IS IT BETTER NOW, DOCTOR?

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1 INTRODUCTION

RECTOR, DEAN, LADIES AND GENTLEMEN,

The professorial chair I formally accept today bears the title, *Operations Management in Health Care.* I am a member of the department of Industrial Engineering & Business Information Systems, whose main focus is the programmes in Industrial Engineering & Management, and Business & IT. My chair is also embedded within the CTIT research centre ‘CHOIR’, which I established in association with my colleague Prof.dr. Richard Boucherie.

During this lecture, I shall explain what Operations Management in Health Care entails. I shall describe some developments that illustrate the importance of the chair and I shall outline the challenges they create for my research. I shall also consider our methodology and the results we have achieved to date.

An abridged version of this lecture was given on 9 April 2015.

2 WHAT IS 'OPERATIONS MANAGEMENT IN HEALTH CARE'?

Before I describe the research challenges facing my chair and department, I would like to explain the term 'Operations Management in Health Care'. What does it entail?

Operations Management is the organization of processes to make them as *efficient* and *effective* as possible. My specific focus is those processes that take place within the health sector.

Efficiency is closely allied to *productivity*. It refers to the relative degree to which maximum output can be derived from the available resources ('inputs'). 'Output' can be defined in various ways: the number of patients treated, the number of CT scans performed, the number of days that beds are occupied. We must set output against the costs associated with the finite, often scarce resources on which the care processes rely: doctors and other staff, operating theatres, expensive equipment such as MRI and CT scanners, and everyday supplies or 'non-renewable resources'.

Effectiveness says something about the quality of the output. It relates to the quality of care itself ('patient outcomes') as well as to the quality of the working experience for staff: their 'job satisfaction'.

In short, my work is concerned with improving care processes so that they are not only more efficient (and hence less expensive), but also more effective. The patient receives better care; staff find it more fulfilling to work in the care sector. The scientific challenge is to develop new management models that can optimize the countless, disparate processes and all the many complex types of health care organization, at both sector and local level. We do so through Operations Research – the discipline that deals with the application of advanced analytical methods to help make better decisions – and by using computer simulations to reveal the impact that new management models will have on performance. This brings yet another challenge, in that the management models themselves must not be too complex. Complexity, either mathematical or scientific, could impede their successful implementation in practice.

Within the care sector, my discipline is termed 'care logistics' or sometimes 'patient logistics' to emphasize that 'everything revolves around the patient'. In fact, Operations Management is concerned with all aspects of the processes, including materials logistics, financial management and IT management. I shall return to this point in a moment but before I explain *what* we do I would like to say a few words about *why* we do it.

There have been a number of major developments in the health care sector, which underscore the relevance of my research. In the past, health care has been subject to significant changes. If we browse through the professional literature of the last fifty years or so, we find many statements to the effect that 'health care is changing, so now is the time to review the efficient organization of care processes.' The difference between then and now is that today's changes come with increasing frequency and have ever greater impact.

3 DEVELOPMENTS AND CHALLENGES

3.1 The waiting list issue

We in the Netherlands enjoy a remarkably high standard of medical care, which is acknowledged to be among the best in the world. This is, of course, something to cherish. However, inefficient organization can have a major negative impact on quality. When I started my research some twelve years ago, the sector devoted very little attention to operations management. There was no financial incentive for hospitals or other institutions to pursue efficiency, and a long waiting list was seen as a sort of status symbol for doctors (Van Loon, Horstman, & Houtepen, 2002). It was not unusual for patients to have to wait well over a year for a hip replacement, which although a complex operation is everyday practice for most hospitals. My grandmother was among those patients. In the mid-1990s she needed a new hip and was told that she would have to wait eighteen months. Meanwhile, the pain became so severe that she had to take morphine. When the morphine was discontinued after the operation, she suffered serious withdrawal symptoms. She developed cardiovascular problems, which eventually caused her death. Although most elective, routine surgery is not urgent, an excessive delay can have a major impact on the overall quality of care. One basic principle of my research is that efficiency improvements must never be at the cost of quality. Fortunately, in most cases we see a parallel movement: when efficiency increases, so does quality.

3.2 Increased costs and expenditure

Worldwide, and certainly among the industrialized countries, we see an unremitting trend of increasing expenditure on health care. According to the Netherlands' Ministry of Health and Welfare (VWS), costs have risen each and every year for the past six decades, which means that every family is now spending a quarter of its income on health care. Those costs have doubled over the past ten years. The VWS report suggests that, if this trend continues for another ten years, we will all be spending almost half of our income on health care.

Recent decades have seen little effort to reduce costs by forgoing quality. Rather, the emphasis has been on maintaining and enhancing quality. Our life expectancy has increased as a result. We now receive better care, which often relies on expensive new drugs or technology, and on complex medical interventions.

The rising costs of health care provision are often attributed to population ageing. Demographic analyses reveal that this trend has scarcely begun. At present, people over 65 represent 15% of the population. Within a few decades, this figure will have increased to 26.5%. The demand for health care services will inevitably rise. At the same time, there will be fewer people of working age, whereupon there will be pressure on the supply side as well. And yet we now read about redundancies in the care sector and cuts to frontline services such as domiciliary care. Recent graduates have difficulty in finding employment. Doing away with services altogether may seem an easy way of cutting costs, but that only applies to the *financial* costs. The *social* costs are likely to rise beyond measure. The challenge in my research is to adapt the organization of care processes in order to increase efficiency while maintaining quality. This entails making cost-effective use of technology to support the professional staff working in the sector. The operative word here is 'support'. Technology cannot and must not replace people, and neither must it make their work less satisfying. In my research, the quality of the work experience is an important optimization factor, alongside the quality of care itself and maximization of productivity and efficiency.

The manner in which the health care system is funded is also subject to frequent change and is extremely complex. There remain too few incentives to pursue efficiency. It is easy to calculate precisely how many beds can be moved out of the wards, how much overtime can be avoided, or how much longer patients can be asked to wait for treatment. However, the financial consequences of these measures are far more difficult to quantify. A rough estimate may be the best we can hope for. The link between costs and logistics is rarely made. A radiology department may, for example, schedule maintenance activities during regular working hours because it is more expensive to have technicians work evenings or weekends. No one bothers to weigh the savings against the costs to patients in terms of treatment delay. Another challenge within my research is therefore finding ways to interlink financial management and logistics.

3.3 Government measures: market forces and specialization

In the early years of this century, long waiting lists and burgeoning costs prompted the government to implement a number of very significant changes to the Netherlands' health care system.

The most significant change was the introduction of free market competition. It is prohibitively expensive for hospitals to offer a "complete" range of health care services as they did in the past. (It is perhaps also questionable from the perspective of quality). The new system encouraged hospitals to adopt some degree of specialization. Rather than covering the entire range of health services from A to Z, they had to make certain choices. This has had a major impact on the way in which health processes are organized and has created several more challenges for my research. Let me give some examples.

Many patients must now travel a greater distance to see the appropriate specialists and receive the treatment they need. In our research, we try to optimize the planning of the various hospital activities so that it is possible for the patient to attend a series of appointments all on the same day – the so-called "one-stop shop" (Braaksma, Kortbeek, Post, & Nollet, 2014). This calls for a coordinated approach at several management levels. The schedules of the various specialists must be coordinated so that patients can visit them all in turn on the same day and this calls for advanced multi-appointment scheduling methods. Ideally, the patient should be presented with various optimized schedules, routes and appointment times, from which he can choose the most convenient with one click on the computer mouse. Aleida Braaksma, a former PhD student at CHOIR, designed just such as system as part of her graduation project at the AMC Paediatric Neuromuscular Centre, for which she received the Menzis Doctoral Dissertation Prize 2011 (Menzis, 2011).

Another challenge is to identify and quantify the implications of the choices that health care organizations make. It should be obvious that opting to offer some types of care but not others will have a major impact in terms of the resources required.

Moreover, specialization creates the need for better coordination between health care organizations. A hospital must know where to refer patients who need a form of treatment it does not provide. In some cases only certain components of the care process need be 'outsourced' in this way. In the absence of a central point of contact who coordinates the chain as a whole, the patient must never find himself having to recount his entire medical history at each visit. An investment at one point in the care chain could account for significant returns elsewhere in the chain. Where the various parties are entirely independent of each other but nevertheless required to cooperate, an integrated operations management approach is a *sine qua non* of process optimization. A sub-optimal situation will also be seen within one and the same hospital when departments are judged on their own individual results, as is increasingly the case. The 'Results-Accountable Unit' structure, in which hospital departments are organized as single cost centres, is incompatible with an integrated logistics approach.

3.4 Government measures: the shift to first-line care

Greater emphasis on cooperation is also the result of another significant government measure: the shift from second-line to first-line care (NIVEL, 2013). These terms require some explanation. In the Dutch health care system, there are various 'levels' or lines, ranging from zero-line care (at home, with no professional intervention) through to third-line care. The first-line, broadly equivalent to primary care elsewhere, comprises generalists with broad-based training: GPs, dentists, domiciliary care workers, etc. The second line is made up of specialists who have followed in-depth training in a particular discipline. They work in hospitals and clinics. The third line comprises the senior clinicians of the academic hospitals and accredited centres of excellence. It is less expensive to provide simple, straightforward care in the first-line setting, and doing so has a positive impact on quality. For more specialist care, patients are referred to the second line. This system is highly effective but demands better coordination between the first and second lines. An example of such improved cooperation can be seen in the integration of out-of-hours GP services with hospital A&E departments to form an 'emergency post'. The patient presents himself at the reception desk where trained staff assesses the care requirement. He will then be seen by a general practitioner or an on-call specialist. This system avoids patients making unnecessary use of second-line care, whereupon those who do require specialist attention will be helped more promptly. Costs are reduced, quality is enhanced (Eichler, et al., 2013). In a research project funded by ZonMW and involving our colleagues Carine Doggen, Ingrid Vliegen and Martijn Mes, we helped to optimize operational processes at an integrated emergency post in Almelo. We developed an extremely detailed discrete event simulation model, which allowed us to assess the effects of various solutions before putting those solutions into practice (Bruens, 2013). My PhD student Nardo Borgman selected this as his master's graduation project and was awarded the Menzis MSc Thesis Prize for his valuable contribution (Borgman, 2012).

Another example of the shift is seen in the funding arrangements. In the past, certain health risks, which were not covered by individual insurance policies, were regarded as a collective social responsibility under legislation such as the *Algemene Wet Bijzondere Ziektekosten* (General Exceptional Medical Expenses Act; AWBZ). This has since been replaced by the *Wet langdurige zorg* (Long Term Care Act) and the *Wet Maatschappelijke Ondersteuning* 2015 (Social Support Act; WMO). The WMO passes considerable financial responsibility to local authorities, which must now fund services for a large proportion of the 800,000 patients in various target groups, such as those with physical or mental disability, somatic symptom disorders or a psychogeriatric condition. The purpose of the reforms was to allow people to live independently in their own homes for as long as possible, drawing upon the support of patients' existing social networks. However, this development has been accompanied by significant budget cutbacks, which have resulted in a wave of staff redundancies in the health care sector. Local authorities face major organizational challenges, including those of ascertaining an individual's care requirement and contracting the relevant professional organizations. I see an equally significant challenge in terms of the scientific research to be undertaken by my department and my colleagues in the CHOIR research group. I therefore hope to work closely alongside my UT colleague René Torenvlied, who is Professor of Public Management.

3.5 Performance under scrutiny

Not so very long ago, a patient would simply make an appointment with his GP and, if necessary, at the nearest hospital. Today's patient is far better informed about where to obtain the best care for a particularly condition. This is largely due to the emergence of the Internet. Patients share their experiences on social media and there are several comparison websites that rate the quality of health care organizations. At the same time, we see increasing media coverage of the waiting list issue and the apparent inefficiency of care processes. All such developments serve to raise patients' expectations in terms of the quality of care, which in turn increases costs.

For the media, performance comparison (also known as 'benchmarking') is a popular way of scrutinizing the performance of health care institutions. Familiar examples include the 'Top 100 Hospitals' rankings published in Elsevier and the AD newspaper. Unfortunately, the intention would appear to be 'naming, shaming and blaming'. This will not give the public better hospitals. These rankings are based on questionable data and are not directly comparable. The methodology of the AD ranking is not even consistent from one year to the next (Martens & Gernaat, 2012). Neither ranking offers hospitals any insight as to how they can *learn* from each other, which is surely the prime purpose of benchmarking. A spin-off of my research, and one of which I am particularly proud, is the 'Surgical Department Benchmarking' project. It grew out of a graduation project undertaken by Arjan van Hoorn at Erasmus MC in 2004. This benchmark examines various performance indicators of the surgical departments at all eight academic hospitals in the Netherlands, the objective being to encourage mutual development: the hospitals learn from each other's best practices. Every year, a vast quantity of process information from the surgical departments is collected, collated and entered into a data warehouse to ensure a fair and balanced comparison of performance. Various analyses can rely on sound scientific research, including that performed by UT graduates (Van Hoorn, Van Houdenhoven, Wullink, Hans, & Kazemier, 2007). For over ten years, the benchmarking project has organized an annual conference at which results are discussed and the surgical departments can draw lessons from each other's improvement projects and best practices.

3.6 Technological developments

Another aspect that has a very marked impact on the health care landscape is technological development.

Technology enables *earlier*, *faster* and *more effective* diagnosis. This effect is strengthened by the shift from second-line to first-line care, and to some extent has been made possible by that shift.

Oncology is one discipline to have benefited greatly from the rapid advances in diagnostic technology. At a recent CHOIR seminar, my fellow professor Sabine Siesling presented her vision of developments in oncological care (Siesling, 2015). It is a field in which diagnostic technology is becoming ever more complex. It is known that different tumours require a different approach and there is now greater demand for 'tailor-made' care. Hospitals have therefore begun to focus on certain specific types of tumour in order to create efficiency. This calls for more cooperation and coordination between hospitals. We can use mathematical modelling to analyse the degree to which concentration is needed, and we can apply operations management techniques to optimize coordination between centres and hopefully organize the processes in such as way as to ensure that all cancer patients have prompt access to diagnostics and treatment. This is the topic that currently occupies the time and talent of my PhD student Gréanne Leeftink.

Technology has also given us better, faster communication. That is most welcome, since the increased cooperation between health care institutions and the greater involvement of the first-line care have created a demand for better coordination and better communication. Unfortunately, the situation is undermined by the diversity of information systems adopted by the care providers. As a result, it is not unusual for second-line providers to repeat the early diagnostic processes already undertaken by the first line, much to the frustration of patients. Research to find ways of linking information systems more effectively may help to rectify the problem. But the problem exists not only *between* health care institutions but also *within* them. We have seen hospitals that are using literally hundreds of different information systems. The ability to create compatible interfaces between those systems is essential to my research, given that the aim is to optimize the overall care process. Fragmented information management and slow communication make this surprisingly difficult in this information era.

The information that we require from these systems is *logistic* information. It will allow us to diagnose the logistic bottlenecks and will provide realistic process data as input for the mathematical models. However, the care institutions themselves record information primarily for medical and financial reasons. The information I need for my research is often not available, or can be retrieved from the information systems only with extreme difficulty. Technological developments in the field of Data Visualization and Data Mining can come to the rescue. Data visualisation software enables us to access the contents of diverse information systems and to arrange the data in a way that provides the answers to our specific questions. This not only speeds up the data analysis process, but also helps to visualize the logistic bottlenecks, including unforeseen or unsuspected problems. Visualization creates understanding, understanding creates commitment, and commitment leads to implementation. The commitment of care professionals is essential if real impact is to be made in practice. Data mining tools enable us to identify patterns in the data: the rules and 'natural laws'. We can for example analyse the extent to which the care process follows the established protocols. This helps us to make more accurate forecasts to support better planning. Data mining also make it possible to process data drawn from actual practice to form the input for our models and simulations. It then becomes easier to identify certain patient types, whereupon we can assess the likely duration of an operation for any patient type based on statistical probability. Nevertheless, there is still a long way to go before this technology can support operations management in a completely effective manner. To reach that situation will demand significant investments in capacity and training, to which very little attention is being devoted at present. This investment will pay for itself many times over.

ICT technology is also responsible for the emergence of 'remote' care, otherwise known as 'transmural' care. In the future, telemedicine and remote monitoring will become increasingly important, as will the use of personal care robots. This is a desirable development in that it obviates the need for patients to travel to a hospital or clinic which, due to specialization in the sector, may be some distance away.

Because diagnostic processes are becoming ever more refined, sometimes at the level of an individual's DNA, they are generating an ever larger quantity of data. 'Big data' research techniques can be used to combine and analyse large datasets in a relatively short time, which improves both diagnosis and treatment opportunities.

Technology means fewer errors, which in turn means fewer process disruptions and fewer unwanted variations. I shall explain why this is particularly important to operations management in a few moments.

Various research groups within the UT research institutes CTIT, IGS and MIRA, as well as spin-off companies active in health and life sciences, have made a significant contribution to the technological developments I have described thus far. I intend to pursue cooperation with these groups wherever possible. The combination of expertise that we at UT can offer is unique and creates unbounded opportunity.

One of the challenges facing us is the question of cost effectiveness. Whenever we consider technology, the costs-returns ratio will soon rear its head. Operations management and operations research models can play an important part in analysing the cost-effectiveness of technology. In this context, I believe that collaboration with Prof. Maarten IJzerman's Health Technology & Services Research department will prove to be fruitful.

3.7 Conclusion

The developments I have described make it essential for care institutions to review the organization of their processes, and to reassess the services they wish to provide. My chair and department does not have a macro-economic orientation. My research is not directly concerned with the large, macro-economic changes to health care provision. Rather, I examine the effects of those changes for the care providers themselves. How will the developments affect the way in which care processes must be organized in order to remain cost-effective? We must not forget that the market economy approach has resulted in a greater number of providers and a greater degree of specialization. How must all these providers be organized to create a contiguous 'care chain', thus optimizing the overall care process for the patient?

4 OPTIMIZATION... OF WHAT?

Our research projects begin with a question from the health care field. In most cases, this question is based on the perception that a problem exists but can be resolved or averted. It is not unusual for the question to propose its own solution. For example, “our patients and staff are complaining, so *obviously* we need more capacity. Please calculate how much extra capacity we need and how we should plan its deployment.” However, the solution is not the problem. In many cases, no one has been able to define the problem because too little is known about the organization’s logistic performance.

The term ‘process optimization’ implies that something is going to be improved. But what is the actual *performance* of the process? In the health care sector, this aspect is usually far more complex than in industry. It is not for us, the researchers, to determine the desired performance of a care process. This is a matter for the organization itself. Performance means different things to different people. A performance indicator such as the occupancy rate of an operating theatre is seen as important, and is therefore subject to frequent comparison with past data and with the rates achieved by other hospitals. However, if you ask five people from five different hospitals what this performance indicator actually means, or even five people from the same hospital, you will probably get five different answers. As part of the NFU benchmarking project I mentioned earlier, we spent a year defining uniform performance indicators for the surgical departments of the eight university medical centres (Van Houdenhoven, et al., 2006).

A crucial phase in our research projects involves helping the care provider to determine what satisfactory or unsatisfactory performance of the processes entails. We can then formulate the Key Performance Indicators (KPIs) with which performance can be measured. The care provider’s initial perception of performance is then brought into perspective, set alongside the actual situation. Based on the results and on the performance targets that the organization has set itself, the next stage is to design an appropriate operations management model. In our research, we use the KPIs and targets within our mathematical models and computer simulations to design a new management model or to optimize the one already in place. Because different organizations have different ideas about what performance entails, and have different standards and targets, there can be extremely diverse solutions to similar logistical issues.

In industry, a company need have no qualms about showing favouritism. Everything can be geared to the customer who pays the highest prices. The health care sector, by contrast, is based on the principle of equality. Everyone has the same right to care, regardless of income, wealth or lifestyle. Performance must therefore be *evenly* divided. ‘Performance’ is, however, a very complex concept because it comprises so many different aspects. It can have a short-term perspective and a long-term perspective. It can be very difficult to quantify.

The patient is not the only stakeholder in the care process: there are many others. In the past the focus or optimization was the care provider, particularly with regard to the most expensive resources, such as doctors, operating theatres and costly medical equipment. Increasing, the focus is now the patient, although often within the narrow scope of a single department. By definition, the patient is involved in the entire care process from start to finish. Optimization must therefore address the entire care process, which means that KPIs must be developed for the entire care chain, not merely the individual components within that chain. Many care institutions are now aware of this requirement, although there is still some way to go in terms of its implementation.

In the vast majority of cases, existing KPIs for care processes are concerned with the quality of care and care outcomes. We also examine effectiveness and the quality of the work process. Processes must be effective, but they must also be efficient. Moreover, the staff involved in those processes must derive appropriate satisfaction and fulfilment. We therefore attempt to reduce the pressure of work and even out the fluctuations in the workload. In my research, the term ‘performance’ embraces aspects such as effectiveness, the quality of care and the quality of the working experience. The challenge is to create maximum objectivity in the performance analysis by rendering these aspects quantifiable in different scenarios and with different solutions. But it is not all about cold, hard figures. Patient interaction, perceived suffering and safety are all important performance aspects, which must be taken into account in the organization of the care processes. Emotions and complex ethical issues are also highly relevant. Although they do not play a prominent role in my research, they are factors to which health care institutions must devote attention. Fortunately, many already do.

I would like to conclude this part of my presentation by touching upon the financial benefits of process optimization. It is usually very easy to calculate how many beds are surplus to requirements, how many patients are seen within the target waiting period or by how much the occupancy rate of the operating theatre can be increased. But what are the financial implications? Conducting routine maintenance of CT scanners outside regular working hours will be more expensive, but can the additional costs be justified in view of the logistic consequences of the alternative? Why do we see so many cuts in services while there seems to be more than enough money available to build huge new hospitals? There is astonishingly little knowledge available with regard to the exact costs of providing care, which is why costs are rarely if ever set alongside the ‘patient outcomes’. In the incisive words of my colleague Berend Roorda, “Wrong valuation is a splendid basis for bad decisions!”

5 THE LAWS OF (CARE) PROCESSES

Operations management is concerned with the optimization of care processes, which is achieved through redesigning or improving their planning and implementation. A care process is subject to considerable variability and is subject to various logistical 'laws', which we attempt to control through effective planning. Before I examine the planning and management of care processes themselves, I would like to explain the nature of the logistical laws which apply. Research into process optimization in industry has a long and productive history. The principles I describe here have been familiar in this context for several decades (Hopp & Spearman, 2011) but have yet to gain widespread currency in the health care setting.

5.1 Little's Law

Perhaps the best known theorem in the field is Little's Law (1961), which establishes a relationship between the expected number of customers in a queue system (i.e. work backlog), the long-term average effective arrival rate, and the average time each customer, or for our purposes patient, will spend in the system. For example, if a doctor spends an average of 10 minutes with each patient, and there are 10 ten patients before you in the queue, you can expect to wait 100 minutes. It is a surprisingly intuitive law, which is nevertheless applicable in many different situations and provides considerable insight. If a care process has two stages, the addition of extra capacity to the first stage will increase the throughput time of both stages. This undesirable effect has been seen in hospitals that have attempted to introduce fast-track diagnostics for oncology patients. In the one-stop shop concept, patients undertake all phases of the diagnostic process in a single day. Having done so, they are given their diagnosis and, if appropriate, a treatment plan. Many care managers regard 'more capacity' as a panacea: the cure to all logistical problems. However, adding capacity to one phase or subsystem creates a bottleneck (backlog of work) in the next. The attention of the staff in that next subsystem must be divided among a greater number of patients, resulting in reduced productivity. Little's Law states that the two effects – the increase in the number of patients and the reduction in productivity – are mutually reinforcing, whereupon the throughput time for the system as a whole increases to an even greater degree.

5.2 Local optimization, variability in the chain

This example illustrates the importance of coordination within the chain. *Local optimization* without adequate coordination leads to a sub-optimal situation throughout the chain. In the example, capacity should have been increased in both subsystems in order to avoid a serious increase in throughout time.

Organization of one health care institution is complex enough; attempting to organize cooperation between two or more health care institutions is even more so. There is often no one party who is given, or assumes, responsibility for organizing the overall care process for the individual patient. There are, however, organizations that direct and coordinate certain types of health care service. In the Twente region, for example, *Acute Zorg Euregio* has assumed this role in respect of emergency medical services. The health insurance companies are also taking on a role of coordinator, based on their influential contracting positions. Nevertheless, encouraging cooperation between professional care providers is an extremely complex task. It often involves a clash of cultures, different approaches, incompatible information systems and perhaps conflicting interests. An investment in one can bring about significant improvements in another. Government regulation is essential because, in the competitive health care sector, local interests might otherwise overshadow collective, societal interests. One example is the 'emergency post' concept I discussed earlier, which is actually more expensive for the individual hospital but results in significant savings for society at large.

Local optimization therefore detracts from the quality of the system as a whole. The phenomenon is not only seen with a chain of health care institutions, but in the chain of health care processes within one and the same institution. There are several reasons for this; I shall limit my remarks to the most significant. Clinicians working in the medical setting have, of course, undergone long and intensive training. However, that training devotes little or no attention to the discipline of operations management. Medical specialists learn everything there is to know about a particular part of the human body. As a result, their view of care processes is likely to be less integrated than that of specialists in logistics or in engineering and management. If the clinicians are allowed to undertake their own process planning, the natural tendency will be for them to organize the processes around themselves. To be fair, even the professional planners are guilty of this. Doctors are, after all, scarce and expensive resources. It is natural to place their interests to the fore. In industry, we often see that managers attempt to organize everything around the most expensive resource. While people are queuing up to use the latest, most expensive piece of machinery, the conventional machines are standing idle. And so it is in the health care setting: optimization of one department will result in peaks and troughs, understaffing or overstaffing, and unpredictable waiting times elsewhere. The aim must always be to optimize the entire care process: all components in the chain. In a hospital, it is often the surgical department that takes priority in the planning procedures. Other departments are secondary, whereupon we see significant fluctuation in the demand for beds and unnecessarily high staffing costs at certain times. If surgical planning takes account of the patient throughflow in those other departments, a more even and manageable workload can be achieved for everyone without adversely affecting the performance of the surgical department. It will be possible to reduce both the number of beds to be kept open and the number of nursing staff on duty at any one time. We have developed several solutions for this issue (Van Oostrum, et al., 2008; Bosch, Hans, Van Essen, & Van der Zalm, 2011; Vanberkel, et al., 2011). The most recent is the work of Arvid Glerum, whose graduation project involved developing a set of planning guidelines for the surgical department at St. Antonius Hospital in Nieuwegein (Glerum, Rouppe van der Voort, Hans, & Mes, 2014). Operations are planned on certain days of the week, depending on the expected duration of the patient's stay in hospital. The result is a reduction in the variation in bed demand during the course of any given week and over a period of several weeks, and a very marked reduction in the variation in the number of admissions.

Local optimization is often a consequence of the 'Results-Accountable Unit' structure in which individual departments are single cost centres, thus responsible (only) for their own results. It is also the result of the greater autonomy now enjoyed by the staff of care organizations. If a surgeon decides that the operating theatre is understocked – perhaps there are not enough swabs or drapes – he will submit an urgent order, unaware that the materials manager has already done so. Local optimization can even be the result of doctors having sworn the Hippocratic Oath (KNMG, 2003). By doing so, they undertake to observe certain ethical rules. One of the most important is that the doctor will "apply, for the benefit of the sick, all measures which are required…". The decisions he or she takes in order to fulfil this promise may be in the best interests of the patient in the room at the time, but could undermine the interests of other patients. In one hospital, for example, we found that doctors were admitting patients in order to 'jump the queue' for a CT scan. This prevented other doctors from performing surgery on their patients because there were no available beds. It is planning – or operations management – which determines which patient is in the doctor's consulting room at any given moment. Through my research, I must find ways of supporting doctors so that they are able to fulfil their promise to *all* patients.

5.3 Natural and unnatural variability

The variability of care processes is a key aspect in my research. If everyone were identical and we could predict exactly when a patient will present with a certain health problem, the planning of care processes would be considerably easier. Moreover, there would be no waiting lists. Planning is, however, extremely complex because every aspect is subject to considerable variability. Every patient is different, the time of presentation is generally unknown, staff may be absent due to their own illness, equipment goes 'on the blink', errors are made, and even standard interventions can prompt different patient responses. Many of the unknowns are due to *natural variability*: no one can predict when an injured patient will arrive in the emergency room. But there are also factors that fall under the heading of *unnatural variability*: they are actually organized and hence predictable. The diagnostic labs are much busier during and immediately after outpatient clinic hours than at other times, for example. Access to doctors and diagnostic equipment is generally limited to certain periods during the day. This creates considerable variation in processes elsewhere in the chain. The same effect is seen where a batch processing system is in place.

Variability in care processes results in longer waiting times for patients and extremes of activity and inactivity for care providers. Variability in supply and demand, when coupled with a rigidly organized chain, results in the 'bullwhip' effect. To counter this phenomenon, many hospitals have rationalized their processes to create a 'one stop shop' concept. Capacity is devoted to a large group of patients who can then undertake various stages of the care process in a single day. There is a welcome knock-on effect in that routine, repetitive work becomes more efficient. The less welcome effect is that other patients do not enjoy such ready access to the care process. One way of improving the flow is to have reserved 'slots' for each patient group. However, this must be organized at the level of the overall chain. If it is organized at local level, we are likely to see the 'bullwhip' effect. A major challenge in my research is therefore determining how to organize the processes, with capacity deployed in such a way that performance is equally satisfactory for all patients.

5.4 Queue length versus service time distribution

As I have already mentioned, variability gives rise to delay. Waiting times are longer. In queuing theory, we use the Pollaczek–Khinchine formula (Pollaczek, 1930; Khintchine, 1932) to establish the relationship between queue length and service time distribution. Most people will be familiar with the queue at a supermarket checkout, although the same applies at the tollbooths on a French motorway. As things get busier, the queue grows more rapidly. The standard management paradigm is to maximize utilization of the most expensive resources. However, this too results in the queue becoming much longer, as well as creating marked fluctuations in the staff workload. When analysing the supply and demand within care processes, we often see that the available capacity is on a par with peak average demand in recent years. There are usually significant fluctuations in demand over time, and those fluctuations are made even more extreme if we attempt to maximize the utilization of the resources. The aim should be to reduce the fluctuations, i.e. the variability in demand. After all, when demand is stable, staff will not experience the constant 'stop and go' workload. Their productivity will increase. Patient access will improve, as will the flow of the process. It will be possible to scale back the capacity reserve, whereupon the capacity utilization rate will increase.

5.5 Risk pooling

Another important concept is the Risk Pooling Effect (Vanberkel, Boucherie, Hans, Hurink, & Litvak, Efficiency evaluation for pooling resources in health care, 2012). The natural variability in demand can be reduced by increasing volume. In other words, the more patients there are, the lower the variability. It has been standard practice to create capacity buffers in order to compensate for variability (Van Houdenhoven, Hans, Klein, Wullink, & Kazemier, 2007). The greater the variability, the larger the buffers, the lower the effective utilization of resources, the higher the costs, or the longer patients have to wait. The Risk Pooling Effect calls for (low-volume) care processes of a similar type to be more concentrated. There is much empirical evidence to show that this not only offers logistical advantages but also results in higher quality.

In almost all research projects we will see these laws at work within the processes. We design or optimize the planning and management of those processes in such a way as to control the undesirable effects to the greatest extent possible. Unfortunately, there is no universal, one size fits all, solution. The process characteristics differ too much from one situation to another. Organizations have their own idea of what good performance entails and what norms they wish to achieve. The process characteristics, logistics theorems and performance norms form the key input for the design or optimization of the management model. I shall now describe how we approach process optimization itself.

6 HOW WE GO ABOUT PROCESS OPTIMIZATION

The care institutions with which we work apply two process optimization approaches in parallel: *bottom-up* and *top-down*. I shall examine each in turn.

6.1 Bottom-up process optimization: ongoing improvement

Bottom-up process optimization involves creating a culture of ongoing improvement, eliminating variations and errors within processes, communicating more effectively with each other, reducing complexity, and tackling the underlying causes of the problems which are identified within the processes. The entire organization must be involved in all aspects.

There are a number of logistical improvement paradigms used in industry on which we can draw. The best known are ‘Lean’ and ‘Six Sigma’. Both involve a phased, trial-and-error approach to process optimization, such as the Plan-Do-Check-Act cycle. There is much evidence to confirm the effectiveness of these improvement paradigms, particularly Lean and Lean-Six-Sigma (Rouppe van der Voort & Benders, 2012 and 2014). They result in better protocols for the care processes, better coordination between departments, fewer system disturbances and fewer workarounds (Rouppe van der Voort, 2015).

There are differences between the various improvement paradigms but there are also certain similarities. If we were to merge them all into one, our aim would be threefold: to maximize added value (which entails minimizing waste), to minimize variability and to minimize complexity. Of the three, the maximization of added value is the only aspect that has a direct relationship with the strategy of an organization. The strategy is, after all, concerned with creating maximum added value for patients, with as little wastage as possible. In other words, it pursues maximum efficiency. The other two aspects are concerned with the organization of the process. Reducing variability will optimize the flow of the processes. Minimizing complexity is a question of organizing the processes in the simplest possible manner. The simplest form of planning that actually works is the best: it will seek flexibility of resources and avoid rigid schedules.

However, these two approaches are diametrically opposed and create something of a paradox. One reduces complexity by planning less, e.g. with walk-in clinics rather than a system of scheduled appointments, but this introduces greater variability. One reduces variability through planning, which is in essence ‘variability management’, but doing so introduces greater complexity. What is the optimal balance between variability and complexity, allowing maximum value to be added in an efficient manner? This question relates to the form and design of the integrated management model. This brings me to the main topic of my research: top-down process improvement through the design and optimization of the integrated management model.

6.2 Top-down process improvement: the management model

Whenever we speak about the ‘integrated management of care processes’, we are actually talking about the entire health care chain, all management domains and all management levels. To identify the management domains and hierarchical management levels, Mark van Houdenhoven, Peter Hulshof and I designed the framework shown in Table 1, below (Hans, Van Houdenhoven, & Hulshof, 2011).

TABLE 1. MANAGEMENT FRAMEWORK FOR CARE PROCESSES (HANS, VAN HOUDENHOVEN, & HULSHOF, 2011)

	Medical planning	Resource planning	Materials planning	Financial planning
Strategic				
Tactical				
Offline operational				
Online operational				

This 4x4 framework shows four management domains in its four columns. 'Medical planning' refers to decisions made by clinical staff with a view to providing patient care. Everything that happens in a care institution is driven by these medical decisions. The other three domains are facilitative. 'Resource planning' relates to the deployment of personnel, facilities and equipment, also termed *renewable* resources. 'Materials planning' relates to the procurement and distribution of *non-renewable* resources, while 'Financial planning' is concerned with financial operations. My chair is primarily concerned with the second and third columns: the planning and management of renewable and non-renewable resources. Planning is in effect the process of reconciling demand ('what does the patient or the process require?') with supply (capacity or availability of resources). Medical planning provides important input for the demand side of resource planning, since it is the clinicians who decide what a patient needs, how urgent each patient case is, and so on. If we were considering an industrial production environment, this column would be headed 'technological planning', with the decisions taken by the engineers and designers who, through macro- and micro-process planning, determine how products are to be manufactured. Clinicians are the 'engineers' of a health care organization.

The financial planning column is relevant because we wish to arrive at a cost-effective planning and management model. Budgets are limited, so we must attempt to distribute output performance as fairly as possible. According to Clayton Christensen (2008), a system under which hospitals attempt to fund all activities – diagnostics, interventions and chronic care – within a single uniform funding model is no longer viable. Charging for diagnostics per case, interventions on the basis of outcomes, and chronic care by means of a subscription system is far more in keeping with the nature of the activities concerned. As I have already said, the current financial allocation model is extremely complex and includes rules that fail to reward efficiency. There is an enormous challenge for specialists who offer a combination of technology management and financial engineering. We have such specialists here at UT and I see great promise in combining the financial component with the logistical aspects. It seems strange that this particular avenue of research remains unexplored.

The four rows of the framework represent the natural hierarchy of planning processes. I shall explain them using the example of the surgical department.

At the lowest level, *Online operational*, we see the management of the process during the course of an actual working day. It is therefore a question of process monitoring and making adjustments to accommodate unexpected events, such as the admission of a patient requiring emergency surgery. A medical decision will determine the urgency of the patient's case and whether surgery is indeed needed. A capacity planning decision must then be taken with regard to when, and in which operating theatre, the surgery will be performed. It will then be necessary to liaise with materials planning to ensure that the required resources are available, and that they are delivered to the appropriate operating theatre.

Offline operational relates to short-term advance planning, usually for the coming week or the next few days for which the (elective) demand is known and resources are in place. Given the short-term nature, there is little or no opportunity to plan extra staff capacity. Surgeons will be expected to inform the medical planning staff of any circumstances that are likely to affect the duration of a planned procedure. Anaesthetists must assess the patient's fitness to undergo surgery in advance. Resource planning will allocate an operating theatre at the required time, while materials planning will ensure that the non-renewable resources are in place.

The next level up is that of *Tactical management*. This relates to planning activities for the medium term (typically a few weeks or months), in which demand is partly known or can be predicted, and where there is greater flexibility in terms of resources (most notably staff capacity). At this level, it is possible to allocate resources in 'blocks' to certain types or groups of patients. For example, an operating theatre can be reserved for the use of certain specialisms or individual surgeons on a given day of the week. It would be possible to extend an operating theatre's hours to accommodate an anticipated increase in demand or to help clear the waiting list. A specialist might announce his absence on certain days, whereupon the operating theatre can be reallocated to someone else.

The highest level is that of *Strategic management,* which relates to long-term planning (typically a year or more in advance), entirely on the basis of projected demand. Ideally, the adopted process design and organization will reflect the vision, mission and strategy of the organization, with resources dimensioned accordingly. Examples of aspects that may be decided at this level include investments in physical facilities, staff training, expansion of storeroom capacity, the development of new treatment procedures, and central purchasing arrangements.

The managers of care processes generally focus on the operational planning levels. After all, this is where urgency is greatest and the problems are most tangible. However, this often results in quick solutions, which do not address the root causes of a problem or its knock-on effects elsewhere in the chain. When those effects become evident, as they inevitably will, managers reach for the 'universal solution to all logistical problems': more resources and more capacity. This is a strategic decision. In the course of our research, we have seen very few situations in which there was a shortage of capacity. So what is going wrong?

The higher the planning level, the longer the time horizon, the more difficult it is to forecast demand, and the greater the flexibility of resources. At the strategic level, it is possible to expand capacity and to train staff. At the tactical level, resources can be allocated to certain specialisms or individual specialists at certain times, or can be adapted in line with known demand. At the offline operational level, there is no flexibility of resources. The only option is to reschedule activities within the time available. Finally, at the online operational level, activities can be postponed or cancelled. If absolutely necessary, the protocols themselves can be modified. In short, the lower down the framework we go, the more ad hoc decision-making becomes.

We often find that hospitals devote too little attention to the tactical level at which medium-term planning takes place. It offers greater flexibility than the operational levels on which the options are largely limited to postponement or cancellation of activities. At the tactical level, you have time to adjust the allocation of (blocks of) resources on a temporary basis in order to address anticipated problems such as a spike in demand. This is not possible in the very short term. It is possible to take advantage of the flexibility offered by the level to engage in 'smart' planning, which will avoid problems at the operational level altogether. In essence, planning is the process of matching supply to demand, and using the flexibility (in supply and demand) to create a more stable level of activity within the operational process. It is not a question of working *harder,* but of working *more effectively*. In my research I am constantly looking for the flexibility that can be used to counteract the effects of variability. As we look, we often encounter the very opposite of flexibility in the form of ingrained habits. "This is how it has to be done, there is no alternative!" Our mathematical models and computer simulations enable us to respond in an objective manner, demonstrating what will happen if these 'hard conditions' are abandoned or moderated.

An excellent example of my department's work is a solution devised by former PhD student Peter Vanberkel. We were approached by the Netherlands Cancer Institute, which planned to open an additional operating theatre at the Antoni van Leeuwenhoek Hospital in Amsterdam. How many extra inpatient beds would it require? We refined this question to become, "Assuming that the surgical department works to a time-block system, what is the projected flow of patients onto the medical nursing wards?" Based on empirical data and probability distributions with regard to the number of operations that can be performed in the time-blocks and the duration of a patient's admission, we arrived at a mathematical model that calculates the projected flow of patients onto the wards (Vanberkel, et al., 2011) (Vanberkel, et al., 2011). We were then able to mitigate the peaks in bed occupancy by adjusting the surgical schedule. Peter was able to demonstrate that it would be possible to bring another operating theatre into service without having to add any inpatient beds at all. The study won the ORTEC Excellence in Practice Award and the OR in Practice Award of the Canadian Operational Research Society.

As I mentioned a few moments ago, my research is predominantly concerned with the second column: the planning of resources such as personnel, facilities and equipment. I also said that planning is in essence 'variability management' and I touched upon the often conflicting autonomy of doctors and care managements. Let me return to this point.

When we analyse the care process, we look at both short-term and long-term variability. In the case of short-term variability, we usually consider a single shared resource or a department that represents just one phase in the overall care process. We zoom in on the predictability of the process with specific reference to that department or shared resource. The short-term variability therefore says something about the predictability of *one* step in the patient's care process, or to put it another way, how well we can predict the length of the required appointment at the outpatient clinic, or the duration of an operation? The less accurate we can be in making that prediction, the more *robust* our resource planning must be. We may opt to reserve a buffer to allow for the variability. As a result, the utilization rate of the resource falls. In practice, we see that most programmes include an hour's buffer time at the end of the day. Sometimes, every appointment has a standard buffer time added 'just in case'. The necessity of doing so, and the length of buffer time to be reserved, are both influenced by the predictability of the programme. Having the same buffer for all programmes or appointments leads to serious under-utilization of resources (Van Houdenhoven, Hans, Klein, Wullink, & Kazemier, 2007).

Long-term variability refers to the predictability – or otherwise – of the entire care process. In other words, how well can we predict every step of that process in combination? The more accurate we can be, the easier it becomes to plan the care process centrally. If there is a lesser degree of predictability, the doctors at the local level play a more significant role and it is necessary to give those doctors greater autonomy. The organization can derive much benefit from plotting the entire patient population on a graph, which has short-term variability as its Y-axis and long-term variability as the X-axis. This visual aid would, for example, support decisions about the division of resources between patients with a higher and lower degree of long-term variability. This would avoid problems due to conflicting autonomy and greatly reduce the complexity of the planning process. The graph also allows the organization to determine the buffers that will be required to offset the effects of short-term variability on the various shared resources.

6.3 Materials logistics

The framework in Table 1 includes a column headed 'Materials planning', which can also be termed *materials logistics.* Although it does fall within the domain of Industrial Engineering and Management, there has been very little research examining materials logistics in the health care sector, where it is overshadowed by research into *patient logistics*. Care managers often say to us, "Listen – this has to be about the patient!" Nevertheless, as any care professional will confirm, the materials are always there, often in large quantities. I believe this is due to the serious overstocking in most hospitals. Few people within the hospital are aware of the costs involved, which are therefore not seen as a problem. The few studies we have conducted in this area have consistently revealed vast potential for performance improvement. At one of the country's largest hospitals, for example, we demonstrated that a large proportion of the instruments in the surgical department were 'dead steel' (Florijn, 2008; Kamphorst, 2012; Kroes, 2009; Wolbers, 2008). The instruments were never likely to be used, but were being cleaned, sterilized, repaired, stored, laid out on the trays at the start of every operation and counted back in at the end. The required 'spare' stock had never been calculated and far too much was being kept on hand. Hundreds of instruments were taking up storage space in the most expensive place possible: the surgical suite itself. We calculated that the hospital could save millions. In another research project, my colleague Ingrid Vliegen and Rogier van Vliet of the Medisch Spectrum Twente hospital group devised an effective materials logistics strategy for the infusion pumps used on medical wards. The pumps had always been kept on individual wards even when not in use. This made maintenance more time-consuming. Pumps were not immediately available where they were actually needed. A central management strategy was introduced. Maintenance became more efficient and the availability rate of the infusion pumps increased from 70% to 99%.

6.4 Top-down versus bottom-up

The top-down approach to process optimization is the perspective preferred by scientists. The bottom-up approach is favoured by organization consultants. The two groups have something of a strained relationship. The scientists despair of what they see as unscientific reporting of the results of Lean-like approaches. "If you improve really lousy performance by 10%, you've still got pretty lousy performance," they point out, adding, "Organizations tend to choose an improvement paradigm based on the enthusiasm of the consultant, not on its proven effectiveness." (Van Harten, Hans, & Van Lent, 2010). For their part, the consultants accuse the scientists of being distant and overly concerned with abstract theory. It is unfortunately true that the vast majority of scientific publications have too little direct practical relevance (Brailsford, Harper, Patel, & Pitt, 2009). However, I believe that the bottom-up and top-down approaches are complementary and mutually reinforcing. The bottom-up approach creates a culture of ongoing improvement, better communication, attention for performance and effective analysis of processes and results. This provides important input for the optimization of the management model. However, it is very unlikely that bottom-up paradigms will lead to any change in the upper levels of the management model. Such changes will struggle to achieve acceptance by the organization until the operational problems – the so-called low-hanging fruit – have been resolved. I have joined my CHOIR colleagues Richard Boucherie and Ingrid Vliegen in developing a management course in patient logistics. Its main focus is the top-down approach (CHOIR cursus patiëntenlogistiek, 2015). We explain the principles and theorems that apply to care processes and we demonstrate how those processes can be optimized through effective planning and management. To date, all hospitals whose senior managers have attended this course have also organized a Lean or Lean-Six Sigma course for their middle management.

7 VALORIZATION OF RESEARCH

In the CHOIR research group, we strive to achieve the greatest possible impact. Our scientific research must have practical relevance. Cooperation with the health care sector is therefore very important. Twelve years ago, when I first embarked upon this research path, the sector was entering a period in which rising costs and excessive waiting lists would prompt it to devote close attention to the efficient organization of the care process. The developments I described earlier ensured that our research initiatives met with an enthusiastic response from hospitals and other health care organizations the length and breadth of the country. Within a few years, we had built a network of partner organizations. We now regularly organize seminars and symposia for those partners, either here at UT or on location. Collaboration with external field organizations enables us to tackle topical, relevant issues. It also enables us to involve the partner organizations in our research, whereby we attach great importance to the input of qualified clinicians. Indeed, we regard their contribution as essential. These care professionals are asked to reflect on current practice and what performance means in terms of each process. What is it that must be improved? They are invited to brainstorm alternative methodologies, and will be offered an objective insight into the likely impact of those methodologies. Our mathematical models and computer simulations are environments in which we can experiment safely, and can develop scenarios that have never actually been seen in practice thus far.

The health care sector faces significant changes and challenges. Fortunately, an increasing number of doctors are now open to the type of research that my colleagues and I perform. In the early years of that research, there was a small and select group of 'champions' whose support proved crucial. In particular, I would like to acknowledge Professor Geert Kazemier of Erasmus MC (now at VUmc Amsterdam), Professor Emeritus Piet Bakker of the AMC, and Dr Joost Klaase of Medisch Spectrum Twente. Although they were not familiar with my discipline or with the way in which it uses mathematics, they quickly came to realize that collaboration would offer added value. Our joint efforts led to valuable scientific results and, in some cases, significant practical impact.

All our researchers and students have been able to gain practical experience in the real-life setting of a health care institution. Within those organizations, they are usually seen as the 'go to guy' (or *girl)* for anyone with questions about the logistics of care processes. We have a practical focus. We like to concentrate on issues that are likely to affect the field as a whole. Our research findings are useful to several care locations rather than just one. The physical presence of our researchers at those locations allows us to provide some support, albeit minor, to those who have to implement the research findings. However, our involvement is generally not enough to further the development of decision-support software, or to achieve major organizational changes while solving the resultant change management problems. For this reason, the creation of the CHOIR spin-off *Rhythm*, set up in association with ORTEC, is, in my opinion, essential to provide care institutions with the level of support they need and deserve. Rhythm is unique in that it brings together knowledge of the health care domain, of operational research and operational management, of decision-support software and of change management. It will form a valuable interface between scientific research and practice. In my view, valorization by means of spin-offs is not just a 'UT thing'. Spin-offs enable us to offer a far broader service package, and are essential in cementing long-term relationships between the university and external organizations. Moreover, researchers derive much satisfaction from seeing their results making a real contribution in practice.

I have personally supervised around sixty BSc graduation projects and around one hundred MSc research projects in the care sector. The CHOIR research group has hosted over two hundred students, mostly from the programmes in Industrial Engineering and Management, Applied Mathematics or Health Sciences. We have involved these students very closely in CHOIR's activities, which I hope has greatly enriched their knowledge. They have certainly made a significant contribution to our research volume and to valorization. Students who enrolled on engineering or mathematics programmes may not have envisaged a career in the health care sector. Nevertheless, many are now working as care logistics experts. We see a 'snowball effect' as an increasing number of graduates are taking the CHOIR principles and methods into the field. It is possible that these alumni are indirectly making the greatest contribution to CHOIR's impact. I no longer need to explain terms such as 'tactical planning' or 'integrated resource management'. They have become almost buzzwords!

Valorization of research, or in other words *making an impact*, is particularly important to our 'High-Tech Human Touch' university. Sometimes, however, it can be difficult to reconcile the practical approach with the demands of science, and in particular with those of the operations research and operations management literature in which we publish. These journals demand elegant mathematics and groundbreaking new methodologies. In practice, the rule of thumb is that the simplest solution, which produces satisfactory results, is the best solution. After all, it will be easy to explain, which will lower the threshold to its adoption. In the literature, actual implementation seems to be of secondary importance and merely the inspiration for mathematical development. The literature generally shows calculations based on fictitious situations and data. There are no benchmark sets for algorithms addressing real-world issues such as surgical department planning. There are no explanations or advice to care managers about how to interpret the results. The journals rarely report on the implementation of research in the practical health care setting, and are even less likely to include any analysis of the impact.

Our research approach and our close cooperation with the sector itself will enable us to overcome such limitations. We can make the difference. I see this as the key challenge facing my department. How are we to rise to that challenge? Mathematical models and algorithms are not familiar territory in the health care sector. As a first step, we shall therefore use simple methods to demonstrate that it is indeed possible to improve performance by a significant margin. Once these methods are more widely known and trusted, the likelihood of more advanced methods being adopted is that much greater. We need advanced models and algorithms in order to calculate the absolute performance level, against which we can compare the output of the simple methods. We will then know how close the simple methods come to the theoretical optimum and how much improvement potential remains.

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