Proceedings of the 2017 Winter Simulation Conference
W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page, eds.

USING DISCRETE EVENT SIMULATION AND SOFT SYSTEMS METHODOLOGY FOR OPTIMIZING PATIENT FLOW AND RESOURCE UTILIZATION AT THE SURGICAL UNIT OF RADIUMHOSPITALET IN OSLO, NORWAY

Lene Berge Holm

Department of Life Sciences and Health, Oslo and
Akershus University College of applied sciences
PO Box 4 St.Olavs plass
NO-0130 Oslo
NORWAY

Tone Bjornenak
Guri Galtung Kjaeserud
Harald Noddeland

Oslo University Hospital HF

Postboks 4950 Nydalen
NO-0424 OSLO
NORWAY

ABSTRACT

This study has a multimethodological approach where discrete event simulation (DES) modelling and Soft Systems Methodology (SSM) are used in combination at the surgical unit at Radiumhospitalet in Norway. The aim was to investigate the effect of different interventions on patient flow and resource utilization. The multimethodological approach ensured well anchoring and a feeling of ownership of the project among all staff groups. This increases the probability of acceptance of model results. The multimethodology also ensured that it was the most relevant, desirable and feasible interventions that was evaluated with the simulation model. This project has provided the hospital management with a massive amount of structured information, based both on results from the SSM and the DES processes. Several assumptions have been quantified and are used as tools in the discussion on how to meet the increased demand of cancer surgeries due to recently implemented cancer pathways in Norway.

1 INTRODUCTION

Radiumhospitalet is a specialized cancer hospital within Oslo University Hospital (OUS). In 2007 Radiumhospitalet merged with Rikshospitalet University Hospital , and in 2009 these merged with Aker University Hospital and Ullevaal University Hospital to form OUS (OUS 2017). Although Radiumhospitalet is a part of OUS, the surgical unit of Radiumhospitalet is located separately from the rest of the surgical units of OUS, and has mainly dedicated staff working only at this site. Radiumhospitalet has nine operating rooms (ORs) shared between six departments; Gastric surgery, Gynecology, Urology, Breast Cancer and Endocrinology, Orthopedics, and Plastic Surgery. It is a day-based hospital, which only perform elective surgeries mostly from 7.30 AM to 3.30 PM. The anesthesiologists, surgical nurses, anesthesia nurses and other supporting staff are centralized resources in the surgical unit, while surgeons naturally belongs to the department of their specialty.

In 2015, The Norwegian Directorate of Health introduced a concept of prioritized cancer pathways for certain cancer types (Helsedirektoratet 2017b). The cancer pathways are discipline-based national standardized pathways. They are intended to give patients and relatives predictability and security. The aim is to speed up the assessment of each patient and the start of treatment and minimize waiting times, in order to make the assessment period as predictable and stress-free as possible. (Helsedirektoratet 2017a).

This national strategy had consequences on many levels for the surgical unit at Radiumhospitalet. First of all, the volume of cancer surgeries needed to increase, preferably faster than the possible increase in resources. On another level, this issue also led to emotional stress for the staff. The health care personnel working with cancer patients at Radiumhospitalet says that they always “go the extra mile” to ensure best possible care to all cancer patients and are therefore afraid of not being able to do so with an increased patient throughput.

OUS has since 2013 worked to increase the use of scarce ORs. An advisory board (The Surgical Operating Board) was established in 2013 under the management of the Department Head of the Acute Clinic. The board gathers all leaders of all locations and specializations regularly in order to discuss optimization possibilities. However, there is a lack of evidence as on what measurers prove to be the most effective. Therefore this project was a unique opportunity to investigate which interventions would lead to the most efficient increase in patient volume, without compromising patient safety or workload for staff.

2 METHODS

The methods of this project are inspired by the multimethodology developed by Holm et al. (Holm, Dahl, and Barra 2013). The multimethodology is based on the combined use of Soft Systems Methodology (SSM) and Discrete Event Simulation (DES) modelling and describes six phases. 1) identification and expression of problem situation, 2) development of root definitions and conceptual models, and charting the flows for DES model, 3) development and first implementation of DES model, 4) comparing conceptual models, DES model and the real-world, 5) DES-analysis of feasibility of candidate changes to system and evaluate cultural feasibility, and finally 6) action to improve and acceptance. These six phases overlap to a certain degree and are performed during observation periods, interviews, workshops, and data collection periods. Further details on the multimethodology, including a schematic description, can be seen in the original publication (Holm, Dahl, and Barra 2013), as well as SSM (Checkland 2000, 2001, Checkland and Poulter 2006) and DES (Carson et al. 2005).

The first part of the project at Radiumhospitalet was to establish a project group. This group consisted of management and staff (one surgeon and one anesthesiologist), from the surgical unit at Radiumhospitalet, representatives from the administration of OUS, and the modeler. This group was considered to be the project owners. Another larger working group was also established. In addition to the representatives in the project group, this working group consisted of two or more representatives from all staff groups working at or in close cooperation with the surgical unit: surgical nurses, anesthesia nurses, anesthesiologists, surgeons, maintenance staff, post-operative staff, bed area staff and local management.

The responsibilities of the project group and the working group, and the methodological process of the project will be described in the following subsections according to the six phases of the above-described multimethodology.

2.1 Phase 1: Identification and expression of problem situation

After formal clarifications of the project, the modeler spent a few days observing the workflow at the surgical and the post-operative unit of Radiumhospitalet. Thereafter a full day workshop with the working group was scheduled. A two-day workshop was originally intended, however, due to budgetary constraints, this was not possible. During the first part of the workshop, all staff groups were challenged to identify and express problem situations from their own perspectives through the use of SSM root definitions. Thereafter they were challenged to describe possible problem situations for the other staff groups too. This was all presented in plenum at the workshop. This initial phase of the multimethodology follows the two first standard steps of SSM.

2.2 Phase 2: Development of root definitions and conceptual models, and charting the flows for DES model

During the first part of the workshop, the modeler began, in cooperation with all participants of the workshop, drafting a conceptual model consisting of input and root definitions from all staff groups and their perspectives. This is step three and four in the original SSM. A picture of the conceptual model with root definitions can be seen in figures 1 and 2 below.

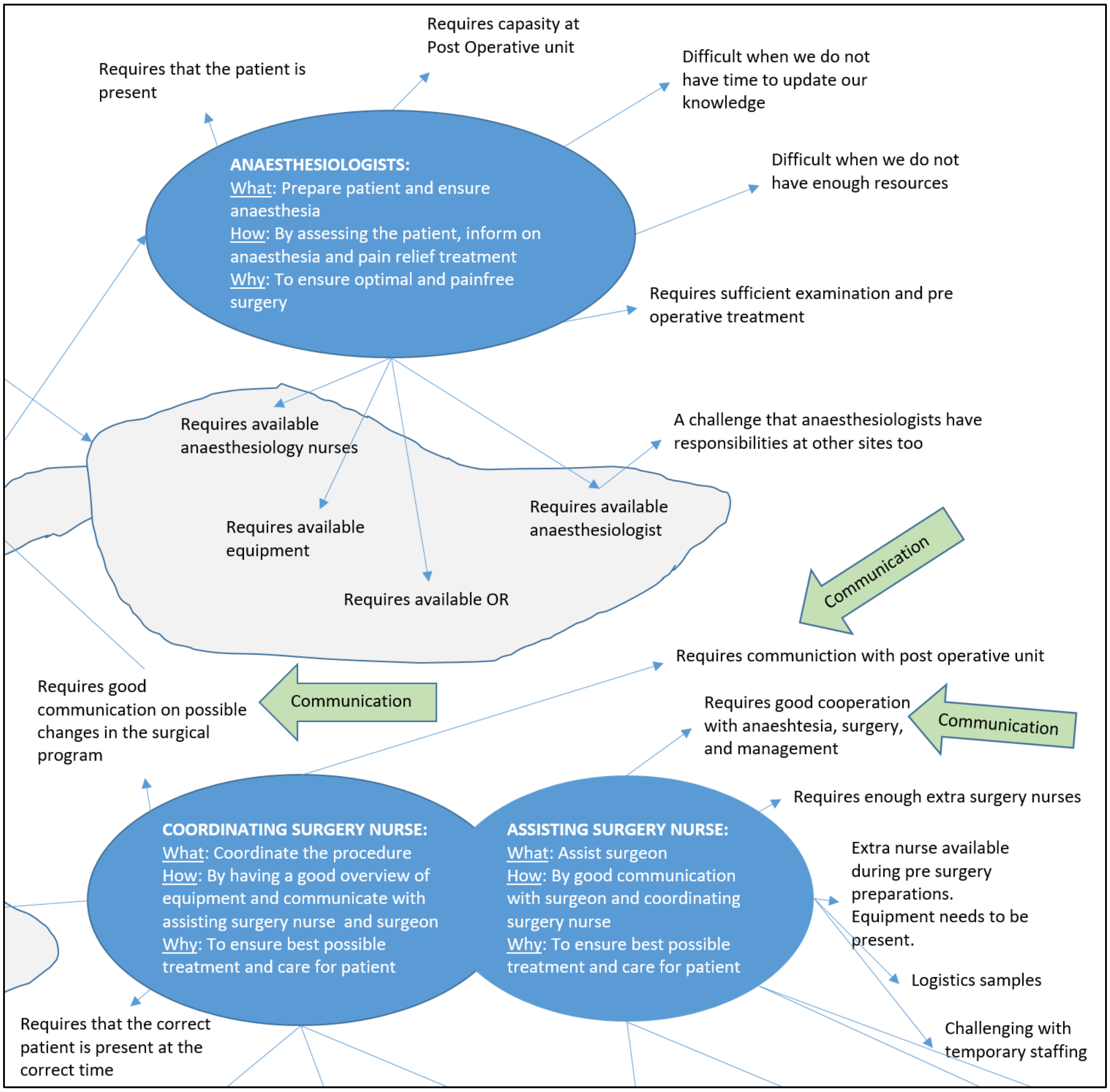

Figure 1: A zoomed part of the conceptual model

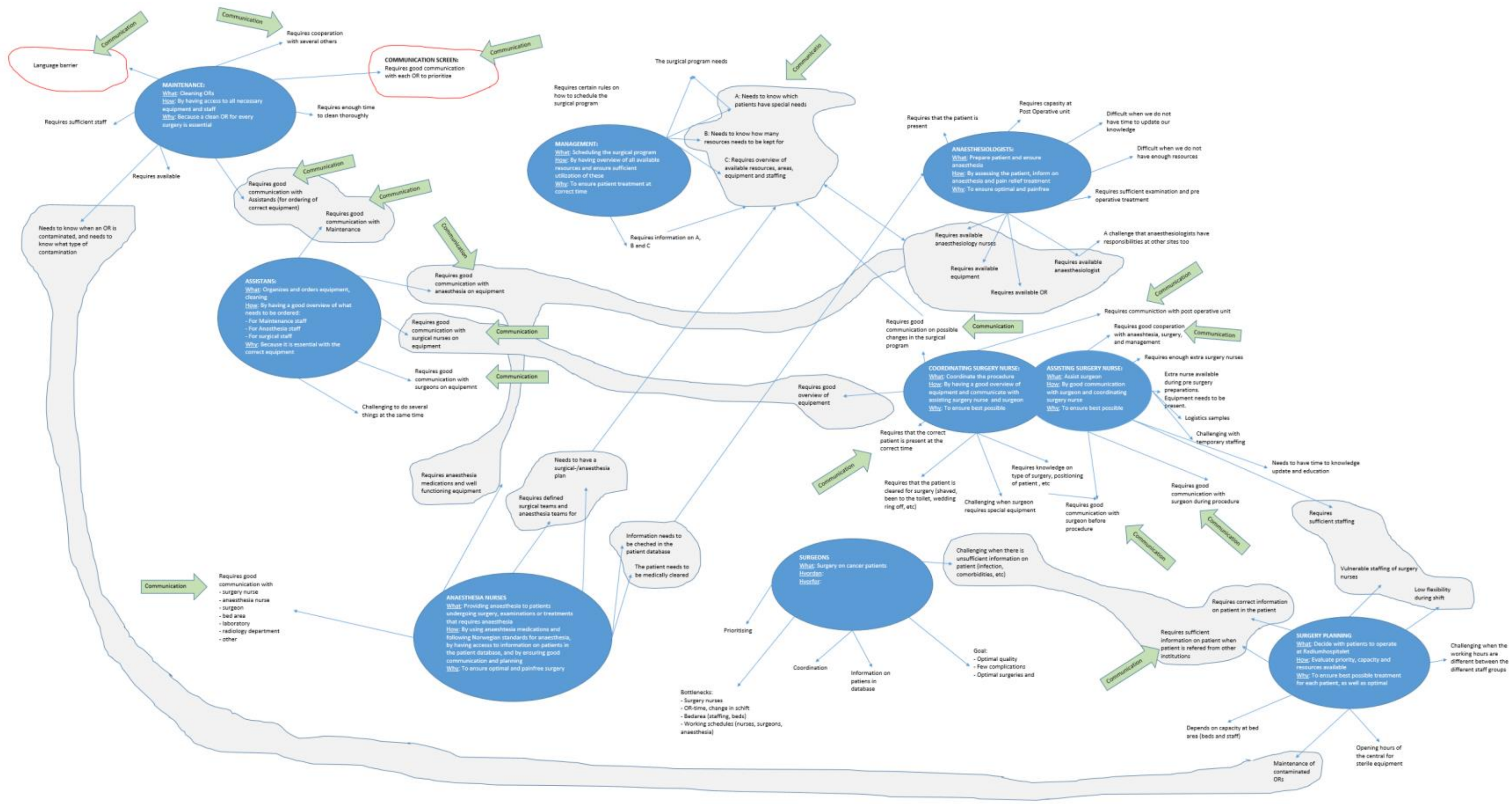

Figure 2: Full size Conceptual Model. (Please refer to Figure 2 for a readable zoomed part of the model). The blue circles shows the root definitions for each staff group's perspective. The arrows and text are comments relating to the root definitions. The grey areas show links between these comments. The green arrows points towards all areas where communication is experienced as troublesome.

During the second part of the workshop, the staff groups were again challenged to work together to define all the processes involved in the surgery of a patient. They were asked to describe each process on a (big) post it note, in a short, well defined and clear way. On the same post it note, they were to describe all processes, which had to be completed in order for this process to happen, and to describe the processes, which this process would trigger. Once again, this was all presented in plenum, and all post it notes where placed by the modeler on a very large piece of paper on the wall.

Each of the processes presented were discussed in turn, and comments and arrows where drawn between the post it notes. In this way, all the participants were a part of drafting the DES model, which ensured a feeling of ownership to the model.

After the workshop with the working group, the modeler summarized the draft of the model and printed this on a large poster, which was placed on the wall in the surgical unit of Radiumhospitalet. Here the staff (all staff, not only the participants of the workshop) were encouraged to comment on the model. This model validation process also ensured a further feeling of ownership to the model. The final flowchart of the model is shown in figure 3 below.

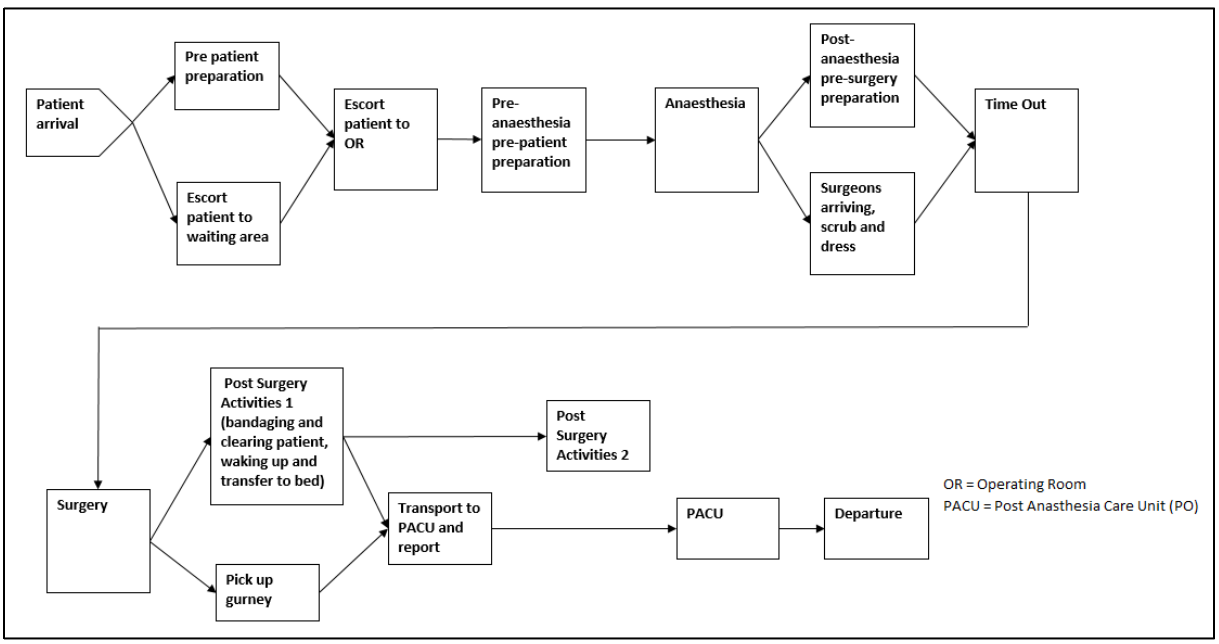

Figure 3: The flowchart of the model

Next, a long period of data collection followed. Data was collected in three ways. Firstly, all data available through the electronic patient registries (DIPS) were collected. Then, a two-week registration period was carried out. All processes in all surgeries in all ORs were registered. This was a time consuming and costly process. Medical students and retired surgery nurses were hired to help in the registration phase in addition to the modeler and a few representatives from the project group. In addition to DIPS and registration-data, subject matter expert (SME) opinions were registered for processes where additional information was needed. SME opinions were also used regularly to validate the model input data.

2.3 Step 3: Development and first implementation of DES model

In this section, the DES model is briefly described. After thorough validation of the flow chart of the model (shown in figure 3 above), and punching and structuring the results from the data collection phase, the modeler implemented the model in FlexSim Healthcare®. The reason for choosing this software was the modeler's familiarity with and availability of the software. The statistical tool Expert fit was used to choose the best probability distribution for each of the processes in the model. Separate probability distributions were used for each process for each of the six departments (Gastric surgery, Gynecology, Urology, Breast Cancer and Endocrinology, Orthopedics, and Plastic Surgery). See figure 4 below for one example.

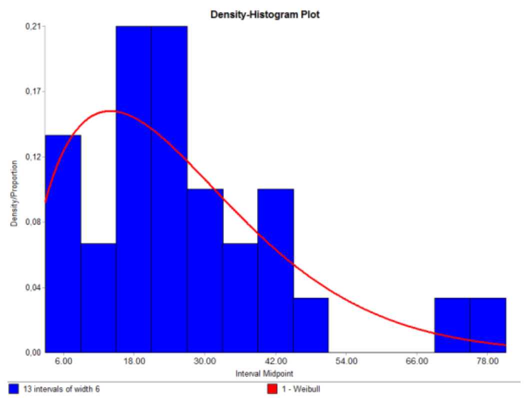

Figure 4: Probability distribution for the process "Pre patient preparations" Gynecology. The Weibull distribution was the best fit for this process. (X-axis in minutes).

All arrivals were scheduled according to the weekly surgery program, which is decided two weeks in advance. The surgery schedule is based on predefined full day blocks and are shown in table 1 below. Only seven ORs are included in the model. The eighth and ninth OR are reserved for gastroscopic and endoscopic examinations. This one-week program was simulated both in the base case model and for each scenario. The model was run 1000 times for each scenario. An algorithm for optimal scheduling of one week planned surgeries within the timeslots shown below was also developed. This algorithm took into account the opening hours for each OR and the expected duration of each planned surgery based on the data collected in the observation period. An extra set of simulations were run for all scenarios where the scheduling algorithm also included a flexibility in the scheduling where every non-used slot could be utilized by other departments.

Table 1: Weekly surgery schedule.

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
OR 1	Gastric	Gastric	Gastric	-	Gyn
OR 2	Gyn	Uro	Gyn	Uro	-
OR 3	Gyn	-	Gyn	Gyn	Gyn
OR 4	Gastric	Gastric	Gastric	Gastric	Breast Cancer
OR 5	Uro	Gyn	Uro	Gyn	Uro
OR 6	Ortho	Ortho	Plastic / Breast Cancer	Breast Cancer	Ortho / other
OR 7	Ortho / other	Plastic	Plastic	Plastic	-

The model went through a wide range of validation and verification processes. Time of arrivals and the duration of each process from the base case model run was compared to both DIPS-data and to the data collected in the registration period. The total time used for each type of surgery in the model were also validated against existing data. The validation and verification processes ensured a model, which represented the real world with sufficient accuracy for the planed analyses.

2.4 Step 4: Comparing conceptual models, DES model and the real-world

Comparing the conceptual model with the real world is a central part of SSM. Possible ways to do this are summarized in Holm, Dahl and Barra (2013) and will not be elaborated further here. By the thorough process of developing and validating the simulation model of the surgical unit of Radiumhospitalet, we believe that the model represents the real world fairly accurately. In a staff meeting, the simulation model and the conceptual model from the workshop were presented and discussed. Possible changes to the system to improve patient flow and resource utilization were discussed. This was to be evaluated in scenario analysis in the simulation model (step 5 of the multimethodology).

In addition to serving as a comparison tool for the simulation model, the conceptual model and results connected to this phase of the project are interesting on their own, and will also be presented in the results section of this paper.

2.5 Step 5: DES-analysis of feasibility of candidate changes to system and evaluation of cultural feasibility

Possible changes to the system to improve patient flow and resource utilization were discussed at the staff meeting as mentioned above. The most desirable and feasible suggestions were selected by the project group to be evaluated with the simulation model. The different scenarios selected to be run are:

- Increasing the OR opening hours
- Overbooking the surgical program
- Removing or adding extra staff in pre-surgery preparation processes
- Having the surgeon and/or anesthesiologist present in the OR during pre-surgery preparations
- Common or overlapping lunch breaks

2.6 Step 6: Action to improve and acceptance

The results from the whole project were presented and discussed in several meetings at OUS. The project deliverable was a report, which describes in detail the current situation of Radiumhospitalet and the simulated results from the evaluated scenarios. This report is currently being used as a strategic tool for the local management of Radiumhospitalet and the central management of OUS in the discussions around which interventions to implement to meet the increased demand for cancer surgeries due to the cancer pathways currently being implemented.

3 RESULTS

The results from this project was reported to the management in four dimensions: The conceptual world as captured in the workshop; the real world as described by observations and collected data; the real world as described by the base case simulation model; and the results from the scenarios of the simulation model. The following subsections present the results of the conceptual world and the simulation scenarios.

3.1 Conceptual world

Using systematic text condensation (Malterud 2012), five main problem areas evolved during observations, conversations with staff, and the workshop. These are 1) information flow and communication, 2) staffing, 3) use of temporary workers, 4) new employees and teaching responsibility, 5) balance between optimal utilization of OR-time and number of surgeries versus cancellations per day, and 6) equipment. These aspects are described and suggestions for improvements from the workshop participants are presented below.

One of the most important issues observed was the need for a better and more structured flow of information. This applies to several levels. It is often found that information from the institutions referring the patients to the surgical unit of Radiumhospitalet is inadequate. It is therefore challenging for the management to schedule the surgeries and plan the resource requirements for the procedure. This also applies for information flow within the hospital, and within the surgical unit itself.

In terms of staffing, almost all staff groups express a feeling of shortage of staff. It is important to have a flexibility that takes unexpected irregularities in the staffing into account. The anesthesiologists are in charge of several locations at the same time, which often is a challenge. The use of temporary staff, new employees and teaching are also factors that can contribute to delays. An easy solution here is to coordinate the use of temporary workers between the surgery nurses and anesthesia nurses, so that you do not have two temporary workers in the same OR.

Another important issue discussed was the balance between optimal utilization of OR-time and number of surgeries versus cancellations per day. There are two dimensions here. One dimension is cancellations of surgeries due to medical reasons. The other dimension is cancellations of surgeries because the risk of not being finished with the procedure before the shift ends (normally at 3.30 PM) is too high. In both cases, valuable OR-time might be wasted. In either case, one could consider the possibility of having backup patients that can be included in the program on short notice when free OR-time suddenly appears. However, this might be a burden for the bed area, as well as it raises an important ethical issue. Another possibility is to make sure that the medical examination of the patient is done earlier, so that cancellations are known as soon as possible. This, however, might have patient logistics challenges. Another possibility is to investigate the opportunity to increase the opening hours of some ORs, or open up for more use of overtime so that procedures do not have to be cancelled when there is a risk of not being finished before 3:30 PM.

Issues and possible solutions discussed in the workshop made the foundation for the scenarios analyzed in the simulation model. At the same time, the workshop was important for anchoring the project among all staff groups and including them in the decision-making processes. This helps ensure a more successful implementation of possible interventions from the project (Holm 2013).

3.2 Simulated scenarios

After processing the information from observations and the workshop, and after discussing this with the staff at the surgical unit, the project group decided on five desirable and feasible scenarios to simulate the effect of. (Please refer to bullet points above).

The main outcome parameter for each simulation scenario was the number of surgeries possible to schedule during a one-week program. This was based on the scheduling algorithm. The scheduled program was then run in the simulation model. The model finished all surgeries, even if it passed the OR-closing time. The secondary outcome parameter was then the proportion of surgeries, which was not finished within the OR-opening hours, and the proportion of surgeries, which was not finished within the OR-opening hours + 30 minutes. The results from each of these scenarios are presented below, with and without the scheduling flexibility described in section 2.3 above.

3.2.1 The effect of increasing the OR opening hours

The observant reader will notice that on Tuesdays and Thursdays there are only six active ORs, and on Fridays five. This is because one surgical team (surgery nurses, anesthesia nurses, surgeons and anesthesiologists) are busy with gastroscopic and endoscopic examinations each Tuesday and Thursday. On Fridays, there are only five active teams in the surgical unit.

Of the seven ORs, five are open from 7:30 AM to 3:30 PM; one is open from 7:30 AM to 6 PM; and one from 7:30 AM to 9 PM (with the possibility to run for 24 hours if necessary). This scenario evaluated the effect of increasing the opening hours for some ORs. The results are shown in table 2 below.

Table 2: Results from increasing opening hours. Scenario 1a is the base case. The second column describes the extended opening hours for each OR. The results from the simulations using a flexibility in the scheduling algorithm are presented in parenthesis.

Scenario description (extended opening hours)	Mean weekly number of surgeries possible to schedule	Mean proportion of surgeries not finished within the OR-opening hours	Mean proportion of surgeries not finished within the OR-opening hours + 30 min
OR 5: 6 PM OR 4: 9 PM	61 (65)	16% (14%)	13% (12%)
OR 5: 9 PM OR 4: 9 PM	64 (69)	20% (21%)	18% (16%)
OR 5: 9 PM OR 4: 9 PM OR 2: 6 PM	65 (70)	14% (13%)	11% (12%)
OR 4: 9 PM All others: 6 PM	70 (77)	10% (11%)	10% (11%)
OR 5: 9 PM OR 4: 9 PM All others: 6 PM	73 (80)	10% (8%)	10% (8%)
OR 5: 6 PM OR 4: 9 PM OR 2: 6 PM	63 (67)	18% (15%)	13% (14%)

3.2.2 The effect of overbooking the surgical program

In this scenario, we wanted to look at the effect of overbooking the surgical program. The reason for this is the same as when flights are overbooked. If one passenger (patient) is not arriving, his spot will be given to one of the overbooked passengers (patients). This will naturally lead to a higher proportion of cancelled surgeries, but the OR utilization will increase. The results are shown in table 3 below.

Table 3: Results from overbooking the surgical program

Mean weekly number of scheduled surgeries	Mean proportion of surgeries not finished within the OR-opening hours	Mean proportion of surgeries not finished within the OR-opening hours + 30 min
148	57 %	55 %
131	51 %	48 %
109	44 %	40 %
101	35 %	33 %
89	31 %	27 %
81	25 %	20 %
70	20 %	13 %
65	13 %	10 %
60	10 %	8 %
50	8 %	7 %

3.2.3 The effect of removing or adding extra staff in pre-surgery preparation processes

This scenario is based on the assumption that an extra surgery nurse present during the surgical preparation processes will decrease the time spent on preparations. From the data collected in the registration period, we see that half of the surgeries have an extra surgery nurse present during preparation. We also see that this extra nurse spends on average 26 minutes in the preparation phase for each surgery. By removing this extra surgery nurse, the weekly number of surgeries possible to schedule decreased with 10. Adding an additional surgery nurse for surgeries who did not already have additional help only increased the weekly number of surgeries possible to schedule with 2.

3.2.4 The effect of having the surgeon and/or anesthesiologist present in the OR during pre-surgery preparations

Normally, the surgeon and the anesthesiologist are not present during the preparation phases of each surgery. They are called upon when needed. In this scenario, the assumption is that by having the surgeon and/or the anesthesiologist present in the OR during the preparations, the preparation time will decrease. A 10, 15 or 20 minutes decrease in pre-surgery preparation time will increase the number of surgeries possible to schedule with 2, 7 and 10 respectively.

3.2.5 The effect of common or overlapping lunch breaks

In this scenario, we have modelled the effect of pausing the surgical program and having a collective lunch break for all surgical and anesthesia nurses. Today, when a nurse go on breaks, another nurse will fill in for him/her. This requires planning and extra resources, especially around lunchtime. Due to the nature of the model, this does not influence the number of surgeries possible to schedule, however it will naturally increase the proportion of surgeries not finished within the opening time. The actual possibility of pausing the surgical program might be difficult.

4 DISCUSSION

In this project DES and SSM was used in a combined fashion like the multimethodology described by Holm, Dahl and Barra (2013). This was a successful approach. This process ensured that the project was well anchored among all staff groups working in and around the surgical unit. Everyone had a possibility to be involved in the project, and representatives from all staff groups were active partners during the workshop. The workshop served as a place for the participants to express their frustrations and define the problem situations and perspectives relevant for their own staff groups. The results from the workshop were summarized using a qualitative text condensation approach and presented for the management at OUS. Hence, results from the root definition and conceptual model-building phase were relevant on their own, in addition to serve as a precursor for the scenarios evaluated with the simulation model.

In an SSM process, the conceptual world and the real world are compared in order to evaluate desirable and feasible changes to the system, which finally can lead to actions to improve the system. In this project, the conceptual model and the results from the real world simulation model were compared and discussed with both staff and management at the surgical unit at Radiumhospitalet and management of OUS. Actions to improve the situation were suggested, and are currently being decided on.

The results from the scenarios where the effect of increasing the opening hours of certain ORs were evaluated show us that it is more effective to increase the opening hours of one additional OR till 9 PM than increasing the opening hours of two ORs till 6 PM. The second set of scenario analysis show the results of overbooking the surgical program in order to increase the utilization of OR time and increase the weekly throughput, with the cost of increasing the number of cancelled surgeries as well. This, however, raises an important ethical issue as described in section 3.1. The third and fourth set of scenarios show the effect of increasing or decreasing the time spent on pre-surgery preparations, either due to the presence or not of an additional surgery nurse, or by having the surgeon and/or anesthesiologist present earlier than as of today. However, increasing the number of staff in the pre-surgery preparation phases might not necessarily decrease the pre-surgery preparation time; "too many cooks spoil the broth". Insufficient flow of information was one of the main results from the workshop. A more present surgeon and anesthesiologist might however have a positive effect on the communication in the team, and thereby decrease unnecessary time spent on for instance last minute equipment changes.

The project was limited to evaluate the five scenarios described in section 2.5. However, the model will also be available to evaluate other scenarios in the future. The different scenarios simulated are based on today's casemix, i.e. the mix of patients from the six departments (Gastric surgery, Gynecology, Urology, Breast Cancer and Endocrinology, Orthopedics, and Plastic Surgery). A change in casemix is a scenario that could be relevant to study in the future. In addition, a temporary, or permanent, change in available ORs, or a change in surgical methods which might require a change in composition of surgical teams, equipment, and/or surgical time, are scenarios which might be relevant to evaluate.

In this paper, only the results from the simulated scenarios are presented. However, a large amount of other results has evolved from this project too. This project has provided the surgical unit at Radiumhospitalet, and the management of OUS, with a massive amount of structured information. Several assumptions have been quantified and can now be used as tools in the discussion on how to meet the increase in demand in cancer surgeries due to the recently implemented cancer pathways.

ACKNOWLEDGMENTS

We would like to express our appreciation to all the participants in this project, both at Radiumhospitalet and Oslo University Hospital. We are also grateful to the medical students and retired nurses participating in the data collection phase.

CONFLICT OF INTERESTS

This project was initially a cooperation between Oslo University Hospital and Helsim AS, a consultancy providing services within health care simulation to Norwegian hospitals. The first author of this paper has her main affiliation at Oslo and Akershus University College of applied sciences as well as being the CEO of Helsim AS.

REFERENCES

Carson, II, David M Nicol, Barry L Nelson, and Jerry Banks. 2005. Discrete-event system simulation. Pearson.

Checkland, Peter. 2000. "Soft systems methodology: a thirty year retrospective." *Systems research and behavioral science* 17 (S1):S11.

Checkland, Peter. 2001. "Soft systems methodology in action: participative creation of an information strategy for an acute hospital." *Rational Analysis for a Problematic World Revisited, Chichester, John Wiley and Sons*.

Checkland, Peter, and John Poulter. 2006. *Learning for action: a short definitive account of soft systems methodology and its use for practitioner, teachers, and students*. Vol. 26: Wiley Chichester.

Helsedirektoratet. 2017a. "Cancer Pathways. Information for patients. Procedures and tests for suspected acute leukaemia *https://helsedirektoratet.no/Lists/Publikasjoner/Attachments/1302/Leukemia_cancer_pathway_patient%20information_A5.pdf*

Helsedirektoratet. 2017b. "Pakkeforløp for kreft [cancer pathways]." *https://helsedirektoratet.no/kreft/pakkeforlop-for-kreft*.

Holm, Lene Berge. 2013. "Combining Soft Systems Methodology and Discrete Event Simulaiton modelling for optimising hospital patient flow and resource utilisation." *Thesis for the degree of Philosophiae Doctor (PhD), HØKH, Universiy of Oslo*.

Holm, Lene Berge, Fredrik A Dahl, and Mathias Barra. 2013. "Towards a multimethodology in health care – synergies between Soft Systems Methodology and Discrete Event Simulation." *Health Systems* 2 (1):11-23. doi: 10.1057/hs.2012.21.

Malterud, K. 2012. "Systematic text condensation: a strategy for qualitative analysis." *Scand J Public Health* 40 (8):795-805. doi: 10.1177/1403494812465030.

OUS. 2017. "Radiumhospitalet." *https://oslo-universitetssykehus.no/steder/radiumhospitalet*.

AUTHOR BIOGRAPHIES

LENE BERGE HOLM is an Associate Professor of the Department of Life Sciences and Health, Faculty of Health Sciences at Oslo and Akershus University College of applied sciences. She is also the CEO of Helsim AS. She holds a Master's Degree in Pharmacy and a Ph.D. from the Institute of Clinical Medicine at University of Oslo and Akershus University Hospital. Her research interests includes discrete-event simulation, soft systems methodology, patient flow, medicines and patient safety. Her email address is lene.holm@hioa.no.

TONE BJORNENAK is the head of the surgical unit at Radiumhospitalet. Her email address is tbjoerne@ous-hf.no.

GURI GALTUNG KJAESERUD is working for the Department of Finance, Legal Affairs and Information Technology at Oslo University Hospital she holds at Cand.econ from University of Oslo, MSc in Health Economics from University of York. She was the hospital project manager for the study. Her email address is gkjeserud@ous-hf.no.

HARALD NODDELAND is a specialist in anesthesiology (MD, PhD) and present position is Deputy Head of the Division of Emergencies and Critical Care at Oslo University Hospital. His particular field of interest is the interaction between clinical workflow and clinical information systems. His email address is harnod@ous-hf.no.