Game

The BedGame—A Classroom Game Based on Real Healthcare Challenges

I. M. H. Vliegen,ᵃ M. E. Zonderlandᵇ,ᶜ

ᵃ Department of Industrial Engineering and Innovation Sciences, Eindhoven University of Technology, Eindhoven, The Netherlands;
ᵇ Centre for Healthcare Operations Improvement and Research, University of Twente, Enschede, The Netherlands; ᶜ Zonderland
ZorgLogistiek, Laag-Soeren, The Netherlands
Contact: i.m.h.vliegen@tue.nl (IMHV); m.e.zonderland@utwente.nl

Abstract. The BedGame is a classroom game to introduce Operations Management (OM) in healthcare, more specifically to introduce the effects of centralized versus decentralized planning, and the concepts of variability and queueing theory. In the BedGame, players assign medical and surgical specialties to nursing wards to obtain a balanced bed distribution, while fulfilling as many of the specialty-specific requirements as possible. The game was first designed to support decision making in a hospital in The Netherlands, and afterwards converted to a classroom game. The game has been successfully used in several courses at the University of Twente including "Operations Management in Health Care" (undergraduate), "Quantitative Methods for Operations Management in Health Care" (graduate), and a course on patient logistics for healthcare professionals.

1. Introduction

In 2006, the Dutch government dramatically reformed the healthcare sector and the underlying financial system (Westert et al. 2009). The reforms were designed to decrease costs and improve efficiency. Since residents of The Netherlands are obliged to buy health insurance, the government decided to give the health insurers a major role in enforcing a new paradigm of market thinking in the Dutch healthcare system. Since the financial funds and thus the supply of healthcare is finite, policy makers must ration care and make choices on how to distribute physical, human, and monetary resources. Such choices must be made on a hospital level and on a departmental level.[1]

Together with changing healthcare demand, many hospitals face complicated capacity decisions. This was also the case at Leiden University Medical Center (LUMC), one of the eight university hospitals in The Netherlands. The game we describe in this paper was first designed to support the decision-making process in the reorganization of the nursing wards at the LUMC, where a new allocation of specialties to nursing wards was made. Subsequently, it was developed into a classroom game.

In the game, we consider a hospital with two buildings, each with several wards. There are multiple medical and surgical specialties in the hospital. The number of beds (i.e., the capacity) of each ward is known, as well as the expected number of patients arriving per day and the average length-of-stay (LOS) in days (i.e., demand) for each specialty. Specialties have preferences and/or requirements with regard to their locations in the hospital. Each player is responsible for ten (parts of) specialties,[2] and needs to allocate each one to one of the wards. The goal is to make this allocation in such a way that the requirements and preferences are fulfilled as much as possible, while the blocking probability, i.e., the probability that all beds are occupied and an arriving patient is blocked, is acceptable. The game is played in two rounds. In the first round, players only consider their own specialties while allocating their specialties to the wards; in the second round a group consensus about the allocation needs to be reached. Several concepts are discussed during the game or the wrap-up, although not all in-depth.

In Section 2, we briefly describe the challenge the LUMC faced and how the game supported the decision-making process. In Section 3, we provide some background information and describe the required

Table 1. Concepts in the BedGame

Term	Description	Link to the BedGame
Queueing theory	Queueing theory is the mathematical study of waiting lines or queues. Modeling a waiting process as a queueing system facilitates calculation of several performance measures such as waiting time, time spent in the system, and use of the system.	Each ward in the game is modelled as a queue, using the Erlang Loss model. In this model, patients who cannot be admitted immediately are blocked. In real life, this means that these patients are sent to another ward or hospital, or their surgery or treatment is cancelled.
Variability in demand	The extent to which patient demand fluctuates.	If the demand and LOS would not vary, it would be possible to fully occupy all beds without blocking patients. However, due to the variability in demand (reflected by a Poisson arrival rate), some slack is needed. In the game, we therefore explicitly mention the capacity of a ward and the maximum patient load for a 5% blocking probability.
Variability in length-of stay	The extent to which patient LOS fluctuates.	
Decentralized planning	Each department makes their planning decisions individually.	In the first round of the game (i.e., decentralized planning), each player makes decisions for his specialties without taking into account the interest of the other specialties. In the second round (i.e., centralized planning), consensus needs to be reached, leading to a better overall solution.
Centralized planning	Planning decisions are made centrally, incorporating department specific targets (for example, utilization levels) and an overall target (for example, patient LOS for the entire care trajectory).	

preparation for the game. In Section 4, we describe how the game should be played. Section 5 briefly outlines our experiences with the game. Conclusions are presented in Section 6. Table 1 introduces the concepts used in the remainder of this article.

2. The LUMC Case

In the aforementioned reorganization project, the LUMC wanted to reallocate specialties to nursing wards to obtain a more balanced bed distribution. The aim was to obtain balance not only from a medical perspective (allocate specialties together on one ward for a natural combination, for instance cardiology and thoracic surgery) but also from an operational perspective (allocate specialties such that a utilization rate of 85% and a blocking probability of no more than 5% is attained[3]). One of the authors (MZ) supported the working group that was formed to develop the reorganization plan. She observed that it was difficult for hospital management to determine which patient groups could be combined in a ward from a quantitative perspective, i.e., with what combinations of specialties the desired operational performance could be achieved. Therefore, she printed a large map of the hospital with the locations of the wards. For each ward the maximum value of patient load, i.e., the daily arrival rate of patients multiplied by the average LOS in days, with a 5% blocking probability, was printed on the map.[4] Also, cards were made per specialty and type of care, for instance day patients, inpatient care, urgent, elective, etc., which indicated the patient load for this specific patient group. Hospital managers would receive cards of the specialties for which they were responsible, and could discuss with the other managers how their specialties should be allocated to the wards, given

medical requirements and the operational requirements in terms of patient load. In this way several new nursing ward designs, fulfilling the requirements, could be developed in a session that lasted only a few hours.

3. Background and Preparation

After this idea was successfully applied at the LUMC, we converted it into a game such that it could be used in a classroom environment.

3.1. Background: Goals of the BedGame

The first goal of the BedGame is to give Health Sciences (HS) students an introduction to OM. HS students are accustomed to focusing primarily on quality aspects, and sometimes ignore the effect of a decision on overall hospital efficiency. In our course, we take a "helicopter" view, and study several patient groups at once, including quality and efficiency indicators. We show students the effect of decisions on the system as a whole, and demonstrate that optimization for a single patient or patient group is not always preferable. This way, we also give insight into the effect of centralized versus decentralized planning. In the first round players only take into account their own specialties when making decisions, usually leading to a suboptimal solution. In the second round, consensus between the players is sought to reach a better solution for the hospital as a whole.

The second goal is to provide an introduction to the concepts of variability and queueing theory, both covered in more detail during the rest of the course. A common mistake in hospitals is to dimension capacity equal to the average demand; this might lead to long waiting lists or a high number of blocked patients.

In the game, we make a distinction between the number of available beds on a ward, and the patient load allowed to obtain a 5% blocking probability (assuming a Poisson arrival process). Students are allowed to assign more patients to a ward, but this will lead to a higher blocking probability, which has a penalty attached. Although we use a queueing model to determine the blocking probabilities, no specific attention is given to this in the first lecture. During a subsequent lecture on queueing theory, the bed game is discussed again when explaining the Erlang Loss model.

3.2. Preparation: Required Materials

To use the game in a classroom setting, supporting material was developed. Insights we have gained in the Center for Healthcare Operations Improvement and Research (CHOIR) research group while collaborating with hospitals throughout The Netherlands were used to make the choices described below.

The game is played with five players. To play the game, the following materials are needed:

1. *A hospital map*. Either the map provided (see the online Appendix A) or a hospital-specific map, preferably printed on U.S. size D or European size A1 paper.

The map provided is of a fictitious hospital, consisting of two buildings. For this hospital, we used demand and capacity figures that represent larger Dutch hospitals, without being case specific. The map was developed such that the supporting departments were placed in logical locations, i.e., the outpatient clinics, service and maintenance department, and the Emergency Department are on the ground floor, while the Intensive Care unit, the Operating Rooms, and all wards are on the other floors. For each of the nursing wards, the map shows the maximum patient load (demand) for a 5% blocking probability, followed by the number of beds (capacity).

2. *Playing cards*. Either the cards (fifty in total) provided (see the online Appendix B), or hospital-specific cards, with different colors per set.

The cards show the name of the specialty, some background information on whether the specialty is a surgical or medical specialty and whether it concerns in-patients or day patients, together with the patient load of this specialty. Each of the fifty cards is different with respect to the specific characteristics of the specialty. The patient load is calculated by multiplying the daily arrival rate of that patient group with the average LOS in days. Since the underlying queueing model is an Erlang Loss model, the distribution of the LOS is not relevant to calculate the blocking probability. Finally, the cards show the requirements and preferences of the specialty. The following requirements were included:

—"Close to"-requirements. For medical reasons, some specialties need to be close to the Emergency Department, the Operating Rooms or other supporting departments. Other specialties may not be situated near a specific supporting department. For example, infectious diseases is usually not in proximity to the Operating Rooms, due to increased infection risk for surgical patients. We define "close to" as on the same floor or one floor up or down as the department referred to, although a hospital-specific definition is possible.

—"In the same ward"-requirements. For some specialties, it is preferable to share a ward with another specialty, while other specialties preferably should not be in the same ward.

Five sets were made of ten cards each, reflecting the specialties allocated to the five players (the managers). Each set has a specific color to make them easily distinguishable during the game. The cards were arbitrarily divided over the sets, without considering medical similarity; only the number of points that can be gained were taken into account. More information on the point system is provided in Section 4.3.

3. *An overview of the blocking probabilities for specific ward sizes and patient load*. As provided in the online Appendix C.

This overview shows the blocking probability for a given patient load (demand) assigned to wards of different sizes (capacities); when multiple specialties are assigned to the same ward, the total patient load over all assigned specialties must be considered. The blocking probabilities are calculated using the Erlang loss formula, assuming a Poisson arrival rate to the system, see Zonderland and Boucherie (2011) for details.

4. *Two scoring forms*. As provided in the online Appendix D.

5. *A pencil*.

6. *A dice*.

A presentation including an introduction to the game and a wrap-up is also useful. The authors can provide a PowerPoint presentation on request.

4. Playing the Game

As said, the game is played with five players, in two rounds. In the first (i.e., the individual) round each player plays for his own specialties; discussion is not allowed. In the second round, discussion is allowed, and players are asked not only to take into account their own preferences but also those of the hospital. After each round the score is determined for each player.

4.1. Round 1: Individual Round

Usually, a certain hierarchy exists in a hospital, where one specialty implicitly has more power than another. In the first round of the classroom game, we take this into account creating two random power assignments. At the beginning of the individual round, the order in which players are allowed to assign specialties to wards is determined by throwing a dice.

Then, for each playing round a player throws the dice another time to determine the number of specialties to assign (1 = 1 specialty, 6 = six specialties), starting with the player with the most power.

This is continued until all players have placed all cards, i.e., all specialties are assigned to a ward. Afterwards, the scores are determined.

4.2. Round 2: Discussion Round

In the discussion round, players must reach a consensus over the assignment of specialties to nursing wards. No direction is given on how this consensus should be reached, but a discussion on the method used can be interesting, see Section 4.4. A time limit of 10 minutes may be set. Afterwards, the scores are determined.

4.3. Scoring

The scores of each player can be determined by examining the requirements fulfilled and the penalties received. The "close to" and "in the same ward" requirements as explained in Section 3.2 lead to a bonus if fulfilled, which is shown on the cards.

Penalties are given when the blocking probability in a certain ward exceeds 5%, given the total patient load of all specialties assigned. The specialties know on average how many patients to expect. However, due to variability more beds are needed to ensure a sufficient service level. The players are allowed to assign a larger patient population (i.e., patient load) to a ward than suggested on the playing board, but this might lead to more refused patients (i.e., higher blocking probability). One penalty point is given for each percentage point by which the blocking probability exceeds 5%. This penalty applies for all specialties that have patients at the ward considered. An overview of the consequences of a higher utilization is given in Appendix C. Appendix E shows an example counting for one ward.

When all points are counted in the first round, the second round can be started. After all points are counted in the second round, a comparison can be made between the two rounds, together with a reflection on the method used to come to a collaborative solution.

4.4. Classroom Wrap-Up

In the wrap-up, first some general comments are made. We begin by making a distinction between the holistic view of a problem compared to the view of a healthcare professional, and combine with that the possible gains from centralizing decision making. Healthcare professionals often focus on the patient in front of them, while OM professionals look at all patients and the system as a whole. The fact that collaboration and centralized decision making might lead to better solutions is not new to our students. However, it is difficult to convince healthcare professionals of the added value. Therefore, the focus of the rest of our course is to demonstrate to our students how to quantify the possible improvements using mathematical models such as queueing theory.

We then discuss specific questions as heard during playing the game. One example is a discussion on the quality of the solutions. What is the influence of the solution on how much doctors need to walk? Is it better to have all day patients close to each other, or should the distribution of specialties over the wards be based only on medical incentives? Are the indicators used (i.e., the requirements and blocking probability) the best and only indicators to consider or are there any other indicators that should be included in the discussion?

Another topic to discuss is the method used to reach a collaborative solution. In most games, students start by grouping specialties with the same requirements, and/or grouping all surgical and non-surgical specialties. Furthermore, most groups use a kind of bottleneck scheduling technique, focusing on the most difficult specialties to assign. In this way, they intuitively use well known OM techniques.

Scores as determined during the game are used to show the advantages of collaborative planning. A competitive angle could be added by comparing the group scores.

During later lectures on variability and queueing theory we refer to the game. We demonstrate that making capacity decisions, using only averages, might lead to low service levels. Also, we give insight into how the blocking probability is actually determined.

4.5. Different Teaching Environments

The game can be used for different types of students, and the specific goals for using the game might be different. The game was developed for HS students who are unfamiliar with OM. However, OR and OM students, with little knowledge of healthcare topics, could also learn from playing this game. In this case, the focus should not be on variability and introducing OM concepts, but on the different aspects to take into account in a healthcare setting and how complicated this can be when there are multiple stakeholders involved. Since the playing cards show all the preferences and requirements that are needed to play the game, it is not necessary for students to have any medical background. It would be helpful, however, if the game leader has some insights in the healthcare system to discuss why one solution might be better than another.

5. Our Experiences

The game has now been used for several years in several courses. At the University of Twente, it has been used in the course "Operations Management in Health

Table 2. Evaluation Results Students/Instructors

Question	Student responses (%)					Instructor (%)
	Strongly agree	Agree	?	Disagree	Strongly disagree	% (strongly) agree
1. Thanks to the BedGame, I have a better idea what Operations Management is.	10	77	13	0	0	100
2. Thanks to the BedGame, I have a better idea what to expect from the rest of the OM course.	6	48	35	10	0	80
3. The BedGame has increased my awareness of possible problems arising from decentralized planning.	16	74	6	3	0	80
4. The BedGame has increased my awareness of the need to have extra capacity to deal with variability.	23	61	13	3	0	80
5. The BedGame has increased my interest in operations management.	19	61	16	0	3	100
6. Thanks to the BedGame, I am more convinced that operations management techniques can be applied to healthcare problems.	29	58	6	3	3	80
7. If I had the opportunity to specialize in a particular subject (via long or short courses), then the BedGame would contribute to the fact that I am more inclined to choose a direction related to operations management.	3	48	39	6	3	80
8. The BedGame has increased my interest in a job (academic, consultancy, business...) within the field of operations management.	13	45	26	13	3	100

Table 3. Evaluation Results Extra Questions Instructors

Question	Strongly agree (%)	Agree (%)	?	Disagree	Strongly disagree
9. I think the bed game is a useful tool to introduce OM concepts to students.	80	20			
10. If I need to teach a course for healthcare students not familiar to Operations Management, I will consider playing the bed game within this course.	60	40			
11. If I need to teach a course for healthcare professionals, I will consider playing the bed game within this course.	40	60			

Care" in the undergraduate university college program, and in the course "Quantitative Methods for Operations Management in Health Care" (graduate level). Furthermore, the game is used during a course on patient logistics for healthcare professionals. We have received positive feedback from students in all of these classes.

To more formally evaluate the game, we adjusted the first part of the questionnaire by Beliën et al. (2011) so that it would comply with our game and objectives. In these questions, we measure (1) to what extent the game facilitated the learning of specific concepts (e.g., variability, centralized planning), and (2) to what extent the students' interest in and knowledge of OM is increased. During spring 2016, the questionnaire was handed out to a group of potential instructors ($n = 5$)

and to a group of first year HS students ($n = 31$), unfamiliar with OM. The questions asked the instructors were rephrased towards the instructors, e.g., question 1 was rephrased to "Thanks to the BedGame, students will have a better idea what Operations Management is." Questions and responses are shown in Table 2.

The instructors were also asked about their willingness to use to game in their own teaching. See Table 3 for an overview of the results.

These results show that after playing the BedGame 87% of the students had a better understanding of OM, and 87% was more convinced about the applicability of OM techniques to healthcare. Eighty-one percent of all students had an increased interest in OM after playing the game. For the specific goals on variability and decentralized planning, respectively, 84% and 90%

of the students (strongly) agreed that their awareness had increased. Fifty-two percent and 58% of students would consider OM as a subject to specialize or work in: This is a high percentage given that this course is part of a very broadly oriented bachelor program. Looking at the instructors' answers, we see similar positive results. Almost all agree with the goals that can be reached with the BedGame, and all would consider using the game in their teaching.

Students and instructors were also asked some open questions about the game. Points mentioned by the instructors included: "Interaction," "Two different rounds that truly represent practice as well as the ideal situation," "Good complexity, and indication of difficulty even small problems already can have."

6. Conclusions

We have described a game that focuses on the assignment of specialties to wards in a hospital, taking into account the demand for the specialties, the capacities of the wards, and several requirements and constraints with respect to the location of the specialties. Our experience showed that the game was useful in a real life setting (hospital environment) as well as in a classroom environment.

The game was used at LUMC to allocate specialties to wards. At other hospitals, the game was used to obtain insights into OM, and to study the consequences of several allocation decisions. In the classroom environment, the game was a stimulating way to introduce OM, the effects of centralized versus decentralized planning, variability and queueing (see Table 1 for more details), and was also used to discuss differ-

ent hospital layout options with students. Finally, the game has proven to be an accessible way to begin a new course, for students and for the instructor.

Other organizations, teaching institutions as well as hospitals, can use the game map and cards as shown in the appendices of this paper. However, a custom-made map and playing cards may improve the insights gained from the course.

Endnotes
[1] The text in this paragraph is based on Zonderland (2012, p. 3).

[2] The term "Part of" specialties refers to the type of care for a certain specialty, for example the facility for day patients.

[3] Note that attaining both performance measures at the same time might not be possible, depending on the size of a ward and the variability of demand. However, hospital management often strives for this performance. For further reference, see de Bruin et al. (2010).

[4] The exact formulas used to calculate patient load are given in Zonderland and Boucherie (2011, pp. 231–234).

References
Beliën J, Goossens D, Van Reeth D, De Boeck L (2011) Using mixed-integer programming to win a cycling game. *INFORMS Trans. Ed.* 11(3):93–99.

de Bruin AM, Bekker R, van Zanten L, Koole GM (2010) Dimensioning hospital wards using the Erlang loss model. *Ann. Oper. Res.* 178(1):23–43.

Westert GP, Burgers JS, Verkleij H (2009) The Netherlands: Regulated competition behind the dykes? *British Medical J.* 339:839–842.

Zonderland ME (2012) Curing the queue. PhD thesis, University of Twente, Netherlands.

Zonderland ME, Boucherie RJ (2011) Queuing networks in healthcare systems. Hall RW, ed. *Handbook of Healthcare System Scheduling* (Springer, New York), 201–243.