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HOSPITAL REORGANIZATION: HOW TO HELP DECISION MAKERS? A DECISION SUPPORT SOFTWARE FOR THE SURGICAL SUITE REENGINEERING

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Abstract: *This paper proposes a global and complete decision support tool able to help decision makers in the reengineering of a surgical suite. Under increasing economic pressure and subject to rapid evolutions of technology and surgical protocols, hospitals have to consider radical organisational changes to ensure continuous efficiency. Recent findings in enterprise modelling highlight the importance of having a global, complete and 'generic' model to support the design of a new surgical suite. In another field, researches on decision support tool using discreet event simulation and optimisation techniques mostly focus on specific reengineering issues (i.e., number of operating rooms, PACU beds, efficiency of the surgical planning) without addressing globally the challenges related to overall efficiency of the surgical suite. The decision support platform that has been developed is based on a 'generic' surgical suit model able to evaluate the impact of hospital managers' choices during each phase of the reengineering project thanks to a discreet even simulation kernel. Created from the experience of five private and public hospitals and using an automatic generation of simulation models, this decision support tool exceeds the limits of currents simulation models and offers a full adaptability to a large variability of hospital practices. Following several steps, this approach supports strategic choices about infrastructure, and enables to progressively define the surgical suite functioning by assessing the impact of choices related to peripheral resources, support processes and personnel organisation*.

Keywords: decision support tool, reengineering, discreet event simulation, operating theatre, surgical suite, generic model

1. Introduction

In the current economical, political and sociological context, in France as well as in other OCDE countries (USA, Canada, Western Europe), health care organisations are prompted to initiate modernization projects in order to answer to the increasing care demand and to reduce health care expenses, while guaranteeing a high level of quality of care. Such reengineering projects raise a certain number of issues, particularly regarding the design of the new facilities. Along this reorganization process, decisions that are taken will have a great impact during the next 10 to 30 years (i.e., size of the buildings and of specific resources, work organization, personnel management policies). At the end of the reengineering project, the choices still have to be questioned according to the environment changes, in order to maintain an efficient organization. In practice, these decisions are taken without any decision support tools and are generally based on individual expertise, which does not guaranty that the best decisions are made.

The surgical suite is one of the most expensive facilities in a hospital and is usually the place which concentrates a lot of interest during a reengineering project. A certain number of hospitals have chosen to group surgical facilities. Hence, form several mono-disciplinary surgical suites physically partitioned, the project leads to move toward a multi-disciplinary surgical suite, which gathers the activity form several specialties. Three main objectives are announced when heading for such grouping: increasing security of the patient, increasing the flexibility of the resources, reducing the global cost. This kind of project however raises a certain number of issues: how many operating rooms (OR), beds in the recovery room, induction areas, will be necessary? Which scheduling rules will apply to the OR? What will be the Master Surgical Schedule? How will the evacuation of waste be organized? How many nurses, stretcher-bearer, housekeepers will be required? These questions are difficult to answer considering the complexity of processes performed in the surgical suite and the diversity of surgical activities. The new surgical suite will also put together people from different specialties, used to work separately. The design of the new structure must rely on a consensus, based on quantitative and objective results and not only on subjective considerations.

In the literature, studies dealing with surgical suites' reengineering are available. Some tools have been developed to tackle the strategic level of reengineering projects in hospitals. They use different technical approaches (i.e., enterprise modelling, simulation, optimization) to tackle different aspects of the surgical suite organisation (i.e., technical facilities, operational process, decision process). Among them we find studies using enterprise modelling which aim to depict the main aspects of the surgical suites through different point of views [Trilling, 2006]. Starting from well known modelling approaches, such as IDEF, ARIS, GRAI, researches in healthcare led to develop new approaches and models to meet hospitals' requirements. Research projects from [Pourcel and Clémentz, 2006; Fletcher and Worthington, 2007] start from the similarity amongst hospital functioning and try to define complete and "generic" models used in the design of new surgical suite. Other studies address the problem of determining the size of the resources required to perform the activity. Authors use simulation approaches to size critical equipments and facilities (bottle neck) [Lowery and Davis, 1999] according to patient and logistical flow carried out [Ballard and Kuhl, 2006]. Simulation can also be used to evaluate several organisational and architectural alternatives [Centeno et al., 2001]. In parallel, studies using optimization establish new rules for affecting activities to resources [Marcon et al., 2001; Guinet and Chaabane, 2003; Beliën and Demeulemeester, 2007; Hans et al., 2007]. Recent works combine simulation models and optimization for finding at the same time the right number of critical resources such as operating room as well as the set of planning rules, both integrated in a global approach of reengineering [Marcon, 2003; Denton et al., 2006]. Centeno enlarged the simulation model of the surgical suite to consider the personnel requirement and to propose organizational improvements. However this model was relatively limited for designing precise personnel organization [Centeno et al., 2001]. To overcome this drawback, other authors propose advanced decision support tools that automate the design of personnel shifts. These tools are based on hybrid approach combining simulation and linear programming [Centeno et al., 2003; Trilling et al., 2006], meta heuristic algorithms [Yeh and Lin, 2007] or specific heuristic [Trilling et al., 2006] in order to optimize the personnel shift scheduling and to increase the global performance of the service.

One of the limits of classical simulation approaches lies in the difficulty to design a model both precise and generic. With current modelling and simulation languages, it is possible de create a generic model that could fit to several hospitals, but the model will represent the reality with a coarse level of details, and would not be able to solve real problems. In order to create a precise model, it is necessary to define accurately each situation that could occur. A precise model is generally designed to answer specific issues for specific hospital and thus can not be considered as a generic model.

The difficulty to design a model both precise and generic is particularly present for the issues relative to personnel management (position definition, staffing and shift scheduling). In a surgical suite, especially in a multidisciplinary one, the way the workforce is organized can be very different from a hospital to another. These main differences are for example:

1. **Position definition**: definition of personnel categories according to their position (i.e., physician, registered nurses, anesthesiology nurses, auxiliary nurse, …)
2. **Position allocation**: allocation of personnel categories to the tasks they have to perform.
3. **Team definition**: choice between polyvalence and specialization of personnel with the same position on specific tasks that can be differentiated by the localization or the surgical specialty.
4. **Workforce sizing**: definition of the number of employees belonging to each team.
5. **Shift scheduling**: for each team, definition of shifts and the workforce for each shift.

In most of the models presented above, the decision maker can adjust the number of resources available. More seldom, he can test several personnel allocation scenarios (point 3) [Albert and Marcon, 2006], but the constraints have to be integrated since the creation of the model by a simulation expert. In others papers, the models allow to act on the working shifts of employees (point 5) [Centeno et al., 2001; Yeh and Lin, 2007] [Trilling et al., 2006] but only for a single team performing specific tasks.

There is no reference in the literature, which propose a surgical suite reengineering model that : (1) allow the decision maker to describe the personnel organization throw the 5 levels of description, (2) can assess the performance of the specific organizations and (3) can be adapted to different hospitals configurations without requiring programming adaptations. That is the reason why we focused our research on a complete decision support tool able to help decision makers in the reengineering of a surgical suite from the global infrastructure design to the precise personnel organization.

Our purpose is to develop a decision support approach and software that could guide the decision makers all along the reengineering of a surgical suite. This approach combines several of the aforementioned decision support tools integrated in a global and 'generic' surgical suite model. To link these different techniques, we used a hierarchical decomposition of choices in several levels of decision, such as found in [Marcon, 2003; Denton et al., 2006]. The main objective of this software is to provide an objective assessment of several organizational alternatives before implementing any of them for real. Supported by a computerized application, the proposed approach will allow saving a large amount of time in the reengineering process. The decision support software must help the surgical suite manager to analyse and capitalise knowledge about the processes. In order to facilitate the appropriation of the software by an operating room manager, we found interesting to give autonomy in the exploitation of the decision making tool.

The paper is organized as follows. Section 2 describes the methodology that has been followed to design the structure of the decision support platform for surgical suite reengineering and describes the different steps of its use. In section 3 we describe how the platform has been experimented to support a real hospital reengineering project. Finally in section 4 we discuss the feedbacks of this platform and highlight tracks for further works.

2. Methods

2.1 Methodology

Our approach of reengineering methodology is based on enterprise modelling. Enterprise modelling methods give a graphical representation of the system according to a set of different views [Davis, 2001]: physical view, information view, decision view, resources view, process view, and so forth. The advantage of the multi-view modelling is a comprehensive representation for a complex system. This representation is used along the whole reengineering project to support the existing analysis and to design the future organisation in a univocal way, which every actor can share, criticize and validate.

The classical reengineering methodology includes several steps as show on figure 1: (1) as-is modelling, (2) as-is diagnosis, (3) to-be design, (4) to-be implementation. The first step consists in formulating a common representation of the service functioning (as-is system), from information gathered thanks to interviews and observations. This representation is established according to several complementary views. The second step concerns the diagnosis of the existing functioning (as-is diagnosis) and the identification of malfunctioning. Activities with non-added value, bottleneck and waste times can be identified through the use of simple diagnosis tools (5 whys, Ishikawa, etc.). The diagnosis could be reinforced by the use of flow simulation, which permits to give quantitative evaluation of a given system efficiency. The performance of the actual system is assessed according to the classical triptych: quality, delay, cost. The gap between objectives and the performance of the actual system permits to identify the main malfunctioning and organisational weaknesses to tackle and to establish an action plan to implement in order to improve the global performance. The third step consists in designing the model of the future system. The decision maker has to define organisation rules, to design the processes, to chose and to size the resources which will be implemented in the future system (fourth step). The difficulty of the to-be design is to figure out what could be the consequences of the different choices, without previously assessing them in the real world. Simulation could assist the design tasks, since it is able to give a faithful image of the performances of the service before materially implementing it. If the performance of the tested configuration does not satisfy the objectives, simulation results (performance indicators in the form of dashboards) could be exploited to adjust the to-be model. If the performances satisfy all the objectives, then the designed organisation could be validated and implemented (fourth step).

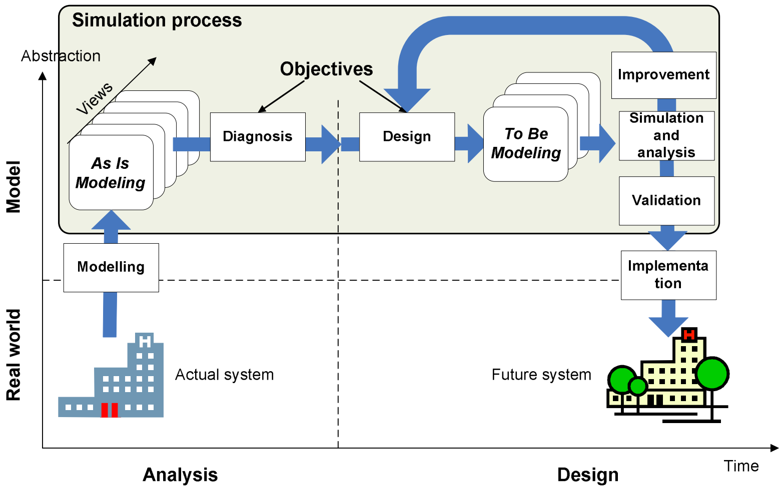


Figure 1: Reengineering methodology

2.2 Description of the platform dedicated to surgical suite reengineering

Since most hospitals, at least in France, are subject to the same regulation and are doing the same job (i.e. taking care of the patients), we found it interesting to think about a decision support tool comprehensive enough to fit a wide range of hospitals involved in reengineering projects. Therefore, the design of this tool includes successive interfaces allowing the user to setup in an easy and intuitive way the model of the existing structure (as-is model) as well as the model of the future organisation (to-be model). The utilisation of this tool is progressive, since it describes the process with rough details at the beginning and incrementally adds details on the process, until the target organisation is extensively defined. At the beginning, with very few details, the tool is able to define the main activity scheduling rules and to size the critical resources such as architectural resources. When details are added to the process (succession of elementary activities, material and human resources associated to each activity), it becomes possible to evaluate and to adjust the number of other resources required.

Using the principles of the enterprise modelling, the simulation, and the optimization techniques, we developed a platform based on 3 models: (1) an activity flow model driving the user to the definition of the activity demand, (2) a process model helping for the design and the assessment of various configurations, thanks to simulation, and (3) an organization model which involves tools for resources sizing. Through a set of user interfaces, this platform which supports our approach guides the user in the reengineering process. It helps him for considering decisions relative to the three hierarchic levels: (a) design, configuration and sizing of the most critical resources (bottleneck, expensive resources, like operating rooms in the case of a surgical suite) according to a global activity to perform, (b) sizing of other non critical resources (for example, the number of beds in the recovery room), (c) definition of the staff required to perform the activity according to the work organization (skills, responsibilities, activity scheduling). Although the approach proposed could be applied to a wide range of reengineering projects, the platform developed is specific to surgical suite reengineering. Figure 1 describes the successive steps in using the decision-support platform:

Organisation of critical resources: The user gives the specification of the surgical suite organization (names of the specialties, number of operating rooms, number of post-anaesthesia care units (PACU), number of receptions, number of induction rooms, etc.) and is invited to provide details about the relation between the operating rooms and the others resources. For example, after a patient is operated in operating room #1, #2 or #3, he is transported to PACU #2 for his recovery. If the patient is operated in operating room #4, #5, #6, #7, he is transported to PACU #1.

Process modelling: Then the user describes the processes related to the patient care, as well as the logistical processes. In total, seven processes are linked together (patient care process, sterile medical device management process, operating room cleaning process, waste management process, stretcher and operating table management process, bed cleaning process, linen and shoes cleaning process). The process modelling is facilitated by a generic template that covers all the activities requiring material and human resources of the surgical suite. This process is considered as generic because it includes all the different practices observed in surgical suite of French hospitals. We have identified seven different practices in the French surgical suite such as “the induction is performed in a specific induction room or directly in the operating room” or “the patient recovers in the recovery room on his bed or on a stretcher” for example. With the global process map of the surgical suite designed, the user can at any time define tasks durations and assign staff to each task.

Data collection and extrapolation: The activity data need to be defined. The activity data are characterized by the number of cases usually performed per period and the statistical duration law for each speciality on each type of surgery (ambulatory, regular, elective case). These activity data are extrapolated in order to figure out the evolution of the activity for the next 10 years.

Scheduling and assignment rules: In the fourth step, the surgeon (or surgeons' group) block time assignment is defined. This step could be considered as the building of the Master Surgical Schedule (MSS).
Then we check if for each surgeon, the surgeon's block time assignment fits with the actual surgical activity (balance between load and capacity). After this checking step the simulation model can be generated.

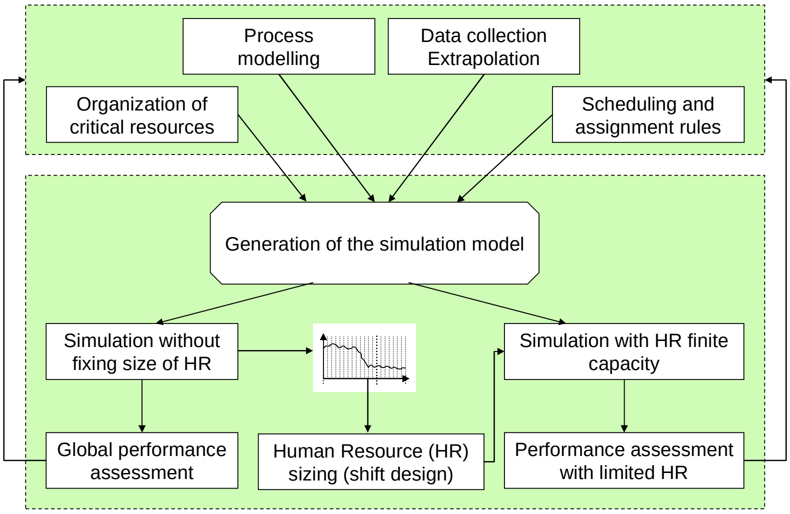


Figure 2: Structure of the decision support platform

The next step is an infinite capacity discrete events simulation to obtain the global performance of the surgical suite. This simulation also provides workload curves of the resources, which traduces for each time slot of the day the number of material and/or human resources required for each skill category. This workload curves are used to define the most efficient shift design, and to implement the timetable of human resources into the simulation model. It also allows assessing the performance of the surgical suite under limited human resources. After this first infinite resource simulation, the human resources organization can be adjusted in order to improve performances.

3. Application and results

The approach and the platform supporting it have been developed within the scope of the HRP² project involving a consortium of several French hospitals and academic research laboratories. This approach has shown its effectiveness when it was used to size the resources of a hospital external to the HRP2 consortium and involved in the reengineering of its multi-disciplinary surgical suite. The partnership was built on reciprocal profits. For the HRP2 partners the experimentation on a new case could permit to validate the relevance and the interest of such a decision support tool in a real situation of reengineering process. For the hospital external to the HRP2 consortium the results given by the simulation could quantitatively validate the organisation choices and identify eventual inconsistencies.

3.1 Description of the case

The Regional Hospital of Annecy was involved in a reorganization project named NHRA (Nouvel Hôpital Regional d'Annecy) that leads to build a new hospital by end of 2007. During this project, the Regional Hospital of Annecy initiated an important operating room (OR) merging process. Before the transfer in the new facilities, there were two surgical suites located at two different floor of the hospital:

- One multi-disciplinary operating theatre producing 8600 surgical cases per year composed by 4 induction rooms, 8 operating rooms and a 11 beds in recovery room.
- One specialities operating theatre, open half a day, composed by 3 operating rooms and performing 1200 surgical cases per year.

After their surgery all the patients of the two surgical suites were transferred to the central recovery room by specific stretcher bearer. The emergency surgical activity oversteps 2500 surgical cases per year, constraining the OR and the recovery room to be opened 24 hours a day. By merging the surgical suites, decisions makers expected to reach financial savings while reducing patient transfers as well as the number of required resources. More precisely, the main issues for this hospital were:

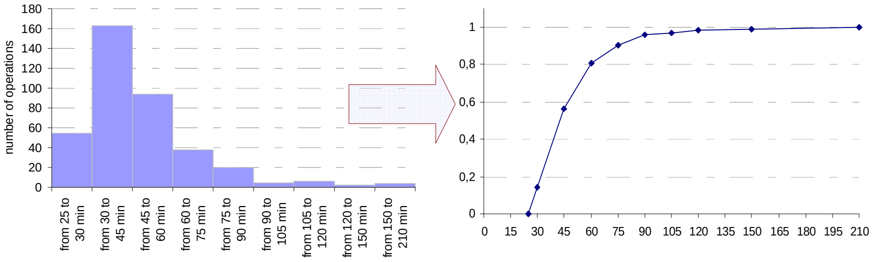
(1) to assess the performance of the current state of the surgical department (i.e., operating rooms split into several independent surgical suites),
(2) to figure out what could be the best organization of a merged multi-disciplinary surgical suite,
(3) to evaluate the global benefits of the reorganization project, including financial and flexibility aspects.

3.2 Implementation: parameterization

Before this study begins, the decision maker received a half-day preliminary training, including a presentation of the tool (data required and output information for each strategic level of decisions), as well as the set up of the decision support tool on his computer. Afterwards, the continuation of the reengineering study was done by phone meetings and emails.

The manager of the reengineering project decided to lead two approaches for the reengineering of his surgical suite at the same time: (1) a classical approach based on the calculation of average activities and meeting with surgeons; and (2) a new reengineering approach using the decision support software.

For the strategic reengineering level, the surgical activity data was collected relatively easily, since the surgical suite already used an information system for supervising the activity. The surgical activity of the past 6 months was extracted from the database to an Excel worksheet. Then, using advanced excel functions the decision maker could produce statistics on the activity and tasks duration. The data analysis stage was the most difficult task, due to the knowledge required to build the statistical distribution laws of activities duration and emergency case arrivals. But this operation was done relatively well by doing analogies between statistical duration laws with a histogram representing the distribution of the past activity for several duration range.



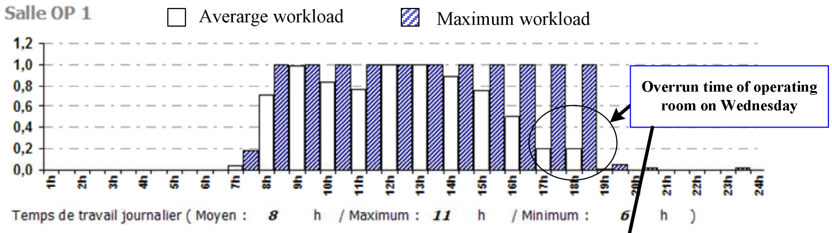
Duration Histogram of the gastroenterological surgical operation

Duration cumulative law of the gastroenterological surgical operation

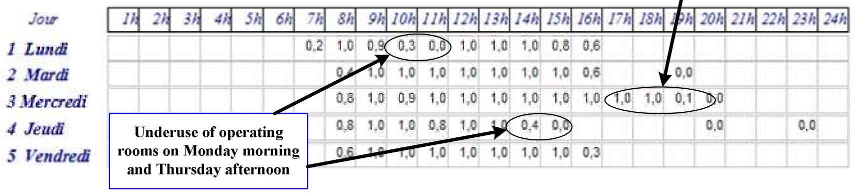
Figure 3. Duration histogram and cumulative law of the gastroenterological operation

After the data gathering and analysis step, the decision maker implemented the software, following the interfaces and information requests. The first results permitted to evaluate the performance of the current organization (HRA) by assessing the workload curves of operating rooms along the day, giving the operating room workload hour per hour and for each day of the week (Figure 4). These results were validated by the supervisory staff by comparing them to the current functioning. Thus, the results of the simulation corroborated the activity study performed previously by the supervisory staff. These two comparisons created an interest in the simulation results and a relative trust in the decision support tool relevance.

The second simulation campaign led to evaluate the relevance of a first scenario of the future NHRA (NHRA#1). In this scenario, the goal was to open 14 operating rooms each day. The analysis of simulation results showed that all the expected surgical activity (i.e., average activity) could be performed into 9 operating rooms with almost the same opening range, only by changing the main activity planning. The use of our tool highlighted that it was unnecessary to open 14 operating rooms, and led the decision maker to develop other scenarios. The negotiation and the explanation to surgeons for such decrease of operating room number is a sensitive and crucial stage for the reengineering project. In this difficult negotiation, the workload curves like the one shown on Figure 4 were used as a powerful negotiation support showing objectively the situation.



Averarge and maximum workload foreach hour



Jour	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
1 Lundi							0,2	1,0	0,9	0,3	0,0	1,0	1,0	1,0	0,8	0,6								
2 Mardi								0,4	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,6			0,0					
3 Mercredi								0,8	1,0	0,9	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,0				
4 Jeudi								0,8	1,0	1,0	0,8	1,0	1,0	0,4	0,0					0,0			0,0	
5 Vendredi								0,6	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,3								

Averarge workload foreach hour and each week day

Figure 4: Example of efficiency analyse with workload curves

For defining more precisely the resources required in recovery and induction rooms, the decision maker used the second core part of the software, by giving more details about the processes and the resources' organisation. The user defined the patient process durations for each task through a graphical interactive interface. This interface displays all the processes (i.e, patient, wastes, cleaning …) of the surgical suite and allows the user to set different parameters like activity durations. In the reengineering process, this interface also enables to assign staff to each task.

The graphical models initially instantiated and parameterized by the decision maker facilitated the negotiation between actors and managers by giving a single and global point of view of the actual organisation and of the projected organization. These interfaces enable to easily understand the links among different activities and help to analyse the causes of eventual malfunctioning (figure 5).

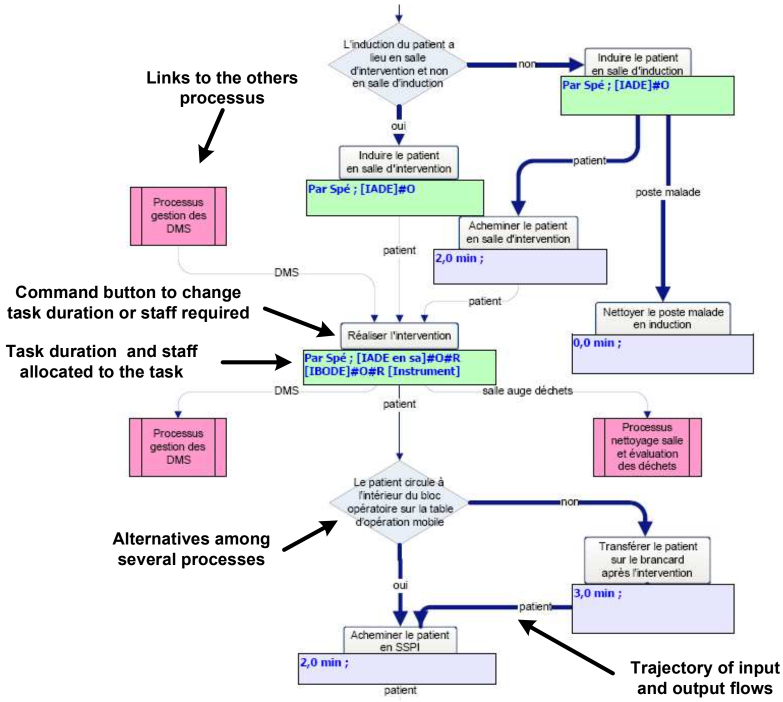


Figure 5: Example of the process definition interface

The simulation of the processes provides workload curves for other resources and could determine the most appropriate number of PACU beds and induction areas required. These results compared with the preliminary project led to identify ways of improvement and to define other organisational scenarios. These new organizations were defined with collaborative consent and enabled decision makers to choose a solution, both cost effective and accepting activity fluctuations. The final NHRA project was obtained after two more iterations (NHRA#2 and NHRA#3) and converged to a surgical suite with 9 ORs and with longer working durations.

Finally, 4 configurations have been tested and have led the decision maker to a robust compromise:

1. Evaluation of the current surgical suite (HRA)
2. Evaluation of the initial project (NHRA#1)
3. Evaluation of two new alternatives (NHRA#2 & #3)
4. Choice of a robust compromise (NHRA#4).

3.3 Conclusion of the implementation

The surgical suite reengineering project of the NRAH supported by our software lasted 3 months, and required almost five days of accompaniment work for one engineer (i.e., including data analysis validation). Thanks to the decision support tool handling, the hospital manager could capitalize knowledge and acquire a good understanding of the processes performed in the surgical suite. The decision support tool has helped the decision maker to:

- **size the number of operating rooms define the opening hours and the master surgical schedule (MSS)**: the originally MSS presented a high variability of the occupational rate among the operating rooms (form 30% to 98%). The utilisation of the decision-support platform led to reduce the number ORs required from 14 (NHRA#1) to 9 (NHRA#4). It also enabled to re-dispatch the surgical activities among the ORs in order to balance the workload and reduce the gap between the most occupied OR (rate 82% instead of 98%) and the less occupied OR (rate 50% instead of 30%).
- **determine the secondary resources workload and their opening period**: for example, concerning the Post Anaesthesia Care Unit (PACU), the use of the platform showed that 10 beds were sufficient instead of the 23 beds initially planned. However, it has been decided that the final configuration would include 11 beds.
- **determine the staff requirement for specific transversal workers**: the platform has provided workload curves that were transformed in staff requirements for each time slot of the day and for specifics skill categories in the new structure.

4. Conclusion

In this paper, we have presented the design process and the structure of a decision support tool for the reengineering of surgical suites. The originality of this tool based on simulation lies in several aspects: its adaptability to a large panel of hospitals situation; its capability to describe and simulate precise, complex and specifics organisations; its user friendly interface allowing hospitals managers to use it by themselves without simulation languages background.

The feedbacks of the experimentation of the tool by the Regional Hospital of Annecy were very instructive for our project, highlighting the strengths and weaknesses of the platform, as felt and experienced by the users. The interactive software has been rapidly appropriated by the hospital decision makers since they had the possibility to assess by themselves the performance of the current facility as well as the performance of the future one (through the adjustment of several parameters), and to compare both according to the same criteria. Despite some difficulties with statistical durations, they found the approach easy to follow, and helpful to define new organizations. They were interested by having such a tool permanently for supporting organizational decisions.

The managers have appreciated the user interface approach and were satisfied by the relevance of the results given by the tool, particularly regarding the first two stages of the approach. The interest of the managers for the first two stages was due to the rapid progress along the modelling process, thanks to a pre-parameterized generic model of surgical suite. Managers adapted a generic model by changing parameters (i.e., statistics on surgical activity, surgery durations, master surgical scheduling, process specificities), then the platform could run simulation and plot the occupation rate of each critical resources (operating rooms) and other material resources (i.e., PACU beds, induction area, stretchers, etc.). According to them, the performance indicators were sufficiently meaningful and detailed to support the negotiation between the staff and the managers. The third stage, dealing with human resources, provided workload curve for several skills category (stretcher-bearer, housekeeper, nursing auxiliary, nurse) and for each area of the surgical suite. This part of the reengineering process was long and tedious for the managers, because there was a great diversity of possible organizations and each organization required precise description of staff's activities. These facts partially explain the difficulties encountered in this decision level. In order to avoid these concerns, it could be interesting to develop and improve automatic approaches of optimization linked to the simulation model. This could lead to time savings for manager during the parameterisation step.

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References

[Albert and Marcon, 2006] Albert, F. and E. Marcon (2006). How to combine transversal staff skills in operating rooms? INCOM, St Etienne.

[Ballard and Kuhl, 2006] Ballard, S. M. and M. E. Kuhl (2006). The use of simulation to determine maximum capacity in the surgical suite operating room. Winter Simulation Conference, Monterey, California.

[Beliën and Demeulemeester, 2007] Beliën, J. and E. Demeulemeester (2007). Building cyclic master surgery schedules with leveled resulting bed occupancy. *European Journal of Operational Research*, 176(2), 1185-1204.

[Centeno et al., 2003] Centeno, M. A., R. E. Giachetti, R. J. Linn and A. M. Ismail (2003). Emergency departments II: a simulation-ilp based tool for scheduling ER staff. 2003 Winter Simulation Conference, New Orleans, Louisiana.

[Centeno et al., 2001] Centeno, M. A., M. A. Lee, E. Lopez, H. R. Fernandez, M. Carrillo and T. Ogazon (2001). A simulation study of the labor and delivery rooms at JMH. 2001 Winter Simulation Conference, Arlington, Virginia.

[Centeno et al., 2001] Centeno, M. A., E. Lopez, M. A. Lee, M. Carillo and T. Ogazon (2001). Challenges of simulating hospital facilities. the 12th annual conference of the Production and Operations Management society POM, Orlando.

[Davis, 2001] Davis, R. (2001). Business Process Modelling With Aris: A Practical Guide, Springer.

[Denton et al., 2006] Denton, B. T., A. S. Rahman, H. Nelson and A. C. Bailey (2006). Simulation of a multiple operating room surgical suite. the 38th Winter Simulation Conference, Monterey, California.

[Fletcher and Worthington, 2007] Fletcher, A. and D. Worthington (2007). What is a 'generic' hospital model? Working Paper. *Lancaster University Management School*.

[Guinet and Chaabane, 2003] Guinet, A. and S. Chaabane (2003). Operating Theatre Planning. *International Journal of Production Economics (IJPE)*, I85(1), 69-81.

[Hans et al., 2007] Hans, E., G. Wullink, M. van Houdenhoven and G. Kazemier (2007). Robust surgery loading. *European Journal of Operational Research*, Article in Press.

[Lowery and Davis, 1999] Lowery, J. C. and J. A. Davis (1999). Determination of operating room requirements using simulation. Winter Simulation Conference.

[Marcon, 2003] Marcon, E. (2003). Aide à la Décision pour les Systèmes Hospitaliers : Application à la Ré-ingénierie et au Pilotage des plateaux médico-techniques. Senior researcher thesis. *Université Jean Monnet de Saint-Etienne*.

[Marcon et al., 2001] Marcon, E., S. Kharraja and G. Simonnet (2001). Minimization of the risk of non realization for the planning of the surgical interventions into the operating theatre. IEEE International Conference on Emerging Technologies and Factory Automation.

[Pourcel and Clémentz, 2006] Pourcel, C. and C. Clémentz (2006). Approche modulaire pour l'aide à la conception de l'organisation d'un système de production de soins. GISEH Conference, Luxembourg.

[Trilling, 2006] Trilling, L. (2006). Aide à la décision pour le dimensionnement et le pilotage de ressources humaines mutualisées en milieu hospitalier. PhD Thesis. *INSA de Lyon*.

[Trilling et al., 2006] Trilling, L., F. Albert and E. Marcon (2006). Simulation and integer programming approach for efficient shift design. INCOM'2006, St Etienne, France.

[Yeh and Lin, 2007] Yeh, J.-Y. and W.-S. Lin (2007). Using simulation technique and genetic algorithm to improve the quality care of a hospital emergency department. *Expert Systems with Applications*, 32(4), 1073-1083.