Patient flow based allocation of hospital resources

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PATIENT FLOW
based
ALLOCATION
of
HOSPITAL
RESOURCES

Jan M.H. Vissers

PATIENT FLOW
based
ALLOCATION of HOSPITAL RESOURCES

PROEFSCHRIFT

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PREFACE

This doctoral thesis is the result of a research project on Hospital Capacity Management that started in 1987. As a researcher at the Dutch Hospital Institute I had by that time become involved in a project with a number of hospital managers. They were interested in improving the co-ordination between different planning efforts: activity planning in outpatient departments and operating theatres, resource planning and specialty planning. The report on this project recommended developing a computer model that would support hospital decision making in these areas; they called it a 'model for schedule co-ordination'. It became the cornerstone of this PhD research. After many years of modelling, implementation studies and absorbing theory on production control and organizational change one can still recognize the origin of this research. The added value of the PhD research setting resulted in a more profound understanding of the underlying mechanisms that explain much of the complexity of the hospital as a production system. The interactive way in which the models were developed together with hospitals has kept the focus steady on implementability of research outcomes. Over time Schedule Co-ordination became Master Scheduling of Hospital Resources and, finally, Hospital Capacity Management. This illustrates to some extent the maturation process towards the research outcome of this thesis.

The title I chose for this thesis contains a reference to the research topic studied (**allocation of hospital resources**) and also indicates where my approach (**patient flow based**) differs from traditional ones. The present ways of allocating hospital resources such as beds, nursing staff, operating theatre time and operating theatre staff, often lack a rational basis. They are usually based on historical rights of specialists or expert lobbying rather than on any profound insight into the need for resources rising from patient demand. This may result in loss of effective capacity, which in health care implies fewer patients treated and higher costs of running a hospital. Because of the pressure on hospital expenditure, as is common in many countries, hospital resources tend to be scarce and are often shared between different specialties. Furthermore, the hospital production system shows many dependencies between resources. When a patient is admitted he or she needs a bed, nursing care and, sometimes, operating theatre resources. When a patient consults a specialist in the outpatient department he or she may also need to visit the x-ray department. These dependencies need to be taken into account when allocating hospital resources. This requires some co-ordination effort at hospital level, but most of all a profound insight into the dispersion of patient flows within the hospital system. This should be the basis of resource allocation within a hospital, whatever the organizational structure chosen.

The scientific ambition of this research is to analyze the capacity co-ordination requirements which are inherent to the hospital's complex production system, to develop tools that help hospitals in the decision making process on resource allocation issues to take better account of the capacity co-ordination requirements, and to investigate whether the use of these tools in a project-setting with a participative and learning approach works.

What I, furthermore, would like to accomplish with this thesis can be summarised in a few

statements. First of all, I would like to contribute to improved hospital planning, benefitting those who need to use hospitals and those who work in hospitals. From my first acquaintance with hospitals as researcher with an Applied Operational Research background I was challenged to contribute to hospital practice. The complexity of hospital processes at operational level would presume many sophisticated tools to be necessary to support hospital planning. Strangely enough, the state of the art of hospital planning does not meet these expectations. Apart from the numerous departmental systems and financial systems one rarely encounters integrative systems that take the patient 'order' as starting point and knit the different departments serving patients together. Neither will you see many managerial tools to bridge the gap between hospital strategic planning and day-to-day management of operations. Looking for a research topic it is tempting then to turn to one of many planning problems at operational level, like admission planning or appointment scheduling. After all, this is closest to the operating core of the hospital, where much the greatest part of managerial attention goes to. On reflection I turned to the medium term level of planning for my research, which receives only a very small part of managerial attention. This area is also known as tactical planning or, as I prefer, management control. This is where the conditions for operational planning are supposed to be created as a result of hospital strategic goal setting. This is in my opinion the area where hospitals can benefit most from improvements in the planning process. If it is not possible to make a step forward at this level of planning it does not make much sense to increase the planning effort at operational level. That is what I found out in my earlier research on outpatient appointment systems [Visser, 1979; Visser and Wijngaard, 1979] and in many projects in hospitals since then. The problem of waiting times for patients in outpatient departments is not caused by a lack of planning at operational level but by the implicit decision about the service level in outpatient departments taken at higher levels of planning. This is why I chose to focus on the management control level of planning.

Secondly, I would like to contribute to bridging the gap between micro and macro research approaches to resource management of hospitals. On the one hand there are econometric studies using large amounts of data from many hospitals to try and explain why some hospitals are more cost-effective than others. Apart from the statistical evidence for the importance of variables like hospital-size and bed occupancy-rate, they have little explaining power when it comes to recommendations to improve the use of hospital resources. On the other hand there are the efficiency-type studies which look at the functioning of a specific department using specially collected data. They make it easy to formulate tailor-made recommendations for improvement but they lack the ability to be generalized. Furthermore they tend to create sub-optimal solutions, which may be beneficial to the department investigated but not necessarily to the hospital as a whole - because they lack an overall perspective. With this experience in mind I felt challenged to develop an approach that would combine the generalizability and global perspective of the macro approaches with the insight into the clockwork of the hospital provided by the micro type of studies.

Thirdly, I wanted to develop tools that would be implementable and act as agents of change for hospitals in this area. Tools that can support the dialogue between professionals and managers as to how to improve the use of resources in hospitals. Tools that with some manipulation of existing data or some additional data collection create common consciousness about the business profile of that part of the hospital studied and of the

hospital as a whole. The reason for this design oriented approach stems from my applied educational background and from my involvement with hospital management development at the Dutch Hospital Institute.

This thesis is ultimately intended for researchers and management consultants working in the area of patient logistics and resource management in health care. The case-studies provide also much illustrative material for hospital managers and hospital professionals with managerial interest. Because of the similarities in hospital production systems in general the thesis may also be of interest to hospital settings in other countries.

Acknowledgments

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I owe much to the management of the Dutch Hospital Institute and my colleagues there that enabled me to spend so much time on this research topic during these years. Wijnand Westerink helped me with the modelling, and Patricia van den Ham with the many manuscripts and manuals. The institute's position and its close links with hospital managers offers excellent opportunities for taking up research that contributes to health care management development. I hope this research, though its primary objective is a scientific one, offers much in return to the Dutch hospitals that have enabled me to perform this study.

Finally, I wish to thank my wife Miranda, for her stimulation to my academic career and for her support during hard times and busy supposedly free times, and everyone else for stimulating to bring out the best in me.

CONTENTS

	Page
Preface	iii
Chapter 1. Introduction and Orientation	1
1.1 Research topic: hospital resource allocation	1
1.2 Research context: process and resources, demand and supply, financial and managerial settings, interest groups	5
1.3 Research outline and outline thesis	11
Chapter 2. Problem Analysis	15
2.1 Problem orientation, terminology, problem formulation and research questions	15
2.2 Literature review	21
2.3 Hospital capacity structure	24
2.4 Capacity co-ordination requirements	32
2.5 Outpatient department time-table and diagnostic departments' workload	38
2.6 Evaluating reduction of workload variation	47
Chapter 3. Case-study: Knock-on Effects Operating Theatre Reorganization	51
3.1 Hospital setting	51
3.2 Operating theatre capacity configuration change	53
3.3 Impacts of operating theatre time-table reorganization	55
3.4 Discussion of results reference-case	62
Chapter 4. Model Development, Implementation Strategy and Case-study Design	65
4.1 A production control framework for patient flow and capacity management	65
4.2 Decision support model set on Hospital Capacity Management	76
4.3 Implementation strategy for case-studies	85
4.4 Case-study design	94
Chapter 5. Case one: Reorganizing General Surgery in a Multi-Location Setting	97
5.1 Hospital context and planning problem	97
5.2 Prior organization of surgical activities	99
5.3 In search of a new organization	101
5.4 New organization of surgical activities	110
5.5 Evaluation and discussion case one	116
Chapter 6. Case two: Improving X-ray Workload and Waiting Times of Walk-in Patients from Outpatient Departments	121
6.1 Hospital context and planning problem	121
6.2 Prior organization of x-ray services	123
6.3 Learning to handle the interface with outpatient clinics	128
6.4 Adaptations in the organization of x-ray services	136
6.5 Evaluation and discussion case two	139

Chapter 7. Case three: Flexible and Coherent Allocation of Inpatient Resources	143
7.1 Hospital context and planning problem	143
7.2 Current organization of inpatient resource allocation	145
7.3 Developing a method for flexible and coherent resource allocation	152
7.4 Analyses required for inpatient resource allocation	156
7.5 Outline method for inpatient resource allocation	163
7.6 Evaluation and discussion case three	166
Chapter 8. Comparison of Case-study Findings	171
8.1 Main findings case-studies	171
8.2 Links between cases from the case-study design perspective	174
8.3 Experiences with models without use of the implementation strategy	176
8.4 Conclusions case-studies	179
Chapter 9. Conclusions and Research Recommendations	183
9.1 Main research findings	184
9.2 Research implications and recommendations for future research	189
References	193
Appendix: Description Model Set on Hospital Capacity Management	199
Summary	225
Samenvatting (Summary in Dutch)	229
Curriculum Vitae	235

CHAPTER 1

INTRODUCTION AND ORIENTATION

Increased market-orientation and focus on the client, improved product line management including the relationship with the general practitioner, more involvement of medical staff in managerial decision making, improved overall performance of the hospital system, are main challenges to hospital management today. At the same time hospital resources have become scarcer. Rising health care expenditures as a percentage of the Gross National Product have led to limits being set to health care expenditures at a national level. Although this percentage has stabilized since 1985 [OECD, 1992; van der Zwan, 1993] the scarcity of health care resources has increased because demand is still growing. This tension between demand and supply is especially felt at the hospital level. This makes allocation of scarce hospital resources to specialties within a hospital - the subject of this thesis - an interesting area for managerial decision making and applied scientific research.

This opening chapter introduces the research topic chosen and puts it in a contextual framework. We will illustrate how hospital resource allocation relates to the core process of the hospital, to the matching of demand and supply at hospital level, to the financial setting of hospitals, to developments in the hospital's managerial and organizational structure and application of information technology, and to the different interest groups within the hospital. This is also meant to underline the relevance of the research topic chosen as a key area of hospital managerial decision making whatever changes in managerial context occur. After this broad orientation on hospital resource allocation we will outline the research undertaken and the structure of this thesis, which in short falls into three parts: an analysis of the capacity requirements and supply structure of the hospital, the development of a set of computer models to support hospital managerial decision making on resource allocation issues, and a number of case-studies to illustrate the use of the models in concrete settings.

1.1 Research topic: hospital resource allocation

Hospital resources such as beds and operating theatre time are allocated to specialties in order to enable the provision of care to patients. We will use the term capacity instead of resource when considering the amount of resource allocated to a specialty to perform a specific activity (these concepts will be defined more precisely in the next chapter). These allocations tend to be fixed for the whole year, apart possibly from holiday period arrangements. Resource allocation in hospitals can be characterized as a medium term planning activity. It creates the conditions for the day-to-day operational activities. If the choices made in resource allocation are wrong this will effect daily hospital practice.

Examples of such 'wrong' decisions are:

- wrong level of allocation

When a specialty gets too many or too few resources compared to the demand for

services this results in under-use or over-use of its capacity.

- wrong timing of allocation within the production cycle

The hospital production system is, largely, characterized by a weekly enrolment of activities. If the allocation of resources does not take this weekly production cycle into account this results in structural peaks and troughs in the need for ward resources, operating theatre resources, etc. by the specialty.

- wrong co-ordination of resource allocations

Many hospital resources such as beds, operating theatres and diagnostic departments are shared by specialties. If the allocations of these shared resources to specialties are not co-ordinated well this results in peak and troughs in the workload of wards and other departments.

These decisions result in loss of capacity which can only partly be recovered by flexibility in the use of resources at operational level. To illustrate the occurrence of capacity losses in health care we will provide some data on the use of resources by Dutch hospitals.

Figure 1.1 shows patterns in admissions, discharges and average bed occupancy rates averaged over all hospitals in the Netherlands (1991).

Figure 1.1: Distribution of patient admissions, patient discharges and average bed occupancy rates in Dutch hospitals in 1991 [source: Stichting Informatiecentrum Gezondheidszorg, Utrecht].

From Figure 1.1 one can see that most admissions are concentrated in the beginning of the week and most discharges at the end of the week resulting in a pattern of average bed occupancy rates with an accumulation in the middle of the week. These business profiles also exist on the individual hospital level and for other types of hospital resources as will be shown in the case-studies.

Table 1.1 shows some resource-use related performance measures of Dutch hospitals (1992). While acknowledging the over-simplification of showing such crude ratios Table 1.1 nevertheless illustrates the wide range in performances hospitals show in the use of beds, operating theatres, outpatient clinic sessions and x-ray facilities.

Patients per bed		Occupancy rate beds (percentage)		Procedures per operating theatre		Visits per clinic hour		Procedures per x-ray room	
class	%hosp.	class	%hosp.	class	%hosp.	class	%hosp.	class	%hosp.
<17	2.9	<40		<1000	3.8	<2.0		<3000	
18-20	19.2	40-49	2.9	1000-1500	7.7	2.0-2.9	3.3	3000-4000	5.8
21-23	26.9	50-59	6.7	1500-2000	25.0	3.0-3.9	17.8	4000-5000	25.0
24-26	30.8	60-69	23.1	2000-2500	33.7	4.0-4.9	37.8	5000-6000	29.8
27-29	15.4	70-79	58.7	2500-3000	12.5	5.0-5.9	28.9	6000-7000	17.3
30-32	2.9	80-89	7.7	3000-3500	10.6	6.0-6.9	11.1	7000-8000	9.6
>32	1.9	>90	1.0	>3500	6.7	>7.0	1.1	>8000	12.5

Table 1.1: Distribution of Dutch hospitals over classes of resource-use related performance measures [source: Dutch Hospital Institute, 1992; tool of analysis: BELIS].

These national data on patterns and levels of resource use raise further research questions for this micro level study such as:

- What explanations can be given at the level of an individual hospital for the wide range in resource-use performance?
- What would be reasonable capacity load targets for scarce hospital resources?

The research undertaken may also be relevant for other countries facing scarcity of health care resources. In the Netherlands resource management became particularly important in 1983 when the budgeting of hospital expenditures was introduced. The Dutch hospitals faced a bed-reduction programme of the government to reduce the number of beds per 1000 inhabitants from 5.0 (1974) to 3.4 (1995). Further reductions already are on the way (the 1992 rate for bed availability is 3.5; the new target rate will probably become 2.9). Due to these pressures on the hospital system resources such as beds, operating theatres, nursing staff and paramedical staff became increasingly scarce. The allocation of these resources therefore requires special attention from the hospital management. Most Western European countries show a similar development of a scarce resources driven system, while the U.S.A. system still shows relative over-capacity. The health care system determines the influence of the local hospital management on hospital resource decisions. Table 1.2 illustrates for a number of decisions considered in this study the influence of the government (or agencies above the local hospital level) versus the influence of the local hospital management under different types of health care systems. The influence indications are based on the author's interpretation, as the actual location of decisions in a system depends very much on whether one uses a budgeting system for allocating health care resources.

Resource	Strong government regulated system		Moderate government regulated system		Market regulated system	
	GVMT	MNGT	GVMT	MNGT	GVMT	MNGT
Number of hospital beds	+	--	+	--	--	+
Number of beds per specialty	+	±	--	+	--	+
Hospital specialties	+	--	+	--	±	±
Number of specialists	+	--	±	+	--	+
Number of operating theatres	+	±	±	+	--	+
Number of OT sessions per specialty	+	±	--	+	--	+
Number of outpatient units	+	±	±	+	--	+
Number of clinic sessions per specialty	+	±	--	+	--	+

Table 1.2: Influence on hospital resource decisions by government (GVMT) and hospital management (MNGT) in health care systems with different types of governmental regulation.
Legend for influence indications: + strong, ± moderate, – low.

From the content of Table 1.2 one can see that the degrees of managerial freedom with respect to hospital resource decisions increase as one moves to a system with more market influence, as one would expect. The Dutch health care system stands example for a moderately government-regulated system, the National Health Service in the United Kingdom in its pre-reform (1991) stage for a system that is strongly government-ruled, and the U.S.A health care system for a setting with strong market regulations. As a point of reference for the resource performance level in these different systems one can take the average bed utilization rate [source: OECD]: 73% for the Netherlands (1991), 76% for the United Kingdom (1988) and 66% for the U.S.A.(1991). In the health care setting with moderate governmental influence the dimensions of the hospital are regulated by the government, while the hospital management can decide about the internal allocation of resources to specialties. In the health care setting with strong governmental influence there is less local managerial influence on resource decisions. In the United Kingdom - before hospitals could become autonomous hospital trusts - the little managerial influence was due to the role of the Regional and District Health Authorities, which sometimes even decided about allocation of resources to specialties within a hospital. However, the Hospital Trusts within the new health care system will make the local hospital management position much more like the Dutch situation. The market regulated health care system shows the most managerial freedom, including even decisions regarding the dimensions of the hospital. Because in this system hospitals often show relative over-capacity of resources the internal allocation process draws less managerial attention. If one considers, however, for example

the recent ideas about a reform of the health care system in the U.S.A. involving more government influence this is likely to move the hospital management position towards the situation in Western Europe. This supports the relevance of this study for hospital settings in other health care systems.

1.2 Research context: process and resources, demand and supply, financial and managerial settings, interest groups

To picture the context of the research topic chosen we will describe how resource allocation relates to the core process of the hospital and to the way demand and supply of hospital services is matched at hospital level. We will also describe how allocation of hospital resources relates to the budgeting system for hospitals, to the developments in the organizational and managerial structure of the hospital and the application of information technology, and to the different interest groups within the hospital system. Despite the fact that part of this contextual framework is specific for the Dutch health care system there are many parallels with developments in other countries that make it easy to translate this study on hospital resource allocation to health care settings elsewhere.

Process and resources

The progress of the patient through the hospital is the core process of the hospital as a production system. A simplified picture of this process through the hospital is presented in Figure 1.2. The size of the flows of patients on an annual basis in an average hospital setting is also indicated.

Figure 1.2: Patient process, average patient flows and resources in a hospital [source: Dutch Hospital Institute, 1992; tool of analysis: BELIS].

Patients can enter the hospital system in different ways. Most enter via the outpatient department on referral by a general practitioner (GP) to a specialist clinic. De Melker [1983] and Kersten [1991] pointed at the many administrative referrals controlled by specialists when patients need to be treated for more than one year. The specialist usually refers the patient to diagnostic departments such as x-ray or laboratory. Treatment can then either be outpatient, including different therapies or one-day surgery, or inpatient involving an admission at a ward. Of all outpatients seen about 20% need to be admitted and there is a trend towards increasing the proportion of outpatient treatment.

Alternatively, patients requiring urgent treatment enter the hospital system via the emergency department. This may involve some diagnostic tests and treatment at the department. Some of these patients can return home or are referred for further treatment to the general practitioner. Others need to be admitted as inpatients for treatment. The rest will return for follow-up visits to the outpatient department.

The third way to enter the hospital system is as GP-patient requiring some diagnostic tests to enable the general practitioner to diagnose or treat the patient or to decide about a referral to the specialist. This service of hospitals to general practitioners has developed very rapidly in the Netherlands, accounting for up to 20% of the laboratory workload and more than 25% of the x-ray department workload.

To deliver these services to patients hospitals need resources. Figure 1.2 already contained some indications of the type of resources required. Table 1.3 shows the size of some patient flows and the amount of available resources for a Dutch hospital setting, based on average annual figures over all hospitals in the Netherlands (1992).

Patient flow	Average yearly size in production units	Resources	Average availability in numbers of resource units
outpatients	40.000 first visits	clinic hours	740 hours per week
inpatients	12.000 admissions	beds	450 beds
operations	23.000 procedures	operating theatres	10 theatres
x-ray procedures	80.000 procedures	x-ray rooms	11 rooms

Table 1.3: Patient flows and available resources in a hospital (average figures over all hospitals in the Netherlands) [source: Dutch Hospital Institute, 1992; tool of analysis: BELIS].

Outpatient department resources, ward resources and operating theatre resources need to be allocated to specialties which are responsible for the delivery of outpatient and inpatient treatment to patients. Other departments such as the x-ray department or the laboratory need resources to render a general type of service to all specialties or to general practitioners.

Demand and supply at hospital level

Now that we have explored the supply side at hospital level, we will turn to the demand side. It is an easily made mistake to consider the patient flows shown before as equivalents to the demand for hospital services. Patient flows are based on historical data on hospital

production and stand for the consumption of hospital services by the population using the hospital. Part of the demand for hospital services is not met because of the phenomenon of waiting lists. Demand for services is not the same as need [Culyer, 1976]. Effective health care management should be aimed at maximizing the overlap between need, demand and provision of services [Symes, 1991]. Demand stands for what prospective patients want. Need stands for what the body of professional opinion accepts as legitimate wants. Provision stands for the way resources are provided and organized. In practice we do not achieve total overlap as Figure 1.3 illustrates.

Figure 1.3: Demand, need and provision of services.

When we have an overlap between what customers want (demand) and what is recognized by the body of professional opinion as legitimate (need) but resources are insufficient to meet that demand, this gives rise to waiting lists. In a similar way we could identify other incomplete overlaps as frivolous services (provided but not considered as need, e.g. cosmetic surgery) and unpopular services (provided, considered as need but not very much asked for, e.g. prevention). All of these areas are challenging from a research point of view. In this study, however, we will focus on the area in the middle that represents the overlap between demand, need and provision. This is the care provided to patients that patients want and that is considered as effective by professionals. Waste of hospital resources in this area is primarily a matter of efficiency.

This may be a good point to address the phenomenon of supply-induced demand in health care. Demand for health care services is strongly influenced by supply of services. When a new technology is introduced it will almost inevitably lead to additional demand, resulting sometimes in new demand when the new technology is additional to instead of a substitute

for existing ones. Specialists also have much influence on the demand for services because of the decisions made by them on the length of stay in case of an admission, or on the number of revisits in case of an outpatient treatment, or on the amount of diagnostic services needed. That is why we consider health care as a supply-driven system. As long as demand for services exceeds available health care resources, allocation of hospital resources by the hospital management will inevitably be based on the demand for services as realized in the past.

As zero budgetary growth is likely to be the normal state in health care, the following strategies can be distinguished [Lagergren, 1993]: reducing the demand for care or more effective use of resources. At the hospital management level there are few possibilities to influence demand. One option is to improve the support to the general practitioners to enable them to increase their scope of services. Most options to influence demand are outside the individual hospital management's influence and are related to the health care system like raising the thresholds for access to publicly financed care or increasing co-payments. Hospital management can exercise more influence in the area of efficient use of resources. Options to consider are structural re-designs in the hospital's production system (reduction of inpatient beds, increased use of day-surgery, etc.) or improved systems for management, cost control, monitoring and evaluation of hospital resource use.

Financial setting for hospitals

The Dutch health care system represents a blend of social insurance and private insurance models [Kirkman-Liff and Maarse, 1992]. All employers are obliged to insure their low and middle-income employees while higher-income employees can choose to purchase a private insurance. Employers contribute to this insurance an amount equal to the amount given to the obligatory insured employees. Together with state-support for those who are unemployed, in effect almost every Dutch inhabitant is insured.

The insurers are obligated to accept all middle and low-income people and to operate as economically as possible. This means that the insurers must make every effort to pay the lowest possible fees to the medical providers, and to ensure that hospital budgets are not excessive. These fees and budgets are established through regional and national negotiations between organizations representing insurers and providers. The health insurers are in a transition phase from an administrative role (paying the bills) to a more strategic role (organizing medical care delivery). This is part of the reforms in health care since 1987 that are aimed at introducing more market influence.

Providers such as GPs, specialists and hospitals are mostly private organisations. Providers are obligated to care for all patients. Except for minor co-payments, providers cannot charge patients additional amounts to these agreed upon fees and budgets. Almost all specialists are hospital-based. Patients are free to choose their specialist and hospital once they have a referral from a GP. Specialists are paid on a fee-for-service basis by insurers. They have a contract with the hospital to perform practice, and are generally organized into single specialty 'firms' within the hospital. The firm can use hospital facilities and hospital staff for patient care activities but has to lease office space and pay for clerical staff as far as it concerns financial administration and correspondence.

There are annual negotiations between an individual hospital and the insurer about the budget for the following year. The budget system used is a mixture of fixed and variable

elements. The fixed elements are related to the catchment area of the hospital and to government-regulated dimensions of the hospital, expressed in number of beds and number of full-time equivalent specialists attached to the hospital. The catchment area calculation is based on the number of inpatients and is adjusted every 5 years. The rest of the budget (approximately 50%) is variable and based on the following weighted elements in the production (year's output) of a hospital: admissions, bed days, first outpatient visits and day cases. The weighing factor depends on the hospital size and corresponds with the contribution of the production-unit to the hospital budget formula. Table 1.4 presents an overview of the budget structure for Dutch hospitals [Vandermeulen, Hirs and Wiggers, 1992; Broertjes, 1992].

Fixed elements	percentage of budget	Variable elements	weighing factor	percentage of budget
catchment area	15%	admissions	1150	20%
number of beds	10%	bed days	60	12%
number of FTE specialists	25%	first visits	150	14%
		day cases	410	2%

Table 1.4: Overview budget formula Dutch hospitals.

The negotiations between the insurer and the hospital management involve a discussion on the production for the following year taking into account trends in the production of previous years. Changes could relate to a fast growing specialty, or to a proposal to reduce a long waiting list, or to a continued shift to outpatient care instead of inpatient care. The budget agreed upon and the production volumes related to the budget are a starting point for resource allocation throughout the year. Resources such as beds, operating theatre hours and clinic hours are allocated or adjusted to create capacity for the production targets set. The hospital management does not make detailed production plans from month to month but rather places the resources for production to the specialty's disposal.

Managerial, organizational and information technology developments

The recent years have shown many developments in the managerial and organizational structure and in the application of information technology within a hospital that are relevant for the allocation of resources. The most important managerial developments have been the increase in authority of the board of directors and the involvement of specialists in managerial decision making. The dominant development in the organizational structure is the decentralization and creation of semi-autonomous units within the hospital. These changes in the managerial and organizational structure have a broad support. They are regarded as answers to the contemporary demands from society for an effective and efficient hospital organization that produces patient-centred care as a contribution to the health care system it makes part of. The information technology development has provided us with many data, but its support for managerial decision making is in many areas still disappointing. We will turn to each of these developments below.

During recent years the increased authority of the hospital boards of directors has reflected the demands of society to make these bodies responsible for the use of resources. It also reflects the increasing demand from the public on the shape of services to be provided. Usually a board of directors in a Dutch hospital consists of two directors: a director of general affairs (including finance), and a director of patient services.

Specialists do not bear responsibility for the patient volumes and costs generated by them in the present hospital structure. Allocation of resources (to departments) is traditionally an area of decision making that is separate from the utilization of resources (by specialties). This has become an increasingly unmanageable situation as budgets have decreased, while demand has continued to grow. It has become necessary therefore to improve the integration of specialists into the hospital organization and to ultimately share with them the responsibility for the hospital production and costs [Van Montfort, 1991]. This has been realized by involving specialists gradually more in hospital managerial decision making [Versluis and Hesselink, 1993]. Allocation of hospital resources, linked to resource utilization, is one of the most obvious areas for development of management participation by specialists. This could be by involvement of medical specialists in resource allocation advisory committees such as an admission policy and bed allocation committee or an operating theatres committee, or by negotiations between the hospital management and one of the specialists representing the firm for production arrangements.

The more strategic role of the board of directors in the contemporary hospital organization consequently has led to changes in the internal organizational structure of the hospital. It has become necessary to distinguish semi-autonomous units that report to the board of directors [Van Montfort, 1991; Versluis and Hesselink, 1993]. This is a development similar to the development of clinical directorates in United Kingdom hospitals [Rea, 1992]. In theory this decentralized structure should enable adaptation to developments in the market-segment addressed by the unit, and the units should be able to strike a better balance between demand for services and supply of services. This development of a decentralized hospital structure is highly relevant to the allocation of hospital resources since management autonomy at the specialty level may conflict with the optimal use of shared resources, such as operating theatres, x-ray facilities, etc.

The development of hospital information systems is in many ways important for improving hospital operations and resource management [Lettink, School, Touw and van Vondel, 1991]. The development of applications has traditionally focused on registration of patient activities in different departmental systems, while integration of data at patient level has been underdeveloped. Management information system applications, requiring data from different departmental systems are, therefore, difficult to realize. Based on this observation De Vries [1991] concludes that management information, or better the lack of good management information systems, is an important area for improvement. Allocation of hospital resources is an area of managerial decision making requiring cross-hospital analyses of patient flows and their resource impacts, where one could benefit from management information systems - if they were available. The lack of this type of applications in the current hospital information systems was the main reason why it was necessary to develop in this study dedicated software tools supporting resource allocation decision making.

Interest groups in the hospital

One way of looking to the hospital is to regard the hospital as a political organization with different interest groups [Mur en de Man, 1990]. To know these interests is relevant for a study on hospital resource allocation. The decision making process related to resource allocation requires negotiations between the board of directors, the managers of service departments and the specialties who need resources to produce services.

The board of directors' interest in these negotiations is to ensure that the production volumes are realized as agreed with the insurer. Another interest of the board lies in the potential conflicts between specialties in their battle for scarce resources. When one specialty needs more resources but all resources are in use by specialties, this requires decisions about what specialty will be faced with a reduction of resources.

The amount of resources available for a specialty acts as an upper limit to its production. A specialty will strive therefore to have as many resources as possible to allow for uninterrupted production and also because it does not have to pay for those resources. A high utilization rate of specialty resources, however, makes it less likely that the hospital management will withdraw capacity due to hospital budget cutbacks, or a desire to direct resources elsewhere. As surgical specialties are paid per procedure they tend to concentrate on using operating theatre resources. Medical specialties, however, are paid per bed-day which makes them focus on beds as a resource.

The service department managers play an intermediate role between the demand for resources by specialties and the available resources. Examples of service department managers are operating theatre department managers, outpatient department managers, nursing ward managers, and managers of diagnostic departments such as x-ray or laboratory services. These managers' interest is to ensure a high but stable occupancy level of their resources. The high level of resource use secures the amount of department's staff. The stable occupancy level prevents capacity loss and staff de-motivation because of workload peaks and troughs. The department managers are also able to address opportunities for flexibility in the system. If an operating theatre session is cancelled by a specialist they can try to fill this gap by a session of another specialist who is in need of extra operating theatre capacity.

These three interest groups see for a balanced decision process on hospital resource allocation because of their different responsibility and interest focus.

1.3 Research outline and outline thesis

Having explored the contextual setting we will next outline the research undertaken and the outline of the thesis.

Research outline

The research undertaken falls, broadly speaking, into three parts. The first part is devoted to an analysis of the hospital's supply structure focusing on the hospital's production system. This involves a study of the resources needed for hospital production, the characteristics of these resources and the dependencies between resources when used for generating production. To demonstrate these dependencies and as a reference to a traditional approach, we will study a resource allocation change in a hospital that did not use model support or the participative approach we developed. It concerns a reorganization of the operating theatre

time-table. We will look at the consequences of this change for other parts of the hospital system.

The second part involves different modelling activities. First, a framework for resource management decision making is developed, based on Anthony's three-level hierarchical planning approach [Anthony, 1965 and 1980]: strategic planning, management control and operational control. This research focuses on the management control level, because this is the level for resource allocation decisions. However, we will also discuss links with both other levels. Secondly, a set of 5 computer models was developed to support hospital managerial decision making on resource allocation issues. This modelling activity was a parallel activity throughout the research period and was rooted in a project 'Hospital Capacity Management' at the Dutch Hospital Institute. The models make it possible to analyze a range of resource management issues by visualizing patient flows, resource requirements of patient flows and resource consequences of alternative plans for resource allocation. Each of the models was developed for one or more pilot-hospitals that were faced by resource allocation decisions within the scope of the research topic. Thus, one of the models, for example, addresses the relation between admission planning and the allocation of inpatient resources like beds, nursing staff and operating theatre resources. Each of the models involved a study of the patient flow characteristics, the resource characteristics, relations between flows and resources, decisions to consider and information requirements for decision making. Based on the experiences in the pilot-studies generalized versions of the models were made available as commercial software to hospitals via the institute. Parallel to these commercial activities the models were also used as tools for research activities. The third modelling activity is to develop an implementation strategy for the use of the models in a project setting in hospitals, leading to a participative approach involving the different interest groups in a problem solving process using the models as decision support.

The third part of this research is devoted to a number of case-studies. These case-studies are meant to study the impacts of the use of the models and approach chosen and to illustrate the use of the models in concrete settings. Three case-studies will be reported in which one or more of the models is used, combined with a participative project approach. The first case-study looks at a reorganization of the general surgeons' master planning of activities in a two-location hospital setting. One of the models is used to redesign the surgeons' time-table while taking into account the resource impacts elsewhere in the hospital. Case two concerns a hospital that wants to improve the use of radiology facilities, focusing on the direct flow of patients from outpatient clinics needing immediate service. Two of the models are used to analyze the x-ray department's workload and to propose changes in the x-ray department's planning and in the clinic schedules of those specialties responsible for the peaks and troughs in the flow of direct patients to the x-ray department. The third case concerns a hospital that wants to be more flexible in the allocation of inpatient resources and to improve the co-ordination of allocations of different inpatient resources like operating theatre hours, beds and nursing staff. Two of the models are used to project the future need for inpatient resources per specialty and to develop an approach for yearly adjustments in the allocation of the three interdependent resources.

The three parts distinguishable in the research (hospital capacity structure analysis, modelling activities and case-studies) will return as a threefold in the outline of the thesis.

Outline of the thesis

After this introductory chapter the threefold character of the rest of this thesis is illustrated in Table 1.5.

ANALYSIS HOSPITAL CAPACITY STRUCTURE		
Problem Analysis (Chapter 2)	Demonstration of knock-on effects operating theatre reorganization (Chapter 3)	
MODEL DEVELOPMENT (Chapter 4)		
Production Control Framework	Resource Allocation Decision Support Models	Implementation Strategy & Case-study Design
CASE STUDIES		
Case one Reorganizing General Surgery (Chapter 5)	Case two Interface X-ray Department & Outpatient Department (Chapter 6)	Case three Coherent Inpatient Resource Allocation (Chapter 7)
Comparison of Case-study Findings (Chapter 8)		

Table 1.5: Outline thesis.

The first part of the thesis concentrates on the hospital's capacity structure. In Chapter 2 the problem studied is analyzed by a more precise formulation of the problem and the research questions, a literature review, an analysis of the hospital capacity structure and the co-ordination requirements for optimized capacity management. The effects of not considering capacity co-ordination requirements are demonstrated in Chapter 3 in a case-study that describes the impacts of an operating theatre reorganization on other parts of the hospital organization.

The second part of the thesis reports on the modelling activities undertaken. The production control framework used for resource allocation decisions is described in Paragraph 4.1. Next the development of the set of 5 computer models for resource allocation decision making is reported (Paragraph 4.2). Appendix 1 contains more information on the models. Paragraph 4.3 describes the implementation strategy developed for using the models for resource allocation issues and Paragraph 4.4 the design used for the case-studies.

The third part of the thesis consists of three case-studies in which one or more of the models were used according to the implementation strategy developed (Chapters 5-7). In Chapter 8 the findings of the three case-studies are compared and related to the research questions to be answered.

The thesis concludes in Chapter 9 with conclusions, research implications and recommendations for further research on the topic studied.

CHAPTER 2

PROBLEM ANALYSIS

In this chapter we will analyze the problem investigated in more depth. We will start with a further orientation on the problem, introduce some terminology used in this study and formulate the problem investigated and the research questions to be answered (2.1). Next, we will give a literature review of publications that are relevant for this study on hospital resource allocation (2.2). The emphasis in this chapter lies on the second part where we analyze the capacity structure of the hospital (2.3) and the co-ordination requirements for optimized capacity management (2.4). One of these capacity co-ordination requirements will be illustrated with a statistical analysis of the relationship between the clinic organization of the outpatient department and the workload of diagnostic departments (2.5). Finally, we will discuss how impacts on different resources can be compared and evaluated (2.6).

2.1 Problem orientation, terminology, problem formulation and research questions

In this chapter we will formulate the resource allocation problem more precisely by defining the resources involved, the type of decisions looked at, and performance criteria used to compare alternative resource allocation decisions. Then we will formulate the problem investigated in this study and the research questions to be answered. First, however, we will elaborate on our definition of resource and capacity.

Terminology

Resources can be defined as objects that are used in the production process, but not transformed or consumed by production (such as materials). Examples of resources are operators, buildings, and equipment. Capacity as term is used with different interpretations: one is the ability of a resource to generate production, measured in the amount of products per unit of time; the second is the amount of resource that is available for production. An example of the first of these would be the capacity of an x-ray room expressed in number of procedures per year. The inpatient capacity of a specialty expressed in the number of beds allocated, is an example of the second, and we will focus on this interpretation in our study.

We will focus in this study on **scarce shared resources**. Sharing of resources occurs when different product lines use the same resource, and either requires priority setting for orders arriving at the same time, or specification of the periods where a resource is allocated to one user only. Examples of these in a hospital setting are 'walk-in' patients at an x-ray department, or scheduled sessions for a specialist in the operating theatre department. It needs to be stipulated here that both of these characteristics of resource types (scarce, shared) are used in a relative sense. Scarcity of resources can result from limitations of the available budget or from limited availability on the labour market. Both these types of limitation exist for hospitals. We already discussed the pressure on the hospital budget in the previous chapter. There are also shortages in the labour market for nurses, operating theatre

staff and paramedical staff. Concerning sharing of resources one can distinguish different degrees of sharing between an x-ray department and an operating theatre department. Moreover, in a workstation such as a ward or an outpatient clinic one of the resources used in the station might be shared (e.g. beds or rooms) while another resource (e.g. specialized personnel) might be not shared (see also 2.3). Furthermore, the resources included in this study are restricted to the more general type of resources like rooms and staff that are available in all hospital settings. Equipment is only taken into account as resource as far as linked to room availability, for example an x-ray room for thorax examinations. A listing of resources included and their characteristics is given in 2.3. Because of the labour-intensive character of the hospital as a system this covers the bulk of hospital resources.

Within this range of resources a further distinction can be made that is relevant for the problem formulation, i.e. **'leading' versus 'following' resources**. We call a resource 'leading' if it is the trigger for generating production on other resources, which 'follow'. In Materials Requirement Planning (MRP I) and Manufacturing Resource Planning (MRP II) one uses similar concepts (independent and dependent demand). The 'leading' resource for inpatient production for a surgical specialty is the operating theatre capacity. Bed capacity and nursing staff capacity are 'following' resources because the timing of the capacity requirements of these resource types is determined by the day of operation of patients. In case of the inpatient production for a medical specialty the bed capacity is 'leading' and the nursing staff is 'following'. In general, however, we will not distinguish between these resources and approach the ward as an aggregate resource. The 'leading' resource for outpatient production is the clinic capacity, while the diagnostic department resources are 'following'. The timing of capacity requirements for outpatients at diagnostic departments is determined by the timing of the patient's visit to the specialist clinic. The labels 'leading' and 'following' should not be confused with qualifying resources as bottleneck or not-bottleneck. A bottleneck resource is that resource that is most scarce and therefore determining for the volume of production. In general one tries to maximize the use of the bottleneck resource. Even when the bed capacity or nursing staff capacity would be the bottleneck for inpatient production, still the operating theatre capacity would stay 'leading' in terms of generating production and capacity needs. Bottleneck resources appear as constraints and are capacity oriented terms, while 'leading' and 'following' resources refer to resource requirements of patients and are therefore patient flow based terms.

A third characteristic of resources is whether they are **continuously or intermittently available**. Some resources are available on a continuous basis such as beds and the emergency department; others are, in principle, only available during specified hours, such as regular clinics in the outpatient department, operating theatre sessions, and regular opening hours at diagnostic departments.

In this research we will concentrate on changes in the allocation of 'leading', intermittently available, scarce shared resources in inpatient and outpatient production, and the consequences of their allocation to patient flows for capacity requirements or allocations of 'following' resources.

The type of resource allocation decisions considered in this research can be qualified as **medium term decisions**, so allocation of resources for a period of a few months to one or

two years. More important for the type of decisions made is that they are initiated by an event that is generally accepted as a legitimate moment for reallocation of resources. These events could be labelled as '**critical resource incidents**'. These are events that cause a major shift in the allocation of resources and are therefore critical for the need/use of resources. Examples of 'critical resource incidents' and the decisions taken are:

- an increase in medical staff, leading to a decision to allocate resources to allow for production by the new specialist;
- reshuffling of operating theatre hours because of a need for more time by one specialty and a need for reduction of hours for another specialty, leading to a decision to reorganize the operating theatre time-table;
- cutbacks in nursing staff because of budget reductions, resulting in a decision to close a nursing ward;
- merger of two hospitals, implying a revised allocation of resources for the different locations;
- a new hospital, involving a setting up of time-tables for the new operating theatre facilities and outpatient department facilities.

More examples of 'critical resource incidents' can be given. Essential for the level of support that is required for change in the multi-actor hospital system, is that the immediate cause for reallocation is broadly accepted. We will return to this in Chapter four where we describe the implementation strategy used in this study.

Performance criteria

We should also formulate at this stage how different allocation decisions are compared as to their impact on resource requirements and resource use, i.e. **resource need/use performance criteria**. As we will focus on impacts of allocation decisions of 'leading' resources on the capacity needs of 'following' resources, the figures shown often relate to resource requirements. These figures also represent estimates of the expected use of resources. When we address the actual use of resources we will talk explicitly about resource use instead of resource need. As stipulated in Chapter 1 resource needs in this study refer to average figures based on historical data. We will use three types of criteria for evaluating resource impacts:

- level of resource need/use,
- fluctuations in resource need/use,
- violations of resource restrictions.

We will discuss each of them further down in this section.

To be able to look at resource need/use we will first distinguish different capacity concepts [Dirne, 1990]:

- **potential capacity**: this is the total amount of resources available of one resource type when all resources would be used for production. If we take an operating theatre department with ten operating theatres as an example, the hospital's **potential** operating theatre capacity is said to be ten. Part of the potential capacity is not available for production when part of the capacity is put out of use. This can be labelled as **non-available** capacity. In case of the operating theatre department two theatres could have been put out of use.
- **available capacity**: this is the total amount of capacity that is, in principle, available for production. In this example it would be eight theatres. Part of the available capacity cannot be used for production because of restrictions in use. This can be labelled as **non-**

usable capacity. In this example restrictions in use could be that only one theatre is available for emergency operations outside office hours and that each theatre is not available for one afternoon per month because of scheduled maintenance.

- **usable capacity:** this is the capacity that is normally available for production and that is taken as reference point for calculation of utilization figures. Part of the usable capacity is not used for production because there is no work available. This we can call **idle capacity**. This loss of capacity for an operating theatre department can arise when a scheduled session is cancelled by a specialist or when a session takes less time than scheduled.
- **utilized capacity:** this is that part of the available capacity that is actually used for production, viz. the difference between the usable capacity and the idle capacity. Part of the utilized capacity may be used for non-productive purposes such as set-up activities. This will be labelled as **set-up capacity**. In the example of the operating theatre department set-up capacity will be needed to prepare theatres and to change-over from one patient to another patient within a session.

The remaining capacity will be called the **productive capacity**. In Figure 2.1 these capacity concepts are illustrated.

Figure 2.1: Capacity concepts for resources.

Here we focus on the utilized capacity in relation to the usable capacity, whereby the usable capacity represents the allocated capacity as spoken before. The utilization rate of a resource is the ratio between these two capacity measures, and will be used as criterion for resource requirement or resource use.

The **level of resource need/use** will be calculated by averaging the utilization rates of the sessions or days during a longer period, say a few months to a year.

Fluctuations in the need/use of resources will be determined by calculating the deviations of the (half) daily utilization rates from the average utilization rate. See Figure 2.2 for an illustration of a one week pattern of resource use for an operating theatre department.

Figure 2.2: Average resource utilization level and deviations from the average in a week.

Figure 2.2 shows the utilization rate of, for example, an operating theatre department in half-day units of time during a week. The average level of utilization is 65%; there are considerable differences in the utilization rates between morning and afternoon. In practice one will use a target for the average utilization level of for example 85%.

In this study we are particularly interested in the fluctuations in the need/use of resources over the days of the week. To get enough statistical support for the existence of these weekly patterns of variations in capacity need/use it is necessary to analyze data for a number of weeks. We will use the coefficient of variation as a standardized measure to enable comparison of fluctuations in capacity need/use of different resources or different allocation-schemes for resources. The coefficient of variation is defined as the standard deviation divided by the average (mean value), and will be expressed as a percentage.

There are many restrictions in the allocation and use of scarce shared resources that need to be taken into account. **Violations of restrictions** will be a third category of performance criteria when we compare different allocation-schemes. Examples of restrictions are:

- the totalled sum of specialty resource allocation figures cannot exceed the total hospital capacity for each type of resource;
- the totalled sum of allocations for all types of resources to one specialty cannot exceed

-
- the capacity of the specialty; the same applies also to the individual specialist level;
 - the allocations of specialists within a specialty to different activities for each day of the week should accord with the task structure agreed for the specialty; an example of this type of restriction would be that not more than two out of four surgeons should be allocated simultaneously to operating theatre sessions to allow for emergency attendance;
 - allocations should take into account opening hours of facilities or periods of restricted use of a department; an example of the latter type of restriction is the agreement between a nursing ward and specialists not to make a ward round to see patients during patients' lunch hours or relatives' visiting hours.

These different restrictions imposed on hospital resource allocation make it difficult to optimize the need/use of resources in a hospital setting.

This may be a good point to discuss the definition of efficiency used in this study. Efficiency is the amount of resources used for achieving an objective [Culyer, 1976]. Effectiveness refers to the effects in terms of outcome of the combination of resources used. Efficiency embraces the costs, as well as the effectiveness, of different resource combinations. It recognizes that if the resources are used for the proposed purpose then they are not available for some alternative use. In this study we will investigate the use of resources at an aggregate level of patient flows per specialty. We will be not so much interested in the utilization of a single resource, but focus on the utilization of the combination of resources used by specialties to achieve their patient care objectives.

Problem formulation and research questions

The problem we are investigating in this study is the occurrence of capacity losses in hospitals due to not taking into account capacity co-ordination requirements when changing resource allocations, and the possibilities to prevent these losses. We will especially focus on 'leading' resources such as operating theatres, outpatient clinics and specialists as resource, and investigate how their allocations may introduce peaks and troughs in the workload of 'following' resources.

The research questions which were reasons to start this study on hospital resource allocation can be summarized as follows:

- What are the dependencies between resources in the hospital's production system?
- What are the variations in the use of resources over the part-days within the week?
- To what extent are these variations caused by the way resources are allocated?
- What are the requirements for co-ordination of capacity allocations of resources and what are the goals we are trying to achieve?
- What would a method for resource allocation look like that would fulfil these requirements?
- What approach can be suggested for implementation of this method?
- What are results of applying this method to real-life resource management problems in hospitals?
- What are the conditions for other hospitals to achieve similar results using this method?

The first four questions will be dealt with in the remainder of this chapter, after a review of literature on the subject. The remaining questions will be the starting points for Chapter 1, where we describe the method we developed for hospital resource allocation and the approach used in the case-studies.

2.2 Literature review

This review of literature is limited to studies on resource allocation in health care. According to Bertrand and De Vries [1993] health care requires its own production control approach, due to its specific characteristics and the small support offered by the main streams in production control theory (MRP, Just-In-Time: JIT and Optimized Production Technology: OPT) because of the underlying assumptions used. Some of these specific characteristics and assumptions are:

- production control in an industrial setting focuses on the flow of materials or goods while in a hospital the flow of patients is a primary concern;
- the price-performance level plays a less important role in the health care market, though the importance of it will increase in future health care reforms;
- most industrial production control concepts (such as MRP) assume knowledge about specifications of products and delivery-arrangements, which are not available to this extent in health care;
- specialists are as well as generators of hospital demand as operators in hospital production which requires specialist-time as resource;
- health care services cannot be stocked; therefore, buffers take always the form of waiting lines.

Therefore we will concentrate on health care applications. As we did not find many studies that were comparable or related with our study, we will follow in this review a historical line of operational research health care applications with an emphasis on resource allocation. First, we will point at some overview studies that have addressed resource allocation as one of the application areas of operational research. Next, we will look at studies on resource allocation at the level of the health care system. Finally, we will review some studies that address resource allocation within a hospital setting and that have influenced our study.

Review studies

During the last two decades a number of review studies have been published on operational research applications in health care. We start with a study by Stimson and Stimson [1972] who reviewed nearly 600 studies with only some 25 studies that relate to resource allocation at the overall hospital level. The applicability of these studies was judged to be limited due to the experimental stage of the models developed and by the heavy demand on availability of data in order to make the models operational. Another study published by Shuman, Dixon Speas and Young [1975] pointed at the focusing of most operational research studies on hospital departmental level and the likeliness of sub-optimization in the overall hospital system when one does not take into account the interdepartmental relationships ('housekeeping' approach versus 'whole system' approach). However, the development of such hospital models that allow for study of interactions between components of the complex system was as yet considered to be beyond reach. Then there are two studies by Fries [1976, 1979] reviewing over 300 applications of operational research techniques to the delivery of health care, mostly concerning the different hospital departments.

Apart from these review studies there are also textbooks on operational research applications in health care. A seminal text is 'Patients, Hospitals and Operational Research' [Luck, Luckman, Smith and Stringer, 1971]. Other examples are: Barber [1976], Boldy [1981] and Nelson [1982]. These textbooks represent a mixture of theory on techniques and case-studies as illustrations, which still offer inspiration for those entering this research field. Moreover, these textbooks show increasing eye for the many interactions within the hospital

as a system, which leads to use of less sophisticated techniques and the avoidance of optimization approaches. A few of these case-studies will be mentioned further on as these relate closely to the research approach in this text.

Finally there is a review study specifically on capacity management in health care by Smith-Daniëls, Schweikhart and Smith-Daniëls [1988], which offered much support to position our research. It included 124 studies. They stress the importance of a critical review of literature in this area because of the increased competitive setting in the U.S. health care setting and a need to reconsider future research directions. Instead of focusing on hospitals, they plead for an effective resource management across the entire health care system. A distinction is made between long-term decisions on the acquisition of resources, and medium-term decisions on the allocation of three type of resources: work force, equipment and facilities. In Table 2.1 this classification of capacity decisions is given with the topics that have emerged in the literature.

type of decisions	facility resources	work-force resources
acquisition decisions	facility location and aggregate capacity size, size of inpatient care units, size of ambulatory care facilities	hospital staffing, ambulatory care staffing
allocation decisions	inpatient admission scheduling, surgical facility scheduling, ambulatory care scheduling	assign workers to days and shifts, assign workers to units, assign workers to tasks

Table 2.1: Capacity decision themes in literature.

The majority of research reviewed in each of the categories uses Operational Research techniques and models, such as linear programming, queuing theory, stochastic modelling or simulation. Without going into the details of this table, we notice that the framework presented would label the internal allocation of hospital resources to specialties (our research topic) as an acquisition decision. In Chapter 4 we will introduce a more refined classification of resource decisions that allows a better positioning of research studies in this area. The review study of Smith-Daniëls, Schweikhart and Smith-Daniëls offers further the following recommendations for future research directions in the U.S health care setting:

- more emphasis on ambulatory care studies instead of the traditional focusing on inpatient facilities;
- incorporating organizational goals in capacity decisions to evaluate the trade-off between customer service and resource utilization;
- more emphasis on product-line management instead of process orientation;
- more attention paid to vertical integrated systems which reduce the uncertainty of demand volume.

Some of the research questions posed are of interest to the current research. These are:

- Should we study capacity decisions with an integrated model or should we use a

disaggregation approach similar to the materials requirements planning framework?

- Is a centralized approach to the management of capacity resources a more effective strategy than decentralization?
- How much duplication of services should be offered to satisfy consumer preferences and utilize resources effectively?

The final conclusion of Smith-Daniëls, Schweikhart and Smith-Daniëls is that the future challenge will not be to balance the diverse objectives of for example physicians, nurses and managers; rather it will be to plan and integrate capacity units.

While we underline the importance of looking at integrated systems instead of separate units, we think that our study will show that services that need to be shared because of limited hospital budgets require recognition of the different objectives present in the multi-actor hospital system. But perhaps this applies more strongly to the European health care setting (as opposed to the U.S.A. setting) where competition is more regulated and resource utilization is of a higher level.

Resource allocation in health care

Resource allocation as research topic is foremost used at the level of the health care system. Examples are: the allocation of resources to different regions in a national health care system setting, the allocation of resources to different hospitals in a regional setting, the allocation of resources to different services (i.e. community care versus hospital care) in a vertically integrated system. As our study does not relate to the level of the health care system but to the hospital level, we will not elaborate on this category of studies. Important to note, however, is that these studies often use an econometric approach [Gibbs, 1981], including optimization.

Resource allocation at hospital level

The same types of technique as for the health care system setting have also been applied to the hospital level [a.o. Dowling, 1976; van Montfort, 1980] to describe hospital production. The interactions between the different subsystems in the hospital, as discussed before, make it difficult to use these approaches for specific problems of allocating resources to departments within a hospital. A systems oriented approach that considers the hospital as consisting of many interdependent subsystems and improved availability of data make it possible to take into account the interactions within the hospital system [Güntert, 1990].

Resource allocation at hospital level is still too broad a label to describe studies that are relevant to the present study. Also, resource management is too broad a concept to be useful for this purpose. The Resource Management Initiative in the United Kingdom's National Health Service, for example, tried to utilize resources more effectively by integrating clinicians into management through a clinical directorate, by establishing a closer external auditing of the medical profession, and by implementing information systems [Kirkman-Liff and Maarse, 1992]. The present study falls also in the category of resource management studies but focuses much more on the production control aspect of resource management. To end this review two studies will be described that relate most to the approach followed in this study. Luck, Luckman, Smith and Stringer [1971] report an application that was concerned with the uneven workload forced on some of the paramedical departments because of the way outpatient clinics were organized. A computer programme was written to offer support to hospitals that wanted to improve their clinic time-table's workload for these

departments. This program calculated the impacts of proposed changes on resource use. Because of the restricted availability of computers at that time hospitals were asked to send in their time-table and to provide some data concerning workload impacts on paramedical departments. The processed results with some recommendations were sent back to the hospital to feed the discussion in the hospital. There is also one case-study reported by Nelson [1982] which deals with the construction of a time-table to optimize the use of facilities in an ambulatory care setting.

In this study we will address the same problem as considered by Luck, Luckman, Smith and Stringer (relationship between clinic organization and workload of paramedical departments) but we will also use this approach to other parts of the hospital. We will, however, use in our study the same basic technique of workload balancing. We try to improve on this method in different ways:

- We have first analyzed the most important information requirements for capacity coordination in the hospital, and developed capacity load levelling techniques not only for balancing of resources between departments at overall hospital level but also for balancing of resources at the level of individual specialties.
- Therefore, we have used a more global hospital view to resource allocation problems in a hospital, to allow visualization of resource impacts and knock-on effects throughout the hospital production system.
- Finally we have enabled decision-makers to use this method in their own setting without outside help by developing decision support computer models that act as vehicle for the use of this planning philosophy, and that can be used as tools for data collection and analysis by those involved in a project.

2.3 Hospital capacity structure

To analyze the way hospital capacities are organized we will first describe the different resources considered in this study on hospital resource allocation and then the way these resources are used for hospital production.

Resources considered

In this study we will take a workstation as the basic unit for allocating resources. This is a processing point in the production chain, which requires a mix of resources to contribute to production. One of the resources will be used as a basis for allocation; the amount of other resources needed is determined by a fixed relationship between capacities in the workstation. A workstation in a hospital usually consists of a combination of personnel, accommodation, equipment and specialist-time (see Figure 2.3).

The scheduled specialist-time available in the workstation is a capacity that is not within control of the workstation, despite the fact that workstations are of course controlled within the management structure. The specialist decides where to allocate his or hers time to. The specialist capacity on the other hand is essential to produce. This makes the specialist capacity a critical resource for the workstation. We will later on return to the specialist as a resource and the special features of this resource that explains for a large part the complexity of the problem investigated. In this study we will use an aggregate interpretation

Figure 2.3: A workstation as configuration of resources.

of a workstation, referring to the whole of activities needed to perform for example an operation on a patient. We will not breaking this activity down in for example giving the anaesthetic and performing the surgical procedure, like is done in more detailed analyses for developing systems for operational planning where the analysis is performed at entity level. This reflects also the definition of efficiency used in this study that is not focused on the efficiency of the individual operator but on the efficiency of all resources required for an activity.

Below we will list the workstations in the hospital that are included in this study.

1. operating theatres

The operating theatres department (OT) is one of t he most important resources in the hospital. This is because the work performed in this station is very labour-intensive and involves expensive equipment and materials. Moreover, it is a shared resource and a 'leading' resource for the inpatient production of surgical specialties. The configuration of resources in this workstation exists of theatres, equipment, nursing staff that assists during the operation, the specialist sometimes assisted by a trainee, and the anaesthetist. The allocation of operating theatre capacity to specialties is based on operating theatre hours and is regulated by the operating theatre time-table.

As target level for the capacity utilization of regular sessions in the operating theatre department one often uses in Dutch hospitals an average of 85%. Above this level it becomes difficult to handle semi-urgent operations which are added to the session; assuming there is a spare theatre for the real urgent operations, this high utilization rate can easily result in many hours for proclaimed urgent operations outside office hours.

2. nursing wards

These comprise beds as well as nursing staff. Nursing wards can act as 'leading' capacity or as 'following' capacity. This depends on the type of specialty (surgical versus medical) and on the identification of the bottleneck resource. Most hospitals in the Netherlands use a bed-allocation scheme to allocate beds to specialties. Many have a centralized ward for day cases (one day admissions) or for short-stay patients (with a length of stay up to five days). These

beds tend not to be allocated to specialties. Most wards accommodate different specialties. Nursing staff in general are allocated to wards instead of specialties. The unit of allocation is beds (per specialty) and full-time equivalent (FTE) nurses (per ward).

As a target level for the utilization of beds during the week one often uses in hospital practice an average of 90%. Above this level it becomes difficult on busy days to find an empty bed in case of an urgent admission. As target level for the workload for the nursing staff one uses 100%, reflecting the flexibility of this resource to adapt to circumstances.

3. outpatient department

The outpatient department (OPD) accommodates different clinics where specialists can be consulted by ambulant patients referred by general practitioners. The OPD is the 'leading' resource that generates resource requirements at diagnostic departments. The clinic as workstation combines as resources: accommodation (consulting and examination rooms), nursing and administrative staff, and specialist-time. Sharing of resources between specialties may occur for rooms and staff. The larger the hospital or the specialty, the more sharing of rooms and staff is restricted to the clinics held by specialists belonging to the same specialty. When the hospital's spatial capacity allows for, most specialists prefer to have their own consulting room which also serves as office outside clinic hours.

Clinic hours are used as unit for OPD capacity allocation. For each type of clinic there is a fixed relationship with room needs and staff requirements. The OPD allocation is regulated by a clinic time-table.

4. diagnostic departments

This concerns departments like x-ray, laboratories and organ examination departments (electrocardiograms, lung functions, endoscopies, etc.). In the x-ray department most rooms are only suited for specific categories of examinations linked to the equipment that is located in the room. X-ray technicians can handle most categories of examinations. The intake capacity of laboratories is determined by the specimen collection unit, where blood and other specimen are collected. The capacity of organ examination departments (e.g. ECG, EEG, etc.) is determined by the available rooms, which often have a dedicated purpose, as well as by the often specialized paramedical staff. Some diagnostic investigations are performed by a specialist, requiring specialist-time as resource.

The diagnostic departments are often centralized, general purpose departments, used by more specialties for inpatients as well as outpatients. When a department is almost exclusively used by one specialty, the department often is integrated into the clinic of that specialty. The x-ray department often has a few rooms that handle the walk-in patients flow referred by specialists or general practitioners, that can be examined immediately.

The capacity of diagnostic departments is not allocated to specialties, apart from examinations that are performed by the specialist. Requests for examinations are handled as they arrive, with some examinations requiring preparation and an appointment to be made in advance.

5. treatment departments

Apart from the operating theatres discussed above this concerns departments such as physiotherapy, radiotherapy and occupational therapy. These departments could be described in a similar way as the general purpose diagnostic departments, but they are not included in this study because they are not much affected by allocation decisions at 'leading' resources

and are able to control their workload by an appointment system. While interesting from a point of view of resource use, the emergency department is left out of this study because of its focus on emergency patient flows, while we are concentrating on the regular patient flows. The intensive care department would have been an even more interesting department for resource management, but we decided to leave this resource outside the study's scope because the emphasis here lies more on resource use than on resource allocation.

6. specialist-time as resource

Apart from the resources discussed before, which are allocated to specialties or used by specialties, there is the capacity of the specialist or specialty self to consider as resource. This requires some explanation as this resource is quite different from the other resources considered up to now. The specialist (or a consultant, which term is used in the United Kingdom) as a medical decision-maker generates production within the hospital system [Visser, 1991]. When holding a clinic in the outpatient department they will decide to refer the patient for examinations to diagnostic departments, or to admit the patient as inpatient, or to ask the patient to return for continued outpatient treatment. These actions generate resource requirements, involving often also specialist-time as a resource. In this study we will not go into the diagnostic and treatment process followed by the specialist as a decision-maker to help an individual patient, but will look instead at an aggregate level of patient flows and resources, where we encounter again the specialist but this time as a resource. Specialist-time is the label we use in this study when addressing the specialist as a resource. This is the amount of time available for a specialist to allocate to different categories of activities in the hospital. A general surgeon for example needs to allocate time to the following activity types:

- clinic: to see or treat outpatients in the outpatient department;
- diagnostic examinations: to examine patients using equipment requiring attendance of the specialist, mostly taking place in a special organ examination department (for example gastroenterology);
- operations: to operate on patients in the operating theatre department;
- minor surgery: to perform minor operations on patients in for example a treatment room located in the outpatient department;
- ward round: to see inpatients in wards, for example before or after an operation;
- other activities not in direct contact with patients, such as administration, committees or external activities.

The specialist-time is distributed over different workstations in the hospital. From this point of view specialist-time as a resource can be labelled as a shared resource. It is possible to define per hour of each of the activity types the amount of other resources needed. As specialist-time in the analysis of the hospital capacity structure is so important, we will consider it in more depth.

Specialist-time as shared resource

As we have seen when discussing the resources of workstations, most involve some specialist-time. Specialist-time is a bottleneck capacity for the workstation, because specialists want their time to be fully utilized instead of the capacity of the workstation. Moreover, they are required to enable production in the workstation using the other resources. This makes specialist-time a critical resource for the resource use performance of all workstations.

Specialist-time at the 'aggregate level of a specialist' is, however, a very flexible human resource. The length of the working week of a specialist is not defined. But also when

restricted to office-hours the specialist needs much flexibility in hospital practice. This is because all 100% of 'office-hours' of specialist-time is allocated. When the first scheduled activity of a specialist during a day overruns the scheduled time, this results in start delays of subsequent scheduled activities. During a working day the available specialist-time draws a critical path through a number of workstations. There is no equivalent to the specialist as resource known in production control applications in industrial settings. Considered at the level of a product line (for example diabetic patients) the specialist acts as an operator at different stages of the product line (seeing patients in the outpatient department, referring patients for further examination, deciding to admit a patient, treating patients during their stay at the ward, etc). The specialist is the 'product line key operator' as no one else is able to take over the specialist's tasks, and other categories of personnel assist the specialist in the different workstations. Considered at the level of a specialty, with a number of specialists available within the specialty, the specialist can be considered as a 'multi-functional operator' [Bertrand, Wortmann and Wijngaard, 1990] going from one station to another station, each time being the critical resource for generating production. From a specialty point of view, supposing that each specialist can perform all tasks within a specialty, specialists can be allocated to different functions. Figure 2.4 illustrates this and shows how the hospital's capacity structure on the level of an individual specialist can be represented as a match between specialist-time and workstations.

Figure 2.4: Representation of the hospital's supply structure as an interaction between specialist-time and workstations.

Figure 2.4 shows that the four workstations indicated are dependent on the availability of the operator specialist for the different activities scheduled subsequently during a day. The degree of dependency of departments on the availability of the specialist differs for the departments considered. Outpatient department and operating theatre department are fully dependent on the availability of specialist-time, while diagnostic departments and nursing departments are only dependent for their production as far as they need the attendance of a

specialist. For example, the ward round which requires the attendance of the specialist represents an important but nevertheless a small part of the activities at a nursing ward.

One way of looking at the hospital supply structure would be to consider its capacity as a combination of a number of these individual specialist related capacity structures. This picture can further be complicated by the interactions of these individual structures in workstations that are shared between specialists. Hospitals use sessions to regulate these shared resource interactions in practice.

Sessions as batch-processing mechanism

A session is the period of time allotted to a specialist in a workstation (for instance a clinic) to treat a number of patients (a batch) requiring the same type of activity and resources. It is usual for a session to take a few hours, half a day, or a day, on a regular weekly basis. However, sometimes the frequency of sessions differs from this one-week production cycle. Sometimes sessions are allotted to the specialty instead of a specialist, which gives the opportunity to decide the individual allotment at a later stage. Examples of sessions for a general surgeon are: a general type of clinic session on Monday morning, a session with vascular operations on Monday afternoon, a general type of operating theatre session on Tuesday morning, a fracture clinic on Tuesday afternoon, and so on. Patients are scheduled for these sessions from an elective waiting list (in case of inpatients) or at the moment the need for this service arises (in case of outpatients referred by a general practitioner). Time-tables regulate the allotment of sessions within a workstation to specialists or specialties. The most important time-tables are the OT time-table, which regulates the operating theatre sessions allotment, and the OPD time-table, which regulates the allotment of clinic sessions in the outpatient department. These time-tables tend to perform the same function as Master Production Schedules in industrial settings [Vollmann, Berry and Whybark, 1988]. Instead of defining the number of patients to be treated per production period as the Master Production Schedule does, the time-table can be considered as a production schedule for each week of the year.

One may ask why hospitals use this session-mechanism. Why not organize production around the most critical resource, i.e. the specialist? An alternative along this line would be to create a multi-functional workstation for a specialist, offering all the resources the specialist needs to treat patients. In this way the specialist would be able to treat patients as they turn up: for example, the first patient needing an inpatient treatment involving an operation and post-operative care, the second patient needing an outpatient treatment involving a consultation and some diagnostic procedures, the third patient a minor surgical operation that can be dealt with immediately, etc. In this way the expensive operator-time of the specialist is used in an optimal way. It may be clear that this would require enormous investments in resources to create such a multi-functional workstation that would act as a small hospital operated by a single specialist. This alternative would also be less advantageous for patients requiring consulting two or more specialties for their diagnosis and treatment. Another alternative way of organizing hospital production would be that a specialist requests for instance for operating theatre time as soon as an individual patient needs it, and that this scarce shared resource department decides about the due date to fit this patient in a program with other individually scheduled combinations of patients and specialists. This would optimize the use of the operating theatres as scarce shared resource.

The main reasons why regular production in hospitals is organized in sessions is primarily because of the costs of some of the resources. Operating theatre hours, for example, are very

expensive, involving a room, equipment and various types of surgical personnel. To use this resource efficiently one has to define exactly when specialist and resources are to 'meet' to realize production, not for one patient but for a series of patients. In this way change-over times are minimized, going from one type of operation to another type of operation. Instead of only optimizing the time of the doctor, the question now is to optimize also the time expensive resources are being used. Also, because specialist-time is a flexible resource while this does not apply to operating theatres. Another reason why sessions as combinations of specialist-time and other resources during a defined time-interval are being used, is the fact that the same resources need to be shared between different specialists and different specialties. This is again because of the costs of the resources involved. On the other hand, resources are not easily exchangeable, so that an operating theatre session prepared for a general surgeon can not be exchanged with a session for a gynaecologist without changing the configuration of resources needed.

This way of organizing production in hospitals using the session-mechanism optimizes the use of session hours, but has a number of negative effects, such as:

- It introduces an extra waiting time because sessions are only organized once or twice a week.
- It introduces patterns of workload for other resources required for patients before or after this stage of the process.
- It creates a rigid planning of specialists and resources. Because of the dependency in the system one change of sessions may cause a number of changes elsewhere. Fixing the schedule for one specialist is usually regarded as the maximum attainable. This makes it difficult to rearrange master schedules, once fixed, even if such a rearrangement would benefit the total use of resources at the level of the hospital.

The length of the session or size of the batch is one of the decisions to be made. One alternative would be to use only whole-day sessions (maximal batch size) to avoid change-over times between sessions during the day and to optimize the use of a resource. This system of allocation is often used for operating theatres, because of the expensive character of this resource type. This will require larger 'buffers' of patients for these sessions and it introduces waiting times for patients because sessions are less frequently organized. This is also a reason for some specialties to prefer a balanced distribution of sessions over weekdays. Another consequence of long sessions can be that this requires larger numbers of patients to be admitted at the same day, which can cause peaks and troughs in the requirements for beds and nursing staff at wards.

The use of the session-mechanism as a guarantee for optimized use of specialist-time and expensive resources creates the typical pattern of peaks and troughs in the use of resources at the hospital level. This is because the present way of allocating 'leading' resources that use this session-mechanism does not take into account the overall impact on 'following' resources for the hospital as a whole.

Hospital production management

Having described the different resources considered in this study and the session-mechanism to bring resources together for production, we will now illustrate how this all fits together in hospital practice. Figure 2.5 shows a representation of the production system for the hospital at the aggregate level of planning that relates to the allocation of hospital resources.

Figure 2.5: Representation of the hospital production system at resource allocation level.

Figure 2.5 shows how allocated resources are used for inpatient and outpatient production. It reflects the many interactions in the hospital system, requiring a concept of efficiency that focuses on the combined use of resources. Looking at inpatient production we see that the OT time-table determines when elective patients are admitted via admission planning. This determines when the admitted patients will need a bed and nursing care. The OT time-table can therefore be labelled as the master production schedule that drives the inpatient production. The allocated resources for the operating theatre and the nursing wards, related to the resource requirements resulting from the OT time-table, determine the expected utilization rates of inpatient resources. This applies to surgical specialties because of the involvement of the operating theatre resources. In case of a medical specialty the inpatient production system should be adjusted as production is driven by bed availability. For the outpatient production there are similarities with the inpatient production system. Here the OPD time-table is the driving force behind the outpatient production that determines the fluctuations in the need for resources. This time-table determines when scheduled patients are allotted an appointment via appointment scheduling. This determines again when scheduled outpatients will require clinic resources and diagnostic department resources. The allocated clinic resources and diagnostic departments resources, related to the resource requirements resulting from the OPD time-table, determine the expected utilization rates of outpatient resources.

The OT and the OPD time-tables are both interdependent via the specialty time-table. Most hospitals do not have this time-table available in a detailed and complete way; sometimes a specialty is in possession of such a time-table to enable discussion on the internal organization of the specialty, but often this information is only available piecemeal at hospital level. The importance of this information is obvious. The evaluation of the OT and OPD time-table on resource consequences for 'following' resources can reveal systematic fluctuations in resource requirements. From the point of view of a specialty the specialty time-table offers the necessary information on the allowance to manipulate other time-tables, when looking for alternatives with a better resource need performance. How this evaluation can be performed in a systematic way is considered next, when we look at the requirements for this co-ordination of resources.

Figure 2.5 shows also the importance of considering resource consequences resulting from changed specialty practice. Examples can be given of specialties that for quality or efficiency reasons changed their practice, for instance by introducing outpatient treatment for diagnoses that before required admission, or by introducing a one-day outpatient programme, including clinic visits and diagnostic tests instead of having patients scheduled for visits and tests on separate days. When these specialty practice changes are not extended to the resource consequences for service departments, then this will result in loss in the quality of specialty service intended and in capacity loss or extra capacity requirements at service departments.

2.4 Capacity co-ordination requirements

To avoid variation in the need for resources arising from master schedules around scarce shared resources (i.e. operating theatre, outpatient department and specialty time-table),

different co-ordination mechanisms are required:

- a. co-ordination of the allocations of 'leading' resources to specialties sharing the same resource (capacity load levelling per 'leading' resource department)
- b. co-ordination of the allocations of different resources to one specialty (capacity load levelling per specialty)
- c. co-ordination of the resource-impacts for 'following' resource departments that are shared by specialties but often not allocated to specialties (load levelling per 'following' resource department, for example x-ray)
- d. co-ordination of specialist capacity within a specialty (specialty planning restrictions).

Ignoring these needs results in capacity loss (a-c) or in violations of the specialty's planning restrictions because of the characterization of the specialist as a 'multi-functional operator' (considered within a specialty). We will go into these four requirements for capacity-co-ordination in more detail. First we will represent this problem more formally.

Formal description

This formal description of the problem investigated is meant to formulate the problem in a concise way, and to explore the possibility to approach it as a type of mathematical programming problem.

Notation:

Let: $i = 1, 2, \dots, I$ be 'leading' resource type i
 $j = 1, 2, \dots, J$ be 'following' resource type j
 $\ell = 1, 2, \dots, L$ be specialty ℓ
 $t = 1, 2, \dots, T$ and
 $\tau = 1, 2, \dots, T$ be (half) day periods within a week

and: $x_i(\ell, t)$ =
 amount of capacity of 'leading' resource i at period t allocated to specialty ℓ (allocation function)
 $y_j(i, \ell, \tau)$ =
 amount of capacity of 'following' resource j required in period τ due to resource i allocations to specialty ℓ (workload function)

Then for 'leading' resource i :

- (1) Total amount of capacity allocated at period t

$$X_i(t) = \sum_{\ell} x_i(\ell, t)$$

- (2) Restrictions

$$X_i(t) = TOTCAP_i(t)$$

Total of all allocations in period t equals the total capacity available, i.e. all capacity must be allocated.

And for 'following' resource j:

(1) Total amount of capacity required in period τ

$$Y_j(\tau) = \sum_i y_j(i, \tau)$$

$$\text{with: } y_j(i, \tau) = \sum_l y_j(i, l, \tau)$$

$$\text{and: } y_j(i, l, \tau) = \sum_t a_{i,j,l}(\tau, t) \cdot x_i(l, t)$$

with: $a_{i,j,l}(\tau, t)$ =
amount of capacity (of following resource j) required in period τ due to a unit allocation (of leading resource i) to specialty l in period t .

which represent $i \cdot j \cdot l$ matrices of T by T of the following kind:

$$\begin{vmatrix} a_{1,1} & a_{1,T} \\ & a_{\tau,\tau} \\ a_{T,1} & a_{T,T} \end{vmatrix}$$

(2) Restriction

$$\sum Y_j(\tau) \leq TOTCAP_j(\tau)$$

Total of capacity requirements for period τ is equal or less to total capacity available of resource j at period τ .

Objective function

$$MIN \sum_{i,j} [U_i \cdot CV_i\{X_i(t)\} + V_j \cdot CV_j\{Y_j(\tau)\}]$$

Minimization of the weighted coefficients of variation of allocated capacities of resource i and capacity requirements of resource j over the periods within the week, with:

$$(1) \quad CV_i\{X_i(t)\} = \sqrt{\frac{1}{n-1} \sum_t [X_i(t) - \bar{X}(i)]^2 / \bar{X}(i)}$$

$$\text{and } \bar{X}(i) = \frac{1}{n} \sum_t X_i(t)$$

(2) U_i = weighing function for resource i

(3) $CV_j\{Y_j(\tau)\}$ and V_j analogously defined as for resource i.

The description can be further refined by adding:

- a more refined weighing function with different weighing factors depending on the day of the week and on the part of the day;
- a more detailed level of consideration, i.e. per specialist instead of specialty.

Formulated in this way, the problem could perhaps be approached via Constraint Programming. Constraint Programming [Saraswat, 1993] is a planning method that supports finding feasible solutions in case of many variables that need to be taken into account, when utilization of resources is very high and when the objective function is difficult to define. This seems to apply well to the problem of resource allocation in hospitals. However, in this study we do not follow this route, as will be explained in Chapter 4 where we discuss the modelling part of our study. We can conclude here on the formal representation of the problem as part of this chapter on the problem analysis, that it is possible to define it as a type of mathematical programming problem.

Load levelling of allocated capacities per 'leading' resource department

Each resource department whose resources are allocated to specialties requires co-ordination of allocations over specialties per period, to avoid peaks and troughs in the need of this resource during the weekly production cycle. This procedure is called capacity load levelling [Bertrand, Wortmann and Wijngaard, 1990], and applies to departments such as operating theatres, outpatients and wards (in case of a medical specialty).

In case of the operating theatre department utilization as shown before (Figure 2.2) a considerable reduction of variations in OT resource requirements could be reached if a number of sessions were shifted from morning to afternoon. See Figure 2.6 for a levelled resource requirement scenario. Of course, at this stage we are not yet concerned if these shifts will accord with the commitments of specialists.

Figure 2.6: Capacity load levelling per 'leading' resource department.

If one succeeds in shifting a number of operating theatre sessions to the afternoon, thereby levelling the need for operating theatre resources, the maximum of 32 OT hours could be reduced to 24 OT hours. Alternatively expressed in number of OT crews needed per half day, this would reduce the number of teams to staff all sessions from eight to six.

Load levelling of allocated capacities per specialty

When allocated capacities to specialties are not in balance for each specialty, this may result in one capacity always being overloaded - thus becoming the bottleneck for this specialty - and other resources being under-used. In Figure 2.7 this is illustrated for the workstations in the inpatient process of a surgical specialty.

Figure 2.7: Capacity load levelling per specialty inpatient process.

The figure shows imbalances between the allocated capacities OT-hours, beds and nursing staff. The inter-dependency of these resource types is also investigated by Groot [1993]. In this case one can expect a considerable under-use of allocated OT-time because the bottleneck-capacity nursing staff is already fully used. Alternatively, one might reduce the OT-time allocated and the amount of beds - thereby levelling the successive capacities in the inpatient process per specialty - and still realize the same level of production as before. Of course, if the bottleneck capacity is beds or operating theatres the procedure for levelling needs to be adapted accordingly.

Load levelling for departments that do not allocate resources

Also, one needs to look whether allocations of 'leading' resources to various specialties do not result in peaks and troughs in the requirements for 'following' resources that often do not allocate capacity to specialties. This applies to diagnostic departments like x-ray, laboratories and organ examination departments. A particular good example of this are the peaks and troughs in the workload of the x-ray department when general surgery and orthopaedics, which refer many patients for direct examination to the x-ray department, have their clinics organized concurrently. This lack of co-ordination for resource requirements at 'following' workstations can also arise at a ward that accommodates more surgical specialties whose peak hours for the ward coincide because their OT sessions are not distributed evenly over the days of the week. To prevent these peaks and troughs - implying the occurrence of

capacity losses - requires levelling of capacity needs at 'following' workstations due to allocation of capacity at 'leading' workstations.

Co-ordination of allocated capacities per specialist within a specialty

The last category of capacity co-ordination requirements refers to the intra-specialty organization of activities. As we have seen that sessions involve some specialist-time, every reallocation at a leading workstation influences the internal specialty organization. Reorganization of time-tables therefore requires co-ordination of the allocations of specialty-time from the point of view of a single specialty or even a single specialist. This co-ordination at the level of a specialty prevents violation of arrangements that are agreed upon as important for optimizing the intra-specialty organization. Examples of such arrangements have been given before when discussing restrictions in allocation and use of resources. One example was limiting the number of specialists that are simultaneously scheduled for the same type of activity or expressed differently, levelling of specialist-time allocations of one type of activity throughout the week over the different specialists belonging to the specialty considered. The co-ordination at the level of an individual specialist within a specialty prevents development of a weekly planning that is contra-productive from a point of view of good practice for an individual specialist. An example of this would be a concentration of all OT sessions in the first half of the week. To prevent this, requires a weekly planning for an individual specialist that shows well-distributed time allocations to the same type of activity throughout the week, thus taking care for a good distribution of for example OT sessions over the days of the week.

Capacity losses due to lack of capacity co-ordination

When we summarize the different capacity co-ordination requirements due to the use of the session mechanism for master production scheduling in the hospital, we arrive at the following categories of capacity losses that can occur at the allocation level of planning:

- a. loss of capacity at 'leading' workstations when allocations over specialties are not co-ordinated;
- b. loss of capacities allocated to successive workstations in the inpatient or outpatient process of a specialty when the allocations are not balanced for each specialty;
- c. loss of capacity at 'following' workstations when resource requirements resulting from different specialties are not co-ordinated as to their impact on the workstation's workload;
- d. violations of planning restrictions for optimized practice at the level of a specialty or at the level of an individual specialist, resulting in decreased productivity of specialists and probably capacity loss of specialist-time.

Illustrations of each type of capacity loss will be given at various places in this thesis. However, illustrations are not always proof enough for the general occurrence of these capacity losses in hospitals. This requires more statistical support. To prove the existence of capacity losses reported above, statistical evidence is required on the following points:

- what are the patterns in the use of resources across days of the week?
- to what extent are patterns in capacity use of 'following' resources brought about by patterns in capacity allocations of 'leading' resources, and workload ratios between sessions at 'leading' resources and resource requirements at 'following' resources?
- to what extent do the OT and OPD time-tables represent reality?

Below we will discuss statistical material for the relationship between the OPD time-table and the workload of the diagnostic departments. The relationship between the OT time-table

and ward workload is the subject of one of the case-studies reported in the last part of this thesis.

2.5 Outpatient department time-table and diagnostic departments' workload

To investigate the relationship between the clinic time-table in the outpatient department and the workload of diagnostic departments we analyzed data from a 650 bed hospital. We will focus first at the x-ray department and turn at a later stage to the other diagnostic departments. The x-ray department represents one of the diagnostic departments in the hospital which have a very close relationship with the outpatient department. Other diagnostic departments who have a similar relationship with the OPD are the laboratories and the organ examination departments. Outpatients referred by specialists from outpatient clinics represent the major part of these departments' workload. We selected the x-ray department for this analysis because many outpatients return to the outpatient department with the x-ray picture to see once more the specialist, making the x-ray department the most vivid example of a diagnostic department whose resource utilization performance is very much linked with the OPD clinic organization. We will return to the linkages between the OPD and other diagnostic departments subsequently.

To answer these questions data were analyzed on 7000 clinics held in the first half of 1992, on 110.000 visits by outpatients in this period and on 40.000 examinations in the x-ray department during this period. Data were extracted from the hospital information system and analyzed with a database package [Jacobs and Vissers, 1993a]. This amount of data was necessary to produce reliable statistics based on averages of 26 weeks of workload production. The x-ray department examinations considered concern the central x-ray facilities. Examinations outside the x-ray department (emergency department, wards and operating theatres) were excluded as well as examinations requiring special facilities located elsewhere in the hospital (MRI, CT, etc.).

The x-ray department serves different patient flows that can be labelled as follows:

- appointments flow: outpatients and GP patients who are served with an appointment;
- inpatient flow: inpatients admitted to a ward and served during defined off-peak periods in a day;
- direct clinics flow: patients who are referred from outpatient clinics and are served without an appointment;
- direct GP's flow: patients who are referred by general practitioners and are served without an appointment.

These flows are distinguished because they differ in controllability. Also we expect less fluctuation in the latter two flows and larger fluctuations in the direct flows. It may be clear that we are most interested in the direct clinics flow as we hope to level this flow via the OPD time-table.

Fluctuations in x-ray workload per day of the week

We will first show the size of these flows and its fluctuations at a daily level. The figures shown in Table 2.1 represent numbers of examinations performed. This is not identical to numbers of patients as more examinations per patient do occur. Because of the close relationship between examinations and patients and because our primarily interest is in

fluctuations rather than absolute values it is justified to use these figures as patient surrogates.

Category of patient flow	1 Monday	2 Tuesday	3 Wednesday	4 Thursday	5 Friday	6 overall	7 weekday averages
Inpatients flow: - average number - coeff. of variation	65.0 26.0%	64.7 22.6%	66.5 17.4%	63.1 22.1%	59.5 18.6%	63.7 21.5%	63.7 4.2%
Appointments flow: - average number - coeff. of variation	83.7 15.5%	81.2 14.2%	78.3 15.7%	80.2 12.4%	66.4 16.9%	77.8 16.7%	77.8 8.6%
Direct clinics flow: - average number - coeff. of variation	81.0 21.9%	108.9 18.9%	56.4 26.3%	90.3 18.9%	80.0 18.2%	83.0 28.9%	83.0 22.9%
Direct GP's flow: - average number - coeff. of variation	93.2 15.2%	86.1 19.6%	83.0 15.7%	77.7 16.3%	73.4 18.2%	82.6 18.7%	82.6 9.2%
Total patient flow: - average number - coeff. of variation	323.0 13.9%	340.8 9.9%	284.2 8.5%	311.3 9.8%	279.3 11.5%	307.2 13.2%	307.2 8.5%

Table 2.1: Size of flows per day of the week for the x-ray department (average number of patients per day and coefficient of variation: standard deviation divided by the mean, expressed as percentage; 26 weeks).

Analyzing the data of Table 2.1 one can draw the following conclusions:

- The direct patient flow (clinics and GP's) represents more than half the total flow, where the clinics flow equals the GP's flow (see column 6).
- The direct clinics flow shows the largest overall fluctuations (see column 6).
- Looking at the distribution of flows over the days of the week the direct clinics flow shows the largest fluctuations; the levelled inpatients flow and appointments flow (except for the 'quiet' Friday afternoon) can be explained because these flows are controlled by the x-ray department. The GP flow is out of the department's control because these patients are referred from the various GP clinics. As these clinics are well distributed throughout the week one can expect this flow to be evenly distributed over the days (apart from the increase of GP referrals after the weekend). Column 7 shows the coefficient of variation based on the weekday-averages and illustrates convincingly that the direct clinics flow fluctuates most.

The relative size of the fluctuations in the direct clinics flow compared to the fluctuations in the overall flow for the x-ray department is illustrated below in Figures 2.8 and 2.9.

From Figure 2.8 one can see that the peak day for the direct clinics flow is Tuesday while Wednesday shows a trough. A possible explanation could be that the number of clinics held on Tuesday is larger and the number of clinics held on Wednesday is smaller than on the other days, or that the type of clinics held on these days explains for the differences in number of referrals to the x-ray department. Looking at the fluctuations in the overall flow

Figure 2.8: Direct clinics flow per day of the week

Figure 2.9: Total flow per day of the week

in Figure 2.9 one still recognizes the pattern as shown in the direct clinics flow but the fluctuations are relatively much smaller. One may wonder what gain is to be made by levelling the direct clinics flow when the overall flow does not show tremendous fluctuations. The small size of the fluctuations for the overall flow can also be illustrated by the small coefficient of variation of the mean figures in Table 2.1 (column 7). This requires a closer look at the way an x-ray department is organized. One of the case-studies later on will also address the x-ray department.

The x-ray department has a number of examination rooms, whose functioning divides the x-ray department in two parts. The larger part of the x-ray department consists of special purpose examination rooms with specialized equipment; the type of examinations performed here requires preparation of the patients and can therefore only be done on appointment. This part of the department works on a programmed basis; the amount of work is fully controlled by the department by appointments or by ordering inpatients during slack hours. Therefore, fluctuations in this part of the x-ray department can be kept minimal. The second part of the x-ray department consists of general purpose rooms where various examinations can be performed that do not require an appointment to be made in advance. The workload of this part cannot be controlled by the department. The staff kept apart for serving this part of the department can be considered as a residual capacity after deduction of the staff for programmed examinations. This smaller residual staff is confronted with the relatively larger fluctuations concentrated in this direct-service part of the x-ray department. Therefore, it makes sense to concentrate this analysis on the impact of levelling the direct flow of patients. Table 2.2. illustrates the size of the fluctuations in this total direct flow, broken down to the direct clinics flow and the direct GPs flow.

Using the one-way analysis of variance the hypothesis of identical means for the total direct flow on the five days can be rejected ($P < 0.01$). This supports the existence of at least one factor related to the day of the week that influences the number of direct referrals to the x-ray department. We suppose that one factor is represented by the OPD time-table. As the GPs flow is out of the x-ray department's control, levelling of the direct patient flow should be realized by addressing the direct clinics flow. To calculate the possible gain to be made in the reduction of fluctuations in the total direct flow, we suppose that we are able to eliminate the fluctuations in the direct clinics flow by changing the OPD time-table, while

Type of flow	Monday	Tuesday	Wednesday	Thursday	Friday	overall
Direct clinics flow: - average number - standard deviation	81.0 17.7	108.9 20.6	56.4 14.8	90.3 17.1	80.0 14.5	83.0 16.9
Direct GP's flow: - average number - standard deviation	93.2 14.1	86.1 16.9	83.0 13.0	77.7 12.6	73.4 13.4	82.6 14.0
Total direct flow: - average number - standard deviation	174.3 27.6	195.0 30.6	139.4 20.0	168.0 21.3	153.5 18.5	165.6 30.3

Table 2.2: Direct flows x-ray department and standard deviations per day (based on 26 weeks).

taking care of the evenly distribution throughout the week of the direct referrals resulting from this clinic time-table. From the last column in Table 2.2 one can see that this will reduce the standard deviation of the overall total direct flow, roughly, to about half the size. Due to the variations from week to week not all of the fluctuations can be eliminated. When we calculate the gain in reduction of fluctuations more precisely, it turns out that we can reduce the standard deviation of the total direct flow with 22.6%. Further on (in 2.6) we will discuss the relevance of such a reduction for the resource use of the x-ray department.

A further reduction could be reached at by making the direct clinics flow complementary to the direct GP's flow, resulting in complete levelling of the total direct patient flow. First, we have to check again if the differences in the average direct referrals by GP's per day are significant. This proves to be true ($P < 0.01$). This supports the general notion that the number of direct GP referrals in the beginning of the week is higher than in the second half of the week. Taking again the weekly fluctuations into account we can reduce the standard deviation of the total direct flow with 26.8%. Compared to the reduction by levelling the direct clinics flow, this extra reduction, however, does not have much impact.

Specialty clinic referrals to the x-ray department

Now that we have shown that levelling of the direct clinics flow leads to a considerable reduction in the fluctuations of the total direct flow of patients to the x-ray department, the next step will be to find out how this levelling can be realized. The most important condition that needs to be fulfilled is that an individual clinic session within a week can be characterized by an average number of direct referrals to the x-ray department. Furthermore, when looking at impacts of changes of sessions in the OPD time-table, we assume that the number of referrals from a specific session does not depend on the number of referrals from other sessions or on the day of the week the session is scheduled on. When these conditions are fulfilled the OPD time-table can be used to level the direct clinics patient flow to the x-ray department.

First, we analyze the x-ray production to find out what are the specialties that refer most direct patients to the x-ray department. It appears that Orthopaedics, General Medicine and General Surgery account for more than 50% of the x-ray production. Therefore, we will concentrate the analysis on these three specialties. Table 2.3 shows the average number of patients referred by these specialties for direct x-ray examinations on the different days of

the week and the corresponding coefficients of variation.

Specialty	Monday	Tuesday	Wednesday	Thursday	Friday	weekday averages
Orthopaedics: - average number - coeff. of variation	21.7 31.3%	39.0 23.1%	8.9 46.1%	13.0 50.0%	19.8 46.5%	20.5 56.6%
General Medicine: - average number - coeff. of variation	16.0 42.5%	13.0 49.2%	13.9 41.0%	15.6 34.0%	13.5 45.9%	14.4 9.0%
General Surgery: - average number - coeff. of variation	6.3 71.4%	22.3 24.7%	3.1 77.4%	20.3 32.0%	16.6 39.2%	13.7 62.8%
Other specialties: - average number - coeff. of variation	37.1 29.1%	34.6 34.7%	30.4 32.6%	41.4 26.8%	30.1 32.2%	35.0 13.7%

Table 2.3: Direct patient flow from specialties to the x-ray department per day of the week (based on 26 weeks).

Looking at the specialty referral figures to the x-ray department in Table 2.3 one can arrive at the following conclusions:

- Orthopaedics and General Surgery show large fluctuations in the number of referrals per day. General Medicine shows a balanced pattern of referrals over the days of the week. This is also illustrated by the figures in the last column that represent the overall average and the coefficient of variation of the mean number of patients per day.
- The fluctuations in each specialty do not cancel out. Orthopaedics and General Surgery both show a peak on Tuesday and a trough on Wednesday. This can be illustrated by calculating the coefficient of variation of the mean combined flow of the three specialties resulting in a coefficient of variation of 35.6.
- The total flow of other specialties is reasonably well-distributed over the days of the week, leading to a low coefficient of variation of the mean number of referrals of 13.7% compared to the coefficient of variation of 35.6 of the three specialties together. Also the size of the rest-flow (35 patients per day) is much less than the size of the flow of the three specialties together (49 patients per day).

This leads to the conclusion that the large fluctuations in the direct clinics flow is largely due to the fluctuations produced by referrals from Orthopaedics and General Surgery clinics.

Secondly, we investigate the relationship between the number of patients referred for direct examinations to the x-ray department and an individual clinic session, characterized by the specialist, day of the week and type of clinic (i.e. general or specific). To find this out we analyzed the clinic data of the three major referring specialties at individual session level over 26 weeks. In Table 2.4 we present selected results of this analysis; one specialist per specialty out of a total of 3 orthopaedic surgeons, 11 internists and 7 general surgeons). As sessions were not organized throughout this period due to holidays or other reasons the number of observations per session can be less than 26. The figures mentioned relate to patients referred from clinics, while up to now we have analyzed numbers of x-ray

examinations and used these as approximations to number of patients.

Clinic session			N weeks	average duration (min.)	average number of patients	number of direct x-ray referrals generated by clinic			
Specialist	Weekday	Type				average	coefficient of variation	min.	max.
ORT2	TU-am	general	22	249	28.9	8.5	22.6	5	13
ORT2	TU-pm	general	22	174	16.4	6.1	32.4	2	10
ORT2	FR-am	fracture	23	284	37.0	13.9	23.2	7	19
INT1	MO-am	general	24	257	28.8	3.0	67.2	0	7
INT1	TU-pm	general	23	223	21.3	2.3	68.5	0	6
INT1	WE-am	general	25	259	27.7	2.8	55.5	0	6
INT1	TH-am	general	20	207	19.6	2.0	61.1	0	4
INT1	FR-pm	general	23	227	21.3	2.5	68.5	0	5
SUR7	MO-pm	general	22	186	34.3	4.8	60.0	0	12
SUR7	TH-am	fracture	22	163	46.3	13.7	25.6	7	19

Table 2.4: Number of direct referrals to the x-ray department from individual clinic sessions.

Looking at the figures in Table 2.4 one can draw the following conclusions at the level of individual clinic sessions for the selected specialties:

- Orthopaedics: The general orthopaedic clinic is characterized by a lower average number of referrals, while the fracture clinic has a much higher number of referrals. The low coefficient of variation indicates that the fluctuations from week to week are relatively small.
- General Medicine: The differences between the clinics in number of referrals are small. The number of referrals seems to correspond with the duration of the clinic or the number of patients seen. The larger coefficient of variation indicates larger fluctuations in the number of referrals from a clinic from week to week.
- General Surgery: Here as with Orthopaedics the fracture clinic has a much higher number of referrals than the general clinic. However, the fluctuations in the number of referrals of the general clinic are much larger.

This suggests that there might be a statistically significant relationship between the individual clinic and the number of direct referrals to the x-ray department; the type of clinic appears to be the principal determinant factor for the variations in the level of referrals.

OPD time-table as predictor for direct x-ray referrals

Next, we need the OPD time-table for these specialties to check whether the number of referrals per specialty as shown in Table 2.2 can be explained for by the distribution of clinics of various types throughout the week. For the three specialties and for the other specialties (calculated apart but totalled for the group of specialties) Table 2.5 shows the number of clinic sessions per day of the week and the number of calculated referrals using the referral rates from the different clinic types.

specialty	Mon day	Tues day	Wed nesday	Thurs day	Friday
Orthopaedics:					
- number of general clinics (6.8)	2	4		2	
- number of fracture clinics (13.9)					1
- number of calculated referrals	13.6	27.2		13.6	13.9
- number of referrals observed	21.7	39.0		13.0	19.8
General Medicine:					
- number of general clinics (1.7)	9	6	6	7	8
- number of diabetes clinics (0.1)		1			
- number of calculated referrals	15.7	10.5	10.4	12.2	13.9
- number of referrals observed	16.0	13.0	13.9	15.6	13.5
General Surgery:					
- number of general clinics (2.3)	1	2	2	2	1
- number of fracture clinics (14.0)		1		1	1
- number of arterial clinics (0.5)	2	1	2	1	2
- number of calculated referrals	3.3	19.1	5.6	19.1	17.3
- number of referrals observed	6.3	22.3	3.1	20.3	16.6
Other specialties:					
- number of clinics	43	39	36	42	26
- number of calculated referrals	35.7	33.8	28.6	37.6	35.2
- number of referrals observed	37.1	34.6	30.4	41.4	30.1
Total:					
- number of clinics	57	54	46	55	39
- number of calculated referrals	68.3	90.6	44.6	82.3	70.3
- number of referrals observed	81.1	108.9	56.4	90.3	80.0

Table 2.5: Calculated number of referrals per specialty (based on a fixed time-table and an average referral rate per clinic type) compared to the actual number of referrals (based on 26 weeks).

N.B. between brackets is indicated the average number of referrals per type of clinic.

When we compare the calculated numbers of referrals with the numbers of referrals observed in Table 2.5 we see that the actual numbers tend to be higher than the calculated numbers based on the OPD time-table and average referral rates per type of clinic. An explanation for these differences may be that the actual number is based on examinations while the calculated number is expressed in patients. Furthermore, the actual clinics held during the period of analysis can deviate from the time-table due to holiday, cancellation of sessions or an extra session. Also, the referral rate used to calculate numbers of referrals is an average rate over all sessions of the same type during the week; the number of referrals per session is assumed to be related to the type of session and independent of the day in the week. It is important to note, however, that despite these discrepancies between calculated and actual numbers the order of the days in number of referrals is virtually the same; only Monday and Friday have changed positions but their absolute values are almost at a similar level. Furthermore, when calculating the coefficient of variation over the five day averages the OPD time-table based coefficient of variation appears to be 24.5% while the actual coefficient of variation turns out to be 22.9%. This supports our hypothesis that calculations based on the OPD time-table can be used as approximations to the fluctuations in the direct

referrals to the x-ray department.

Looking at the fluctuations per specialty we see that the large fluctuations for Orthopaedics are mainly due to an unbalanced distribution of clinics over the week, while the high-referring fracture clinic is in balance with two general type clinics on other days. For General Medicine the clinics are well-distributed over the week, which combined with little differences between clinic referral rates leads to a rather balanced number of direct x-ray referrals over the days of the week. For General Surgery the large fluctuations are mainly due to the three high-referring fracture clinics, while the clinics are well-distributed over the week.

OPD time-table and other diagnostic departments

Now that we have shown that the OPD time-table can be used to level the flow of direct clinic patients to the x-ray department we can follow the same approach to other diagnostic departments. To do this we calculated the referral rates from types of clinics per specialty to these departments, making a distinction between direct referrals and indirect referrals (on appointment) and between referrals of patients with a first visit and referrals of patients with a follow-up visit. The indirect referrals were included in this analysis to create a complete picture of the clinics' workload for diagnostic departments. The distinction between first visits and re-visits makes it possible to take into account the patient-mix per clinic and to use specific referral rates for these categories of patients as a refinement of the procedure used up to now. The available data did not allow for some specialties to break down to the same type of clinics as distinguished before (i.e. Orthopaedics and General Surgery). The calculated referral rates are given in Table 2.6.

As can be seen from Table 2.6 referral rates can differ considerably between types of clinic within a specialty, between first and subsequent visits, and between referrals to different diagnostic departments. General types of clinics for General Medicine, for example, generate more x-ray referrals than diabetics clinics, while the referrals to the lab show an opposite picture. Referral rates for first visits tend to be higher for all specialties. The organ examination departments represent a group of departments, some of which have a general purpose and can be visited on a walk-in basis (e.g. ECG) and others are strongly related to one specialty and can only be performed by appointment (e.g. endoscopies); as the figures shown relate to the group of departments the total referral rate can be more than 100%.

To calculate the number of (direct) referrals to diagnostic departments resulting from an OPD time-table one has to calculate the number of referrals per clinic, taking into account the mix of first visits and re-visits and the corresponding referral rates, and sum the clinic referrals per specialty per day of the week. In Table 2.7 is shown for the organ examination departments and for the laboratories what distribution of direct referrals can be expected from the specialty clinics based on the OPD time-table. The grouping of specialties is the same as in Table 2.5.

As can be seen from Table 2.7 also the workload of direct referrals to Organ Examination Departments and Laboratories shows considerable fluctuations over the days of the week. However, compared with the x-ray department the fluctuations of these departments are smaller (coefficients of variation: 14.1% and 11.9%). For the Organ Examination Departments the bulk of direct referrals comes from Cardiology, General Medicine,

Table 2.6: Referral rates from specialty clinics to diagnostic departments.

Specialty	Clinic			X-Ray				Organ Examinations				Laboratories			
	type	average # first visits	average # follow-up visits	First visits		Re-visits		First visits		Re-visits		First visits		Re-visits	
				direct	indirect	direct	indirect	direct	indirect	direct	indirect	direct	indirect	direct	indirect
Cardiology	general	2.0	15.7	13.9	8.3	2.3	4.1	91.9	112.3	84.4	26.8	22.0	38.0	17.6	12.6
General Surgery	general	4.8	25.2	10.6	9.9	11.9	3.7	5.2	1.6	1.4	0.7	8.3	6.2	3.0	2.6
Gynecology	general	4.1	15.0	0.5	1.2	0.5	1.2	11.6	1.1	5.7	1.7	16.6	7.6	8.6	9.9
	obstetrics	4.2	31.1	0.2	0.2	0	0.4	9.4	8.0	2.6	11.0	16.5	7.7	11.4	7.9
	IVF	6.1	5.2	0	0	0	0.5	0	0	2.3	0.5	0.8	27.6	2.3	37.9
Dermatology	general	3.7	16.3	0.3	0	1.0	0	0.3	0.5	1.0	0.0	6.3	0.2	6.3	0.7
	warts	2.5	12.7	0	0	0	0	0	0	0.7	0	0	33.3	6.6	0.7
General Medicine	general	2.3	16.5	32.4	27.1	6.0	7.0	24.8	4.2	2.7	1.8	77.3	13.8	51.5	11.3
	diabetics	0.1	3.8	0	0	1.1	1.1	50.0	0	1.1	0	100.0	50.0	86.4	10.2
ENT	general	9.0	25.7	20.8	8.7	4.2	2.3	0.4	0.1	0.2	0.0	10.8	0.5	1.9	0.1
	specific	2.5	10.8	20.0	13.3	4.6	0	13.3	0	0	0	6.7	0	3.1	0
Pulmonology	general	2.2	28.0	20.4	7.8	7.0	4.0	43.8	11.6	12.2	3.2	34.5	8.5	9.9	5.2
Dental Surgery	general	5.1	6.9	7.8	0.2	4.8	0.5	0	0.0	0.2	0.0	1.7	0.2	2.0	0.5
Neurosurgery	general	2.8	10.7	4.9	11.7	5.8	5.1	0	3.8	0.1	1.0	0.5	7.9	0.6	2.6
Neurology	general	4.5	11.4	19.3	26.5	1.8	5.4	0.9	0.9	0.4	0.7	14.5	8.4	4.9	3.6
Ophthalmology	general	11.5	19.4	0.6	0.6	0.9	0.3	0.1	0.1	0.5	0.1	1.5	0.2	1.9	0.4
Orthopaedics	general	7.5	16.4	41.8	7.1	19.7	3.9	1.8	0.1	1.0	0.3	5.4	1.1	4.5	1.4
Paediatrics	general	2.8	14.0	25.2	6.4	5.8	3.2	1.0	0.9	0.7	0.4	41.1	6.4	10.6	4.7
	specific	0.6	4.8	15.4	19.2	7.5	4.5	0	7.6	2.0	0	61.5	11.5	15.9	3.5
Plastic Surgery	general	9.4	14.5	3.5	1.4	2.0	0.8	1.4	0.6	1.0	0.6	7.3	3.0	5.5	2.9
Psychiatry	general	0.4	2.5	1.3	0	0.6	0	0	0	0.5	0	12.0	8.0	4.4	1.6
Rheumatology	general	1.8	15.3	42.7	2.1	6.5	2.2	1.7	0.9	1.6	0.3	76.5	2.6	42.4	18.4
Rehabilitation	general	1.0	5.2	8.4	2.0	2.6	0.8	0.3	0	0.1	0	1.3	0	1.0	0
Urology	general	5.5	21.9	4.1	21.4	6.8	5.4	2.4	4.4	1.5	1.2	21.9	6.7	9.3	3.4

Specialty	direct referrals organ examination departments					direct referrals laboratories				
	MO	TU	WE	TH	FR	MO	TU	WE	TH	FR
Orthopaedics	0.6	1.2		0.6	0.3	2.2	4.4		2.2	1.1
General Medicine	9.0	7.0	6.0	7.0	8.0	92.7	72.1	61.8	72.1	82.4
General Surgery	1.8	2.4	2.4	2.4	2.4	3.6	4.8	4.8	4.8	4.8
Other specialties	52.2	47.3	43.7	51.0	31.6	83.4	75.6	69.8	81.5	50.4
Total	63.6	57.9	52.1	61.0	43.9	181.9	156.9	136.4	160.6	138.7

Table 2.7: Expected distribution over the weekdays of direct referrals from specialty clinics to organ examination departments and laboratories based on the OPD time-table.

Pulmonology and Gynaecology (see also Table 2.6). Levelling of the direct clinic flow should concentrate on these specialties. Moreover, levelling should take place for each of the departments involved. For the Laboratories most direct referrals are generated by General Medicine, Pulmonology, Cardiology, Gynaecology, Paediatrics and Rheumatology. Levelling of the direct referrals from these departments could be important for the amount of staff necessary at the sample-post and consequently for the waiting-time for patients visiting the sample-post.

Conclusions analysis OPD time-table and workload diagnostic departments

We summarize here the conclusions from the analysis described before on the relationship between the OPD time-table and the workload of diagnostic departments.

The first conclusion is that the fluctuations in the patient flow to the x-ray department are largely due to the direct flow of patients from outpatient clinics. The large fluctuations in the direct clinics flow are caused by a few high-referring specialties. The gain of 23% that can be made in the reduction of fluctuations in the total direct flow is important to the x-ray department because these fluctuations are dealt with by a relatively small part of the department that functions as a separate unit from the rest of the department that deals with the appointment regulated flow of larger examinations.

The second conclusion from the analysis performed is that the OPD time-table combined with referral rates per type of clinic can be used to predict the fluctuations in numbers of direct referrals to the x-ray department. The larger the patient flow considered (all specialties together or a group of high-referring specialties) the better the performance of the OPD time-table as predictor of the direct workload. This makes the OPD time-table a reliable tool for levelling the x-ray department's workload.

The third conclusion is that under the same assumptions as for the x-ray department the OPD time-table can also be used for levelling the workload of other diagnostic departments. The relevance of reducing fluctuations for the department considered, however, can only be discussed when taking into account the internal organization of a department and the way fluctuations in workload are dealt with.

2.6 Evaluating reduction of workload variation

In this study we try to reduce the variation in the workload of various resources (OT-hours, OPD-hours, beds, nursing staff, medical support services) over the days or the part-days of

the week. We assume that this reduction of variation in the use of resources will contribute to the overall efficiency of the hospital, as discussed in Section 2.1, by either treating more patients with the same amount of resources or by treating the same number of patients with less resources. We need, however, a more precise definition of measures that can be used for evaluating the outcomes of our study on hospital resource allocation. We will therefore turn to the method of capacity load levelling used in this study.

Capacity load levelling is an important technique to fulfil requirements for capacity coordination. Before going into this, we should first consider the following points:

- What is the relevance of reduction in workload variation?
- Which reference points are used to evaluate workload differences over days of the week and mornings/afternoons?
- When are differences in workload large enough to justify corrective measures?

Answering these questions will sometimes require subjective judgment, as hard data are not always available. Nevertheless, it is necessary to do so, as otherwise it will not be possible to compare impacts for different resources, which we will need to do in the case-studies later on. We will turn to each of these questions below.

Relevance of workload variation reduction

To reduce the variation in workload over days and part-days of the week is in principle to be considered as a general strategy with positive effects for patients and hospital staff. A smooth flow of patients optimizes the use of facilities, such as reception and waiting rooms, without much overcrowding of facilities and long waiting times. A smooth flow of work has a positive effect on workload perception by hospital staff, which influences staff motivation [De Vries, 1984].

Another strategy would be to adapt the amount of resources to the requirement for resources based on the patient flow. This is possible when resources are flexible enough to adapt to different levels of demand. This is in general easier for personnel resources than for facilities such as rooms and equipment. Personnel resources are more flexible because one can use part-time contracts and a pool for stand-by. For facilities one room extra or one equipment extra for one day may result in idle facilities on other days. Flexibility of resources should, however, be considered at the level of workstations, as in general a mix of resources is required for hospital production. We will turn to the most important workstations as described in 2.3.

For operating theatres flexibility of resources is limited, as operations involve various categories of hospital staff and much expensive equipment. This makes that the reduction of one theatre or one operation team means a real saving of the costs of running the operating theatre department.

For an outpatient department flexibility is easier, as clinics involve mainly administrative supporting staff (often part-time) and less expensive facilities. When the spatial capacity of the outpatient department is not a bottleneck, it should not be too difficult to follow the business profile of the clinics. One should, however, not forget the knock-on effect of clinics on medical support services.

Medical support services departments such as x-ray are again less flexible as the resource mix involves specialized paramedical staff and rooms/equipment. Part-time contracts are less attractive to paramedical staff than in outpatient departments. Here again a reduction of one x-ray room would imply a real saving of the running costs, though it will be less compared with one theatre less in the operating theatre department.

For nursing resources (beds, nursing staff) one should look at flexibility at ward level. Flexibility in beds available for a specialty can be realized by borrowing beds of other specialties; when one ward accommodates different specialties this is easier to accomplish than in case of borrowing beds at other wards. Beds act, overall considered, as a not very flexible resource as specialties prefer to have their own beds without sharing them with other specialties. Nursing staff resources are more flexible and can be adapted to the business profile of a ward by shift scheduling. The many rules and commitments that need to be taken into account for scheduling make it, however, difficult to change existing shift arrangements. This makes nursing staff a less flexible resource than considered at first sight. When it is possible to close a ward or a part of a ward, this will result in savings in the running costs of the hospital.

Finally, specialty resources are, considered separate from other resource, a very flexible resource. Specialists can easily change their schedule as far their own time is concerned. Since specialist-time is linked to planning of workstations, much of this apparent flexibility is restricted by the lesser flexibility of these workstations. Therefore, flexibility of specialty resources should be considered as part of these workstations' flexibility.

Based on these considerations we have given the resources in Table 2.8 a relative weighing factor, between zero and 100, to express the importance of reduction of variation in the use of this resource. A higher weighing factor implies more importance of variation reduction, resulting in more savings in the running costs of a hospital.

Workstation	Weighing factor
Operating theatres	100
Outpatient department	25
Medical support department	50
Ward (beds, nursing staff)	75

Table 2.8: Relative weighing factors for evaluating reduction of variation in resource workload.

From Table 2.8 one can see that we have assigned operating theatres the highest weighing factor and the outpatient department the lowest, with the other resources in between. These rather subjective weighings will help to compare results in reduction of variation in different resources. We will use these weighing factors later on in the case-studies whenever different resources are involved. The use of these factors also reflects our broad definition of efficiency, encompassing the combined performance of all resources involved in the delivery of patient services.

Reference points for workload differences

It is not realistic to strive for perfect balance over the days of the week and over part-days. It is for instance to be expected that Mondays will be in general more busy than Fridays, and that mornings in general will be more busy than afternoons. Again there are no hard data available for what can be considered as reasonable targets, but for the purpose of this study we will use as reference points:

- Mondays and mornings: 10% higher workload
- Fridays and afternoons: 10% lower workload

Thus we will for instance consider a 60-40% workload difference between morning and afternoon as a reasonably balanced situation. Again, we will use these reference points to

discuss resource performance of case-study hospitals.

Reference point for corrective measures

Apart from the above reference points for business profiles that can be considered as normal, we need a reference point for the size of variation that justifies corrective measures to be taken. In a study on uneven workloads in service departments by Luck, Luckman, Smith and Stringer [1971], a coefficient of variation of more than 20% is considered as a rough and ready guide for intolerable day-to-day variation. A very small value of say 0.1 or less would indicate a very smooth workload, while a large value of say 0.4 or more would indicate serious peaks and troughs in the workload. They suggest that improvement should be sought if the coefficient of variation is greater than about 0.15 for half-daily data, or 0.2 for daily data. These values are roughly equivalent to saying that the departmental workloads are fluctuating about the average by plus and minus 20%. De Vries [1984] showed for the workload of a number of nursing wards that the coefficient of variation could be reduced from 20-40% to 10-20%.

When we apply these reference points to the analysis of the fluctuations in the workload of the x-ray department (in 2.5), we can conclude that the coefficient of variation of the direct clinics flow of 28.9% (see Table 2.1) justifies corrective actions.

CHAPTER 3

DEMONSTRATION OF KNOCK-ON EFFECTS: OPERATING THEATRE REORGANIZATION

In this chapter we will illustrate the consequences of not taking into account capacity co-ordination requirements. Therefore, we approached a typical hospital to see how it dealt with changes in its capacity configuration over the past few years. Interviews were held with members of the board of directors and with department managers in outpatient and inpatient services. The talks with the hospital managers focused on the way requests for permanent increases in allocated resources from specialties were dealt with in relation to the annual production agreements with the health care insurance organization. The talks with the department managers were designed to follow through these changes in capacity configuration at the level of individual departments. This contributed to insight as to how the capacity configuration changes investigated in this research were dealt with in hospital practice. The most important change in capacity configuration during recent years was a change in operating theatre allocation due to a reorganization of the operating theatre department. In consultation with the hospital management we decided to concentrate our further study in this hospital on the way this major change in resource allocation was dealt with and on the consequences for other departments in the hospital (Jacobs and Vissers, 1993b). This was of particular interest as these type of 'critical resource incidents' are precisely the subject of our research. Also, because we developed an approach in this study to tackle this type of problem more effectively while this hospital had followed their own course. This offered the opportunity for a case-study that would allow for a comparison with the case-studies to be discussed further on in this text that used the approach developed in this study. This reference case-study concludes the first part of our research described in Chapters 1-3 with an increased focusing on the problem investigated in this study.

First, we will provide some background information on the reference-case hospital and on the reorganization of the operating theatre department that is the subject of this case-study (3.1). Secondly, we will describe the changes in operating theatre capacity configuration in more detail (3.2). Then we will try to simulate the effects that have arisen in other parts of the hospital because of this change in the operating theatre department allocation to specialties. In doing this we will track down the impacts of the operating theatre reallocation on inpatient resource use and the impacts on outpatient resource use due to the forced change of the clinic organization (3.3). We conclude this case-study with a discussion of the results obtained (3.4).

3.1 Hospital setting

The reference-case hospital is a medium-sized general hospital with 276 beds and 15 specialties, offering the full range of basic hospital services for a catchment area of about 80.000 inhabitants. The hospital's organizational chart shows a traditional structure with, below top-management level, a division between inpatient services and outpatient services.

Within inpatient services there are a number of departments such as the admissions department, operating theatre department, and wards. The outpatient services are made up of all the clinics, the centralized information, registration and appointments desk, the emergency department and the organ examination departments. Table 3.1 gives some production statistics of the hospital for 1991/1992, in which period the changes in the operating theatre time-table took place.

Specialty	Number of specialists	Number of admissions		Number of nursing days		Number of day-cases		Number of outpatient visits	
		1991	1992	1991	1992	1991	1992	1991	1992
General Medicine	4	1614	1415	17321	15234	58	77	18226	15269
Pulmonology	1							747	771
Cardiology	2	430	646	4117	5782	3	4	3853	4406
Paediatrics	3	1009	935	8355	7396	66	6	8198	6748
Dermatology	1	4	0	43	0	2	0	10884	8860
Rehabilitation	1							554	684
General Surgery	4	1671	1626	18810	16307	324	379	26959	19200
Orthopaedics	1	402	307	3891	2885	279	257	5757	5124
Urology	1	538	528	3528	3826	131	153	7369	7900
Gynaecology	3	1695	1640	7592	6840	257	249	12013	10413
Ophthalmology	2	268	298	1077	964	41	39	15992	12753
Dental Surgery	1	59	95	176	334	65	92	4862	4900
ENT	3	507	469	2219	2010	993	961	13089	12032
Neurology	2	822	924	10208	12918			10190	8120
Anaesthesiology	2	35	33	146	140	1427	1437	1595	1377
Total	31	9054	8916	77483	74636	3646	3654	140288	118557

Table 3.1: Production statistics reference-case hospital 1991/1992 (source: hospital administration).

Comparing Table 3.1 with some national statistics (1992) the reference-case hospital is characterized by:

- an above-average percentage of day-cases related to admissions plus day-cases (29%, national figure: 24%),
- a short average length of stay (8.4 days, national figure: 10.3 days),
- an about average ratio between outpatient visits and admissions (13.3, national figure: 14.3).

We also looked at the trend in the hospital's production from 1987-1992, which showed the following developments:

- an 8% increase in admissions over the whole period with 1992 being the first year of a drop in admissions, while nursing days steadily decrease;
- a decrease in bed occupancy rate from 80% in the beginning to 75% at the end of the period;
- an increase in operations on inpatients of 25% and on outpatients of 90%;
- an increase of 25% in outpatient visits and in day-cases.

The hospital had known a period of growth in production, followed by an increase in hospital resources by more full-time equivalent (FTE) specialist positions, new specialties and increase in the hospital's budget. The yearly negotiations between the board of directors and the insurance organization followed the developments in production. The hospital management decided on requests from specialties for extra capacities allocated to them by considering production development, development in waiting lists and utilization of facilities.

During the years the hospital management had taken some initiatives to rationalize the utilization of resources. A 38 bed short-stay ward had been introduced that functions as a shared facility for all specialties and whose admissions are regulated by an admission department that also arranges pre-admission tests. Also, a policy had been developed to reduce the number of beds in low-production periods, including a cut-down scheme for operating theatre facilities in the days before the bed closure period.

In 1991 the board of managing directors decided to ask a management consultancy firm to investigate the functioning of the operating theatre department. One of the problems was that the utilization of operating theatre resources by specialties was below standard. Based on a detailed analysis of the functioning of the department and on the use of resources, the consultants made a number of recommendations. They recommended a change in organizational structure and management of the operating theatre department, in the planning of theatres and sessions, and in the staffing of the theatres. They also recommended:

- introduction of whole-day allocations
Instead of the traditional half-day allocations, with a break between morning and afternoon sessions of 1.5 hours, a theatre is allocated to a specialty for a whole day with a flexible timing of a break of half an hour. The advantage of whole-day allocations is that over-running of sessions is dealt with within a specialty and that the breaks can be shortened, resulting in a better utilization of operating theatre hours.
- introduction of an afternoon session for semi-urgent operations
Instead of adding operations, that cannot be postponed to scheduled sessions that are already fully booked, one theatre is kept free every afternoon to use for this category of operations. This allows a better utilization of scheduled sessions by elective surgery.
- development of a revised time-table
To implement the above changes, and also a revision of operating theatre hours because of production developments, a new time-table needed to be developed.

The consultants' report contained a proposal for a revised time-table that would meet the requirements. This new time-table will be described in the next paragraph. During the development of this proposal there had been only small contacts with for example the outpatient department manager to explore possible conflicts in planning. However, there had been no systematic evaluation of the impacts of this change in operating theatre planning on other parts of the hospital organization.

3.2 Operating theatre capacity configuration change

The previous operating theatre (OT) time-table was characterized by four morning-sessions each day and three afternoon sessions from Monday to Thursday (see Figure 3.1). The total capacity of the operating theatre program illustrated in Figure 3.1 is 112 hours. The time-table shown contains already a few whole-day allocations (day-program) introduced at an earlier stage. For the new time-table the consultants considered two options: each day

	OT 1	OT 2	OT 3	OT 4	OT 5
Monday	Gen.Surg.1	Gyn.1	Uro.1	Gen. Surg.2	Anaest.1
	Gen.Surg.1	ENT.1	Orth.1		
Tuesday	Gen.Surg.2	Uro.1	Gen.Surg.3	Ophth.1	
	ENT.1	Dent.Surg.1	Gen.Surg.3		
Wednesday	Orth.1	ENT.2	Gen.Surg.4	Gyn.2	
	Uro.1	ENT.2	Gen.Surg.4		
Thursday	Orth.1	Gen.Surg.2	Gen.Surg.1	Uro.1	Anaest.2
	Orth.1	ENT.2	Gyn.3		
Friday	Gyn.3	Gen.Surg.4	Gen.Surg.3	Ophth.2	Anaest.1
					Anaest.2

Figure 3.1: Original time-table of operating theatre hours allocation.

(N.B.: the Tuesday-afternoon session of Dental Surgery is bi-weekly allocated to Gyn.3, while the Thursday-afternoon session of Gyn.3 is bi-weekly allocated to Dental Surgery)

four whole-day allocations or, alternatively, each day two whole-day allocations and two morning-sessions. The second option offered more flexibility in allocating OT hours to specialties and was therefore recommended by the management consultants (see Figure 3.1).

	OT 1	OT 2	OT 3	OT 4	OT 5
Monday	Gen.Surg.3	ENT.2	Gyn.1	Ophth.1	Anaest.1
	Gen.Surg.3	ENT.2	Acute		
Tuesday	Gen.Surg.1	Orth.1	Dent.Surg.1	Gen. Surg.2	
	Gen.Surg.1	Orth.1	Acute		
Wednesday	Gen.Surg.4	Uro.1	Gyn.2	Gen.Surg.3	
	Gen.Surg.4	Uro.1	Acute		
Thursday	ENT.1	Gen.Surg.2	Uro.1	Gen.Surg.1	Anaest.2
	ENT.1	Gen.Surg.2	Acute		
Friday	Orth.1	Gyn.3	Gen.Surg.4	Ophth.2	Anaest.1
	Orth.1	Gyn.3			Anaest.2

Figure 3.2: Revised operating theatre time-table.

The total capacity of the revised OT program shown in Figure 3.2 is 120 hours. Compared to the whole-day allocations already present in the previous time-table, General Surgery was increased from 3 to 4 sessions, Orthopaedics and Ear-Nose-Throat (ENT) from 1 to 2 sessions, and Urology and Gynaecology from 0 to 1 session.

The largest changes in terms of whole-day allocations occurred therefore for Urology and Gynaecology, which did not have day-programs before and ENT with a doubling of day-programs. The change for General Surgery was the smallest.

The distribution of OT hours over the days of the week is shown in Table 3.2 for the most important surgical specialties.

Specialty	Monday		Tuesday		Wednesday		Thursday		Friday	
	old	new	old	new	old	new	old	new	old	new
General Surgery	10.6	7.0	10.6	11.5	6.6	11.5	8.4	11.5	8.4	4.5
Gynaecology	4.2	4.5	2.2	0.0	4.2	4.5	2.2	0.0	4.2	7.0
ENT	2.2	7.0	2.2	0.0	6.6	0.0	2.2	7.0	0.0	0.0
Ophthalmology	0.0	4.5	4.2	0.0	0.0	0.0	0.0	0.0	4.2	4.5
Orthopaedics	2.2	0.0	0.0	7.0	4.2	0.0	6.6	0.0	2.2	7.0
Urology	4.2	4.5	4.2	0.0	2.2	7.0	4.2	4.5	0.0	0.0
Hospital	26.9	31.0	25.6	23.0	23.8	23.0	29.3	26.5	24.7	28.7

Table 3.2: Distribution of OT hours over the days of the week.

From Table 3.4 one can see that the distribution of OT hours over the days of the week has worsened for most specialties: Gynaecology, ENT and Orthopaedics have on two more days no sessions, Urology on one more day, and for Ophthalmology the time-span between sessions has increased with one day.

3.3 Impacts of operating theatre time-table reorganization

A reorganization of the operating theatre time-table will in general evoke changes in the use of resources elsewhere in the hospital, through the involvement of specialist capacity as a shared resource (viz. 2.3 and 2.4). Changes may, first of all, arise in the use of inpatient resources that are 'following' on the 'leading' resource OT. One might also expect changes in the use of outpatient resources because the OT time-table change will force a reorganization of the outpatient department (OPD) time-table. Figure 3.3 lists the impacts that may arise from an OT time-table reorganization.

The introduction of whole-day allocations for the operating theatres implies a concentration of operating theatre capacity for specialties on certain days of the week, especially for those specialties which do not require operating theatre capacity every day. This concentration of operating theatre capacity will probably introduce structural variations in the need for beds and nursing staff. Patients admitted to be operated on in these OT sessions will arrive in larger groups than before and less well-distributed over weekdays, which leads to

Figure 3.3: Changes in the hospital due to a reorganization of the OT time-table.

concentration of bed requirements and nursing staff requirements around admission days. This could lead to more and sharper peaks and troughs in, for example, nursing workload as patients require more care in the period immediately after the date of operation. The new OT time-table will make it also necessary to change the clinic hours for those specialists who will have changed operating theatre session times. The changes in the time-table of the outpatient department will cause changes in the workload of diagnostic departments such as x-ray and lab, as part of the patients seen in a clinic will be referred for direct examination to these departments.

We will use the scheme of changes illustrated in Figure 3.3 to discuss the impacts introduced in other parts of the hospital because of the new OT time-table.

Changes in inpatient resource use

To observe the changes in inpatient resource use we collected data on 4 weeks of admissions before the introduction of the new time-table (March 1992) and 4 weeks of admissions after its introduction. The periods selected (November 1991 and March 1992) were thought to be comparable in terms of production level. Both are known as busy periods that are not interrupted by (public) holidays. For all of these admissions we extracted from the hospital information system data on the use of beds and the use of operating theatre time. This made it possible to link patient flows in both periods to the OT time-tables in use for these periods, as illustrated in Table 3.3. The various ways of analysis performed with these data are indicated in the table.

As can be seen from Table 3.3 different analyses have been performed to follow through the impacts of a changed OT time-table on the use of inpatient resources. Options one and two seem self-evident: compare the new situation with the previous situation using the data from the corresponding periods. However, to enable inferences about the impacts of the OT time-table change, it is assumed that the patient flows in both periods are about equal. Despite

	OT time-table period one	OT time-table period two
Patient Flow period one	option 1: situation before introduction of new time-table	option 3: simulation of new time-table linked with old patient flow
Patient Flow period two		option 2: situation after introduction of new time-table

Table 3.3: Analyses performed by linking patient flows and time-tables in periods one and two.

the careful selection of comparable periods it turned out that the patient flow in the second period was smaller than expected. This made it difficult to draw conclusions about the cause of the differences between the results of the periods. Later on, the overall production figures for 1992 supported our finding that the number of admissions had been lower than previous year's figures. Therefore, we added a third analysis by linking the patient flow of period one with the new OT time-table. In this way we simulated the impacts of the new time-table by keeping the patient flow in both periods constant. This required some manipulation of data, because all surgical admissions had to be re-directed to the new operating theatre sessions. In Table 3.4 are shown the data on resource use based on the old and the new time-table, using options one and three of Table 3.3. Only the specialties with whole-day allocations are shown.

Specialty	Admissions (per week)	OT utilization		Bed occupancy				Nursing workload			
				average		coefficient of variation		average		coefficient of variation	
		old/new	old	new	old	new	old	new	old	new	old
General Surgery	38	75%	74%	74%	74%	0.12	0.12	79%	79%	0.14	0.14
Gynaecology	44	109%	95%	94%	94%	0.17	0.17	98%	98%	0.16	0.18
ENT	17	127%	131%	55%	56%	0.43	0.41	82%	87%	0.39	0.45
Ophthalmology	8	32%	43%	126%	126%	0.35	0.26	71%	78%	0.23	0.47
Orthopaedics	18	101%	96%	130%	130%	0.16	0.14	77%	78%	0.15	0.13
Urology	15	75%	80%	125%	125%	0.34	0.36	117%	119%	0.47	0.51
Hospital	268	92%	90%	88%	88%	0.07	0.06	79%	79%	0.05	0.06

Table 3.4: Overview of inpatient resource impacts per specialty due to the introduction of a new OT time-table.

From Table 3.4 one can see that for specialties overall:

- average OT utilization decreases marginally,
- average and coefficient of variation of bed occupancy do not change,
- average nursing workload does hardly change, but the coefficient of variation of nursing

workload has increased substantially for ENT, Ophthalmology and Urology. These results suggest that the introduction of the new OT time-table does not cause serious changes in the average use of resources but it certainly will increase peaks and troughs in the workload of nursing staff. The fact that this phenomenon does not show up for bed resources, can be explained by the more close link between operation days of patients and amount of nursing care required while bed requirements are constant throughout the patient's stay.

Considering impacts of the introduction of a new OT time-table for individual specialties one can say that:

- for General Surgery no changes in resource use are expected. This can be explained by the fact that the change in OT allocation is very small and that it concerns a large specialty with OT sessions on all days of the week; the arrival pattern of patients will therefore not be easily influenced by a few reallocations of sessions.
- for Gynaecology one can expect a lower but still very high utilization of OT hours and a small increase in the variation of nursing workload. Here introduction of the new time-table does not lead to serious changes in inpatient resource use.
- for ENT the variation in bed use is slightly decreased while average and variation of nursing workload are increased. This suggests that the introduction of the new time-table will have serious consequences in the use of inpatient resources by this specialty.
- for Ophthalmology an increase in average utilization of OT hours and beds can be expected, while variation in bed requirements decreases and variation in nursing workload doubles. The large nursing workload variation increase is also caused by the new session on Monday that requires patients to be admitted on Sunday, when nursing staff availability is low. Therefore we can say that the inpatient resource use of this specialty will be seriously affected by the change introduced.
- for Orthopaedics one can expect an average lower but still very high OT utilization, with slightly decreases in the variation of bed requirements and nursing workload. Introduction of the new time-table has had small positive effects for the inpatient resource use by this specialty.
- for Urology one can expect a higher OT hours utilization, but variation in bed requirements and especially nursing workload have increased. Therefore one can say that the new time-table does lead to serious consequences for this specialty.

To summarize, the consequences of the introduction of the new time-table are most serious for the variation in nursing workload requirements, which show considerable increase for ENT, Ophthalmology and Urology.

Another way of looking at the impacts on inpatient resource use is to show results for the nursing wards. This makes sense because the hospital has multi-specialty wards and a policy not to allocate beds too strictly to specialties. The results of Table 3.4 are based on a projected allocation of beds and nursing staff. The results in Table 3.5 are therefore a better representation of the consequences for bed occupancy and nursing workload in the hospital.

Looking at impacts on ward resource use in Table 3.5 one can say that:

- the consequences of the introduction of the new OT time-table on bed requirements are negligible; the average has of course not changed because the amount of admissions is

Ward	Number of admissions (per week)	Bed occupancy				Nursing workload			
		average		coefficient of variation		average		coefficient of variation	
		old/new	old	new	old	new	old	new	old
Day-surgery	76	152%	152%	0.22	0.22	86%	86%	0.17	0.17
Short-stay	30	98%	98%	0.41	0.40	116%	117%	0.37	0.35
IC ward	8	36%	36%	0.43	0.43	8%	8%	0.48	0.48
Ward 1	26	99%	99%	0.07	0.07	85%	85%	0.08	0.09
Ward 2	36	83%	83%	0.06	0.06	80%	80%	0.09	0.10
Ward 3	43	72%	72%	0.12	0.11	98%	98%	0.14	0.15
Ward 4	36	78%	78%	0.18	0.15	84%	84%	0.15	0.14
Ward 5	13	98%	98%	0.12	0.12	79%	79%	0.13	0.14
Hospital	268	88%	88%	0.07	0.06	79%	79%	0.05	0.06

Table 3.5: Overview of inpatient resource impacts per ward due to the introduction of a new OT time-table.

kept the same, but the variation in bed requirements has not increased and sometimes even decreased.

- the consequences for nursing staff workload at ward level are slightly negative as far as the variation of nursing workload is concerned; four wards show increased variation while two wards show decrease.

Overall, the consequences of the introduction of the new OT time-table for wards are small, and are larger for nursing workload than for bed requirements. The consequences at specialty level are probably out-balanced at ward level as all wards accommodate different specialities.

Changes in outpatient resource use

The OT time-table change caused 32 clinic sessions to be rescheduled in the outpatient department (OPD) time-table. All but two specialties were confronted with changes in the clinic time-table. This was not restricted to only the surgical specialties because of the sharing of facilities and staff in the outpatient department. To calculate the changes in outpatient resource use evoked by the new OT time-table, the old and the new OPD time-table were evaluated on resource impacts by multiplying session hours with facility and staffing requirements and with estimates for the number of direct referrals to diagnostic departments. This led to the overview of outpatient resource impacts for the whole outpatient department shown in Table 3.6. This table shows per day of the week and per part of each day the consequences for personnel requirements (expressed in full-time equivalent hours needed to staff the clinic), for facility/room requirements (expressed in the number of units needed for clinics), and for the workload of diagnostic departments such as x-ray, lab and organ examination (expressed in the number of direct referrals from clinics).

Table 3.6 shows that there are considerable shifts in outpatient resource use due to the introduction of the new OT time-table, when considered at day or part-day level. For the

Day and part-day		Personnel (FTE hours)		Facilities (units)		Direct referrals diagnostic departments					
						X-ray		Laboratories		Organ Exam. Depts.	
		old	new	old	new	old	new	old	new	old	new
Monday	a.m.	75	70	16	15	78	64	82	80	48	35
	p.m.	61	66	12	14	36	49	45	51	24	28
Tuesday	a.m.	78	80	16	17	87	82	90	99	61	63
	p.m.	61	62	13	14	29	38	62	62	18	30
Wednesday	a.m.	85	65	17	14	67	70	87	75	41	53
	p.m.	41	47	9	11	38	55	46	54	23	36
Thursday	a.m.	77	69	16	14	72	58	91	74	54	38
	p.m.	58	55	12	12	39	30	48	49	24	20
Friday	a.m.	56	62	12	13	60	54	54	59	34	39
	p.m.	35	37	8	9	28	30	24	29	15	14
Average		62.7	61.3	13.1	13.3	53.4	53.0	62.9	63.2	34.9	35.0
Coefficient of variation		0.26	0.20	0.24	0.17	0.41	0.32	0.37	0.31	0.47	0.41

Table 3.6: Overview outpatient resource impacts due to the introduction of a new OT time-table.

overall outpatient resource use, Table 3.6 suggests the following conclusions:

- the average need for staff decreased slightly;
- the average need for facilities increased marginally;
- the average number of direct referrals to diagnostic departments did not change;
- the fluctuations of all effects reported over the days/part-days reduced considerably.

Although the reorganization of the OPD time-table implied only a re-distribution of the same clinics over the days of the week, differences in average staff and facility requirements per week can occur due to changes in possibilities for sharing staff and facilities between different specialty clinics. There is no influence from the new time-table on the number of direct referrals from individual clinics to the diagnostic departments, which explains why the average for direct referrals per week has not changed (apart from small rounding-off effects). The fluctuations in outpatient resource impacts over the part-days of the week as shown in Table 3.6 are real differences and do have statistical significance, even though the differences are small, as we suppose a weekly fixed time-table and fixed workloads per clinic.

Routine hospital statistics on clinics held during a whole year (1991) showed that in less than 5% of the clinics cancellations of clinic sessions were necessary or extra clinic sessions were held, which supports our assumption about the fixed character of the OPD time-table. Personnel requirements and facility requirements are strictly fixed per type of clinic. Only the direct referrals from clinics to diagnostic departments represent a workload with statistical fluctuations from day to day. We did not have statistical data on referrals available, so we used for this purpose estimates for average referral rates from clinic staff and the OPD manager. In our analysis on the relationship between the outpatient department and the diagnostic departments discussed in the previous chapter (2.5) we showed statistical

material on the fluctuations in the direct workload from clinics. For the purpose of the analysis in Table 3.6 we left these fluctuations out of consideration and supposed a fixed workload for direct referrals.

Therefore it is allowed to conclude from these figures that the impacts of the introduction of the new OT time-table for resource use were favourable for the whole of the outpatient department activities. However, these impacts or their exact size and the exact spot of occurrence were not planned for or known in advance and the departments involved were not able to prepare for these changes. The diagnostic departments, for example, were confronted with considerable changes in the patient flows per day and part-day - although the average week-figures did not change and the fluctuations over the days/part-days even decreased.

The reasons for these improvements in outpatient resource use become clear when one looks at the change in distribution of activities over morning and afternoon, which coincidentally took place by this reorganization. This is presented in Table 3.7.

Day-part		Personnel (FTE-hours)		Facilities (units)		Direct referrals diagnostic departments					
		old	new	old	new	X-ray		Laboratories		Organ Exam. Departments	
						old	new	old	new	old	new
A.M.	average	74.2	69.2	15.4	14.6	72.8	65.6	80.8	77.4	47.6	45.6
	coefficient of variation	0.15	0.10	0.12	0.10	0.14	0.17	0.19	0.19	0.22	0.26
P.M.	average	51.2	53.4	10.8	12.0	34.0	40.4	45.0	49.0	20.8	25.6
	coefficient of variation	0.24	0.22	0.20	0.18	0.15	0.28	0.30	0.25	0.20	0.34

Table 3.7: Differences in outpatient resource requirements between morning and afternoon.

From Table 3.7 one can see that the differences between morning and afternoon have been reduced considerably. In the previous situation the workload of outpatient clinics appeared to be concentrated in the morning. Part of this workload has been shifted to the afternoon due to the new OPD time-table. Although the fluctuations for morning/afternoon over the days of the week have been decreased for most resource types, these changes are only small compared to the changes in fluctuations when one considers all part-days separately (see last line in Table 3.6). Further evidence for the improved balance between morning and afternoon can be found from the reduced differences between morning and afternoon in the new setting. Illustrative for the decreased fluctuations at part-day level by a better balance between morning and afternoon is offered by the x-ray referrals and referrals for organ examinations, that show for morning/afternoon even an increase of fluctuations. Apparently, the increased within part-days fluctuations are compensated for by a better balance between morning and afternoon, resulting in decreased fluctuations between days and part of days.

3.4 Discussion of results reference-case

The purpose of this case-study was to illustrate the consequences of not taking into account knock-on effects on other parts of the hospital when one introduces changes in one part of the hospital. This case concerns an introduction of a new time-table in the operating theatre department. Based on the analysis of the impacts of the new time-table we can draw the following conclusions:

- For inpatient resources the introduction will have most consequences for nursing workload. One can expect increase in peaks and troughs in nursing workload over the days of the week, especially for ENT, Ophthalmology and Urology. Considered at ward level the consequences for nursing workload are less compared to consequences at specialty level, as wards accommodate more specialties.
- For outpatient resources the introduction of the new OT time-table will cause many shifts of clinics and resource requirements between days and part-days within the week. Considered at an overall level, however, all the shifts together result in favourable consequences for outpatient resource use, in that fluctuations for morning/afternoon over the days of the week have decreased. However, as exact size and spot of these consequences were not known in advance, departments were not able to prepare for these consequences.

To come to an overall conclusion on all the resource impacts due to the new OT time-table we can use the weighing function for evaluating reduction of variation in resource workloads as described in 2.6. There we assigned weighing factors to resources to express the importance of reduction of variation of resources, based on some qualitative considerations. Using this information for the 14% decrease of variation in bed requirements achieved, the 20% increase in variation of nursing workload, the about 30% decrease of variation in outpatient staff and facility requirements and the about 25% reduction of variation in workloads of diagnostic departments, the overall result can be qualified as positive ($+14 \times 75 - 20 \times 75 + 30 \times 25 + 25 \times 50 = 1550$). This implies that the negative consequences for nursing workload variation are outbalanced by positive changes in bed requirements, outpatient resource requirements and workload of diagnostic departments. Or expressed in terms of our concept of efficiency used in this study, the combined resource efficiency has increased, though some resources considered separately show decreased efficiency.

Though it is difficult to give evidence, it would have been possible to achieve further improvements in resource use, especially by avoiding increase in nursing workload variation i.e. peaks and troughs in the nursing workloads from day-to-day, while maintaining the positive effects of the proposed change. More gain in resource use could have been reached by making use of the following insights based on this case-study:

- Gain in resource use performance of one type of resource should be balanced with possible negative impacts for other resource types. This is necessary to avoid a situation where the solution which was considered optimal for this resource turns out to be sub-optimal for all resources together.
- Hospitals that do not take explicitly knock-on effects into account in the introduction of a change in one resource type, do not necessarily incur many negative resource impacts for other resource types. The case-study hospital is a nice example, in that many positive effects were realized, probably based on implicit handling of interactions in the hospital. However, as these impacts as to their exact size and spot of occurrence were not known

in advance, departments were not able to prepare for these changes. It might have turned out the other way. Nevertheless, the case shows that changing the time-tables can produce significant effects.

- Inpatient resource impacts of changes considered need to be looked at from as well a specialty perspective as a ward perspective. As wards accommodate different specialties, interactions between specialties using the same ward can reinforce or compensate specialty impacts.

The case-study illustrates that there are many knock-on effects in a hospital when one introduces a change in operating theatre allocation. Though the case-study hospital actually performed quite well in terms of other resource impacts, it did not make fully use of the opportunities offered by this 'critical resource incident' to avoid negative resource impacts elsewhere and to realize further improvements. How one can use these knock-on effects in an explicit way for the benefit of overall resource use at hospital level will be discussed in the next chapter, where we describe models developed to support hospitals in this type of resource management issues and an implementation approach to tackle these problems more effectively.

CHAPTER 4

MODEL DEVELOPMENT, IMPLEMENTATION STRATEGY and CASE-STUDY DESIGN

In the first part of this study (Chapters 1-3) we introduced, analyzed and illustrated the problem of capacity-losses due to resource allocation changes, which do not take into account the capacity co-ordination requirements that are inherent to the hospital's capacity structure. We found out that this problem arises when changes in the hospital production system affect the time-tables of the operating theatre department, the outpatient department or the specialists. Their 'leading' character causes changes in the allocation of these resource types to have effects on 'following' resource types, which may result in structural peaks and troughs in the workload and therefore in capacity-losses. The reference-case also demonstrated that an introduction of a new operating theatre time-table has many impacts for inpatient and outpatient resource requirements. Some of them may turn out to be positive and some of them negative. However, these impacts are coincidental and not part of a planned change.

What we set out in this chapter is developing an approach to the type of problems investigated, that helps hospitals to tackle these problems more effectively by:

- placing the problem in a framework for production control decisions in a hospital,
- supporting decision making via dedicated software that visualizes the resource impacts of capacity co-ordination requirements,
- bringing those concerned together in a participative and learning project setting.

Each of the aspects of the approach developed for changes in the hospital production system will be discussed in turn. First, we will introduce a generalized framework for production control decision making in hospitals and focus it further on our study on resource allocation (4.1). Next, we will describe the way a set of computer models was developed to support hospital managerial decision making on resource allocation issues (4.2). Then, we will elaborate on the implementation strategy that we advise to be used in the problem solving approach to this type of problems (4.3). The approach developed will be illustrated in a number of case-studies in subsequent chapters. The final part of this chapter (4.4) is therefore devoted to the choice for the case-study method used in the case-studies and the design for the case-study description.

4.1 A production control framework for patient flow and capacity management

The need to develop a production control framework specifically designed for hospitals arose when the literature search performed suggested that such a framework was missing. This makes it difficult to place research activities in a wider context. The framework developed by Smith-Daniëls [1988] and discussed in 2.2 had a literature review purpose and did not offer enough support for the different levels of production control decision making in hospitals. Another framework, the Brunell scheme of work strata in organizations, is also less suitable

for production control decision making, but it will be described here to relate our approach to a classification of levels of work in an organization that can be easily linked to the way professionals such as physicians and nurses look at a hospital. The original scheme of Rowbottom and Billis [1977] distinguished five strata for the work to be done in organizations:

1. Prescribed output: the output required of the worker is completely prescribed or prescribable, as are the specific circumstances in which this or that task should be pursued. Examples in a hospital setting are: performing an operation, an examination, a test, a nursing activity.
2. Situational response: carrying out work where the precise objectives to be pursued have to be judged according to the needs of each specific concrete situation. Examples in a hospital setting are: the decision to prescribe a treatment for a specific patient.
3. Systematic service provision: making systematic provision of services of some given kinds shaped to the needs of a continuous sequence of concrete situations. An example of this would be the development of a treatment programme for a specific category of patients.
4. Comprehensive service provision: making comprehensive provision of services of some kinds according to the total and continuing needs for them throughout some given territorial or organizational society. An example would be the development of a strategic plan for a hospital which describes the services of the hospital.
5. Comprehensive field coverage: making comprehensive provision of services within some general field of need throughout some given territorial or organizational society. An example in a health care setting would be the development of a regional health services provision plan.

Jacques [1965] has in earlier stage suggested that this scheme could be extended to 7 levels, including interactions of different fields of need at national and international level. Van der Meer [1985] and Van Montfort [1986] have applied this scheme to a Dutch health care setting, represented in Figure 4.1.

Figure 4.1 shows that there is a separating line between level IV and V, illustrating the different character of types of work at the hospital level and at the above-hospital level where the focus is on health care policy development and implementation. The dominant development on hospital level is the integration between patient care activities by health care professionals and the effective organization and management of operations to ensure an efficient use of available resources. This is where the models for resource allocation developed in this study can contribute. The protocol-based way professionals in hospitals think and act makes it possible to describe activities of specialists for logistic planning purposes and offers excellent opportunities to link allocation of resources to the utilization of resources. The framework can also be used to describe the different roles and responsibilities of professionals, managers, health care providers and health care purchasers. However, we will not go into this, as its description is meant to link our production control framework to this existing taxonomy of type of work and related decisions in health care from a health care professional perspective.

Kusters [1991] introduced as an aside in his paper on nursing workload measurement a sketch of a framework, that shows similarity to the framework we will use in this study.

Figure 4.1: Brunell scheme of work strata in health care.

Together with some colleagues who were faced with the same lack of a framework as a wider context for their research, a framework was developed for production control decisions in hospitals using principles from production control theory [Groot, Kremer and Vissers, 1993]. First, we will elaborate a production control perspective on hospitals and the principles used in production control theory to develop a production control framework. Next, we will introduce the framework for hospital production control, followed by a description of each of the levels distinguished in the framework. Finally, we will focus this general framework to our resource perspective by describing the capacity management framework used for this study on hospital resource allocation.

Production control perspective on hospitals

Bertrand, Wortmann and Wijngaard [1990] define production control as all activities aimed at the co-ordination of supply activities and production activities in manufacturing systems to achieve a specific delivery flexibility and reliability at minimum cost. We will show that this definition with a number of adaptations can also be applied to hospitals.

First of all, supply activities in manufacturing systems refer to goods while in hospital systems this will relate primarily to patients and only secondarily to goods. Therefore the primary focus of production control in hospitals should be on patient flows. The hospital products are represented by the services rendered to patients. Patient services can in general

not be stocked [De Vries, 1988] but can only be produced when patient and service provider meet; Güntert [1990] refers to this as the 'uno actu' principle.

Secondly, production activities in a manufacturing environment find their equivalent in the diagnostic and therapeutic activities in hospitals. The most important difference with manufacturing systems is that these activities are predominantly shaped by human resources which account for about 70% of the hospital budget. Hospital production is further characterized by an unmatched interaction between human beings on the demand side (patients) and human beings on the supply side (physicians, nurses, paramedics). This will ask for much flexibility in the final delivery of services to a patient. Therefore, a job-shop approach is often put forward as being applicable to the hospital production system [Bertrand and De Vries, 1993]; the low material complexity (the patient is the only part involved) and the high capacity complexity with many inter-dependencies support this. In a job-shop every order is handled as a separate job, allowing for wide variations in resource-mix and routing. However, leaving aside the final human touch that requires utmost flexibility during final assembly and that makes the hospital look like a job-shop, at the level of hospital processes there is so much routine and so much standardization as all disciplines are accustomed to use protocols that one could equally well approach the hospital production system as a flow shop.

Thirdly, co-ordination between patient flows and diagnostic & therapeutic activities in hospitals is less focused on achieving specific targets for delivery flexibility and reliability at minimum costs, but according to Anthony [1980] on providing the best possible service with available resources, or according to Güntert [1990] the treatment of as many patients as possible with the available resources, starting from a predefined mix of patients. This does not mean that hospitals do not distinguish delivery flexibility (elective/appointment, semi-urgent, urgent) or delivery reliability (waiting lists, waiting-times), but these are to a large extent defined by the financial restrictions imposed on hospitals.

Analogous to the definition of production control in an industrial setting we can, therefore, define production control in hospitals, i.e. health service organizations as the design, planning, implementation and control of co-ordination mechanisms between patient flows and diagnostic & therapeutic activities in health service organizations to maximize output/throughput with available resources, taking into account different requirements for delivery flexibility (elective/appointment, semi-urgent, urgent) and acceptable standards for delivery reliability (waiting lists, waiting-times) and acceptable medical outcomes.

This makes it plausible that production control theory principles, such as decomposition and aggregation, can be used to construct a production control framework for hospitals. Decomposition means breaking down a complex problem into a number of smaller, less complicated problems. These are related to each other, but can be solved relatively independently. Aggregation is a method to relate the decomposed parts, investigated separately, to the original problem. Decomposition can be performed in a number of ways. In their work on hierarchical planning, Hax and Meal [1975] use decomposition based upon levels in the product structure: items (products), families (groups of products that make use of the same machines) and types (groups of families with analogous production costs and demand patterns). Another way of breaking down a problem into sub-problems is decomposition based upon the decisions that have to be taken. An example of this kind of decomposition is given by Anthony [1965]. He proposed that managerial activities fall into three broad categories, often referred to as strategic planning, management control and operational control. Strategic planning clearly has a long term scope and is the responsibility

of top management. Management control (also referred to as tactical planning) is a medium term activity involving middle and top management, concerned with the effective use of existing resources within a given market setting. Finally, operational control involves short term activities, typically executed by lower levels of management and non-managerial personnel to carry out efficiently the day-to-day activities of the organization.

In manufacturing systems, decomposition according to levels in the product structure is used most frequently. This happens almost naturally, since capacity planning is, in many manufacturing systems, a derivative of product planning. In those systems, products often can be produced to stock, meaning that all available capacity can be used with very little idle capacity. In hospitals, capacity planning is of much more significance, because care is not a commodity that can be stocked. Fluctuations in the demand for services can only be dealt with by using buffers of patients before entering the hospital system (waiting lists) or after having entered the hospital system (waiting times). A poor allocation of resources may lead directly to a loss of capacity. The most important factor in capacity planning is the planning horizon. This is the reason for using the type of decision that has to be made as the basis for decomposition.

Hospital production control framework

To design a framework for production control in hospitals, the production control problem needs to be broken down according to the type of decisions to be taken. These decisions are then arranged in such a way that the decisions with impacts at a further horizon are placed at a higher level in the framework and set the boundaries within which decisions at a lower level are taken. Applying this type of decomposition to the production control decisions in a hospital leads to five levels as illustrated in Table 4.1. This framework does not describe the optimal way to control hospital activities but instead describes a logical way of co-ordination hospital activities within the perspective of the current hospital organization.

Type of decision	Decision makers	Framework Level	Horizon
What is the future direction of the hospital?	Top Management	Strategic Planning	2 - 5 years
What will be the development of hospital activities in the next year?	Top management	Main Patient Flow Planning	1 - 2 years
How are resources allocated to specialties or departments? (lump sum allocation)	Top and middle management	Capacity Allocation	months - 1 year
How are capacities scheduled in time? (time-phased allocation)	Middle management	Capacity Scheduling	weeks - months
Which patient is treated at what time?	Planning officers	Operational Management	days - weeks

Table 4.1: Production control decisions in a hospital.

Some remarks need to be made about the levels chosen compared to Anthony's 3-level hierarchy [Anthony, 1965 and 1980]. Strategic Planning and Main Patient Flow Planning together form the strategic planning level used by Anthony. However, Strategic Planning does not make part of what is commonly referred to as production control. Capacity Allocation and Capacity Scheduling together form the management control level. Finally, Operational Management is comparable to Anthony's operational control level. The reason for distinguishing five instead of three levels is that in this way we can describe separately decisions regarding long term developments of the hospital versus defining the hospital budget (Strategic Planning and Main Patient Flow Planning) and decisions regarding the total amount of resources available at annual level per specialty versus the allocation of session hours within a week (Capacity Allocation and Capacity Scheduling).

To guarantee that decisions at a lower level of control are taken and executed within the boundaries set at a higher level, a control function needs to be implemented. This function measures the performance on a predefined set of performance indicators. This set of performance indicators must be constructed in such a way that decisions can be evaluated and deviations from targets set can be explained. Moreover, it is necessary to be able to evaluate whether the health service organization as a whole is heading in the direction defined by Strategic Planning. Different types of control can be distinguished, analogous to the distinction made by Kuipers and Van Amelsfoort [1990]:

- horizontal control loops, taking care of the co-ordination between units or aspects at the same level;
- vertical control loops, taking care of the co-ordination between units or aspects at different levels of planning.

Both types of control can be used in a feed forward way and in a feedback way. Using these controls in combination with the levels of production control described above, the production control framework can be derived that is shown in Figure 4.2, and which has similarities with Stafford Beer's 'Brain of the Firm' [1972].

The framework in Figure 4.2 shows that every level needs a horizontal control mechanism to match patient flows with resources and that a vertical control mechanism is needed to check whether activities develop within the boundaries set by higher levels. The different levels and their corresponding controls will be elaborated below.

Planning levels

Strategic Planning is the highest level of production control within this framework, although it is not a part of what usually is called production control. Nevertheless, this level is taken into account in our framework because of the planning and financial restrictions imposed on hospitals by national and regional governments and by health insurance companies. These restrictions significantly influence decisions taken by Strategic Planning and by Main Patient Flow Planning. Strategic Planning decisions concern the direction in which a hospital is heading for the next two to five years. Decisions are taken concerning the categories of patients the hospital wants to serve in the future, the target mix and volumes of patients for the hospital. Also decisions are taken regarding investments and divestment of resources. Table 4.2 lists the various decisions regarding patient flows and resources at this level of planning and the corresponding control functions.

Figure 4.2: Framework for production control in hospitals.

Decisions regarding patient flows	Decisions regarding resources	Control functions
catchment area served by the hospital, treatment policies (inpatient versus outpatient based), addition/removal or increase/decrease of a function or specialty	investments or divestment of resources, co-operation with other institutions, priority-setting	horizontal: co-ordination of demand and supply; feedback: realized versus target patient flows; feed-forward: consequences of changes in population and technology; vertical: feed forward on boundaries for patient flow volumes and aggregate resource requirements, target resource utilization rates

Table 4.2: Decisions and control function for Strategic Planning.

Main Patient Flow Planning is the second level of production control in the framework. Decisions regarding the main patient flows consist of determining the number of patients per diagnostic family. A diagnostic family could be represented by the diagnoses within a specialty or based upon, for example, diagnostic related groups (DRG's). In order to determine the number of patients within such a family, the demographic characteristics of the population surrounding the facility, historical data regarding the number of patients in that family and patient volumes agreed upon with the health insurance companies are used as input data. A rough estimate of the resources needed per specialty or department is required. In production control terminology this is called a rough-cut capacity plan. A decision must be made regarding how much capacity a diagnostic family needs based upon the number of patients within this family and how much extra capacity is needed to guarantee that this number of patients can be treated in the next year, considering the targets set for the occupancy of resources. Finally, it is necessary that the decisions concerning the patient flows and the resources are consistent with each other and with the decisions taken at the strategic planning level. Table 4.3 summarizes the decisions which need to be taken at this level and the control functions which need to be performed.

Decisions regarding patient flows	Decisions regarding resources	Control functions
number of patients per diagnostic family, production volume agreements with health insurance companies	rough outline of required capacities per diagnostic family	horizontal: co-ordination of demand and supply; vertical: feedback on targets for resource utilization, feed forward on service level standards (maximum length of the waiting list and waiting-times per specialty)

Table 4.3: Decisions and control functions for Main Patient Flow Planning.

The third level in our framework is called **Capacity Allocation**. The decisions taken at this level are concerned with the allocation of resources to specialties and departments. These decisions are taken approximately once each year. Allocation decisions are based on a more detailed insight into the patient flow per specialty. Therefore, the patient flow is broken down into diagnostic groups that require the same amounts of capacity (iso-resource grouping as in the DRG approach). Each diagnostic family can be broken down into one or more diagnostic groups. For each diagnostic group the projected number of patients for the next period is determined and the amount of capacity required. Depending on the resource type, the allocation of resources can take place in different ways:

- a lump sum allocation of capacity (e.g. full time equivalents of nursing capacity)
- a specific allocation of capacity in time (e.g. blocks of operating capacity during session hours within the week)

Table 4.4 provides an overview of decisions and control functions at this level of planning.

The fourth level in our framework is called **Capacity Scheduling**. This level cannot usually be found in production control structures for manufacturing systems. It is added to the production control structure of hospitals because some types of resource in hospitals are allocated to specialties, in the first stage in terms of a lump sum and in a later stage in a

Decisions regarding patient flows	Decisions regarding resources	Control functions
expected number of patients per diagnostic group	allocation of resources to specialties or departments	horizontal: co-ordination of demand and supply per specialty; vertical: feedback on aggregate capacity use by specialties and departments, feed forward on available capacity per specialty or department

Table 4.4: Decisions and control functions for Capacity Allocation.

time-phased manner by allocating session hours within a week. As the way in which these session time-tables are set up can affect the performance in other parts of the hospital, this type of decision requires co-ordination at hospital level and cannot be solved at the department level as is the case in most manufacturing systems. At this level of planning detailing of patient flows to production periods is required, taking into account seasonal influences. This allows for adjustments in the allocation of resources for high seasons and for low seasons. Table 4.5 lists the decisions and control functions for Capacity Scheduling.

Decisions regarding patient flows	Decisions regarding capacities	Control functions
projected number of patients per diagnostic group per period (seasonal influence)	scheduling of facilities and staff	horizontal: co-ordination of demand and supply (expected number of patients versus capacities used); vertical: feedback regarding capacity allocation, re-adjustment of service level standards

Table 4.5: Decisions and control functions for Capacity Scheduling.

Operational Management is the lowest level in our framework. It is equivalent to the operational control level mentioned by Anthony [1965, 1980]. This level is concerned with the processes used in facilitating the day-to-day activities of the organization. These activities consist of rules, procedures, forms and other devices which govern the performance of specific tasks. Operational control is the process of assuring that specific tasks are carried out effectively and efficiently. The day-to-day activities of a hospital include scheduling of individual patients for admission, for outpatient consultation or for examinations. Time-tables for resources used for capacity scheduling set limits to the availability of capacity at operational control. Table 4.6 gives an overview of the decisions and control functions at this level.

Capacity management framework

We have presented a generalized framework describing the various production control activities a hospital has to perform in order to achieve its objectives. Now we will focus on this framework from a capacity management perspective and build up the production control framework we use for our study on hospital resource allocation. First, we will give some considerations that have led to a capacity management perspective instead of a patient flow

Decisions regarding patient flows	Decisions regarding capacities	Control functions
scheduling of patients for admission, outpatient visits, diagnostic examinations, etc.	allocating capacity to individual patients	horizontal: co-ordination of demand and supply (adjustments for peak hours); vertical: feedback regarding performance on service level standards, capacity utilization

Table 4.6: Decisions and control functions for Operational Management.

perspective for this study.

First of all, capacity management refers to the higher levels of the production control framework where aggregated patient flows are matched with aggregated capacities; this part of production control is also referred to as aggregate production control.

Hospital production control activities, especially on the higher levels of control, are under-developed considering the complexity of the hospital's production system. The emphasis of this system lies on the operational level with planning officers and specialists making decisions for the day-to-day hospital practice. Having said this, it would be tempting to focus production control development in hospitals on the lower levels in the framework. We purposely did not choose this option in our research. Firstly, because this would require a very detailed approach to catch all the complexities and intricacies that are present in the hospital system. Such an approach, if at all realizable, would also be very threatening to specialists who would associate it with systems monitoring their performance step by step "like a monkey on their back" or "big brother watching you" [Reinhardt, 1983]. Secondly, the higher levels of production control in hospitals fail to set and develop clear boundaries for operational control. Because targets for lower level production control are not set or used vertical control mechanisms cannot work. This pleads for an approach to concentrate on aggregate production control. By developing these levels of control in hospitals a set of conditions can be realized that would direct the activities at operational level. Capacity management would then condition patient flow management.

Finally, considering the complexity of the hospital production system and the production control tasks to be performed, it is advisable to use decomposition when developing a production control framework addressing capacity management in hospitals.

In our study on hospital resource allocation we are looking at different alternatives of allocating resources and to the impact of these alternatives on resource requirements. While our study concentrates on Capacity Allocation and Capacity Scheduling in the framework, we will also need the links to Main Patient Flow Planning and to Operational Management. First of all, we will call the combination of Capacity Allocation and Capacity Scheduling Time-phased Resource Allocation. This refers to the fact that using the session-mechanism for allocation of 'leading' resources in hospitals, resource allocation and capacity scheduling are one and the same. The link to the above level, that we have labelled Resource Planning because of our capacity management perspective, is needed because the 'rough-cut capacity checks' performed at that level to determine the amount of resources required makes use of capacity load factors determined by lower level performance. The link to the lower level is needed because the capacity configuration chosen, as a result of considering alternatives for resource allocation, conditions the way capacities can be used for operational planning. This

leads to the following framework for capacity management for hospitals that we have used for our study (Figure 4.3).

Figure 4.3: Production Control Framework Hospital Capacity Management.

As can be seen from Figure 4.3 Time-phased Resource Allocation for 'leading' resources produces capacity configuration plans for the whole hospital which are evaluated on capacity requirements performance. This is done via detailed capacity checks on the fluctuations of capacity requirements throughout the week and on opportunities for capacity load levelling. The plan that is selected introduces a capacity loss due to the level of fluctuations accepted or imbalances in capacity loads of different resources.

The capacity configuration plan defines the available capacity per specialty as input to

Operational Planning. Moreover, it defines target workload profiles for capacities to be filled up with scheduled patients via Operational Planning. When Operational Planning does not keep up to these profiles it introduces another capacity loss, this time due to operational performance.

The losses of capacity due to the performance of the capacity configuration plan chosen and due to operational performance influences the capacity load factors used for determining the resource requirements for the whole hospital via the rough-cut capacity check.

4.2 Decision support model set on Hospital Capacity Management

To support hospital managerial decision making in developing capacity configuration plans with optimized capacity requirements performance, a set of five computer models was developed. This section will cover in more depth this crucial part of the research; crucial, because the models developed have a central role in the approach chosen to tackle the capacity management issues investigated in this study. First, we will give some consideration to the modelling philosophy used as a source of inspiration for our modelling efforts and to the choices made in our modelling activities. Secondly, we will describe the way the models were developed, starting with the preparatory studies of the content and context of capacity management problems in hospital practice, continuing with the pilot-studies with first prototype models, and ending with the final products for hospital capacity management decision making. Finally, we will describe and characterize the different models as far as they are relevant to this section that focuses on the motives and arguments used for our modelling part of this study. We have described the different models in more detail in Appendix 1.

Modelling considerations

The modelling part of this study was much inspired by the discussions on modelling and Operational Research in general by professional researchers in this field. This requires a short elaboration on Operational Research and on the activities of the European Working Group on Operational Research Applied to Health Services. Operational Research as a concept was introduced in World War II. Its basic idea was the approach of using scientific device and scientific methods to guide decisions concerning military operations. After the war, Operational Research evolved in many different directions and into different areas. Among these areas were the Health Services [Lagergren, 1991]. There are many quasi-synonymous concepts. Sometimes we talk about systems analysis, systems engineering, systems science or cost effectiveness analysis. The common core of all these activities is the systematic scientific approach using quantitative methods. The definition of Operational Research has developed during the years. One definition is: "Operational Research is systematic quantitative analysis in support of rational policy and decision making". It can be augmented by: "Development of information support and tools for effective management".

The European Working Group on Operational Research Applied to Health Services represents a network of researchers working at universities, health services research institutes, in government positions or as management consultant. In yearly meetings they share findings of applications of Operational Research in the health care field. In this way in almost 20 years a vast knowledge on health care applications was built up, documented in proceedings of meetings and a few books [Luck, Luckman and Stringer, 1971; Boldy, 1981].

The title of the Working Group reflects the premise that "the major challenge for Operational Researchers working in the health care field lies not in developing new and/or more sophisticated techniques, but in using what expertise they currently possess to make more of an impact on the delivery of health care". The modelling activities in this study follow this research philosophy by a steady focus on implementation questions.

A central concept in Operational Research is modelling, i.e. the art of creating some kind of abstract image of the area under study in order to facilitate analysis [Lagergren, 1992]. The primary advantage of modelling is that in this way it is possible to study much faster and at a much lower price than through actual experimentation the properties of a system and the effects of different alternatives for changing it. Models can be used for making forecasts of future behaviour of the system under certain conditions, for evaluating different alternatives of change or just to improve the insight into the properties of the system. Making a model amounts essentially to making a more or less formal description of the system. The way this description is made - what is included and what is left out - depends on the purpose of the description, i.e. the specific problem or properties we want to study. Constructing a quantitative model demands that concepts are precisely defined. The model will also serve as a framework into which to put different data. This is the second major advantage of modelling. It puts the data describing the system into a meaningful context, resulting in a deepened knowledge of the system. As models are constructs of reality they require careful validation, i.e. does the model do what it is intended to do? Models must never be accepted at face value. Results of models should be critically evaluated. A simple and transparent model is to be preferred because results can easier be understood and supported by logical explanations.

Rosenhead [1989] points to a shift in paradigm of Operational Research (Table 4.7).

Characteristics of dominant current paradigm of Operational Research	Characteristics for an alternative paradigm Operational Research
Problem formulation in terms of a single objective and optimization. Multiple objectives, if recognized, are subjected to trade-off on a common scale.	Non-optimizing; seeks alternative solutions which are acceptable on separate dimensions without trade-offs.
Overwhelming data demands, with consequent problems of distortion, data availability and data credibility.	Reduced data demands, achieved by greater integration of hard and soft data with social judgements.
Scientization and depoliticization, assumed consensus.	Simplicity and clarity, aimed at clarifying the terms of conflict.
People are treated as passive objects.	Conceptualizes people as active subjects.
Assumption of a single decision maker with abstract objectives from which concrete actions can be deduced for implementation through a hierarchical chain of command.	Facilitates planning from the bottom-up.
Attempts to abolish future uncertainty, and pre-take future decisions.	Accepts uncertainty, and aims to keep options open for later resolution.

Table 4.7: Shift in paradigm of Operational Research according to Rosenhead [1989].

The change in paradigm of Operational Research as illustrated in Table 4.7 from a closed approach to a more open approach, accords well with the characteristics of health care institutions as people processing organizations whose primarily resources are people working as professionals in hospitals. In the modelling part (and in the case-study part) of this study we moved away from the left part in the table and tried to incorporate right hand characteristics of the new paradigm. This paradigmatic change is not reserved for Operational Research, but parallels can be drawn with many other schools of thought. It reflects also a different look on the way decisions are taken in organizations, with Simon [March and Simon, 1969] being one of the first to distinguish arenas with interest groups. The change from an optimization approach to a satisficing approach is, in a technical sense, a reduction in the level of modelling ambition. This seems to be a must when one attempts to address the hospital as a whole, considering the literature review findings discussed in 2.2. While the formal description of the problem investigated as presented in 2.4 could easily have been seen as a starting point for a mathematical programming model approach including optimization efforts, we did deliberately not follow this route for the following reasons:

- First of all, there is no clear objective function for the hospital setting available that could be used for optimization purposes. The different objectives of the various actors in the hospital system as discussed in 1.2 cannot be expressed on a common scale.
- Optimal solutions derived from a model, even if possible, would not be accepted by the actors in the hospital system as solutions are part of a negotiating process between the different parties concerned in which a lot of other arguments not covered by the model play a role. A better fitting ambition for a model contribution in this setting would be to prevent worst choices.
- Our tentative conclusion that the higher levels of production control are underdeveloped in hospitals leads to the further conclusion that we do not believe hospitals are ready yet for more sophisticated model support.

Indeed, the contribution of models to the type of problems investigated should be put into the right perspective. Anthony [1965] addressed this question when describing the different planning levels. The characteristics of the planning levels defines in his view the need and requirements for decision support. Models for Operational Planning, whose nature is primarily rational, should be much more detailed and precise to be of value to this planning level for day-to-day practice. Models for Management Control, whose nature is primarily psychological, should be less detailed but offer more global support to compare alternative actions considered. Management Control is said to have a psychological nature, as Anthony [1965] defines it as the process by which managers influence other members of the organization to implement the organization's strategies. Güntert [1990] in his systems analysis approach to hospitals presents a network of interrelated variables that play a role when considering resource allocation decisions; he warns that information support should not be tempted to cover all aspects of this problem in one model but should rather focus on well-defined areas of decision making.

The choices we have made in our modelling activities can be listed as follows:

- Decomposition was used in different ways. The first decomposition used was that we followed the levels of planning as discussed in the production control framework, concentrating on the higher levels. Capacity management in hospitals could be improved

significantly by avoiding capacity losses introduced at higher levels of planning while at the same time creating improved conditions for operational planning.

- The second decomposition used was to define areas within the hospital setting where decisions are taken about resource allocations. These areas should be: well-defined and recognizable within the hospital organization, centred around scarce shared resources, inhabited by users who have interests in the performance of capacity configuration plans for the area considered, and large enough to include important interfaces between 'leading' and 'following' resources. These areas will be discussed later on when describing the models.
- The ambition for the sophistication level of modelling was, in a technical sense, kept low. The models can be compared with simple spread-sheet models visualizing patient flows and resource requirements in the area considered and allowing for investigation of alternative capacity configuration plans by answering 'what-if' questions.
- The ambition for the scope of modelling was wide, in that we tried to develop a set of models that would cover the full range - however, a selection - of the resource allocation decisions taken at this level of planning. The selection of decisions covered by the models involved a concentration on the most important resources, but more important a focusing on changes in the resource configuration that have a major impact on resource requirements and resource use, i.e. what we have labelled as 'critical resource incidents'. The wide range of modelling was chosen to enable following through consequences of changes throughout the whole hospital. This is because of the dependencies and knock-on effects that are inherent to the hospital's production system. Taking a decision to increase the number of operating theatre hours for a specialty involves answering a number of questions that are related to this decision. Using the model set offers the hospital management an overall perspective on changes considered, which can help to avoid introducing advantageous changes in one part of the hospital that are outbalanced by the disadvantages in other parts of the hospital.

This has led to a set of models that can be labelled as 'wide but global', avoiding too much detail and offering support to globalized management of changes in the hospital's resource configuration. The decision to do this with a set of models rather than with one all-encompassing one should be clear from the modelling philosophy described above. As a consequence of this decision the relationship between the different models needs attention. Some would consider this to be a weak point in our modelling, as we were not able to develop interfaces between the models to take care of data-handling from one model to another model. However, this is more an information technology problem than a modelling one. The concepts used are the same, as are the design principles used to build the models, but the models represent indeed a very loosely coupled system. From an information technology point of view this might be considered as a problem. However, from the state of art of production control development in hospitals and for our purpose in this study we do not regard this of much importance.

Further design-principles that have been used to develop the models (in addition to traditional requirements such as validity, accuracy and robustness) are:

- transparency: the model needs to be transparent to allow the user to follow through what the model does with data provided by the user;
- user friendliness: the model should be easy to handle by users to enhance the use by decision makers instead of only by staff or by outside management consultants;
- decision aid: the model should support the decision maker but not take over the role of

the decision maker;

- creativity enhancement: the model should stimulate the creativity of the decision maker to try alternative solutions;
- multi-perspective: the model should not choose for one perspective or one decision maker but show the problem from different perspectives and angles;
- reality-match: the model should represent reality to a degree that the model is accepted as a description of hospital practice;
- problem-structuring: the model should help the user to structure data, information and alternatives;
- visualization: the models need to have much visualizing power to show resource impacts of changes considered in a glance to decision makers; this can be realized for instance by using graphical presentation instead of tables.

This list of design-principles used as reference-points during the building stages of the models helped to develop a set of models that aims first of all at increasing insight of decision makers into the problem and to allow decision making while all relevant perspectives have been considered. It is meant to support first of all the decision making process. The models, therefore, can be said to have primarily a learning function for hospital management to handle the many co-ordination mechanisms that are inherent to the hospital production system.

Development process of the model set

The different modelling activities have taken place between 1987 and 1992. Appendix 1 contains a chronological listing of model activities and related publications that gives an insight into the work related with this part of the research. The process of developing the models is illustrated in Figure 4.4, that links this part of the study also to the case-studies in the third part of this study.

Figure 4.4: Development process model set.

The lower part of Figure 4.4 shows the model building loop gone through during the development stage of the models. When we started this research there was only a rather rough sketch of the scientific research questions underlying this study available, but many problems were reported by hospitals as falling into the range of the yet to be defined research framework. These became the starting point for the development process together with the hospital(s) involved, which took the following steps for each of the models developed:

- First, a preparatory study was performed of the content and the context of the capacity management problem faced by the hospital. This involved an organizational as well as a logistic and systems analysis. The organizational analysis focused on the departments and resources involved, the different actors involved, their view of the problem and their interest in outcomes. The logistic analysis involved an analysis of patient flows, resource requirements by patient flows, resource use performances and workload profiles of departments involved. The systems analysis involved an analysis of the relationships between the different subsystems to clarify what are controllable and uncontrollable variables and what are the cause-effect relationships between variables. This systems analysis was concluded with a recommendation about the demarcation of the problem as input to the next step.
- Next, an information requirements analysis was performed of the information needed by managers to support them in their decision making role concerning the resource management issue investigated. This phase of the study involved much consultation with decision makers. As a result of this, the first outline of a decision support model that would support the information requirements of decision makers involved could be drafted. Based on this, specifications of a prototype decision support model were written in such a way that potential users were able to give feedback on the part of the model that was of interest to them. These first two steps of the development process were mostly performed by master students with an industrial engineering and management science background in their final project of eight to nine month, which ended in a MSc. thesis.
- The third step involved the building of a first prototype model by a student with an Operational Research/modelling background. During the building phase consultations took place with the hospital managers involved. Sometimes the model building phase already started while the previous step was not finished yet to ensure a continued development process for the hospital concerned. Initial versions were improved and completed based on comments and first hand-on experiences of potential users.
- The last step involved the testing and the validation of the model with example data from the hospital and comparison between model outcomes and hospital information where available. Because the calculations used in the model were more or less straightforward this procedure of testing formulas and calculations was considered as enough guarantee for the model validity. The experiences of the one or two pilot-hospitals was, finally, used to finish the first version of a model as output of the model building development cycle.

The models were next prepared for release to hospitals that wanted to use one or more of the models because of a resource management problem. Parallel to this commercial follow-

up of the model-building phase the models were used in case-study settings as part of our research. The results of the use of the models in the case-studies and by the hospitals that have used the models on their own will be reported later on. The consequences of these further experiences with the models for the future development of the models will also be discussed at a later stage in this thesis.

The set of models

Now we will describe the set of models that has been developed as part of the modelling activities in our study. The models all aim for visualizing hospital practice by patient flows and resource use at an aggregated level of planning for well-defined areas of resource management decision making. The set of models consists of one model addressing what we in our capacity management framework have labelled Capacity Planning and of four models addressing what we have called Time-phased Resource Allocation. Table 4.8 introduces the different models by giving some general characteristics.

Model name	Resource issue addressed	Main users
1. Patient Flows and Resources	What are the impacts on the amount of resources required for the hospital as a whole because of a change in patient flows to the hospital due to demographic and epidemiological developments or to referral policy changes?	directors and their staff, consultancy staff
2. Inpatient Capacity Management	What are the impacts on the inpatient resource requirements (beds, operating theatre time, nursing staff) from the current and alternative organization of admissions?	managers of nursing services, OT manager, admission officer, consultancy staff
3. Outpatient Capacity Management	What are the impacts of the current and alternative organization of outpatient clinics on resource requirements in outpatient services (facilities, staff, diagnostic services)?	OPD manager, diagnostic department managers, specialists, consultancy staff
4. X-ray Capacity Management	What are the impacts on the use of x-ray resources of the current and alternative organization of x-ray services for outpatients, inpatients and patients sent in by general practitioners?	X-ray department manager, radiologists, OPD manager, consultancy staff
5. Specialist Capacity Management	What are the impacts of the current and alternative organization of specialist activities per specialty on the use of resources in OPD, OT department, etc.?	specialists, OPD manager, OT manager, manager of nursing services, consultancy staff

Table 4.8: General characteristics of the five models for Hospital Capacity Management.

The arguments for including one model for strategic level Capacity Planning issues is that, even though the sole objective is to make inferences about the Time-phased Resource Allocation level, one cannot disregard the highest level of production control planning. When one enters discussions with specialists or department managers about improving performance

of capacity configuration plans chosen, one first has to answer their questions on the potential discrepancies between the long term demand for hospital services and the available hospital resources.

Inpatient Capacity Management as area of capacity management decision making was chosen because of the discussions in hospitals about how to reach a better balance between the use of operating theatre resources and nursing ward resources.

Outpatient Capacity Management was added last to the set of models to be able to include this area of growing importance in capacity load levelling efforts throughout the hospital. This argument weighed heavier than the relatively under-developed state of managerial and capacity management thinking in this area, which asked for quite a different approach to visualize resource requirements of outpatient practice by specialists.

One could argue that a weak point of the current set of models is that there is no model available to link outpatient and inpatient activity development of specialties. In terms of the current set investigation of the complete activity profile of a specialty would require the use of different models. The specialist model developed does cover the whole practice of the specialty but its structure does not allow for instance for the simulation of the effect of an increase in outpatient activities of a specialty on the inpatient activities of that specialty. We deliberately did not build such a model because it would force to build one model covering all hospital activities, while literature on hospital model development warned of the pitfalls for such ambitions.

The X-ray Capacity Management model was developed because this department is a good example of a department that has to serve different flows of patients from various sources while there are only limited means available to exercise control over the organization of the inflow into the department.

Finally, the Specialist Capacity Planning model was there from the start of this research as the core model bringing the different pieces together and pointing to the crucial role of the organization of specialist activities for the use of hospital resources throughout the hospital system. Every change of resource allocation in one or other part of the hospital is influenced by the way specialist activities are organized and should therefore also be checked on feasibility from a specialty practice point of view.

Table 4.9 shows more specific characteristics for the five models by summarizing the input requirements per model and the sorts of output from each model.

As can be seen from Table 4.9 the models use quite different input arrangements, from readily available demographic and hospital statistics over a number of years, to sample data on patient flows for a number of weeks, and to professional judgement estimates using a protocol-based approach.

In Appendix 1 more information is given on the models, describing in more detail the planning problem addressed by the model, the outline of the model's structure and a representative example of the model's output.

We will conclude this description of the model set by going briefly into the relationships between the different models as illustrated in Figure 4.5.

Model name	Input requirements	Types of output
1. Patient Flows and Resources	<ul style="list-style-type: none"> - long term demographic data - last years production data on admissions, also (pooled) from neighbouring hospitals - hospital resource configuration - resource requirements ratios per specialty and capacity load factors 	<ul style="list-style-type: none"> - admissions - required resources - resource utilization - waiting list development - population development
2. Inpatient Capacity Management	<ul style="list-style-type: none"> - a sample of 4 weeks of admissions including the resource use by these admissions - capacity configuration plan of OT and ward resources 	<ul style="list-style-type: none"> - development of OT, bed and nursing staff utilization per day and week - average occupancy of beds, nursing staff and OT hours (over 4-weeks) per specialty and ward
3. Outpatient Capacity Management	<ul style="list-style-type: none"> - a protocol based description of outpatient patient processing by specialty - capacity configuration plan of OPD and diagnostic departments 	<ul style="list-style-type: none"> - patient throughput - physician workload - outpatient resource occupancy - medical department occupancy - treatment time outpatient programmes
4. X-ray Capacity Management	<ul style="list-style-type: none"> - a sample of 2 weeks of patient flows from the various sources, including their x-ray resource requirements - capacity configuration x-ray department - room programming of examinations 	<ul style="list-style-type: none"> - occupancy examination groups - room occupancy - access time for appointments - waiting times for walk-in patients
5. Specialist Capacity Management	<ul style="list-style-type: none"> - specialty time-tables - OPD time-table, OT time-table and other time-tables that involve specialist capacity - resource requirements resulting from time-tables - planning restrictions per specialty - capacity configuration of OPD, OT, etc. 	<ul style="list-style-type: none"> - workloads (resulting from schedules) for operating theatres, outpatient department, etc. - violations of planning restrictions for specialties and departments

Table 4.9: Input requirements and sorts of output per model.

As can be seen from Figure 4.5 the core of the model set is represented by the Specialist Capacity Management model. This reflects the premise that all resource allocation changes in hospitals require consultation of specialty planning organization, because this refers to the key human resource in the hospital. The three capacity management models surrounding the specialist model allow for investigation of resource allocation changes in separate areas of capacity management decision making, trying to arrange a balanced use of resources at a medium term level of planning, i.e. one year. Using one of these models will always require the use of the specialist model at the same time, because of the interactions between specialist activity planning organization and the planning organization covering these areas. This also illustrates the integrative perspective required on the contribution of the different professional subsystems to the overall hospital objectives.

The strategic level support model Patient Flows and Resources surrounds the management control level support model set, reflecting another premise that resource allocation issues can only be discussed after having looked at the long term balance between demand and supply

Figure 4.5: Relationship model set Hospital Capacity Management.

for the hospital considered.

Depending on the resource management issue looked at, the different questions to be answered may require the use of a combination of models shown. This will be illustrated in the third part of this study, where the models will be shown at work as part of the case-studies performed.

4.3 Implementation strategy for case-studies

The third part of our modelling was concerned with developing an implementation approach for the use of the models in tackling a resource management issue faced by the hospital. In this section we will introduce the implementation model used in the case-studies and give support for it from reorganization and change literature.

Implementation model

The model's function is twofold. First of all it provides us with guidelines on how to implement our approach. Secondly, it serves as a reference for interpreting the changes, which have occurred in the projects. The implementation model is shown in Figure 4.6.

Figure 4.6: Heuristic model of variables affecting the implementation of the resource allocation decision making approach.

We will turn to each part of Figure 4.6 for further elucidation of the different variables in the model. In this way we will illustrate how, in our model, outcome variables on resource allocation are related to the three variables of our implementation strategy via a set of intermediate variables.

First we will look at the three elements of our **implementation strategy**:

1. Problem oriented

We consider the existence of a formal and concrete problem that legitimizes our activities as a condition and prerequisite for a project on resource allocation. This requires a closer look at the types of changes considered in the projects. Earlier, in our analysis of the problem we introduced the term 'critical resource incidents' referring to events such as an increase of medical staff, a reorganization of the operating theatres, a merger of hospitals. These events cause a major shift in the allocation of resources, and are therefore 'critical' to resource

requirements and their use. Furthermore, these events are generally accepted as legitimate occasions for considering the configuration of resources, offering opportunities for achieving a better balanced workload profile for resources. This illustrates that we have deliberately linked our study objective (a better distribution of workload during a time period) to a formal reorganization process with its own objective. This reorganization process or formal cause can act as a stepping-stone for reaching the balanced workload objectives of our study. This approach is followed because in our view optimization of resource use as such should not be applied as first and sole objective for a project in a hospital setting. Such an attempt would fail due to lack of support in the multi-actor hospital system. Instead, we link our effort to a reorganization process or formal cause by supporting decision making in a problem that is part of the formal problem setting. In the example of the reference-case that concerned a reorganization of an operating theatre time-table we could have supported the development of a time-table that would have fitted the new operating theatre planning objectives, while looking at the same time at the resource impacts of this change on other parts of the hospital. The changes studied can therefore be characterized by the fact that they build on the acceptance of a reorganization process or a formal cause.

2. decision support

Crucial to our approach and distinguishing it from the usual management consultancy approach, is the use and role of decision support computer models. The models provide information on the capacity co-ordination requirements and offer the different parties concerned a global perspective on the problem investigated. The models act as learning tools to handle the complexities of the hospital's production system by visualizing resource impacts, within a wider hospital context, of changes in the allocation of scarce shared resources that are 'leading' in the hospital's production system and have consequences for other 'following' resources.

The models contribute to the capability of the organization to process information on relations between departments within the hospital. Developing these lateral relations is one of the options of management to capacity co-ordination requirements. According to Galbraith [1973], looking at organizations as information-processing networks, there are five ways to handle capacity co-ordination problems in organizations:

- environmental management
Instead of modifying its own structure and processes, the organization can attempt to modify the environment. The x-ray department, for example, can arrange with the general practitioners that they cannot refer patients without an appointment.
- creation of slack resources
By bringing in additional resources, management can reduce the need for co-ordination. This implies a reduction in the level of performance and additional costs to the organization.
- creation of self-contained tasks
In this case the need for co-ordination is reduced by changing from a functional task design to one in which each group has all the resources it needs to perform its task.
- investment in 'vertical' information systems
To increase the organization's capacity to handle information concerning co-ordination issues, management can decide to develop vertical information systems. These systems collect information at the points of origin and direct it to appropriate places in the hierarchy.

-
- development of lateral relations

The last way to handle co-ordination problems is to employ selectively lateral decision processes which cut across lines of authority and to develop lateral information systems along these lines. This way moves the level of decision making down to where the information exists rather than bringing the information up to the points of decision. It decentralizes decisions but without creating self-contained groups.

The second variable of our implementation strategy, the use of decision support tools, can therefore be said to build on the lateral relations in the organization. This choice was made as we are dealing with scarce shared resources, and because hospital information systems are departmentally based and do not offer support for interdepartmental relations across the organization. The capacity to handle lateral information in relation to one's own task can act as a restriction to the development of lateral information systems.

3. participation

The third element of our implementation strategy involves a participative method of executing the project. Participation can in this case be defined as involvement of departments or groups in decision making concerning allocation of resources that will effect them. The Vroom-Yetton-Jago model for levels of participation, that was first suggested by Vroom and Yetton [1973] and later expanded by Vroom and Jago [1988], assumes that the degree of participation in decision making depends on the characteristics of the situation. Their normative model assumes the leader will determine an appropriate decision style, taking into account the following variables:

- how important is the technical quality of this decision?
- how important is subordinate commitment to the decision?
- does the leader have sufficient information to make a high-quality decision?
- is the problem well-structured?
- if the leader will make the decision by himself, is it certain that subordinates will be committed to the decision?
- do subordinates share the organizational goals to be attained in solving this problem?
- are there different opinions among subordinates about preferred solutions?
- do subordinates have sufficient information to make a high-quality decision?

Depending on these characteristics of the situation one of the following styles of participation is suggested (A: autocratic, C: consultative, G: group):

- AI: the manager makes the decision alone;
- AII: the manager makes the decision alone, but asks subordinates for information;
- CI: the manager alone makes the decision, but the situation is shared with individual subordinates;
- CII: the manager makes the decision, but meets with the group to discuss the situation;
- GII: the group makes the decision, after a meeting of the manager with the group to discuss the situation.

The expanded model uses a decision tree to define a recommended course of action, by following a path through the tree based on the assessment of the situation by the leader using the different variables.

The Vroom-Yetton-Jago model links very well with a problem-oriented approach as suggested in this study. It assumes a leader, who is ultimately responsible for the decision made and who can make a decision when subordinates do not achieve a joint decision.

In this study we are dealing with situations which:

- require a high technical quality of the decision (many dependencies between resources with high occupancy levels),
- require a high commitment to the decision (relative autonomy of specialists),
- does not allow hospital management to make the decision on their own because the lack of information (lack of management information in hospital information systems),
- are poorly structured (no clear decision procedure available),
- does not allow hospital management to make the decision on their own as it is not certain that subordinates will be committed to these decisions,
- are faced with goal incongruence (different interests of specialties and departments) and different ideas about solutions,
- produce high-quality decisions if use is made of the local expertise available with subordinates.

The Vroom-Yetton-Jago model suggests that this combination of characteristics requires higher levels of participation, such as CII and GII.

Van Tuijl and Kuipers [1985] suggest also participation as change strategy when problems are poorly structured and differences exist in shared values and interests among those involved. They distinguish two major reasons for maximizing participation:

- those involved can bring in local expertise that decision makers do not have;
- involvement in decision making can increase commitment to the problem solving process and to the implementation of solutions.

However, when changes considered create advantage for one group and disadvantage for another group (win-lose situations), they suggest to add negotiation to the strategy for implementation.

In a hospital setting, participation is a prerequisite for effective decision making on resource allocation issues studied because:

- the power structure within a hospital does not allow decision making by hospital management alone, but rather asks for a balancing of interests and views;
- hospital management does not have sufficient information to consider all consequences of this type of decision for all specialties and departments involved, while this information is here available;
- there are many committees in a hospital (such as an operating theatres committee or an admission policy and bed allocation committee) that need to be asked advice before hospital management can take resource allocation decisions.

Therefore, hospital management will in general follow a participative approach in these type of decisions, building on project teams or committees that have worked out feasible solutions.

In the case-studies we have used the following means of participation:

- a project team with involvement of key persons that has an active role in data collection

-
- and creating support for the project,
 - a steering group function by existing committees,
 - consultation rounds with specialties and departments,
 - plenary meetings to report project progress and check on acceptance of alternatives considered.

In this way we tried to stimulate participation of the various parties involved during the different steps of implementation. In our approach we include more parties in the problem solving process than is usually done in projects in this area. In the example of the reference-case the parties involved with the reorganization of the operating theatre time-table were limited to surgical specialties, the operating theatre department, and to a lesser extent the admissions department. When we would have been involved in this project at the time of development of the time-table to apply our approach to look at the impacts of the new operating theatre time-table on other departments, we would also have included the perspectives of the wards, of the outpatient department and diagnostic departments linked with the OPD time-table, and of non-surgical specialties in the scope of the project.

Next, we will consider how our strategy elements affect a set of **intermediate variables** that help to explain the outcomes of the decision making process. In Figure 4.5 the relationships between strategy variables, intermediate variables and outcome variables are indicated, concentrating on those relationships that play a major role in our model.

4. system coherence understanding

This variable refers to the understanding of the coherence in the hospital's production system (subsystems, linkages between subsystems, knock-on effects, etc.) by the actor involved in the decision making process. We assume that the better the actor understands the coherence of the system the more he or she will be able to influence the decision making process. The ability of actors to understand system coherence can be enhanced by decision support models. The insight gained can either be used to benefit solutions that serve the interests of the organization as a whole, or used to benefit the personal interests of the individual.

5 and 6. ability to identify the interest of the organization and self interest

These variables refer to the extent that the individual actor can see the interests of the organization as a whole (objectives of the organization, contribution of alternatives to objectives, etc.) or is focused on the interests of the individual.

We assume that the more the individual actor can see the organization's interests, then the more he or she can and will take part in the decision making process towards the objectives of the organization. This can be done via supporting decisions that are favourable for the hospital as a whole, or by convincing other actors to look at the organization's interest. Furthermore, we suppose in the model that this ability is being enhanced by a better understanding of the system coherence.

The insight gained by actors from increased understanding of the system can in case of win-lose situations also be used in a negative sense for our project by using this information to serve the own interests of the individual actor. This can be done by withholding information or support that is essential for the project or by trying to influence the decision process in a direction that will primarily benefit the actor.

7. project commitment

The problem oriented approach and the participative mode of the project are assumed to have a positive effect on the commitment of actors to the project and the project outcome. The literature on participation discussed in this section supports this assumption.

The intermediate variables discussed above influence the **outcome variables** of the decision making process:

8 and 9. decision process and decision performance quality

The first variable refers to the quality of the decision making process, and can be expressed in the number of alternatives considered or in the opinions of actors on the possibilities offered for influencing the decision making process.

The second variable refers to the quality of the decision taken, and can be expressed in terms of the improvement achieved in resource requirements or resource use.

We expect that the intermediate variables (4-7) influence both output variables (8 and 9) as shown in Figure 4.6, without differentiating between the two output variables.

Support from reorganization and change literature

After this introduction of the implementation model we turn to literature on reorganization and change processes for further support for our approach. We will position our approach within a framework of general strategies for change.

Chin and Benne (1970) distinguish the following **general strategies for effecting change** in human systems:

- empirical-rational strategies

The assumption underlying these strategies is that human beings will make rational decisions and are willing to change when they view the proposed change as being in line with their interests. This refers to a sort of 'objective rationality' as it assumes quantitative targets and measurable outputs can convince someone that the proposed change contributes to their short or long term interests.

- normative re-educative strategies

These strategies focus on the influence that norms, values and attitudes of groups have on individuals. According to these strategies resistance to change arises when the proposed change is not in accord with the pattern of norms and values in use. This can only be overcome by a change in attitude of individuals and by their adoption of new norms and values - a time-consuming process.

- power-coercive strategies

In this case change can be forced upon individuals or groups of individuals by using political, financial or moral power. This assumes that those in power can use sanctions or incentives to influence those less powerful in the required direction.

In practice one will often use a mix of the strategies above. For example, one can start by presenting objective information to create a rational basis for change, then continue by bringing in normative ideas to provoke and discuss resistance to change, and finally by confronting those who are in the end unwilling to change with sanctions.

The implementation approach we are using in this study can be characterized as a mix of the

empirical-rational strategy and the normative re-educative strategy. By presenting information on current practice and alternatives considered via computer model support we assume that participants become convinced of the benefits of change for the organization as a whole. The normative re-educative element comes in when, during joint meetings, participants discuss the negative resource impacts of individual strategies or short term strategies, and alternatives which instead benefit the organization as a whole and take a longer term perspective. While we are aware that the focus of participants is first of all on individual interest and short term perspective, we hope to achieve with this strategy the development by participants of more feeling for organizational interests and long term perspectives and attach comparatively greater value to these. By teaching individuals how to handle the complexities in the hospital production system in this project we assume that this knowledge and experience will have also a further educational impact when dealing with similar problems in the future. An approach based on the power-coercive strategy is not used much in health care because of the complex line of authorities and the little use of sanctions in professional organizations such as a hospital.

The variable 'system coherence understanding' in our implementation model shows parallels with the system's perspective as advocated by Senge [1991] for **organizational learning**. Organizational learning instead of individual learning occurs when learning experience is shared between individuals and embedded in organizational memory. Three levels of learning are distinguished (Argyris and Schön (1978):

- single-loop learning

This refers to the detection of deviations from targets set by the organization and the corrective actions taken to permit the organization to carry on its present policies.

- double-loop learning

Double-loop learning occurs when deviations are detected and corrected in ways that involve the modification of an organization's underlying norms, policies and objectives.

- deutero-learning

Organizations that have learnt to carry out single-loop and double-loop learning, and have therefore learnt how to learn, are engaged in deutero-learning.

One of the prerequisites for higher levels of learning is according to Senge (1991) that individuals adopt a system's perspective.

Returning once more to the approach we follow in our study on changes in resource allocation in hospitals we can compare the global hospital perspective on the problem investigated that we want to achieve in our approach to the system perspective for organizational learning by Senge [1991]. We have used this perspective in Figure 4.7 to illustrate how different levels of learning play a role in our approach. Following Senge's assumption, we have supposed that a wider system perspective enhances higher levels of learning, as the increased scope is a prerequisite to discuss the present policies and organization and to move from single-loop to double-loop learning. It should be stressed, however, that the scope of system perspective does not correspond self-evidently with type of learning, and that also lower level learning occurs at higher level of system perspective or vice versa.

Single-loop learning in resource allocation management happens when department two adapts its amount of resources allocated to its process B to achieve a better correspondence

Figure 4.7: System's perspective on hospital resource allocation management.

between the utilization of resources as observed in reality and the target utilization set (target b). For example, a ward might reduce its nursing staff because the average nursing staff occupancy is 80%, while the target set for nursing workload equals 100%.

Double-loop learning would occur when target b becomes object of discussion. The ward, for instance, could argue that a target nursing staff utilization of 90% would be more realistic because of capacity loss due to fluctuations in workload. To enter this discussion the ward has increased its area of influence by including the target setting in its scope. The focus, however, is on optimization of the department's objectives.

Further learning will happen when a global hospital perspective is adopted to consider the most feasible utilization target for department two. Then it appears to be that the three departments are interdependent, concerning the amount of resources allocated to their processes, and that the best target set to the utilization of department two depends on the utilization performances of the other departments. The focus will then be on optimization of the objectives of the hospital.

Deutero-learning will happen when the organization has learned from this experience how this problem can be tackled more effectively next time, or when this approach is applied to other similar problems elsewhere in the organization.

4.4 Case-study Design

The third part of our research involves three case-studies which illustrate the use of our approach (problem oriented, model support, participative) to resource management issues in concrete hospital settings. The case-studies, furthermore, have to shed light on the following questions:

- What is the change in the need and use of resources?
- To what extent can this change be attributed to the approach followed?
- What other impacts do occur?

Effects expected due to the implementation model used such as increased understanding of the system's coherence and improved eye for the organization's interests, and side-effects that were not expected but came along with the change process.

- Under which conditions can these results be achieved?

We have chosen for a multiple case-study approach for our field research activities. A case-study is, according to Yin [1989], an empirical inquiry:

- that investigates a contemporary phenomenon within its real-life context;
- when the boundaries between phenomenon and context are not clearly evident;
- and in which multiple sources of evidence are used.

The phenomenon investigated is the application of a dedicated approach to resource allocation problems in hospitals, in which decision support computer models that visualize resource impacts of patient flows due to alternative configurations of resources play a crucial role. As this approach is part of a project on a real-life resource management issue in a hospital setting the boundaries between phenomenon and context will not be very clear, and therefore we will have to look for different sources of evidence for changes that will occur in the use of resources studied.

The case-study as research strategy is preferred instead of an experiment or survey when the research questions focus on 'how' and 'why', and when there is little or no control over events and when the focus is on contemporary events. A case-study can in principle be used for two different purposes [Van der Zwaan, 1984]:

- exploration and orientation of problem areas that are yet not fully explored;
- deepening knowledge about already explored areas by means of explanation and interpretation of underlying processes.

In fact, the preparatory studies that preceded the development of our decision support computer models can be regarded as representatives of the first type of case-studies. The case-studies we performed as part of our field research activities fall into the second category, because we are interested in finding out in an exploratory way how the knowledge developed so far (decision support models and implementation approach) can best be used to solve a specific resource allocation problem and what effects will result. The explanatory power of the case-study is considered to be small due to the lack of comparison. It is, however, possible to compensate for this, by considering a number of cases i.e. a multiple case-study design. This is not meant to aim for generalizability of the research outcomes as is the case in a comparative research design. The case-study approach has great power when it comes to visualizing patterns of relationships within a system as a representation of the internal system logic. The challenge of the case-study approach is to balance the advantages of the case-study in describing underlying processes and effects with the few comparative possibilities.

In total four case-studies were performed: one to demonstrate knock-on effects in a hospital (reported in Chapter 3) and three to illustrate the use of our implementation approach. However, we have purposely chosen different resource allocation problems for each of the case-studies. This is to illustrate that the approach developed can be applied to different resource allocation issues within a hospital setting and that the conditions for implementation are in principle the same. Table 4.10 summarizes some characteristics of the case-studies performed.

Case	Resource Management Issue	Model use
Reference (Chapter 3)	Operating theatres time-table reorganization	Inpatient & Specialist
One (Chapter 5)	Specialty time-table reorganization	Specialist
Two (Chapter 6)	Interface x-ray department and outpatient department	X-ray & Specialist
Three (Chapter 7)	Reorganization of inpatient resources	Patient Flows and Resources & Inpatient

Table 4.10: Overview of case-study characteristics.

As can be seen from Table 4.10 each case-study focuses on a different resource management issue. Moreover, in each case-study different models or combinations of models are used. The models are described in 4.2 and in Appendix 1. However, regardless of these differences in resource management problem and model use, the case-studies can be compared in that they all:

- deal with resource allocation decisions concerning scarce shared resources;
- involve several departments or groups within the hospital;
- use the approach suggested in this study, i.e. problem oriented, use of decision support tools and a participative mode.

Case-study report

The report on each of the case-studies in the succeeding chapters will follow the same structure, covering the research questions to be answered. We list these questions here under the headings of the case-study report structure used:

1. Hospital context and planning problem
 - What is the resource allocation problem faced by the hospital and what is the context of the problem?
2. Current organization of resource allocation
 - How are decisions concerning this allocation problem currently taken and what are the problems associated with it?
 - What is the current resource utilization performance?

3. Project organization and progress report

- How is the project organized and how is the general implementation strategy operationalized in this case-study?
- How did the project develop and what were important events in the project history?
- What are the alternatives considered in the project to solve the problem and what alternative was ultimately chosen?
- How was the solution implemented and what were the problems encountered when implementing the solution?

4. New organization of resource allocation

- What does the new organization of resource allocation look like?
- What is the change in the need and/or use of 'leading' and 'following' resources?

5. Evaluation and discussion

- What was the contribution of the approach followed according to the participants in the project?
- What was the contribution of the researcher as outside agent?
- What other impacts can be reported?
- What conditions were lacking that impeded implementation and should be fulfilled next time?

CHAPTER 5

CASE ONE: REORGANIZING GENERAL SURGERY IN A MULTI-LOCATION SETTING

This case-study deals with a reorganization of the activities of a group of eight general surgeons working in a hospital on two sites. First, we will give some background information on the hospital, the group of surgeons and the planning problem (5.1). Next, we will describe the organization of General Surgery activities prior to the start of the study, the impacts of this organization on resource needs and resource use, the problems associated with it, and experiences with previous attempts to overcome these problems (5.2). This is followed by a report on the approach used in the project, with emphasis on participation of different actors involved and on the use of model support, and on the developments that took place during the different stages of the project (5.3). Then we will turn to the new organization of activities of the surgeons and on the impacts of this new organization on resource needs and resource use (5.4). Finally, we will evaluate the results of this case in the light of the research objectives such as: resource impacts, contribution of our approach, other impacts whether expected or not, and the conditions that are necessary to achieve these results and impacts in another hospital setting (5.5).

5.1 Hospital context and planning problem

The hospital is a general hospital with 650 beds and 17 specialties, offering basic hospital services for a catchment area of about 160.000 inhabitants. The hospital operates on two sites about six kilometres apart. This is the result of a merger between two local hospitals at the end of the 1980s. It was the ultimate intention of this merger to concentrate activities in one location but, as government permission to rebuild on one location was delayed, it was decided to continue to operate on the two locations. To make better use of facilities it was then decided to concentrate from 1991 specialties on particular locations. In the summer of 1992 General Surgery was scheduled to start the concentration process on one site. It was not considered realistic to attempt to concentrate for 100% due to the crucial role of the specialty in the functioning of the hospitals and to the shortage of operating theatre resources on location B, the future location for General Surgery. Therefore, it was decided to concentrate most services, especially the more acute ones, on location B while some other less-acute services continued to be delivered on location A.

Prior to this, each location accommodated four surgeons. The partial concentration targeted for implied that all surgeons would operate on location B, but that on average two surgeons would serve location A on a rotating basis. The surgeons work on a fee-for-service system and had already formed one firm since the merger. The surgeons as well as the board of directors were aware that the concentration of General Surgery activities would have many consequences. It would require not only extra resources on location B such as beds, operating theatre facilities and outpatient department facilities, but also a complete new

schedule for the eight surgeons. Moreover, it would have consequences for other supporting services such as x-ray and laboratories. There was a need to design a master schedule for surgical activities covering both locations, taking into account planning restrictions from surgeons and from resource availability. The surgeons had already at an earlier stage tried on their own behalf to develop with some outside support a computer model for this problem but this attempt had failed. Now the hospital board of directors decided together with the surgeons to start a project to look in a systematic way at the development of such a new master plan. The project would involve not only the surgeons but also the departments that would experience the consequences of the concentration of surgical activities. This was done on purpose because the project's objectives were not only to develop a new master schedule for the general surgeons but also to look at optimization of the consequences of this schedule for the hospital resources involved. In the meantime the hospital management had become familiar with the computer models on 'Hospital Capacity Management' developed by the Dutch Hospital Institute. As one of the models - i.e. the 'Specialist Capacity Management' model - is meant to support reorganizations of master schedules for specialties and departments, the hospital management decided to use this model for the project. Furthermore, they were prepared to participate with the project in our research and to act as case-study. The project started in May 1992 and had to result in a schedule by the beginning of August 1992 as the date for moving the specialty was fixed for 26th of August. Before turning to the project we give in Table 5.1 some activity statistics of General Surgery for 1991/1992 and describe the organization of the hospital.

Activity statistic	Annual figures		Figures per specialist	
	1991	1992	Hospital	National
Number of admissions	3098	3206	401	375
Average length of stay	12.0	10.8	10.8	10.8
Number of first visits	14305	10816	1352	1445
Number of re-visits	34278	33089	4136	3325
Number of day-cases	728	710	89	not available
Number of inpatient operations	3824	3914	489	not available
Number of outpatient operations	9969	9370	1171	not available

Table 5.1: Activity statistics General Surgery (source: hospital administration).

The figures in Table 5.1 suggest an increase of inpatient activities combined with a reduction in the length of stay, and a decrease of outpatient activities. When we compare with 1992 national figures on General Surgery services [source: Dutch Hospital Institute] the case-study hospital shows higher figures on admissions and re-visits per surgeon and lower figures on first visits per surgeon.

The hospital's organizational structure was in transition during the project. Coming from a traditional structure with discipline-oriented departments, the board of directors had recently introduced a new concept based on semi-autonomous units around the core process of

patient care. General Surgery together with Orthopaedics formed one unit. The management of the unit would be in the hands of a management team consisting of a specialist and a nurse, supported by what was called a facilitator working for a group of units. The facilitator helped with administrative and organizational matters.

5.2 Prior organization of surgical activities

The first step in the project plan, which will be described in more detail in 5.3, involved a description of the organization of surgical activities in the two-location setting before the concentration. Figure 5.1 shows the specialty schedule for General Surgery before the concentration.

Schedule : Specialists										
	Monday		Tuesday		Wednesday		Thursday		Friday	
Specialty SUR	am	pm	am	pm	am	pm	am	pm	am	pm
Specialist 1	WPC ;	W	W	OP ² ;	PC	O	O	PPC ;	C	O
Specialist 2	WMCP ;	WO ²	WMO	WCPP	WM	WCP	WMC	WP	WMO	W
Specialist 3	MWO	WWMM	MWCP	WWFM	MWCW≈	WC	MWO	WCPW ; ²	MWC	WW
Specialist 4	WMO ²	WCPM≈ ²	WMWC	WAM	WMO	WW	WMWC≈	WP	WMOW ; ²	WC
Specialist 5	o	wp ²	wc	wp ²	wc	wom ²	wp	wom ²	f	wc ²
Specialist 6	c	wom	p	wcpm ²	o	wfm ² !	c	wcm	pw	wom
Specialist 7	awp ²	wcm ²	f	wo ²	apw	wcmm ²	o	wmm ²	acp ;	wa ²
Specialist 8	c	wwcm≈ ²	c	woam ²	o	wpm ²	a	wcmm ²	o	wf ²

key: O/o = operations
C/c = clinic
P/p = procedures
W/w = ward
N.B. activities in location A are shown in small letters and activities in location B in capitals

M/m = meeting
A/a = administration
F/f = free

; = overlap (allowed)
! = overlap
≈ = more activities
² = alternating weekly

Figure 5.1: Specialty schedule before concentration.

This schedule shows what activities are programmed for each surgeon during the part-days of the week. This can vary from operations in the operating theatre department, clinics in the outpatient department, minor surgical procedures in treatment departments, ward rounds in nursing departments, to other general type of activities such as meetings, administration or free. The activities shown are limited to office hours and do not include duties for emergencies, etc. The four surgeons working in location A are listed in the second half of the schedule.

When we compare locations the surgeons' schedules show a number of differences:

- location A has a less stable schedule, showing many activities that alternate bi-weekly; the alternating activities in location B, however, revolve around operating theatre sessions while the operating theatre sessions in location A are fixed and alternations here relate to meetings;
- location B has a more detailed schedule, especially in the morning;

- the surgeons in location B visit first the ward and have a short meeting before they continue with the morning session, while the surgeons in location A have a longer joint meeting at the intensive care ward before the afternoon session;
- all of the surgeons in location A have one free part-day in the week.

More differences in practice become visible when we compare some statistics for both locations in Table 5.2. The hours shown only relate to activities during office hours, and exclude emergency duties and urgent operations.

Activity	Location A (averages per surgeon)		Location B (averages per surgeon)	
	number of sessions	number of hours	number of sessions	number of hours
Operations	2.6	9.8	2.6	10.3
Clinic	3.0	9.4	4.0	6.9
Minor surgical procedures	2.9	4.9	4.3	5.9
Ward rounds	1.8	2.0	6.8	5.6
Intensive care	5.0	5.0	3.5	1.8
Meetings	4.8	3.4	5.3	2.3
Administration		2.9		3.8
Free		4.0		2.5
Other				1.5
Total scheduled		41.4		40.6

Table 5.2: Practice statistics General Surgery location A and B.

Looking at the figures of both practices in Table 5.2 one can notice some further differences between location A and B:

- the surgeons of location A spend on average more time on outpatient activities and use longer clinic sessions;
- the surgeons of location B spend on average more time on inpatient activities, such as operations and ward rounds;
- the surgeons of location A have more time set apart for intensive care meetings, administration and a half day off.

The surgeons were aware that the concentration envisaged would have many consequences for their joint practice at location B. Despite the fact that they were already one firm for a number of years their joint activities were limited up to now to meetings. Their knowledge of each other's practice was, therefore, limited. Experiences with schedule changes up to then were based on smaller scale changes due for example to a new operating theatre time-table in one of the locations. In case of such an operating theatre time-table change the surgeons normally would adapt the rest of their practice to the choices made in fixing the operating

theatre time-table, as operating theatre sessions are considered as their most important activities and also as one of the most expensive hospital resources. The natural inclination among surgeons and hospital management was to follow a similar approach in this case by reorganizing in a co-ordinated way the operating theatre time-tables on both sites, also because the operating theatres on both locations had already been merged to one operating theatre department before. This, however, would have caused many changes for other specialties, both those which had and those which had not yet concentrated. Also, this would not have solved the problem for the surgeons of creating a balanced schedule for the group of surgeons. The surgeons recognized that this piecemeal approach had been used before and had harmed their practice. They were in favour of an approach that would focus on the whole scope of the practice of General Surgery. However, there was no experience available on such an approach, apart from an earlier attempt to have a computer model build with some outside programming support. One of the surgeons had suggested in an earlier meeting that a new specialty schedule was required as a preparatory step for the pending concentration. This attempt did not succeed as the surgeons found out that the development of such model - and also the problem of creating a new specialty schedule - was a more complex task than originally thought. The group of surgeons, therefore, supported the project as the approach suggested would focus on the specialty's organization as a whole and would make use of a computer model that had already been applied to similar problems in other hospitals.

5.3 In search of a new organization

First, we will describe the organizational aspects of the project and the different stages of the project. Next, we will show how our implementation approach worked out in this setting. Finally we will report the developments during the different stages of the project.

Project organization

After the decision was taken by the board of directors to start a project for the development of a master schedule for the group of surgeons as part of their concentration on one location, a project team was established and a project plan. This plan was based on a project proposal by the researcher after a consultation meeting with one director, one surgeon and the manager of the operating theatre department. In this meeting, that took place half May 1992, the planning problem of the surgeons was discussed as well as the possible contribution of the researcher. The computer model 'Specialist Capacity Management' was demonstrated and discussed in terms of the applicability to the planning problem of the surgeons. The participative approach as suggested by the researcher, implying the involvement of all parts of the hospital organization, was received favourably. In this meeting, furthermore, the decision was taken not to focus on the change of the operating theatre time-table that was also pending, but instead to concentrate on the master schedule of the general surgeons. In the project plan this was made more explicit by considering the hospital operating theatre time-table as given - as a factor that can not be influenced within the scope of the project. The project's objectives were to make up an inventory of the changes for the group of surgeons and for other departments involved due to the concentration of General Surgery on one location, and to develop a master schedule for the surgeons that would first of all optimize the organization of General Surgery activities but would also take into account the

resource impacts for the other departments involved. This broad scope of the project was further limited to the following relationships:

- the use of operating theatre facilities by General Surgery;
- the use of outpatient department facilities by General Surgery clinics;
- the use of facilities in treatment department for minor surgical procedures by General Surgery;
- the consequences of the new General Surgery organization for the work organization of the Anaesthetists;
- the consequences for the nursing departments used for General Surgery admissions.

As stages in the project were distinguished:

1. Description of present organization of General Surgery activities:
 - current schedules for General Surgery activities on both locations;
 - problems with the current schedules.
2. Inventory of demands, wants and suggestions concerning the new organization:
 - interviews with each of the surgeons;
 - development of proposals.
3. Consultation with other departments involved.
4. Reporting to the board of directors.

It was suggested that a small project team be established consisting of one general surgeon (chairman), a staff officer for issues on patient logistics (secretary), the treatment department and operating theatre department managers for location B, the manager of nursing services and the researcher as outside consultant.

Moreover, a larger group of representatives of departments would act as sounding board for the proposals of the project team. There was a heavy time-pressure on the execution of the project plan as the new schedule needed to be available in the beginning of August due to the concentration date of 26th of August. This implied that steps 1-3 needed to be finished by the end of July, and that evaluation and reporting would follow after the introduction of the new schedule.

The plan found approval with all attenders at the larger group meeting held on the 29th of May before the start of the project. The first meeting of the project team held on the 2nd of June can be regarded as the formal start of the project activities. The project team met bi-weekly to discuss the progress of project activities, while between meetings the members had to perform some tasks related to the project. The interviews and the analysis of data was mainly done by the researcher together with the staff officer.

Implementation approach

Now we describe how we used in this project our implementation strategy developed for this study as given in 4.3. We turn to each of the elements of our strategy which can be summarized as: problem oriented, use of decision support tools, and a participative way of execution of the project.

The **problem oriented** approach in the project has already been thoroughly discussed. It suffices to say that everybody was aware that there was a problem, that the new master schedule for the group of general surgeons would have many implications for other

departments and that the choice to focus on the change for General Surgery as specialty found broad support.

The use of **decision support** tools in the project was operationalized by the choice to make use of the 'Specialist Capacity Management' model to help in the development of a specialty time-table. The model is described in more detail in the appendix. The model was used to collect data on the current organization of the activities of General Surgery in both locations and to visualize the resource impacts of the time-table on other departments. The contribution of the model during the different stages of the project will be reported further on.

The **participative mode** of execution of the project was operationalized in different ways. First of all by the involvement of key persons in the project team. They were expected to keep in touch over project affairs with the groups they represented and to bring in information on their part of the hospital organization regarding workload impacts and feasibility of proposals. The larger group, acting as a sounding board, also provided an opportunity to influence the project for those who were not directly involved in the project. Apart from these meetings, consultation rounds were very important tools for participation. This applied especially to the group of general surgeons as their tight time-schedule allowed for little time for project purposes. The way these participation tools played a role in the project becomes clear in the next part.

Project progress report

The time-pressure on the project caused a prosperous development of project activities. We will below report on the developments during the different stages of the project. As the project continued after the due date of concentration on 26th of August 1992 we also include this part of the project in our report.

1. current organization of General Surgery activities

This first step of the project involved a description of the specialty schedules for General Surgery in both locations. As these schedules were not available in written form, we used the schedules of the operating theatre department, the outpatient department, the treatment department, etc. to collect data on the sessions of the surgeons in these departments. We asked the members of the project team to bring in this information to involve them in the project execution. This information was fed into the computer model; the model was used in a project meeting to present the available information on the current schedules. The specialty time-tables produced by the model were next checked and completed with other activities of the surgeons by way of a consultation round including all surgeons. This was done by the staff officer. This led to the representation of the current specialty schedule as shown in Figure 5.1 and to insight into the differences in practices between locations presented in Table 5.2.

2. first consultation round with general surgeons

The next step involved interviewing all surgeons by the researcher. The topics discussed were:

- What is the importance of the specialty time-table for the surgeon?
- Is the description of the current time-table correct and what are the problems with the current schedule?

-
- What should be the premises for the new schedule for the specialty in terms of for instance a task structure within the specialty and in terms of activity development at the both locations?
 - What are the demands and what are the wants for each surgeon relating to his individual time-table?
 - What influence may other departments have on the specialty time-table because of workload management reasons?

The information from these interviews provided much insight into the planning problem that proved to be useful during the further execution of the project. We will only report the main findings of this first round:

- First of all, it became apparent that the surgeons all found the time-table of extreme importance to their practice. The time-table is a guideline for their daily practice. A well-balanced time-table improves the quality of the specialty practice, for instance by taking care of joint meetings. A good time-table must be easy to memorize; most surgeons wanted therefore to get rid of the alternating character of activities.
- The problems with the current schedule concentrate on the bi-weekly character of some activities, the difficulties of attending joint meetings or of commitments elsewhere, the too short breaks between major surgery sessions and outpatient clinics, and the difficulty of realizing the scheduled free time.
- The premises for the new specialty time-table were to be:
 - . no bi-weekly alternating activities;
 - . on average the same number of session hours for each surgeon as was the case in the previous schedules;
 - . on average one day per specialist scheduled for location A, focusing on day surgery and minor surgical procedures and an outpatient clinic;
 - . good arrangement of joint meetings;
 - . one part-day off for each surgeon per week.
- The individual demands and wants of the surgeons were considered such as:
 - . preference for a sports clinic on Monday morning followed by an operating theatre session to handle sport injuries from the weekend;
 - . parallel scheduling of activities with other specialty clinics to enable interdisciplinary consultation or multi-disciplinary work;
 - . preference for morning operating theatre sessions or a particular day for the part-day off;
- The surgeons were prepared to take into account workload imbalances for other departments, especially for the operating theatres, anaesthesia services and nursing wards. First, however, the General Surgery time-table needs to be optimized before looking after the interests of other departments.

The report on the findings of these interviews was discussed in a project meeting, in which the project surgeon gave feedback from his insight into the practices of the different surgeons. Based on this information the task of developing a new master schedule was taken in hand.

3. development of new master schedule

The next step involved the development of a new time-table that accorded with these premises and demands. The analytical work in this stage was done by the staff officer, the

researcher and a student involved in another project in the hospital. It took about one day for this team to develop a time-table that would suit best the list of premises of the specialty as a whole, the individual demands of surgeons that were considered as a general interest, and the individual wants of the surgeons that were not considered as prerequisites for the new schedule. This exercise was done by hand using empty schedules, as the computer model proved to be not supportive enough for this task. The model was developed first of all to support partial changes in existing schedules (for example due to the start of a new specialist). The model can also be used to develop completely new schedules, but experience learned that it was less effective here compared with a manual procedure. The reasons were that in this way the team had a better overview by using dedicated forms, was better able to check progress of a schedule with the list of premises, demands and wants, and was more flexible to jump from one variant to another variant.

There are of course many ways to develop a feasible alternative from the information available. The team used their own rules of thumb:

- first fixing the operating theatre sessions per specialist, as these are regarded as most restrictive;
- next fixing the outpatient clinic sessions as the number of units available for parallel sessions was limited;
- at the same time looking at the required distribution of activities and surgeons availability over the two locations, with priority given to an optimal use of the restricted availability of resources in location B;
- in the last part of this exercise we finished first the schedules of specialists who were thought of as having more restrictions on their schedule;
- finally, all restrictions on schedules were checked on specialty level as well as on individual specialist level.

In short: start with those activities that are most restrictive and continue with activities that are next from most restrictive, and so on.

This procedure assumes that the operating theatre capacity available to the specialty is already fixed at hospital level. The operating theatre department had recently established a new time-table for both locations to allow for the concentration of General Surgery but also including some updates necessary for other specialties. This decision was outside the direct influence of our project because of our deliberately chosen boundaries, but indirectly via the planning officer and the board of directors we had influence on the decision on the new operating theatre time-table. In effect, when the new hours for General Surgery operating theatre sessions became available for our project, the alternating character of operating theatre sessions for General Surgery that were imposed on the surgeons by the previous operating theatre schedule had disappeared. One other event happened in this stage of the project that influenced our project. As one of the surgeons would retire at the end of the year the envisaged new schedule would only be valid for a few months. The replacement was due to come into effect 1st of January 1993.

4. first evaluation and adaptations

In consultation with the chairman of the project team (a surgeon) the proposal for a new schedule was offered to the group of surgeons together with the list of premises and other considerations used to develop the schedule. This was discussed in an internal meeting of the

group chaired by one of the surgeons - different from the one that participated in the project team. The new schedule was received favourably, especially the fixed character per week, but they proposed a number of changes:

- the number of session hours per specialist should be more evenly distributed;
- fewer clinics in location A, as this would require more personnel for General Surgery to a stay at this site;
- a concentration of activities of each surgeon in location A on one day, to avoid travelling between locations and to avoid major surgical morning sessions on location B that could not be given the necessary aftercare.

During this meeting the surgeon who would soon retire brought in an alternative that had not been considered up to this point. In this idea one of the surgeons would in turn stay for a whole week in location A. As this idea was brought in at a late stage of the meeting and was not worked out properly, the chairman decided that this proposal would be considered in a subsequent meeting provided the idea was worked out in more detail.

We also held a short consultation round on our proposal with other departments involved. The most important conclusions of this round were that the schedule developed would cause an uneven workload of outpatient supporting personnel in location A and that the hours for minor surgical procedures needed to be adapted. One other weak point of the schedule for location A was that the operating theatre sessions made available to the surgeons were concentrated on afternoons in the second half of the week, forcing a concentration of other activities of surgeons on these days in location A; moreover, this allocation of operating theatre resources was not in accordance with the emphasis on minor surgery procedures on day cases or short-stay patients, which requires morning sessions and sessions in the beginning of the week.

Based on these comments we managed to develop a revised version, building on the experience of the first exercise. During this second exercise the surgeon who had brought in the alternative in the surgeons meeting contacted us to show the schedule that he had developed based on his idea of one fixed surgeon per week for location A. We contacted the chairman of the surgeons meeting - as the surgeon participating in our project team was on holiday - who informed us that the group's decision had been that this alternative should not be taken into account by us, unless the group would decide otherwise based on a written plan put forward to the group by the surgeon. As time ran out before the due date of concentration, our revised version of the schedule was made definite, with some minor adjustments by the group of surgeons, on the 20th of August. Therefore, this schedule was implemented after the concentration. This schedule and its resource impacts will be discussed in 5.4. Due to the time-pressure we were not able to look at a more balanced use of, for example, outpatient facilities, but all time had gone into the development of a feasible alternative that satisfied the scheduling restrictions - as the surgeons kept changing and adding requirements each time a proposal was put forward.

Experiences with the new schedule led to a number of changes to it, focusing on outpatient clinics. A new consultation round with the individual surgeons was held, resulting in the following conclusions:

- The clinics in location A were not well used, as the surgeons would have liked a complete concentration in location B. This led to overcrowded clinics in location B.
- Another problem was that the way the clinics were organized in location B did not suit the surgeons coming over from location A. At this stage it became apparent that there was no agreement within the group on the way to handle fracture and wound dressing patients, either in a separate clinic or spread out over general clinics.

It was decided to add a few clinic sessions to the schedule in location B and to report to the board of directors that the pressure on facilities in location B increased as the scheduled use of facilities in location A stayed in practice below the target set before the concentration.

5. project interruption and continuation

The new schedule was used from September to December as the new surgeon was due to start 1st of January 1993. It was decided to wait till this date with further updating of the schedule including an improvement in the use of outpatient facilities. In the meantime a meeting was held with the larger group to inform them on the development of the new master schedule for the general surgeons and to demonstrate the resource implications for the departments involved. Here the computer model came again into focus. Data related to the new schedule had been fed into the computer model, which allowed comparison of resource impacts of both schedules. The model was used in this meeting to visualize the schedules and the resource impacts of the schedules.

At the end of the year the surgeons requested the board of directors to allow an almost complete concentration on location B. The facilities on location A remained under-used, not only because of the reluctance of the surgeons to work in location A but also because the allocation of operating theatre sessions did not allow admission of many day cases and short-stay patients in location A. The board of directors decided to perform a feasibility-study to check whether the plan of the surgeons could be realized. This implied a temporary interruption of the master schedule project, as this project was restricted to the scheduling of resources, given the amount of resources made available to a specialty. However, the researcher was involved as advisor to the project team that investigated the feasibility of further concentration. The outcome of this study was that further concentration in location B would be possible if other specialties would be prepared to accept a reduction of operating theatre hours that from an analysis on operating theatre sessions utilization figures appeared to be redundant. The board of directors, however, hesitated to implement this recommendation because of the opposition expected from other specialties that would not accept the outcome of this analysis of historical data and would point to new developments. The new surgeon was given a number of sessions left over from the surgeon who had retired, and the schedule was used with these amendments during most of 1993. There was no opportunity to continue the master schedule project as the surgeons were not pleased with the progress of their plan for further concentration. A new chance came at the end of 1993 when the decision was taken to fill the empty position of a surgeon who had left in between. In the meantime the facilitator had developed his supportive role towards the group of surgeons to such an extent that the development of a new schedule to allow for the eighth surgeon had become a major concern. After consultation with the board of directors and the chairman of the group of general surgeons it was decided that the facilitator and the researcher would take up the project again.

6. second consultation round

To continue the project it was decided to hold a second interview round among the surgeons. The topics for the interview were:

- problems with the current schedule,
- suggestions for the new schedule,
- criteria for schedule evaluation.

Here we will only report on the last topic, as the other points were simply dealt with by small schedule adaptations. To develop criteria for evaluation of the master schedule from the point of view of the surgeons we had formulated a questionnaire with questions concerning criteria of a good performing schedule as perceived by the specialists. These points were also discussed in the first round, but now we wanted more precise answers based on the experiences with the current schedule.

The questions dealt with the following items:

- fixed or alternating character of activities,
- priority of activities for the surgeon's practice,
- importance of spreading of sessions within the week,
- required slack-time between consecutive sessions,
- importance of co-ordinating schedules of individual surgeons,
- consideration of joint meetings,
- emphasis on fully planned mornings,
- consideration of preferences for morning/afternoon or free part-day,
- scheduling of ward rounds
- consideration of resource implications for other departments,
- required flexibility of the schedule for taking over sessions in case of absence of a surgeon.

The interviews were held with the six surgeons that were present during this period. Table 5.3 lists the major findings based on the questionnaire.

The information in Table 5.3 provides important support for evaluating the master schedule presented in 5.4. However, one criterion that one surgeon reported as most important for a surgeon's practice is the ability to handle urgent patients. This cannot be judged from the time-table's information but requires arrangements for acute services apart from the scheduled services. When these arrangements are insufficient, then schedules will be pulled down.

7. development second master schedule

The last step reported in this case-study involves the development of a second master schedule that would be used for 1994 and include the activities of the eighth surgeon. Most of the scheduling was done by the facilitator in consultation with the researcher. Much benefit was got from the experience with the previous scheduling exercise. Again, we had to wait till the new operating theatre time-table came available before we could start with the master schedule for the group of general surgeons. When finally the OT schedule was available, some alternating sessions had to be accepted in the specialty time-table. This time

Performance criteria	Opinions of the surgeons (n=6)
1. Fixed character schedule	5 surgeons (3 strongly) favoured a fixed schedule and 1 surgeon did not care much if it would be alternating bi-weekly
2. Priority of activities	first priority are the operating theatre sessions because of its restricted character, and the rest follows with a bit higher priority for clinic sessions
3. Spreading of sessions	spreading of sessions throughout the week is important for operating theatre sessions, clinic sessions and ward rounds; 1 surgeon preferred a concentration of clinic sessions on a few days and 1 surgeon did not matter
4. Slack-time between sessions	preferred slack-time between: <ul style="list-style-type: none"> - OT and OPD sessions: 45-60 minutes - OPD and minor surgery or procedures sessions: 30 minutes - OT and minor surgery sessions: 45-60 minutes
5. Co-ordination of specialist schedules	everybody agreed that this is necessary in a large group of surgeons but the limited resources force already in this direction
6. Joint meetings	important but have less priority; some find it irritating that over-running clinics do not allow attendance at them
7. Morning emphasis	everybody agreed that there is a natural inclination to do so - which is considered correct - but this should not be over-exaggerated
8. Preferences	preferences should be taken into account provided there is room for them - which isn't often; most prefer a morning as free part-day instead of the traditional afternoon which can improve meeting attendance
9. Ward rounds	all agreed that there should be fixed times for the major ward rounds, which should be part of the schedule
10. Workload departments	this differs for the various departments involved: <ul style="list-style-type: none"> - OT: very important, but already controlled by the OT department - ward: very important, but taken care of by allocating supervisory surgeons to the different wards - OPD: important but forced by restricted facilities - minor surgery/procedures: important but controlled by treatment departments - x-ray: less important (service department) but already taken care of by forced spreading of clinic sessions
11. Flexibility for taking over of sessions	this is considered as very important especially to allow taking over OT sessions, but not realistic in practice; one surgeon suggested that instead of requiring flexibility for each surgeon it would be better to concentrate flexibility in one surgeon that would be scheduled as 'free'

Table 5.3: Opinions of the surgeons on schedule performance criteria.

the scheduling procedure already included some resource implications for other departments by using business profiles that were available for General Surgery sessions in the outpatient and treatment departments. The scheduling had to take account of a list of requirements that the specialty had formulated on their own behalf:

- two morning and one afternoon operating theatre session per surgeon;
- one afternoon session daily for the specialty to operate on non-elective patients brought in the night or morning before, with an option to continue till 8.00 p.m.;

- four clinic sessions of two hours per surgeon, excluding fracture and wound dressing clinics;
- one morning clinic daily for the specialty to handle fractures and wound dressing patients;
- one specific clinic weekly for varicose patients at location A.

Due to his increased involvement with the specialty's organization the facilitator had also collected during the year a list of specific wants for each practice of the surgeons. Based on this information in total eight variants of schedules were developed. Each time a new schedule was discussed with the chairman of the group and brought in to the internal meetings of the group - in which the facilitator did not participate - the group put forward new demands and developed new insights. The eighth schedule was finally accepted, partly because time ran out before the start of the new surgeon. This schedule will be discussed in more detail in 5.4.

5.4 New organization of surgical activities

As the project development did go through two distinct phases, each leading to a new master schedule for the group of general surgeons, we will turn to both schedules and consider their resource implications. Here, we will also use the schedule performance criteria of the surgeons to evaluate the schedules.

Master schedule 1

The specialty schedule that was developed as result of the first phase of the project is shown in Figure 5.2.

Schedule : Specialists											
		Monday		Tuesday		Wednesday		Thursday		Friday	
Specialty	SUR	am	pm	am	pm	am	pm	am	pm	am	pm
Specialist 1		C	O	cp ²	o ²	C	F	O	CP ²	PC	C
Specialist 2		O	C	PC	E	PC	O	o	F	p	
Specialist 3	PC		C	O	CP	P	C	o	p	O	F
Specialist 4	O			PC	C	CP	O	cp	o	C	F
Specialist 5	c	p		c		o			F	c	o
Specialist 6	p	C		CP	O	F	C	O	Cp	C	O
Specialist 7	CP	M		O	F	cp	C	CP	O	o	
Specialist 8	PC			cp ²	o ²	O	F	C	CP ²	CP	O

key: O/o = operations M/m = meeting ² = alternating weekly
 C/c = clinic E/e = external
 P/p = procedures F/f = free
 N.B. activities in location A in small letters, in location B in capitals

Figure 5.2: Specialty schedule after concentration (schedule 1).

The master schedule after concentration shown in Figure 5.2 contains only sessions and not the joint meetings or other activities. Comparing the sessions schedules before and after concentration shows that the number of alternating sessions has been reduced considerably.

We will see at the end of this paragraph how the schedules perform related to the criteria indicated by the surgeons. At the individual specialist level we also managed to realize some improvements. Specialist 1 was allocated a sports clinic followed by an operating theatre session on Monday. On Tuesday afternoon specialist 2 was not scheduled for sessions to enable commitments elsewhere, etc. The schedule for specialist 6 shows, however, one flaw as a transfer between locations is necessary halfway through Thursday afternoon. To illustrate the resource impacts of this schedule we will concentrate on outpatient staffing and on outpatient direct referrals to supporting service departments such as x-ray, lab, etc.

Figure 5.3 shows the impact of schedule 1 on the use of clerical staff for outpatient clinics over both locations.

Figure 5.3: Clerical staff required for outpatient General Surgery clinics over the part-days of the week (schedule 1).

This sort of graph, produced by the model, shows the resource impacts of the chosen timetable. In this case, Figure 5.3 shows clearly that there are many peaks and troughs in the pattern of clerical staff required for outpatient clinics as part of the specialty schedule for General Surgery that was developed as a result of the first phase of the project.

Figure 5.4 shows the number of patients that can expect to be referred from General Surgery clinics for direct examination to one of the supporting service departments, i.e. the x-ray department.

From Figure 5.4 one can see that Monday and Wednesday morning clinic sessions show a high peak while Thursday morning and some afternoons produce rather troughs in the number of patients that can be expected for direct service at the x-ray department referred from these General Surgery clinics. This is an important indication that this could lead to overload of this department, resulting probably in long waiting times for patients. We will return to the resource performance of schedules in a later part within this section where we compare the different schedules. However, it is important to note that the rather peaky graphs on outpatient resource impacts illustrate that schedule 1 does not perform very well here, which is probably due to the fact that there was no time available to look at resource impacts while developing schedule 1 (see the project progress report in 5.3).

Figure 5.4: Expected number of direct referrals to the x-ray department from General Surgery clinics over the part-days of the week (schedule 1).

Master schedule 2

The specialty schedule that was developed during the second part of the project is shown in Figure 5.5.

Schedule : Specialists											
		Monday		Tuesday		Wednesday		Thursday		Friday	
Specialty	SUR	am	pm	am	pm	am	pm	am	pm	am	pm
Specialist 1		CC	O*	WC	o²	WP	WF	CP	WO	O	WM
Specialist 2		CC	WO	PP	O*	WC	C	O	WF	o	owM
Specialist 3		F	WP	O	C	CC	O²	cp	o	CP	OMO*
Specialist 4		O	C	F	O	Pc	wo	CWP	WO*	pC	WM
Specialist 5		PC	WF	o	pc	O	O	W	WC	CC	WM
Specialist 6		WPW	o	PC	C	WCC	WO	O	O*F	WP	M
Specialist 7		o	WC	WCC	O*	O	WP	PC	O	F	WM
Specialist 8		O	C	CWP	o	F	O*	PC	WC	O²	OM

key: O/o = operations

C/c = clinic

P/p = procedures

W/w = ward round

N.B. activities in location A in small letters, in location B in capitals

M = meeting

F = free

² = alternating weekly

* = optional session for non-elective operations

Figure 5.5: Final specialty schedule (schedule 2).

Again as for schedule 1, the schedule shown in Figure 5.5 contains only scheduled sessions, including most ward rounds, but not other activities such as administration. Comparison of both schedules is complicated by the fact that the surgeons were allocated more operating theatre hours due to their request for more resources as reported in 5.3. However, the overall picture shows a well-balanced schedule with a few alternating operating theatre sessions. Other remarkable differences to the previous schedule is the further reduction of

activities in location A, and the Friday afternoon reservation for a joint meeting. Also optional operating theatre sessions for semi-urgent non-elective operations are allocated to specialists, which often can be shared between two specialists. Further on we will compare the schedules using the performance criteria indicated by the surgeons. The quality of the schedule at the individual specialist level was further optimized. Specialist 1 for example was given an operating theatre session for semi-urgent cases on Monday afternoon with an option to continue till 8.00 p.m. Travelling between locations was reduced, however, specialist 4 had to change location halfway through Wednesday and Friday morning as this was a specific clinic requiring facilities only available in location A.

To illustrate the resource impacts of the final schedule we will again concentrate on outpatient services. Figure 5.6 shows the impact of schedule 2 on the use of clerical staff for outpatient clinics.

Figure 5.6: Clerical staff required for outpatient General Surgery clinics over the part-days of the week (schedule 2).

Figure 5.6 shows for schedule 2, compared with Figure 5.3 for schedule 1, that there are less-high peaks and troughs in the pattern of clerical staff required for outpatient clinics in schedule 2. This will be quantified more precisely further on in this section, where we compare the performance of the different schedules. In the new schedule note that Wednesday instead of Monday morning has become the highest peak of the week. The workload balance over the days of the week has improved, apart from Friday afternoon where no sessions are organized due to the decision to keep this part-day free for meetings. The difference in the workload at day level between the busiest day (Monday) and the least busy day (Thursday) is not more than 25%, which is slightly more than the reference point of 20% difference between days suggested in 2.6. The workload balance between mornings and afternoons can be considered as reasonable, apart from the dip on Wednesday afternoon and Friday afternoon. On the other days the balance between the workloads in the morning and in the afternoon is about 65-35%, which is slightly more than the 60-40% balance suggested as a reference point in 2.6.

Figure 5.7 shows the number of patients that can expect to be referred for direct examination to the x-ray department from General Surgery clinics in the new schedule.

Figure 5.7: Expected number of direct referrals to the x-ray department from General Surgery clinics over the part-days of the week (schedule 2).

From Figure 5.7, compared with Figure 5.4 for schedule 1 (which has a different scale), one can see that the new schedule also produces less-high peaks and troughs in the number of patients that can expect to be referred for direct service at the x-ray department. We see a similar pattern as for the personnel impact, with more workload concentrated in the mornings due to fracture clinics. The more regular pattern can be regarded as an indication of improvement of the workload distribution of the x-ray department.

To enable comparison between the impacts of the different schedules (original schedule, schedule 1, schedule 2) we have listed in Table 5.4 a number of items; some of these items describe resource impacts and others are selected from the list of criteria for schedule performance according to the surgeons as described in Table 5.3.

Comparing the performance of the different schedules according to the items in Table 5.4 it is difficult to arrive at an overall conclusion about the best schedule, as there is no common scale available that can be used for trade-offs between items. We can of course try to develop such a scale as we did for some of the items in 2.6, but we will never be able to cover all items mentioned as they represent a mixture of quantitative and qualitative objectives. Rosenhead's shift in Operational Research paradigm, described in 4.2, pointed at this problem and warned for optimization efforts while it is better to consider separate dimensions. We will therefore first look at the performance on separate dimensions before trying to formulate an overall conclusion. Single dimension observations are:

- Resource implications for operating theatres have improved markedly, going from the original schedule to schedule 1 and schedule 2. The coefficient of variation in operating theatre staff requirements reduced with 33%.
- The negative resource implications for outpatient services that were introduced by schedule 1 have been reduced considerably in the final schedule, though its performance is lower on this item than the original schedule.
- Also, the fluctuations in the flow of patients from outpatient clinics to the x-ray department have been reduced in the final schedule, compared to schedule 1, but they are larger than in the original schedule.

Performance criteria	Original schedule	Master schedule 1	Master schedule 2
Fluctuations in operating theatre staff requirements	Coefficient of variation (perc.) : 47.9	Coefficient of variation (perc.) : 35.6	Coefficient of variation (perc.) : 32.2
Fluctuations in outpatient supporting staff requirements	Coefficient of variation (perc.) : 37.8	Coefficient of variation (perc.) : 54.4	Coefficient of variation (perc.) : 42.3
Fluctuations in direct referrals to the x-ray department	Coefficient of variation (perc.) : 43.4	Coefficient of variation (perc.) : 64.0	Coefficient of variation (perc.) : 48.4
Number of bi-weekly alternating sessions	OT-sessions: 4 clinic sessions: 0 minor surgery sessions: 5	OT-sessions: 2 clinic sessions: 2 minor surgery sessions: 2	OT-sessions: 3 clinic sessions: 0 minor surgery sessions: 0
Spreading of sessions over the days of the week	reasonable	reasonable	reasonable but also whole-day sessions in case of surgeon's preference
Slack-time between sessions	not taken into account	taken into account for the 45-60 mins required between OT and OPD but not for the 30 mins required between OPD and minor surgery	all required slack-times are taken into account
Joint meetings	part of schedule but hard to keep to	taken into account but still problems with attendance	clinics are scheduled till 15.30 and Friday afternoon is scheduled for meetings
Flexibility in the schedule	no facilities for semi-urgent cases	no facilities for semi-urgent cases	daily session for non-elective operations

Table 5.4: Comparison of performance of the schedules at the start of the project and as outcomes of phase 1 and 2 of the project.

- The final schedule shows the lowest overall number of alternating sessions, though one more alternating OT session than schedule 1.
- Schedule 2 performs also best on the other items mentioned, such as the distribution of sessions over the days of the week, the slack-time between sessions, the consideration of joint meetings, and the flexibility in the schedule to take care of urgent and semi-urgent patients.

Also schedule 2 performs best considering the combined performance on different items, using the weighing function for evaluating reduction of variation in resource workloads described in 2.6. Using these weighing factors for the 33% reduction of variation in operating theatre staff requirements, the 12% increase of the variation in outpatient staff requirements and the 12% increase of variation in workload of the x-ray department, the overall result can

be qualified as positive ($+33 \times 100 - 12 \times 25 - 12 \times 50 = 2400$). The difference in outpatient resource use that still remains compared to the original schedule is the price that has to be paid for the improvement in operating theatre resource use and the overall improvement of the schedule according to the opinions of the general surgeons.

The coefficients of variation of the different resource workloads are, however, still considerable and above the level of 20% suggested in 2.6 as reference point for considering corrective action. This suggests that there is still room for further improvement.

5.5 Evaluation and discussion case one

Based on the results of the project as discussed before, we now turn to the evaluation of the case in the light of the objectives of our research. Therefore, we discuss the improvement in resource use achieved, the contribution of our approach to this achievement, other side-effects that occurred during the project, and the conditions to achieve these results and effects.

Improvement in resource use

The improvements in resource requirements have been discussed more extensively in 5.4. One should of course be aware that resource requirements tell only something about the expected resource use and not about the actual resource use in the end. On the other hand, it may be clear that a well-balanced schedule is a prerequisite for a proper execution of planning. Bearing this limitation in mind, the results show considerable improvements in resource use for operating theatres and a slightly deteriorated outpatient resource use. This shortcoming is more than balanced by the improvement in the way specialist-time as a resource is organized within the specialty according to the views of the general surgeons.

Contribution of approach

The **problem orientation** of our approach to resource allocation and resource scheduling issues in hospitals was crucial in this case. We used for the first phase of the project the due date of the concentration as a stepping-stone to look at resource impact improvements by developing a new time-table for the group of surgeons. In the end of this first phase we had difficulties in continuing our project to optimize resource use by further adaptations of the schedule. This can be explained by the lack of a natural moment that could create an urgency for updating the schedule. The discussions between the surgeons and the board of directors about their request to concentrate completely on one location and about the allotment of more facilities further complicated the continuation of the project at that time. This discussion was of more importance to the surgeons, as it determines practice organization and acts as a condition for a specialty schedule. After things had settled down, the project could be continued making use of the coming of a new surgeon; this can again be seen as a natural moment to update the specialty schedule. The linking of a project to improve resource use to a reorganization or other natural moment has, however, as consequence that it becomes difficult to evaluate what part of improvements can be attributed to the reorganization or to the research approach.

The contribution of the **decision support computer model** to the project was different in the various stages. First of all, it was used successfully to demonstrate to the surgeons and hospital managers that the model fitted their problem and that the researcher would bring in

valuable expertise because of his previous experience with this sort of problems in other hospitals. The model was also used successfully to collect data about the current organization of General Surgery activities and to describe the specialty time-table in use and its resource impacts. During the project the model was actually not used for designing the new schedules, as the model proved to be not supportive enough for the schedule development part of the project. Project team members performed better in having an overview of variants tried and restrictions checked and were more flexible to switch from one variant to another variant. A model that would be more flexible in creating alternative schedules that fulfil the many requirements and restrictions would give better support during this stage of the project; this is probably an area where Constraint Programming as discussed in 2.4 can contribute. However, the current model served as a guidance for the project team as the lines of action were already set out by the philosophy and principles used to develop the model. The model was also supportive for visualizing resource impacts of the schedules and this feature of the model was also used in further demonstrations with the model to report on the progress of the project to the surgeons and hospital managers involved.

The use of the **participative mode** for the execution of the project activities contributed to the support for the project. As tools of participation were used: presentations to and discussions with the larger group of representatives of departments; a project team with involvement of key persons; an active role of project team members in collecting data and creating support for the project; consultation rounds with surgeons and department managers. However, it is difficult to judge the exact size of the contribution of the participative approach to the project's outcomes. When the various participants were interviewed on this point they brought forward that this approach gave everybody opportunity to bring in comments or suggestions, and that this approach fitted very well with the type of project, as so many groups and departments were involved in this planning problem. One person cannot oversee all the consequences of the introduction of a new schedule for a hospital-wide operating specialty such as General Surgery, however intricate the planning tools used; to complete the picture one needs to have everybody's view on the problem. Another support for the success of the participative approach was that the second phase of the project was almost without outside help from the researcher executed by the facilitator building on the experience of the first phase.

Other effects

Time and project progress did not allow a systematic evaluation performed on the possible other effects of the project, such as an increased understanding of the system's coherence, an improved attention to the interest of the individual or group versus the interest of the organization as a whole (the intermediate variables in our implementation model described in 4.3). Many observations in support of these effects can be drawn from the project's report in 5.3 and from the evaluation of the project as discussed before. One example considered as a key lesson learned from this project is the growing ability of a group of surgeons to develop a policy for creating good conditions for surgical practice, provided they are given the right support. The project provided this support by putting forward concrete proposals, specialty schedules and lists of questions to be answered, requiring decision making of the group of surgeons. Each report or proposal to the group led to new demands (to put it negatively) or to new insights (to put it positively). Without these stimuli from the project the surgeons would not have been able (or would at least have taken much longer) to define their conditions for surgical practice, which can be seen as in their interests. Without this clarification of the surgeons' interests it would not have been possible to look at the resource

implications of the surgeons' organization for the hospital as a whole. The surgeons had already indicated in the beginning of the project that they were quite willing to look at resource implications for departments, provided there was first clarity about a specialty schedule for General Surgery as a prerequisite for a balanced surgical practice of the group. In an interview with the chairman of the group of surgeons to evaluate the project, some further effects on General Surgery practice were brought forward:

- As the time-table made each surgeon's practice visible to all, it supported co-operation within the group as communication lines were shortened.
- The development of specialisations within the group of surgeons (trauma, varices, oncology, gastroenterology, etc) was supported by the availability of the schedule, as this requires time made free within the current schedule of specialists to develop these ambitions.
- Also very important for the functioning of the group is that the new schedule allows for joint meetings. This is due to the decision taken to finish afternoon clinics before 16.00 p.m. and to reserve Friday afternoon for the joint meeting of the group.

According to the chairman the group of surgeons was positive about the way the schedule was developed and about the outcome of the project. When based on experiences with the new schedule further adaptations are required, the project performed will help to implement these changes fairly easy. This indicates that the group has learnt how to tackle this sort of problems and that the group will probably be able to use this knowledge to other problems, which is an indication of deuterio learning as described in 4.3.

Conditions

A few conditions can be mentioned as necessary for the success of a similar project in another hospital setting. Most important is that there is support from the group of specialists, from the board of directors and from department managers. As the project is in the interests of the specialty, support for the project from the group of specialists will not be difficult to get. However, it would be better even if one of the specialists would be actively involved in the project, either as part of the project team or as contact with the group. Support from the board of directors is necessary to create conditions for developing a balanced specialty schedule. Decisions taken by the board regarding the specialty's resources should be well considered in terms of their impact on the project. An example in this project was the influence the board of directors used to prevent an allocation of operating theatre resources to General Surgery that would force the specialty to accept many bi-weekly alternating sessions in their time-table. Also, the managers of other departments can contribute to the project's success when they are prepared to develop resource allocation plans within a wider hospital perspective instead of limiting them to their own department.

We recommend the use of the approach for the project described in this study: problem oriented, use of a decision support tool to visualize schedules and their resource impacts, and a participative mode of project execution. It seems to be obvious from this study that the existence of a problem is a prerequisite to start such a project. The computer model used performed very well as catalyst for discussion, as tool for demonstration and as guidance for the project. The support from the model for fast developing of alternatives could, however, be improved. It would also be possible to replace the model by another model, as long as this would provide the same sort of information to enable the hospital perspective on the

problem. Availability of data to develop schedules or to visualize resource impacts of schedules proved to be no problem in this project. The participative mode of executing the project can be shaped by using a project team with key persons and other tools used in this project or similar ones. The help of an outside researcher or advisor could be useful to collect opinions or views on current problems related to schedules that are otherwise not shared by the actors in the decision making process with insiders.

CHAPTER 6

CASE TWO: IMPROVING X-RAY WORKLOAD AND WAITING TIMES OF WALK-IN PATIENTS FROM OUTPATIENT DEPARTMENTS

This chapter describes the second case-study which focuses on the interface between the x-ray department and the outpatient department within a hospital setting. In 6.1 we give background information on the hospital in which the case-study was performed, on both departments that play a central role in this case-study and on the planning problem addressed. Next, we describe in 6.2 the planning of examinations and allocation of x-ray resources at the start of our study, the problems with waiting times at the x-ray department that were the major reason for starting the project, and the previous attempts made to solve this problem. In 6.3 we describe the approach followed in this project as an operationalization of the implementation strategy used in this study on hospital resource allocation issues, and we report on the developments that took place during the different stages of the project. Then we address the new planning of the x-ray department, including the changes made on the interface between x-ray department and outpatient department, and describe the impacts of this new organization on the utilization of x-ray resources and on the service-aspects for the patients referred to the x-ray department (6.4). The last part of this chapter (6.5) considers the results of this case-study within the framework of the research objectives.

6.1 Hospital context and planning problem

This case-study hospital is a medium-sized acute general hospital with 340 beds and 17 specialties, offering a range of basic hospital services to patients in a catchment area of about 100.000 inhabitants. During previous investigations into the x-ray department's functioning, analysis of the department's workload and waiting times for patients showed poor performance. There was a large flow of outpatients that did not have an appointment made for an x-ray examination, causing peaks and troughs in the x-ray department's workload. At these hours the waiting times for these patients increased to unacceptable levels (average waiting time 21 minutes and maximum waits of over 1 hour). Many of these direct patients have to return later on to the clinic to see the specialist once more. In case of long waiting times in the x-ray department the clinic will probably run over time.

The hospital management decided to start a project, involving the x-ray department and the specialties that had the highest number of direct referrals from their clinics to the x-ray department. The project's objective was to improve patient flow management at the interface between the x-ray department and the outpatient department, by either changing the x-ray department's planning or by adapting the outpatient department's clinic organization for these specialties, resulting in shorter waits for the specialty's patients referred to the x-ray department and fewer peaks and troughs in the workload for the x-ray department.

They had already purchased the models on 'Hospital Capacity Management' needed for this project because they wanted to improve the use of resources for the hospital as a whole by

improving the management of patient flows at the interfaces between departments. They considered this project as a pilot-study for other interfaces in the hospital. The project chosen would involve the use of the model 'X-ray Capacity Management', which is meant to investigate alternative ways of organizing the x-ray department's planning, and the model 'Specialist Capacity Management' because of the links between the direct referrals from specialty clinics in the outpatient department and the clinic time-table of these specialties. The hospital asked for support for this project and was quite willing to be reported as a case-study on Hospital Capacity Management.

Table 6.1 contains some production statistics on activities in the outpatient department and the x-ray department of the hospital during 1991/1992.

Specialty	Total outpatient visits		Total x-ray examination requests		% out-patients
	1991	1992	1991	1992	1992
Internal Medicine	20.682	15.888	8.917	9.049	62.4%
Paediatrics	4.708	4.885	1.128	1.365	68.0%
Cardiology	5.760	5.360	2.380	2.513	34.7%
Pulmonology	3.105	3.239	2.548	2.934	57.0%
Dermatology	9.490	8.773	9	54	18.5%
Neurology	5.670	4.395	1.336	1.800	47.1%
General Surgery	28.298	28.145	15.403	16.553	72.4%
Gynaecology	6.838	7.551	1.670	1.529	83.4%
Orthopaedics	10.668	9.649	5.265	5.443	88.9%
Rehabilitation	108	597	19	294	99.0%
Urology	3.952	3.966	1.399	1.502	80.1%
Dental Surgery	3.226	3.219	45	31	77.4%
E.N.T.	17.758	14.633	1.714	1.767	98.5%
Ophthalmology	14.510	14.259	89	144	88.2%
Anaesthesia	549	643	856	925	39.7%
Psychiatry	3.308	3.776	-	-	-
Rheumatology	-	183	-	-	-
General practitioners	-	-	12.546	12.741	-
Others	-	-	1.765	1.596	-
Total Hospital	138.630	129.163	57.089	60.240	76.4%

Table 6.1: Production statistics outpatient department and x-ray department 1991/1992
(source: hospital administration).

From Table 6.1 one can see that outpatient visits have decreased from 1991 to 1992, and that the number of x-ray examinations has increased. However, the level of outpatient visits to

Pulmonology and General Surgery, whose clinics play an important role in this case, has stayed the same, while the number of x-ray requests from these specialties has increased even more sharply than the hospital's total figures. The percentage of outpatient x-ray examinations as part of the total number indicated in the table is about 75% and has not changed.

The hospital's organizational structure is characterized by a split between ambulatory and inpatient services, headed by two general managers. Ambulatory care services comprise outpatient departments (including centralized facilities for reception, registration and appointment making), diagnostic departments such as x-ray, etc that are most used by outpatients, and outpatient treatment departments. The Radiology department is managed by a head for organizational matters (a senior x-ray radiographer) together with a medical head (one of the radiologists). Inpatient services comprise the nursing wards, the operating theatre departments, the day surgery department and some treatment departments that are mainly used by inpatients.

6.2 Prior organization of x-ray services

The first part of the project, that will be described in more detail in 6.3, comprised an analysis of the workload of the x-ray department and an analysis of the patient flows from the outpatient department, general practitioners and wards, that cause this workload. We will draw from this analysis to describe the organization of x-ray services at the start of the project and the consequences of this organization for x-ray resource utilization and patient waiting times at the x-ray department.

Figure 6.1 shows how the x-ray department allocates its resources to different categories of services delivered to patients:

- examinations outside the x-ray department (e.g. emergency department, operating theatres, etc.);
- large examinations that need preparation and an appointment to be made;
- small examinations that can be performed without preparation but are given appointments to improve the regulation of the x-ray's patient flows and reduce waiting times for patients;
- small examinations that are performed for walk-in patients from clinics or elsewhere, who did not make an appointment for this examination.

According to Figure 6.1 first the resources needed to cover the demand for x-ray services elsewhere in the hospital are set apart. Next, the resources needed for the large examinations are allocated to the room programmes for this type of examinations. Thirdly, resources are allocated to small examinations for which appointments were made. The remaining capacity has to service all of the unscheduled demand for small examinations for which no appointments are made. When the demand for the direct service exceeds the available spare capacity, waiting times will arise for new walk-in patients coming in, assuming that the scheduled rooms do not offer opportunities to take care of it. For this case-study we can therefore concentrate on the small examinations without appointment and the resources available for this type of services.

Figure 6.1: Allocation of x-ray resources to x-ray examinations demand.

Table 6.2 shows an overview of the examination programs for the ten x-ray rooms of the x-ray department. This is a summary presented by the model to have an overview of the planning of the x-ray rooms, whose more detailed planning is also held by the model.

Room	Monday		Tuesday		Wednesday		Thursday		Friday	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
ROOM 1 THORAX	4s:--	3s:--	4s:--	3s:--	4s:--	3s:--	4s:--	3s:--	4s:--	3s:--
ROOM 2 BUCKY	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--
ROOM 3 TRAUMA	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--
ROOM 4 ECHO	--:5L	--:3L	--:5L	--:3L	--:5L	--:3L	--:5L	--:3L	--:5L	--:3L
ROOM 5 IVP/IVC	--:4L	--:3L	--:4L	--:3L	--:4L	--:3L	--:3L	3s:--	--:4L	--:3L
ROOM 6 GASTROENTERO	--:5L	--:--	--:5L	--:--	--:5L	--:--	--:5L	--:--	--:5L	--:--
ROOM 7 THORAX/MAMMO	4s:--	--:3L	4s:--	--:3L	4s:--	--:--	4s:--	--:3L	4s:--	--:--
ROOM 8 ECHO	--:5L	--:--	--:5L	--:--	--:5L	--:3L	--:5L	--:--	--:5L	--:3L
ROOM 9 DSA	--:--	--:--	--:--	--:--	--:--	--:3L	--:--	--:3L	--:--	--:--
ROOM10 CT	--:5L	--:3L	--:5L	--:3L	--:5L	--:--	--:5L	--:1L	--:5L	--:3L

Table 6.2: Overview of room programs in the x-ray department.

For each of the 10 x-ray rooms available at the hospital's x-ray department, Table 6.2 summarizes reservations of the number of hours per day-part that rooms are programmed for large (L) or small (s) examinations on appointment. Each room has a label attached to its number referring to the type of examinations that are mostly performed in the room, also depending on the type of equipment available. Bucky, for example, refers to the examinations that are done with Bucky equipment such as extremities. Rooms 1-3 and 5 can be used for examinations without appointment (such as thorax, extremities, skulls) as far as hours are not reserved for programs or appointments.

To develop a policy for the direct service puts the x-ray department in the dilemma of balancing two objectives:

- For managing the x-ray department's workload it would be better if the direct service was minimized by giving more patients for small examinations an appointment. This would also help in reducing the waiting times for patients, as the previous investigations into the x-ray department's functioning pointed out that patients with appointments have to wait for a shorter time (circa 15 minutes) than walk-in patients (circa 25 minutes).
- However, the direct service is highly appreciated by referring specialties and their patients as this shortens the period for making the diagnosis and also saves patients an extra visit to the hospital for the x-ray examination. Therefore, this would be an argument for keeping this service at the level required by specialties. To prevent long waiting times for direct service patients, the x-ray department needs spare capacity or knowledge about the number of patients that on average can expect to be referred as direct service patients from the specialty clinics to the x-ray department.

The last option requires shared knowledge between outpatient clinics and the x-ray department about x-ray workloads from clinics and the clinics' time-table. Most of the time this communication link does not exist. Long waits for this category of service are not only annoying to patients but also to specialists who have to see the patient once more during the clinic session with the result of the examination to discuss diagnosis and treatment.

One way to collect information on the interface between the x-ray and the outpatient department is to perform a patient flow analysis of the flows between outpatient clinics and the x-ray department and a workload analysis of the impacts of these flows on the utilization of x-ray resources. We will show some examples of this analysis, which is output from the two computer models used for this project. First, we will show the x-ray workload distribution for small examinations without appointments during the days of the week (Figure 6.2). The drawn upper line shows the available capacity, the stacked build up line shows the workload, and the figures between both lines represent the occupancy per day of the week. Business profiles are shown for two weeks to allow for bi-weekly alternating planning cycles, but in this case there is no difference between the two weeks shown.

From Figure 6.2 one can see that Wednesday and Thursday are the busiest days with occupancies of over 100%. The drawn upper line shows the capacity left for small examinations without appointment. The capacity needed for the direct patient flow is shown below, build up by examinations for emergency patients, outpatients and inpatients (see keys for origin of flow). The technician capacity proved to be the most scarce resource for the x-ray department rather than room or radiologist capacity. The further analysis therefore concentrates on the occupancy of technician capacity on Wednesday and Thursday. The capacity line shows dips on Wednesday and Thursday and a peak on Friday. The dips on

Figure 6.2: Occupancy technician capacity for walk-in patients during the week.

these days were caused by educational and meeting obligations of some x-ray radiographers and the peak by one x-ray room less in operation on Friday. One solution to the over-loading on Wednesday and Thursday would apparently be to move some of the over-capacity on Friday to these days. This was, however, not possible due to labour regulations to concentrate labour compensation days near weekends. Figure 6.3 shows the occupancy of technician capacity per hour of the day on Wednesday.

Figure 6.3: Occupancy technician capacity for walk-in patients during Wednesday.

According to Figure 6.3 the busiest hours on Wednesday are between 9 and 12 in the morning and between 2 and 4 in the afternoon, with occupancies of sometimes far beyond 100%. Figure 6.4 presents the occupancy of technician capacity on Thursday.

Figure 6.4: Occupancy technician capacity for walk-in patients during Thursday.

Figure 6.4 illustrates that on Thursday the busiest hours are between 9 and 11 in the morning and between 2 and 5 in the afternoon.

During the peak demand hours, as occupancies rise above 100%, waiting times for walk-in patients build up. The computer model produces an approximation for the development of waiting times, depending on the occupancy rate during one hour and the left-over work from previous hours. This is illustrated in Figures 6.5 and 6.6.

Figure 6.5: Development of average waiting times for walk-in patients on Wednesday.

The upper part of the diagram represents a projection of the waiting time based on the development of the occupancy rate of technician capacity as shown in the lower part. Waiting time will build up during hours with more than 100% occupancy; the work that cannot be performed during those hours will be added to the work that needs to be dealt with in the next hour, which leads to excessive waits at the end of the day or patients asked to return on

Figure 6.6: Development of average waiting times for walk-in patients on Thursday.

appointment on another day. These projections - even if they can only approximate reality via a waiting time function - helped the project participants to link department workload problems with service quality for patients involved.

The analysis of the problems in the current setting as described before was accepted as a good reflection of reality but did not reveal anything new to the hospital management. The previous studies on waiting time problems in the x-ray department had arrived at similar conclusions. To analyze patient flows and workloads was not the problem. The problem was to effect a change in the management of the interface between the x-ray department and the outpatient department. Previous reports had put forward recommendations to do something on the problem of over-long waiting times, either by making more appointments for small examinations or by suggesting changes in outpatient clinic times, but up to now nothing had been done. There appeared to be no support for change. The x-ray department did not find support from specialties to reduce the direct service in favour of the volume of examinations performed on appointment, nor did they manage to convince specialties of the advantages of changing clinic times. Regarding this last option specialties also felt a dilemma. Did the shortened waiting times for patients outbalance the far-reaching consequences of changing clinic times as this would involve a rearrangement of their complete practice? These were some of the major reasons why nothing had happened. The objective of the project envisaged was not to stop there, but to take it up from there and to investigate opportunities for improving the situation.

6.3 Learning to handle the interface with outpatient clinics

As in the first case-study we first describe the organizational aspects of the project and the different project stages. Secondly, we discuss the implementation approach used in this project. Finally, we report the major events during the different stages of the project.

Project organization

From the onset of the project discussions were held from time to time as to what would be the most adequate organization for the project. Some were in favour of a hospital-wide steering group, supervising project teams that were looking at resource management issues involving specific departments. One team, for instance, would look at the interface between x-ray and outpatients, while another team would look at the interface between wards and operating theatres. This scenario for project development stemmed from the hospital scope needed for effective hospital capacity management, and was also based on a first project proposal put forward by the researcher. Others were in favour of a small-scale project approach, illustrating its effect in a setting that offered good opportunities for improvement. The second option prevailed and led to the establishment of a project team for the improvement of patient flow and resource management on the interface between the x-ray department and the outpatient department. The board of directors also supported this option because it would be easier to convince the medical staff by a success than to convince them to participate in a large-scale - and perhaps too ambitious - project on hospital capacity management. Moreover, in this way the project could build on the previous investigations on the functioning of the x-ray department. Also, the start of the project would be at the x-ray department which would make it less threatening to specialties, and the actual involvement of specialties in the project could be postponed till analyses to be performed had pointed out which specialties were needed to bring the project further.

The project team consisted of the ambulatory services manager (chairman), the organizational head of the x-ray department, the hospital's management consultant, a student who would perform most of the analyses and other research activities, supervised by the researcher which also attended the meetings of the project team. Also, a representative of the hospital information services department attended meetings in case information needed to be extracted from the hospital information system. The project team met regularly from September 1992 until June 1993 with intervals of 3-4 weeks between meetings to discuss progress. In the second half of the project, when two working groups had been installed for working on specific specialty related problems, the project team acted as sounding board for working group experiences and for evaluating the outcomes of the project.

The project plan contained three distinct stages of phasing.

- analysis current situation

During the first stage an analysis of the current situation was to be made consisting of an analysis of the workload of the x-ray department, the flow of patients from outpatient clinics to the x-ray department, and the workload consequences of the outpatient flow for the x-ray department. For this analysis use was to be made of the computer models 'X-ray Capacity Management' and 'Specialist Capacity Management'. The first model enabled an analysis of the x-ray department's workload based on input on the flow of patients arriving from different sources. The second model enabled a link to be made between this analysis and the flow of patients referred from outpatient clinics as part of the organization of specialty activities in the hospital. The outcome of this first phase would therefore be an insight into the effects of the current organization of the x-ray department and the interface with the outpatient department, and into the problems associated with this.

- specialty working groups

The second stage of the project was to involve specialties that were considered crucial for solution of the problems put forward by the previous phase. This phase foresaw the establishment of small working groups for specific specialties looking at the interface between a specialty and the x-ray department and trying to work out changes that would

improve the interface problems. Changes could either be on the part of the x-ray department or on the part of the specialty's clinic organization. The small groups would in principle consist of a specialist and a clinic supporting staff representative and one or two representatives from the x-ray department, supported by the student and by other project team members when necessary. The student would bring in results of the analysis of the previous phase as a starting point for discussion and perform additional analyses when required.

- **evaluation**

The third stage of the project was to involve an evaluation of the impacts of the suggestions for change made in the small groups on the problems indicated at the start. This phase would also offer opportunities to indicate other areas or interfaces that would need to be involved in a subsequent project to achieve further improvements, assuming they were linked to the current problem investigated and assuming that the approach suggested in this project would work out effectively.

Implementation approach

We now look at how the implementation approach as suggested in this study was applied to this project on the interface between the x-ray department and the outpatient department.

The **problem orientation** of this project focused on the problems acknowledged by previous investigations into the functioning of the x-ray department: imbalances in the workload of the x-ray department due to walk-in patients without an appointment from outpatient clinics, and long waiting-times for this category of patients. Though these were considered as serious problems and the outcomes of the previous studies were accepted as being true, there was however no immediate cause that would urge participants to take action. Not long after the start of the project, however, there was a change in the configuration of x-ray resources due the installation of new x-ray equipment, which had consequences for room designations and offered opportunities to implement changes that were favourable for the project.

The use of **decision support** tools in the project was effected by using the models 'X-ray Capacity Management' and 'Specialist Capacity Management'. Both models are described in more detail in the appendix. The model 'X-ray Capacity Management' was used to analyze the workload of the x-ray department. The model 'Specialist Capacity Management' was used to analyze the source of the outpatient flow of walk-in patients without an appointment, i.e. the outpatient clinics of specialties in the outpatient department and the referrals from these clinics to the x-ray department. It is important to note that this project was a test for the combined use of models in a concrete project setting.

The **participative mode** of the execution of the project was operationalized in different ways. The project team consisted of key persons for an effective management of the project on main lines, and acted as sounding board for the student and the experiences of the two working groups. In the project team the management of the two organizational units that were involved in the project were participating. Other tools of participation used were the working groups, consultation rounds and meetings to present results. The working group acted as change teams looking at a specific specialty's interface with the x-ray department. The general composition of this working group has been discussed before. Important for the support of the activities of the working group was the involvement of key persons in the specialty's clinic organization and from x-ray management who were familiar with the type of examination requests from this specialty. In this way the specific knowledge necessary to enable change was brought together in the meetings. The knowledge about each other's view

on the interface was further enhanced by adopting an organizational learning approach to look at the various opportunities for improving the management of the interface. Consultation rounds were held with other representatives from the specialty clinics and from the x-ray department to create a wider perspective on the problems encountered in the working groups. One working group, for instance, decided that it would be necessary to have the opinion of all the specialists of the specialty on the current problems in the functioning of the outpatient clinic organization. Finally, meetings were held in the final stage of the project to discuss with hospital management and representatives of medical staff the findings of the project and the potentials of the approach to other interface problem areas in the hospital.

Project progress report

The report on the developments in the project will follow the outline of the different stages in the project as discussed before.

1. Analysis of x-ray workload and referrals from outpatient clinics

In the first phase of the project activities were mainly of an analytical nature and focused around project team meetings. The first meetings were devoted to outlining the project and to exploring the potentials of the models to contribute to the project. Demonstrations were held of both models and discussions took place regarding the collection of data required as input to the models. The ambulatory services manager and the x-ray department manager were responsible for providing the student with data about resource characteristics of the outpatient department and the x-ray department. As availability of data from the hospital information system needed to be checked, involvement of a representative of the hospital information services department was arranged. To extract the data needed from the hospital information system, it was necessary to link data from the automated appointment system with data from administrative systems concerning x-ray examinations performed on patients. In this way it was possible to produce weekly statistics as averages over 13 weeks on referrals from outpatient clinics to the x-ray department for patients who had visited a specialist in an outpatient clinic on the same day. This analysis provided important insight into the volumes of direct patient flows from specialty clinics to the x-ray department. Table 6.3 illustrates the findings of this analysis, concentrating on specialties with the highest numbers of referrals.

For our analysis not only were the volumes of the direct flows important, but also the way in which they were distributed over the days of the week and, within days, over the hours of the day. For the whole of the x-ray department and the total flow of direct referrals from all outpatient clinics this was made visible using the 'X-ray Capacity Management' model. This output of the model was already discussed earlier in 6.2 (see Figures 6.2 to 6.4). Now, however, we were interested in direct referrals from individual specialties, and the relationship with the clinics from these specialties held during the part-days of the week. This was made visible by using the 'Specialist Capacity Management' model. Based on this information on the volumes of the direct patient flow per specialty to the x-ray department and the way this flow was linked to individual specialty clinics, we selected two specialties that were important generators of direct referrals and whose distribution of clinics during the week was considered as major cause for the imbalances in the direct flow of patients to the x-ray department. This proved to be General Surgery and Pulmonology. The relevant output from the model is shown in Figures 6.7 and 6.8.

Specialty	Average number of direct x-ray referrals per week per type of examination					Standard deviation of the number of referrals per week
	Thorax	Skull	Extre- mities	Verte- brae	Total	
Orthopaedics	3.7	-	37.5	7.2	48.4	13.7
Internal Medicine	31.8	0.8	2.2	1.5	36.3	6.3
General Surgery	5.4	0.1	59.1	2.5	67.1	8.2
ENT	0.8	17.7	-	0.3	18.8	7.3
Cardiology	10.8	-	-	-	10.8	5.7
Pulmonology	22.6	1.0	0.1	0.1	23.8	9.2
Paediatrics	3.2	1.9	1.5	0.3	6.9	2.5
Other	4.5	0.5	2.7	2.5	10.2	5.2
Hospital total	82.8	22.0	103.1	14.4	222.3	29.8

Table 6.3: Average and standard deviation of the number of direct referrals to the x-ray department per week (n=13 weeks).

Figure 6.7: Direct referrals from General Surgery clinics to the x-ray department.

From Figure 6.7 one can see that the number of General Surgery clinic referrals is about the same for each day but within each day an imbalance occurs between morning and afternoon. The time-table for General Surgery clinics also showed this concentration of clinics in the afternoon, which is by the way exceptional - though not necessarily negative from a point of resource use - compared to the traditional emphasis on morning sessions in General Surgery practices in other hospitals. The large number of direct referrals from General Surgery clinics during the afternoon can easily lead to overcrowding of the x-ray department during these hours and can be considered as a major cause of the long waiting times for walk-in patients, for instance on Wednesday and Thursday afternoon as shown before in Figures 6.5.

and 6.6. Further analysis of data showed that this concerned mainly x-ray examinations of limb extremities, which fitted well with the type of referrals from General Surgery clinics. The only other specialty that referred many direct referrals for this type of examination was Orthopaedics but this specialty showed a regularly distribution of referrals over the days of the week and over the hours of the day due to an even distribution of clinics during the week.

Figure 6.8: Direct referrals from Pulmonology clinics to the x-ray department.

The direct referrals from Pulmonology clinics in Figure 6.8 show a similar picture to General Surgery. Again the number of direct referrals per day did not differ much but the imbalances are striking when considered at part-day level. The time-table for Pulmonology indicated only afternoon clinics. Although the number of referrals were not so large as in case of General Surgery, the Pulmonology referrals also contributed to the peak loads and long waiting times on Wednesday and Thursday because it concerns only one type of examination, of the thorax. The other specialty that referred many patients for this type of examination was Internal Medicine but this specialty's clinics were spread evenly over the part-days of the week.

This concluded the analysis performed in the first phase, and, although the outcomes did not reveal anything new compared to previous studies, the project team was very happy with the clarity of the diagnosis and the possibility of sharing these results with those concerned. It was decided to establish two working groups for each of the specialty interfaces with the x-ray department.

One important event in this first part of the project was the rearrangement of rooms due to the introduction of new x-ray equipment in April 1992, at the end of the first phase. The manager of the x-ray department managed to use this rearrangement to add a fourth room for Bucky examinations to the room capacity for direct examinations. Although rooms were not the bottleneck but technicians, this change in resource configuration worked out positively because the increased availability of rooms made it possible to make better use of the flexibility of technician capacity than before; this allowed for an extra direct examination in case of a labour intensive examination that took less time than scheduled. When this change was reported in a project team meeting the first reactions of the other team members

were expressions of disappointment as this would complicate the evaluation of the project and it also would have been an excellent opportunity for a planned change based on the project findings. On reflection we accepted this as part of reality, also because the head of the x-ray department had taken on own behalf the best course of action. In 6.4 we will return to this change in the x-ray department's resource configuration and to the consequences of this and other changes for the x-ray's resource utilization.

2. Specialty-related working groups

The first working group started was Pulmonology, so we will discuss the developments in this working group first before turning to General Surgery.

The working group on the interface between **Pulmonology clinics and x-ray department** consisted of a Pulmonology specialist, an administrative support staff representative from Pulmonology clinic organization, a senior technician and the manager of the x-ray department, supported by the student and occasionally other members of the project team. The working group met three times with short intervals in between meetings. The first meeting was used to present the major findings of the previous part of the project, focusing on the relevant part for outpatient Pulmonology referrals. The results were recognized by the working group members as reflecting reality. In the second meeting discussions started how to improve things without taking time to consider different options and consequences of alternatives. The specialist expressed the view that the situation was unbearable and that the only proper solution would be to install thorax examination equipment in his practice rooms, as had been indicated by him before. Pulmonology would think about alternatives for improvement, but also promised to report in the next meeting on the findings of a small survey into x-ray waiting times for patients who had to visit the x-ray department before seeing the specialist a second time during the same clinic. The manager of the x-ray department, who had put forward during the meeting that the situation probably had improved due to the extra Bucky-room, also decided to do a survey into waiting times for walk-in patients from Pulmonology clinics. The third meeting both 'parties' reported independently that the waiting times had indeed improved (Pulmonology: average 28.5 mins. between leaving and returning to the clinic, including a thorax examination with a duration of about 8 mins.; x-ray department: average 18.5 mins. waiting at the department, excluding the x-ray examination time) and were no longer considered as a problem. This cleared the air, and proposals were then put forward for further improvements. Apart from a number of minor improvements they decided the following 'trade-off'. The x-ray department said they would make a reservation each afternoon of 8 slots for thorax examinations of walk-in patients from Pulmonology - which was the number of average direct referrals indicated by the patient flow analysis - and Pulmonology said they would each day give a list of patients they expected for next day's clinic to be referred for direct examinations. The impact of this change will be discussed in 6.4.

The second working group on the interface between **General Surgery clinics and the x-ray department** had more difficulties to start with and had a more erratic development. The surgeons were not much inclined to participate in the project. They did not bother much about the possible long waits of their patients at the x-ray department as their clinics were so overcrowded that they never experienced the problem. Also, tensions within the group of surgeons took so much energy that they preferred not to participate in the working group meetings but to be consulted individually when necessary. A senior nurse represented the General Surgery clinic organization in the working group, apart from an incidental

attendance by one of the surgeons. The x-ray department manager and another senior technician participated on behalf of the x-ray department. The nurse acknowledged that the results indicated by the study reflected reality as the supporting staff noticed better than the surgeons when patients stayed away long for an x-ray examination before returning to the clinic. According to her, the way in which General Surgery clinics were organized with a number of bi-weekly alternating sessions caused many problems in the effective handling of patient flows during the clinic sessions, including the unbalanced referral pattern to the x-ray department. When the progress of the working group was discussed in the project team we came to the conclusion that the scope of our project was too limited for General Surgery. To be able to improve the referral pattern from General Surgery clinics we would have to be prepared to look at the overall organization of outpatient activities for General Surgery. This was also the conclusion of a consultation round involving some of the surgeons and some of the clinics administrative support staff. The surgeons indicated that some improvements in the organization of clinics were necessary and would probably also help to improve the interface problems with the x-ray department, but that this would also involve rearranging operating theatre sessions. As this was beyond the scope of the current project the decision was taken during the third meeting to conclude the activities of the working group by a more detailed description of the current time-table and the problems associated with it according to the interviews, and to recommend a follow-up project taking care firstly of the problems of General Surgery before turning to the referrals from General Surgery clinics to the x-ray department.

The models were not used in this part of the project, apart from the demonstration during the first meeting of the results from the analysis. The discussions in the working group did not need this sort of support, which came in this case from additional data collection and analyses that were tailored to specific issues. The models would in any case not have been able to provide this detailed and specific information as their main purpose was to create a more global overview. The models would therefore not be able to 'compete' with the more profound insight in daily practice of the working group members.

3. Evaluation

During the last phase of the project most activities concentrated around project team meetings. This involved reflection on the developments in the working groups, data collection of a quantitative evaluation of resource impacts on the x-ray department of the changes introduced, data collection for the qualitative evaluation of the project, and presentations of the project findings. We will consider each of these activities in turn.

We have already described the sounding board function of the project team for the developments within the two working groups. This proved to be a great help as many unexpected things happened in the working groups, like the hidden irritations between Pulmonology and the x-ray department over long-existing problems and the re-defining of the project's scope to proceed with General Surgery. The greater distance to the events in the working groups appeared to be necessary to keep on the right track of the project as a whole and not to get involved in problems that we could not tackle within our assignment by the board of directors.

The data collection for the quantitative evaluation of the x-ray resource impacts involved an update of the x-ray department's resource configuration, including a new assignment and programming of rooms, and a similar extraction from the hospital information system of the direct referrals to the x-ray department in the new setting.

The qualitative evaluation of the project involved interviews by the student with the individual members of the project team about their opinions on the results achieved and the approach used. The working group members were not involved in this round as the few meetings did not give opportunity to familiarize them with the philosophy behind the project approach. Moreover, the project team members were also involved in the working groups which made it possible to include the working group experiences via them. The interviews were based on the following list of topics:

- appreciation of the approach followed in this project;
- difference from previous approaches used;
- appreciation of the outcomes of the project;
- contribution of the computer models;
- perceived improvement of insight into the system's coherence;
- application of this insight to future decision making.

The findings of this qualitative evaluation will be reported in 6.4.

At the end of the project, presentations were held on the outcomes of the project and on the possibilities of using this approach also for other areas within the hospital organization where similar interface problems exist. The first meeting involved the hospital management team, consisting of the board of directors and the general managers of amongst others inpatient services and ambulatory services. The second meeting involved a larger audience including representatives of the medical staff. The general impression of those present was that the results were not spectacular in that the findings of the study did not put forward something completely new, but that the most important contribution was that this approach helped to overcome long-existing problems at interfaces that were considered as insoluble. Important also was the proposal put forward by the inpatient services manager to use a similar approach to the interface between operating theatres and nursing wards.

6.4 Adaptations in the organization of x-ray services

We now turn to the current organization of x-ray services, based on the changes introduced during the project period, and look at the impact of these changes on the use of x-ray resources and on the waiting times for walk-in patients from outpatient clinics. The changes introduced during the project are:

- increase of room-capacity for direct examinations by adding a fourth room to the rooms that allow examinations with Bucky equipment;
- change of room-programmes because of the introduction of new specialized equipment;
- reservation of 8 thorax examination slots in the afternoon of each day for walk-in patients from Pulmonology clinics.

To visualize the resource impacts of these changes for the x-ray department we will use again some output produced by the 'X-ray Capacity Management' model. Table 6.4 presents an overview of the room programmes in the new setting.

Comparing the former room programming (Table 6.2) with the new programming of rooms as shown in Table 6.4, one can see that room 9 is prepared for the introduction of new MRI equipment and that other rooms now have combined equipment, which allows for an extra

Room	Monday		Tuesday		Wednesday		Thursday		Friday	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
ROOM 1 THORAX	--:--	3s:--	--:--	3s:--	--:--	3s:--	--:--	3s:--	--:--	3s:--
ROOM 2 BUCKY OVERFL	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--
ROOM 3 BUCKY/TRAUMA	4s:--	4s:--	4s:--	4s:--	4s:--	4s:--	4s:--	4s:--	4s:--	4s:--
ROOM 4 BUCKY/GP's	5s:--	3s:--	5s:--	3s:--	5s:--	3s:--	5s:--	3s:--	5s:--	3s:--
ROOM 5 IVP/IVC/INT.	--:3L	--:3L	--:4L	--:3L	--:4L	--:3L	--:3L	--:3L	--:4L	--:3L
ROOM 6 GASTRO/DSA	--:5L	--:--	--:5L	--:--	--:5L	--:3L	--:5L	--:3L	--:5L	--:--
ROOM 7 ECHO/MAMMO	--:4L	--:3L	--:4L	--:3L	--:4L	--:--	--:4L	--:3L	--:4L	--:--
ROOM 8 ECHO	--:5L	--:--	--:5L	--:--	--:5L	--:3L	--:5L	--:--	--:5L	--:3L
ROOM 9 MRI	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--	--:--
ROOM10 CT	--:5L	--:3L	--:5L	--:3L	--:5L	--:3L	--:5L	--:3L	--:5L	--:3L

Table 6.4: Overview room programmes new setting.

room (room 4) for direct examinations. Also, the reservations for appointments have been increased considerably.

Figure 6.9 shows for the days of the week the occupancy of technicians for direct examinations without appointment.

Figure 6.9: Occupancy technician capacity for walk-in patients during the week.

As can be seen from Figure 6.9 all days, including Wednesday and Thursday, show an occupancy for direct examinations below 100%, which is a considerable improvement compared to the picture before as shown in Figure 6.2.

Figure 6.10 shows the occupancy of technician capacity for direct examinations on Wednesday, the day that had previously shown the worst picture in terms of high occupancy and long waiting times.

Comparing Figure 6.10 with Figure 6.3, we see that the different time slots on Wednesday all show occupancy rates of below 100%. The direct examinations for inpatients can be dealt

Figure 6.10: Occupancy technician capacity for walk-in patients during Wednesday.

with around noon when the direct patient flow from clinics shows a dip.

Figure 6.11 illustrates the development of waiting times for direct examinations without appointment on Wednesday.

Figure 6.11: Development of average waiting times for walk-in patients on Wednesday.

As can be seen from Figure 6.11 average waiting times for patients will during morning hours rise to about 30 minutes and during the afternoon to about 25 minutes, which is a considerable reduction compared to the picture shown in Figure 6.5 with a peak of about 100 minutes in the morning and even longer waits at the end of the afternoon.

6.5 Evaluation and discussion case two

Here we will return to the objectives of our research to discuss once more the case-study findings in terms of the improvements in resource use achieved, the contribution of our approach to this achievement, other (side)effects that happened during the project, and the conditions that enabled the outcomes of the project to be attained.

Improvement in resource use

The improvements in x-ray department resource use have been discussed in 6.4. The set of changes (extra room for direct examinations, change of room programmes and reservation of examination slots for direct referrals from Pulmonology clinics) resulted in a better balance between the requirements and availability of direct examination capacity. This directly affects the waiting times for walk-in patients from outpatient clinics. Projections of average waiting time during peak hours showed a reduction from more than 100 minutes to 25-30 minutes.

Contribution of approach

The **problem orientation** as a characteristic of this case-study differs from case one where we had to deal with a large-scale reorganization that was widely accepted. The fact that there was a problem with the long waiting times for patients, had been proved by two previous studies and was not questioned. Patients had also complained about this and the long waiting times at the x-ray department had even reached the local newspaper. But in the end the problem as such did not have enough momentum to bring about change without a helping hand, in this case the introduction of new x-ray equipment allowing a rearrangement of rooms and programmes. This change was not a planned change as part of the project and was larger than the small-scale change induced by the project for walk-in patients referred from Pulmonology clinics, which makes it difficult to evaluate the origin of the improvements achieved.

The use of **decision support tools** differed for the various project stages. In the first stage of the project the models were demonstrated to the project team members as a help to outline the project and the data collection. The models proved to be very convincing in visualizing the diagnosis of the problem. The use of the models in an interactive way during meetings, supporting instant evaluation of alternative solutions, was rather limited. This had been regarded as a target objective for use of the models at the start of the project but proved not to be realistic, as it required more time to collect input data for alternatives and the manipulations with the model during meetings would take too much time. The use of the model in the first stage of the project therefore was mainly as a tool of data collection and a tool of analysis. During the second stage of the project - the working groups - the models were not used, apart from the presentation of the models' output during the first meeting. In the third part of the project the models were used for evaluation purposes in a similar way as during the first phase. It was regarded as an important advantage of the models that they dealt very effectively and efficiently with the data collection and analysis part of the study, which would in a traditional way have led to a thick report with a lot of tables and figures in which non-experts tend to get lost.

The use of a **participative mode** of project execution was particularly important in the second phase of the project. Tools of participation in the project used were: a project team with involvement of key persons, an active role of the members of the project team to collect data regarding their department and to support the student's activities in this area, the working groups for the interfaces between the specialties considered and the x-ray department, the

consultation rounds with specialists and supporting staff of General Surgery, and the presentations and discussions organized at the end of the project to present the project findings and to discuss the opportunities for using this approach also for other problems in the hospital. It is not possible to define the exact contribution of each of these elements to the project outcomes. However, it may be clear that the working group construction offered possibilities for participation that were considered as crucial to the results achieved. It appeared that the scope of those in charge of daily practice about problems and solutions at this level far exceeded that of their superiors or of outside experts. The ideas brought forward by working group members could never have been generated during project team meetings because of the distance from daily practice.

Other effects

From the project-log of the student on the events during the project we can only mention again one major event, i.e. the rearrangement of rooms and consequently the re-programming of rooms for examinations by the x-ray department manager. This event was not brought in by the x-ray manager during the meetings of the project team in a stage that enabled it to be linked with the project. The manager apparently did not define this decision as belonging to the project domain. When questioned during the evaluation interviews, the manager acknowledged this and also that the rearrangement of rooms and room-programmes had been based on the findings from the analysis performed during the first stage of the project. This decision of the x-ray manager, inspired by the project but not directly part of it, had an important influence on the project outcomes.

The suggestion to use the same approach to another interface in the hospital between operating theatres and wards, as put forward during a presentation of the project, may indicate an example of deuterio learning, as described in 4.3.

Conditions

The most important conditions for achieving similar results in another hospital setting is support from the management of the x-ray department, the management of the outpatient department, specialists of specialties involved, and the board of directors. Support from the management of the x-ray department and the outpatient department should not be difficult to get, as the project is of benefit to both departments. Support from the management of the x-ray department should however include also the medical head or the group of radiologists. It will be clear from the case-study report that support from specialists can only be got when there is concrete evidence for improvement and the trade-off between the gain to be made (no idle-time because of patients who have not returned in time from the x-ray department, no irritated patients because of the long wait at the x-ray department) outbalances the rearrangement of the clinic's organization. In case of a surgical specialty, this balance will most of the time not be in favour of the patient service aspect as a rearrangement of clinic organization often implies a complete reorganization of the specialty practice. The support from the board of directors concentrates on their interest in the effectiveness of this approach to overcome long-existing problems at interfaces in the hospital that have been a constant nuisance to every-one but are generally considered as insoluble.

We can recommend the approach followed in this project to other hospitals: problem oriented, use of decision support computer models to visualize alternative organizations of x-ray services on resource and service impacts, and a participative mode of executing project activities. The case-study has made clear that over-long waiting times for patients at the x-ray

department did not in itself have enough momentum to drive the project. Additional natural moments for changing the x-ray department's organization were required to achieve improvements. The decision support models proved to be useful to ease the data collection and the analysis part of the project and were convincing to participants where and in what direction actions needed to be taken. The combined use of the models as a target objective of this case-study proved to be a success in that in this way the problem could be approached from both sides (and views) of the interface. Moreover, they brought the persons around the table for the change part of the project via the working groups for specific interfaces between specialties and x-ray department. The essential support during this part of the project, however, did not come from the models but from insight and creativity of those in charge of daily practice. Data availability to feed the models proves to be a problem, not because of too high data demands by the models but because of the energy it takes to get hold of the data in a way required for a proper analysis. When available in the hospital information system (x-ray booking system, x-ray patient and financial administration systems, automated outpatient appointment system) extraction of the right information can be quite cumbersome. The alternative of collecting the required data by a special survey during say 2-4 weeks takes also much time and energy but can help to create broad involvement of the x-ray department with the project. The participative mode of executing the project was in this case mainly shaped by a project team with key persons involved at department management level and working groups with involvement of those in charge of managing daily practice. The involvement of outsiders - in this case the student and the researcher - can contribute first of all to the time-consuming data collection and analysis part of the project but also to view the project progress from time to time from a 'learning' distance.

CHAPTER 7

CASE THREE: FLEXIBLE AND COHERENT ALLOCATION OF INPATIENT RESOURCES

This chapter describes the third case-study that deals with the development of a method for a flexible and coherent allocation of the inpatient resources (beds, nursing staff, operating theatres, operating theatre staff) in a hospital that experienced problems in this area. First, some background information will be given in 7.1 on the hospital and the planning problem addressed. Next, we describe in 7.2 the present way of allocating inpatient resources in the hospital and the current use of inpatient resources. In 7.3 we report on the project organization and approach followed in the project, and on the major events in the project history. Then we will describe in 7.4 the analyses that have to be performed to develop a new method for resource allocation. Next, we turn in 7.5 to the suggested method for allocating inpatient resources in the future, and to the resource impacts of the new way of allocation. Finally in 7.6, we consider the results from the perspective of the case-study objectives.

7.1 Hospital context and planning problem

The third case-study is set in a medium-sized acute general hospital with about 330 beds and 17 specialties, offering basic hospital services to patients in a catchment area of about 95.000 inhabitants. There are two other larger hospitals nearby. The hospital's organizational chart shows a traditional structure with direct lines from the board of managing directors to a number of departments, resulting in a rather flat structure. The departments are clustered into three groups. The first comprises departments with a primarily clinical treatment and nursing function, such as nursing wards. The second contains all medical supporting departments, such as the outpatient department, the operating theatre department and the x-ray department. The third group consists of facilitating departments, such as the patient and financial administration department.

Previous investigations highlighted imbalances in the use of inpatient resources. One specialty did have a shortage of operating theatre time while the use of beds was below average, another specialty showed a shortage of beds. Allocation of resources was based on historical 'rights' rather than on real data on the need for and use of resources. Up to now it had been almost impossible to discuss a reallocation of resources. However, a number of specialties asked the hospital management to reconsider the allocation of resources, as they faced increasingly problems with very long waiting lists. The bottleneck capacity was identified as beds, leading to many days when there is a stop on new admissions for specialties who do not have beds free any more. The board of directors of the hospital decided to start a project to reach for more flexibility in the allocation of resources by an annual revision of the allocation of inpatient resources. The project's objective was to develop a method for a more dynamic capacity planning and a more flexible allocation of inpatient resources, taking into account developments in the catchment area, and technology, and a balanced use of resources per specialty. This instead of the current rather rigid

allocation of inpatient resources, which - when reallocation would be considered at all - would result in a piecemeal approach to the separate resources: a new operating theatre allocation in the first year, followed by a need for a new bed-allocation plan next year, to find out that the nursing staff allocation needs to be reconsidered the year after. Hospital management commissioned the project to consider these resources in a joint approach. This would involve the use of the model 'Patient Flows and Resources' to look at the longer term projection of patient flows and resource needs, and the model 'Inpatient Capacity Management' to look at a balanced use of inpatient resources. Because the hospital was involved as pilot hospital for the development of the latter model, hospital management was familiar with the study on Hospital Capacity Management and asked to participate as case-study in the project as a continuation of previous activities in the hospital.

Before going into more detail on the current organization of inpatient resources allocation and the problems associated with it, we will first give in Table 7.1 production statistics on hospital services for 1991, one of the years we have used further on in the case-study for analyses.

Specialty	Number of FTE specialists	Number of admissions	Number of nursing days	Number of day-cases	Number of outpatient visits
General Medicine	6.0	1.611	23.379	584	25.422
Cardiology	3.0	924	6.640	30	8.964
Pulmonology	3.0	289	4.333	42	8.409
Rheumatology	2.0	167	3.812	1	10.647
Anaesthesiology	4.0	17	110	473	174
General Surgery	4.0	1.647	16.135	499	20.118
Urology	2.0	478	3.549	249	5.009
Orthopaedics	3.0	740	8.044	564	11.617
Plastic Surgery	1.5	266	1.314	153	3.186
Dental Surgery	0.2	2	5	1	1.008
Gynaecology	4.0	882	5.924	529	9.775
Paediatrics	2.0	576	5.466	52	5.478
Neurology	3.0	1.062	9.866	190	12.467
Dermatology	1.0	34	889		12.467
ENT	2.0	618	1.911	642	12.834
Ophthalmology	2.0	369	1.619	57	12.610
Radiology	4.0	135	279	79	-
Hospital total	46.7	9.817	95.612	4.569	160.800

Table 7.1: Activity statistics hospital case three for 1991
(source: hospital administration).

The development of these production characteristics during the recent years, taking 1991 as base year, is shown in Figure 7.1.

Figure 7.1: Development production characteristics 1987-1991.

When we look at the development of production during the years, one can see that admissions, outpatient visits and day-cases (very strongly) have been rising while nursing days decrease. The average length of stay in the hospital was in 1991 equal to the national average figure of 10.3 days.

7.2 Current organization of inpatient resource allocation

Having looked at some basic hospital production statistics, we now describe the current way of allocating inpatient resources and its consequences for inpatient resource use. We will address the following resources: beds, operating theatres, and nursing staff. Also, we consider the simultaneous utilization of these different resources by each specialty.

Allocation and utilization of beds

The hospital uses a fixed allocation of beds to specialties. This allocation has not been changed for years and is based on historical 'rights' of specialists and the historical development of their specialties. The current allocation is used for the annual projections of next year's output for the negotiations with the health care insurance organization about the hospital budget. The available beds can be distinguished according to the length of stay of patients:

- day-case beds:

The hospital has a centralized facility for day cases of 12 beds which are used for one day-surgery or one day observation patients. These beds are not allocated to specialties but can be used by all specialties.

- short-stay beds:

There is also a centralized facility of 39 beds for short-stay patients who have a length of stay of not more than 5 days. The beds are in practice used for general purpose but in principle the beds are allocated to specialties.

- regular beds:

The rest of the beds are scattered over the different wards and used primarily for patients who have a length of stay of more than 5 days. These beds are allocated to specialties, except for a group of general purpose beds.

The bed allocation to specialties and wards is shown in Table 7.2.

Specialty	Ward	2	3	short stay	5	6	7	8	9	IC/CC	Total
General Medicine							17	39	8		64
Cardiology			1							17	18
Pulmonology									14		14
Rheumatology									14		14
General Surgery			7	37	8					2	54
Urology			3		12						15
Orthopaedics			9		19						28
Plastic Surgery			2	1	2						5
Gynaecology			24								24
Paediatrics	24										24
Neurology			2				19		3		24
Dermatology							3				3
ENT			10								10
Ophthalmology			5								5
Radiology			1								1
Total number of allocated beds		24	26	39	39	39	39	39	39	19	303
Day-cases											12
General purpose beds		11	2							1	14
Hospital total											329

Table 7.2: Bed allocation to specialties and wards.

As can be seen from Table 7.2 most wards accommodate a variety of specialties. As the short-stay ward beds can also be allocated to specialties, this ward is shown as a column. The general purpose beds are a group of beds that are not allocated to specialties. There are no beds allocated to Anaesthesiology, Neurosurgery and Dental Surgery as these specialties in principle do not admit elective patients. The way these beds are used by specialties can be seen in Table 7.3.

Specialty	Allocated number of beds	Average number of beds in use (n=12)	Standard deviation beds in use (n=12)	Percentage "own" beds in use	Occupancy rate of allocated beds	Beds used from other wards	Number of day-case beds used	Number of admission stops
General Medicine	64	63.8	2.8	94.7%	99.6%	3.2	1.1	30
Cardiology	17.7	18.3	1.5	99.0%	103.5%	0.8	0.1	67
Pulmonology	14	11.9	1.5	80.7%	84.9%	0.6	0.1	4
Rheumatology	14	10.4	2.2	72.3%	74.5%	0.3	-	12
Anaesthesiology	-	0.1	0.0	-	-	0.1	0.9	-
General Surgery	52	44.2	4.3	79.8%	85.0%	2.7	1.3	2
Urology	14.1	9.8	1.8	64.4%	69.2%	0.7	1.0	1
Orthopaedics	25.2	22.1	2.6	76.2%	87.6%	2.9	2.2	6
Plastic Surgery	4.7	3.6	0.8	73.2%	75.4%	0.1	0.6	1
Gynaecology	24	18.0	2.3	73.0%	74.9%	0.5	2.0	2
Paediatrics	24	15.0	2.9	53.6%	62.4%	2.1	0.2	5
Neurology	23.4	27.1	2.3	101.2%	115.7%	3.4	0.5	42
Dermatology	3	2.5	0.7	71.7%	81.7%	0.3	-	3
ENT	7.1	5.2	0.7	42.6%	72.8%	2.2	2.5	-
Ophthalmology	3.6	4.3	1.1	111.3%	121.4%	0.4	0.2	-
Radiology	0.7	0.8	0.0	112.7%	112.7%	0.0	0.3	-
'Wrong-bed' patients	-	5.9	1.2	-	-	5.9	-	-
Hospital total	304.1	262.9	9.0	86.5%	86.5%	-	13.0	175

N.B.: The number of allocated beds in the second column is calculated based on a 5-day availability of short-stay beds, which explains the small differences with Table 7.2.

Table 7.3: Utilization of bed resources by specialty (based on monthly figures over 1991).

In Table 7.3 a distinction has been made between the use of beds by a specialty in the allocated wards and the use of beds outside these wards. This is an indication of the number of beds borrowed from other specialties. General Medicine, for example, uses on average 63.8 beds of which 3.2 beds are in wards where no beds are allocated to this specialty. This results in an overall occupancy rate of 99.6%, but of 94.7% when looking at the occupancy of the beds on the wards allocated to General Medicine. Also Neurology has a high occupancy rate of own beds combined with a large number of borrowed beds elsewhere. The average occupancy rate at hospital level of more than 85% is quite high, which indicates that beds can be considered as a bottleneck. The occupancy rates of Urology and Paediatrics are below 70%. The beds in use by 'wrong-bed' patients refer to patients who have been discharged from hospital but are waiting for a bed in a nursing home or elsewhere. As the number of beds in use varies - as can be seen from the fluctuations at monthly level - there are

occasions when no bed will be available to admit a patient. In this case the hospital is forced to use an 'admission-stop' for one or more days. During 1991 in total 175 'admission-stops' have been occurred, most of them concentrating in General Medicine, Cardiology and Neurology. This large number of 'admission-stops' is a further indication of beds as most important bottleneck in the case-study hospital.

Allocation and utilization of operating theatres

The operating theatre department has six theatres that are allocated to specialties during weekdays. Monday to Thursday there are two sessions per theatre per day with a duration of four hours. On Friday only one session is scheduled with a duration of five hours. Theatre 6 is not fully used, as the equipment available does not allow all types of operation. The operating theatre time-table is shown in Figure 7.2.

	OT 1	OT 2	OT 3	OT 4	OT 5	OT 6
Monday	Orthopaedics	General Surgery	Urology	Gynaecology	ENT	Urology
	Orthopaedics	General Surgery	General Surgery	Plastic Surgery	ENT	
Tuesday	Orthopaedics	General Surgery	Ophthalmology	General Surgery	Urology	Urology
	Orthopaedics	General Surgery	Ophthalmology	Gynaecology	ENT	
Wednesday	Orthopaedics	General Surgery	General Surgery	Gynaecology	ENT	Plastic Surgery
	Orthopaedics	General Surgery	Neurosurgery	Neurosurgery	ENT	
Thursday	Orthopaedics	General Surgery	General Surgery	Gynaecology	Urology	Urology
	Orthopaedics	General Surgery	Plastic Surgery	Plastic Surgery	ENT	
Friday	Orthopaedics	General Surgery	General Surgery	Gynaecology	Urology	Urology

Figure 7.2: Operating theatre time-table (1991).

Some specialties have their own theatre (General Surgery, Orthopaedics) while the other specialties share theatres. Some specialists (Urology, Neurosurgery, Plastic Surgery) use parallel sessions in two theatres to minimize change-over time between operations.

Table 7.4 shows the utilization of operating theatre sessions by specialty, based on a 4-week sample of session times. The routine information system did not allow us to calculate session utilization, so we had to use these averages of a rather short period instead of figures over the whole year.

Specialty	Occupancy rate of allocated OT-hours				
	Monday	Tuesday	Wednesday	Thursday	Friday
General Surgery	88.9%	94.0%	87.9%	94.6%	92.0%
Urology	41.0%	58.1%	-	44.4%	43.6%
Orthopaedics	96.4%	81.4%	55.3%	77.2%	71.1%
Neurosurgery	-	-	59.3%	-	-
Plastic Surgery	78.2%	-	100.0%	47.6%	-
Gynaecology	73.8%	83.7%	90.3%	84.3%	87.2%
ENT	85.7%	99.8%	68.7%	82.2%	-
Ophthalmology	-	96.1%	-	-	-
Hospital total	77%	92%	75%	72%	76%

Table 7.4: Utilization of operating theatre sessions by specialty
(4-week sample 1992).

From Table 7.4 one can see that Tuesday is the busiest day for the operating theatre department. Specialties with overall high occupancies are General Surgery, Orthopaedics (except on Wednesday), Gynaecology, ENT and Ophthalmology. Urology, Neurosurgery and Plastic Surgery (Thursday), which use parallel sessions, have a low occupancy rate of their sessions.

Allocation and utilization of nursing staff

Nursing staff is not allocated to specialties but to wards. Each year a staffing plan is made for each of the wards. This plan defines the number of FTE nursing staff positions needed to staff the ward, based on the outcomes of a patient classification and scoring system for nurse workload measurement [De Vries, 1984]. As we will concentrate in this study on hospital resource allocation during office hours, we are interested in the number of FTE nursing staff positions for the day shifts, excluding evening and night shifts. Table 7.5 summarizes the number of FTE nursing staff positions for day shifts allocated to each of the wards.

Day Ward	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Day nursing unit	2.5	2.5	2.5	2.5	2.5	-	-
Ward 2	9.5	9.5	9.5	9.5	9.5	7.5	7.5
Ward 3	10	10	10	10	10	9	9
Short-stay ward	7	8	8	8	7	-	-
Ward 5	12	12	12	12	12	8	8
Ward 6	12	12	12	12	12	8	8
Ward 7	12	12	12	12	12	8	8
Ward 8	12	12	12	12	12	8	8
Ward 9	12	12	12	12	12	7.5	7.5
IC/CC	7.5	8	9	9	10	9	8
Hospital total	96.5	98	99	99	99	65	64

Table 7.5: Number of FTE nursing staff positions for day-shifts allocated to wards
(according to schedule, 1991).

The numbers of nursing staff positions shown in Table 7.5 refer to the scheduled number according to the rota system. The number of nursing staff actually available can deviate from this number due to illness, etc. Most wards use a fixed allocation for weekdays with a lower number for weekends. The short-stay ward and the IC/CC unit use an allocation that differs from this fixed number for some days of the week, probably due to an activity profile that depends on the day of the week. Apart from these allocated nursing resources the hospital uses a pool of about 20 nurses who can be called in when necessary.

Workload pressure rather than occupancy rates is a better way of describing the utilization of these nursing staff resources. This pressure is defined by the workload, i.e. the number of FTE positions required according to workload measurement, divided by the number of FTE positions allocated. As overheads are included in the workload measures and allocations, a 100% workload pressure can be used as target. The workload pressure of the nursing staff in a number of wards over the days of the week is shown in Table 7.6.

Ward	Percentage utilization of nursing staff per day of the week															
	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Total	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
Ward 5	85%	11%	84%	14%	90%	13%	93%	15%	92%	12%	93%	14%	90%	19%	90%	15%
Ward 6	87%	9%	86%	11%	86%	9%	91%	13%	91%	12%	68%	11%	67%	10%	82%	15%
Ward 7	89%	14%	87%	14%	91%	12%	92%	17%	93%	12%	83%	14%	81%	13%	88%	15%
Ward 8	89%	12%	88%	11%	89%	13%	88%	11%	87%	9%	79%	11%	78%	13%	86%	11%
Ward 9	88%	15%	89%	14%	90%	13%	90%	14%	90%	13%	99%	14%	98%	16%	92%	15%

Table 7.6: Percentage utilization of nursing staff during the day by nursing ward (52 weeks, 1991).

The nursing workload pressure data in Table 7.6 are limited to the wards shown as data were only available for these wards. According to this the workload pressure during the week is about the same for most wards. For the wards 5-7 it is higher at the end of the week compared to the first part of the week. The pressure during the weekend for ward 6 is lower than for the other wards. The overall average workload pressure of about 90% does not seem to be high, when we consider the target set of 100%. However, considering the large standard deviations of the nursing workload pressure, there are many peaks and troughs in the daily workload, which makes a 90% average not such a poor performance. As the nursing wards cannot control their workload because this is determined by the decisions of specialists and admissions department to admit patients, the wards can only try to have enough nursing staff allocated.

Simultaneous utilization of different inpatient resources per specialty

Having discussed first the allocation and utilization of each of the resources involved separately, we now look at the simultaneous utilization of the various resources by specialties. After all, the performance of a specialty in terms of inpatient resource utilization should not be judged by the separate performances regarding each of the resources but by the combined use of the resources used for the specialty's inpatient services. This information was not routinely available via the hospital information system, but required linking data stored in different information systems within the hospital. In this case, data for four weeks of admissions were collected and linked with data from the operating theatres

department and data from the workload measurement information systems on the nursing wards. As this analysis required very much effort we had to limit the data collection to four weeks. We selected a period of four weeks that was considered as a busy period. Table 7.7 summarizes the results of this analysis.

Specialty	Number of admissions per specialty				Average occupancy rate per week		
	Day cases	Short cases	Regular admissions	Total admissions	Beds	Nursing staff	OT hours
General Medicine	11	5	25	41	104%	89%	-
Cardiology	2	10	8	20	119%	95%	-
Pulmonology	2	0	4	5	51% °	98%	-
Rheumatology	0	0	4	4	101%	97%	-
Anaesthesiology	11	1	0	11	0	0	-
General Surgery	11	15	19	45	98%	101%	74%
Urology	3	5	4	12	70%	96%	23%
Orthopaedics	11	10	7	29	111%	110%	68%
Plastic Surgery	5	3	2	10	91%	157% °	64%
Gynaecology	9	11	10	31	83%	98%	75%
Paediatrics	1	4	11	15	85%	91%	-
Neurology	4	13	10	27	139%	101%	35%
Dermatology	0	0	1	1	103%	97%	-
ENT	18	12	1	31	143% °	75%	81%
Ophthalmology	1	6	0	7	0%	0%	72%
Radiology	2	2	0	4	0%	0%	-
Hospital total	89	99	105	293	99%	95%	73%

N.B.: With ° marked figures show deviations from expected values that can be explained by the short period of data collection (Pulmonology), the inability to take into account short stay beds (ENT) and the lack of good nursing workload measurement data (Plastic Surgery).

Table 7.7: Simultaneous use of inpatient resources by specialty (January 1991).

Table 7.7 shows that in a busy period on average 293 patients are admitted, of whom were 89 day-cases and 99 short-stay patients, resulting in an average bed occupancy of 99%, an average nursing workload pressure of 95% and an average operating theatre occupancy of 73%. This implies that it is not only the beds which act as a bottleneck but that also nursing staff utilization is of the same high level, while the utilization of operating theatre resources stays behind. Or expressed in another way, the high bed occupancy and nursing workload prevent a higher utilization of operating theatre resources.

The specialty bed occupancy figures only relate to the regular beds. The overall hospital bed occupancy figure takes also day-case beds and short-stay beds into account. General Surgery, Orthopaedics, Plastic Surgery and Neurology/Neurosurgery show the same picture as for the overall hospital: an imbalance between the use of bed resources and the use of operating theatre resources due to a shortage of beds or a over-capacity of operating theatre hours. Internal Medicine and Cardiology show imbalance between the use of bed resources and the use of nursing staff resources. Specialties with a well-balanced use of all inpatient resources are Rheumatology, Gynaecology, Paediatrics and Dermatology.

7.3 Developing a method for flexible and coherent resource allocation

The current utilization of inpatient resources described in 7.2 shows that the level of utilization of beds and nursing staff for the hospital as a whole is very high, compared to the utilization of operating theatres, and that there are many imbalances in the simultaneous utilization of inpatient resources by specialties. Facing the limits of available hospital resources and acknowledging that the resource utilization performance could hardly improve because of the imbalances, hospital management launched a project to develop a method that could support the hospital's attempts to keep the right balance between patient demand and hospital supply in these challenging circumstances, while trying to prevent loss of capacity due to imbalances in the use of resources by specialties. First, we describe the project organization and project staging. Next, we show how the general implementation strategy of this research was used in the project. We conclude this paragraph with a report on the major developments within the project history.

Project organization

The decision to start the project was based on recommendations included in a report on the previous study and a project proposal, put forward to hospital management by the hospital's management consultant together with the researcher [Eydemis-Janssen and Vissers, 1992]. The management was in favour of such a project, seeing it as giving support in their annual task of negotiating with health care insurance organizations about the next year's budget and to discuss internally with specialties a fair distribution of resources within the limits set by the hospital budget. As resources were fully used an increase of resources for one specialty to cover a growing demand, would automatically imply a reduction of resources for another specialty. The method to be developed could support this task by visualizing the longer term development of patient flows, and by building again on patient flows - this time on the shorter term and combined with insight into the use of resources - for the annual allocation of inpatient resources. The annual procedure for updating inpatient resource allocations would allow a more dynamic planning of resources in response to external developments. The board of directors asked advice from the 'admission policy and bed allocation committee', with representatives of specialties and departments involved (admissions department, nursing wards, operating theatres department). This committee also supported the project proposal. They also revealed that one of their major problems was, that due to shortage of resources admissions from internal specialties (such as General Medicine, Cardiology and Neurology) tended to break in on resources required for surgical specialties. It would be necessary to take also a fair distribution of resource allocations to these two groups of specialties into account. Hospital management asked the committee to act as steering group for the project, which role they accepted as it was in perfect line with their committee's tasks.

A student was asked to perform the project as his MSc-project, supported by a project team consisting of the hospital management consultant (who had been involved with a number of resource management projects in the hospital before), the head of hospital business planning (involved with the annual negotiations with the health insurance organization and with the internal discussions with specialties about next year's plans), and the researcher as supervisor of the student and outside expert. The project team was kept small on purpose as the project would involve a lot of analytical work. The department heads and the specialties would be involved via the steering group and bi-lateral consultations with the student. The project

team met regularly every 3-4 weeks between September 1992 and June 1993. Most activities were performed by the student who became the driving force behind the project.

As a first step a more detailed project plan was developed by the student and discussed at the meetings of the project team, with consultations between of department managers and members of the committee and the board of managing directors. The objective of the project was to develop a method to support the hospital in matching allocation of inpatient resources to the demand for resources by specialties while preventing loss of capacity due to unbalanced use of resources. The approach followed would involve a sensitivity analysis of each of the variables involved in the need for resources. The method to be developed included capacity planning in the long term and capacity allocation in the medium term. The outcome of the project needed to be usable for answering future questions in these areas of planning. The method needed to be **flexible** in that it could be used annually or bi-annually to reconsider resource allocations. The method needed to be **coherent** to take into account allocation and use of the three interdependent resources at the same time. Furthermore, it was stated that the project would be limited to the three inpatient resources mentioned before, leaving other inpatient resources such as intensive care and all outpatient resources outside the scope of the project.

As stages in the project were distinguished:

1. Analysis at strategic level of developments in patient flows and influence of:
 - changes in population structure,
 - changes in demand for care,
 - changes in market share,
 - changes in length of stay.

This would involve the use of the model 'Patient Flows and Resources'.

2. Analysis of the current use of inpatient resources:
 - seasonal trends in use of resources,
 - imbalances in simultaneous use of resources.

This would involve the model 'Inpatient Capacity Management'.

3. Development of a method for flexible and coherent resource allocation.

Implementation approach

The **problem orientation** element of our implementation strategy in this case-study is of a different nature compared to the previous case-studies. The scarcity of inpatient resources is a problem that everyone in the hospital is aware of, because of the constant search for free beds and the frequent occurrence of 'admission stops'. Therefore, we can assume that there is a broad acceptance for a project like this. On the other hand, there is no immediate reason for a radical change as the situation has existed for a long time. As in this stage it concerns only the development of a method for reallocating inpatient resources, the general awareness of the problem is thought to offer enough ground for the development of the project.

The **decision support** tools used in the project were the models 'Patient Flows and Resources' to investigate the longer term developments in the inflow of patients to the hospital and the consequences for future resource requirements, and 'Inpatient Capacity Management' to investigate the simultaneous use of inpatient resources by specialties and the occurrence of imbalances in resource utilization. Also, this case involved the combined use of two of the models within one project setting. Both models are described in the appendix.

The **participative mode** of executing the project as third element of our implementation strategy was in this project operationalized by a project team as analyst-group and think-tank, an already existing committee 'admission policy and bed allocation' as steering group, a number of consultation rounds with individual department managers and one round with specialties, and a number of presentations on the project. The way these tools of participation were used in the project will be described in the following report on the project development.

Project progress report

We will follow the different stages of the project to structure the most important events during the project.

1. Analysis of patient flow developments

The first part of the project was concentrated around the meetings of the project team and the use of the model 'Patient Flows and Resources'. First of all, an outline was made of the variables involved in the study and their relationships, which provided insight into the different analyses to be performed. This is illustrated in Figure 7.3.

Figure 7.3: Overview analyses patient flow development.

Figure 7.3 shows that the inflow of patients into the hospital is determined by the demand for inpatient care from patients in the catchment area of the hospital and by the market-share of the hospital. The demand (development) for inpatient care in the catchment area in turn is determined by the population structure (development) and the need for care (development). Both variables determine the total demand for inpatient care in the

catchment area (the 'market') while the market-share (development) of the hospital determines which part of the market is covered by the hospital and which part goes to other hospitals in the area. The next variable in the diagram is medical technological developments, such as use of non-invasive surgery, which influences the throughput of patients by shortening the length of stay. The influence of each of these variables on the inflow of patients into the hospital and the throughput of patients was investigated, first by varying one variable and keeping the other variables constant and next by looking at the combined effect of variables. The results of these analyses will be reported in 7.4. To perform these analyses use was made of the model 'Patient Flows and Resources' and of data on population projections and on consumption of inpatient care by the inhabitants of the catchment area. The model proved to be a great help in handling the large amounts of data involved and was furthermore a guidance to the different analyses. The data on population projections for 1990 (the base year chosen for analysis), 1995, 2000 and 2005 were easily obtained via TNO - an organization that uses these sort of projections for their research purposes. The data on hospital inpatient services consumption for 1989, 1990 and 1991 were obtained via the SIG - an organization that collects and processes data on inpatient admissions for all hospitals in the Netherlands. This took much energy and time, and the 1991 data only became available at the end of 1992. The model helped in this collection of data as it defined what data were needed including the format.

During this stage of the project one presentation was held to the steering group on the approach the project team would follow for the project and what outcome we foresaw. The plan found approval, though the rather hectic discussions held pointed out that it was not clear yet to everyone what the project would do. An example of this was the discussion on elective admissions versus urgent admissions, while we had tried to make clear that in the first part of the study - the analyses at strategic level - we would look at the total flow of patients and that this distinction was not relevant at this level but would come into focus in a later stage of the project. Due to the contribution of the medical director discussions were brought back to the lines of the plan, and it was decided to hold a further meeting with the steering group when there would be concrete results to show. At the end of this part of the project an interview round was held with representatives of specialties about their expert opinions on the development of the length of stay due to new medical technologies. The results of this round will also be discussed in 7.4.

2. Analysis of current use of resources

The second part of the project involved an analysis of the current use of the resources as indicated in the lower part of Figure 7.3. Again the major activities were clustered around the meeting of the project team. First an analysis was made of the use of each of the resources during the year, to find out possible trends or seasonal effects. As the departments were very keen on a correct representation of their activities and resource use in the project, much attention and time was spent on consultation with department managers to increase their involvement with the project. During this part of the project the student acted as a diplomat, creating support for the third part of the project. For the simultaneous use of resources by specialties two periods of 4 weeks were selected with a different busyness profile: a very busy period which knew many 'admission stops' and an average busy period. This part of the analysis was performed with the use of the model 'Inpatient Capacity Management' as this model links the use of different resources per specialty. Results of the analysis for the busy period were shown in 7.2 as part of the description of the current use of resources; the results for the average busy period will be discussed in 7.4. The model

performed very well, though due to the short period of analysis specialties with long average lengths of stay were not as well represented as other specialties .

3. Development of method for resource allocation

The last part of the project involved the development of an alternative method for allocating inpatient resources, build on the insights from the previously performed analyses. The method will be illustrated in more detail in the next paragraph. Much valuable work in this stage of the study was done by the student, who had by this time developed much support for the project. In this way the method when presented during a meeting with the steering group, the board of managing directors and other persons involved in the project received broad support as it was regarded as a logical consequence of the previous analyses. This final meeting also offered much insight into learning effects of the project for those attending. After a short presentation of the project's outcomes and the suggested method for future inpatient resource allocation, discussions showed that the attenders at the meeting were able to structure the different problems concerning inpatient resource use and to place them within the framework of resource planning and resource allocation given to them by the project. For instance, it became clear that problems with emergency admissions could either be tackled at resource allocation level by labelling resources as dedicated for emergency (emergency beds, a theatre for emergencies, etc.) or by procedures for handling emergencies at operational level. Or that, if no decisions were made at hospital allocation level about the amount of resources available to surgical specialties, the admissions planning department would fill in this strategic decision at operational level. The general conclusion of this meeting as formulated by the medical director and supported by all present was, that the project had brought the hospital an important step forward not only by developing a method based on sound analyses and broad support, but also because of the increased level of understanding within the hospital about this complex matter.

7.4 Analyses required for inpatient resource allocation

The method of resource allocation suggested by this project builds on the analyses performed on:

- the influence of long term developments in the inflow and throughput of the hospital;
- the current utilization of resources throughout the year;
- the simultaneous use of resources by specialties.

Before turning to the method in 7.5 we will first summarize the main results of the analyses that have to be performed to use the suggested method.

Influence of long term developments

Table 7.8 shows the development of the total population in the region investigated, broken down by specified sub-regions.

From Table 7.8 one can see that the development of the population in the central sub-region, where the case-study hospital is situated, lags behind the development of the whole region. In 1995 population will increase by 4.5% while the increase of population in the central region stays below 4%. The number of inhabitants in the whole region shows a steady increase.

Sub-region	Number of inhabitants 1990	Percentage change (base year 1990)			Expected number of inhabitants 2005
		1995	2000	2005	
North-West	47.879	3.0%	7.2%	10.4%	52.857
North-East	165.330	5.6%	10.8%	14.9%	190.017
Central	191.467	3.8%	6.8%	9.3%	209.220
South-West	140.063	4.7%	9.7%	13.4%	158.901
South-East	102.035	4.3%	8.5%	11.5%	113.797
Region total	646.774	4.5%	8.8%	12.1%	724.792

Table 7.8: Development of population within the region.

Table 7.9 shows the development in population structure for different age-groups.

Year	Percentage distribution over age categories (years)				
	0 - 14	15 - 44	45 - 64	65 - 74	> 74
1990	18.2%	49.2%	22.1%	6.4%	4.1%
1995	18.2%	46.2%	23.9%	7.2%	4.4%
2000	18.5%	43.6%	25.0%	7.8%	5.2%
2005	18.4%	41.1%	26.6%	8.1%	5.8%

Table 7.9: Development in population structure of whole region.

From Table 7.9 one can see that the population structure shows also a steady decrease in the category 15-44 and an increase in the categories of above 45 years of age. The development does not differ between males and females.

Using current demand figures and market-share with the model 'Patient Flows and Resources' the influence of the 1995 population development on the inflow of patients for selected specialties is shown in Figure 7.4.

Figure 7.4 shows that the inflow in 1995 due to population developments is estimated to increase by more than 6%, and that some specialties will be faced with a larger increase than other specialties while other specialties will stay below the overall increase level.

The second variable investigated concerns the development in the **need for care**. As we had three years data on hospital consumption available (1989, 1990, 1991), we were only able to investigate the direction of possible trends. When consumption for a specialty was increasing three years in a row, we labelled this as an increasing trend. In this way we could track down trends in the need for care with eight specialties, such as General Medicine (increase for males above 45, decrease for females 45-74), Cardiology (increase for males above 74, decrease for females above 74), Gynaecology (decrease for females 15-44), Neurology (increase for males and females above 45), etc. As some of the developments per specialty compensate, an overall impact on specialty level was only traceable for the specialties shown in Table 7.10.

Figure 7.4: Increase of inflow for selected specialties in 1995 compared with 1990 due to population developments.

Specialty	Percentage change in calculated number of admissions (base year 1990)		
	1989	1990	1991
General Medicine	+2.6%	0%	-0.3%
Gynaecology	+4.4%	0%	-2.9%
ENT	+1.6%	0%	-4.5%
Neurology	-5.5%	0%	+10.3%

Table 7.10: Influence of change in need for care on inflow hospital.

In Table 7.10 is shown the percentage deviation in the number of admissions to the hospital where 1990 is taken as base year. This implies that for General Medicine the need for care has decreased in three years time by about 3%. For Gynaecology the decrease is more than 7%, For ENT it is about 6%, while for Neurology we see an increase in the need for care with more than 15%.

We have also looked at the influence of the **market-share** of the hospital on the inflow. The market-share is defined as the number of patients admitted into the hospital divided by the number of patients from the region defined who have been admitted to any hospital in the Netherlands. It appeared that the hospital had a steady 14% of the total market of about 67.000 patients per year. The market-shares per specialty varied from very low (Dental Surgery: 1%) to average (General Surgery: 15%) and to high (Neurology: 21%). The market-shares per specialty showed minor changes over the years, again based on a 3-year period. The influence of the market-share development on the inflow of patients to the hospital only

showed major changes for the specialties given in Table 7.11 (keeping population and need for care constant).

Specialty	Percentage change in the number of calculated admissions (base year 1990)		
	1989	1990	1991
General Surgery	-4.2%	0%	+0.7%
Urology	+4.2%	0%	-5.8%
Gynaecology	+4.4%	0%	-3.3%
Plastic Surgery	-27.6%	0%	+37.0%
Neurology	+7.8%	0%	-1.5%
Ophthalmology	-17.5%	0%	+14.0%

Table 7.11: Influence change in market-share on inflow to hospital.

From Table 7.11 one can see that the influence of market-share development over three years time for General Surgery would be an increase in admissions of about 5%. For Urology the market-share development would lead to a decrease of about 10%, for Gynaecology of about 8%, and for Neurology of more than 9%, while for Plastic Surgery and Ophthalmology one sees sharp increases.

Considering the three variables we have discussed before, only the population development showed a clear trend for all specialties while the other variables (need for care, market-share) showed for some specialties indications of trends. These can only be qualified as indications because of the limited number of years that were available for analyses. Though the relative influence of these variables on the inflow of patients for some specialties was quite strong we decided to include only the population development in the projection of future resource requirements. Using statistics on the average length of stay, a target bed occupancy of 90%, and ratios between admissions and day-cases and operations, we were able to make the projections for resource requirements as shown in Table 7.12. The calculations were made for the three base years available separately to get an impression of the sensitivity of the outcomes. We show here the results at hospital level, but these calculations have also been made at specialty level.

Base year of calculation	Occupancy rate in base year (in %)			Projections of occupancy rate in 1995 (in %)			Required resources in base year (in numbers)			Resource requirements projections for 1995 (in numbers)		
	1989	1990	1991	1989	1990	1991	1989	1990	1991	1989	1990	1991
Hospital overall figures												
Inpatient beds	86.7	85.4	85.0	93.1	90.8	89.3	267	263	262	287	280	275
Day-cases beds	101.7	104.7	112.4	108.4	111.6	119.1	12.2	12.6	13.5	13.0	13.4	14.3
Operating theatres	76.1	74.8	79.9	80.8	78.7	83.3	4.6	4.5	4.8	4.9	4.7	5.0

Table 7.12: Resource impact projections for 1995 due to population development.

Looking at the results of Table 7.12 the following conclusions can be drawn for the different resources considered:

- The current total number of beds of 276, that are used for about 85%, will not be enough to cover future demand based on population development.
- The current number of day-case beds of 12 should be increased to at least 14.
- The current number of 6 operating theatres seems to be enough to cover future demand in 1995.

These calculations were based on the assumption that the average length of stay will stay the same. To get an impression of the projections of length of stay development we asked some specialties to give their expert opinion on this. We preferred to use this approach instead of analyzing for example national statistics so as to involve the specialties with the project and to make use of their local knowledge on conditions for length of stay development such as equipment available or the resistance of some specialists to use new operating techniques. The results of the interview rounds among specialties on length of stay development are summarized in Table 7.13.

Specialty	Development length of stay	Reasons for development
General Medicine	decrease: 0.5 day	shorter length of stay for younger patients
Cardiology	decrease: 0.3 day	medical technology (non-invasive techniques for diagnosis)
General Surgery	decrease: 1.0 day	medical technology and short-stay development
Urology	decrease: 0.5 day	not specified
Gynaecology	decrease: 1.4 days	non-invasive surgery techniques
Orthopaedics	increase: 0.3 day	increased percentage of elderly
Paediatrics	decrease: 1.0 day	changed admission policy for early-born
Neurology	decrease: 1.0 day	less 'wrong-bed' patients due to improved capacity of nursing homes

Table 7.13: Development of length of stay for some specialties according to opinions of specialists.

According to Table 7.13 most specialties expect a decrease in the length of stay. These projections of the development in length of stay were then used to look at the consequences for resource use. It appeared that at hospital level the calculated increase of resource requirements of 6% due to population development (see Figure 7.4) would be compensated for by a decrease in resource requirements due to a shorter length of stay.

Current utilization of resources

As far as individual resources are concerned, their current use has already been discussed in 7.2 as part of the description of the consequences of the current organization of inpatient resource allocation on the use of resources. From that description it was clear that taken over a year the beds are the bottleneck resource for hospital production. For a more detailed description of the development of bed occupancy throughout the year we will first have to

look at the development in the number of admissions from week to week as is shown in Figure 7.5.

Figure 7.5: Development in weekly number of admissions (1991).

According to Figure 7.5 on average 270 patients are admitted per week. Day-care patients, short-stay patients and regular patients, each make up one-third of the number of admissions. Concentrating on regular admissions it appears that the admission pattern does not show large peaks and troughs in weekly admissions or seasonal trends. These are much more evident when considering short-stay patients and day-cases. The dips here are assumed to be caused by the preference of patients not to be admitted during holiday periods.

For surgical specialties the admission pattern within a week shows a definite shape. Figure 7.6 shows for example the admission pattern per day of the week for General Surgery.

Figure 7.6 shows that there is clearly a pattern of admissions during the week for General Surgery. Below the graph are shown the number of operating theatre hours available per day. Patients with a length of stay of more than five days are in general admitted one day before the operation. On Sunday on average three patients are admitted to be operated on Monday. Short-stay patients are admitted on the day of operation. General Surgery will try to use fully its seven beds on the short stay ward in the beginning of the week as this offers the patients best conditions for rehabilitation, without having to be transferred to a regular ward on Friday. As the week proceeds fewer patients are admitted. Surgical specialties in particular show these patterns, which seem related to the days operating theatre facilities are available.

Figure 7.6: Average number of admissions (with 95% confidence limits) per day of the week for General Surgery (1991).

These patterns in the number of admissions influence the utilization of the different resources that are required for admissions. In this case we are interested in the simultaneous use of resources for specialty admissions. This can be investigated by collecting four weeks of data on admissions and analyzing these with the help of the model 'Inpatient Capacity Management'. This model visualizes whether or not a specialty - given its admission pattern - uses its resources in a coherent way. The model's output was already used in 7.2 to illustrate the simultaneous use of inpatient resources in a busy period. What in this hospital's practise is regarded as busy, average and below average, is shown below the graph in Figure 7.5. The first period of analysis was week 3-6 (January/February). The average number of admissions per week in this period was 290. As four weeks are a short period for analysis, a second period of analysis was chosen. An average busy period (week 35-38, August/September) was deliberately chosen, to make it possible to compare a period with many 'admission stops' with a period with few 'admission stops'. The average number of admissions per week in the second period was 270. The results of the analysis for the busy period were shown in Table 7.7. In Table 7.14 we show the results for the average period.

Looking first at the hospital overall figures in Table 7.14, one sees that in an average busy period there are no shortages of resources. Bed utilization and nursing workload pressure are balanced while operating theatre resource utilization stays behind compared with the two other resources. At specialty level most specialties follow the overall hospital picture. With the exceptions of Orthopaedics and Ophthalmology all surgical specialties have lower bed occupancy and nursing workload pressure figures. The operating theatre capacity utilization followed the decrease in the utilization of other resource, while keeping the same distance in performance level as in the busy period.

Comparing both periods, coherence in the use of resources is about the same in both periods. At hospital level as well as at specialty level the utilization of bed resources and

Specialty	Number of admissions per week				Average occupancy rate per week		
	Day cases	Shortstay	Regular	Total	Beds	Nursing workload	OT hours
General Medicine	13	9	24	46	99%	85%	-
Cardiology	1	7	7	15	88%	68%	-
Pulmonology	1	1	3	5	45% °	93%	-
Rheumatology	0	0	5	5	102%	93%	-
Anaesthesiology	10	0	0	11	0%	0%	-
General Surgery	8	15	14	37	60%	87%	60%
Urology	2	7	6	14	96% °	81%	21%
Orthopaedics	13	5	8	26	110%	77%	56%
Plastic Surgery	2	5	2	8	65%	82%	50%
Gynaecology	9	6	11	25	79%	85%	66%
Paediatrics	1	4	6	10	50%	78%	-
Neurology	6	16	8	30	148%	105%	29%
Dermatology	0	0	1	1	57%	162% °	-
ENT	13	13	1	27	122% °	74%	80%
Ophthalmology	2	6	1	8	0%	86%	76%
Radiology	1	3	0	4	0%	0%	-
Hospital total	83	94	94	271	87%	84%	63%

N.B.: the figures marked with ° show deviations that can again be explained by similar reasons as in Table 7.7.

Table 7.14: Simultaneous use of inpatient resources by specialty (August 1991).

nursing staff resources are well-balanced while operating theatre resource utilization stays behind (except for Gynaecology and ENT). The only specialty that shows a high bed utilization in both periods is Orthopaedics. The utilization of operating theatre resources by this specialty, however, stays also behind despite the long waiting list for Orthopaedic admissions. This could point to a structural shortage of beds for this specialty. Other structural bottleneck resources are beds for General Medicine, Rheumatology and Neurology and nursing staff for Neurology.

7.5 Outline method for inpatient resource allocation

The results of the analyses of 7.4 have been used to develop a method for flexible and coherent allocation of inpatient resources. This approach is, in principle, also applicable in other hospital settings. As the three resource types of beds, nursing staff and operating theatres are interdependent, a step-wise approach can be chosen to allocate resources, starting with the bottleneck resource. The approach is as follows:

1. Defining the bottleneck resource as the resource that is most critical for hospital inpatient production. This is based on occupancy rate figures (average and standard deviation) as realized in the past.
2. Allocating the bottleneck resource to specialties or departments. This is based on the current use of the bottleneck resource.
3. Allocating the other resources to specialties or departments.

The procedure for resource allocation is illustrated in Figure 7.7.

Figure 7.7: Procedure for allocating resources.

The allocation of the bottleneck resource is in principle based on the current utilization of resources. Hospital management, however, can decide to increase or decrease capacity for the bottleneck resource based on strategic considerations for the future profile of the hospital. Information on current use and the analyses on population, need and market-share development as shown in 7.4 are used to support decisions concerning the actual allocation of the bottleneck resource. This is the first phase of resource allocation as shown in Figure 7.7. In the second phase, again the basis for allocation is the current utilization of the resource at hand. When the current use of the resource does not produce any difficulties (e.g. sharp peaks and troughs), the current allocation can be maintained. Otherwise, some adaptations need to be made to alleviate resource impacts. To achieve coherence in resource use, every change in allocation of one of the resources needs to be checked on resource impacts for the other resources. This is illustrated in Figure 7.7 by the vertical arrows. The checks on coherent resource use can be supported by the model 'Inpatient Capacity Management'.

We should also use some reference points here for what can be considered as a target capacity loads in case of a balanced use of inpatient resources. What we learned from the analyses in the very busy and average busy periods is that the three resources show different capacity load performances but that the differences between resources are, relatively considered, the same in both periods. Based on the results of this case-study we would suggest as capacity load targets for beds, operating theatres and nursing staff at overall hospital level: 85% - 80% - 100%. For specialties with more or less than average urgent admissions, this should be corrected with about 5%.

Application to case-study hospital

As beds are the bottleneck resource for the case-study hospital, the allocation procedure should start with this resource. From the analyses before it may be clear that the available beds will from time to time not be enough to cover all demand for specialties, resulting in 'admission stops'. This requires managerial decisions to protect specialties that are important for the hospital strategic profile from not being able to meet demand, as their beds are used by other specialties that borrow beds to be able to admit patients in these busy periods. The current use of beds by specialties differs from the historical based allocations as has been shown in Table 7.3. In the setting of the case-study hospital this does not result in capacity losses because the actual use of beds at operational level is very flexible. This results, however, for example in on average four beds more in use than allocated to Neurology and eight beds fewer in use than allocated to General Surgery. This illustrates that the actual use of beds by specialties has moved away from the allocated numbers, and that hospital management does not use bed allocation as a tool of management to shape the future according to hospital strategy. To make room for allocating beds to specialties that need to be stimulated, different options can be considered. This could be done either by reallocating bed resources, or by stimulating shorter length of stay or by finding solutions for 'wrong-bed' patients. We illustrate below an example of the first option, i.e. a review of the current bed allocation based on the current use of beds. The calculations are shown in Table 7.15. The allocation of the other resources can be calculated in a similar way.

Specialty	Allocated number of beds	Average number of beds in use	Standard-deviation average number of beds	New bed allocation	Old bed occupancy	New bed occupancy
General Medicine	64	63.8	0.8	65.6	99.6%	97.4%
Cardiology	17.7	18.3	0.4	19.2	103.5%	95.3%
Pulmonology	14	11.9	0.4	12.9	84.9%	92.2%
Rheumatology	14	10.4	0.6	11.8	74.5%	88.1%
Anaesthesiology	-	0.1	-	-	-	-
General Surgery	52	44.2	1.2	46.9	85.0%	94.2%
Urology	14.1	9.8	0.5	10.9	69.2%	89.9%
Orthopaedics	25.2	22.1	0.7	23.7	87.6%	93.2%
Neurosurgery	-	-	-	-	-	-
Plastic Surgery	4.7	3.6	0.2	4.1	75.4%	87.8%
Dental Surgery	-	-	-	-	-	-
Gynaecology	20	16.5	0.5	17.7	74.9%	93.2%
Paediatrics	24	15.0	0.8	16.8	62.4%	89.3%
Neurology	23.4	27.1	0.7	28.6	115.7%	94.8%
Dermatology	3	2.5	0.2	2.9	81.7%	86.2%
ENT	7.1	5.2	0.2	5.6	72.8%	92.8%
Ophthalmology	3.6	4.3	0.3	5.0	121.4%	86.0%
Radiology	0.7	0.8	-	0.7	112.7%	-
Obstetric beds	4.0	1.5	-	4.0	37.5%	37.5%
Wrong-bed patients	-	5.9	-	(5.9)	-	-
Total allocated	291.5	-	-	282.3	-	-
Not allocated beds	-	-	-	9.2	-	-

Table 7.15: Example bed allocation scheme based on actual resource use.

The bed allocation scheme suggested results in average bed occupancies of about 90% for most specialties. Apart from the average use of beds the fluctuations in bed usage also need to be taken into account. In this example the suggested number of beds allocated is equal to the upper confidence limit (95%) for the average number of beds in use. It should be noticed that this calculation is based on monthly figures. Fluctuations from day to day can be much higher but could not be calculated as bed occupancy figures in the hospital were not collected for each day. It should also be noted that this procedure benefits those specialties with high occupancy levels. Hospital management has again the task to check that the allocations suggested do not harm specialties that need to be stimulated. The allocation scheme shown leaves allocation of about nine beds to the discretion of hospital management. The bed occupancy figures for most specialties are at about 90%, which can be considered as a high bed utilization performance.

7.6 Evaluation and discussion case three

At the end of this case-study we will discuss the outcomes of the study in the perspective of our research objectives, i.e. improvements in resource use, contribution of our approach, other effects, and conditions for a similar project elsewhere.

Improvement in resource use

As the project was limited to the development of a method for resource allocation improvement we can refer to the example bed allocation scheme as discussed in 7.5, where we managed to create managerial decision space of nine beds that could be allocated to specialties that need to be stimulated because of the strategic chosen hospital profile. This is an indication of the possible gain to be made by the suggested method of inpatient resource allocation that takes into account the current utilization and a balanced use of resources by specialties.

Contribution of approach

The **problem orientation** dimension of our implementation strategy was important to create acceptance for the project and the method suggested. As has become clear from the case-study the shortage of beds was a real problem and felt by everyone in the hospital. It was, therefore, not too difficult to get the support needed. Also, we must remember that the project only involved the development of a methodology and not the implementation of it. It would perhaps have been different if the project had also involved the application of the method with an actual reorganisation of resources. Again, the problem perception would also have given the same support, but there would also have been much more resistance from specialties whose resources would need to be reduced. This challenge to our approach is still ahead.

The **decision support** tools used in the project were a combination of models: 'Patient Flows and Resources' was used to look at longer term developments in the inflow of patients to the hospital, and 'Inpatient Capacity Management' was used to look at coherence in the use of resources by specialties at the medium term of planning. The models were used as analytical tools for the project team, but not during presentations where only the output of the models was included. This was preferred as it allowed to focus better on the method for resource allocation proposed instead of on the models or on all the data. Both models performed very

well for the purposes used in the project, although the experiences with the models led to suggestions to improve the models at some points. Important for the project was that the elements of the philosophy underlying the method developed were already built in into the models, i.e. the variables that influence the inflow of a hospital (population, need, and market-share) and coherence in the use of the three major resources for inpatient services. The combined use of the models performed very well in that they covered well the problem space that was present in this case-study

The **participative mode** of executing the project involved a small project team as group of analysts and think-tank with active roles for key persons in hospital business planning, an existing 'admission policy and bed allocation' committee as steering group with representatives of specialties and departments, consultation rounds with specialties and departments and presentations on the project. This offered much opportunity for participation by those involved in the project, and although the actual involvement of those outside the scope of the project team was limited (measured in the amount of time spend on the project) it was felt as sufficient by participants. This was also due to the many bi-lateral contacts to department managers and others. Participation in this case-study was not so much aiming at actual involvement in the analytical part of the project as creating support for the method developed. As in the final presentation there was broad acceptance for the method this suggests that the participative strategy has worked out well.

Other effects

The evaluation of the impacts of the project contained the following effects that were linked to the project but were not expected in advance:

- During the final presentation those present showed that they had learned from the project to distinguish different levels of planning and that to solve some of the problems experienced (such as the handling of acute admissions) required actions to be taken at different levels.
- Hospital management acknowledged that if they were not able to take the decisions required at strategic level to the desired hospital profile to be obtained, then managers and planning officers at operational level would have to make decisions. This contributed to the importance of the roles of the admission planning department and operating theatre department for effective resource management.
- Specialists tend to use the argument of population development as a reason for extra resources required, while the analysis performed made clear that for instance market-share development and length of stay development have much greater impact on inflow of patients and resource requirements.
- A suggestion was made during the presentation to create a pool of beds for surgical specialties that would be used for emergency admissions when no bed is available at the regular wards. However these beds cannot be used by medical specialties, to prevent them from taking too large a share of the beds. The 'admission policy and bed allocation' committee considered this a good idea, which would also contribute to a reduction of the fluctuations in bed requirements.
- Nursing workload measurement data were available at ward level as they were up to now used for manpower planning purposes. To enable the use of these data also for patient flow management and coherent use of all resources involved, it was suggested that the specialty of the patient should be included in the nursing workload data collection.

These examples show that the project has also contributed to improve the insight, of those involved, in the complexity of the hospital's production system and who were thus able to suggest improvements that were considered worthwhile.

Conditions

The conditions that need to be fulfilled for a similar project in another hospital can be headed under support from hospital management, medical staff and departments, and under availability of data for the analyses.

If the problem is broadly experienced in the hospital, as in this case, it will not be too difficult to get the support needed for the project. Support from the three categories mentioned is essential for a successful project. Support from the board of directors is needed to make clear to other groups in the hospital that the project is regarded as important in tackling a problem that is high on the priority list of hospital management. Support from the medical staff is necessary because they have to agree with the assumptions that are used for developing a method for allocation of resources. The department managers have to support the project as they have the knowledge of the current resource allocation and the problems with the use of resources.

Data availability can be a problem as the analyses to be performed require a considerable amount of data and of a detailed level that is often not available in a hospital. To investigate the influence of longer term developments requires for the region considered population projection data per age-sex group for four 5-year periods and hospital inpatient consumption data for say at least five years. As these latter type of data also include other hospitals' statistics, one needs an information processing agency (such as the SIG) to produce these pooled data, but also a considerable project budget to buy these data. In our case-study we used three years of data which enables only an indication of possible trends without being able to give statistical proofs. Further data are required to investigate the development of occupancy of resources during the year. These data should be available within the hospital information system, but often not in the right format or level of detail. In our case the operating theatre statistics did not allow us to calculate the occupancy of operating theatre sessions during office hours, and the bed occupancy figures were not available on a day-to-day level. The case-study hospital performed very well on availability of nursing workload measurement data though they were only available at ward level without a linkage with specialty. The investigation of simultaneous use of resources by specialties requires a special data collection, building on admission data of four weeks and completing them with operating duration times and nursing workload statistics. This can be done for two periods of four weeks to be selected after consideration of bed occupancy development during the year, or for one average busy period as bottlenecks in an average busy period will certainly be bottlenecks in a very busy period.

The approach as followed in this project can be recommended to other hospitals: problem oriented, use of decision support tools to visualize resource impacts of alternative allocation schemes, and a participative mode of executing project activities. It may be clear from the case-study that a reallocation of inpatient resources - or even the development of a method for allocation as in this case - can only be legitimized by the existence of real shortages of resources that is experienced by many in the hospital. The problem as such has enough momentum to drive a project like this. The combination of the decision support models used in this case was successful in that it offered support for as well as the longer term analyses as the medium term analyses on coherence in resource use. They were mainly used as back-

office analytical tools by the project team, and not so much as tools of communication as in the other cases. However, the models were extremely valuable to guide the data collection and analysis, and to develop the philosophy underlying the method for resource allocation. Data availability can be problematic as the analyses to be performed require lots of data, some of them need to be bought from outside agencies, some of them can be extracted from hospital information systems and some require special data collection. The participative mode of executing the project was in this case mainly shaped by involving key persons for hospital business planning in the project team, by the many bi-lateral contacts between the student and departments, and by the plenary presentations on the project which increased the support for the method of inpatient resource allocation but also offered many learning points as side-effects of the project.

CHAPTER 8

COMPARISON OF CASE-STUDY FINDINGS

This chapter compares the three case-studies reported in Chapters 5 to 7, and draws conclusions on the research questions posed in 4.3 and 4.4. To summarize these questions:

- Has there been a change in the need and use of resources and what is the size of this change?
- To what extent can this change be attributed to the implementation approach followed? (problem oriented, use of decision support models, participative mode)
- Under which conditions can these results be achieved?
- What other impacts and side-effects occur?
What effects were expected according to the implementation model used (in which we used as intermediate variables: system coherence understanding, ability to identify interests of the organization versus self interest, commitment) and what were side-effects that accompanied the change process?

We start with a summary of the main findings of the case-studies (8.1). Then we draw some links between the cases and the different models used in them (8.2). In 8.3 we compare the results achieved using the case-study approach, with the results achieved by hospitals which have used one of the models without further support. Finally, we will draw conclusions on this third part of our research, focusing on the contribution of the different elements of our implementation strategy (8.4).

8.1 Main findings case-studies

In Table 8.1 we have listed the most important characteristics and results of the case-studies.

CHARACTERISTICS	CASE ONE	CASE TWO	CASE THREE
1. resource management issue	reorganisation of the specialty time table of 8 general surgeons in a multi-location hospital	improving the workload of an x-ray department and the waiting times of walk-in patients from outpatient clinics	development of a method for flexible and coherent allocation of inpatient resources
2. models used	Specialist Capacity Management	X-ray & Specialist Capacity Management	Patient Flows and Resources & Inpatient Capacity Management
3. composition project team	representatives of specialty and direct involved departments, and staff officers	managers of departments involved and staff officer	small team composed of analysts

4. steering group function	larger group of department representatives and board of directors representative	hospital management team meeting	admission policy & bed allocation committee
5. ways of data collection	interview rounds surgeons & departments	interview rounds, extraction of data from hospital information system	extraction from external and internal information systems, interview rounds
6. analyses done by	staff officers & researcher	student & working groups per specialty	student and project team
RESULTS CASES			
1. problem solution	new time-table with better performance for individual and joint practice surgeons	rearrangement of x-ray room programmes and provision for walk-in patients	accepted method for future allocation of beds, nursing staff & operating theatre hours
2. resource impacts	less fluctuation in OT but more in other resource requirements	better workload control by x-ray department, more capacity available and less waiting time for walk-in patients	less fluctuation in the use of resources during the week and more balanced use of resources by specialties
3. contribution: a. problem orientation b. models c. participation	a. relocation date and new surgeon crucial for progress b. limited use (presentations and resource impact visualization) but essential for acceptance c. crucial for problem and solution perception	a. waiting time problem did not have enough momentum to make progress b. primarily for workload analysis during diagnostic phase c. crucial for bringing in feasible solutions by those direct involved	a. general perception of resource shortage was important for acceptance of project and method b. primarily for analyses of external patient flow development and balanced resource use c. important for creating support for project and method
4. side-effects & learning points	- clarification of specialty policy - method taken over and refined by staff officer - application method for other specialties	rearrangement of room programmes was not part of the project but inspired by the results of the analyses	plenary meetings showed learning to deal with hospital complexity by distinguishing different levels of planning and action
5. conditions required	- support specialty, departments & board of directors	- support from departments and specialties - availability of data	- support from board of directors, medical staff and departments - availability of data

Table 8.1: Overview of characteristics and results case-studies.

From Table 8.1 one can draw a number of observations about the three case-studies performed:

- The resource management problems addressed by the case-studies concern different areas of resource allocation decision making.
- The models applied differ from case to case. All models but one (Outpatient Capacity Management) have been used, often in combination with each other.
- The cases do not show essential differences in the use of project team and steering group functions, apart from case three where a small analyst's group was used as project team. This can be explained by the amount of analytical work that had to be performed by the project team in this case.
- Data collection required more energy and time in cases two and three, compared with case one where most data collection could be done through interviews.
- Analytical work was mostly done by students, researcher and staff officers, apart from case two where two working groups developed the final ideas for improving waiting times at the x-ray department.
- All three cases achieved their objectives and produced solutions that showed improved resource requirements or resource needs. The third case involved only the development of a method and not the implementation of it. It is important to notice that the resource utilization improvement was not the primary objective but came along with the solution found for the problem faced by the hospital, i.e. a specialty time-table, the interface x-ray and OPD, a method for coherent allocation of inpatient resources.
- The contribution of the problem orientation (element of the implementation strategy) to the results achieved was larger when the change aimed for in the project was linked to a broadly accepted reorganization (case one), or a widely experienced shortage of resources that constrains day-to-day practice (case three), than when it considers an improvement in patient service that requires considerable adaptations in department and specialty planning (case two).
- The contribution of the decision support models ranged from tool for demonstration (case one) to tool of analysis (cases two and three). The role of the model was more important in the first part of the project to create acceptance and to guide the data collection and data analysis, while their role was later taken over by participants. We will return to this observation in 8.4.
- The contribution of the participative mode of executing the project was important for all three cases in that it created support for the project. Moreover, participation of specialists and departments produced additional local information and ideas for improvement that otherwise would have been left unnoticed (cases one and two).
- All three cases showed important side-effects that we can attribute wholly or partly to the project but were not intended. The resource impacts of these side-effects were often larger than the impacts from the change as part of the project (specialty policy development in case one and rearrangement of x-ray rooms in case two). Also, all cases showed learning among participants in understanding and handling the complexities of the hospital production system.
- The three cases required similar conditions for a successful project, i.e. support from the board of directors and departments and specialties involved, and availability of data. Support from the board of directors was less important in case two, and data availability proved less problematic in case one.

We will return in 8.4 to some of these observations (problem orientation, decision support models, participative approach) to draw conclusions on the contribution of our implementation approach to the results achieved over the three case-studies.

8.2 Links between cases from the case-study design perspective

The cases chosen for this study on hospital resource allocation can be treated separately as reported in Chapters 3 and 5-7, or can be considered jointly as we intend to do in this paragraph. The cases each have their own focal point, dealing with a separate part of hospital planning and with different parts of the hospital organization, and each using specific combinations of models in support. We now try to link the different cases within a hospital setting, illustrating at the same time relationships between the models on capacity management.

From Figure 8.1 one can see that the three cases cover different areas of hospital resource allocation decision making. Cases one and two focus only on allocated resources, while case three also looks at required resources. One can also see that the three cases together offer broad support for resource allocation issues. Within this framework we will discuss the contribution of each of the cases, including the reference case:

- The Reference-case focused on the development of a new operating theatre time-table and on the resource impacts for the outpatient department, the medical support services departments, and the wards. Although its function was to demonstrate the knock-on effects of a change in the operating theatre time-table, the case also offers a method that can be applied by other hospitals to look at changes in the operating theatre department organization and the consequences for the rest of the hospital. The model 'Inpatient Capacity Management' can offer support for visualizing the inpatient resource impacts, while the 'Specialist Capacity Management' model can offer support for the development of a new operating theatre time-table and for visualizing the outpatient resource impacts. However, the case is limited in that it does not consider the consequences for the practice of a specialty (link with case one) and that it only covers a small part of the resource management problems of medical support services departments such as x-ray (link with case two).
- Case One focused on the development of a specialty time-table that allocates specialist-time as resource to various activities performed by specialists. In this case we have considered the resource impacts of the new time-table on the outpatient department, the operating theatre department and medical support services departments. The importance of this case is that it offers a method to be used for changes in the organization of a specialty, such as rearranging tasks in case of a multi-location setting or the start of a new specialist. The model 'Specialist Capacity Management' can offer support for this type of changes. The limitation of this case is that only one specialty and its resource impacts is considered, which does not cover the whole resource management problem of a 'resource' department such as the operating theatre department. This hospital-wide perspective can be found in the other cases.

Figure 8.1: Relationships between cases and models.

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- Case Two focused on the planning of examinations at the x-ray department and further on the relationship with the outpatient department, which is a major source of x-ray workload and critical to the occurrence of long waiting times at the x-ray department. This case covers the complete resource management picture for the x-ray department and can be used as a method to look at changes in the organization of x-ray services and the consequences for service requests from various sources such as outpatient clinics, wards and general practitioners. The model 'X-ray Capacity Management' can offer support for analyzing the x-ray department workload and the consequences for patient service performance. The case also stands as a model for other medical support service departments such as laboratories and organ examination departments. However, the case is limited in considering the consequences of adaptations in the organization of an outpatient clinic or a specialty practice (link with case one).
 - Case Three adds a new perspective in that it starts with an analysis of resource requirements based on external and longer term developments affecting the inflow of the hospital, before looking at a balanced allocation of inpatient resources. The case offers a perspective on a generalizable method for reallocating inpatient resources, to balance demand for resources with supply of resources over the longer term and prevent capacity losses by allocating resources that are simultaneously used by different specialties in a coherent and balanced way. Support for longer term analyses of patient flow developments and the consequences for resource requirements is offered by the model 'Patient Flows and Resources', and support for the medium term coherent allocation of inpatient resources by the model 'Inpatient Capacity Management'. However, this case is limited to the use of inpatient resources and it does also not provide insight into the consequences for time-tables of specialties (link with case one) or the operating theatre department (link with reference-case).

While each case has its limitations, the total of cases investigated illustrates hospital-wide support for many resource management issues faced by hospitals.

8.3 Experiences with models without use of the implementation strategy

The models on 'Hospital Capacity Management' were also used by hospitals which had acquired them without further support. The appendix on the models lists the number sold (about 40). To include the experiences of these hospitals with the models, we performed a short survey by phone. We first give an overview of the results of this survey and then go into more detail on the experiences with each of the models.

We have summarized the findings of the survey in Table 8.2, classifying the applications of the hospital under the following headings:

- full application, implying the use of a model to a problem and making use of the different features of the model;
- limited application, referring to an application of the model to a particular part of a resource management problem and making use of only a few features of the model;

- waiting on application, referring to a hospital that has purchased a model but that waits for an opportunity for applying it to a concrete problem;
- orientation, referring to a purchase of a model without a direct perspective on a possible application to a real problem.

Model name	Full application	Limited application	Awaiting application	Orientation	Total	Case-study applications
1. Patient Flow and Resources	4	-	1	4	9	2
2. Inpatient Capacity Management	3	1	2	4	10	2
3. Outpatient Capacity Management	1	-	-	3	4	-
4. X-ray Capacity Management	3	-	2	2	7	2
5. Specialist Capacity Management	5	1	1	2	9	3

Table 8.2: Overview applications by hospitals.

Table 8.2 lists the applications of the models by hospitals. The last column shows the application of models in case-study hospitals, including the application in the hospital that was used as pilot-setting for the development of the model; these are also counted as full applications. As can be seen from the number of full applications, the experiences with the models are limited. More than half of the models sold are not (yet) applied to a real problem. After deduction of the case-study applications there remain only nine real applications - full or limited.

Although these experiences with the models are therefore rather limited we will discuss them for each of the models below:

- Patient Flows and Resources

Of the nine copies sold we know of one application in the Netherlands and of one potential application in Scotland. The Dutch application involved a project by a student supervised by an internal management consultant to investigate longer term developments in patient flows. This project can be compared with the experiences with this model as part of case three. The documentation on the project reports a successful application, which was also confirmed upon by personal contact with the hospital management consultant. The project undertaken focused on the market development for the hospital. The project's purpose did not cover to use this information for reconsidering resource allocation.

The potential application in the Scottish Health Service involves a similar type of problem, but in this case not applied to a marketing issue for a single hospital but for a health board as a purchaser of services from different hospitals in the region considered.

The data requirements of the model did not cause any problem; the model will be implemented as soon as the required population data becomes available.

- **Inpatient Capacity Management**
Ten copies have been sold up to now of this model. Apart from the experiences with the model in the reference case and case three, there are no relevant other experiences to report.
- **Outpatient Capacity Management**
Four copies have been sold of this model which has been released recently. A project by a student has recently started in a hospital to use this model for evaluating the resource impacts of a more integrated patient-centred working mode in an outpatient clinic setting versus the resource use performance of the traditional functional organization.
- **X-ray Capacity Management**
Seven copies have been sold. One of the hospitals reports a reasonable successful application for investigating the x-ray workload. This x-ray department manager had been able to collect the rather extensive data required for the model and had used this information for showing specialists the consequences of their clinic organization for the x-ray department's workload.
- **Specialty Capacity Management**
In total nine copies of this model have been delivered to hospitals. In one hospital it has been used to develop an operating theatre time-table as part of a move to a new site of the hospital; this was considered to be a successful application. In another hospital the model was used to give a permanent overview of all the time-tables of specialties and departments. This required constant updating of all the (minor) changes in the model. As this was not part of a project setting, this updating task was considered as an extra administrative task by the clerks who were given this task; the activity was stopped due to lack of return from this work. Experiences of five hospitals with a previous version of this model concerned development of time-tables for the outpatient department and the operating theatre department.

Despite the considerable number of copies of models sold up to now, the reported experiences are rather limited. Though it is difficult to compare this with the reports on the case-studies, the applications of the models reported by hospitals without following the implementation approach suggested in this study indicated in general more success when:

- applied to a specific problem,
- in a project setting,
- and performed by someone who had enough time available.

The best results were therefore achieved in projects performed by someone who had the time to use the models (for instance a student) and who will probably have followed a procedure more or less similar to ours.

8.4 Conclusions case-studies

Based on the different perspectives on the case study findings reported before, we will now list the main conclusions of the third part of this study on hospital resource allocation, involving three case-studies. Doing this we will focus the conclusions on the elements of our implementation strategy for the case-studies.

1. The case-study findings supported our assumption that a **problem oriented approach** is a prerequisite for a successful project using one of the models. Linking our project to an accepted reorganization or a broadly recognized restriction in day-to-day practice proved to be a successful formula. A reorganization of a specialty's time-table as part of a multi-location hospital setting, or a general shortage of beds resulting in many 'admission stop' days showed to provide more momentum than too long waiting times in an x-ray department. Improvement in the use of resources is a by-product of our project whose first objective was to solve the hospital's problem. This 'meta' problem acted as a stepping-stone for achieving our research objectives.

It should be clear that any attempt to improve the use of resources should be considered within the wider strategic context of the hospital. This implies that the decision taken at strategic level, for instance stimulating a specialty that is important for the hospital profile, will define the context for balancing resource use. Case one (decision to concentrate specialties in a multi-location setting) and case three (improving the decision space for the hospital management to allocate resources to selected specialties) illustrate this.

2. The contribution of the **decision support models** was most important for a right start of the project. The models created support for the project as participants perceived in general a good 'organizational fit' to the problem experienced. The models gave also credit to the researcher's role as outside expert. The models further advanced the data collection and data analysis, leaving more time and energy for developing solutions. Halfway the project, however, the role of the model was more or less taken over by the participants. Having internalized the planning philosophy of the models, participants were often better or more fast in developing solutions without model support than with the model. This shows that the models acted as catalyst during the first part of the project but that the support level of the models was too low during the second part. Finally, the models were used again for the project to evaluate the resource impacts of the change introduced.

The case-study reports may raise the question of the necessity to use the decision support models as their role was halfway through the project taken over by the participants. To summarize the benefits of using the models the following arguments can be given:

- the models play an important role as catalysts for discussion of problem and solution perception;
- they further act as guidance for the data collection, and take care of the cumbersome calculations, allowing the participants to spend more energy to finding solutions;
- the standardized method and terminology used in the models makes it possible to compare and repeat results of projects;

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- the models act as vehicle for the planning philosophy which makes them suitable as a learning tool to transfer knowledge and experience of solving the type of problems studied.

Finally, because of these characteristics the standardized method of describing resources and evaluating their impacts makes the models suitable tools for scientific research that requires comparison between projects in different settings and between repeated applications.

3. The **participative approach** followed in the execution of the project was crucial but also considered as 'natural fit' to the multi-actor hospital setting and to the global perspective on the problem as strived for in this study. It was important that there was enough opportunity to bring in views on problems and solutions, and it was just as important to make optimal use of the available expertise of specialists and department representatives on day-to-day practice. The participative mode contributed in this way to the level of support for the project, and to the level of using local expertise for the project.
4. Based on these elements of our implementation strategy (problem oriented, use of decision support tools, participative mode) the following **changes and resource improvements** were achieved:
 - A new specialty time-table for a group of 8 general surgeons in a multi-location hospital setting (case one), with improved performance on the quality of the schedule for the individual surgeons and the group of surgeons. This led to a 33% reduction of the variation in operating theatre staff requirements, a 12% increase of the variation in outpatient staff requirements, and a 12% increase of variation in the workload of the x-ray department; using a weighing function for the reduction of variation of use of different resources with more weight for reduction of the expensive operating theatre resources, the overall result can be qualified as positive.
 - A provision in the planning of x-ray services for walk-in patients from outpatient clinics, with improvements in waiting times for patients and more control over workload by the x-ray department (case two). This resulted in a better balance between the requirements and availability for direct examinations examination capacity; this directly affects the waiting times for walk-in patients from outpatient clinics, whose projected average waiting time during peak hours showed a reduction from more than 100 minutes to 25-30 minutes.
 - A method for more flexible and coherent allocation of inpatient resources (beds, nursing staff, operating theatre hours) to specialties, matching demand for resources with supply of resources at the longer term and preventing capacity losses due to unbalanced requirements of inpatient resources at the medium term (case three). This led to a more balanced use of resources and a managerial decision space of 9 beds that could be allocated to specialties that need to be stimulated because of the strategic hospital profile.
5. The cases also produced many **other impacts and learning points**. Often other effects (not foreseen but linkable to our implementation approach via the influence of intermediate variables) had even more impact on the project's outcome than the change by the project. Examples observed were:

- The decision taken by the board of directors in case one to achieve a weekly fixed operating theatre schedule for the surgeons instead of bi-weekly sessions; this decision acted as an external condition for our project (as we had no direct influence on it), but our project stimulated the taking of this decision in a direction that was favourable for our project.
- The rearrangement of x-ray rooms due to the introduction of new x-ray equipment in case two (a decision outside the scope of our project), which consequently led to adaptations in the room programmes.

Examples of learning points were:

- The growing ability of the group of surgeons in case one to develop a policy for creating good conditions for surgical practice. This was stimulated by the proposals and questions put forward to the group of surgeons by our project.
- The way the rearrangement of x-ray programmes was done by the manager of the x-ray department in case two was inspired by the results of our analyses. By using the planning philosophy developed in the project, more capacity came available for walk-in patients, resulting in less waiting times for these patients.
- The increased ability of participants in case three to distinguish different levels of planning, and awareness that some problems (for instance, the handling of urgent admissions) require action at different levels.

CHAPTER 9

CONCLUSIONS AND RESEARCH RECOMMENDATIONS

In this final chapter we present the conclusions of our study on hospital resource allocation (9.1) and formulate recommendations based on the study (9.2). First, however, we will summarize the research questions for this study. The study focused on hospital resource allocation. The present allocations do not use the development of patient flows as a rationale for allocation but are rather based on historical rights of specialties and best lobbying. When allocations are not patient flow based they can lead to over-capacity of one specialty and under-capacity of another specialty. This can easily result in less optimal use of resources, i.e. fewer patients treated. Another form of capacity loss may arise when the capacities of resources that are simultaneously used by specialties for production are not balanced, resulting in one resource being the bottleneck resource for the specialty and other resources being under-used. The study was concerned with the development of a method for patient flow based allocation of hospital resources. Research questions to start this study, as described in Section 2.1, were:

1. What are the dependencies between resources in the hospital's production system?
2. What are the variations in the use of resources over the part-days within the week?
3. To what extent are these variations caused by the way resources are allocated?
4. What are the requirements for co-ordination of capacity allocations of resources and what are the goals we are trying to achieve?
5. What would a method for resource allocation look like that would fulfil these requirements?
6. What approach can be suggested for implementation of this method?
7. What are results of applying this method to real-life resource management problems in hospitals?
8. What are the conditions for other hospitals to achieve similar results using this method?

From a macro level perspective additional research questions, raised in Section 1.1, are:

- What explanations can be given at the level of an individual hospital for the wide range of performance differences in resource-use among hospitals?
- What would be reasonable capacity load factors for scarce resources in a hospital?

The research activities undertaken can be split up into three parts. The first part involved an analysis of the production system of the hospital, where we looked at the relationships between resources used. Based on this analysis we developed in the second part of the study an approach and tools in support of allocation of hospital resources, that would meet the capacity co-ordination requirements inherent to the hospital capacity structure. The third part of the study involved a number of case-studies in which we applied this approach to different resource management issues faced by the hospitals involved.

9.1 Main research findings

We now list conclusions for each of the three parts of the study: problem analysis, model and implementation strategy development and case-studies.

Problem analysis

This first part of the study involved an analysis of the hospital production system and capacity structure to answer research questions 1 to 4. This also included statistical analysis of data from a hospital on the relationship between the time-table for clinics in an outpatient department and the workload of a diagnostic department.

1. Many of the resources in the hospital concern **scarce shared resources**, such as beds, nursing staff, operating theatre facilities and diagnostic services. The scarcity results from the limited hospital budget or limited availability on the market for resources. Shared resources are resources used by more specialties. Both features make resource management a complicated task for hospital management.
2. Looking at the hospital's capacity structure, one can distinguish '**leading**' resources and '**following**' resources. 'Leading' resources act as triggers for production on 'following' resources. A 'leading' resource for inpatient production of a surgical specialty is the operating theatre capacity allocated to this specialty, while beds and nursing staff are 'following' resources. This distinction is important for allocation of resources.
3. Resource allocation - which is the focus point for this study - is a **medium term decision** with a planning horizon of a few months to one or two years. There is as yet no procedure available in hospitals to update resource allocations on a regular basis. To reallocate resources one needs support for this decision. We have introduced '**critical resource incidents**' as events that cause a major shift in the hospital production system and are critical to the need/use of hospital resources. These events can further act as legitimate triggers for reallocating resources. Examples are: increase of medical staff for a specialty, a request for more operating theatre capacity for a fast growing specialty, a merger of two hospitals, the move to a new hospital. These 'critical resource incidents' can be used to improve the use of resources by a better allocation of resources.
4. The **utilization rate** of a resource, defined as the ratio between the utilized capacity and the usable capacity of the resource, can be used as a measure of resource need/use performance. One should, however, not only look at the average level of utilization but also at the variations in the utilization of resources over day-parts within a week, as these cause variation in resource use at other places in the hospital because of the knock-on effects between interdependent resources.
5. Apart from being the generator of hospital production, the specialist also is one of the most important hospital resources. Almost all hospital production involves **specialist-time as resource**, acting as a 'leading' resource for the workstations in the hospital. As specialists spend their time in more workstations, the specialist as a resource type can be labelled as a '**product line key operator**' (considered at the level of a product line) or a '**multi-functional operator**' (considered at the level of a specialty). To improve hospital

resource allocation it is therefore important to include specialist-time as a resource in the allocation procedure.

6. To handle this complex supply structure, hospitals use for some of the most important 'leading' resources **sessions as a batch processing mechanism**. A session is a period of time allotted to a specialist in a workstation to treat a number of patients that require the same type of resources. Sessions are usually organized for a fixed period in the week. Sessions provide for the short term match between demand for resources and supply of resources.

Time-tables regulate the allotment of sessions in a workstation to specialists. The most important time-tables are the operating theatre time-table for allocating operating theatre sessions, and the outpatient department time-table for allocating clinic sessions. These time-tables perform a similar function to Master Production Schedules in an industrial setting, in that they define a production schedule per period (which in this case is a fixed schedule per week). Investigation of these time-tables, and the linking time-table of specialties, on resource impacts for other departments can identify areas for resource use improvement.

7. The use of the session mechanism and time-tables for scarce shared hospital resources led to the following **requirements for co-ordination of capacity allocations**:
 - co-ordination of the allocations of 'leading' resources to specialties sharing the same resource (capacity load levelling per 'leading' resource department);
 - co-ordination of the allocations of different resources to one specialty (capacity load levelling per specialty);
 - co-ordination of the resource impacts for 'following' resource departments that are shared by specialties but often not allocated to specialties (e.g. x-ray);
 - co-ordination of specialist capacity within a specialty (specialty planning restrictions).

Ignoring these co-ordination requirements may result in avoidable capacity loss or violations of the policy for planning specialty practice.

8. The statistical analysis of the **relationship between the time-table in the outpatient department and the workload of the diagnostic departments** (i.e. the x-ray department), using data on all x-ray examinations during 26 weeks, led to the following findings:
 - the fluctuations in the patient flow to the x-ray department (coefficient of variation based on weekday averages: 8.5%) are largely due to the direct flow of patients from outpatient clinics (coefficient of variation: 22.9%), and concentrate in a few high-referring specialties; specialties such as orthopaedics, general medicine and general surgery account for more than 50% of the referrals to the x-ray department;
 - the other source of direct patient flows, i.e. the patients referred by general practitioners, shows less fluctuations (coefficient of variation: 9.2%) as GP tend to have clinic sessions throughout the week;
 - by levelling the combined direct patient flows from specialty clinics over days a reduction of more than 50% in the variation of the combined direct flow of (clinics and GP) patients can be achieved;
 - the time-table in the outpatient department can be used to approximate the fluctuations in the number of direct referrals to the x-ray department.

Therefore, the clinics time-table can be used for levelling the x-ray department workload.

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9. To illustrate further the problem analysis part of the study we reported on a case-study about a reorganization of an operating theatre time-table in a hospital. This demonstrated that such a change causes many **knock-on effects** on inpatient and outpatient resources. Not taking these knock-on effects into account can easily introduce new imbalances in resource needs elsewhere in the hospital. In this case-study we calculated that the operating theatre time-table change resulted in a 14% decrease of variation in bed requirements, a 20% increase of variation in nursing workload, a 30% decrease in variation of outpatient staff requirements, and a 25% decrease of variation in workloads of diagnostic departments.

Model and implementation strategy development

The modelling part of the study involved the development of a production control framework for our research, the building of a set of computer models to support hospital managerial decision making on resource allocation, and the development of an implementation strategy for our approach to hospital resource allocation. This refers to the research questions 5-6.

1. Apart from some minor adjustments **production control** principles developed for industrial settings can be applied to hospitals. Production control in hospitals or health service organizations can be defined as the design, planning, implementation and control of co-ordination mechanisms between patient flows and diagnostic & therapeutic services in health service organizations to maximize output/throughput with available resources, taking into account different requirements for delivery flexibility (elective/appointment, semi-urgent, urgent), acceptable standards for delivery reliability (waiting lists, waiting times) and acceptable medical outcomes..
2. The **production control framework** developed distinguishes five levels of planning, according to the type of decisions to be made. Decisions with impacts at a further horizon are placed at a higher level in the framework and set boundaries for lower level decision making. Strategic Planning is concerned with the future hospital profile. Main Patient Flow Planning looks at the development of hospital activities in the next year. Resource Allocation concerns the allocation of resources to specialties or departments. Capacity Scheduling considers the scheduling of allocated capacities in time-tables. Operational Planning looks at the planning of day-to-day activities. This systematic description of decisions to be made and controls to be performed, is a framework for production control decision making and allows a precision of planning contributions. The Brunell-scheme of work strata in organizations can be used to link our production control perspective to an existing taxonomy from a health care professional point of view, which facilitates the transfer of the knowledge developed in this study.
3. **Capacity Management** focuses on the higher levels of production control (as opposed to Patient Flow Management on the lower levels) and conditions these levels of planning. In our study we concentrate on Resource Allocation and Capacity Scheduling. The method we have developed for resource allocation, that takes into account capacity co-ordination requirements, is labelled '**Time-phased Resource Allocation**'. This method allows for development of capacity configuration plans that can be evaluated via detailed capacity-checks on the fluctuations of capacity requirements throughout the week and on opportunities for capacity load levelling.

4. It was necessary to develop a **set of dedicated decision support computer models** to provide for the information needed for the co-ordination requirements of capacity allocations (see conclusion 7, problem analysis), as the current hospital information systems do not produce this information. It concerns relatively simple 'what-if' models which visualize patient flows and resource requirements in different areas of hospital resource management decision making. The model 'Patient Flows and Resources' supports the long term decisions on resources required to match future demand. The models 'Inpatient Capacity Management', 'Outpatient Capacity Management' and 'X-ray Capacity Management' each support decision making at medium term level for balancing of resource requirements of services performed in the corresponding parts of the hospital. The model 'Specialist Capacity Management' supports decision making in matching the organization of specialty activities and the time-tables of resource departments such as operating theatres and outpatient clinics. Depending on the resource management problem looked at, single models or combinations of models need to be used. The wide range of the models allows following through consequences of changes throughout the hospital.

The model set can also provide in a need for integration between patient care activities by health care professionals and the effective and efficient use of available resources.

5. The **implementation strategy** for using the method in a hospital setting is characterized by the following elements:
 - problem orientation: the existence of a formal and concrete problem that legitimizes reallocation of resources is considered as a condition for a project (cf. 'critical resource incidents');
 - model support: one or more of the models is used to provide the information for capacity co-ordination requirements, and to offer the parties involved in the resource management problem a global hospital perspective;
 - participation: the different steps in the project are taken with maximum involvement of departments or groups in the decision making process.

According to the change model used, improved understanding of the system coherence in the hospital production system (subsystems, linkages between subsystems, knock-on effects, etc.) is an important intermediate variable to explain the relationship between strategy variables and output variables (improved decisions and improved quality of the decision making process).

Case-studies

The third part of the study involved a number of case-studies to illustrate the use of this approach in concrete hospital settings and to answer in an explorative way among others research questions 7-8. Three case-studies were performed, involving different resource management issues:

- reorganizing a specialty time-table for a group of eight general surgeons as part of a concentration of the specialty on one location of a multi-location hospital;
- improving the interface between the x-ray department and the outpatient department in a hospital that had problems with fluctuations in x-ray workload and waiting times for walk-in patients from outpatient clinics;
- development of a method for a more flexible and coherent allocation of inpatient resources in a hospital that had structural shortages of beds resulting in many 'admission stops'.

The main conclusions of this third part of our study are listed below. As the case-studies have a primarily illustrative and exploratory function, the conclusions have a rather tentative character. The limited number of case-studies did not allow a full test of the implementation strategy. Moreover, when judging the contribution of the implementation strategy it is difficult to discriminate between real effects due to the strategy and effects that were caused by the mere fact of extra attention giving ('Hawthorn'-effect).

1. Each of the elements of the implementation strategy (problem oriented, model use, participation) seems to have contributed to a successful project.

The more accepted or formal the **problem** is, the more support it can give to act as stepping-stone for our project and to achieve improvements in resource use. Improving the use of hospital resources alone without an underlying problem having already been recognized does not create enough support for a project.

The contribution of the **decision support models** was most important for a good start to the project. The models created support for the project because of their good 'organizational fit' to the problem experienced. The model gave also good support for data collection, data analysis and resource impact evaluation. Halfway through the project the role of the model was more or less taken over by participants who had internalized the planning philosophy underlying the models and performed better in the stage of developing solutions. Nevertheless, the models played an important role as catalysts to discuss problem perception and alternative solutions. The standardized method and terminology used allows for comparison of project results in different hospitals and of repeated applications.

The **participative mode** of executing the project was considered as necessary to create commitment in the multi-actor hospital setting and inherent to the type of problem investigated that makes it important to use all local expertise available. However, the hospital characteristics do not leave much room for alternative approaches. The difference with our approach is that we tried to stimulate participation in different ways.

- 2 The resource impacts for the three case-studies can be summarized as follows:

- The reorganization of the specialty time-table of the group of general surgeons (case one) led to a 33% reduction of the variation in operating theatre staff requirements, a 12% increase of the variation in outpatient staff requirements, and a 12% increase of variation in the workload of the x-ray department; using a weighing function for the reduction of variation of use of different resources with a higher weighing factor for reduction of the expensive operating theatre resources, the overall result can be qualified as positive.
- The rearrangement of x-ray room programmes and reservations for direct referrals expected from specialty clinics (case two) resulted in a better balance between the requirements and availability of examination capacity for direct examinations; this directly affects the waiting times for walk-in patients from outpatient clinics, whose projected average waiting time during peak hours showed a reduction from more than 100 minutes to 25-30 minutes.
- The method for a more flexible and coherent allocation of inpatient resources (case three) led to a more balanced use of resources and a managerial decision space of nine beds that could be allocated to specialties that need to be stimulated because of the strategic hospital profile.

- 3 The **conditions for achieving these results** with our implementation approach in other hospital settings are:
 - support from the board of directors (because of the consequences of resource allocations for hospital production and the potential conflicts between specialties),
 - service department managers (as they are responsible for the efficient use of scarce shared resources and are required to adopt an overall hospital perspective on their department's contribution), and
 - specialties involved (as all resource allocations affect the organization of specialty practice), and
 - availability of data. The logistic analyses performed with support of the models requires much data that with some effort can be collected or extracted from routine hospital information systems.
4. The cases showed also many **other impacts** that occurred during the project. These effects were not foreseen as impacts of the change prepared by the project but were influenced in some way by the project. In case two, for instance, the rearrangement of x-ray rooms was, though not part of the project, inspired by the project. Sometimes these other impacts had more effect on resource use than the change proposed by the project. Also many examples of **learning points** were reported. A specialty developed its ability to formulate a policy for good specialty practice organization. Participants learned to distinguish different levels of planning and were able to see that some resource management problems (for example the handling of urgent admissions) require managerial action at different levels. It also made clear to participants that when decisions concerning admission policy were not taken at hospital management level, operational management will be burdened with the need to take them and in the end day-to-day practice will determine these strategic decisions.
5. The use of the computer models by hospitals **without the implementation approach** as suggested in this study tends to be less effective compared to the achievements in the case-studies. A survey among these hospitals showed that more than half of the models purchased were not (yet) applied to a concrete resource management problem. Those hospitals that had used a model showed as a rule less complete applications.
6. The different cases can be linked to another, in that the point where one case stops can act as starting point for another case. This is supported by the complementary role of the models. From this point of view, the sum of cases can be said to offer broad support for resource management issues faced by hospitals.

9.2 Research implications and recommendations for future research

Based on the findings in this study on hospital resource allocation we now discuss some implications of this research in a wider context, and formulate recommendations for future research in this area.

Research implications

In our opening chapter we have introduced our research topic by describing its context, such as the development of the organizational and managerial structure of the hospital. We will

discuss the relevance of the research performed for this wider context of hospital managerial development.

1. The approach to hospital resource allocation issues as described in this thesis can be applied to a wide range of problems. The conditions for this approach (problem oriented, use of decision support models, participative mode) are not difficult to fulfil, as there are plenty of problems that can act as stepping-stones for a project, models are available that have been specially developed for this type of problems, and participation is a change strategy that is familiar to hospitals. Potential areas of application are:
 - reorganization of time-tables for specialty activities, operating theatres and outpatient clinics;
 - improving workload and service levels of medical support services departments (x-ray, laboratories, organ examination departments) caused by interface-problems with other parts of the hospital;
 - reallocation of inpatient resources (beds, operating theatres, nursing staff) due to shortages of for instance beds, or structural over-loading of for instance nursing staff;
 - evaluating impacts of introduction of centralized facilities for day-surgery or short-stay;
 - business planning for a new hospital;
 - multi-location planning problems due to mergers;
 - evaluating impacts of changes in outpatient programs for resource use and treatment times.

According to the experiences with the models in the case-studies and by hospitals who have used the models without further outside support, the implementation of the models requires much time and effort. The support for hospitals using these models can be improved for instance by organizing workshops with users and potential users and making use of the experiences in the case-study hospitals.

2. The wide range in performances which hospitals show in the use of beds, operating theatres, outpatient clinic sessions and x-ray facilities (reported in 1.1), may find partly explanation in the local, hospital dependent, imbalances in the allocation of hospital resources. The models developed by this research can be used to track down these imbalances in the hospital system, as they visualize resource requirements rising from the patient flows faced by the hospital. Taking the patient flow as a rationale for resource allocation may then lead to savings by closing down a ward or an operating theatre without affecting the throughput of patients, though this study has not been motivated by a philosophy of reducing hospital services as the models can equally be applied to expansion situations.
3. Capacity load targets are needed to determine what can be considered as reasonable resource use performance. This study shows that when resources used for the same production are allocated in a coherent way, high utilization rates can be achieved. In the example of resources for inpatient production, capacity load targets for beds, operating theatres and nursing staff at overall hospital level could be set for 85% - 80% - 100%. For specialties with more than average or less than average urgent admissions this should be corrected by about 5%. These are average figures for a busy season. When one would go beyond these levels there is reason to believe that the system will be over-loaded,

resulting in many admission stops or by-passing the elective planning systems by specialists by misuse of the label 'urgent case'.

4. Though it is important that allocations of resources may be flexible to match patient flow development, it is even more important that resources are used flexibly, and that empty beds or under-used sessions that were allocated to one specialty can be used for patients of another specialty. This operational flexibility tends to be more customary in smaller or medium-sized hospitals than in larger hospitals. Also, introduction of centralized facilities for day-surgery or short-stay tends to be more successful in these hospitals. One possible explanation for this phenomenon is that, in general, larger hospitals have more specialized facilities. Therefore, specialties tend to claim their own resources and do not allow other specialties to use their resources. As day-surgery and short-stay introduction require beds to be reallocated from the specialty beds to the general purpose beds of these centralized facilities, larger hospitals have more difficulty in realizing this resource-effective development than other hospitals.
5. The above danger of lower level resource use performance may also apply to hospitals that adopt a divisionalized organizational structure. These hospitals have chosen for decentralisation to reduce co-ordination efforts. Co-ordination effort requirements in organizations increase exponentially with the size of the organization [Kuipers, 1992]. To enable divisions to be managed as business units they require maximum independence, also in resources required for production. In principle each division will require its own beds, nursing staff, operating theatres, outpatient facilities and diagnostic facilities. In this way the operational flexibility within the division increases. This can only be realized without much loss of resource utilization performance when the divisions are large enough, and the specialty-mix of a division is chosen in such a way that shared resources fall within the new boundaries drawn. A hospital with two divisions (one of surgical specialties and another of non-surgical specialties) will have less difficulty in maintaining high resource use performance than a hospital with as many divisions as specialties. The models can as well be used for resource interactions between divisions as for balancing within divisions.

Recommendations for future research

To conclude this study on hospital resource allocation we present the following recommendations for future research in this area of hospital planning:

1. The models on 'Hospital Capacity Management' can be further improved, based on the experiences with the models gained in the case-studies and otherwise. One of the principles used in modelling the current set was to make the models as simple as possible, avoiding claims for optimization. This was done purposely, as this level of support was considered more in balance with the current state of resource management in hospitals and simple, transparent models enhance participation. It was judged more important to help hospitals on the way to a systematic review of resource use and resource allocation than to aim for optimal solutions. Perhaps after a few years' experience with the current tools there will be a need for more sophistication, to give longer support in the decision making process than the present models do. It would be possible to super-impose on the present models a solution generator that would help the user in finding feasible solutions. This would bring the support of the models at a higher

level, though still not at the level of optimization. This level of support will probably remain out of reach as resource allocation requires many variables to be taken account of at the same time, and the sophisticated models required would do harm to participation of those whose input is required for an effective solution. Moreover, as the primary function of the models, according to the case-studies, was to act as catalysts for discussion of problem and solution perception, one might just as well be doubtful of the benefits of further developing the models.

2. Constraint programming may be a useful method for upgrading the level of support given to hospitals. Constraint programming is a planning method that produces feasible solutions where many variables need to be taken into account, when utilizations of resources are very high and when the objective function is difficult to define. This applies particularly to the problem of resource allocation in hospitals as the case-studies have shown.
3. One further improvement could be that these types of models would become available as management tools linked to the Hospital Information System. Though these systems have always claimed this sort of management tool as their contribution to improved management of hospitals, the actual development of the tools in this study was done independently of hospital automation. Instead of taking a data system point of view on the problem of resource allocation, we took a different point of departure by concentrating on the problem and on the management information required to look at it from a hospital-wide perspective, thereby creating a dedicated support system for those involved in the problem solving process. We have demonstrated that this was a necessary way to proceed, because the help needed would not come from hospital information system development; that was too burdened with other preoccupations. However, perhaps now it is time to link both developments. This could result in easier data collection for the dedicated decision support tools for management purposes, and also increase the benefit from the vast amount of data within the hospital information system for improved hospital management.

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APPENDIX

DESCRIPTION MODEL SET ON HOSPITAL CAPACITY MANAGEMENT

This appendix describes the different models that are part of the set of computer models on hospital capacity management¹. These are:

- Patient Flows and Resources (PR),
- Inpatient Capacity Management (ICM),
- Outpatient Capacity Management (OCM),
- X-ray Capacity Management (XCM),
- Specialist Capacity Management (SCM).

For each of the models we describe the planning problem addressed, how it was developed, an outline of its structure, and a representative example of its output. Table 1 gives information on the state of development of the models and on the experience with the models in experimental settings or with the commercial versions. Commercial distribution of the models through the Dutch Hospital Institute began in 1991.

Model	Start of development	Present version	Experimental experiences	Year of release	Commercial version experiences
PR	1989	2	pilot hospital (development and application)	1991	Netherlands: 6 United Kingdom: 1 Poland: 1
ICM	1988	3	pilot hospital (development and application)	1992	Netherlands: 7 United Kingdom: 1 Belgium: 1 Poland: 1
OCM	1990	1	pilot hospital (development)	1993	Netherlands: 3 United Kingdom: 1
XCM	1990	1	pilot hospital (development and application)	1992	Netherlands: 6 Denmark: 1
SCM	1987	4	2 pilot hospitals (development) and 5 hospitals (applications)	1991	Netherlands: 8 Poland: 1

Table 1: State of development and use of the models.

PATIENT FLOWS AND RESOURCES

The 'PATIENT FLOWS AND RESOURCES' model is a PC-based computer model that supports hospital management to balance resources with the demand for services by patients using the hospital. The model visualizes the impact of changes in population, demand, alternative modes of care and orientation to hospitals on the flow of patients to hospitals in a geographical area; it also makes a projection of the amount of resources needed to cope with this flow. The model aims to support decision making on strategic issues at the long term planning of the hospital.

Planning problem

In balancing demand and supply at the long term planning level the following questions may be important to hospital management:

- what are the effects of changes in the populations, such as: increase or decrease in the size of the population, growing percentage of elderly people?
- what are the effects of changes in demand for hospital care, such as: increase of cardiovascular diseases, cancer, hip-replacements?
- what are the effects of changes in alternative modes of care, such as: increase of day-surgery and outpatient care, decrease of length of stay?
- what are the effects of changes in orientation of patients to hospitals, because of a new specialty, improvement in the reputation of a specialty, or a market-campaign with a new type of clinic, etc.?
- what are the effects of changes in the environment of the hospital in general, for example in the specialty-mix of competing hospitals?
- what are the effects of combining resources on one location instead of more locations in the case of multi-location management?

These are the type of management questions that have lead to the development of the 'Patient Flows and Resources' model.

Development of the model

The above mentioned questions served also as reasons for Medisch Spectrum Twente to participate in the development of a decision support model to balance demand and supply at a longer term of planning. The first prototype of the model has been built during a project by a MSc student, and was inspired by a similar model developed in the United Kingdom².

A second version of the model was developed to make the model suitable for release to other hospitals³. This rebuilding took place in 1991. The model was released for distribution to hospitals in 1992. The model in use is based on inpatient statistics because these are available for all hospitals. There is also an outpatient version of the model that can be used if outpatient statistics are available.

Outline model

The outline of the model is shown in Figure 1.

Figure 1: Outline 'Patient Flows and Resources' model.

Population per community (at 4 points in time to allow projection) is multiplied by the demand for hospital care in the area (based on last year's activity), which gives the total flow of patients seeking hospital care in year x. The orientation-mechanism (based on last year's activity data) determines what part of this flow goes to hospital A, B or other hospitals outside the area. Availability of data determines whether hospitals can be shown apart or grouped. The hospitals are characterised by the number of beds, specialties, etc.

Output model

Once these input data are fed into the model, the user can construct various types of output with the help of an output-table (see Figure 2):

One item from each line has to be selected in order to define the output wanted. The different options will be described below

- admissions
The first option gives the admissions per year. One has to define first the age-sex group, the year (1987 concerns historic data, 1990-2000 are based on projections of population), and the patient flow (from which community to which hospital). The format of output can be a graph, a pie-chart or a table.
- resources, required or occupied
This option implies aggregation over all demographic groups and communities. One further has to define the year and the hospital or zone level. Then the user is asked to define the resource to look at.
- waiting lists
Selecting this option implies again aggregation over all demographic groups and communities. Then the user is asked to define the quarter of the year for visualising the

Output:	Admissions	Res - reqd	Res - Occ	waiting lists	population
Sex:	Male	Female	Both		
Age:	0 - 14	15 - 44	45 - 64	65 - 74	> 75 All
Year:	1987	1990	1995	2000	
From :	Communities	Zones	All		
To:	Hospital	Zones			
Format:	graph	pie	table		

Figure 2: Output-table 'Patient Flows and Resources' model.

number of patients on the waiting list. This makes it possible to show an increase in the waiting lists.

- population

This option visualises the population data used per community or zone.

All data are given per specialty. There is, however, also an overview option to see the output for all specialties taken together.

Documentation

The documentation that is available relating to the 'Patient Flows and Resources' model is listed below:

- leaflet 'Patient Flows and Resources' model⁴;
- manual 'Patient Flows and Resources' model⁵;
- MSc thesis⁶.

The model and its use is also extensively illustrated in case three describe in the main text.

INPATIENT CAPACITY MANAGEMENT

The 'INPATIENT CAPACITY MANAGEMENT' model is a PC-program to support issues of structural balancing between admission planning and operating theatre and nursing capacity. The model is not for day-to-day planning purposes but for medium term decisions regarding changes in planning policy or changes in the configuration of inpatient resources such as operating theatres, operating theatre staff, beds and nursing staff.

Planning problem

Inpatient capacity management concentrates on the relationship between admission planning (the inflow of inpatients) and the use of inpatient resources such as beds, operating theatres and nursing staff.

Admission planning regulates the demand for inpatient care in a hospital. A patient once admitted will need resources; in case of a surgical patient this will require operating theatres resources on the day of operation, a bed during his or hers stay in the hospital and nursing care.

The supply of inpatient services is, to a large extent, determined by the amount of capacity available in the operating theatre department (operating theatre personnel, operating theatres) and the nursing wards (beds, nurses). It is important to reach a balance at the medium term level of planning between admission planning and these resources. Imbalance will lead to a systematic over-use or under-use of one of these resources (see Figure 3).

Figure 3: Imbalance inpatient resource use.

The figure illustrates two ways to reach such a balance: by improving admission planning taking into account resource impacts when admitting patients, or by improving the allocation of resources. This model concentrates on the second way and supports two types of managerial questions:

- What is the medium term impact of the present organisation of admissions on operating theatre use, bed occupancy and nursing workload?
- What changes in the organisation of admissions are necessary to reach a target utilization of operating theatres and nursing wards?

To improve the use of inpatient resources by better allocation procedures requires involvement of department managers (admissions planning, operating theatre department, nursing ward) and specialists.

Development of the model

The first outline of the model was based on a study into the relationship between admissions planning, operating theatre management and ward management⁷. This led to a first prototype model in 1988⁸. During 1988 and 1989 the model was used by a hospital, that was interested to improve the structural balancing of inpatient resources. Based on these experiences the model was rebuilt during 1990 and 1991, while keeping contact with the pilot hospital⁹. Further adaptations were made to make the model suitable for other hospitals.

Outline model

The outline of the model is shown in Figures 4 and 5. Figure 4 shows that the model differentiates between surgical patients and non-surgical patients.

Figure 4: Outline 'Inpatient Capacity Management' model.

Admission planning in the model has been operationalized by an admission pattern. This pattern describes the number of admission per specialty and per day of the week. A period of four weeks is taken as a representative sample of the inflow of patients into the hospital. To be able to link admissions with resource use admissions need to be categorized according to length of stay and operation duration.

Operating theatre planning in the model has been defined by the number of hours per specialty the operating theatres are available.

Ward planning in the model is defined by the number of beds available per specialty and the number of nurses available per ward.

Figure 5 shows how occupancies of inpatient resources are calculated.

Figure 5: Outline 'Inpatient Capacity Management' model (continued).

The need for operating theatre resources can be calculated from the admission pattern by calculating the number of patients that need to be operated per day, multiplied by their expected operation duration time.

The need for beds can be calculated from the admission pattern by calculating the number of patients in the wards per day, multiplied by their expected length of stay. The need for nursing staff can be calculated from the admission pattern by multiplying the number of patients in the wards with their need for nursing care. This information can be extracted

from 'care profiles' per specialty, based on nursing workload studies. The care profile defines the amount of care needed by patients during their length of stay.

Output model

Output is available on a more detailed level or on an aggregate level. We will show example outputs from each of these levels.

At the detailed level one can look at occupancies per day of the 4-week period of admissions or averaged per week in the 4-week period. Calculations can be made per ward or per specialty or for the hospital as a whole. One can, furthermore, select to look at operating theatre resources or at ward resources. Figure 6 shows average occupancies per week of the 4-week period for Gynaecology.

Figure 6: Average occupancies inpatient resources per week.

The upper part of the figure shows the average occupancies per week of the nursing staff and the operating theatre capacity (hours, anaesthetic assistants, surgical assistants). The lower part shows average occupancies per week for the bed capacity, broken down to the categories of beds used. It is also possible to show the standard deviation of the occupancies over the days of the week in a similar graph.

An example of aggregate level output is the overview with average results per specialty over the whole period shown in figure 7.

This overview contains average admissions per week and average occupancies, based on the results of the 4-week period. Admissions are broken down in day care patients, short stay patients (with a length of stay of 2-5 days) and regular patients (with a length of stay of more than 5 days). This is calculated independent of the way day care and short stay is organised, whether centralised or decentralised. The occupancies of beds and nursing staff do not take into account day care and short stay if these are organised in central facilities, because these facilities are not broken down per specialty. This overview can be used to check whether the

Specialty :	Admissions per specialty:				Occupancies (%) :		
	day-c.	sh.stay	reg.	tot.	beds:	nurses:	op.hours:
Gynaecology	8	2	6	15	65	54	62
Gen. Surgery	8	7	16	32	68	77	58
Orthopaedics	13	4	6	23	66	102	61
Paediatrics	0	0	0	0	0	0	0
Neurology	0	0	0	0	0	0	0
Gen. Medicine	0	0	0	0	0	0	0
Pulmonology	0	0	0	0	0	0	0
Rheumatology	0	0	0	0	0	0	0
Hospital	29	13	28	69	50	55	40

Figure 8: Final results on inpatient resource utilization by specialty.

inflow per specialty balances the workload of the different resources involved. A similar output can also be produced with average results per ward.

Documentation

The documentation that is available concerning the model 'Inpatient Capacity Management' is listed below:

- leaflet 'Inpatient Capacity Management' model¹⁰;
- manual 'Inpatient Capacity Management' model¹¹;
- MSc thesis D.H.A. Hubers⁷;
- MSc thesis R.J. Baldwin⁸;
- Documentation computer program P. Schepers⁹;
- article in a hospital management journal¹².

The model and its use is also extensively illustrated in case three described in the main text.

OUTPATIENT CAPACITY MANAGEMENT

The 'OUTPATIENT CAPACITY MANAGEMENT' model is a PC-based program to support issues of structural balancing between clinic organization and outpatient departments and medical service departments resources. The model is not for day-to-day planning purposes but for decisions regarding longer term changes in planning policy or changes in the configuration of resources. The model provides information to the management of the outpatient department and to specialists on the impact of these changes on the use of resources and the service-quality for patients. With this information at hand they are able to make better decisions regarding proposals for change.

Planning problem

Clinic organisation regulates the demand for outpatient care in a hospital. The amount of time available in a clinic session for new patients determines the waiting time for a new outpatient to enter the system (access time). The distance in time between the first visit and the follow-up visit (i.e re-appointment interval) depends on the time it takes to perform the examinations needed by a specialist to diagnose the patient. The organisation of visits for a patient will therefore also result in a demand for medical service departments.

The supply of outpatient services depends on the available resources in the outpatient department (clinic hours, clinic personnel, clinic units) and the available diagnostic resources for outpatients at medical service departments such as x-ray and lab.

It is important to reach a balance at the medium term level of planning between clinic organisation and these resources. Imbalance will lead to a systematic over-use or under-use of one of these resources (see Figure 9).

Figure 9: Planning problem outpatient capacity management.

Imbalance in the use of resources results also in a lower throughput of outpatients.

There are different options for the management of the outpatient department and the specialists to consider in case of imbalances:

- Is the ratio between appointment slots for new patients and appointment slots for return patients within a clinic session appropriate?
- Is there a need for an extra clinic session of the specialist and do the available resources allow for this?
- What are the impacts for medical service departments if one considers to organize different types of clinics for different categories of patients within a specialty?
- Is it possible to shorten the throughput time for a diagnostic and treatment programme of outpatients, taken into account requests for examinations arising from visits?

Development of the model

The model was developed to complete the set of decision support computer models on 'Hospital Capacity Management' developed by the Dutch Hospital Institute. There was no direct request from hospitals to develop this model, as was the case with the other models developed. This is partly due to the lack of information on outpatient services in hospitals, and to the lack of management development in this part of the hospital. Because of the growth in outpatient services, we expect however that it will be necessary to have model support for resource management issues available in the near future. First a feasibility-study was performed to look at the planning problem and the possibilities for support by information. In this stage of the project the Canisius Wilhelmina Hospital at Nijmegen acted as pilot location. From this study it became clear that the target for the project could only be a first prototype version that accords with the present insights into the management of outpatient services, based on interviews with managers of outpatient departments and medical service departments. Further experience with the model, involvement of specialists and application in concrete settings, is necessary to enhance the further development of the model. The present version of the model has not been used yet in a project setting, but has been demonstrated to outpatient department managers from several hospitals, which are considering to use the model.

The model was developed to allow a flexible use of the model, depending on the amount of information available. This means that in case of only limited availability of data the model can still be used to get insight into the use of outpatient resources, however in a more limited way. Moreover, the model's application may perhaps stimulate a better collection of data. In case of a wider availability of data more extensive use can be made of the different features of the model, based on a more detailed description of outpatient flows in the model. The model was built in 1990/1991 and finished in 1992/1993¹³.

Outline model

Figure 10 contains a global outline of the model.

The demand for outpatient services is modelled by:

- defining the inflow of outpatients per specialty, broken down by
- categories of patients that are distinguished within the specialty's clinic organization because of a similar way of treatment (e.g. diabetics, oncology patients and general cases within General Medicine), and further broken down by

Figure 10: Global outline
'Outpatient Capacity Management' model.

- treatment profiles per category of patients (e.g. consultation, short treatment, long treatment as profiles for diabetic patients);
- defining the outpatient process for each of these combinations of patient categories and treatment profiles.

This results in a demand for outpatient resources like units/rooms and personnel and for medical services such as x-ray, lab and other diagnostic services.

The supply of outpatient services is modelled by defining the amount of resources available:

- by specialty (units/rooms and personnel), broken down by the different clinics distinguished within the specialty's clinic organisation (like a diabetics clinic, an oncology clinic and general type of clinics for General Medicine)
- by medical service department (units/rooms, personnel and equipment).

Output model

The output of the model shows in what way the present provision of outpatient services (supply) meets the demand for services. Output can be provided on:

- patient throughput,
- physician workload,
- resources occupancy,
- medical department occupancy,
- minimum treatment time.

We will show examples on patient throughput and minimum treatment time for outpatient programmes. Figure 11 shows an overview of patient numbers processed per week.

	Demand	Supply	Occupancy
First Visits	200	200	100
Control Visits	293	301	97
Secondary Visits (hrs)	20.2	21.9	92
Admissions			
Relative First Visits	200	200	100
Relative Control Visits	293	301	97
Relative Sec Visits (hrs)	20.2	21.9	92.4
Relative Admissions	30		

Figure 11: Throughput of patients.

This overview compares the demand for visits (based on inflow numbers and the treatment profiles) with the supply of visits (based on clinics hold per week and the available resources).

In the lower part of the table relative numbers are indicated, taking the supply of first visits as a point of reference. When the demand for first visits is more than the supply of first visits, the numbers of the demand for control visits, etc. will be decreased because the demand for first visits is only partially met.

For each category of visits the numbers can be broken down to match demand for categories of patients with supply of appointment slots for visits by the different types of clinics.

The second example shows the Minimal Treatment Times for Profiles regarding the various categories of patients considered (Figure 12).

For each profile the actual treatment time is compared with the minimum treatment time, based on completion times necessary because of procedures in medical service departments. The difference is the slack-time from the point of view of procedures in medical service departments.

PROFILES	----- Time between Visits (days) -----					TOTAL	+GLOBAL (wks)
	1-2	2-3	3-4	4-5	5-Glb		
consultation							
Actual	15	0	0	0	0	15	15
Minimum	5	0	0	0	0	5	
short treatment							
Actual	10	15	0	0	0	25	15
Minimum	5	5	0	0	0	10	
long treatment							
Actual	5	15	15	0	0	35	15
Minimum	5	0	0	0	0	5	

Figure 12: Profile Treatment Times.

Documentation

The documentation that is available concerning the 'Outpatient Capacity Management' model is listed below:

- leaflet 'Outpatient Capacity Management' model¹⁴;
- manual 'Outpatient Capacity Management' model¹⁵ ;
- MSc thesis¹³.

X-RAY CAPACITY MANAGEMENT

The 'X-RAY CAPACITY MANAGEMENT' model is a PC-based computer-model that supports x-ray departments in their medium-term planning objective to find a balance between the demand for services and the use of available resources. The model is not for day-to-day planning purposes but for decisions regarding longer term changes in planning policy or changes in the configuration of resources. The model provides information to the management of the x-ray department on the impacts of these changes on the use of resources and the service-quality for patients. With this information at hand they are able to make better decisions regarding proposals for change.

Planning problem

The x-ray department is faced by a demand for services from different sources, i.e.: inpatient wards, outpatient clinics, emergency department and general practitioners. The inpatient flow concerns patients admitted to the hospital who need an x-ray examination. Most inpatients need an extensive examination that requires preparation; in case of less-intensive examinations inpatients are often called for by the x-ray department at slack-times. The outpatient flow concerns patients referred by specialists at the outpatient department. Part of this flow is directly related to clinic hours, i.e. the patients who can be examined at the x-ray department without having made an appointment. The emergency patients flow concerns patients who are referred to the x-ray department during a visit to the emergency department. This flow is by its nature a direct flow (without appointment). The GP-flow are patients who are sent to the x-ray department by the general practitioner. Most of the time these are minor examinations, that can be dealt with directly. Part of the GP-flow, however, is examined on appointment.

The resources of the x-ray department to deal with the demand for services consist of x-ray rooms and x-ray equipment, x-ray personnel and radiologists. Every x-ray room has one or two x-ray apparatus and is by this equipment suitable for a number of examinations. The x-ray personnel is most of the time the bottleneck, because there is a general shortage of x-ray technicians. More complicated examinations are performed by the radiologists, but most radiologist's time is needed for decisions about the success or failure of a picture taken and for interpreting pictures.

Below is illustrated the different flows faced by the x-ray department and the configuration of resources (Figure 13).

In case of a multi-location hospital, the picture becomes more complicated because there are often more x-ray departments involved.

There are different options for the management of the x-ray department to deal with the planning problem described before:

1. To change an x-ray room programme.

These changes concern particularly the large x-ray examinations. By moving these sessions with large examinations to less busy periods more personnel is available for doing the small examinations.

Figure 13: Patient flows and resources x-ray department.

2. Looking at clinic times of specialists.
Some clinics refer many patients to the x-ray department for direct examinations. It is important that when the start/end times of these clinics are fixed, the x-ray department is consulted about impacts for the x-ray department.
3. Determining special hours for GP-patients.
This can help to direct the flow of GP-patients to less busy periods.
4. Serving more patients on appointment.
This makes it easier to handle the workload for the x-ray department. However, less direct-service facilities is generally regarded as a loss of service for patients and specialists.
5. Distributing the patient flow over locations.
In case of a multi-location hospital a decision has to be made what flows are served on each location and what resources are needed per location.

Development of the model

The Reinier de Graaf hospital in Delft was faced by a number of problems regarding the management of the x-ray department. Frequently long waiting times occurred and there was a general feeling that improvement in services and in use of resources was possible. As the hospital expected also a future need to improve the planning of the x-ray department it did not look for a one-time solution but for a tool that could help finding an improvement now and in the future.

A feasibility-study was performed during 1989/1990¹⁶. This involved an analysis of the different patient flows and of the planning of the x-ray departments at both locations of the

hospital. Based on this analysis and on notions about how x-ray planning should be performed according to the present state of planning-theory for x-ray departments, the specifications for a decision support model were described that can support the management of the x-ray department.

As a next step, the model was built in 1990/1991 and was finished in 1991/1992¹⁷.

Outline model

A representation of the outline of the model is shown below in the format of an input-output structure (see Figure 14).

Figure 14: Outline 'X-ray Capacity Management' model.

On the input-side it is possible to define the demand for x-ray examinations from different groups of patients:

- inpatients coming from wards
- outpatients referred from specialist's clinics in the outpatient department
- patients referred by general practitioners.

This demand is further broken down into different categories of examinations.

- large examinations, with compulsory appointment
- small examinations, with appointment
- small examinations, without appointment

The resource-configuration can be described by defining the amount of resources available (technicians, rooms, radiologists) and by the way these resources are used for planning x-ray examinations. It is possible to define for each of the rooms to what extent it is reserved for fixed programs of large examinations and to what extent it is free for small examinations. It is also possible to restrict the use of resources to specific periods.

On the output-side it is possible to look at the occupancies of resources (technicians, rooms, radiologists), with a distinction between large examinations, small examinations on appointment and small examinations without appointment. For examinations on appointment projections of the access-times are given. For examinations without appointment projections of waiting-times are given.

Output model

In addition to the list of output options described above, we will illustrate the type of output from the model by an example output on occupancy of x-ray technicians for x-ray examinations without appointment (Figure 15).

Figure 15: Total supply and break down of demand (Technicians, Monday, week1).

The graph in Figure 15 presents the total supply on one day of the week for small examinations without appointment, and the demand by inpatients, outpatients, GP-patients and emergency patients. The difference between the above supply-line and the accumulated demand shows if there is left-over capacity. These figures show under-use in the afternoon and over-use in the morning. At time when the occupancy rate is above 90% (indicated per hour) long waiting times for patients can be expected. This can also be shown for other days of the week and for other resource types.

The supply-line shown represents the supply left after deducting the supply for all examinations with appointment. Another output of the model shows how the total supply of resources for the x-ray department is broken down for large examinations, small

examinations on appointment and examinations outside the x-ray department, resulting in the left-over supply of resources to serve the direct flow of patients without appointment.

Documentation

The documentation that is available concerning the 'X-Ray Capacity Management' model is listed below:

- leaflet 'X-Ray Capacity Management'¹⁸;
- manual 'X-Ray Capacity Management'¹⁹;
- MSc thesis¹⁶;
- Documentation computer programme¹⁷.

The model and its use is also extensively illustrated in case two described in the main text.

SPECIALIST CAPACITY MANAGEMENT

The 'SPECIALIST CAPACITY MANAGEMENT' model is a PC-based computer-model that supports hospitals in finding a balance between specialist activities and hospital resources. The model visualizes the way specialist activities in hospitals are organised, and the relationship between these activities and the resources needed like space, personnel, supporting services, etc. The model is not for day-to-day planning purposes but for decisions about major shifts in activities and/or resources.

Planning problem

The resources (space, personnel, etc.) that are needed by activities of specialists in the different departments of the hospital (operating theatres, outpatient department, etc.) are closely related to the master schedules of these departments. For example: the outpatient department uses a clinic time-table and the operating theatres use a operating theatres time-table. Each department has its own master schedule. These schedules may vary a bit from week to week, due to absence of specialists, etc., but in principle each week-schedule is derived from a master schedule.

The best way to illustrate the problem of master schedule-coordination in hospitals is to look at an example of a working-day of a general surgeon, as shown in Figure 16, and the relationship with the schedules of the departments involved.

Figure 16: An example working-day of a general surgeon and the relation with and between schedules.

It can be seen that most of the work of the specialist is regulated by department schedules, which are interdependent; a delay in one department causes delays in successive departments. For example: if an operating session takes more time than scheduled, perhaps

the specialist will not be able to start in time with a clinic session in the outpatient department. This dependence is often a bottleneck when one wants to redesign a schedule for a specific department. If, for example, some shifts are to be made in the clinic schedule, what will be the consequences for the other activities of the specialist? A further complication is that the workload of the medical service departments is, to a large extent, dependent on the outpatient clinic time-table. At times of a fracture clinic, for example, many patients will visit the x-ray department. Therefore, a direct relationship exists between the clinic schedule of the outpatient department and the workload of some medical service departments. When looking at changes in the working-day of a specialist also these "second-order effects" have to be taken into account.

Development of the model

Two hospitals, different in scale and organization, were selected for a pilot-study. This pilot-study was suggested by a working committee that had investigated this problem and reported on it earlier. This working committee consisted of hospital managers with responsibility for this co-ordination and management consultants with experience in dealing with this type of problem. The committee described the structure of a model to support the problem of schedule co-ordination. The working committee suggested setting up a study in one or two hospitals and to involve the department-managers within the hospital and a few specialists in the pilot. In this way the model could be tailored to the specific situation of the hospital, starting from the description of the model by the working committee.

The first step in the study was to set some boundaries to the problem investigated. The departments involved were interviewed as to their schedule and wishes with respect to schedule co-ordination. Also some specialists were interviewed. As a result the problem could be limited in the following way:

- departments
The most important departments for schedule co-ordination are: the outpatient department, the operating theatres, some diagnostic departments that require specialist availability, the wards.
- relationships
The capacity-restrictions taken into account are: specialist availability, units, personnel. With respect to the relationship between the clinic schedule of the outpatient department and the workload of the medical service departments, only the direct flow of patients between outpatient department and the x-ray department or the lab are looked at.
- schedules
Schedule co-ordination deals with the basic schedules which are more or less fixed for a longer period (master-schedules). The model will not be used for day-to-day or week-to-week changes in schedules. Only those changes are taken into account which are permanent or valid for a longer period.

The second step in the pilot-study involved the specification of the model in terms of output, functions and data-structure. The interviews with department managers and specialists provided the necessary information. The specifications were checked. In this way the outline of the end-system was defined.

After having used the model on these two pilot-sites, the model was rebuilt based on the

experiences with the first prototype. The second version of the model was then used in about 5 hospitals to gain more insight into the impacts of the model. The experiences of these hospitals were again used to make this final version.

Outline model

Figure 17 gives the outline of the model for schedule co-ordination. The core of the model comprises of a number of department schedules, that are related to one-another via specialty schedule.

There are two main approaches to the model: defining data and proposing changes. The output of the model makes visible the impacts of the schedules on the use of resources.

Figure 17: Outline model for schedule co-ordination.

The different parts of the model will be explained below:

- defining data

A number of data for the model are defined such as schedule-data, resources, criteria and restrictions imposed on schedules.

A few examples of restrictions, included in the model, are:

- * the preference of a specialist to operate in the morning
- * the slack between two activities of a specialist
- * the task-structure of a specialty: e.g. not more than one specialist at a time

- involved in operating theatre sessions
- * blocking a department or a ward (e.g. no ward-round during the period of visits by relatives) or blocking a unit (e.g. maintenance of an operating theatre).
- schedules
 - The core of the model exists out of four department schedules and a specialty schedule. The department schedules are: the operating theatre (OT) schedule, the outpatient department (OPD) schedule, the diagnostic departments (DIAGS) schedule and the ward (WARD) schedule.
 - The OT-schedule contains the operating theatre sessions of the specialists, the OPD-schedule contains the clinic sessions of the specialists, the DIAGS schedule contains the sessions at diagnostic departments that require specialist attendance (endoscopies, etc.), and the ward schedule the planned ward rounds of specialists. The department schedules are related to one-another by the specialty schedule. This contains the activities of specialists during the week.
- impacts
 - The schedules can be translated to impacts on units, personnel and diagnostic services.
- proposals for change
 - Different types of proposals can be supported by the model: to add or change an activity, to redesign a schedule, etc.

Output

The output of the model can be used either to visualize the use of resources based on master schedules or to support making changes in master schedules. When data has been entered for the different master schedules and the relationships have been defined between activities and resources, it is possible to visualize the use of resources. Figure 18 contains an example output of the model showing the impact of the OPD time-table on the use of one of the service departments, i.e. the x-ray department.

Figure 18: Impact OPD time-table on x-ray department.

The second type of output focuses on support in making schedule changes by checking them

on conflicts with commitments of specialists elsewhere or on conflicts due to restrictions imposed on schedule co-ordination mentioned before.

The model checks on overlap and on other restrictions on schedules, and reports a list of conflicts (view conflict-log, see Figure 19).

Figure 19: List of conflicts because of an OT-schedule change.

The list reports one conflict (caused by the change) and some violations of restrictions (mainly because of the other activities). This list may help to find a solution for the problem(s) caused by the change. If necessary other changes can be made and checked on their contribution to the problem.

Documentation

The documentation that is available for the 'Specialist Capacity Management' model is listed below:

- leaflet 'Specialist Capacity Management' model²⁰;
- manual 'Specialist Capacity Management' model²¹;
- report committee²²;
- MsC theses^{23,24};
- documentation computer program²⁵.

The model and its use is also extensively illustrated in case one described in the main text.

Notes:

1. Leaflet on 'Hospital Capacity Management', Dutch Hospital Institute, Utrecht, January 1992.
2. Phase: A Resource Allocation Model in Health Care. D. Clayden, Leeds University 1983-1986.
3. Rebuild by D.A. Cromwell, Dutch Hospital Institute, 1991.
4. Leaflet 'Patient Flows and Resources'. Dutch Hospital Institute, Utrecht, January 1992.
5. Manual 'Patient Flows and Resources'. Dutch Hospital Institute, Utrecht, May 1992.
6. Neil Ashton, project Dutch Hospital Institute as part of MSc-course in Operational Research at Lancaster University, 1989.
7. D.H.A. Hubers (1988), Capaciteitsafstemming in 'het klinische zorgproces. MSc-thesis Eindhoven University of Technology, Faculty of Industrial Engineering and Management Science.
8. R.J. Baldwin (1988), A decision support model for balancing hospital's inpatient planning systems. MSc-thesis University of Lancaster.
9. P. Schepers (1991), The inpatient capacity management model. Eindhoven University of Technology, Faculty of Industrial Engineering and Management Science.
10. Leaflet 'Inpatient Capacity Management'. Dutch Hospital Institute, Utrecht, January 1992.
11. Manual 'Inpatient Capacity Management'. Dutch Hospital Institute, Utrecht, January 1992.
12. Eydem-Janssen M.B.M. and Vissers J.M.H. (1992), Capaciteitsmanagement in de klinische zorg. Ziekenhuis Management Magazine, no 11, pp 342-345.
13. Build by D. Cromwell, as part of the MSc project of the OR course at Lancaster University.
14. Leaflet 'Outpatient Capacity Management' model, Dutch Hospital Institute, Utrecht, January 1992.
15. Manual 'Outpatient Capacity Management' model. Dutch Hospital Institute, Utrecht, September 1993.
16. F. Derks (1990), Een capaciteitsmodel voor de röntgenafdeling. MSc-thesis Eindhoven University of Technology, Faculty of Industrial Engineering and Management Science.
17. Build by D.A. Cromwell (1992), Dutch Hospital Institute, Utrecht.
18. Leaflet 'X-ray Capacity Management' model, Dutch hospital Institute, Utrecht, January 1992.
19. Manual 'X-ray Capacity Management' model, Dutch Hospital Institute, Utrecht, January 1992.
20. Leaflet 'Specialist Capacity Management' model. Dutch Hospital Institute, Utrecht, January 1992.
21. Manual 'Specialist Capacity Management' model. Dutch Hospital Institute, Utrecht, January 1992.
22. Werkgroep Coördinatie Capaciteitsinzet (1985), Roosterafstemming in ziekenhuizen. Een aanzet voor een decision support systeem voor management en specialist. Dutch Hospital Institute, Utrecht.
23. N. Janssen (1986), Roosterafstemming in ziekenhuizen. De ontwikkeling van een decision support systeem. MSc-thesis Eindhoven University of Technology, Faculty of Industrial Engineering and Management Science.
24. A. Voets (1988), Het roosterafstemmingsmodel. Een onderzoek naar randvoorwaarden van toepassing van een decision support model voor roosterafstemming tussen specialisten en ziekenhuisorganisatie. MSc-thesis University of Maastricht.
25. The prototype versions (1987) were build by P. van Putten, J. Sim and D. Sonnenberg as part of a project at Delft University, Faculty of Informatics; the final version (1990/1991) was build by M. Croft from Leeds University/Leeds General Infirmary.

SUMMARY

This thesis discusses a method for hospital resource allocation that tries to prevent the occurrence of capacity losses in hospitals. These losses can arise in case of resource allocation changes which do not take into account the requirements of capacity co-ordination of the hospital as a production system. We have especially focused on 'leading' resources such as operating theatres, outpatient clinics and specialists as resource, which act as triggers for hospital production, and investigated how their allocations introduce peaks and troughs in the workload of 'following' resources, such as beds, nursing staff and service departments.

The research questions which were reasons to start this study on hospital resource allocation can be summarized as follows:

- What are the dependencies between resources in the hospital's production system?
- What are the variations in the use of resources within the week?
- To what extent are these variations caused by the way resources are allocated?
- What are the requirements for co-ordination of capacity allocations of resources?
- What would a method for resource allocation look like that would fulfil these requirements?
- What approach for implementation of this method can be suggested?
- What are results of applying this method to real-life resource management problems in hospitals?
- What are the conditions for other hospitals to achieve similar results using this method?

We will turn to each of these questions, and summarize our answers under headings that refer to the threefold in our research activities: an analysis of the hospital capacity structure, the development of a method for resource allocation, and the case-studies performed to illustrate the method.

Analysis of the hospital capacity structure

Using the concept of '**leading**' and '**following**' resources and capacity performance concepts, we described the different scarce shared resources that play a central role in this thesis: operating theatres, nursing wards, outpatient departments, diagnostic departments and specialists as resource type. These resources are shared by different specialties, apart from specialist-time as a resource; this resource acts as a 'leading' resource for the workstations in the hospital and is shared between the fore-mentioned departments.

To handle this complex supply structure, hospitals use for some of the most important 'leading' resources **sessions as a batch processing mechanism**. A session is a period of time allotted to a specialist in a workstation to treat a number of patients that require the same type of resources. Sessions are usually organized for a fixed period in the week. Sessions provide for the short term match between demand for resources and supply of resources.

Time-tables regulate the allotment of sessions in a workstation to specialists. The most important time-tables are the operating theatre time-table for allocating operating theatre sessions, and the outpatient department time-table for allocating clinic sessions. These time-tables perform a similar function to Master Production Schedules in an industrial setting, in that they define a production schedule per period (which in this case is a fixed schedule per week). Investigation of these time-tables, and the linking time-table of specialties, on resource impacts for other departments can identify areas for resource use improvement.

The use of the session mechanism and time-tables for scarce shared hospital resources led to the following **requirements for co-ordination of capacity allocations**:

- co-ordination of the allocations of 'leading' resources to specialties sharing the same resource (capacity load levelling per 'leading' resource department);
- co-ordination of the allocations of different resources to one specialty (capacity load levelling per specialty);
- co-ordination of the resource impacts for 'following' resource departments that are shared by specialties but often not allocated to specialties (e.g. x-ray);
- co-ordination of specialist capacity within a specialty (specialty planning restrictions).

Ignoring these co-ordination requirements may result in avoidable capacity loss or violations of the policy for planning specialty practice.

The resource consequences of not taking account of these capacity co-ordination requirements were illustrated by a statistical analysis of the relationship between the time-table in the outpatient department and the workload of the diagnostic departments, and by a case-study demonstrating the knock-on effects of a reorganization of an operating theatre time-table on 'following' inpatient and outpatient resources.

Model and implementation strategy development

The modelling part of the study involved the development of a production control framework for our research, the building of a set of computer models to support hospital managerial decision making on resource allocation, and the development of an implementation strategy for our approach to hospital resource allocation.

The **production control framework** developed distinguishes five levels of planning, according to the type of decisions to be made. Decisions with impacts at a further horizon are placed at a higher level in the framework and set boundaries for lower level decision making. Strategic Planning is concerned with the future hospital profile. Main Patient Flow Planning looks at the development of hospital activities in the next year. Resource Allocation concerns the allocation of resources to specialties or departments. Capacity Scheduling considers the scheduling of allocated capacities in time-tables. Operational Planning looks at the planning of day-to-day activities. This systematic description of decisions to be made and controls to be performed, is a framework for production control decision making and allows a precision of planning contributions.

It was necessary to develop a **set of dedicated decision support computer models** to provide for the information needed for the co-ordination requirements of capacity allocations, as the current hospital information systems do not produce this information. It concerns relatively simple 'what-if' models which visualize patient flows and resource requirements in different

areas of hospital resource management decision making. The model 'Patient Flows and Resources' supports the long term decisions on resources required to match future demand. The models 'Inpatient Capacity Management', 'Outpatient Capacity Management' and 'X-ray Capacity Management' each support decision making at medium term level for balancing of resource requirements of services performed in the corresponding parts of the hospital. The model 'Specialist Capacity Management' supports decision making in matching the organization of specialty activities and the time-tables of resource departments such as operating theatres and outpatient clinics. Depending on the resource management problem looked at, single models or combinations of models need to be used. The wide range of the models allows following through consequences of changes throughout the hospital.

The **implementation strategy** for using the method in a hospital setting is characterized by the following elements:

- problem orientation: the existence of a formal and concrete problem that legitimizes reallocation of resources is considered as a condition for a project (cf. 'critical resource incidents');
- model support: one or more of the models is used to provide the information for capacity co-ordination requirements, and to offer the parties involved in the resource management problem a global hospital perspective;
- participation: the different steps in the project are taken with maximum involvement of departments or groups in the decision making process.

According to the change model used, improved understanding of the system coherence in the hospital production system (subsystems, linkages between subsystems, knock-on effects, etc.) is an important intermediate variable to explain the relationship between strategy variables and output variables (improved decisions and improved quality of the decision making process).

Case-studies

The third part of the study involved a number of case-studies to illustrate the use of this approach in concrete hospital settings and to answer in an explorative way research questions concerning the impact of the use of our approach. Three case-studies were performed, involving different resource management issues:

- reorganizing a specialty time-table for a group of eight general surgeons as part of a concentration of the specialty on one location of a multi-location hospital;
- improving the interface between the x-ray department and the outpatient department in a hospital that had problems with fluctuations in x-ray workload and waiting times for walk-in patients from outpatient clinics;
- development of a method for a more flexible and coherent allocation of inpatient resources in a hospital that had structural shortages of beds resulting in many 'admission stops'.

The main conclusions of this third part of our study are listed below. As the case-studies have a primarily illustrative and exploratory function, the conclusions have a rather tentative character.

Each of the elements of the implementation strategy (problem oriented, model use, participation) seems to have contributed to a successful project.

- The more accepted or formal the **problem** is, the more support it can give to act as

stepping-stone for our project and to achieve improvements in resource use. Improving the use of hospital resources alone without an underlying problem having already been recognized does not create enough support for a project.

The contribution of the **decision support models** was most important for a good start to the project. The models created support for the project because of their good 'organizational fit' to the problem experienced. The models also gave good support for data collection, data analysis and resource impact evaluation. Halfway through the project, however, the role of the model was more or less taken over by participants who had internalized the planning philosophy underlying the models and performed better in the stage of developing solutions. Nevertheless, the models played an important role as catalysts to discuss problem perception and alternative solutions. The standardized method and terminology used furthermore allows for comparison of project results in different hospitals and of repeated applications.

- The **participative mode** of executing the project was considered as necessary to create commitment in the multi-actor hospital setting and inherent to the type of problem investigated that makes it important to use all local expertise available. However, the hospital characteristics do not leave much room for alternative approaches. The difference with our approach is that we tried to stimulate participation in different ways.

The **resource impacts for the three case-studies** can be summarized as follows:

- The reorganization of the specialty time-table of the group of general surgeons (case one) led to a 33% reduction of the variation in operating theatre staff requirements, a 12% increase of the variation in outpatient staff requirements, and a 12% increase of variation in the workload of the x-ray department; using a weighing function for the reduction of variation of use of different resources with a higher weighing factor for reduction of the expensive operating theatre resources, the overall result can be qualified as positive.
- The rearrangement of x-ray room programmes and reservations for direct referrals expected from specialty clinics (case two) resulted in a better balance between the requirements and availability of capacity for direct examinations; this directly affects the waiting times for walk-in patients from outpatient clinics, whose projected average waiting time during peak hours showed a reduction from more than 100 minutes to 25-30 minutes.
- The method for a more flexible and coherent allocation of inpatient resources (case three) can result in a more balanced use of resources and a managerial decision space of nine beds that could be allocated to specialties that need to be stimulated because of the strategic hospital profile.

The **conditions for achieving these results** with our implementation approach in other hospital settings are support from the board of directors (because of the consequences of resource allocations for hospital production and the potential conflicts between specialties), service department managers (as they are responsible for the efficient use of scarce shared resources and are required to adopt an overall hospital perspective on their department's contribution) and specialties involved (as all resource allocations affect the organization of specialty practice), and availability of data. The logistic analyses performed with support of the models require much data that with some effort can be collected or extracted from routine hospital information systems.

SAMENVATTING: Summary in Dutch

Dit proefschrift behandelt een methode voor toewijzing van capaciteiten in ziekenhuizen met als doel het voorkomen van capaciteitsverliezen. Deze verliezen kunnen ontstaan door veranderingen in toegewezen capaciteiten waarbij niet rekening is gehouden met de behoeften aan capaciteitscoördinatie die inherent zijn aan de produktiestructuur van het ziekenhuis. Met name is gekeken naar 'initiërende' capaciteitssoorten zoals operatiekamers, poliklinieken, en specialist-capaciteit, die fungeren als generator van ziekenhuisproductie. Onderzocht is hoe de toewijzing van deze capaciteitssoorten pieken en dalen introduceert in de capaciteitsbehoefte van 'volgende' capaciteitssoorten zoals bedden, verpleegkundig personeel en diagnostische afdelingen.

De onderzoeksvragen, die de reden voor dit onderzoek naar toewijzing van ziekenhuiscapaciteiten vormden, kunnen als volgt worden samengevat:

- Wat zijn de afhankelijkheden tussen capaciteitssoorten in de produktiestructuur van het ziekenhuis?
- Wat zijn de variaties in het gebruik van capaciteiten binnen de week en kunnen hierin patronen onderkend worden?
- In welke mate worden deze variaties veroorzaakt door de wijze waarop de capaciteiten zijn toegewezen?
- Wat zijn de voorwaarden voor capaciteitscoördinatie bij capaciteitstoewijzing?
- Hoe ziet een methode voor capaciteitstoewijzing eruit die aan deze voorwaarden voldoet?
- Welke aanpak voor implementatie van deze methode wordt voorgesteld?
- Wat zijn resultaten van de toepassing van deze methode voor concrete vraagstukken van capaciteitstoewijzing in ziekenhuizen?
- Aan welke condities moet worden voldaan om deze resultaten ook elders te kunnen behalen?

Op elk van deze vragen zal onderstaand worden ingegaan, waarbij de antwoorden worden samengevat onder het drieluik dat in het uitgevoerde onderzoek kan worden onderkend: een analyse van de capaciteitsstructuur van het ziekenhuis, de ontwikkeling van een methode voor capaciteitstoewijzing, en de case-studies die zijn uitgevoerd om de methode te illustreren.

Analyse van de capaciteitsstructuur van het ziekenhuis

Met behulp van concepten zoals 'initiërende' en 'volgende' capaciteitssoorten, en prestatie-maatstaven voor capaciteitsgebruik, zijn de verschillende gedeelde, schaarse, capaciteitssoorten beschreven die een centrale rol spelen in dit proefschrift: operatiekamers, verpleegafdelingen, poliklinieken, diagnostische afdelingen en specialisten als capaciteitssoort. De eerstgenoemde soorten worden gedeeld door verschillende specialismen; de specialist vormt een

'initiërende' capaciteitssoort voor de werkplekken binnen het ziekenhuis waarop hij of zij activiteiten verricht, en wordt als capaciteit gedeeld door de eerder genoemde afdelingen.

Om deze complexe produktiestructuur te vereenvoudigen hanteert men binnen het ziekenhuis voor de meest belangrijke 'initiërende' capaciteitssoorten een **batch-gewijze productie via het sessie-mechanisme**. Een sessie is een aaneengesloten tijdsperiode waarop capaciteit van een bepaalde soort is toegevoerd aan een specialist om een aantal patiënten te behandelen die dezelfde capaciteitssoort vereisen. Sessies worden doorgaans op een vast moment in de week gepland. Ze zorgen voor de afstemming van vraag en aanbod op de korte termijn.

Roosters regelen de toewijzing van sessies in een werkstation aan specialisten. De meest belangrijke roosters zijn: het operatiekamer rooster voor de planning van operatie-sessies en het polikliniek rooster voor de planning van spreekuursessies. Deze roosters vervullen een soortgelijke functie als het hoofdproductieplan in industriële situaties, aangezien de roosters ook gezien kunnen worden als een productieprogramma per periode. Door deze roosters, en het achterliggende verbindende rooster van de specialisten, te bestuderen op capaciteitsgevolgen voor andere afdelingen, kunnen op een relatief eenvoudige wijze mogelijkheden voor verbetering van capaciteitsgebruik zichtbaar worden gemaakt.

Het gebruik van het sessie-mechanisme en de roosters voor toewijzing van schaarse, gedeelde, capaciteitssoorten, leidt tot de volgende **voorwaarden voor coördinatie van toegewezen capaciteiten**:

- coördinatie van toewijzingen van 'initiërende' capaciteitssoorten aan specialisten die deze capaciteitssoort delen (capaciteitsafvlakking per 'initiërende' capaciteitssoort);
- coördinatie van toewijzingen van verschillende capaciteitssoorten aan één specialisme (capaciteitsbalancerend per specialisme);
- coördinatie van capaciteitseffecten voor 'volgende' capaciteitssoorten (capaciteitsafvlakking per 'volgende' capaciteitssoort, bijvoorbeeld een röntgenafdeling);
- coördinatie van de toegewezen specialist-capaciteit binnen één specialisme.

Indien men deze voorwaarden verontachtzaamt, leidt dit tot vermijdbaar capaciteitsverlies of een aantasting van een goede praktijkvoering binnen een specialisme.

De capaciteitsgevolgen van het niet rekening houden met deze voorwaarden worden onderbouwd met een statistische analyse van de relatie tussen het rooster van spreekuren in de polikliniek en de werklast van diagnostische afdelingen. Daarnaast wordt in een case-studie gedemonstreerd dat een reorganisatie van een operatiekamer rooster vele domino-effecten veroorzaakt voor 'volgende' capaciteitssoorten in de kliniek en in de polikliniek.

Ontwikkeling van een methode voor capaciteitstoewijzing

Binnen het onderzoek hebben de volgende ontwerp-activiteiten plaats gevonden: de ontwikkeling van een besturingsraamwerk, het bouwen van een set van beslissingsondersteunende computermodellen om de besluitvorming over capaciteitstoewijzing te ondersteunen, en de ontwikkeling van een implementatie aanpak voor onze methode.

Het ontwikkelde **besturingsraamwerk** onderscheidt vijf planningsniveaus, gebaseerd op het type te nemen beslissingen. Beslissingen met gevolgen voor de langere termijn bevinden zich

op een hoger niveau binnen het raamwerk en bepalen de grenzen voor besluitvorming op lagere niveaus. Strategische Planning richt zich op de langere termijn besluitvorming over het toekomstige ziekenhuisprofiel. Patiëntenstroom Hoofdplanning richt zich op besluitvorming voor de ontwikkeling van de ziekenhuisproductie voor het volgend jaar. Capaciteitstoewijzing richt zich op de toewijzing van capaciteiten naar specialismen of afdelingen. Capaciteitsroostering richt zich op de planning van toegewezen capaciteiten binnen roosters. Operationele Planning richt zich op de dagelijkse planning van werkzaamheden binnen het ziekenhuis. Deze systematische beschrijving van te nemen beslissingen en koppelingen tussen beslissingen, vormt een raamwerk voor productiebesturingsbeslissingen en maakt het mogelijk planingsbijdragen te positioneren.

Het was noodzakelijk om een set van beslissingsondersteunende computermodellen te ontwikkelen om de benodigde informatie voor capaciteitscoördinatie te verschaffen, aangezien de huidige ziekenhuisinformatiesystemen deze informatie niet leveren. Het betreft relatief eenvoudige 'what-if' modellen die patiëntenstromen en hun capaciteitsbehoefte zichtbaar maken op verschillende terreinen van capaciteitstoewijzing binnen een ziekenhuis. Het model 'Patiëntenstromen en Capaciteiten' ondersteunt de langere termijn beslissingen over de benodigde capaciteiten om te voldoen aan de toekomstige vraag. De modellen 'Capaciteitsmanagement Kliniek', 'Capaciteitsmanagement Polikliniek' en 'Capaciteitsmanagement Röntgen' ondersteunen elk beslissingen op de middellange termijn voor afstemming tussen vraag naar capaciteit en aanbod van capaciteit in de corresponderende onderdelen van het ziekenhuis. Het model 'Capaciteitsmanagement Specialist' ondersteunt beslissingen voor de afstemming tussen de planning van een specialisme en de roosters van capaciteitsafdelingen zoals de operatiekamerafdeling en de polikliniek. Afhankelijk van het capaciteitsmanagementvraagstuk kan een enkel model of een combinatie van modellen nodig zijn. Het brede bereik van de set van modellen maakt het mogelijk capaciteitsgevolgen van veranderingen door het hele ziekenhuis heen zichtbaar te maken.

De **implementatie aanpak** voor gebruik van de methode binnen een ziekenhuis wordt gekenmerkt door de volgende elementen:

- probleemgerichte aanpak: de aanwezigheid van een formeel en concreet probleem dat de herziening van capaciteiten legitimeert wordt beschouwd als een noodzakelijke voorwaarde voor een project (dit hebben we aangeduid als 'kritische capaciteitsgebeurtenissen');
- beslissingsondersteuning: één of meer van de modellen wordt gebruikt om informatie te verschaffen voor de benodigde capaciteitscoördinatie, en om de betrokkenen een ziekenhuis-breed perspectief te bieden op het capaciteitsmanagementvraagstuk;
- participatie: de verschillende stappen in het project worden genomen met maximale betrokkenheid van afdelingen of groeperingen in het besluitvormingsproces.

Volgens het gehanteerde model vormt verbeterd inzicht in de samenhang van het ziekenhuis als systeem een belangrijke intermediaire variabele voor de verklaring van de relatie tussen implementatiestrategie variabelen en outputvariabelen (verbeterde beslissingen en verbeterde kwaliteit van het besluitvormingsproces).

Case-studies

Het derde deel van het onderzoek omvat een aantal case-studies om het gebruik van deze aanpak in concrete ziekenhuissituaties te illustreren en om op een exploratieve manier de onderzoeksvragen omtrent het effect van onze aanpak te beantwoorden. Er werden drie

case-studies uitgevoerd die betrekking hebben op verschillende capaciteitsmanagementvraagstukken:

- een reorganisatie van het artsenrooster voor een groep van acht algemeen chirurgen, deel uitmakend van een functieverdeelpun voor een multi-lokatie ziekenhuis;
- een verbetering van de afstemming tussen de röntgenafdeling en de polikliniek in een ziekenhuis dat problemen had met pieken en dalen in de werklust op de röntgenafdeling en daardoor met wachttijden voor direct onderzoek van patiënten afkomstig van spreekuren in de polikliniek;
- de ontwikkeling van een methode voor een meer flexibele en samenhangende toewijzing van klinische capaciteitssoorten in een ziekenhuis met een structureel tekort aan bedden en daardoor veel 'opnamestops'.

De voornaamste conclusies van dit deel van het onderzoek volgen hierna. Aangezien de case-studies primair een illustratieve en exploratieve functie vervullen, hebben de conclusies een tentatief karakter.

Elk van de elementen van de implementatiestrategie (probleemgericht, modelgebruik, participatie) heeft bijgedragen aan een succesvol project.

- Naarmate het **bestudeerde probleem** meer geaccepteerd is of een meer formeel karakter heeft, biedt het meer draagvlak voor een project dat zich richt op verbetering van capaciteitsgebruik. Verbetering van capaciteitsgebruik op zich, zonder een onderliggend probleem, biedt onvoldoende basis voor een project.

De bijdrage van de **beslissingsondersteunende modellen** was vooral belangrijk voor een goede start van het project. De modellen versterkten het draagvlak voor het project vanwege hun goede organisatorische aansluiting op het bestudeerde vraagstuk. De modellen gaven ook goede steun voor de verzameling van gegevens en de analyse ervan, en voor de evaluatie van capaciteitseffecten. Halverwege het project werd de rol van het model echter min of meer overgenomen door de deelnemers, die zich de planningsfilosofie van de modellen eigen hadden gemaakt en beter in staat waren oplossingen te bedenken. De modellen speelden niettemin een belangrijke rol als katalysator voor een gedachtenwisseling over het probleem en mogelijke oplossingen. De gestandaardiseerde methode en terminologie van de modellen maakt het mogelijk projectresultaten in verschillende ziekenhuizen te vergelijken en een toepassing te herhalen.

- De **participatieve wijze** van uitvoering van het project werd als noodzakelijk beschouwd om commitment te verkrijgen binnen het ziekenhuis met zijn vele actoren, en verder ook om alle aanwezige lokale kennis te benutten. De kenmerken van het ziekenhuis laten weinig ruimte voor een andere aanpak. Onze aanpak verschilt daarin dat participatie op verschillende manieren werd gestimuleerd.

De **capaciteitsgevolgen binnen de drie case-studies** kunnen als volgt samengevat worden:

- De reorganisatie van het artsenrooster van de groep van chirurgen (case-studie 1) leidde tot: 33% reductie van de variatie in de capaciteitsbehoefte van operatiekamer personeel, 12% toename van de variatie in de capaciteitsbehoefte van spreekuurpersoneel, en 12% toename van variatie in de werklust van de röntgenafdeling; gebruik makend van een wegingsfunctie voor de reductie van variatie in capaciteitsgebruik met relatief meer gewicht voor een reductie van de dure operatiekamer capaciteit, kan het eindresultaat als positief worden aangeduid.

- De herziening van programma's voor röntgenkamers en de reserveringen voor directe verwijzingen vanuit spreekuren (case-studie 2) resulteerde in een betere afstemming tussen de behoefte aan en beschikbaarheid van capaciteit voor direct onderzoek; dit beïnvloedt direct de wachttijd voor patiënten die zonder afspraak vanuit de polikliniek komen, waardoor de gemiddelde wachttijd tijdens piekuren naar verwachting af zal nemen van 100 minuten naar 25-30 minuten.
- De methode voor een meer flexibele en samenhangende toewijzing van klinische capaciteitssoorten (case-studie 3) leidde tot een meer gebalanceerd gebruik van capaciteiten en een beslissingsruimte voor het management van 9 bedden die kunnen worden toegewezen aan specialismen die gestimuleerd dienen te worden vanwege het strategisch bepaalde ziekenhuisprofiel.

De **voorwaarden**, waaronder deze resultaten met onze implementatieaanpak in andere ziekenhuizen kunnen worden behaald, zijn: voldoende draagvlak bij de directie (vanwege de consequenties van capaciteitstoewijzingen voor de produktie van het ziekenhuis en vanwege de potentiële conflicten tussen specialismen), managers van ondersteunende afdelingen (omdat zij verantwoordelijk zijn voor een doelmatig gebruik van schaarse, gedeelde, capaciteitssoorten en omdat van hen een ziekenhuis-breed perspectief op het functioneren van hun afdeling gevraagd wordt) en de betrokken specialismen (omdat elke capaciteitstoewijzing de praktijkvoering van het specialisme beïnvloedt). Daarnaast is beschikbaarheid van gegevens een voorwaarde. De logistieke analyses, die met behulp van de modellen uitgevoerd moeten worden, vergen veel gegevens die met enige inspanning kunnen worden verzameld of ontleend aan het ziekenhuisinformatiesysteem.

CURRICULUM VITAE

The author of this thesis was born on May 14, 1951 in Horst in the province of Limburg. In 1969 he received his high school diploma at the pre-university educational level (Gymnasium B) at the Boschveld College in Venray, whereafter he started his study Industrial Engineering and Management Science at Eindhoven University. He received his Master's Degree in January 1975, with a specialization in Operational Research (OR) applied to Health Services. His final research project concerned an investigation into the outpatient flows in the outpatient and diagnostic departments of a large hospital (De Wever Ziekenhuis, Heerlen) and the development of planning tools for improving the handling of these flows and preventing waiting times for patients. During 1975 and 1976 he continued his work for this hospital as a staff officer to implement the methods developed during the research project.

From 1977 till 1980 he conducted research at Eindhoven University, Department of Operations Planning and Control, concerning scheduling and patient flow management of outpatients in general hospitals. This research, supervised by Prof.ir. Wim Monhemius and based on a grant by the Ministry of Health, involved the simulation of various outpatient appointment systems and their impact on patients' waiting times and doctors' idle times, and has resulted in a number of scientific publications and manuals for handling this problem in hospital settings.

In 1980 he joined the Dutch Hospital Institute as research fellow conducting research on innovating hospital care by emphasizing outpatient treatment instead of inpatient treatment and improving transmural co-operation between general practitioners and ambulatory practice of hospital-based specialists. Later he continued his OR-based career by starting a research programme at the institute on hospital capacity management. He joined the European Working Group of Operational Research Applied to Health Services to make use of the expertise available in this network for his research activities in this field. In 1988 he re-established his links with Eindhoven University by a part-time research position at the Department of Operations Planning and Control to conduct the research project reported in this thesis. The project was supervised by Prof.dr.ir. Will Bertrand.

STELLINGEN

behorende bij het proefschrift

Patient Flow based Allocation of Hospital Resources

van

Jan M.H. Vissers

I

Met de huidige ziekenhuiscapaciteit kunnen 5-10% meer patiënten behandeld worden mits er een betere coördinatie van de ingezette capaciteit plaats vindt.

[Dit proefschrift, hoofdstuk 1]

II

Uitgaande van de maatschappelijk opgelegde taakstelling om de beschikbare middelen optimaal te gebruiken, is een hogere benutting van capaciteiten een belangrijkere doelstelling voor de besturing van het ziekenhuis dan een betere dienstverlening aan patiënten.

[Dit proefschrift, hoofdstukken 1, 2 en 4]

III

In de huidige ziekenhuispraktijk wordt te veel gepland op afgeleide capaciteitssoorten en te weinig op de specialist als capaciteitssoort. Mocht men besluiten tot een capaciteitsplanning gebaseerd op specialist-capaciteit, dan dient men niet alleen te letten op een doelmatig gebruik van specialist-capaciteit maar op een doelmatig gebruik van alle capaciteitssoorten die voor ziekenhuisproductie nodig zijn.

[Dit proefschrift, hoofdstuk 2]

IV

Ziekenhuizen kennen een seriegewijze produktie met een vaste seriegrootte en een vaste produktiecyclus. Dit leidt tot een starre inrichting van de produktie waardoor tevens streefwaarden voor de bezettingsgraden van capaciteiten en het service-level aan patiënten komen vast te liggen. De vereenvoudiging die hierdoor in de produktiebesturing van het ziekenhuis wordt aangebracht weegt echter op tegen de nadelen ervan.

[Dit proefschrift, hoofdstukken 2 en 4]

V

De flexibiliteit van het zorgaanbod zou sterk kunnen worden vergroot door jaarlijks de toewijzing van ziekenhuiscapaciteiten aan specialismen te iken op de ontwikkeling van de patiëntenstroom.

[Dit proefschrift, hoofdstuk 4]

VI

In de huidige ziekenhuispraktijk wordt door het management onvoldoende gebruik gemaakt van sturing via capaciteiten, vanwege de conflicten die dit met zich mee kan brengen met specialismen.

VII

Spanning tussen vraag en aanbod (schaarste) stuurt sterker dan structuur.

VIII

Ziekenhuizen hebben meer baat bij projecten gericht op herontwerp van productieprocessen dan bij projecten gericht op bijsturing van bestaande processen.

IX

Eerst wanneer specialisten bereid zijn om de eis van een 100% bezettingsgraad van de eigen capaciteit los te laten, zullen de lange wachttijden voor patiënten in de polikliniek worden opgelost.

[Vissers J.M.H. (1979), *Selecting a suitable appointment system in an outpatient setting*. Medical Care, Vol. 17, pp. 1207-1220, en Vissers J.M.H. (1993), *Wachttijden: niet te vermijden, wel te verbeteren*. NZi-Notities, Nationaal Ziekenhuisinstituut, Utrecht]

X

Om tot een effectievere logistieke besturing van ziekenhuizen te komen zou meer gebruik moeten worden gemaakt van het protocollaire denken en handelen van specialisten.

XI

Om de nadelen van specialisatie binnen het ziekenhuis beter op te kunnen vangen zou het overweging verdienen niet meer te werken met maatschappen per specialisme maar met multidisciplinair samengestelde maatschappen.

[H. Kuipers, *Sociotechniek in de gezondheidszorg? Bijdrage symposium 'Sturing van Zorgprocessen'*, Alphen a/d Rijn, november 1992]

XII

Onkruid bestaat niet. Hooguit gaat het om een plant die op de verkeerde plaats groeit.