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Operational and strategic decision making in the perioperative setting: Meeting budgetary challenges and quality of care goals

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Efficient operating room (OR) management is a constant balancing act between optimal OR capacity, allocation of ORs to surgeons, assignment of staff, ordering of materials, and reliable scheduling, while according the highest priority to patient safety. We provide an overview of common concepts in OR management, specifically addressing the areas of strategic, tactical, and operational decision making (DM), and parameters to measure OR efficiency.
For optimal OR productivity, a surgical suite needs to define its main stakeholders, identify and create strategies to meet their needs, and ensure staff and patient satisfaction. OR planning should be based on real-life data at every stage and should apply newly developed algorithms.

Abbreviations: AI, artificial intelligence; CM, contribution margin; DM, decision-making; NORA, non-operating-room anaesthesia; OR, operating room; PACU, post-anaesthesia care unit; ROTEM, rotational thromboelastometry; TT, turnover time.

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Introduction

Efficient operating room (OR) management is a key driver of a hospital's economic success. Increasing economic pressure on hospitals [1] has led to a constant balancing act between optimal OR capacity, allocation of ORs to surgeons, assignment of staff, ordering of materials, and reliable scheduling of the cost-intensive OR [2], while keeping patient safety incidents rates low [3]. Several approaches have been applied to optimize OR management, including easy-to-use formulae, complex algorithms, and artificial intelligence (AI) [4]. We provide an overview of common concepts in OR management, specifically addressing the areas of strategic, tactical, and operational decision making (DM). In addition, concerns regarding reliable parameters are discussed to measure OR efficiency and evaluate the potential of new approaches to optimize revenue and minimize inefficiency. Finally, the DM processes involved in maximizing productivity—defined as the ratio of input and output [5] —are divided into strategic, tactical, and operational stages (Table 1).

Tactical decisions build the basis for case-volume planning, and like strategic decisions, are made by specialized staff with a background in management studies and a solid understanding of an institution's long-term vision and stakeholders [6]. Operational DM is typically performed by clinicians who, taking an interdisciplinary approach, integrate medical needs, the urgency of procedures, surgeon availability and skills, and the expected modality of postoperative care [7]. The main goal must be to maintain patient safety, and the approach should be based on a quantitative process and outcome metrics [8–12].

Process and outcome metrics

A procedure is defined as the time between pre-incision, incision, and post-incision [9]. It usually involves activities performed by specialists drawn from disciplines outside the OR, such as radiologists or pathologists. The inclusion of anaesthesia in procedure time can vary [9].

The time during which a surgeon is not actively involved and the time parallel work can be scheduled is referred to as “idle time”.

Turnover time (TT) refers to the time needed for one patient to leave the OR and the next to enter it [9]. If an “anaesthesia preparation room” exists, TT refers to the time needed for cleaning the OR after the previous procedure and setting up for the next scheduled procedure [10]. Additionally, surgeon TT refers to the time at which an individual surgeon should be ready for active involvement in the next procedure [11].

Furthermore, increasing OR revenue mainly aims at optimizing costs in relation to OR efficiency [12,13]. In healthcare, efficiency can be defined as the maximum intermediate output (e.g., number of procedures) or final output (e.g., patients cured by surgery) in relation to all inputs (e.g., fixed and variable costs) [14].

OR utilization can be used as a measure of performance [20]. “Raw OR utilization” is defined as the ratio between the length of time needed for each surgical procedure and the amount of time allocated for it [15–17]. Well-staffed and well-equipped ORs allow initiation of anaesthesia for the next scheduled operation while the current procedure is still underway. “Adjusted OR utilization”—which

Table 1
Aims and examples of the three stages in OR management DM.

	Aims	Examples
Tactical	Allocation of OR time Planning approximately 1 year in advance	Allocation of OR capacity stage 1: equipment and expert staff planning based on future workload [55]
Strategic	Long-term changes in OR capacity	Creating new partnerships with hospital networks, welcoming new disciplines to an existing facility [55]
Operational	Weekly/day-to-day planning	Scheduling procedures into OR time and respective appropriate staffing accordingly, shifting scheduled procedures to other ORs, setting priorities for emergency cases, planning add-on cases [55]

Abbreviations: OR – operating room.

accounts for TT by incorporating it into the total time of case duration before setting the total time of cases in relation to allocated OR time—might be a more meaningful outcome parameter [18,19].

TT is indispensable for all procedures [23]. It is a potential target for optimization, increasing OR productivity and staff satisfaction [23]. However, it is limited by some factors such as the existence of anaesthesia preparation rooms, sufficient staffing, optimized anaesthetics, and the availability of process protocols or holding areas in close proximity [19,20]. Despite a resulting quantitative increase in cases, faster TT only helps reduce direct and indirect staffing costs and has little effect on revenue [21]. On the other hand, adequate capacity planning during the tactical DM stage can lower costs and increase the quality of care [22].

Tactical capacity planning relies on computer software analysis of historical OR times in a specific hospital or institution, including TT, case cancellation rate, or even admission to a post-anaesthesia care unit (PACU) or an intensive care unit (ICU) [23,24]. The most frequently used model of capacity planning assigns dedicated blocks of time to specialities or to individual surgeons [25]. However, the supposed convenience of strategically flexible OR times has led to delays and scattered work for surgeons in several studies [26,27]. Patient and surgeon satisfaction were diminished, leading to lower OR utilization and productivity [28].

Modified block scheduling, a third OR capacity planning strategy, allows for compensation of underutilization caused by a speciality blocking the OR [29]. A block of time can be made available to other surgeons or specialities in advance if underutilization is likely [29].

Outcome measurement parameters for tactical DM

The most accurate outcome measurement parameter for tactical DM is contribution margins (CM) per OR hour [30]. Allocation of OR blocks to subspecialities must aim at maximizing CM per OR hour overall. It is necessary to identify, prioritize, and support subspecialities or surgeons who have a higher-than-average CM per OR hour, in order to ensure that surgeons with less-than-average CM per OR hour can still perform their procedures without a huge effect on profitability [7]. For such a model to succeed, an open, honest communication with non-prioritized surgeons is needed (see Fig. 1).

Once capacity planning is finished, there are two options within the tactical DM process: advance scheduling and allocation scheduling. During advance scheduling, an OR and a date are assigned to each intervention, whereas allocation scheduling determines the starting time of the procedure [31–33].

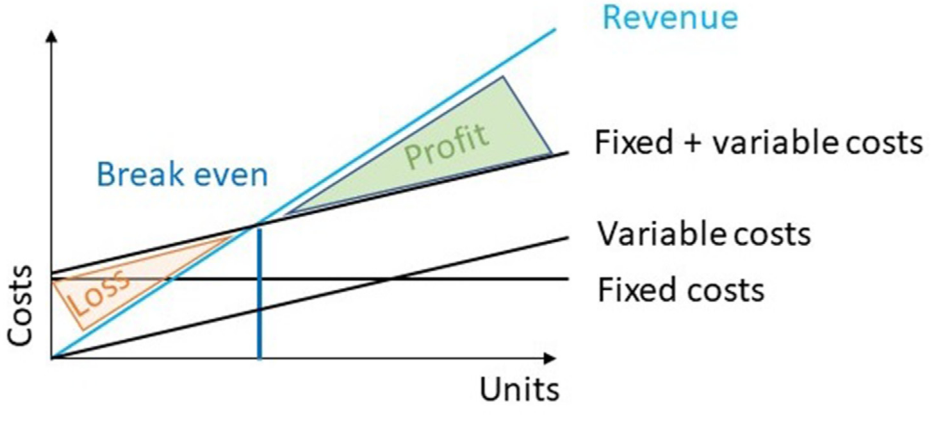

Fig. 1. Illustration of productivity-dependent (volume/number of "units" or procedures) profitability and loss (CM per OR hour = (revenue − variable cost)/OR hour). CM, contribution margin; OR, operating room.

Numerous limitations complicate these processes. Even historically recorded data can be biased due to factors such as low caseload numbers. The more number of surgeries per week a surgeon performs, the more accurately OR utilization can be calculated and used as an outcome parameter [34]. Studies assessing the daily elective caseload of an individual surgeon in Iowa or Florida suggest that this surgeon usually has only one or two scheduled cases per day [35,36] making both "raw" and adjusted OR utilization for each surgeon very wide. This is the reason why the allocation of OR blocks cannot be based solely on OR utilization, especially in the case of low-volume surgeons [35].

The duration of surgery is highly uncertain [30,37] and may vary depending on the team's skills, the patient's condition [38], the time needed for induction and emergence from anaesthesia [39,40], late arrival of patients (or surgeons), unforeseen emergency surgeries, lack of sufficient resources, and additional care requirements. Some situations involving highly-comorbid patients with conditions such as diabetes, elderly patients, and children can be planned for in advance [41], but there may also be a procedure-related [42] higher risk of uncertainties, as in the case of cardiac or neurologic surgery [43]. Cleaning between infectious patients might also lead to delays [44]. Therefore, each institution—whether a teaching hospital, a community-based hospital, a trauma centre, etc.—has a unique set of circumstances. The degree of clinical experience showed no significant association with variance in the time that anaesthesia trainees needed for induction, but the predicted amount of time needed by a trainee varied a lot more from the actual time needed [45].

For an 8-h OR schedule, surgeons' predicted OR time on average underestimates "real procedure time" by 22 min [46]. Such confounders may result in a case of cancellation and in the loss of OR capacity [47]. Thus attempts to optimize the predictive value of case duration are ongoing [48].

Outcome parameters in operational DM

Operational decisions aim at optimizing pre-arranged schedules to include the immediate effect of all the aforementioned uncertainties. Decisions are made during daily business and are followed by immediate actions/changes. In contrast to strategic or tactical DM, operational DM relies on OR utilization as its main outcome parameter.

Block utilization refers to profitable surgical activity during a dedicated time block, and OR utilization quantifies OR "room use" [19]. It is a measure of the quality of planning by the occupational groups directly involved in the OR, including the scrub nurses, cleaning staff, anaesthetists and OR coordinators. Block utilization, on the other hand, depends greatly on surgeons' reliable block-time filling [19].

OR utilization is the main performance indicator in operational DM. It allows a comparison of OR time allocated and OR time used for the treated patients [19].

Early closing of ORs leads to underutilized time [19]. Underutilized time is inefficient, since fixed costs are covered on an operational DM level. Staff are assigned in advance during tactical DM and need to be paid no matter how long the OR is in use. However, underutilized OR time has no additional costs.

Additional unplanned OR time is referred to as overutilized time [19]. An overutilized hour has a 1.75 times higher negative impact on financial expenditures [21,49]. It generates direct and indirect costs, such as staff dissatisfaction due to longer work hours, or expenditures for unforeseen prolonged childcare [21]. Adequate scheduling of cases in accordance with the planned working hours should keep the incidence of overtime and early ends within a 10% margin compared to the optimal plan [50]. While managing the speed of teams as a part of productivity maximization is targeted in operational scheduling [51,52]. Adequacy of OR schedules additionally affects efficiency through improvements in staff satisfaction [53].

Allocation of a start time is another important aspect of operational DM since impacts patient waiting times and influences patient satisfaction—a key performance objective of an OR [8]. Studies revealed that 45 min is the average amount of start-time tardiness for an 8-h schedule [54–57].

To sum up, operational efficiency optimization needs to take several metrics into account: OR utilization, over-or underutilized time, patient waiting time, and start time.

Several studies have tried to compare the value of tactical versus operational management decisions in maximizing OR efficiency. Peltokorpi et al. [58] believed that operative decisions have a greater impact on productivity than strategic decisions, highlighting the importance of a clear institutional strategy in order to better plan OR hours and staff [58]. Other studies propagate early (2–3 months in advance) OR allocation and staffing as having the greatest impact on OR planning, while a reduction in TT and prevention of start-time tardiness have negligible effects on cost [7]. At least, reasonable process organisation, provision of accurate information at correct times, and tools to monitor such parameters are drivers of successful OR management and adaptations during all three DM phases [59].

Implementation of mathematical models

Maximal economic performance in the OR can help a healthcare institution succeed only if patient satisfaction and quality of care are ensured [60].

Numerous mathematical models aim at optimizing OR capacity planning. Already in 1999, Dexter et al. applied a bin-packing model to optimize add-on case fitting while keeping OR utilization at a maximum [61]. ORs are represented as bins and as procedures that need to be packed into the bins. The authors differentiate between online bin-packing—through which sequential scheduling of procedures is done according to urgency—and off-line planning, in which previously batched procedures are simultaneously allocated. Off-line batching helped fit in additional procedures. The authors conclude that a best fit descending scheduling strategy could maximize OR utilization. Other bin-packing models were reviewed by Erdogan et al. [5].

Other studies have successfully used a “mixed-integer linear programming model with multiple objectives” instead of the standard “Benders' decomposition method” to optimize planning in tactical DM, based on modified block scheduling. Such an approach would integrate cancellation of cases or patient tardiness, overtime, surgeon idle time, and target minimal delay in starting emergency procedures [62].

Some authors have applied a bee colony algorithm to establish optimal planning in open OR scheduling systems, balancing out the aim of minimizing total operating cost and overutilized OR time while ensuring maximal OR utilization [4]. It resulted in better-than-expected and excellent performance for high (>110) and low (<110) scales, respectively, for surgical slot planning [4].

A significant reduction in unused time and attributable costs, and overtime operating costs also resulted from applying a “hybrid genetic algorithm” in the planning of an openly scheduled OR [4]. Zhang et al. applied a genetic algorithm to solve the problem of dynamic scheduling during daily business. This allowed better resource utilization (measured by surgeon waiting time and OR idle time) [63].

Many other approaches show promising results in theory. Among these are stochastic models [64,65], exact algorithms (column generation, dynamic programming, branch and bound, branch and cut, branch and price), heuristic algorithms, and simulation-based studies (the Monte Carlo method, discrete-event simulation, and the Markov decision process) [64]. Gul et al. proposed Multi-criteria models and compared a dozen heuristics of sequencing and patient appointment time setting, and showed that a bi-criteria genetic algorithm could be effective in balancing OR overtime against patient waiting time [66].

An analysis of the usability of a combination of operational and strategic/tactical DM was conducted based on a stochastic mixed-integer programming model [10]. The model allows an evaluation of pooled ORs vs. block scheduling, giving credit to the parallelizability of surgical procedures. Such integrative approaches are important for integrating research into real-life realities.

Finally, since postoperative care is an important aspect of the perioperative setting and needs to be incorporated into a hospital's organization process outside of the OR, other authors have tried to apply swarm optimization algorithms to coordinate the optimal number of open ORs per day in terms of the availability of recovery beds [67].

Future research should aim at closing or at least narrowing the gap between theory and practice. Simple measures can be economically beneficial, such as giving surgeons feedback on cost, efficiency, and productivity [68]. Studies in future should examine the effects of flexible allocation models apart from block booking [69].

Contribution of anaesthesiologists to cost-effectiveness

Finally, literature on the cost-effectiveness of treatments used in anaesthesiology is scarce [70,71]. Despite a relatively low proportion of costs attributable to general anaesthesia (5.6%) [72], reducing inefficiency by minimizing anaesthesia-related variable costs is paramount. The use of new anaesthesia drugs, as well as safety equipment and monitoring devices, can help shorten emergence from anaesthesia and time in a PACU while maintaining patient safety and even lowering the incidence of postoperative complications [73] or reducing unplanned ICU admissions [74]. Despite their additional costs, such measures are highly effective [75]. Since the introduction of patient blood management, the use of erythrocyte concentrations and fresh-frozen plasma has been decreasing, along with the use of expensive diagnostic measures such as ROTEM, with positive effects on cost-efficiency [71].

Adequate staffing for safe and efficient anaesthesia is a necessity in cost optimization [60] and must be based on historical data. Short-term staffing plans based on as little as 30 workdays can have a beneficial effect on cost and productivity (35% decreased costs, 27% increased productivity). For longer planning periods (quarterly), 9–12 months of data are optimal [76].

Optimization of perioperative care—including fast-tracking and standardization of recovery protocols and prevention of delirium and other postoperative complications—has the highest impact on cost-efficiency [70]. Realistic PACU planning is a prerequisite for efficient OR management [77,78], and optimization of cost-efficiency remains a collaborative interdisciplinary duty.

Scheduling the nonoperating room anaesthesia suite (NORA)

With the increasing number of procedures performed in an ambulatory setting and expansion in the scope of procedures conducted in the NORA suite, scheduling of interventions outside of the OR has become a novel and quickly emerging task [79]. Warner et al. claimed that high satisfaction of both patients and interventionalists can be achieved through block scheduling in a 2 weeks interval [80]. Preoperative assessments and postoperative management form an important part of NORA-based procedures, and NORA scheduling should therefore be entrusted to anaesthesiologists [80].

Conclusion

A plan of action aligned with the demand for profitable ORs is urgently needed. For optimal OR productivity, a surgical suite needs to define its main stakeholders, identify and create strategies to meet their needs, and ensure staff and patient satisfaction. OR planning should be based on historical data at every stage and should apply newly developed algorithms. Operational planning adjustments are only possible based on realistic OR and staff scheduling and should take place well in advance. Computerized plans tend to exclude key factors in human interactions, thereby ignoring important team-based effects on OR efficiency. Holistic planning will allow full attention to be paid to the patient on the day of surgery, increase patient and staff satisfaction, and maximize productivity. Financially-driven changes in OR management will inevitably lead to a change in hospital culture. They will ultimately be beneficial for both economic and medical optimization of current OR management.

Practice points

- Operating room (OR) management consists of three inclusive decision-making stages — strategic, tactical, and operational — with clinicians actively involved, at least, in the second and third stages.
- Acquisition of institution-specific historical data on length of surgery, turnover times, OR utilization and related costs allows for optimal staffing over the long term, allocation of OR times to surgeons, and quick but adequate adjustments of short-term, day-to-day decisions, with a resulting increase in OR profitability.
- The establishment of numerous algorithms and theories has led to a complexity in OR management that requires interdisciplinary teamwork involving experts from all fields.
- The goal is to ensure the quality of care while meeting the demands of economic challenges.

Research agenda

- The practicability of flexible OR capacity allocation models and their effects on efficiency and productivity need to be examined in detail.
- Service-specific cost-effectiveness studies are needed to improve OR efficiency, increase staff and patient satisfaction, and most importantly guarantee patient safety and high quality of care.
- Further research should aim at closing the gap between theoretical optimization of OR planning and application in daily management decisions.
- Operational and strategic decision making in the perioperative setting: meeting budgetary challenges and quality of care goals

Attestation

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Declaration of competing interest

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