Operating Room Manager Game

Authors:

Erwin (E.W.) Hans*,

Tim (T.) Nieberg

* Corresponding author:

Email: e.w.hans@utwente.nl, tel. +31(0)534893523

Address:

University of Twente

School of Business, Public Administration and Technology

Dep. Operational Methods for Production and Logistics

7500 AE Enschede, the Netherlands

Abstract

The operating room (OR) department of a hospital forms the heart of the organization, where the single largest cost is incurred. This document presents and reports on the "Operating Room Manager Game", developed to give insight into managing a large hospital's OR department at various levels of control, and the difficulties of applying OR/MS techniques in healthcare.

The players take on the role of management teams of the OR department, and in subsequent rounds follow the actual planning and scheduling process—starting with strategic choices on capacities for an upcoming year, and ending with daily, online planning of actual surgeries in each operating room—. The game ends with each team also benchmarking and evaluating the strategies of all players.

The game is motivated by the actual setting of a large academic hospital in the Netherlands, which also provided real-life data. It is currently used as part of the lecture on "Optimization of Healthcare Processes" in the Industrial Engineering & Management master's program at the University of Twente. It integrates students' foreknowledge regarding various OR/MS subjects, applied in a healthcare setting.

1 Introduction

While healthcare is one of the largest industries in the developed world, it is surprising that only few operations research people have specialized in this field (Carter, 2002). Since this observation, healthcare expenditures have only risen and are expected to do so for decades to come. Healthcare managers are traditionally focused on providing the best possible service. They neither have the training nor the knowledge to make the best use of resources, and they do not appreciate what OR/MS has to offer (Carter, 2002). Strengthened further by the dreadful state of healthcare information systems and data, hospitals typically have a low level of efficiency.

In the Netherlands, this is no different. Due to the severe waiting list problems and an ageing population, the public has pressured Dutch hospitals to increasingly focus on optimizing their efficiency (see e.g. Better Faster Program, 2003). As a result, there is an increasing demand for hospital (department) managers who can redesign processes and optimize resource efficiency using techniques that have been proven successful in other industries. Such a job requires competences in many fields, such as OR/MS, logistics, healthcare policy and finance, quality management, management of technology innovation, ethics, and human resource management. Since every management decision affects the health and well-being of both individuals and communities, possible outcomes of decisions must always be carefully evaluated (ACHE code of ethics, 2006). As nicely illustrated by Glouberman and Mintzberg (2001), a hospital is a professional organization where multiple decision-makers have conflicting objectives. When striving for efficiency, hospital managers must not neglect other objectives like the quality of labor and especially the quality of care.

In the Netherlands, there is a lack of healthcare managers that have the combined aforementioned competences. On the one hand, traditionally, healthcare management master programs insufficiently address OR/MS techniques and logistics. On the other hand, production and logistics master programs predominantly focus on manufacturing industries and the transportation sector, and mostly ignore the public sector. In light of this background, in 2005, we designed a new course “Optimization of Healthcare Processes” for the Industrial Engineering & Management master’s program of the University of Twente in the Netherlands. The aim of this course is to bridge the field of “Production and Logistics Management” with “Healthcare Technology Management”. Instead of addressing all possible areas of healthcare process optimization, which would hardly allow any thorough study, this course focuses on a specific case study: the operating room. This allows a more in-depth study, and an integration of foreknowledge regarding various OR/MS subjects, applied in a healthcare setting.

This paper describes the Operating Room Manager Game, which plays a central role in this course. The Operating Room (OR) department is one of the key hospital resources, as 60-70% of all hospital admissions are caused by surgical interventions. It is a highly complex environment, where multiple stakeholders act with conflicting interests. It has a high interdependency with other hospital departments, high labor and resource dependency and intensity. Aside from these complexities, OR managers are faced with continuous public pressure for high quality care and cost effectiveness. In other words, OR management encompasses all the aforementioned difficulties of healthcare management.

In the Operating Room Manager Game, each player—usually a small student group—is the manager of a virtual operating room department. In a series of four rounds, the players get acquainted with all hierarchical levels of control, and many facets of the complexity of healthcare management. They must apply their foreknowledge concerning subjects like: planning and scheduling, financial management, simulation, organization management, combinatorial optimization, healthcare management, and quality management. Each player must try to design the "best" operating room department, regarding multiple objectives including efficiency, quality of care, and quality of labor. The winner of the game is selected by benchmarking (using Data Envelopment Analysis, DEA), combined by voting. Parallel to the exercise classes in which the game is played, in a series of lectures we address various relevant healthcare process optimization topics, case studies, and techniques. In addition, guest lecturers (a.o. an OR department manager, a clinician, a hospital staff planning software company representative, and a healthcare simulation consultant) provide useful information and ideas for the players to use in the game.

In the following, we present the Operating Room Manager Game, outlined as follows. Section 2 gives a literature overview of hospital management games. In Section 3 we discuss the target group, the objectives, and the learning aspects of the Operating Room Manager Game. Section 4 gives a game description, discusses the tools we use to play the game, and possible extensions of the game. Section 5 discusses our past experiences with the game, and in Section 6 we give some conclusions.

2 Literature review: hospital management games

Generally speaking, simulation based medical games that are used both in classroom teaching and employee training mostly focus on medical skills required for physicians (Lane *et al.*, 2001). For hospital management and planning, there are also games that specifically deal with these issues. We give a short overview of existing work in this area.

Focusing on the processes inside a hospital, "ASTERIKS" (Schwarz, 1992) is a game that deals with scheduling issues of departments. Based on simulations, the game evaluates the introduced operational routines, appointment systems, and investment choices of the players. At the beginning of the game, players are able to identify their own set of goals based on patient and staff satisfaction, length of stay, and utilization of resources. However, this game is no longer available.

Specifically dealing with the Canadian healthcare system, the "Canadian Hospital Executive Simulation System (CHESS)" (Pink *et al.*, 1991), simulates the key management decisions of a hospital. Modeling the German healthcare reimbursement system, the game "KLIMA" evaluates managerial decisions on, e.g., production, investment, and staff planning. It has been updated to include the German DRG-based system in Schwandt (1998). In order to familiarize players with the Australian DRG system, Cromwell *et al.* (1998) simulate a hospital where the players learn how costs are influenced by case-mix decisions, and how case-mix data can be used for monitoring.

Recently, the internet-based management game "COREmain" (Rauner *et al.*, 2006; Kraus *et al.*, 2006) has been announced. Here, different hospitals in a specific region compete over a period of several periods. The main goal of the game is to illustrate the effect of different reimbursement systems and the resulting choices in capacity planning and patient admission. Players have to consider the areas of financial, resource and process management, also with respect to their competition.

Finally, we also mention the commercial single-player strategy games like Theme Hospital and Hospital Tycoon, which both revolve around hospital management in a real-time simulation setting. Although they familiarize the player with many hospital management aspects, these games are focused rather on entertainment than education.

3 Objectives of the game

Section 3.1 discusses the learning aspects of the Operating Room Manager Game, and Section 3.2 discusses the target group for the game.

3.1 Learning aspects

As discussed in the introduction, this game was designed for the course "Optimization of Healthcare Processes" for the Industrial Engineering & Management graduate program at the University of Twente in the Netherlands. As this course is at the end of the program (just before the graduation project), in previous courses the students have been familiarized with typical OR/MS subjects like: combinatorial optimization, queuing theory, simulation, advanced planning and scheduling, transportation and supply chain management, warehousing, purchasing, organization management, production and logistics management, and financial management. Perhaps the most important learning aspect of the Operating Room

Manager Game is the *joint application of earlier learned OR/MS techniques* in a specific in-depth case study, which deals with *typical healthcare management issues*. These include techniques like: financial management, planning, offline and online scheduling, simulation, and benchmarking / performance analysis.

The players apply these techniques for decision making at multiple levels of planning and control. As a result, they learn the operational consequences of strategic decisions taken earlier. In particular, in Round 1, the players must make several strategic decisions concerning the size of the department (i.e., the number of inpatient/outpatient/emergency rooms and their staffing), and tactical decisions concerning the allocation of capacity to specialties. Given the chosen configuration of the operating room department, in Round 2 (operational decision making), elective patients must be scheduled in these rooms for the upcoming planning period keeping in mind uncertainties that may arise. In Round 3 (online operational decision making), the entire operating room department and the schedule from the previous round are simulated, and all uncertainties materialize such as emergencies and no-shows. Here, the effects of the strategic decisions made in Round 1 are felt the most, and the players experience the effect of uncertainty. The performance of the designed system is evaluated in Round 4, in which all players are benchmarked against each other using DEA techniques. The players thus learn from each others practices, successes and failures, as is the idea of benchmarking.

Another key learning aspect is that players must base their decisions on many criteria, not all of which are quantifiable. Also, typical for healthcare, there are multiple performance criteria to focus on, and some of these are conflicting. Many performance measures like the number of cancelled patients, average overtime per operating room, and utilization are easily measured. However, quality of work and equity aspects are much harder to quantify.

During the lecture we invite a number of guest lecturers who are involved in healthcare management and process optimization in healthcare. These include: an operating room department manager, a clinician, a representative of a company that develops hospital staff planning software, the project coordinator of the Dutch operating room benchmarking project, and a healthcare simulation consultant. They provide useful information and ideas for the players to use in the game, and an overview of current trends and developments.

3.2 Target Group

The Operating Room Manager Game is targeted for students of Industrial Engineering & Management, Applied Mathematics, Production, Logistics & Operations Management, and Health Care (Technology) Management. In the form we have played the game, knowledge of simulation software and basic programming skills is required. However, if a ready-to-use simulation model would be supplied, in which the game choices could be made and analyzed immediately without any programming, the game could also be played by healthcare practitioners who do not have these programming skills. This is subject of further work.

4 Game description

In the hospital's operating room (OR) department, at most 25 operating rooms can be staffed and prepared to accommodate patients and perform surgery. During the game, the players have to organize the OR department, i.e. staff a number of ORs, and accommodate patients.

4.1 Rounds of the game

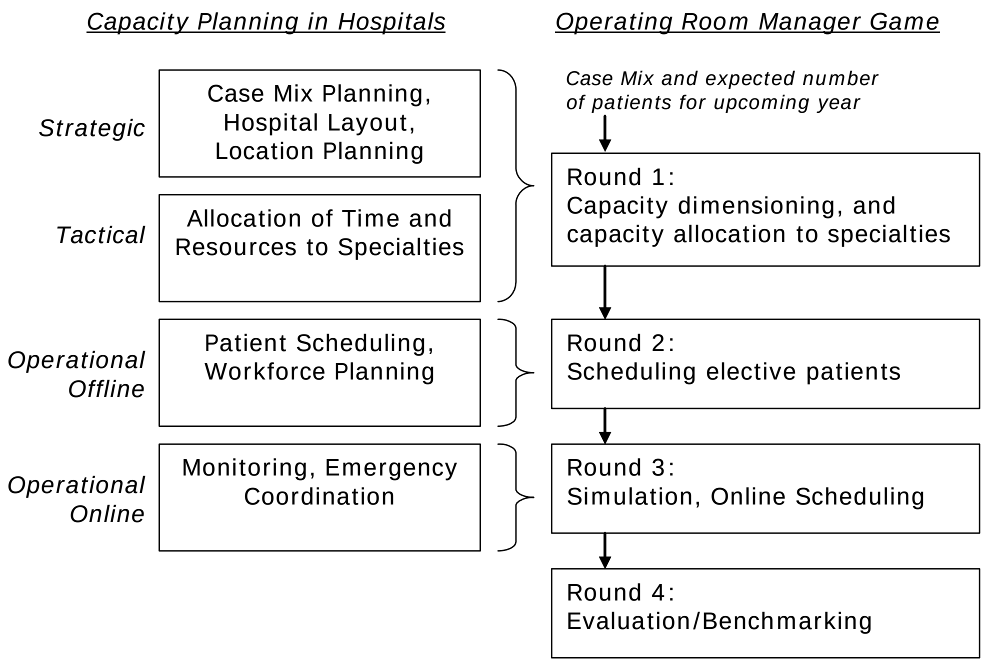

Figure 1: Capacity planning and control in hospitals and the Operating Room Manager Game.

The OR-management issues are introduced step-by-step in four assignments that correspond to the four rounds of the game and that closely map planning and control in reality (see Figure 1). In Round 1, strategic and tactical management choices are made concerning respectively system characteristics and capacity allocations, and a set of evaluation criteria are selected and motivated. These management choices include, e.g., the actual number of staffed operating rooms, their division over the specialties, and the possible separation of dedicated inpatient, outpatient and emergency rooms. The choices made form the input for Round 2, where a scheduling strategy of assigning the elective patients to the ORs is to be developed. The resulting schedule, a list of patients per OR per day for a planning period of 52 weeks, is used for Round 3, which deals with the operational level. Here, a simulation study is used to evaluate the performance of the OR-department. During the simulation all uncertainty materializes, e.g. regarding surgery durations, no-shows and emergency patients. Like day-coordinators in the OR department, the players must implement online scheduling rules to deal with these uncertainties. As input for the next round, a number of performance measures are calculated, such as cancelled patients, overtime, and utilization. In Round 4, the winner of the game is determined by the players. The system characteristics and performance of each player is handed out to all groups. Using this information, each group has to determine the best OR-manager based on their own set of performance criteria chosen in Round 1. To support this analysis, we shall use the benchmarking technique Data Envelopment Analysis (DEA).

We now continue to present each round in more detail, and also give the specific assignments of these. We provide some background information on how each round finishes from the point of view of the players, and the game manager. We would like to point out that once a round has finished, a player may not come back to the decisions taken and change these. The reason for this lies in the fact that we would like the players to think about their choices, and motivate them beforehand. In addition, this approach leads to a variety of OR department configurations and planning ideas, of which a comparison is of interest even from a scientific point of view.

4.1.1 Round 1: Strategic Management Decisions

At the start of the game, the players are told about the outcome of the meeting between the hospital board and the health insurers. An agreement for the upcoming year concerning the case mix to be performed at the hospital and the expected number of elective patients is presented. In total, there are 17,000 patients to be treated, divided over the 10 specialties as given in Table 1.

Specialty	*Relative part of total patient volume*
1. General surgery	0.181
2. Gynecological surgery	0.094
3. Oral surgery	0.073
4. ENT surgery	0.155
5. Pulmonary surgery	0.018
6. Neurosurgery	0.056
7. Eye surgery	0.115

8. Orthopedic surgery	0.088
9. Plastic surgery	0.109
10. Urological surgery	0.111
Total	1.000

Table 1: Division of patients over the specialties

Furthermore, a detailed list of surgery characteristics is given for each specialty. Actual surgeries are divided into categories, and for each category, relative frequency, expected duration, and standard deviation are given (see Table 4 in the Appendix). Additionally, there is a distinction between inpatients that stay for at least one night in the hospital and outpatients that can leave the same day. Of the outpatient group, approximately 10% do not show up on the planned day of surgery. Of the inpatient surgeries, approximately 5% have to be cancelled, e.g. due to insufficient capacity at the wards or in the ICU, or that are medically unfit for surgery. These values cannot be influenced by the players.

Of course, these data can only represent the elective patients which allow for some advanced planning based on the presented aggregates. Emergency patients on the other hand cannot be planned beforehand. They may arrive at any point in time, and have to be helped as soon as possible. Nevertheless, capacity for these types of surgeries should be taken into account. Based on historical data, some average numbers of emergency surgeries are also given in Figure 2, together with their average duration in Figure 3.

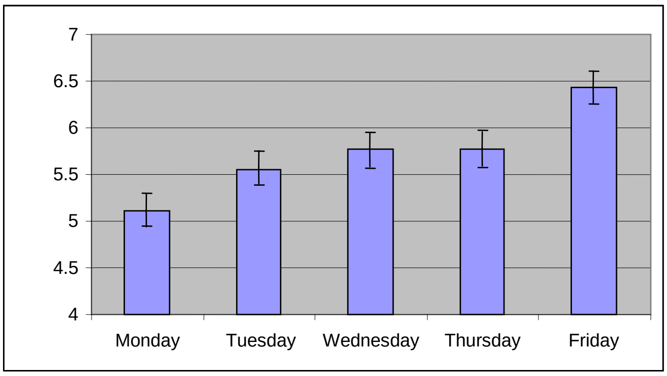

Figure 2: The average number of emergency surgeries during the day (including 95% confidence interval of the mean).

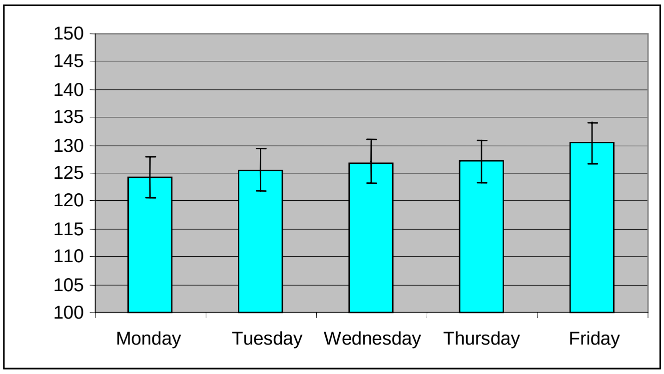

Figure 3: The average duration of an emergency surgery during the day in minutes (including the 95% confidence interval of the mean).

At the hospital, up to 25 rooms can be staffed and prepared to perform surgeries in. During a surgery several professionals are present in an OR. We distinguish five different types of professionals: surgeons, anesthetists, anesthesia assistants, surgery assistants, and holding staff. The surgeons are employed by the respective specialties, and thus do not have to be accounted for by the OR department. However, in each specialty, there are only a limited number of specialists available during the week, see Table 2.

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

Table 2: Available surgeons per specialty.

Anesthetists, anesthesia and surgery assistants are members of the OR department as they are used for surgeries of any surgeon and specialty. Of course there are personnel and fixed costs involved in the decision to open an OR; these are given in Table 3. Here, the actual OR costs include staffing with holding staff.

Subject	*Annual cost (€)*
1 anesthesia assistant	60,000
1 anesthetist	170,000

1 surgery assistant	60,000
1 generic inpatient OR	500,000
1 dedicated inpatient OR	400,000
1 emergency OR	400,000
1 outpatient OR	350,000

Table 3: Fixed annual personnel and OR costs

As can be seen, there is a distinction between ORs used for inpatient, outpatient, and emergency surgeries. As we shall explain below, inpatient ORs can be dedicated or generic. A dedicated inpatient OR can be used by one specialty during a day, a generic inpatient OR can be used by all specialties throughout the day. As a result, a generic inpatient OR is more expensive. While a generic/dedicated inpatient OR can also be used to perform outpatient and emergency surgeries as well, the latter two types are dedicated to these types of surgeries. In terms of staffing, an inpatient OR requires at least 0.5 anesthetists (i.e. 1 anesthetist per 2 ORs), 2.4 surgery assistants, and 1.1 anesthesia assistants. For an emergency OR, the same requirements must be met. An outpatient OR needs at least 0.25 anesthetists, 1 surgery, and 1 anesthesia assistant. Sharing personnel between different types of rooms is not allowed.

Each operating room opens for 450 regular minutes per day, Monday to Friday. Overtime is costly and restricted by collective labor agreements. However, due to the variability in surgery times, it cannot be avoided. To avoid overtime and patient cancellations, the players have to abide by the hospital board decision which poses a bound on the probability of overtime. All surgeries have to be completed within regular time with a probability of at least 69%. A surgery is cancelled on site if more than 20% of the expected duration is in overtime. To avoid this, and to deal with variations in surgery durations, hospital management demands that sufficient slack (reserved time) is planned in each OR. Assuming for simplicity that the total planned surgery duration is normally distributed, to obtain a probability of 69% that surgeries are completed within regular time, the planned slack must be at least 0.5 times the standard deviation of the total planned surgery duration.

In addition to the strategic choices concerning the number of operating rooms to be opened, their staffing and possible division into inpatient / outpatient / emergency rooms, each player has to make a tactical choice regarding the allocation of the inpatient OR capacity to the specialties. While outpatient ORs can always be used by any specialty (i.e. they are generic ORs), inpatient ORs may either be dedicated to a specialty, or made generic (i.e. such that all specialties may use this OR every day of the week). Dedicated inpatient ORs may be given to a different specialty on any day of the week which reduces the costs by € 20,000 annually, however, every week must be the same. The advantage of a dedicated OR is that surgeons will usually work in only one OR. As a result, if a surgery's duration is longer than expected and the surgeon must perform another surgery afterwards, this will not lead to waiting time/unused capacity in another OR. Also, the scheduling of elective patients becomes easier. The advantage of generic ORs is that this provides more planning flexibility.

Summarizing, the first round ends with the players having made motivated strategic decisions on the number of operating rooms to be opened, their staffing and possible division into inpatient, outpatient, and emergency rooms. In addition, the players have made tactical decisions regarding the allocation of inpatient OR capacity to specialties.

4.1.2 *Round 2: Operational Scheduling*

Based on the strategic and tactical capacity decisions of the previous round, which are now considered fixed and may not be changed, operational control and offline planning is the focus of this round: the players have to assign and schedule the elective patients in the operating rooms on the particular days.

As input for this round, the players are presented a list of roughly 17,000 elective patients, including all characteristics needed for scheduling them. In particular, for each patient, a unique identifier, the week in which he is to be operated, and the surgery type (including expected length, duration standard deviation, in-/outpatient information, and specialty) are given. The players have to design, describe, and implement two algorithms for the offline planning process: a constructive heuristic that assigns the patients to a specific OR/day combination and a local search method that can be used to improve an existing solution. The optimization criteria have to be determined (and motivated) by the players. At this stage of the planning process, the sequence of patients in each OR is of less importance, this is resolved by the online scheduling of Round 3. However, choices like dedicated outpatient operating rooms and surgeon availability cannot be neglected.

A tool for the construction of the algorithms is given to the players. The focus of this round is not on implementation, but on the approach and its motivation. To this end, a programming framework has been developed using Delphi in which data structures and several supporting procedures are already present. In this framework, the decisions of Round 1 are included, and the algorithms can be tested, and solutions can be verified and analyzed (see screenshot in Figure 4). The program also provides an OR schedule Gantt-chart component, which can be used to visually inspect solutions. Basically, there exists a complete planning tool which only lacks the implementation of the actual optimization that is required by this round's assignment.

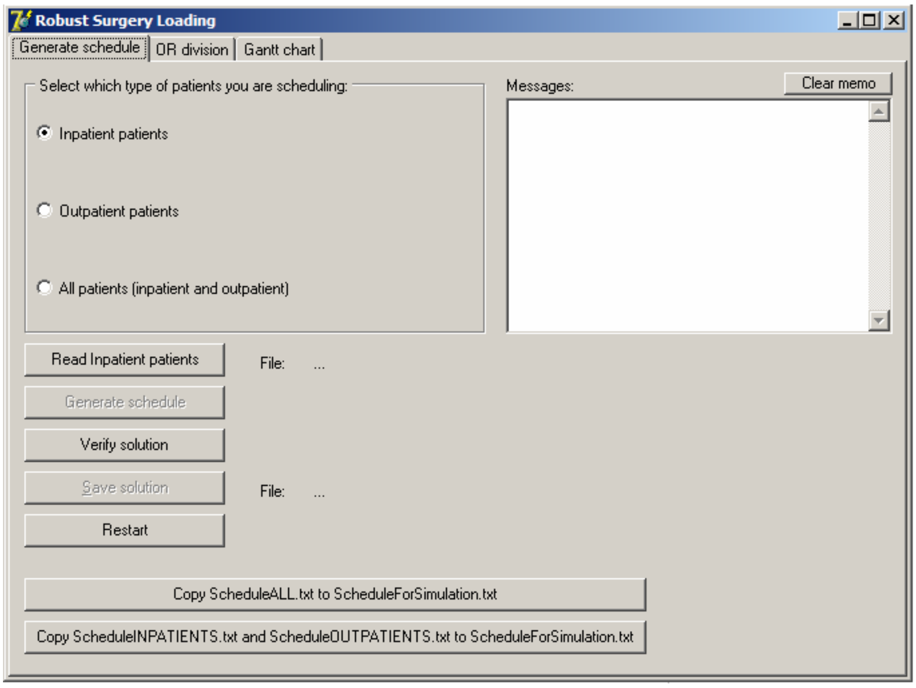

Figure 4: Example Delphi program window for Round 2.

Furthermore, as mentioned earlier, in order to ease the later planning process, we allow the assignment of OR/day combinations to specialties (see screenshot in Figure 5). There, the players can allow or disallow the use of a specific OR for the specialties per day of the week. Note that in this round, possible dedicated emergency ORs do not play a role. However, if a group decided against such an approach, emergencies arriving should be kept in mind when assigning patients to ORs.

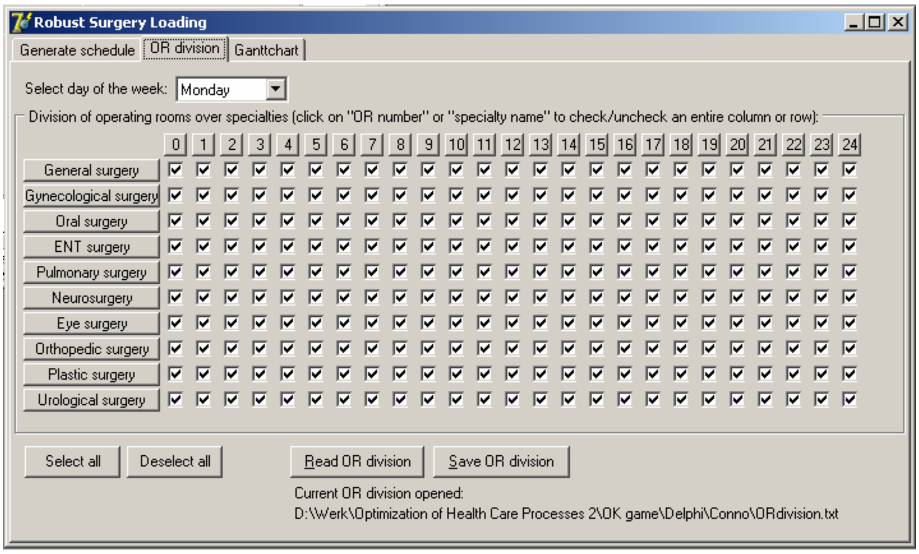

Figure 5: Dedicated operating rooms for specialties.

The outcome of this round thus consists of a detailed schedule that gives each elective patient a day and an OR for surgery. Each player is also required to hand in a small report justifying the approaches taken for the planning algorithms.

4.1.3 Round 3: Online operational control

This round is about running the OR department on a daily basis. This is done with the help of a (provided) discrete event simulation model of the OR department designed in the previous rounds. Each day, the waiting rooms for the ORs are filled with the elective patients as decided in Round 2. Note that there might be cancellations, and an OR can thus be empty during the course of the day. In the simulation, an OR planner (an entity of the simulation model) takes care of the daily operations in each operating room. The players perform the task of an advisor. Basically, the players have to respond to two types of questions the OR planner poses during the course of each day: what to do with an empty OR and where to treat an arriving emergency patient (see Figure 6). These questions are triggered by corresponding events in the simulation.

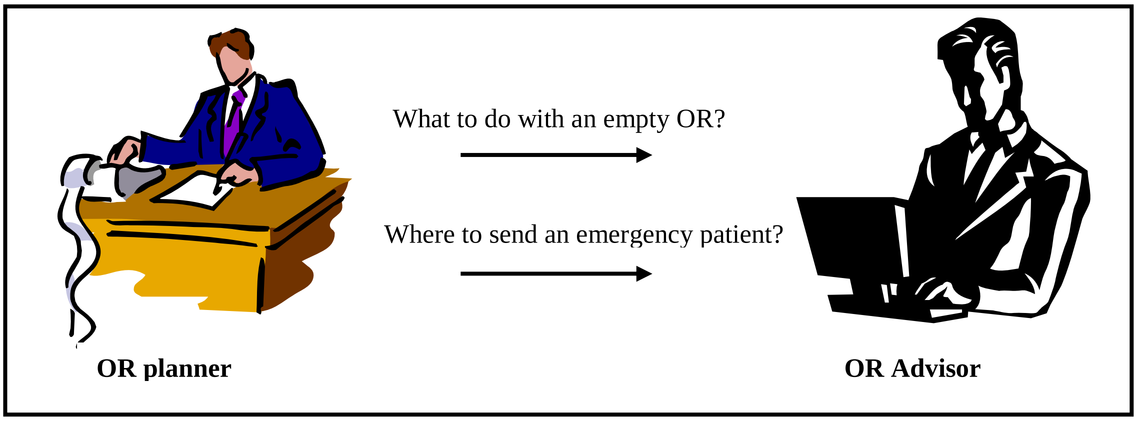

Figure 6: Interaction between simulation (OR planner) and player (advisor).

For the two questions asked by the simulation, the players have to correspond as follows.

- *Empty Operating Room*

  This question is posed after a surgery has finished, and no patients are waiting in the waiting room of the OR. The players can then decide whether to operate on another patient, or to leave the room empty. In case the next patient is to be helped, the name has to be given.

- *Arriving Emergency Patients*

  This question is posed upon the arrival of an emergency patient. The players then have to give the operating room where the patient is to be treated. If that OR is empty, the patient is helped immediately. Otherwise, the patient is placed in the respective waiting room, at the front of the queue. An emergency patient may not be cancelled.

The answers to the above requests by the OR planner are given by implementing an online algorithm for the simulation environment.

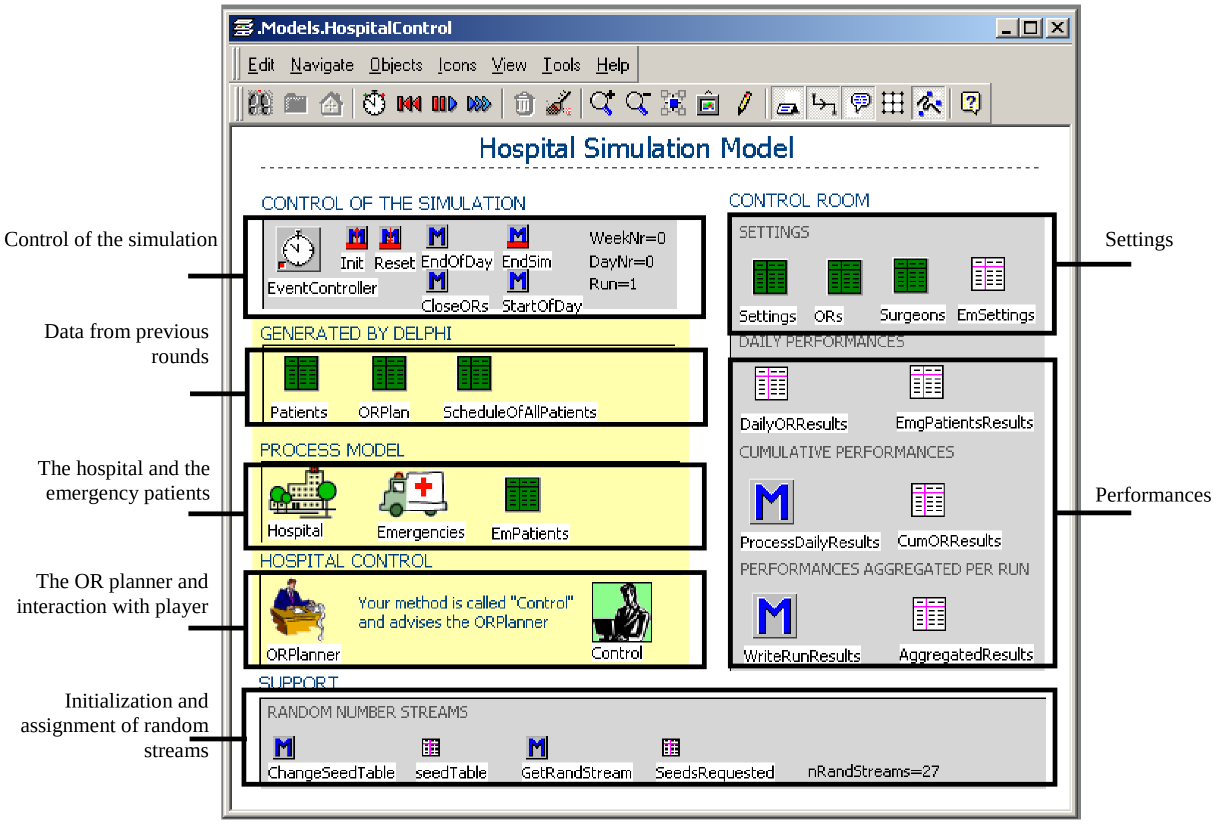

Figure 7: Simulation model for the OR department.

An overview of the simulation is presented in Figure 5. In addition to the questions from the OR planner, the players have access to information on the planned patients for each day. Since actual surgery times and emergency patients are not known in advance, there is also some limited information about the status of an ongoing operation in each OR, which helps the decisions to be taken ad hoc.

There are several performance measures which are calculated and registered during the simulation, including OR utilization in regular time, unused regular OR time, overtime, the number of cancelled patients due to insufficient capacity, and the average waiting time for arriving emergency surgeries. These performance measures are written to a text file, which is used as a basis for Round 4, the benchmarking of all players' OR departments.

4.1.4 *Round 4: Evaluation and Benchmarking*

In the final round of the game, the players conduct a Data Envelopment Analysis (DEA) to benchmark the competing OR departments. Having different perspectives on how an OR department should be managed, the performance indicators ("input" for the DEA) and system characteristics ("output") vary over the groups. Nevertheless, each group must choose and motivate a set of weighing factors, and then evaluate all approaches accordingly.

The overall analysis is based on the decisions taken in previous rounds, and not only on the results from the simulation in Round 3. In the end, each group determines a ranking. Additionally, the players are asked not only to reflect their own approach, but also to give advice to other groups in areas which they deem insufficiently organized. In a concluding session, the players have to present these results. Finally, the winner of the game is selected by voting.

4.2 Useful resources

In Round 1, the required calculations can be done with Microsoft Excel. Round 2 involves implementing an algorithm for assigning patients to ORs. For this purpose, any basic programming language suffices. We use Borland Delphi, and provide a basic user interface and data structure, so that the players can focus on designing and implementing the algorithm, instead of designing a user interface. We also provide an OR schedule Gantt-chart component, which can be used to inspect solutions in the Delphi application. The tool also provides a procedure to export an OR schedule to a basic text file, which is used as input for the simulation model in Round 3. This round requires the use of a discrete event simulation tool. We use Tecnomatix eMPower, but there are alternatives such as: ProModel/MedModel, Simul8, Arena, Enterprise Dynamics. Finally, Round 4 is based on the use of an LP solver or a DEA tool. There are quite a few commercial and non-commercial DEA tools available, standalone, or as add-in for Microsoft Excel (see e.g. Zhu, 2003).

4.3 Game extensions and variations

The Operating Room Manager Game was designed for a graduate course with a maximum workload of 160 hours, including the lectures. There are, however, quite a few possible extensions and variations of the game. Based on the experience we have with this game, we suggest these possible extensions/variations:

- Simulate each week as a single round. In Round 2, the players have to assign patients to the OR for an entire year in advance. This planning horizon is quite unrealistic, but it yields an instance that is large enough for the following round. In practice, such a schedule is typically created about a week in advance, and only for a single week at a time. A possible extension would therefore be to divide the second round into smaller planning horizons, which are evaluated by simulation just like in Round 3, and then allow for adjustments in the planning of weeks that are still to come.

- To obtain a probability of 69% that elective surgeries complete within regular time, the players now have to plan 0.5 times the standard deviation of the total planned surgery duration slack time in each OR. This restriction could be omitted, such that the players can develop their own approach for dealing with variation. Comparing these approaches may give some interesting insights.
- Usually, each operating room uses specialized equipment, in this game we assume this equipment to be mobile, and thus available in all rooms. Introducing specialized equipment mainly has financial consequences, but may also limit the choices in OR scheduling. The choices in OR scheduling can be limited further by including nurse scheduling aspects.
- An additional round can be introduced, before the current Round 1, in which the players have to make agreements with health insurers about the case mix and number of patients they shall focus on. This would introduce an interesting dynamic to the game, as specialized, and different sized OR department may emerge, which will be benchmarked against each other.
- A common reason for surgery cancellations is the unavailability of an ICU bed. In many hospitals, the OR and ICU department are not planned integrally (van Oostrum et al., 2006). Moreover, specialties often do not coordinate amongst each other how many patients are expected to require an ICU bed. For every patient category, an additional property could be introduced, which indicates the probability that a patient requires an ICU bed after surgery, and e.g. the expected length-of-stay at the ICU. This is a step towards patient flow coordination / care pathway logistics. Consequently, the OR scheduling in Round 2 has to consider ICU capacity restrictions, and the simulation model in Round 3 should include the ICU department. Here, the ICU department also receives patients from other sources, such as the ER and wards.
- By fixing the scheduling algorithms in Round 2 or 3 to straightforward rules like best or first fit, the game can be shortened. By providing a list of standardized scheduling approaches, and online scheduling rules, the players can focus on capacity decisions and

explore the operational effects of these. Similarly, the focus can be shifted towards scheduling approaches only, by fixing the capacity decisions. This will allow the game to be played for example as part of shorter classes or tutorials for practitioners.

Of course this list is incomplete; the authors welcome any ideas concerning extensions and variations of the game.

5 Experiences with the game

We play the game during a period of 8 weeks. In every week one or two (guest) lectures are planned, and one 2-hour exercise class, where support is given for the game. The players are formed by groups of two. The time given to the players for each assignment is as follows. Round 1: 1 week, Round 2: 2 weeks, Round 3: 3 weeks, Round 4: 2 weeks. A student's total workload for the game is estimated to be no more than 120 hours.

Thus far, we have played the game twice, in 2005 and 2006. In these two years, the game has become very popular: the number of students that have chosen this course has more than tripled. In the assessment of 2005, the game received a very high rating from the students. The players are very fanatic, as our reward for the winners is an excursion to a real operating room. Both years, the game has led to a wide variety of OR department configurations and planning ideas, of which a comparison is of interest even from a scientific point of view. Players for which the chosen OR configuration in Round 1 is (almost) the same, end up with very different results in Round 4, because of the many choices for tactical and (offline and online) operational planning. On request, lecturers can obtain example results of the game from this year.[1]

6 Conclusions

In a time where process optimization in healthcare becomes increasingly popular amongst operational researchers, the Operating Room Manager Game offers a powerful concept for acquainting students with the application of OR/MS techniques in healthcare. Through a series of rounds, the planning process of an OR department is followed. The game explicitly does not have a given goal for winning (e.g. most profit), but let's each group decide on their important measures at the beginning. This way, different strategies emerge that are

---

[1] *Note: the game/benchmarking results of this year are available within a few weeks. If desired, these can be included in this paper.*

benchmarked at the end to determine a winner. Also, there are many possibilities for variations and extensions.

References

- ACHE code of ethics (2003), http://www.ache.org/ABT_ACHE/code.cfm, American College of Healthcare Executives.
- Better Faster Program (2003), http://www.snellerbeter.nl/english/, website of the hospital performance improvement program, started by the Netherlands Ministry of Health, Welfare and Sport and the Dutch Hospital Association in November 2003.
- Carter, M.W. (2002), "Diagnosis: Mismanagement of Resources," *OR/MS Today*, Vol. 29, No. 2, pp. 26-32.
- Cromwell, D.A., Priddis, D. and Hindle, D. (1998), "Using simulation to educate hospital staff about casemix", *Health Care Management Science*, Vol. 1, No. 2, pp. 87-93.
- Glouberman, S. and H. Mintzberg (2001), "Managing the care of health and the cure of disease: Part I: Differentiation, Part II: Integration," *Health Care Management Review*, Vol. 26, No. 1, pp. 56-84.
- Kraus, M., Gesselbauer, J., Rauner, M. and S. Schwarz (2006), "The COREmain hospital game: implications for teaching, research, and policy making", presentation at the *INFORMS* international meeting, Hong Kong, June 25-28.
- Lane, J.L., Slavin, S. and A. Ziv (2001), "Simulation in Medical Education: A Review," *Simulation & Gaming*, Vol. 32, No. 3, pp. 297-314.
- Van Oostrum, J.M., Van Houdenhoven, M., Hurink, J.L., Hans, E.W., Wullink, G., and G. Kazemier (2006), "A master surgical scheduling approach for cyclic scheduling in operating room departments", to appear in OR Spectrum.
- Pink, G.H., Knotts, U.A., Parrish, L.G. and C.A. Shields (1991), "The Canadian Hospital Executive Simulation System (CHESS)," *Healthcare Management Forum 1991 Spring*, Vol. 4, No. 1, pp. 16-23.
- Rauner, M.S., Kraus, M. and S. Schwarz (2006), "Competition under Different Reimbursement Systems: The Concept of an Internet-Based Hospital Management Game," to appear in *European Journal of Operational Research*.
- Schwandt, S. (1998), "Entwicklung eines Planspiels zum Klinikmanagement mit Fallpauschalen-orientierter Finanzierung: KLIMA FORTE (in German)," Ph.D. Thesis, University of Erlangen-Nuremberg, Germany.
- Schwarz, S. (1992), "ASTERIKS - a Management Game for Hospitals," *Journal of Social Health Systems*, Vol. 3, No. 3, pp. 5-14.
- Zhu, J. (2003), *Quantitative Models for Performance Evaluation and Benchmarking: DEA with Spreadsheets and DEA Excel Solver*, Springer / Kluwer Academic Publishers, Boston.

Acknowledgements

The authors acknowledge *Mark van Houdenhoven* and *Gerhard Wullink* of the operating room department of ErasmusMC, Rotterdam, for kindly providing data and valuable ideas for the Operating Room Manager Game; and *Renata Kopach* of Purdue University for kindly reviewing the game and providing valuable ideas.

Appendix

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

Table 4: General elective surgery duration characteristics (Excel file)