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DEVELOPMENT OF A TAILORED TOOL FOR THE OPTIMIZATION OF THE SURGERY SESSIONS

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ABSTRACT

During the last few years many Six Sigma applications in Healthcare have been made, in particular in North America. The results obtained have shown the importance of the use of a structured approach, such as Six Sigma, to increase hospital quality performance.

In this paper the Six Sigma approach is used to improve the occupation index and to reduce the costs connected with the surgery block of a hospital. In particular the attention is on the surgery session which is composed of a planned case mix of surgeries. In fact the session uses a high level of resources (temporal resources, human resources, material resources and economical resources) and it appears as one of the most critical processes in the hospital system.

Usually this kind of process is affected by a large and random variability due to the predominance of human factors caused by both the patients and the health staff. This variability is necessary to the process but causes a coupled process flow. Through the use of Six Sigma and Axiomatic Design a tailored tool that is useful for the measurement, control, and planning of the surgery session has been developed. This tool is based on the estimation of the duration and the costs of each surgery. In this way it is possible to identify the best, sustainable case mix in the planning phase. The case mix is defined for each surgery session and it is based on Diagnosis Related Groups (DRG), the doctor's capability and surgery difficulties.

The result obtained with the proposed approach is an accurate planning of the surgery session, a higher efficiency level and a general empowerment of health staff and consequently an important reduction in costs.

Keywords: surgery session, six sigma, case mix evaluation and planning, cost reduction, diagnosis related groups.

1 INTRODUCTION

Performance and process improvement are not new to healthcare. Healthcare organizations strive to achieve consistent and predictable positive outcomes in patient care and in their business operations. Six Sigma is a highly effective improvement approach that has been tried and tested across many industries [1, 2]. However, applying Six Sigma to healthcare requires an understanding of how its tools and methodologies translate to the people-intensive processes of patient care. Healthcare providers can use quality-improvement techniques and tools to reduce medical errors and help ensure patient safety [3]. There are also non-clinical aspects of the healthcare system, which can consume physician resources and have an impact on hospital finances, having a major impact on both patient care as well as operational efficiencies.

Also the Healthcare insurance company has begun to use Six Sigma to not only make itself more efficient and effective internally, but is now also directing its energies toward lowering medical costs while improving patient service and outcomes [4]. This engineering approach, adapted to healthcare, has been adopted especially in North America.

Six Sigma requires many specialized tools: one of them is Axiomatic Design, i.e. a fundamental set of principles that determine good design practice, can help to facilitate a project team to accelerate the generation of good design concepts, to focus on functional requirements, to achieve design intents and maximise product reliability [5].

The AD helps to design complex systems like *Health Care System,* affected by a large random variability due to the predominance of human factors. The health care delivery system is one of the least studied complex systems [6]. In a case study the engineering tools developed for manufacturing systems were applied to health care systems: the main objective was to develop and apply the performance measurement systems for these based on an axiomatic design-based decomposition of a general set of functional requirements and design parameters for a manufacturing system. Incremental calculus was suggested as a means of measuring the performance of the health care systems. Using incremental calculus, it was possible to observe the impact of small changes to the main objective using marginal analysis, which focused on how sensitively each factor will affect the main objective [6].

Productivity is of vital importance to a health care system's ability to compete and survive over time. A health care system that is not able to efficiently utilize its resources in creating

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value for its patients, will not survive with the ever-increasing costs of care. However, the development of fully functional and suitable performance measurement systems to measure productivity has proven to be a very challenging task [6].
Following this train of thought, the objective of this work is to improve the performance of a surgery block through the use of Six Sigma approach. In particular Axiomatic design is used during Improve and Control phases to systematically analyze the transformation of customer needs into functional requirements and design parameters and to develop the right solution.

2 CASE STUDY DESCRIPTION: INITIAL PERFOMANCE LEVEL

The surgery block allows planned major operations in an accredited regime by the National Health Service. When a patient's discharge paper is closed, his operation is codified with DRG (diagnosis-related groups) rates, using the codification of the International Classification of Diseases - 9th revision - Clinical Modification (ICD-9-CM) [7]. In this DRG prospective payment system, Health System pays hospitals a flat rate per case for in-patient hospital care so that efficient hospitals are rewarded for their efficiency and inefficient hospitals have an incentive to become more efficient. The DRGs classify all human diseases according to the affected organ system, surgical procedures performed on patients, morbidity and sex of the patient [8].
Every three years the Italian Health Service establishes the annual budget for each accredited hospital. In order to produce a positive gain for the hospital, it is important that the operation case mix does not exceed this budget because surplus would be remunerate by the hospital itself. Operation case mix is the whole set of surgery operations made in the block, considering frequency and the branch of each operation. Every operation requires temporal resources, human resources and material resources, each of which embodies some type of cost.
The difficulty of the hospital is the organization of surgery sessions due to the random variability of the health care processes and the lack of a control system, and this results in increasing costs.
The organization of the surgery session must consider the occupation time of the operating theatre, the gain and the pay-off (resulted from DRG) of each operation typology.
Two numeric indicators are defined to control these parameters and to estimate the performance of the process: an occupation index (1) and a gain index (2).
The first index estimates how the operating theatre is used: we define a potential occupation time of the room (such as six hours and half per day) based on a nurse's shift. If the permanence of the planned session is longer than the potential permanence, costs will increase due to overtime pay. If the permanence of the planned session is shorter than the potential permanence, fixed costs (such as the nurse's pay) will not be covered by the session's pay-off.
The second index estimates the percentage gain of a monthly or daily surgery session; it depends on case mix.

$$Occupation\_Index = \frac{\sum_{j=1}^{s} Actual\_OccupationTime_j}{\sum_{j=1}^{s} Potential\_OccupationTime_j} * 100 \quad (1)$$

j= daily surgery session;
s= total number of surgery sessions in a month.

$$Session\_gain\% = \frac{\sum_{i=1}^{n} (Pay\_off_i - Costs_i)}{\sum_{i=1}^{n} Pay\_off_i} * 100 \quad (2)$$

i=operation;
n= total number of operations in a monthly surgery session;

In order to calculate these indexes, the first step is the data gathering of all information connected with operations (type of anaesthesia, surgeon, type of stay in hospital, number of days stay in hospital, DRG, region of residence, operation permanence) related to a fixed time frame (some months). This information is found through the use of hospital's management software. It is important to identify the voices for the costs of the operation (Table 1). The value of these costs depends on the type of operation, for example, the prosthesis cost is not incurred in surgery for a hernia.

Table 1. Costs' Voice and their value's dependences

Costs' Voice	Dependence
Consumables	Operation typology
Anaesthesia	Type of anaesthesia
Pathological Test	Test type and number of tests
Prosthesis	Producer company, Operation typology
Self-transfusion	Operation typology
Stay in hospital	Type of stay, number of days
Surgeon	Surgeon, Percentage of pay-off
Anaesthetist	Percentage of pay-off
Operating theatre	Operation Permanence

Before this study, the performance of the process, estimated by the use of historical data, were the following:
1. Occupation_Index=51%;
2. Session gain=12%;

The first index highlights a bad organization in planned sessions; improvement ideas are planning full sessions and making programming more dynamic and controlled.
The second ratio highlights that the used approach for the case mix planning was unrewarding for the block. This is mostly due to the difficulties in obtaining a reliable estimation of costs for each surgery of the real process. The direct consequence is the lack of efficiency of surgery process.
The initial activity produces a big amount of data from real surgery process that permit:
1. to know about global activity in surgery block
2. to gather data from Management software;
3. to measure resources of the session;
4. to highlight Critical to Quality characteristics;
5. to clearly define the target of Improve and Control phases.

In the following section is shown the development process, driven by AD, of a tool useful to improve this process.

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3 DEVELOPMENT AND IMPLEMENTATION OF ENGINEERING TOOL

3.1 DESIGN EVALUATION OF THE CURRENT HEALTH SERVICE

Axiomatic Design is a general principle for design analysis and synthesis. It could be applied to all design: hardware, software, materials, manufacturing and organizations.

The AD's goal is establishing a science base for design activity to augment engineering knowledge and experience, providing theoretical foundation based on logical and rational thought process and tools and

improving quality and reliability [9]. AD uses matrix methods to analyze the transformation of customer attributes (CAs, vectors in costumer domain) into functional requirements (FRs, "what to achieve" in functional domain), design parameters (DPs "how to achieve" in physical domain) and process variables (PVs in process domain) [10].

In the case study only the functional and physical domain are considered.

The method gets its name from its use of design Axioms: the **Independence axiom** expecting a good design comprises of DPs that maintain the independence of functional requirements FRs; **Information Axiom** expecting the best design (that satisfy Independence Axiom) is the one that requires the least amount of "information" to achieve the design goal. The mapping between the FRs and DPs domains is executed in a zigzagging hierarchy (Why-How-Why-How) in order to performing the design process [10].

In this project, we define a hierarchical causal model showing the connection of FR and the DP by decomposing the design into several levels (Fig 1). So high level DP and FR are decomposed into lower level FR and DP. This systematic approach allows focusing AD design on what is possible to step in, due to the uncontrollability of the health process.

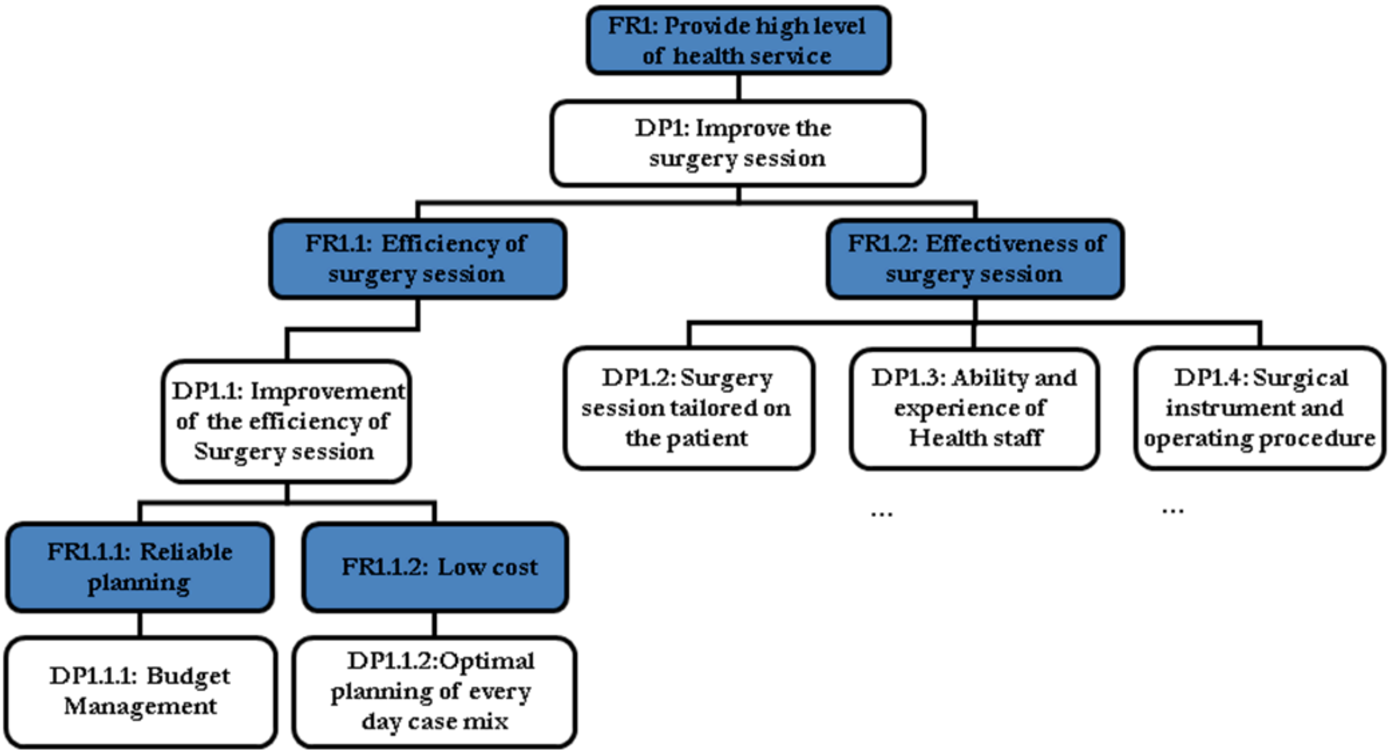

Fig 1. Decomposition model of health care process

Through the analyses described in the upper section and the problems in organization pointed out by health personal, the high level FR (FR1) is "**Provide high level of health service".**

High level DP (DP1) to achieve FR1 is "**Improve the surgery process".** The following step is zigzagging to the define lower levels.

The decomposition model (Fig 1) describes three levels of FR and DP. Only FRs quoted in Table 2 are mapped to DPs in axiomatic matrices.

At the second level DP1.2 and DP1.3 don't take part of next zigzagging: they define two aspects which aren't modified in this engineering project.

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Table 2. Levels of FRs and DPs

Levels	FRs	DPs
1	*FR1: Provide high level of health service*	DP1: Improve the Surgery session
2	*FR1.1: Efficiency of Surgery session*	DP1.1: Improvement of the efficiency of Surgery session
	FR1.2: Effectiveness of Surgery session	DP1.2: Surgery session tailored on the patient
3	*FR1.1.1: Reliable planning*	DP1.1.1: Budget Management
	FR1.1.2: Low cost	DP1.1.2: Optimal planning of every day case mix

Design matrix (Table 3) describes the inter-domain relationships where X means that there is a relationship and 0 means that there is no interaction [9]. It contains a wealth of information about the design and are central to the application of axiomatic design.
The design matrix of this process is coupled; a coupled design is one that cannot be reorganized to a triangular matrix. In this case, the relationship between the design elements and their functions is circular. To satisfy the Independence axiom the matrix design must be diagonal (uncoupled design) or triangular (decoupled design). It's necessary to develop a tool that can remove some of relationships and change the design matrix.

Table 3. Global Matrix Design of the current health service

			DP1		
			DP1.1		DP1.2
			DP1.1.1	DP1.1.2	
FR1	FR1.1	FR1.1.2	X	X	X
		FR1.1.1	X	X	X
	FR1.2		X	X	X

3.2 DESCRIPTION OF ENGINEERING TOOL

To satisfy the independence axiom, we decide to develop a software engineering tool that helps health staff to plan and control surgery sessions with profitable case mix using the operating theatre to its maximum time potentiality.

In particular, the goal is to make the part of management and efficiency independent from the effectiveness of surgery session.
The instrument's features would be:

1. simple use;
2. upgradeability;
3. compatible with existing management software.

The approach we adopt is based on two actions:

a. **direct action:** acting toward costs and pays-off with change of surgeon's case mix; average operating activity of each surgeon is maintained with the exception of activity with high unjustified costs.

b. **indirect action:** acting toward operating session's time through the definition of a standard session's permanence. The standard is potential occupation time of the room defined in section 2.

The global tool (Fig 2) is based on two sub-tool:

1. **sub-tool 1** is a tool for Budget distribution; it allows to allocate Health Service Budget and control utilize and available Budget estimating the number of each surgeon's session. To calculate the number of day sub-tool considers average operating activity and surgeon restriction.
2. **sub-tool 2** (specified in Fig 3) is a tool for planning sessions. This is a dynamic table containing all operation's typologies of surgery block with their associated costs and resources. It is necessary to active the tool setting purposed operation of the session through data entry (day, month, operating theatre, operation's number). Data processing estimates time of session's closing and session-gain% for each day. The health staff must verify the estimated output. If they give consent to apply surgery session, the optimal case mix will be obtained. The limit of sessions' number defined by the sub-tool 1 introduces a relationship between sub-tools.

The estimate of session's number and Budget's consume are based on average activity of surgeon. Effective activity, inserted in sub-tool 2, does not overlap with the average one; therefore the effective available and used amount of Budget could be different. The global tool has a feedback loop to solve the problem. If there is a gap between average and effective activity, sub-tool 2 will modify future operating activity.

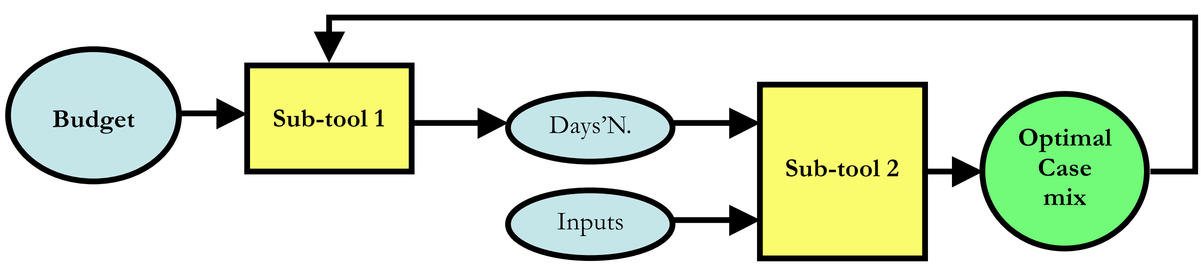

Fig 2. Tool's streamlined diagram

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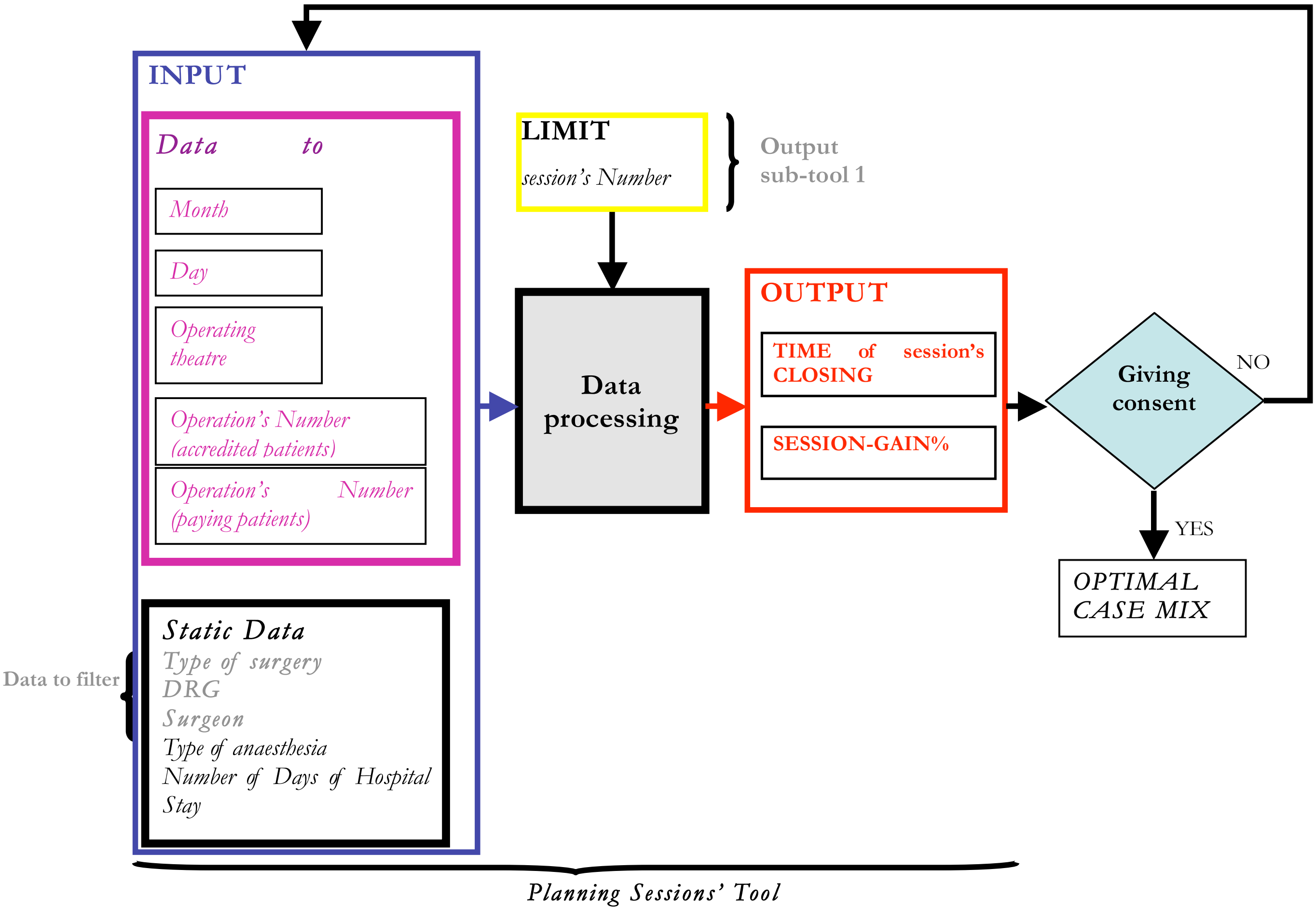

Fig 3. Detailed diagram of sub-tool 2

3.3 AXIOMATIC DESIGN OF THE IMPROVED HEALTH SERVICE

Tools are useful to modify relationships in Matrix design (Table 4). We can identify the advantage of the introduction of the two tools the design matrix.

We obtain a decoupled design at third level because one DP affects two FRs: reliable planning depends only from Budget management and in particular from the implementation of the tool for Budget distribution; requirement of low cost is achieved by using global tool. Employing properly Health Service Budget and planning session through costs' and time control enables to reduce cost.

The goal of tool's Framework is efficiency, not effectiveness of surgery session in term of patient care. We obtain an efficient system that achieves higher levels of performance (outcome, output) relative to the inputs (resources, time, money) consumed.

An uncoupled design results at second level: the requirement effectiveness is, only, achieved by surgery session's tailored on the patient. There are not relationships between FRs of third level and DP1.2 because the tool is based only on the average estimation of surgery activities instead of the variability of each surgery tailored on the patient.

Table 4. Global Matrix Design of the improved health service

			DP1		
			DP1.1		DP1.2
			DP1.1.1	DP1.1.2	
FR1	FR1.1	FR1.1.2	X	0	0
		FR1.1.1	X	X	0
	FR1.2		0	0	X

The chosen solution satisfies also the II° axiom of AD [10]. In fact the distribution of surgery session duration obtained using this tool for the planning of the surgery session (Fig 5) shows a bigger probability of success in timing control compared to the historical duration distribution (Fig 4). This result is obtained considering an optimal value for surgery session duration of 390 minutes (6 hours and half) with an acceptable tolerance of

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an hour (Lower Specific Limit=330 min and Upper Specific Limit = 450 min).

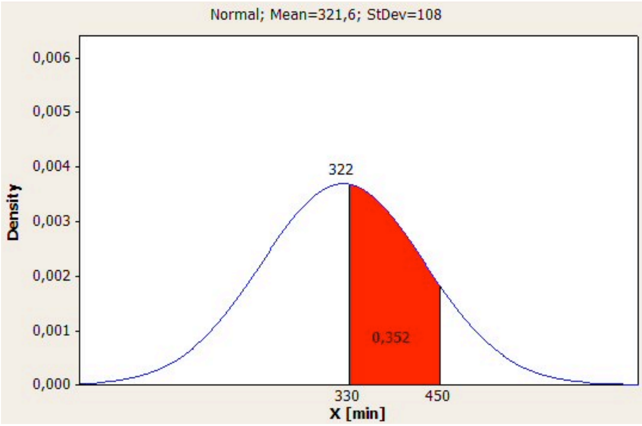

Fig 4. Historical distribution of surgery session durations

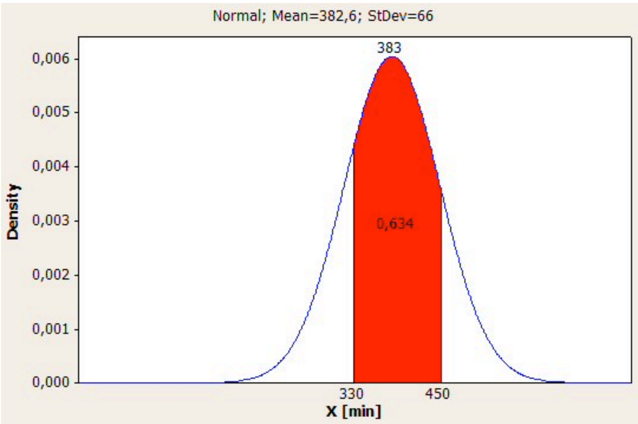

Fig 5. Observed distribution of surgery session durations using engineering tool

4 RESULTS

The tool's implementation helps to organize and supervise session's planning.
We can use output of sub-tool 2 to calculate indicators (defined in section 2) estimating performance of the improved health process: occupation index (1) and a gain index (2).

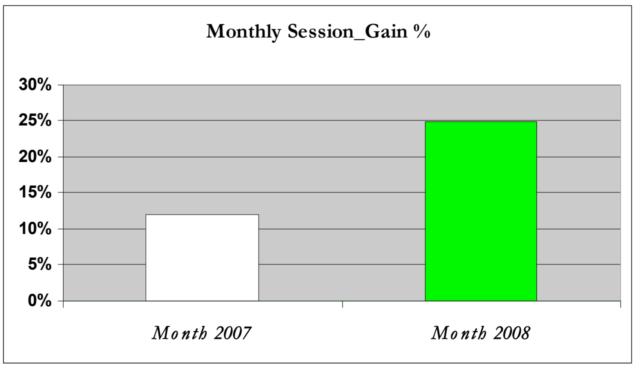

Fig 4. Bar chart of Session – gain's improvement

Performance of improved health process is estimated by an Occupation_Index value of 89% and Session gain value of 25% (Fig 4). The first index shows how health operators understand approach to planning full sessions and cooperate to realize this goal. The second indicator shows how little modifications in case mix and an organized process grow the gain.

5 CONCLUSION

The objective of this work is to develop a system to estimate and control performance of a surgery block based on the estimation of the duration and the costs involved in each surgery. In fact, the main problem is surgery process affecting by a large and random variability due to the predominance of human factors caused by both the patients and the health staff. It is necessary to partially estimate this variability to obtain a strong improvement in the health care system efficiency in term of organization and cost's reduction. In particular, a management strategy, such as Six Sigma and its key algorithm (DMAIC), has been used to gain knowledge, analyze and improve surgery process.
AD was used in Improve phase to design the approach following to develop an engineering tool in order to decouple process flow. Engineering tool's framework allows respecting the Independent axioms. The tool was composed of two parts connected that return estimation of session_gain% and time of session's closing. Outputs are used to calculate the occupation index and gain index (coinciding with session_gain%). Tool's Implementation has improved the organization of surgery block in order to reduce cost. This tool could be useful for any public and private hospital reality considering the possibility of obtain the saturation of operating room (estimated by occupation index). On the other hand, the action that regards the case mix modification could be applied in every hospital with a planned activity. For example, it is very difficult to improve the process of an Emergency Room with this approach. In fact we have developed and adopted this approach in a specific reality, i.e. a private hospital, where all operation are planned; so we have considered both the modification of case mix and the increase of session saturation. Tool's Application achieved important results: occupation index changes from 51% over 89% and gain% from 12% over 25% considering the monthly activity.
Tool's Framework has some advantages:

1. it's simple to use in insertion data;
2. it's complete of all type of surgery and all surgeon of hospital analyzed;
3. it can be modified to remain up-to-date in terms of costs, activities, health staff composition to obtain a reliable planning of surgery sessions;
4. it's versatile because the adopted approach could be applied in any hospital.

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