all policies and is explained in the section with the description of the different policies.

7. Performance measures hospital.
   The last thing we do is updating the performance measures regarding the hospital, namely the utilization rates of the several resources. Because this is the last thing we do each day, you could also say it is the first thing we do the next morning.

As was said before, the list of events is slightly different using ZWT. The difference lies in the fact that elective patients do not have to be planned using ZWT.
The first two events are the same as the two events for MRU, BAWOC or BAWC. Using ZWT, the way the arriving elective patients are handled is almost the same as the way the urgent patients are handled. Difference is that first all the elective patients that were already on the waiting list will be admitted (if possible). Only when those patients can all be admitted, the elective patients arriving that day will be admitted if possible. In other words, the patients which were already on the waiting list have priority over elective patients just arriving.
Again, before admission resources will be checked, and performance measures will be updated.

Once the elective patients are handled, either by admission or by putting on the waiting list, the urgent patients arriving during the night are handled. This is done the same way as was done using MRU, BAWOC or BAWC. Again, updating the performance measures for the hospital is the last thing we do each day.

4 Performance measures

To say that one policy is better that the other we should know what is meant by that. To do so we use several performance measures. This section describes the performance measures we will use. Furthermore we will explain why exactly those measures are important for determining the best policy.

The policies can be compared from the point of view of the hospital and from the point of view of the patients. As was mentioned in the introduction of this report hospitals currently aim for optimal use of the resources. It would be an ideal situation for the hospital if at times the resources are filled there would be no patients waiting and at times the resources aren't filled a new 'can of patients' can be opened. It is easy to see this isn't very patient friendly. The main concern for a patient is the waiting time and (according to the current way of patient handling) the uncertainty about this waiting time.

The above arguments explain why the performance measures should be divided in two categories, one category of performance measures important for the hospital and one category of performance measures important for the patients.

4.1 Hospital

The hospital aims for optimal use of the available resources. A well known performance measure for this is the utilization rate of the resources. This gives us the following measures to compare the policies:

- Utilization rate of the beds;
- Utilization rate of the IC-beds;
- Utilization rate of the OT's;
- Utilization rate of the nurses (nursing pionts);
- Utilization rate of the specialists.

4.2 Patients

It is important for the patients how long they have to wait before they are treated. Therefore, the mean waiting time is a very important performance measure. Apart from the total waiting time it is important to know whether or not the policies are patient friendly. This can be compared using the percentages of cancellations before admission. Cancellation (rejection) is even more important when we consider the urgent patients. Rejecting urgent patients means moving them to an other hospital.

This gives us the following performance measures:

- Mean total waiting time of a elective patient.
- Percentage of all urgent patients that have to be rejected.
- Percentage of all elective patients that have to be canceled.

5 Program validation

Before we simulate the different policies and draw conclusions about which policy is the best to use for hospital production control, we first have to make sure that the program is correct. We have to check that there aren't any errors left. We do this by simulating cases in which we can predict/ calculate the outcome of the simulation. If the actual outcome of the simulation contradicts significantly with what we have predicted/ calculated we have to recheck the program for errors. In this section we list the cases which are used to check the validation of the program. We explain for every case why we use it and which policy will be checked using that case. This list contains both a general check and checks for a specific policy.

5.1 General validation

- No elective patients
  The policies we will use only differ in the way they handle elective patients. In the situation where there aren't any elective patients arriving all policies should give the same results (assuming that each simulation has exactly the same arriving urgent patients). We checked this with an average of 6 urgent patients arriving during the day and an average of 12 urgent patients arriving during the night.
  The results are indeed exactly the same.

- Unstable system
  In case there are not enough resources in the hospital to treat all arriving patients, we can also predict the number of admissions of the different types of patients. Not the exact value can be predicted, but one total in relation to another. Since the urgent patients that arrive during the day are the first new patients each day, the number of admissions will be highest for them. If those patients together with the patients already in the hospital don't require all capacity elective patients will be admitted. At last the urgent patients arriving during the night will be (if possible) admitted. This means that our prediction is that the most patients that will be admitted will be urgent patients arrived during the day, followed by elective patients, followed by urgent patients arrived during the night.
  The predictions stated above will be true when there are no resources

reserved for urgent patients. If there is a certain percentage of the resources reserved for urgent patients, the total number of admissions of urgent patients arrived during the night will be higher, maybe even higher than the total number of elective patients admitted.
We will check this for the situation with no reservation, and with a hospital with resources for exactly 1 patient at the time. This means that the hospital has 1 bed, 1 IC-bed, 5 nursing points, 70 minutes specialist time and 60 minutes OT time. The mean arrivals will be the same as in the 90% situation. We will check this for all policies. For each simulation we use the same arrivals of patients. The results are listed below (number of admissions of urgent patients arrived during the day will be denoted by N_u^d, total number of admitted elective patients will be denoted by N_e and total number of admission of urgent patients arrived during the night will be denoted by N_u^n).

- MRU
  Of all 3014 urgent patients arrived during the day 96,3835% was rejected. This means that $N_u^d = \frac{(100-96{,}3835)}{100} \times 3014 = 109$.
  Of all 5912 urgent patients arrived during the night 99,9323% was rejected. This means that $N_u^n = \frac{(100-99{,}9323)}{100} \times 5912 = 4$.
  No elective patients are admitted, so $N_e = 0$.
  We see that indeed N_u^d is highest. But we also see that $N_u^n > N_e$. This is not what we expected at first. But, this result is rather logical.
  When using MRU elective patients are planned based on the expected available resources in N days (N is the length of the notification period). Since in this simulation $N = 3$, each day the expectation was that there would be NO resources available. Therefore, no elective patients will be planned. So, in case the patient leaves the hospital and that same morning no urgent patients arrive, a possible urgent patient will be admitted that night.

- ZWT

  Of all 3014 urgent patients arrived during the day 96,3504% was rejected, so $N_u^d = 110$.
  All urgent patients arrived during the night were rejected, so $N_u^n = 0$.
  $N_e = 6$ Elective patients were admitted.
  The results are corresponding with what we predicted. Indeed, $N_u^d > N_e > N_u^n$.
  Notice that when using MRU a total of 113 patients were admitted and when using ZWT a total of 116 patients are admitted. This is in contrast with what we would expect. Elective patients have a longer average staying time. Therefore, admitting more elective patients will result in less patients treated in total.
  The reason the results aren't what we would expect is that the average staying time of the urgent patients that are admitted are greater for MRU than for ZWT. In other words, in this simulation MRU admitted more 'long' patients.

- BAWOC

  Note: we set the number of elective patients we can plan each day on 1.
  Of all 3014 urgent patients arrived during the day 96.5163% was rejected, so $N_u^d = 105$.
  Again, all urgent patients arrived during the night were rejected, so $N_u^n = 0$. $N_e = 3$ Elective patients were admitted.
  Again, the results are corresponding with our predictions.
  Notice that although BAWOC and ZWT are somewhat similar to each other in this situation, since in both policies each day there is an elective patient that is 'candidate for admission' (using ZWT the longest waiting patient, using BAWOC the planned patient), the results are different. The cause of this is the fact that for ZWT the 'candidate for admission' is the same every day (until the patient is admitted) and BAWOC has a different 'candidate' each day. After all, using BAWOC an elective patients that is cancelled will be put back on the far end of the waiting list. The fact that BAWOC has less patients admitted than ZWT is coincidence. In another simulation BAWOC could perform 'better' than ZWT (in this case 'better' means treating more patients).

- BAWC

  When we tried this simulation using BAWC the computer crashed. Because with this policy we try to find the earliest possible admission date for a patient. For every admission date (beginning on the day the last patient was planned) we check if there will be enough resources available. This checking is very intensive, since we have to know for each patient planned to be admitted before the day we are considering whether he is still in the hospital that day.

5.2 Policy validation

- Maximum Resource Use

  - More than enough resources

    It is easy to see that in case there are more than enough resources, the mean waiting time of an elective patient will be equal to the length of the notification period (say N). With more than enough resources every elective patient can be planned for admission the same day they arrive, and therefore will be planned N days after their arrival at the waiting list. And, because there are more than enough resources they will never be cancelled.

    We have checked this using four values of N, namely 1, 3, 5 and 10, and with mean arrivals of $\lambda_e = 6$, $\lambda_u^d = 2$ and $\lambda_u^n = 4$. We have triplicated the capacities of the resources. The results indeed show a mean waiting time equal to the length of the notification period.

- Zero Waiting Time
  - More than enough resources
    In case the resources are more than sufficient, the elective patients will all be admitted the same day they arrive. Therefore, the mean waiting time will be zero. Furthermore, there will be no need for rejections of urgent patients (neither day or night).
    The results of our simulation shows what we expected. No waiting time nor rejections. One thing to notice is the average number of patients in the hospital. This is in our simulation equal to 171 (170.645 to be precise). Based on $\lambda_e = 9$, $\lambda_u^d = 3$ and $\lambda_u^n = 6$ we can calculate a prediction of $\lambda_e \cdot 10 + (\lambda_u^d + \lambda_u^n) \cdot 9 = 90 + 81 = 171$.

- Booked Admissions Without Coordination
  - More than enough resources
    Because the planning procedure of the newly arrived patients takes place at the end of a day, the smallest possible waiting time for elective patients is 1 (day). We expect this result in the situation there are more than enough resources. In this simulation we set the 'quota' on 60, equal to the maximum based on an OT-capacity of 3600 minutes.
    Indeed, the results show a mean waiting time of 1 day. Again, the mean number of patients in the hospital round up to 171.

- Booked Admissions With Coordination
  - More than enough resources
    In this situation we expect the results to be the same for the policy BAWC as they were for the policy BAWOC. Our simulation indeed shows this. The only difference is the duration of the simulation. While BAWOC simply plans arrived patients to be admitted the next day, BAWC has to calculate whether an arrived patient can be admitted the next day (which will always be the case).

6 Scenarios

In our simulation we will consider three different situations. In the first situation 70% of the resources will be used on the average in case there are no cancellations. Because a mean number of 18 patients means a percentage of 90%, 70% will be reached if the mean number of patients is $\frac{70}{90} \times 18 = 14$. In the second situation this percentage is set on 80%, resolving in $\frac{80}{90} \times 18 = 16$ patients per day. In the third and last situation this percentage will be set on 90% (and thus 18 patients a day).

To be more specific we give a short list of the situations:

- 70%
  A hospital with 14 patients arriving each day (7 elective patients, $\frac{14}{3}$ urgent patients during nighttime and $\frac{14}{6}$ urgent patients during daytime).

- 80%
  A hospital with 16 patients arriving each day (8 elective patients, $\frac{16}{3}$ urgent patients during nighttime and $\frac{16}{6}$ urgent patients during daytime).

- 90%
  A hospital with 18 patients arriving each day (9 elective patients, 6 urgent patients during nighttime and 3 urgent patients during daytime).

All the simulations that are done have a length of 3100 days, from which the first 100 days are used as warm-up period. The warm-up period is disregarded in the calculation of results.

It is also important to know what the possible settings of the parameters of each policy are.

For MRU, BAWOC and BAWC we have to decide which reservation percentages we are going to use. Since the IC's are expected to be an important factor, we decide to use 16, 33 and 50 as reservation percentages. This corresponds with reserving 1, 2 and 3 IC's for urgent patients respectively.
The other parameter that has to be set is the length of the notification period for MRU. The value of this parameter will be one of 1, 3, 5 or 10.

7 Comparison

Because there are so much possible settings for each policy, we will try to narrow the number of settings we will use to compare the policies.
We have done one large simulation from which the results can be found in appendix B.
The first thing we noticed is that, compared with a notification period of 3 days, an increase of the notification period with 2 or 7 days (to 5 or 10 days) only resolves in (almost) the same increase in the mean waiting time. The percentages of cancellation and rejections are (almost) the same. We therefore decide to disregard those notification periods in our comparison. Important to notice is that we expected to see more cancellations when we increase the length of the notification period. However, this is not the case. The uncertainty about the expected available capacity is the same for both a notification period of 3 days as 10 days.
Furthermore, we noticed that the difference between the results of a simulation with a reservation percentage of 50% and that with a reservation percentage of 33% is similar to the difference between '33%' and '16%'. Decreasing the reservation percentage decreases the mean waiting time for elective patients but increases the percentages of urgent patients that have to be rejected. We decide to leave settings with a reservation percentage of 16% out of our comparison.

To be able to properly compare the different policies we will make sure that in the simulations all the policies will have the exact same arrival proces of exactly the same patients (same time of arrival, same characteristics). We will do this 10 times so we can calculate confidence intervals of the performance measures. Only the relevant performance measures will be listed in the summary of the simulations. The utilization rates of the different categories of resources are not important. This because they were set to be around a certain percentage and they do not differ much from one policy compared to another policy.
We now give the summary of the simulations. Based on these following tables we will compare the several policies for the three different situations (70%, 80% en 90%).

		Perf. Meas.	waiting time	cancel mean #	% reject day	% reject night
70%	N = 1	mean	1.01035	0.00000	0.12071	0.00248
	R = 33	95% CI margin	0.00064	0.00000	0.02844	0.00248
	N = 3	mean	3.01035	0.00000	0.13558	0.00248
	R = 33	95% CI margin	0.00064	0.00000	0.03210	0.00248
70%	N = 1	mean	1.07353	0.00048	0.04023	0.00248
	R = 50	95% CI margin	0.00275	0.00021	0.01968	0.00248
	N = 3	mean	3.07405	0.00041	0.04199	0.00248
	R = 50	95% CI margin	0.00274	0.00019	0.01649	0.00248
80%	N = 1	mean	1.02129	0.00000	0.18435	0.01198
	R = 33	95% CI margin	0.00064	0.00000	0.03698	0.00696
	N = 3	mean	3.02131	0.00000	0.18981	0.01131
	R = 33	95% CI margin	0.00063	0.00000	0.04028	0.00675
80%	N = 1	mean	1.19988	0.00796	0.05707	0.01131
	R = 50	95% CI margin	0.01628	0.00131	0.01571	0.00675
	N = 3	mean	3.20625	0.00707	0.06389	0.01131
	R = 50	95% CI margin	0.01725	0.00134	0.02264	0.00675
90%	N = 1	mean	1.04228	0.00105	0.51469	2.11387
	R = 33	95% CI margin	0.00113	0.00020	0.06697	0.14550
	N = 3	mean	3.04341	0.08472	0.48669	2.10863
	R = 33	95% CI margin	0.00104	0.01729	0.03308	0.14963
90%	N = 1	mean	2.80085	0.05428	0.15631	0.82655
	R = 50	95% CI margin	0.27552	0.00357	0.02642	0.06589
	N = 3	mean	4.81662	0.05290	0.14279	0.82693
	R = 50	95% CI margin	0.25626	0.00353	0.02631	0.10249

Table 3: MRU, N = notification period, R = reservation percentage

	Perf. Meas.	waiting time	cancel mean #	% reject day	% reject night
70%	mean	0.00040	0.00000	0.48220	0.00248
	95% CI margin	0.00013	0.00000	0.08429	0.00248
80%	mean	0.00094	0.00000	0.86038	0.01399
	95% CI margin	0.00015	0.00000	0.07498	0.00884
90%	mean	0.00259	0.00000	1.99262	1.99118
	95% CI margin	0.00040	0.00000	0.12428	0.13156

Table 4: ZWT, R = reservation percentage

		Perf. Meas.	waiting time	cancel mean #	% reject day	% reject night
70%	R = 33	mean	1.01052	0.00879	0.12071	0.00248
		95% CI margin	0.00068	0.00051	0.02844	0.00248
	R = 50	mean	1.09144	0.02926	0.04023	0.00248
		95% CI margin	0.00469	0.00100	0.01968	0.00248
80%	R = 33	mean	1.02203	0.01627	0.18267	0.01198
		95% CI margin	0.00063	0.00063	0.03613	0.00696
	R = 50	mean	1.28123	0.05204	0.05535	0.01131
		95% CI margin	0.02676	0.00438	0.01632	0.00675
90%	R = 33	mean	1.04504	0.02758	0.51135	2.10622
		95% CI margin	0.00155	0.00076	0.06209	0.14148
	R = 50	mean	4.20233	0.77177	0.13953	0.79938
		95% CI margin	0.47643	0.13056	0.02674	0.08738

Table 5: BAWOC, R = reservation percentage

		Perf. Meas.	waiting time	cancel mean #	% reject day	% reject night
70%	R = 33	mean	1.01077	0.00000	0.12239	0.00248
		95% CI margin	0.00087	0.00000	0.02981	0.00248
	R = 50	mean	1.08902	0.00049	0.03859	0.00248
		95% CI margin	0.00584	0.00023	0.01774	0.00248
80%	R = 33	mean	1.02215	0.00000	0.18942	0.01198
		95% CI margin	0.00085	0.00000	0.04083	0.00696
	R = 50	mean	1.28456	0.00754	0.05871	0.01131
		95% CI margin	0.03029	0.00133	0.01647	0.00675
90%	R = 33	mean	1.04586	0.00101	0.51581	2.09372
		95% CI margin	0.00234	0.00013	0.07189	0.14866
	R = 50	mean	7.44864	0.04546	0.15859	0.79046
		95% CI margin	1.35078	0.00242	0.03605	0.07372

Table 6: BAWC, R = reservation percentage

7.1 70%

- Waiting Time
  In this situation the mean waiting time when using MRU is (almost) equal to the length of the notification period. For BAWOC, BAWC and ZWT the mean waiting time is (almost) equal to the minimum possible waiting time (0 days for ZWT and 1 day for the other two policies).
  If the reservation percentage increases, so does the mean waiting time.

- Cancellation Admissions
  For both MRU and ZWT no elective patients are cancelled. Since there are more than sufficient resources for the arriving patients one would expect to find no cancellations for all policies. However, both BAWOC and BAWC have cancelled patients. For BAWC this percentage is negligible. For BAWOC it can be explained by noticing that there is no coordination concerning the IC's. If, on a certain day, the number of arriving elective patients with need for an IC exceeds the IC capacity, they can all be planned on the same day nevertheless.
  As the mean waiting time, also the mean number of cancellations increases if the reservation percentage increases.

- Rejections
  Our first observation is that the percentage of urgent patients arriving during the night that is rejected is equal for all policies. This can be explained be noticing that all rejections are caused by the lack of a (needed) IC. And the chance of a certain number of urgent patients with need of an IC arriving on a certain day is independent of the used policy.
  The fact that the percentage for urgent patients arriving during the day are not equal for all policies is caused by the differences in planning patients.
  As for ZWT we can say that the fact that there is no reservation for urgent patients causes the percentage of rejections of urgent arriving during the day to be higher then the other three policies.
  We also see that a increased reservation percentage causes the percentage of rejections to decrease.

We can conclude that it does not make a real difference which policy is used in this situation. Only ZWT is not recommended because the high percentage

of rejections. If this percentage is not important for the hospital they can consider ZWT because the short (negligible) waiting time.
To decide which reservation percentage to use, the hospital have to weigh waiting time against rejections.

7.2 80%

- Waiting Time
  Even though there are more patients than in the 70% situation, the mean waiting time is still only slightly higher than the notification period /minimum possible waiting time. With a reservation percentage of 50% the mean waiting time is approximately 0.2/0.3 days over the minimum. Exception is ZWT, with a mean waiting time that is still negligible.

- Cancellation Admissions
  Again, the number of cancelled admissions is negligible for all policies. The reasoning is the same as in the 70% situation.

- Rejections
  Again we see that the percentages of rejections of urgent patients arriving during the night are equal. This has the same reason in this situation as in the 70% situation. There is one exception, namely the policy ZWT. When we use this policy, the percentage of rejections of urgent patients arriving during the night is slightly higher. This can be explained by noticing that ZWT is the only policy that does not reserve any resources for urgent patients.
  In the (unlikely) event of a large number of elective patients planned and a large number of urgent patients arriving the reserved resources preserve rejection of the urgent patients.

The conclusion for this situation is also similar to that of the 70% situation. Again, the use of ZWT is not recommended because the high percentages of rejections of urgent patients. And again, there is no significant difference between the other three policies.

7.3 90%

- Waiting Time
  The large number of patients that on the average arrive at the hospital causes that there is only a small amount 'extra' capacity for the resources for the elective patients. And there is even less resources available because urgent patients will sometimes use some of the 'elective resources' (i.e. the resources *not* reserved for urgent patients).
  This has the consequence that there is a significantly increase in the mean waiting time of elective patients. This is because the hospital has to be more careful in planning the elective patients. Compared with the other situations, less patients will be planned per day.
  For MRU this resolves in a mean waiting time which is approximately 2 days longer than the notification period. For BAWOC we have a mean waiting time of 4.2 days and for BAWC the mean waiting time is 7.4 days.
  Only in this situation the main difference between MRU and BAWC is visible in the results. Using MRU, a cancelled elective patient can (and will) be given priority over the elective patients that are on the waiting list but arrived later. This in contrast with the situation in which BAWC is used. Using BAWC, all elective patients on the waiting list are already planned for admission and therefore a cancelled patient can not be given priority. In the results this is found in the 95% confidence interval limit. This limit for BAWC is more than 5 times the limit for MRU.
  For ZWT the mean waiting time is still negligible.

- Cancellation Admissions
  The small amount of resources available for elective patients also has it effect on the mean number of cancellations. Even though the hospital will plan less patients a day, the chance the prediction is bad is greater than in the other situations. Therefore, we see an increase of the mean number of cancellations of elective patients. The worse the prediction is, the higher this number will be. This can be found looking at BAWOC. This policy does not use any prediction at all. This policy can be said to be naive. If for example 50% of the resources are reserved for urgent patients, this policy assumes that the other 50% can be fully used by elective patients. This is very naive, because although elective

patients can not use more than 50%, the urgent patients can (and will). The simulations show that almost every elective patients is cancelled once when using BAWOC. This is very much compared with around 5% procent (when using MRU or BAWC).

- Rejections
  It is interesting to see that the percentages of rejections of urgent patients arriving during the night are no longer equal for the policies MRU, BAWOC and BAWC. They do not differ much, but there is certainly a difference. This can be explained by noticing that the rejections are no longer caused by the IC alone. When we checked the reasons for rejection we saw that also, for example, beds are sometimes lacking, even though a certain percentage of that resource is reserved for urgent patients. Looking at the simulation results it is obvious that for a low percentage of rejections a reservation percentage of 50% is required in this situation. A reservation percentage of 50% revolves in a rejection percentage of approximately 0.8% (this versus approximately 2.1% when we reserve 33% of the resources for urgent patients).
  Also for the rejection percentage of urgent patients arriving during the day applies that it decreases when the reservation percentage is increased. (0.5% versus 0.1/ 0.2%).
  The lack of reservation for ZWT causes 2% of the urgent patients to be rejected (both day and night).

Concluding we can say that in this situation ZWT is only recommendable if the mean waiting time of an elective patient is more important than an high percentage of urgent patient that can be treated. The mean waiting time is namely negligible. The only policy/ setting that can compete with ZWT in that aspect is BAWOC when reserving only 33% of the resources for urgent patients. Using that setting, BAWOC also has a large rejection percentage.
If a high percentage of treated urgent patients is evenly important with a small mean waiting time MRU gives the best results. For MRU the percentage of rejections of urgent patients is almost equal to both BAWOC (50% reservation) and BAWC. The 95% C.I. is smaller for MRU and the mean waiting time is also smaller for MRU. Only if a notification period of 1 day is not practical BAWOC with 50% reservation can be considered. One disadvantage of that setting of BAWOC is that it is not very patient friendly.

8 Conclusions and recommendations

In this section we will summarize the conclusions that can be drawn from all the simulations that are done. After that summary we will give some recommendations for further research.

8.1 Summary

As was said in the introduction MRU is the current policy used by hospitals. This policy has been shown to be not so bad at all. Compared with BAW(O)C it gives similar results. One thing we noticed about MRU is that it, compared with BAW(O)C, does not really have a higher utilization rate of the resources. We notice this fact because a high utilization rate is the main aim of the policy MRU. One advantage of MRU over the other policies is that the length of the notification period can be chosen by the hospital itself. This in contrast with BAW(O)C where the notification period is determined by the planning itself.
ZWT does live up to the aims of the policy. In all situations there is virtually no waiting time for elective patients. A rather logical consequence is the high percentage of urgent patients that have to be rejected.
Concluding we can say that if the hospital is capable of easily treating all arriving patients (the situations 70% en 80%) it should choose to use either MRU or BAWC. BAWOC is not preferred because it give higher mean number of cancellations of admissions.
When we use one of these policies in the 70% situation and we reserve 50% of the resources for urgent patients, the mean waiting time will be near 1 day, and almost all the urgent patients will be admitted.
The same holds for 33% reservation in the 80% situation.
A mean waiting time of almost 3 days is found if we use MRU and reserve 50% of the resources in the 90% situation. In this situation the percentages of rejections is still acceptable.

8.2 Further research

Because in all situations and with every policy the mean waiting time is not very large, we conclude that we have to find the policy that is the best in clearing a waiting list. Once the waiting list is cleared there can be switched to an other policy.
This searching can be done by starting with a large waiting list and check for every policy how long it takes to get a stable (and shorter) waiting list.
A policy capable of clearing a waiting list faster than an other policy is also convenient in case there is a sudden 'explosion' of patients (for example after a disaster).

A Justification settings resources

In this appendix we will show how we have calculated the amounts of the different resources we will use in our simulations as was mentioned in section 2.1 (table 1). We have done our calculations based on the fact that, in the situation where there are an average of 18 patients arriving each day and no patients are cancelled, 90% of each type of resource is in use on the average. We will use $\lambda_e = 9$, $\lambda_u^d = 3$ and $\lambda_u^n = 6$.

- Beds
  Each day a patient is in the hospital he requires a bed. An elective patient has an mean staying time of 10 days. An urgent patient is operated in the day of admission and therefore has an mean staying time of 9 days. From Little's Law ($E(L) = \lambda \cdot E(S)$, with L = mean number of patients in the hospital and S mean staying time) it follows that the mean number of beds used will be:

$$\lambda_e \cdot E(S_e) + (\lambda_u^d + \lambda_u^n) \cdot E(S_u) = 9 \times 10 + 9 \times 9 = 171 \qquad (1)$$

  This means that the amount of beds in the hospital will be set on 190 (since $\frac{90}{100} \times 190 = 171$).

- IC-beds
  Of all patients (elective or urgent) 25% requires an IC-bed after operation. The mean number of IC-beds used will be:

$$\frac{1}{4} \cdot (\lambda_e + \lambda_u^d + \lambda_u^n) = \frac{1}{4} \times 18 = 4\frac{1}{2} \qquad (2)$$

  This means that the amount of IC-beds in the hospital should be set on $\frac{100}{90} \times 4\frac{1}{2} = 5$. However, since there are only few IC's, variation in the requirement of those IC's can not be easily absorbed. Therefore, we assume the hospital to have 6 IC's.

- Nursing points
  Each day an elective patient stays in the hospital he requires 3 nursing points. Both on the day of operation and on the day after the operation the elective patient requires special care and therefore an additional 2 nursing points. This is also valid for urgent patient. Taking into

account the average staying times for elective and urgent patients, the mean number of nursing points will be:

$$\lambda_e \cdot (10 \times 3 + 2 \times 2) + (\lambda_u^d + \lambda_u^n) \cdot (9 \times 3 + 2 \times 2) = 9 \times 34 + 9 \times 31 = 595 \quad (3)$$

This means that the amount of nursing points in the hospital will be set on 662 (since $\frac{100}{90} \times 595 = 661\frac{1}{9}$).

- Specialists Each day a specialist spends 10 minutes for each patient. Each patient that is operated requires an additional 60 minutes (obviously the doctor has to perform the operation). The mean number of minutes of specialist time used will be:

$$\lambda_e \cdot (60 + 10 \times 10) + (\lambda_u^d + \lambda_u^n) \cdot (60 + 9 \times 10) = 9 \times 160 + 9 \times 150 = 2790 \quad (4)$$

  This means that the amount of specialist minutes in the hospital will be set on $\frac{100}{90} \times 2790 = 3100$.

- Operating Theatre The calculations for the Operating Theatre is simple. Each patient has to be operated, every operation requires 60 minutes, and the mean number of patients arriving each day is $\lambda_e + \lambda_u^d + \lambda_u^n = 18$. This means that the mean number of Operation Theatre minutes will be $18 \times 60 = 1080$.
  This means that the amount of Operation Theatre minutes in the hospital will be set on $\frac{10}{9} \times 1080 = 1200$.

B Simulation results

B.1 Maximum Resource Use

R	$N \setminus P$	waiting time	cancel %	cancel mean #	% reject day	% reject night	util. beds	util. IC	util. OT	util. spec.	util. nurses
	1	1.00	0.00	0.00	0.29	0.00	0.65	0.54	0.65	0.65	0.64
16	3	3.00	0.00	0.00	0.23	0.00	0.65	0.54	0.65	0.65	0.64
	5	5.00	0.00	0.00	0.33	0.00	0.66	0.54	0.65	0.65	0.64
	10	10.00	0.00	0.00	0.28	0.00	0.65	0.54	0.65	0.65	0.64
	1	1.01	0.00	0.00	0.12	0.00	0.65	0.54	0.65	0.65	0.64
33	3	3.01	0.00	0.00	0.13	0.00	0.65	0.54	0.65	0.65	0.64
	5	5.01	0.00	0.00	0.10	0.00	0.65	0.54	0.65	0.65	0.64
	10	10.01	0.00	0.00	0.12	0.00	0.65	0.54	0.65	0.65	0.64
	1	1.07	0.04	0.00	0.04	0.00	0.65	0.54	0.65	0.65	0.64
50	3	3.07	0.02	0.00	0.02	0.00	0.65	0.54	0.65	0.65	0.64
	5	5.08	0.03	0.00	0.05	0.00	0.66	0.54	0.65	0.65	0.64
	10	10.07	0.02	0.00	0.02	0.00	0.65	0.54	0.65	0.65	0.64

Table 7: MRU (70%), R = reservation percentage, N = notification period and P = performance measure

R	$N \setminus P$	waiting time	cancel %	cancel mean #	% reject day	% reject night	util. beds	util. IC	util. OT	util. spec.	util. nurses
	1	1.00	0.00	0.00	0.49	0.01	0.75	0.62	0.75	0.75	0.74
16	3	3.00	0.00	0.00	0.45	0.01	0.75	0.62	0.75	0.75	0.74
	5	5.00	0.00	0.00	0.48	0.02	0.75	0.62	0.75	0.75	0.74
	10	10.00	0.00	0.00	0.43	0.01	0.75	0.62	0.75	0.75	0.74
	1	1.02	0.00	0.00	0.18	0.00	0.75	0.63	0.75	0.75	0.74
33	3	3.02	0.00	0.00	0.17	0.01	0.75	0.62	0.75	0.75	0.74
	5	5.02	0.00	0.00	0.15	0.01	0.75	0.62	0.75	0.75	0.74
	10	10.02	0.00	0.00	0.15	0.01	0.75	0.63	0.75	0.75	0.74
	1	1.19	0.82	0.01	0.04	0.01	0.75	0.63	0.75	0.75	0.74
50	3	3.20	0.72	0.01	0.05	0.01	0.75	0.62	0.75	0.75	0.74
	5	5.22	0.67	0.01	0.05	0.01	0.75	0.62	0.75	0.75	0.74
	10	10.24	0.63	0.01	0.04	0.01	0.75	0.63	0.75	0.75	0.74

Table 8: MRU (80%), R = reservation percentage, N = notification period and P = performance measure

R	$N \setminus P$	waiting time	cancel %	cancel mean #	% reject day	% reject night	util. beds	util. IC	util. OT	util. spec.	util. nurses
	1	1.01	0.08	0.00	1.16	2.22	0.89	0.74	0.89	0.89	0.88
16	3	3.01	0.11	0.00	1.19	2.24	0.89	0.74	0.89	0.89	0.88
	5	5.01	0.06	0.00	1.22	2.10	0.89	0.74	0.89	0.89	0.88
	10	10.02	0.12	0.00	1.27	2.15	0.89	0.74	0.89	0.89	0.88
	1	1.04	0.08	0.00	0.50	2.12	0.89	0.74	0.89	0.89	0.88
33	3	3.04	0.11	0.00	0.49	2.15	0.89	0.74	0.89	0.89	0.88
	5	5.04	0.09	0.00	0.51	2.20	0.89	0.74	0.89	0.89	0.88
	10	10.05	0.08	0.00	0.48	2.00	0.89	0.74	0.89	0.89	0.87
	1	2.72	4.92	0.05	0.17	0.85	0.90	0.75	0.90	0.90	0.88
50	3	5.07	5.13	0.06	0.16	0.77	0.90	0.75	0.90	0.90	0.88
	5	7.29	4.70	0.06	0.13	1.02	0.90	0.75	0.90	0.90	0.88
	10	11.86	5.04	0.05	0.15	0.81	0.90	0.74	0.90	0.90	0.88

Table 9: MRU (90%), R = reservation percentage, N = notification period and P = performance measure

B.2 Booked Admissions Without Coordination

reservation	16%	33%	50%
waiting time	1.00	1.01	1.09
cancel %	0.17	0.84	2.90
cancel mean #	0.00	0.01	0.03
% reject day	0.29	0.10	0.03
% reject night	0.00	0.00	0.00
util. beds	0.65	0.65	0.65
util. IC	0.54	0.54	0.54
util. OT	0.65	0.65	0.65
util. spec.	0.65	0.65	0.65
util. nurses	0.64	0.64	0.64

Table 10: BAWOC (70%), O = reservation percentage OT, R = reservation percentage other resources and P = performance measure

reservation	16%	33%	50%
waiting time	1.00	1.12	1.30
cancel %	0.32	1.44	4.84
cancel mean #	0.00	0.01	0.05
% reject day	0.43	0.14	0.04
% reject night	0.02	0.01	0.01
util. beds	0.75	0.75	0.75
util. IC	0.62	0.63	0.62
util. OT	0.75	0.75	0.75
util. spec.	0.75	0.75	0.75
util. nurses	0.74	0.74	0.74

Table 11: BAWOC (80%), O = reservation percentage OT, R = reservation percentage other resources and P = performance measure

reservation	16%	33%	50%
waiting time	1.01	1.04	4.82
cancel %	0.69	2.38	41.28
cancel mean #	0.01	0.03	0.94
% reject day	1.28	0.51	0.18
% reject night	2.37	2.15	0.75
util. beds	0.89	0.89	0.90
util. IC	0.74	0.74	0.75
util. OT	0.89	0.89	0.90
util. spec.	0.89	0.89	0.90
util. nurses	0.88	0.88	0.88

Table 12: BAWOC (90%), O = reservation percentage OT, R = reservation percentage other resources and P = performance measure

B.3 Booked Admissions With Coordination

reservation	16%	33%	50%
waiting time	1.00	1.01	1.09
cancel %	0.00	0.00	0.04
cancel mean #	0.00	0.00	0.00
% reject day	0.25	0.11	0.02
% reject night	0.00	0.00	0.00
util. beds	0.65	0.65	0.65
util. IC	0.54	0.54	0.54
util. OT	0.65	0.65	0.65
util. spec.	0.65	0.65	0.65
util. nurses	0.64	0.64	0.64

Table 13: BAWC(70%)

reservation	16%	33%	50%
waiting time	1.00	1.02	1.28
cancel %	0.00	0.00	0.66
cancel mean #	0.00	0.00	0.01
% reject day	0.42	0.17	0.05
% reject night	0.01	0.01	0.01
util. beds	0.75	0.75	0.76
util. IC	0.62	0.62	0.63
util. OT	0.75	0.75	0.75
util. spec.	0.75	0.75	0.75
util. nurses	0.74	0.74	0.74

Table 14: BAWC(80%)

reservation	16%	33%	50%
waiting time	1.01	1.04	7.12
cancel %	0.11	0.08	4.39
cancel mean #	0.00	0.00	0.04
% reject day	1.23	0.54	0.15
% reject night	2.11	2.07	0.74
util. beds	0.89	0.89	0.90
util. IC	0.74	0.74	0.74
util. OT	0.89	0.89	0.90
util. spec.	0.89	0.89	0.90
util. nurses	0.88	0.88	0.88

Table 15: BAWC(90%)

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