

An Operations Management Approach for Radiology Services

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Abstract: this paper focus on the application of Operations Management techniques in the context of radiological and diagnostic imaging services provision. More specifically, the outpatient appointment scheduling problem for MRI diagnostic imaging services in a radiology clinics is approached and solved taking into account set-up time minimization. This is pursued through the design of an innovative system for the on-line assignment of appointments for specific diagnostic imaging scans. An appointment rule, a patient classification and an heuristic procedure for the booking process are defined in order to better manage uncertainty and improve system performance. The proposed approach was validated on the case of a diagnostic centre of Alliance Medical, a primary multinational company in the field of diagnostic imaging services.

Keywords: Service Operations Management, Healthcare, Radiology, Appointment Scheduling.

1. Introduction

Nowadays, given the extraordinary developments in the field of radiology, the important role of images in modern clinical practice on top of the cost increase of diagnostic imaging services, a competitive and efficient radiology department should necessarily focus on improving process and resource management, mainly in terms of operations efficiency. Computerized Axial Tomography (CAT) and Magnetic Resonance Imaging (MRI) represent strategic assets in radiological departments: reimbursement rates are high while service processing times are generally long. Consequently, the goal of improving these areas should be considered as a priority. Operations Management techniques may help to achieve this goal through the analysis of processes, service levels and quality standards increase, thus supporting the hospital manager in taking the best operative and strategic decisions.

Professionals in radiological sciences are often inexperienced in process reengineering and optimization; they may be persuaded that many critical issues in their departments can be solved through the application of rough-cut solutions which, on the contrary, tend to cause negative side effects: it is not advisable to reduce costs without a deep understanding of the problem that cause the inefficiency; the introduction of newer information systems on top of those already existing increases management complexity; a simple top-down obligation to increase service level is not efficient since this goal is reached only through staff coordination and encouragement.

The aim of this paper is to investigate the potentialities of Operations Management techniques in the context of health services provision and, more specifically, with reference to the radiological and diagnostic imaging field. The literature review shows a growing attention, in recent years, on the application of Operations Management techniques in healthcare, specifically regarding business-

oriented management of public health facilities. It is primarily on hospitals, indeed, that the implementation of Service Operations Management is focused (see, for instance, Butler et al., 1996; Li et al., 2002; Vos et al., 2007) even if the activities of private radiology clinics, which provide diagnostic imaging services to outpatients, certainly represent an interesting target for processes optimization. Indeed, in this paper the latter are described and analyzed. Actually, these healthcare services are becoming more and more competitive because of the great number of new private diagnostic centers growing up. In order to improve key performance indicators, lean approaches were occasionally suggested in literature (see Workman-Germann & Hagg, 2007 or Lodge & Bamford, 2008), but more structured approaches are required in order to achieve radical improvements in the way medical departments operate.

More in detail, aiming at a significant increase in efficiency and in service level, the paper suggests to approach the problem through a radical re-engineering of outpatient appointments scheduling process. "*The objective of outpatient scheduling is to find an appointment system for which a particular measure of performance is optimized in a clinical environment*" (Cayirli & Veral, 2003). It is at this stage, indeed, that the first resource allocation is defined, mainly in terms of matching between exams/patients and diagnostic machines. Correct scheduling of examinations is surely crucial in a radiology center: the activity planning helps to prevent overcrowding, avoid interference between urgencies management and standard exams programming, allows a better assignment of responsibilities among the various functions and helps preventing staff demotivation. Also, especially for public hospitals, a proper scheduling of exams avoids oversizing of departments resources, reduces overtimes and, simultaneously, the extension of hospitalization (see Tattoni et al., 2009). This paper aims to tackle the problem of radiological exams scheduling and to propose an heuristic solution; this has been already

tested on the case of a leading Italian private company in the field of diagnostic imaging service provision.

2. Literature review

Outpatient appointment scheduling problem was approached for the first time by Welch and Bailey (1952) while a comprehensive literature review was provided by Cayirli & Veral (2003) and recently updated by Gupta & Denton (2008). These studies showed that the greatest part of scientific contributions are concentrated on an off-line “static” version of the problem, where the scheduling of all examinations is determined before the first arrival. Only a few number of works focused on the dynamic appointment scheduling problem, where on-line decision-making process still represents one of the most critical complications of the problem (Gupta & Denton, 2008). In the dynamic outpatient appointment scheduling problem, patient requests arrive dynamically over time and, for each request, an appointment has to be promptly determined (Sickinger & Kolish, 2009). Relevant works in this sense are those of Klassen & Rohleder (1996, 2004) and of Rohleder & Klassen (2000, 2002). As described by Cayirli and Veral (2003), in both static and dynamic appointment scheduling problem, performance measurements typically depend on patients waiting/flow time, doctors idle time/overtime, number of patients in the queue/system and very few works seem to deal with the minimization of the time dedicated to complete machines setup.

Indeed, every time a MRI equipment focus on a different part of the patient body, the operator must change the coil and reconfigure the machine; this may take a few or several minutes. Analogously to what happens in industrial companies or in manufacturing environments, it is evident that in the absence of an appropriate procedure that consider set-up minimization in order to reduce downtime on the machine, scheduling is inefficient. Furthermore, given the relatively high tariffs of diagnostic imaging examinations, recovering slack times may lead to increase the number of service provided, which results in a significant impact on turnover and service levels. On the other hand, other benefits could be achieved in terms of the reduction of overtimes and used coils.

Ivanov et al. (2009) applied the classical scheduling model with sequence dependent setup times to Magnetic Resonance Imaging scan processing, in order to minimize the total production time; however, their approach cannot be directly used in the dynamic version of the problem: their two-stages model – in which, in a first stage all the patients requests are collected and then, in the second stage, the optimal scheduling is announced later on – is not compatible with the need of directly fixing the appointments during the patient request. This paper focus specifically on this issue, proposing a re-design of the appointment system for a radiology clinic in a dynamic context. Stochastic inconveniences such as walks-in, no-shows and emergencies are not considered.

3. Problem description

Here the outpatient appointment scheduling problem for the diagnostic imaging department of a radiology clinics is analyzed. More specifically, the problem concerns the on-

line assignment of appointments to outpatient requests for specific diagnostic imaging scans.

As previously stated, this problem differs from the traditional manufacturing two-stages scheduling problem: the scheduling must be performed real-time and appointment needs to be confirmed immediately when requested by the patients; the scheduling, however, must be appropriate so that patients do not suffer inconveniences from long waiting times or delays in their processing on the day scheduled for their examination. Workarounds such as implementing a recall process in the call-center in order to propose appointment shifting cannot be considered because usually the volumes of daily processed patients is too high.

In order to properly assess the benefits arising from improvements on the service process it is at first necessary to identify a set of performance indicators which are obviously consistent with the strategic priorities of the company (service cost, service level, machine availability, etc.). In the specific case of a radiology centre that performs diagnostic imaging examinations, the number of patients processed every day (i.e. productivity, given a fixed number of working hours) may be taken into account as an indicator of service level; note that this indicator is directly linked to Company’s revenue. All examinations that have been scheduled must be performed and it is easy to understand how the accumulation of inefficiencies during the day leads to overtime, which is another element that should be monitored and minimized. With these goals in the reengineering of diagnostic imaging service provision, the minimization of set-ups of diagnostic machines results as one of the most effective intervention in order to aim to an increase in efficiency.

Examinations are performed on parallel machines, each with a number of coils to be used on different areas of the body. Now, if the number of machines was equal to the number of examination types it would be trivial to dedicate each machine to an examination of an area of the body, effectively nullifying the number of coil change. Real-life experiences demonstrate that this would be an inappropriate solution, unless the capacity of the service provider was infinite: there would be an evident problem of load balancing; the number of examinations usually differs from type to type and this would inevitably lead to an overload for some machines and excess of idle time for others. Therefore it is correct to accept the practice that, over the working day, all machines have to run any kind of examination, in order to balance the workload on diagnostic equipment and to avoid blockage situations due to unexpected downtime.

4. Solution approach

As specified by Cayirli & Veral (2003), the design of an appointment scheduling system should deal with three fundamental aspects:

- the appointment rule;
- the patient classification;

- the adjustments for reducing the disruptive effects of uncertainty.

4.1. Appointment rule

An appointment rule is the combination of three variables: *block-size* (n_i), that is the number of outpatients scheduled to the i -th block; *begin-block* (n_1), that is the number of outpatients scheduled to the first block; *appointment interval* (ai), that is the time interval between two successive appointments.

Considering that issues regarding walk-ins, no-shows and emergency patients are not in the scope of the present paper, this appointment system does not comply with overbooking or safety capacity/time, differently from the approach in Tattoni et al., 2009. Block-size and begin-block can be easily fixed equal to the number of parallel machines (servers) that can perform diagnostic imaging scans.

The appointment interval can be determined considering the partition of working day in a number of slots, eventually derived from the analysis of historical data and relative to the number of examinations of each type that are usually performed on every type of diagnostic machine. Variability of examinations duration implies a variability in appointment interval.

Referring to the classification provided by Cayirli & Veral (2003) the appointment rule taken into account in the present paper is called *multiple-block/variable-interval rule without an initial block*. According to literature review, this kind of rule seems not to have been applied in real cases up to now.

4.2. Patient classification

In an appointment system, patient classification plays a crucial role especially when appointments have to be assigned at booking time. Having a preliminary classification of patient in a certain number of groups, these are in turn assigned to pre-marked slots, which helps to increase performance of a real-time scheduling.

With regards to applications in radiology departments, a relevant work was realized by Walter in 1973: he divided patient with similar exam times into different session. However this rules goes exactly in the opposite direction of minimizing the total setup time. Thus, for the proposed appointment system, a better patient partitioning seems to be the one based on grouping together patients with similar exam type (i.e. that request the same coil for the scan).

At this point, taking into account that daily each machine has to perform all the typologies of exams, it is possible to preemptively assign to each machine a fixed number of macro-slots, equal to the number of patient groups (i.e. different exam type). The number of slots per each macro-slots can be determined on the basis of statistical data and is considered the same for all the machines.

4.3. Adjustments for reducing the disruptive effects of uncertainty

No-shows, walk-ins, urgent patients and emergencies are typical inconveniences in a health-care system. However,

as previously stated, these elements are not considered in the present paper: the real-time nature of the dynamic problem already forces the system to cope with uncertainty. This derives from the unpredictability of the request type, of the arrival time and of the number of requests during the day.

An heuristic procedure is proposed for the booking process, in order to better manage the described uncertainty and improve appointment system performance.

4.4. An heuristic procedure for appointment scheduling process

Being k the number of outpatient groups (corresponding to the number of macro-slots per each machine) and m the number of diagnostic imaging parallel machines, S_{ij} is defined as the availability slots previously assigned to the machine i , $i = 1, \dots, m$, for the execution of the exam type j , $j = 1, \dots, n$, in a certain day. S_{ij} is comprised between 0 and S_j , that is the number of slots assigned to each machine per each day for performing the exam type j , $j = 1, \dots, n$. All these slots are available at the moment the daily planning starts.

The following procedure is proposed for a real-time appointment planning in a diagnostic imaging department, per each day in agenda:

Step 0 Set $S_{ij} = S_j$ per each $i = 1, \dots, m, j = 1, \dots, n$.

Step 1 An incoming call of type j occurs.

Step 2 If there is at least a machine i for which $S_{ij} > 0$ then go to step 3, else go to step 4

Step 3 Among the set of machines with available slots for exams of type j , assign the incoming call to the machine with the minimum number of assigned slots for exams of type j (if two or more machines have the same available capacity, choose the machine on the basis of a previously defined numerical order).

Set $S_{ij} = S_{ij} - 1$ and go to step 5.

Step 4 If there are any machines with an available slot immediately following the macro-slot dedicated to exam of type j , among them assign the call to the machine with the minimum number of total assigned slots (if two or more machines have the same available capacity, choose the machine on the basis of a previously defined numerical order). Set

$$S_{ij+1} = S_{ij+1} - 1.$$

Else if there are any machines with an available slot immediately preceding the macro-slot

dedicated to exam of type j , proceed analogously to the previous way. Set $S_{ij-1} = S_{ij-1} - 1$.

Else if there are other available slots, assign the call randomly to one of them. Set $S_{hk} = S_{hk} - 1$, where h is the selected machine and k is the exam type assigned to the selected slot

Else Stop and check the availability in an another day in agenda, following the same procedure.

Step 5 If there are still any machines with available capacity, go back to step 1. Else Stop and carry on the procedure for the next day in agenda.

4. The Case of Alliance Medical

The proposed procedure was validated with the data of Alliance Medical case, a primary multinational company leader in European and Italian sector of diagnostic imaging services. The present case study regards the activities of one of the most important diagnostic centres of Alliance Medical in Italy, the “Istituto Andrea Cisalpino”. The centre, located in Terontola (Arezzo, Tuscany), started the operations 20 years ago and at the moment employs nearly 50 people. Its service area includes Tuscany, Umbria, Marche and Latium regions. The centre perform diagnostic imaging services trough MRI and CAT machines, servicing private and local health authority patients. The case study focuses on the former type of service, for which four machine are dedicated: three of them can be considered as parallel machines, and the last is excluded from the analysis due to its particularly long processing times (it is a specific machine only used for claustrophobic patients). The centre operates 15 hours per day from Monday to Friday and 11 hours on Saturday, performing on average about 70.000 MRI exams per year. The following table shows the number of exams for each type with and without the use of Contrast Agents (CA), referring to the period coming from April 2008 to March 2009. CA utilization requires the presence of an anesthetist.

According to the proposed approach, exams (and relative patient requests) were classified in five typologies, on the basis of the type of used coil. The following table shows this classification, with the indication of the percentage on the total of the exams included in each type.

Type	Exams	Perc.
1	Neck angiography, skull angiography, cholangiography, neck, neck + CA, skull, skull + CA, facial skeleton, facial skeleton + CA, hypophysis, hypophysis + CA, orbits, orbits + CA, parotid + CA.	18%
2	Temporomandibular joint, cervical, cervical + CA, latissimus dorsi, latissimus dorsi + CA, lumbosacral,	41%

	lumbosacral+CA,	
3	Ankle, thigh, thigh + CA, leg, leg + CA, knee, knee + CA, hand, hand + CA, foot, foot + CA, wrist, wrist + CA.	24%
4	Arm, elbow, shoulder, shoulder + CA	10%
5	Superior abdomen angiography, superior abdomen, superior abdomen + CA, pelvis, pelvis + CA, bilateral breast, bilateral breast + CA, mono-lateral breast, thorax, thorax + CA.	7%

Table 1: exam classification

The values of exams and set-up time were assumed equal to the average ones, that are respectively 18 and 2 minutes. This means a theoretical capacity of 50 exams per day from Monday to Friday and about 36 exams per day on Saturday.

According to the proposed approach and described, a 50-slots daily agenda was considered for each machine. Slots were divided on the basis of the percentage of exams of each type on the total. Thus, from Monday to Friday, 9 slots were dedicated to type 1, 20 to type 2, 12 to type 3, 5 to type 4 and 4 to type 5. Slots were assigned on Saturday analogously.

Applying the proposed heuristic procedure to real data regarding incoming calls at Medical Alliance diagnostic centre from April 2008 to March 2009, it resulted that, as an average, only the 4% of the total calls were not directly assigned to dedicated slots (step 3) and had to be reallocated (step 4). The average number of set-up per day was equal to 14, against the 60 setups per day that were calculated on the basis of the real agenda, planned by Medical Alliance dedicated operator.

A reduction of 46 setups is equivalent to an increase in available capacity of about 1,5 hours, that means 5 more exams per day. The increase in available capacity corresponds to a potential increase in the annual turnover of about 170.000 euro.

5. Conclusion and Further Research

Literature on Outpatient Appointment Scheduling Problem seems to be very widen as far as it concerns results deriving from managing uncertain events, such as no-shows, walk-ins and emergency patients through Operations Management techniques. However, all approaches seem to show an important gap regarding setup time and cost consideration. Focusing on the particular case of diagnostic imaging services in radiology centers, setups significantly impact on total production time, generating a reduction of clinic capacity.

The present work succeeded in approaching the problem from this original point of view, proposing a quick and

flexible heuristic procedure for a real-time booking appointments in a diagnostic imaging center.

The model validation on the real case of Alliance Medical has led to the quantification of the benefits that would come from a correct scheduling in booking process. This has proved the opportunity to dramatically reduce the number of coil changes and increase available capacity.

Further research should concentrate on integrating this new kind of approach, that evidently can be refined for better performance, with the state-of-the-art approaches of safety capacity management and overbooking. For instance, the experience in Alliance Medical showed evident opportunities on improving the designed appointment system with an overbooking and recall system. This could further improve the performance of proposed model in terms of efficiency and service level.

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