A Decision-Making Tool for an Operating Room Suite Sizing and Planning

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The surgical unit, an essential element of hospital activity, represents one of a hospital’s main cost generators. To manage these costs, the physical structure, the material, and the human resources must be appropriately sized. Using ASDI methodology (analysis, specification, design, implementation), we propose a decision-making tool based on approximated methods and a simulation model to correctly size and plan operating rooms. This tool provides a decision-making aid at different time horizons (strategic, tactical, and operational) to design a new system or to optimize an existing system.

Keywords - decision-making tool, operating room, sizing, planning, bin packing, approximated methods

Introduction

In 2006, the 30 democracies of the OECD (Organisation for Economic Co-operation and Development) countries spent, on average, around 9% of their GDP (gross domestic product) on health care - growing from around 5% in 1970 and 7% in 1990. However, there are considerable variations between countries and there is ongoing concern regarding the adequacy of resource levels for health care and the way that those resources are used (see Figure 1). Spending exceeded 10% of GDP in seven countries in 2006 - the United States, Switzerland, France, Germany, Belgium, Portugal, and Austria - compared with only the United States exceeding this spending in 1987. In 2006, France was in third place and spent 11.1% of its GDP on health care.

In a report published in 2000, the World Health Organization ranked France’s health care system as first among those of its 191 members, based on the quality of the care provided.

The French health care system is pluralistic because private and public structures coexist side by side.

- The public institutions include the regional hospitals and the local hospitals. The 29 regional hospitals, including 27 teaching and research hospitals (university hospitals), provide specialized care. The local hospitals provide routine health care.
- The private institutions are profit making and nonprofit making. The nonprofit institutions are run using the same management system as the public institutions and have the same public service attributes.

France employs about 1.7 million health sector professionals. They include members of the professions governed by the Public Health Code and other socio-professional groups. The biggest of the health professional groups (accounting for 47% of all health sector jobs) works in the public hospital sector. This sector has witnessed a significant increase in staffing levels, which have grown by 31.3% between 1985 and 2002. The public share of
health spending has fallen in some countries, but has risen in others, even in France, from 78.6% to about 79.7% from 1995 to 2006.

The government has introduced several measures to attempt to curb this trend (e.g., the Social Security Funding Act and the Hospital 2007 Plan). Several arguments have been put forward to justify the objective of cost containment as a central element in plans for health care reform. University hospitals are particularly affected by these measures. Since the 1990s there have been strong efforts to curb health care costs in addition to attempts to reduce medical errors and improve patients' satisfaction with the health care system.

Operating rooms (ORs) are regarded as the most costly of hospital facilities (Spangler et al., 2004; Denton et al., 2007). Due to rising costs and decreasing reimbursements, it is necessary to optimize the efficiency of the operating room suite. Macario et al. (1995) showed that, at Stanford University Medical Center from September 1993 to September 1994, the largest hospital cost category was the operating room (33%) followed by the patient ward (31%). Real savings are more likely to be achieved by reducing the time patients spend in the operating room, recovery area, and surgical wards and thus reducing the staff necessary to care for them. In an increasingly resource-constrained environment, efficiency is critical for maintaining access to quality care.

Even if some efforts have been made in this field, the operating department is still one of the principal costly units in the hospital system. This fact results from the quantity of human resources used along with the investment of properties and furniture and the operating costs for the surgical activity. The design of the surgical unit and its interfaces (recovery, sterilization, etc.) is the subject of rigorous analysis. Surgeons, nurses, and OR administrators more and more turn to new technologies and operations research to help solve this problem.

Persson (2007) aims to investigate the potential of operations research for supporting health care decision makers to improve management policies related to the surgical unit. Due to the interdisciplinary characteristics of operations research, the applied methods are necessarily diverse to solve these problems. However, simulation and optimization are the two most commonly employed tools applied to health care management problems (Jun et al., 1999).

This article shows the use of operation research methods and tools for the operating room management.

We propose a decision-making tool for the management of a future surgical unit. We present the context of the project and the tool specifications before giving a brief review of the literature on the problem. Then, we give our method and we present the decision-making tool with experimentation.

**Context of the project**

Our project context is the building of a new hospital, the “Nouvel Hôpital Estaing” (NHE), which will replace the current “Hôtel-Dieu” (university hospital [UH] of Clermont-Ferrand, France). The NHE will be one of the institutions of the UH of Clermont-Ferrand.

![Figure 1](OCDE Health Expenditure)

**Health Expenditure as a Share of GDP, 2006**

(1) Public and private components are current expenditure, that is, investments are not separated.
(2) Current expenditure.
(3) Data refer to 2005.
(4) Data refer to 2005.

The hospital managers have to reconsider the organization that will merge four surgical units into a single location. These units are currently found at various locations in the hospital buildings. We define the surgical unit or OR suite as a space composed of several normalized elements where patients undergoing a surgical operation are being taken care of. It is generally composed of one or several of the following:

- Operating rooms
- Recovery rooms
- Store
- Staff rooms (e.g., rest room, nurses’ office)
- Anesthetic area
- Other technical rooms (e.g., packaging/unpacking room, etc.)

Figure 2 shows the main elements of the future operating room suite.

For the operating room management, we distinguish the following criteria:

- Strategic operating room management deals with long-term decision making. For example, how many operating rooms should the hospital build for the NHE?
- Tactical operating room management focuses on maximizing operational efficiency at the facility, specifically, to maximize the number of surgical cases that can be done per time period while minimizing the required resources and related costs (medium-term decision making).
- Operational operating room management deals with short-term decision making such as moving patient cases from one OR to another, assigning and relieving staff, prioritizing urgent cases, and scheduling add-on cases.

We aim to provide hospital managers with a decision-making tool that addresses these different decision time horizons.

### Decision-making tool specifications

The first objective of our work is to provide decision makers (managers, physicians, and health managers) of the new hospital with a tool to quickly get an answer on the number of rooms to be built to absorb the whole of the activity within the new structure. Because space is a scarce resource, this is not a trivial question. The result should allow the project manager to complete the ongoing construction of the new hospital while balancing decision trade-offs.

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**Figure 2 Components of the NHE Operating Room Suite (extract)**
This tool has to take into account the following:
- Degree of specialization for the different ORs: The user must be able to choose the number of different types of ORs (dedicated, shared, or multipurpose) as shown in Figure 3.
- OR working hours: The tool must consider a detailed working calendar.
- Changing activity: The tool has to generate configurable activities based on referring data.
- Human resources: The tool has to account for the staffing requirements.

- The time between surgical operations (decontamination): The tool has to take into consideration a planned time between surgical operations, constant or variable (uniformly distributed), by specialty, and the surgical operation itself.

This tool has to have the following outputs:
- The structure sizing: the physical structure sizing (the number of ORs to be opened) and the staffing requirements for each OR (the nursing staff size by surgical specialty and the number of decontamination staff)
- The types of ORs: the test and comparison of operating regulations (multipurpose or dedicated OR, etc.), the study of various configurations (operating room schedule, system load, etc.)
- The performance evaluation: indicators to evaluate different designs such as the OR occupancy and the number of human resources used at any moment

To validate our work and to be valuable to decision makers, the tool has to show the different results quickly and easily.

We consider all the operations executed in the OR except for emergencies, which are out-of-schedule surgical unit working hours (nights and weekends) because the number of ORs to be built for scheduled activity will absorb this emergency demand. Furthermore, we do not take into account recovery rooms. The number of places in the recovery rooms is a function of the number of ORs.

To reach these objectives, we propose to build a surgical unit knowledge model (analysis and formalization of the structure) and the corresponding decision-making.

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**Figure 3**
Specialization levels of ORs

**Table 1**
The Coupling of Time Horizons and Modeling Approaches

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<th>MACROSCOPIC</th>
<th>MESOSCOPIC</th>
<th>MICROSCOPIC</th>
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<tbody>
<tr>
<td><strong>STRATEGIC</strong></td>
<td>Overall design&lt;br&gt;Sizing of the physical structure of the surgical unit</td>
<td>Process design&lt;br&gt;Definition of the operational activity in the surgical unit: specialties, ambulatory, emergencies</td>
<td>Activity design&lt;br&gt;Detailed design of the operational activity</td>
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<tr>
<td><strong>TACTICAL</strong></td>
<td>Flows configuration&lt;br&gt;Resource requirements and planning for the whole of the activity</td>
<td>Process configuration&lt;br&gt;Resource requirements planning for each activity</td>
<td>Activity configuration&lt;br&gt;Resource requirements planning for each operation</td>
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<tr>
<td><strong>OPERATIONAL</strong></td>
<td>System management&lt;br&gt;Human and material resource allocation to all the activities</td>
<td>Process management&lt;br&gt;Human and material resource allocation to each activity</td>
<td>Activity management&lt;br&gt;Scheduling of the operations and resource allocation&lt;br&gt;Regrouping and reassignment</td>
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</table>

Consideration of random events
tool. We consider different time horizons ranging from one day to several years. Finally, this tool has to provide decision-making value at different levels of management.

Chabrol et al. (2006) have classified different types of problems encountered in complex systems modeling and have coupled macroscopic, mesoscopic, and microscopic approaches with different time horizons set by Ballou (1992). We construct a matrix combining the modeling approaches and the time horizons for the OR problems discussed. These different approaches require different levels of granularity for any modeling study carried out to provide useful decision-making tools (see Table 1).

State of the art

The literature

The surgical unit is not only one of the most important areas and the most costly within the majority of hospitals, but it is also one of the most difficult to be managed and to be planned because of many unanticipated events, a large personnel to manage, and the difficulty in standardizing and coordinating surgical activities.

Surgical process management must take into account the following:
- Surgeon needs and constraints
- Anesthetist staff needs and constraints
- Availability of OR nurses and anesthetic nurses
- Patient flow arriving from the emergency department
- Locum activities and night duties
- Links between the OR and sterilization activities
- Supply of various materials (prosthesis, single-use medical instruments, etc.)
- Stretcher bearers
- Staff of recovery room

We have used the definition of Meskens and Riane (2007) for the surgical process management: “Wait list management or surgical process management consists of designing forward-looking schedules for surgical operations to be carried out during a period, generally a week, from surgical departments and external prescribing requests. Surgical process management breaks down into two sequential sub-problems: planning in advance that consists in allocating dates of surgical operations to patients in the future and allocation scheduling that consists of setting surgical operation orders in the OR by day” (p.7).

OR sizing is a combinatorial optimization problem involving the solving of scheduling and planning problems in the OR. One of the steps for better OR management is to look for an optimal operation planning in the preoperative phase for one day or even several days. The planning of hospital systems relates to three hierarchical decision levels (Roth & Dierdonck, 1995):
- Strategic or long-term planning allows determination of the evolution of the hospital according to several tendencies and evolutions (demographic, sociological, technical, etc.).
- Tactical or medium-term planning consists of making forecasts on the request for care, to plan the admissions, and to estimate the requirements of human, material, and financial resources of the hospital for various seasonal variations, making it possible to satisfy the request.
- Operational or short-term planning considers the problems of the patient assignment to the services and the scheduling and sequencing of the resources.

OR planning is a complex task that has to consider many aspects such as surgeon scheduling, surgical team scheduling (included anesthetic staff), patient-related information, (i.e., estimated operating time, priority, and diagnosis), equipment and surrounding activities like intensive care units, and so on.

The existing literature shows different approaches for programming and planning problems in the OR. Salvador (1973) presents a branch and bound to minimize a k-stage no-wait hybrid flow-shop problem. Wittrock (1985) deals with a “flexible flow line.” The objectives may be the profit maximization and the minimization of working time in the process. Beliën and Demeulemeester (2008) propose a branch-and-price approach for integrating nurse and surgery scheduling. They use the column-generation technique to solve nurse scheduling problems.

Kharraja et al. (2002) and Guinet and Chaabane (2003) model this problem as a two-floor hybrid flow-shop. Each stage consists of several identical resources. OR machines are on the first floor and recovery room beds are on the second floor. If we choose the goal of minimizing the closing date of the last intervention, that is, minimizing the makespan (Kharraja et al., 2002), and if we take into account constraints such as the first constraint of transit from the OR to the recovery room without waiting with the addition of a second constraint that takes into account OR decontamination (Guinet & Chaabane, 2003), we model an n patient-scheduling problem as a two-stage hybrid flow-shop problem with several constraints (Gupta, 1988).

Denton et al. (2007) present heuristics for assigning appointments for arrivals at outpatient clinics (e.g., Bailey, 1952; Soriano, 1966; Mercer, 1973; Charnetski, 1984; Ho & Lau, 1992; and references therein). Weiss (1990) and Denton and Gupta (2003) propose stochastic optimization models for determining OR schedules. Strum et al. (1999) describe an application of a news-vendor model as a heuristic for determining the planned OR schedule duration to allocate for surgical subspecialties. Van Oostrum et al. (2008) present a master surgical scheduling approach for cyclic scheduling in operating room departments with exact methods and heuristics.

Dexter et al. (1999) propose the bin packing for operations planning and additional operations as well as
unclear constraints to take into account the uncertainty about the operation time. Guinet and Chaabane (2003) model the operations planning problem with a linear program in integer numbers that enables the assignment of an OR and a time slot at each programmed operation. The program is resolved by a heuristic based on an extension of the Hungarian method. Harold W. Kuhn, in his celebrated paper entitled The Hungarian Method for the assignment problem (Kuhn, 1955) described an algorithm for constructing a maximum weight perfect matching in a bipartite graph.

Many authors are interested in the planning and sequencing of interventions on existing systems but there are not, as far as we know, works about the sizing of a system to be designed.

In previous works (Rodier, 2008; Cassagne, 2009), we identified some software and their main features. These features are grouped for each of the software programs studied in Table 2.

Many software vendors present their products as software tools to support the planning and programming of surgical interventions. However, this information should be interpreted with caution because often the term planning covers only the management of appointments for outpatients. Few vendors have, in fact, truly developed a complete planning function that goes beyond the simple management of appointments. These software programs provide, most of the time, the ability to view in real time the operating room occupancy, but

Table 2
Features of the main OR software (June 2008)

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none, to our knowledge, provides assistance in planning to optimize the occupation of the structure.

**Method**

In order to design a tool that provides a decision-making aid suitable for different time horizons, we choose the methodology ASDI (analysis, specification, design, and implementation) (Gourgand & Kellert, 1991). This methodology enables us to develop a modeling methodology for a class of systems and adopt the generic knowledge model of this class. Then, we design a library (or collection) of software components that is used to generate an action model (program) for a system of the class. This methodology was built after reviewing numerous studies on the modeling and complex systems assessment (industrial systems, urban traffic systems, etc.).

Chabrol et al. (2006) have shown the applicability of this methodology and have adapted it to hospital systems to build, for a given system, knowledge, action, and results models. This results model provides us with, at the same time, a decision-making aid and an action on the system. The knowledge gathering and formalizing of the system are made by extracting of system entities, relationships between these entities, operation rules, and system load. Our approach, using ASDI methodology, is represented by figure 4.

ASDI methodology recommends a systemic vision with a breakdown in three connecting subsystems:
- Physical subsystem (PSS) defines all physical means (for the goods and services production, storage, handling, and transportation), their geographical distribution, and their links.
- Logical subsystem (LSS) consists of entities that the system must process and sets of transactions concerning these flows.
- Decision subsystem (DSS) contains operating regulations and methods of operation.

Although the three subsystems are structurally separated (there is no redundant information), there are functional relationships among each other. Interfaces provide communication between these subsystems. The DSS acts on the PSS (operating regulations, resource allocation, etc.), thanks to the PSS objects methods (method of operation), and on the LSS (operating regulations, choice of various treatments, etc.). The DSS receives permanent information from the other subsystems due to physical and logical sensors and object attributes that reveal the state of the system. The LSS solicits the PSS reconfiguration to take into account significant changes in the system load.

Based on this specification, developed jointly with the future users and the UH management, and by learning in the field and literature analysis, we have built a generic knowledge model of a surgical unit. The logical subsystem consists of human, material, financial, and informational flows. The physical subsystem includes transport units, one or more areas of care, technical premises (decontamination, storage), staff premises, human resources, material resources, and sensors. We have listed about 50 organizational entities. The decision subsystem consists of
sensors, a decision council (the council of surgical unit), and a management centre.

Instantiating the generic knowledge model with the future surgical unit structure of NHE, we can analyze different resolution methods. We examined three possibilities:

- Evalvac, a software system proposed by the MeaH (National Mission of Hospital Expertise and Audit) that considers a strategic horizon according to a macroscopic modeling level (taking into account an average time of intervention by specialty and the average time for opening day rooms for each specialty). This application specifies the quantity of rooms by specialty and is based on the average length of stay by specialty and the number of beds allocated to this specialty.

- A discrete event-simulation model to test different possibilities, for example, of system load (number of interventions) or set-up rooms (multipurpose rooms, specialized rooms, etc.) to see their impact on the number of used resources. This resolution considers a tactical and operational horizon and a microscopic modeling level (details of the time of intervention, opening time for each room, etc.). If it is not coupled with an optimization module, this model fails to optimize the number of ORs. This model is able to show, in detail, the evolution of the system over time. We propose in our approach to couple the simulation model with an optimization approach to optimize the use of human and material resources.

- A mathematical formulation that we have chosen to solve that uses the following approximate methods:
  - Heuristics for the sizing and planning problems. Heuristics allow, more often, to reach the lower bounds and are not limited in terms of the size of the problem (amount of data to be considered), which is the case with exact methods.
  - Metaheuristics for the multicriterion optimization problems

The concept of the decision-making tool is shown in Figure 5.

**Figure 5**  
Concept of the Decision-Making Tool

<table>
<thead>
<tr>
<th>Bin-Packing Heuristics</th>
<th>Sizing: number of OR Planning</th>
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<tbody>
<tr>
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<tr>
<td>Coupling</td>
<td>Evaluation of the different criteria</td>
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<td>Metaheuristics</td>
<td>Optimization of one or several criteria</td>
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</table>

**Sizing and Planning**

The first goal is to size the future surgical unit. To solve the sizing problem, we have to solve the operations planning problem. Our problem is based on a bin-packing problem. In computational complexity theory, the bin-packing problem is a combinatorial NP-hard problem. Objects of different volumes (for example, surgical operations) must be packed into a finite number of bins of capacity $V$ (OR) in a way that minimizes the number of bins used.

Therefore, we develop heuristics for several reasons:

- For NP-hard problems, the most efficient known algorithms use heuristics to accomplish results.
- They are relatively robust. Although they do not guarantee the optimal solution, they generally result in a good solution and in a short amount of time.
- They are relatively simple to implement and they can integrate specific information.
- They enable us to work quickly with large data sets.

Other studied methods complement this approach but do not meet all the objectives set out in the specification.

**Scheduling and Evaluation**

In a second step, we run together a simulation model and the heuristics, which gives the scheduling of the surgical operations and some performance criteria such as the occupancy rates and the number of needed staff at any time.

**Optimization**

The third step is the coupling between the simulation model and the metaheuristics to optimize one or several performance criteria. In fact, other problems can be treated such as the minimization of waiting time for surgeons in their operations, the search for a planning, and an optimal scheduling for a number of medical teams. These problems are multicriteria problems that we study with metaheuristics based on simulated annealing.

1. **Decision-making tool**

Our decision-making tool provides the following:

- At the strategic level (for new or existing system design), the ability to
  - Specify the number of ORs to be built to absorb all the activity
  - Determine the specific capabilities of these ORs (specialized, shared, multipurpose)
  - Determine the requirements in quantity of surgical teams
- At the tactic and operational levels (for an existing system), the ability to
  - Size the number of ORs to be opened among ORs built to absorb the weekly or daily activity
• Determine the specific capabilities of these ORs (specialized, shared, multipurpose)
• Give a feasible plan and an organization for each OR
• Determine the quantity of surgical and medical teams by time interval corresponding to the proposed schedules

The application that we conceived based on heuristics is customizable to enable users to test different scenarios concerning the following:

Figure 6
Heuristics Principle

```
ki = 0  [Initializing the list of assigned operations]
list = ∅

While the operations are not assigned
  For k = 1, nts-1  [For each nonmultipurpose OR]
    Let [j1, j2] be the interval containing the numbers of ORs of type k
    For l = j1, j2  [For each OR of type k]
      For i = 1, jj  [For each day of the studied period]
        S= a(i,j) b(i,l) t(i,l) + ia(l)  [Calculus of the occupancy of the OR j on the day l]
        If S < d(j,l) then  [Is S less than the opening time?]
          ki = ki + 1
          list(ki) = ic
          a(ic,j) = 1  [Operation ic is assigned to the OR j.]
          b(ic,l) = 1  [Operation ic is assigned to the day l.]
        End If
      Next i
    Next l
  Next k

If all the operations are not assigned, then we determine the number of multipurpose ORs needed.

Let [j1, sm] be the interval containing the numbers of multipurpose ORs

For j = j1, sm  [For each multipurpose OR]
  For i = 1, jj  [For each day of the studied period]
    S= a(i,j) b(i,l) t(i,l) + ia(l)
    If S < d(j,l) then
      ki = ki + 1
      list(ki) = ic
      a(ic,j) = 1
      b(ic,l) = 1
    End If
  Next i
Next j
```

Heuristic 1
S + t(ic) + ia(ic) ≤ d(j,l) (ic ∉ list, ic and j compatibles)
[It assigns the first admissible operation of the period.]

Heuristic 2
ic minimize d(j,l) - S - (t(i) + ia(i)) (i ∉ list, i and j compatibles)
[It assigns the best operation of the period.]

Heuristic 3
ic minimize d(j,l) - S - (t(i) + ia(i)) (i ∉ list, i and j compatibles, day(i) = l)
[It assigns the best operation of the day.]
- The activities to consider (number of weeks or days of activity, number of surgical operations) with the detail of the activity (duration, day, specialty for every surgical operation)
- The type of each OR: specialized, shared between several specialties, multipurpose
- The opening time customizable by OR and by day
- The desired performance rate (total percentage of use of the opening timeslot)
- The occupancy time of the OR after each surgical operation (decontamination), customizable by specialty or even by intervention

Various configurations can be tested and compared by varying the activity, the number of opening days by week, the number of ORs (or time slots) allocated to one or several activities, the opening time, the time of decontamination, as well as the desired performance rate.

**Data**

- n: Number of operations
- sm: Maximum number of ORs
- jj: Number of days of the period
- nspec: Number of specialties
- t(i): Time of operation i
- ia(i): Decontamination time of the OR after operation i
- sp(i): Specialty of the operation i
- jour(i): Day planned for the operation i
- d(j,l): Opening time for the OR j the day l
- nts: Number of types of ORs (specialized, shared, etc.)

**Variables**

- \(a(i,j)\) = 1 if the operation i is assigned to the OR j
- \(a(i,j)\) = 0 otherwise
- \(b(i,l)\) = 1 if the operation i is assigned to the day l
- \(b(i,l)\) = 0 otherwise

**Constraints**

Main constraints to verify:

\[
\sum_{i=1}^{n} a(i,j) b(i,l) (t(i) + ia(i)) + d(j,l) \leq \text{nts},
\]

for each OR \(j=1, sm\); for each day of the period \(l=1, jj\)

We propose three heuristics:

- H1: We place the first feasible operation of the period (month, week, etc.).
- H2: We place the best feasible operation of the period (the one that minimizes the remaining time in the OR).
- H3: We place the best feasible operation of the day.

The heuristics provide a feasible operations schedule for each OR and each day and the OR occupancy rate (by day). They build two matrices: the first one for the operations assignment by OR (matrix a), the second for the operations assignment by day (matrix b), but the user can also force the assignment of certain operations in one or several ORs. The principle algorithm of heuristics is shown in figure 6.

Figure 7 shows the breakdown of occupancy for each surgical operation as it is considered in our application. We take the total time of the operation \(t(i)\) (from the entry of the patient in the OR to his or her exit) and we add the time of decontamination (\(ia(i)\)), which includes the possible preparation of the OR before the entry of the next patient. We can also break down the time of surgical operation to identify the occupancy of the main operator (the surgeon) and determine in a finer way the various teams.

**Results**

The output interface of the decision-making aid tool allows us to treat the numerous results supplied by heuristics and to present them under varied forms (e.g., boards and graphs). We take back the matrix of coupling time horizons and the modeling approach to give an outline of the obtained results (see Table 3).

We validated the heuristics on existing data extracted from the activities of the first half of the year 2007 realized in the various surgical units of the Hôtel-Dieu hospital. Then, we tested different configurations (see Table 4 for an example).

We give some examples of output states. At the operational and macroscopic level, figure 8 gives an outline of the occupancy rate of all ORs for week 4. At the operational and microscopic level, figure 9 gives the number of operating teams used in parallel for day 1 and specialization 1.

Figure 10 gives the planning and scheduling for all the ORs on a given day. We note the different levels of specialization of the OR with dedicated rooms (OR 1 to 12), shared rooms (OR 13 and 14), and a multipurpose room (OR 15).

Other output states give the detailed record of all the
operations, which enable us to compare the initial planning realized in the first half of the year 2007 with the one proposed by heuristics. These comparisons have validated our approach.

**Conclusion and prospects**

The decision-making tool achieves the stated objectives by covering various time horizons. At the strategic level, it allows us to size the number of ORs to be built to absorb the surgical activity of the new hospital by testing different variations of activities and organizations in terms of OR openings, performance rate goals, and so on. It also enables us at the tactic and operational levels to provide varied information such as the number of ORs to be opened every week, the number of surgical and decontamination teams to be planned, and feasible scheduling. The results were validated by the surgeons.

On the whole it may be stated the models provided useful information. The information was used as the basis for sizing decisions (number of ORs to build). The decisions themselves, of course, were considered together with the surgeons and the hospital managers.

The accuracy of the models was shown to be sufficient. The tool can be transferred quite easily to different hospitals. The models do

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**Table 3**

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<th>MACROSCOPIC</th>
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<th>MICROSCOPIC</th>
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<tbody>
<tr>
<td>STRATEGIC</td>
<td>- Number of ORs to build to meet the requirements of the activities</td>
<td>- Number of ORs by activity/specialty and number of multipurpose ORs</td>
<td>- Activity broken down by operation time and decontamination time</td>
</tr>
<tr>
<td>TACTICAL</td>
<td>- Number of ORs to be opened by week</td>
<td>- OR characteristics (dedicated, multipurpose, etc.)</td>
<td>- Estimates of the team workload by day, activity/specialty, and slot time</td>
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<tr>
<td></td>
<td>- Maximum number of surgical teams working in parallel to carry out the</td>
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<tr>
<td></td>
<td>activity by period</td>
<td></td>
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<tr>
<td>OPERATIONAL</td>
<td>- Total occupancy rate of the ORs by period (day, week, month)</td>
<td>- Sequence of the activities/specialties by OR and by day</td>
<td>- Sequence of the operation by OR and day with start dates and deadlines of each intervention: feasible scheduling</td>
</tr>
<tr>
<td></td>
<td>- Maximum number of teams by type of teams (surgical team, main operator,</td>
<td>- Estimation of the workload of the medical teams and ancillary medical personnel by type of team (surgical team, main operator, decontamination team)</td>
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<td>decontamination team) in parallel</td>
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**Table 4**

**Example of configuration**

| Data:                  | + 10% for the whole of the activity                                       |
| Heuristic:             | H2: (we place the best feasible operation of the week)                   |
| OR opening time:       | 450 minutes a day for all ORs                                             |
| Assigned OR:           | OR 1 to 3: specialty 1                                                     |
|                        | OR 4 to 6: specialty 2                                                     |
|                        | OR 7 to 10: specialty 3                                                    |
|                        | OR 11 to 12: specialty 4                                                   |
|                        | OR 13 to n: multipurpose                                                   |
| Configuration:         | Opening of all ORs from Monday to Friday                                   |
| Performance rate wished:| 85%                                                                           |
| Decontamination time:  | Constant time of 20 minutes for all surgical operations                   |
require historical data, which is easily obtained by the development of hospital information systems.

In a second step, we intend to couple the simulation models and optimization methods by studying the following criteria: number of surgical teams, number of decontamination teams, inactivity time of the surgeons, and OR occupancy rates.

References


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