Admission planning

Citation for published version (APA):

Document status and date:
Published: 01/01/1991

Publisher Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 24. Apr. 2021
Petra M.A. PETERS-GROOT

ADMISSION PLANNING: PLANNING OF CAPACITY LOADING AND THROUGHPUT

The environment in which Dutch hospitals operate has recently undergone some major changes. Budget financing has replaced open-financing. The total number of beds in hospitals is reduced, the number of elderly people has grown and patients have been emancipated.

These changes have forced hospitals to adapt their operational goals to the new environment. In turn these changed operational goals have demanded other ways of controlling the organization: in particular the flow of patients.

In this paper it is investigated which demands a new way of control must fulfill. Two conclusions are made. Firstly it is concluded that an important demand to a new way of control is the prevention of blocking. Blocking is the phenomenon that occurs in situations where capacity to release new orders is available in one stage but not in the other stage(s) and there is no buffer between the stages. Secondly it is concluded that the demands set are not met in practice nor in the literature.

A research proposal consists of the design of new concepts to control the flow of patients. The new concepts try to prevent the system from blocking and thus maximizing the throughput of patients. This can be done by controlling the case-mix. The actual case-mix is formed by the patients present in the hospital.

The designing process will be supported will be supported by simulation experiments. These experiments must result in a better insight into the relations between different capacity types in hospitals and must investigate the performance of the different concepts.

1. Introduction

Admission planning currently attracts a lot of attention. This attention can be explained by the changes which recently have taken place in the environment.

The introduction of budget financing has brought an end to open-ended

1 Eindhoven University of Technology, Dept. of Industrial Engineering, Eindhoven, NETHERLANDS
financing. The total expenditure a hospital may make is restricted. Along with bed reductions and a growth in the number of elderly people, this change has led to a scarcity of resources.

A second change that has taken place in the emancipation of patients. Patients have been demanding better service including a reduction in waiting time, more information about the supposed admission data and earlier notice of the admission data.

These changes have implicitly led to adaptation of the operational goals of a hospital to the new environment. A high utilization of all resources and better service to the patients are now the main issues to which admissions planning must contribute.

In this paper we determine consequences of such changes in goals for the way in which the flow of patients must be controlled. Therefore, we describe the hospital in terms out of the production control. Considering the structure of a hospital, demands are set for a new way of control.

Research [Groot, 1989] is described in which it is concluded that the current way of controlling the flow of patients, does not agree with the demands set to reach the new goals. From a literature review concerning admissions planning we concluded that these demands are not met there either. A research proposal in presented. This proposal consists of the design of new concepts to control the flow of patients, which meet the demands set. Simulation experiments will be used to support the designing process and to investigate the performance of these new concepts.

2. Consequences of changes in goals for the control of the flow of patients

It is generally known that changes in goals can lead to adjustments in the control. In this section we describe how the control of the flow of patients must be structured to reach a high utilization of resources and a better service to patients. Therefore, we determine the structure of the flow of patients through the hospital. Considering this structure, demands can be made for the design of the control of the flow of patients.

Structure of the flow of patients

The flow of patients will be described in several ways. Firstly we describe the flow at an aggregate level, considering the flow through the hospital as a black box. Secondly we describe this flow in more detail, also looking at the internal flow in the hospital.
At an aggregate level the flow of patients can be divided into two essentially different flows, with respect to their control. The first flow consists of elective patients. These are patients for whom the admission dates can be postponed. It is possible to control this flow by selecting patients from the waiting list to be admitted on a certain day. The second flow consists of emergency patients. These are patients who must be admitted into hospital at once. It is not possible to control this flow. Yet it is possible to take the amount of emergency patients into account. Research has shown that the average amount of emergency patients per day can be predicted fairly well [Newell (1954, 1963), Swartzman (1970), Karas (1975) Kusters (1988)].

The output of the hospital consists of patients who are discharged. One can not control this flow directly. The specialist decides when a patient can be discharged. Yet research has shown [Kusters, 1988] that is possible to predict even before admission the length of stay in hospital for surgical patients with sufficient reliability.

So it can be concluded that a hospital is system in which the input can be controlled partly. Admission planning is the function which controls the input into the hospital; the patient flow is controlled at operational level. This means that admissions planning is a function which selects patients to be admitted into the hospital. This selection is made within the boundaries set at higher levels. As such admissions planning does not include decision about the kind and number of patients that will be treated in a hospital and about the amount of capacity that will be assigned to a specialism.

At a more detailed level the routing of the patients through the hospital is considered. Figure 1 shows the routing of patients through the hospital.

![Figure 1: The routing of patients through the hospital.](image-url)
After a patient is admitted to the hospital, there are roughly three different routes he/she can follow. Firstly he can go to a ward, stay there for one or two days, undergo an operation, return to the ward and stay there until he is cured. Secondly, he can immediately undergo an operation and afterwards go to a ward and stay there until he is cured. Thirdly, a patient can go to a ward and stay until he is cured. The routes described here can be divided into two routes for surgical patients (the first and the second) and one route for internal patients (the third).

A surgical patient in hospital uses operating room capacity and ward capacity. Ward capacity can be divided into two separate capacities: bed capacity and nursing capacity. There is no linear relation between the number of occupied beds and the workload of the nurses. Therefore these capacity types must be controlled separately. Operating room capacity consists of four related capacity types: specialist capacity, nursing capacity, anesthetist capacity and operating room capacity. There is a linear relationship between these capacity, so the most scarce capacity type determines the total capacity (expressed in hours available time).

During the time a patient stays in the ward sometimes examinations are done at some ancillary departments. These examinations differ from diagnosis to diagnosis. For surgical patients the examination mostly is not critical for the time they stay in hospital. For internal patients it is. These patients must undergo several examination to determine the appropriate diagnosis. Delay in the examinations leads to delay in the determination of the diagnosis and so to delay in the total stay of a patient in hospital. This makes the control of the flow of surgical patients essentially different from the flow on internal patients. Controlling the flow of internal patients means planning the examinations in such a way that the waiting time is minimal. Optimality cannot be guaranteed, because admission it is not know which examinations must be done. This is dependent on the results of the first examinations. The route a patient follows resembles a sort of decision tree. On the hand controlling the flow of surgical patients means admitting the patient at such a time that the necessary activities can be done sequentially. The planning of a particular patient can be optimal, because before admission it is know which route he follows and how much capacity he probably needs.

In the following sections of this paper, attention is focused on the flows of surgical elective and emergency patients.

At this level of detail the possible a patient can follow are globally the same. Several stages (places where a patient is treated, i.e. operating room and nursing ward) are visited in the same sequence. The
amount of capacity that patients need at each of these stages depends on the diagnosis, age and sex of the patient. Between the stages no waiting time is allowed. Waiting time in a hospital means that a patient stays longer than necessary in hospital and thus occupies a bed and uses nursing capacity for a longer time. Waiting time in hospitals (longer than a day) may lead to loss of capacities. This is only true if bed capacity or nursing is the bottleneck of the system.

The conclusion can be drawn a hospital can be seen as a flow shop. However it is a special kind of flow shop, because no waiting time is allowed between the stages and the capacity each patient needs at a certain stage depends on diagnosis, age and sex.

Demands on the control

In recent years a hospital has changed from a system with "infinite" capacities into a system with scarce capacities. A hospital can be seen now a a flow shop in which no waiting time is allowed between the stages and the capacity each patient needs at a certain stage depends on diagnosis, age and sex. In such a system the phenomenon of blocking can occur [Altiok and Perros (1986), Brandwajn and Lily Jow (1988), McCormick, Pinedo, Shenker and Wolf (1989)]. Blocking occurs in those situation where capacity to release new "orders" is available in one stage but no in the other stage. The "order" must wait to be released until space is available at the other stage.

Furthermore, patients have changed from passive into demanding persons. These changes have led to new goals: a high utilization of all resources and better service to the patients.

In this section it will be determined which demands the control must fulfill to adopt to these new goals in relation to the position of the system.

To reach a high utilization of all resources, it is necessary to avoid blocking in the system. To do this it is important to select "orders" in such a way that capacity becomes available in the following phase at the moment that the "order" is processed in the previous phase (or the other way around). This means that processing time, i.e. operating time and length of stay (including bed capacity and nursing capacity) will be important factors in a selection mechanism to prevent blocking. All these factor must be included in a heuristic to prevent blocking and reach a high utilization of all resources, because the selection of patients for admission is the only way to control the patient flow on the operational level. Theoretically it is also possible to control the availability of capacities on the operational level, but in practice this possibility is not used often.
To give a better service to patients, i.e. to reduce the waiting time, to give more information about the supposed admission date and to give an earlier notice of the admission date, it is important to have insight into the situation a couple of days ahead.

To give all the patients a waiting time according to their urgency, the maximum allowed waiting time for each category must be known. Patients must be selected from the waiting list according to minimal remaining waiting time (waiting time minus maximum allowed waiting time).

To give more information about the supposed admission date, there must be insight into the throughput of the system. Therefore, a balance must exist between the number of patients selected out of the different categories. A heuristic to prevent blocking can probably take care of the balance between the number of selected patients.

To give earlier notice of the admission date, there must be insight into the available capacity into the future. A heuristic to prevent blocking can create better possibilities to plan on longer terms.

The conclusion can be drawn that to give a better service to patients only extra demands are set to the sequence in which patients are selected. The procedure to prevent blocking gives enough possibilities to reach the other goals.

3. Admissions planning in Dutch hospitals

The way in which admissions planning in hospitals is done at this moment has been investigated [Groot, 1989]. Or that purpose semi-structured interviews have been held in seven hospitals with people involved in the planning of admissions.

The way of planning admissions in these hospitals can be characterized as follows: If it is known that a bed and operating room (o.r.) time are available at the admission date, patients are called up in sequence of their place on the waiting list. The waiting list is sorted by urgency and within urgency by waiting time. Calling up patients usually takes place one day before actual admission. One does not consider the time a patient stays in hospital. Beds for emergency patients are reserved. Operating room time and nursing time are not reserved for emergency patients.

In most cases one does not know how much capacity a patient will need. This information is not gathered systematically or is not gathered at all. The following deficiencies can be determined:

Length of stay and nursing capacity are not included in the selection mechanism;

- Insight into the available capacity into the future is not present;
Patients are not given early notice of the admission dates; Maximum waiting time is not formulated for each patient category. Several problems were mentioned during these interviews.

In most hospitals seemed to be very difficult to reserve beds for emergency patients. It was not only unknown how many beds should be reserved, but specialists also had a tendency to fill all their empty beds. Besides these problems sometimes no beds were available to reserve for emergency patients.

Most admissions planners had problems convincing specialists that certain patients could not be admitted, because there was no capacity available for these patients. This can mainly be seen as an information problem. The consequences of admitting certain patients are not clear. Information about the capacity needs of a certain patient are not available. Decisions are made on the basis of intuition. Specialists do not always accept this.

In most hospitals it appeared to be very difficult to call in patients for admission on longer notice and to say anything about the time span within which patients would be admitted. This was seen as a problem, because a lot of patients would not show up when they were called in at such a short notice and the personnel in the hospital could not prepare anything before the arrival of the patient. The problems is caused a lack of insight into the situation a couple of days ahead and a planning that was not made for use on longer terms. Sometimes no capacity was available in one of the stages to admit new patients. This led to loss of capacity.

4. Literature review

In the literature only a few descriptions of admissions planning can be found [Elmore and Zimmerman (?), Rubinstein (1976), Hancock and Warner (1983), Amladi, Bliven and Butler (1985), Barrick (1985)]. Most authors only describe a part of the system or deal with problems on another level.

Hancock and Warner (1983) described an admissions planning system in which a given number of patients form each specialism are admitted. The number of patients admitted are dependent on the day of the week and are determined via simulations. Every day the admissions planner looks at the available beds in the hospital. If the number of available beds are between a present maximum and minimum, he does not take action. If the number of available beds are below the minimum scheduled patients are canceled until the minimum is reached. If the number of available beds are above the maximum extra patients are called in until the maximum is
reached. In this system most of the patients know their admission date a month ahead. Beds for emergency patients are reserved.

Elmore and Zimmerman described an scheduled admission model which can equalize patient load, minimize patient waiting time for reservations, minimize turnaways and maximize bed capacity. The model is simple three week moving average of four selected hospital parameters. These parameters are beds opened, discharges, midnight census and emergency room admissions. In the model all elective patients are given an admission data in advance.

Rubinstein (1976) described a scheduling algorithm in which the probability of overflowing the hospital for a future day of operations is estimated. This algorithm is used to schedule elective patients accordingly the calculations. Only beds are taken into consideration when calculating the probability of overflowing.

Amladi, Bliven and Butler (1985) described an admissions planning system in which predictions are made about the available beds in the future. These predictions are made on base of information about the last four weeks.

Barrick (1985) described an admission planning system in which a given number of patients per day is admitted. The number of patients to be admitted on a certain day of the week is determined via simulations. The proposed schedules in the simulation were validated against admission and discharge patterns by service as well as other scheduling constraints such as operating room and cardiac catheterization.

We can conclude that most authors only have considered bed capacity in their admissions planning system. The other demands we have set do a high utilization are only met partly in the system described by Barrick (1985). Yet in most systems a major part of the elective patients is given early notice of the admission date (at least the supposed date). The phenomenon of blocking is not described by any of the authors. Possibly, the situation in America is quit different then the situation in Holland.

5. New concepts: a research proposal

Given the structure of the patient flow in hospitals and the changes that have taken place in the environment, new demands are set for the control of the flow of patients on the operational level. Both in practice and in the literature these demands are not met. Therefore new concepts must be designed. These concepts must be able to meet the following goals and conditions:

Goals: - a high utilization of all resources,
- a better service to patients in the form of a reduction in waiting time. More information about the supposed admission date and earlier notice of the admission date.

Conditions:  
- enough capacity to admit emergency patients immediately;  
- a minor chance for elective patients to be rescheduled.

In this section a research proposal is made for the design and testing of new concepts. This proposal can be divided into two parts.

Firstly a method will be designed to reach a high utilization of all resources by preventing the system from blocking. At first this method will not be designed to give better service to patients. So the selection of patients will take place one day before admission.

To prevent the system from blocking the following factors will be included in the methods: operating time, nursing time per day, length of stay. Further a profile will be made to make sure that capacity is available at the right time. This profile is made for every capacity type and gives an overview of the amount of capacity that must be reserved every day. Capacity reservations are made to make sure that there is enough available capacity to admit all emergency patients and such an amount of elective patients that the utilization of the capacities will be high. Emergency patients can be expected on every day. Elective patients will only be admitted one day before those days that operating room capacity is available. A procedure for the selection of patients must be made. Simulation experiments will be used to support the designing process.

Secondly, two methods will be designed to plan the admission on longer terms. For the design of these methods the method to prevent will be used.

To plan on longer terms there must be insight into the availability of capacity a couple of days ahead. The degree of insight into the situation is dependent on the uncertainty of the situation. There are basically three kinds of situations:
- little or no uncertainty;
- medium uncertainty;
- high uncertainty.

Uncertainty occurs in the number of emergency patients and in the processing time of individual patients. We must investigate if the total amount of uncertainty can be measured.

In the situation of little uncertainty, it is assumed that a week pattern can be used. This assumption is justified because the number and kind of patients treated every year does not change much. A mixed integer programming model will be used to make this week pattern. The goal of this model will be to maximize the throughput of patients
according to the available capacity and the actual division of diagnoses between patients.

In a situation of medium uncertainty a combination of week pattern and short term planning can be used. Simulation experiments are used to test this assumption and to tune the division between week pattern and short term planning.

There are two ways to implement a schedule consisting of a combination of a schedule according to a week pattern and a short term schedule:

- a certain percentage of each patient category is planned according to the week pattern. The rest of each patient category is planned on short terms.

- certain patient categories are planned according to the week pattern. The remaining patient categories are planned on short terms.

In the situation of high uncertainty it is assumed that it is not possible to plan on longer terms. In the simulation experiments this assumption must be tested.

References


WSTĘPNE PLANOWANIE PRZYJĘĆ: PLANOWANIE PRZEPUSTOWOŚCI I POJEMNOŚCI

W ostatnim czasie zasadniczym zmianom uległy warunki zewnętrzne pracy szpitali duńskich. Finansowanie budżetowe zastąpiono finansowaniem otwartym, zredukowano globalną liczbę łóżek w szpitalach, zwiększyła się liczba ludzi starych i polepszyła się jakość usług zdrowotnych. Zmiany te spowodowały, że szpitale zmuszone zostały do przystosowania swoich celów operacyjnych do nowych warunków. Z kolei zmienione cele operacyjne wymusiły wprowadzenie innych sposobów kontroli, w szczególności w przepływie pacjentów.

W artykule zbadano jakie założenia powinien spełniać nowy system kontroli. Sformułowane zostały dwa wnioski. Po pierwsze, stwierdzono, że istotną cechą nowego systemu kontroli jest zapobieganie zjawisku blokowania. Blokowanie występuje w sytuacjach, kiedy na określonym poziomie obsługi pacjenta występuje możliwość wykonania usług ale możliwości tych nie ma na innych poziomach obsługi. Po drugie, udowodniono, że wymagane cechy systemu kontroli nie występują w praktyce, nie są także omówione w literaturze.


Proces projektowania będzie wspomagany eksperymentami symulacyjnymi. Eksperymenty te umożliwią lepszą analizę powiązań między różnymi rodzajami pojemności w szpitalach oraz dokonają oceny wykorzystania różnych, proponowanych koncepcji.