A Business Process Reengineering of the Surgical Path through Lean Technique: The Real Case Study of a Midsize Italian Hospital

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Abstract: This period of pandemic has had important consequences on the flow and the entire organization of any hospital. In particular, the number of accesses to the emergency room has increased, with the consequent urgent need to reorganize it quickly. The model proposed in this paper allows to respond to these needs by freeing not only shifts of nursing staff but also surgical staff. This workforce can then be relocated in the emergency room or of the intensive care unit who are in fact at the forefront of emergency management. The aim of this study conducted by the authors is to analyze, inside the context of a midsize Italian hospital, the actual organization model, and then to approach it by Business Process Reengineering (BPR) methodology with the goal to propose a KPI management system that evaluates the efficiency of the whole surgical path. The second objective of the study is to verify if the Operating Rooms (ORs) are properly sized to cover the surgical workload or if it would be necessary to build new ORs (answer to this question is the project mandate by Surgical Wards Chiefs). The last objective is to implement a flexible to cope with emergency situations such as a pandemic. The main result is the approximate maintenance of surgical annual activity (8169 vs 7889). The fewer resources required can be reallocated to deal with emergencies such as the current COVID-19 pandemic. In fact, the surgical shifts decreased during the test case from 464 versus 365 (-15,32%). The rooms' utilization coefficient rose from 41% to over 52%, whereas the surgeons' utilization coefficient rose to 61% (with values over 68% for parallel shifts). The results achieved demonstrate that improving efficiency of surgical processes is feasible and a systematic approach allows to respond to new global health challenges.

Keywords: Operating room, Lean, Surgical Path, Business Process Reengineering (BPR), Surgical planning

I. INTRODUCTION

Europe, like every other developed region, has experienced a rapid expansion of public healthcare expenditures in the last 50 years [1].

The same critical situation is also true for Italy, where healthcare costs have reached levels no longer sustainable for the National Health System. In Italy, political decisions try to contain costs using linear cuts, such as reduction of hospital beds, payment levels, and recruitment blocks [2]. Another strategy used to contain this problem is that of standard costs, or the definition of one cost that is valid across the entire country for each type of activity or purchase [3].

Particular attention on the scientific community has recently focused on Industry 4.0 and the healthcare sector with emphasis on the operating rooms [4-5].

The current scientific literature does not refer an analysis of the complete surgical path; therefore, the authors aim to perform it. In fact, usually, the analysis is focused on the individual phases of the process (e.g. the patient's path, the use of the recovery room, the scheduling algorithm for the operating rooms, etc.), while an overview of the process is often missing [6-16].

The main purpose of this study is to analyze the current organization model, in the context of a midsize public Italian hospital, and then to reengineer the process for proposing a KPI management system being able to evaluate the efficiency of the whole surgical path.

The secondary aim of the study is to verify if the number of the Operating Rooms is sufficient to cover the surgical requirements or, otherwise, if it will be necessary to build new ORs according to the Surgical Wards Chiefs mandate. Finally, health systems have recently been required to implement flexible models that allow for the conversion of resources to be used during emergency situations such as a pandemic.

II. MATERIALS AND METHODS

The analysis has been conducted in a 430-beds hospital with a total of eight ORs distributed as two for urgent surgery, four dedicated to general surgery, and two dedicated to other specialties (with about 8,000 operations/year and a waiting list of more than 5000 patients).

The authors' approach follows the standard Business Process Re-engineering (BPR) steps as shown in Figure 1.

BPR has spread above all in the Anglo-Saxon world in the early 1990s in the private firm sector. In those years, one of the first definitions of BPR has been provided by Hammer in a paper which appeared on Harvard Business Review [17]. In this definition, the author defines this technique as "the substantial afterthought and the radical redesign of the business processes for the purpose of obtaining relevant results in terms of quality and services improvements to the user and enhancement in the productivity (cost reduction in view of a volume rise of the performance provided)" [18]. Later, around the middle of the 1990s, some publications based on this approach also appeared relative to the healthcare sector. The BPR in a managerial approach for the management of the organizational change based on the logic for processes [19].

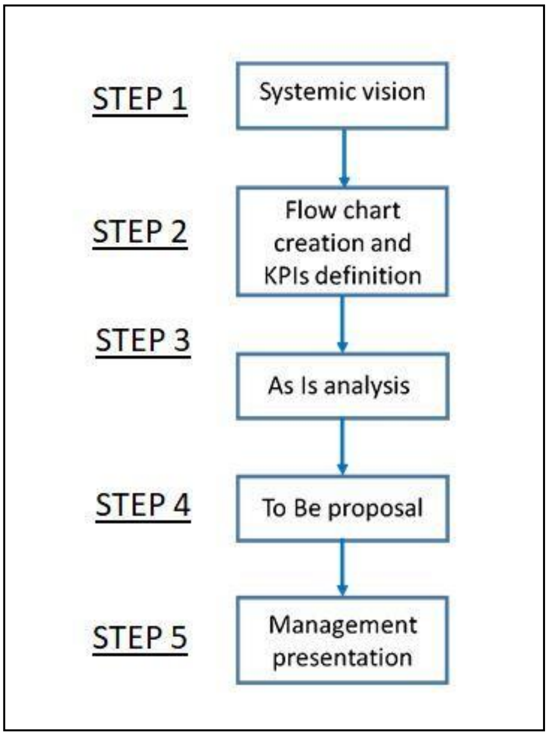

Fig. 1. Authors' approach scheme

Figure 1 shows the BPR approach through the five main subsequent steps:

1. Creation of the flow charts for the main process and for the sub-processes involved;

2. Definition of suitable Key Performance Indicators (KPIs) to study the system;

3. As Is analysis. This means the evaluation of the current situation based on the management's objectives;

4. Definition of the To Be scenario to improve the As Is and evaluation of the new performances with KPIs;

5. Presentation of the new scenario to management.

B. *Step 1*

The Authors, by using the Lean Technique, mapped the paths of the different surgical specialties, aiming to highlight the absence of standardization.

C. *Step 2*

The authors, inspired by the principles of Lean Management, carried out a performance analysis in terms of the efficiency of the operating rooms and of the relevant operating personnel. To this end, they defined a series of KPIs for measuring the performance of each actor involved.

For this purpose, the authors referred to the classic company organization scheme regarding "time analysis" of the surgical tracking (Figure 2).

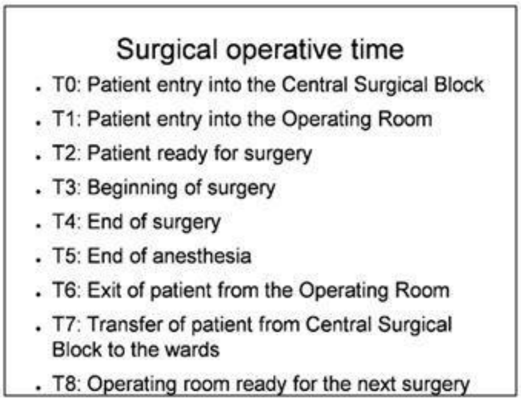

Fig. 2. Detail of the surgical operative time

The surgical operative time tracking was used for further analysis, as follows:

- Direct operating time (T4-T3): time in which the room is occupied by the surgeons who carry out the operation (from cutting to sewing);
- Indirect operating time (T3-T1) + (T8-T4): time during which activities strictly functional to the surgical act are undertaken. On average, between one operation and another about 60 minutes are spent on activities not directly related to operations: about 15 minutes for the anesthesiologic infusion and about 45 minutes for the cleaning, sanitizing, re-equipping, etc. operations. This time breakdown implies a significant limitation of the number of patients that can be operated on in one shift. These times were determined by the information system and subsequently verified by an investigation carried out directly in the operating rooms.
- Operating time (OT): is the sum of the direct operative time (ODT) and the indirect operative time

(NODT) and represents the room activity time (T8-T1).

- Non operative time (NOT): represents the room time lost as a result of system inefficiency (incorrect management of the patient in transfer from the BOC to the operating room, any unavailability of the instruments, etc.). In the case studied by the authors it was calculated as the difference between the time of availability of the room and the operating time.
- Total available time (T) is the theoretical time of availability of the room which was considered to be equal to 13 hours (from 7 am to 8 pm).

Fig. 3 shows the breakdown of the operating room time in a typical day.

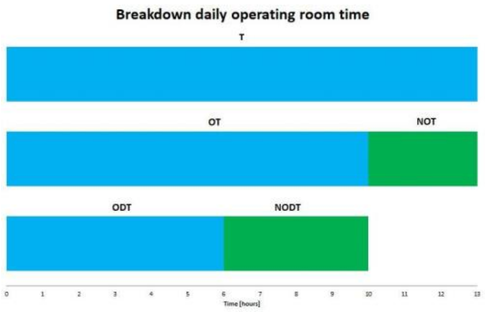

Fig. 3. Breakdown of the operating room time in a typical day

D. *Step 3*

Once the Tx con X (1 ,..,8) have been defined, the following KPIs can be calculated:

- the room’s utilization coefficient relative to strictly surgical activity (C1);
- the room’s utilization coefficient relative to the strictly surgical activity plus other operative activities (C2).

C1 is calculated as a ratio between the room’s direct operating time and the room’s operating time.

C2 is calculated as a ratio between the room’s operating time and the room’s total available time.

Following the methodological dictates of the BPR, the authors have carried out initial data collection.

The main purpose of the As Is analysis, in our model, is to describe three main problems:

- The absence of a standardized process;
- The absence of a single entity to manage the whole process (on one hand there was a total absence of control over the patient's path, with the result that the patient was at the mercy of the system and at risk of being "lost" or forgotten; on the other hand, there were overlapping competences, duplication of functions, interference between the entities, and therefore additional costs).
- The absence of criteria to attribute the surgical slots

E. *Step 4*

TO BE PROPOSAL, consists of three main phases:

a) the organization of a single entity (Centralized Pre-Hospitalization (CPH)), which manages the patient from the first appointment with the clinician through to the operating table. The entity schedules and organizes the procedures, through a close collaboration with a dedicated engineer;

b) according to Step 2 results a management model based on the parallelization of the operating rooms was applied [20]. With such an organizational model, the surgical team which operated in room “A” starts operating on the patient in room “B” after about 15 minutes from the end of the stitching in room “A”, recovering 45 minutes of surgical activity with each patient change. Having finished stitching the patient in room “B” the team is thus ready to start a new operation in room “A” after 15 minutes and so on. Moreover, an operation scheduling instrument capable of proposing automatically and quickly a programming scheme of the rooms was developed.

c) an algorithm for scheduling OR interventions, developed to optimize the KPIs indicated by the management (maximization of the utilization of the surgeons and the operating room staff, maximization of the utilization coefficient of the operating rooms, etc), was implemented. Among the Management philosophies adopted, two stood out:

- To increase the utilization of the surgeons during their work shift as much as possible;
- To maximize the utilization of the operating rooms and the staff assigned during their opening hours.

F. *Step 5*

At first the authors implemented a simulation test case on a one month’s activity.

The results obtained showed foremost a significant decrease in overtime and underuse hours (see Table I and Table II).

TABLE I
OPERATING ROOMS OVERUSE AND UNDERUSE (AS IS)

Week	allocated hours	unused hours	extra hours	total inefficiencies (hours)
WEEK 1	196	16,6	20,8	37,4
WEEK 2	193,5	26,6	17,9	44,5
WEEK 3	189	24	14,2	38,2
WEEK 4	186,5	24,6	7,5	32,1
TOTAL	765	91,8	60,4	152,2

TABLE II
OPERATING ROOMS OVERUSE AND UNDERUSE COMPARISON BETWEEN AS IS AND TO BE SCENARIOS

WEEK	AS IS	TO BE	DIFFERENCE
WEEK 1	37,4	3,87	-33,53
WEEK 2	44,5	9,47	-35,03
WEEK 3	38,2	6,4	-31,8
WEEK 4	32,1	5,25	-26,85
TOTAL	152,2	24,99	-127,21

Considered in terms of the Total Available Time of the rooms allocated, Table III shows for each week the lower number of hours required by the new methodology.

The model proposed by the authors, by reducing the extra hours and improving the scheduling of procedures, also allows the utilization coefficient of the room to recover by 6.6%. Also, thanks to the reduction of the time allocated and not used, the occupation coefficient of the room increases by almost nine absolute percentage points.

Another important improvement concerned the activity of the surgeons.

The Total Availability Time of the surgeons is reduced by around 63 hours as a result of the reduction in the TNDO, thanks firstly to the use of the parallelism and, where possible, to the reduction of consecutive procedures in the same room.

The TE hours saved translate into a lower cost for the entity, added onto the lower TE costs for the room and greater availability of the surgeon himself or herself to carry out further procedures.

TABLE III
TE OF OPERATING ROOMS

WEEK	AS IS	TO BE	DIFFERENCE
WEEK 1	216,8	191	-25,8
WEEK 2	211,4	187,1	-24,3
WEEK 3	203,2	181,8	-21,4
WEEK 4	194	164,5	-29,5
TOTAL	825,4	724,4	-101

Over the four-week period, the total requirement for room time has therefore been reduced by around 100 hours, with a saving of over €50,000. The lower costs of the surgeons and overtime pay also need to be considered, and these may be estimated at around €12,000 for the period in question.

As a further element of the economic benefit for the entity, the revenues derived from the use of the rooms freed up by the new scheduling need to be added, and these may be estimated as revenues attributable to forty procedures of average duration in the "typical" month. If we then analyze the calculation of the inefficiencies between the two management philosophies, other definite advantages in favor of the TO BE version emerge.

Then, considering the positive opinions received in the test after a Management presentation, the health management and the clinicians, in full agreement with the authors, decided to implement the proposed model in a three-months’ test case managed by an industrial engineer and a surgeon.

III. RESULTS

A. *Three months’ Test Case results*

Looking at the surgical process from its inception, the main advantage was that CPH had the rule to revise the supposed waiting lists mainly through a patient recall. In fact, the number of patients present in the list dropped from over 5000 to about 1700.

In regards to the first aim the authors reengineered the surgical path according to the methodology previously described. The main result is that in order to maintain approximately the same surgical activity (8169 vs 7889 in the new model (-3,4%)) in terms of annual surgical intervention numbers, fewer surgical resources were necessary in the three months analyzed: 464 vs 365 surgical shifts (Table IV).

TABLE IV
SURGICAL-ENVISAGED SHIFTS IN THE TRADITIONAL MODEL VS NEW MODEL IN THE DIFFERENT SURGICAL STRUCTURES (A TO I)

Structures	Traditional model shifts	New model single shifts	New model parallel shifts
A	104	63	24
B	89	9	52
C	37	8	22
D	25	13	0
E	26	32	0
F	23	9	0
G	22	8	3
H	57	47	0
I	81	75	0
Subtotal	464	264	101

Table IV shows that the reduction in surgical spaces was obtained through:

1) the reduction of surgical shifts allocation;
2) the principle of parallelization.

Since the medical team is made up of three operating surgeons, the direct consequence is a saving of 297 shifts/surgeon (Table I, right columns). The double saving translates into a possibility of carrying out about 300 operations of an average duration in the 12 weeks. This possibility, if adequately exploited, would drastically reduce the waiting list of patients awaiting surgery. It must

be considered that Table I also contains the structures that use a dedicated operating room. As can be imagined, from this table the shifts have also been rationalized.
Table V shows the comparisons regarding the number of shifts of nurses and anesthetists, with a saving of 196 shifts/nurse against an increase of just two shifts of anesthetists.

TABLE V
NURSES AND ANESTHETISTS SHIFTS IN THE TRADITIONAL MODEL VS NEW MODEL

Structures	A*	B*	C*	D*	E*	F*
A	312	285	104	312	111	261
B	267	235	89	267	113	183
C	111	112	37	111	52	90
D	75	39	25	75	13	39
E	78	96	26	78	32	96
F	69	27	23	69	9	27
G	66	36	22	66	14	33
H	171	141	57	171	47	141
I	243	225	81	243	75	225
Total	1392	1196	464		466	

A* nurses shifts-traditional model
B* nurses shifts-new model
C* anesthetist shifts-traditional model
D* surgical team shifts-traditional model
E* anesthetist shifts-new model
F* surgical team shifts-new model

The coefficients C1 and C2 are thus calculated (see Table VI).

TABLE VI
KPIS IN THE TRADITIONAL AND IN THE NEW MODEL

KPIs	Traditional model	New model
C1	40,99%	52,33%
C2	47,83%	61,05% (68%)

From the data shown in Table VI it can be seen that, apart from savings in the room availability and personnel shifts, the new organizational model also allows the following results:

- the rooms' utilization coefficient rises from 41% to over 52%;
- the surgeons' utilization coefficient rises to 61% with values over 68% for the surgeons who have worked in parallel.

As a direct consequence of the previous results the authors concluded there is no need to build new operating rooms. In fact, 2 operating rooms dedicated to the day surgery activity, which were in another building, were included in the eight operating rooms available (see Discussion).

B. *Possible scenarios for using the results during a pandemic*

The emergency department plays a crucial role in the hospital flow management [21]. This period of pandemic, completely unforeseen, has had important consequences on the flow and the entire organization of any hospital. In particular, the number of accesses to the emergency room has increased, with the consequent urgent need to reorganise it quickly. This epidemic occurred without warning and required hospital structures to have models already studied and tested that would free up resources in a short time. In addition, this pandemic has also infected many healthcare workers with the consequent need to replace the infected to ensure constant patient care. Moreover, the intensive care units had to respond to treatment on patients who were expected to increase their care time on Covid 19 patients.

The model proposed in this paper, now consolidated, allows to respond to these needs by freeing not only shifts of nursing staff but also surgical staff. This staff can then be relocated to support colleagues in the emergency room or of the intensive care unit who are in fact at the forefront of emergency management.

IV. DISCUSSION

According to the literature there is a number of papers that address the topic of surgical activity. Some authors approached the study through a segmentary way in order to achieve a more economic [22-23] or a more efficient [24-26] process. Correll et al. highlighted one of the aspects pointed out in this paper [27]. In particular they underlined the positive effects of an entity capable of managing the patient throughout the whole surgical path on improving the efficiency of the operating rooms. The vision of the entity is similar to the role that the authors gave to CPH but a BPR approach is missing in Harders et al. [28]. Then, there are many authors who tackled the problem of scheduling the operations in the operating rooms from different viewpoints [29-36].

The work of Cardoen et al. is particularly remarkable; in it they report a broad critical analysis of the literature regarding planning and scheduling the operating rooms [37].

Finally, the study of Cima et al. is of particular interest, considering the problem of globally improving the efficiency of the operating path [38]. However, the work differs from the approach proposed in this paper because it is strongly characterized by the motivation of reducing the costs and increasing the revenue.

Looking back on the examination of the management models proposed in the literature, the idea of addressing the issue of optimizing the utilization of the operating rooms and/or of the surgical staff is a winning approach. This has been done considering the process in its entirety rather than evaluating individual subsystems. It has been confirmed, at the implementation phase, that the methodology developed has the versatility and capacity for generalization that the authors intended for it (see Table III). The approach proposed has also proved capable of being adapted relatively easily to the most diverse operating contexts. The fact that the type of algorithm used for scheduling the rooms/operating staff can also be varied, adapting it to the specific efficiency requirements of the system, has proved to be a determining asset in enabling the management of each structure to achieve its predetermined targets.

The process of rationalizing resources not only allows optimizing the staff working performances but also allows increasing the performance coefficients of the staff and the operating rooms.

The authors consider an official positive signature of the present paper as the institution of a formal Surgical Path Regulation approved by the management: in this document all the implementation rules have been reported.

Secondly, it has been demonstrated that the operating rooms are sufficient. In fact, it has been possible to allocate in BOC also the Day Surgery operating rooms which were two operating rooms located in another building of the hospital.

Finally, the authors believe that this flexible model can be used to relocate staff where they are really needed and the recent pandemic underlined the needing of fast and flexible solutions.

V. CONCLUSION

The authors concluded that improving efficiency of surgical process is feasible. The main result of the study is that a systematic approach is necessary to achieve the results reported.

This approach made it possible to:

- free up the surgical departments from wasting time with bureaucratic formalities (first and foremost calling patients and drawing up lists), with no added value;
- improve the capacity of interfacing and integrating with the other hospital services (radiology, blood transfusion centre, etc.) thanks to a structured plan/program;
- envisage the need of services in an increasingly punctual and precise manner as the date of the operation approaches.

Moreover:

- the patient is at the centre of the programming of the surgical activity;
- all patients undergo their operations in certain times;
- no patient is forgotten after being staged and, as a consequence, the hospital does not lose the costs of the staging;
- the waiting lists are always updated.

In the future, the authors will further address the question of whether the methods proposed to analyze the surgical process could also lead to a more rationale use of resources functional to surgery (e.g. disposable surgical devices, pathology, radiology …). In fact, improved relations with the ancillary services to the BOC are an added benefit deriving from the introduction of the weekly operating list. Indeed, being aware of the operating list means that the structures which are responsible for supplies can check the availability of the material, thus guaranteeing the devices necessary for that planning. Previously, the daily operating list (and not the weekly one) was sent to the Services the day before the operations, in the late afternoon, thus preventing supplies of missing materials with a consequent delay in the scheduled operations.

While on the one hand the BPR is a technique extendable to all the contexts, obviously the results achieved are correlated to a specific context. One of the limits of this study is linked to the period reported (three months) even if the consequent six-twelve months confirmed the important trend achieved.

All of the results discussed translates into lower costs from inefficiencies and, in some cases, also into greater revenues for the entity as a result of the increase in productivity or to manage a pandemic. Moreover, where possible, the economic benefit that can be derived from introducing the proposed methodology could be directed towards achieving greater efficacy in the care provided to the patient.

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REFERENCES

[1] Erixon, F., and Van der Marel, E. (2011). What is driving the rise in health care expenditures? An inquiry into the nature and causes of the cost disease (No. 05/2011). *ECIPE working paper.*

[2] Ongaro, E., Ferrè, F., and Fattore, G. (2015).The fiscal crisis in the health sector: Patterns of cutback management across Europe, *Health Policy*, vol. 119, no.7, pp. 954-963.

[3] Crupi, D., Lagostena, A., and Pasdera, A. (2008). Standard cost recovery, *Franco Angeli Publisher*, Milan, Italy.

[4] Patrone, C., Khodabakhsh, A., Lattuada, M., and Revetria, R. (2018). Internet of things application in the healthcare sector. *Hospital*, 4(2), 3.

[5] Galli, G., Patrone, C., Bellam, A. C., Annapareddy, N. R., and Revetria, R. (2019). Improving process using digital twin: a methodology for the automatic creation of models. In *Lecture notes in engineering and computer science: proceedings of the world congress on engineering and computer science,* pp. 22-24.

[6] Thiele, R. H., Rea, K. M., Turrentine, F. E., Friel, C. M., Hassinger, T. E., Goudreau, B. J., ... and McMurry, T. L. (2015). Standardization of care: impact of an enhanced recovery protocol on length of stay, complications, and direct costs after colorectal surgery. *Journal of the American College of Surgeons*, 220(4), 430-443.

[7] Ito, M., Kobayashi, F., and Takashima, R. (2018). Minimizing conditional-value-at-risk for a single operating room scheduling problems. In *Proceedings of the International MultiConference of Engineers and Computer Scientists*, Vol. 2.

[8] Erekat, A., Servis, G., Madathil, S.C., and Khasawneh, M.T. (2018). Efficient operating room planning using an ensemble learning approach to predict surgery cancellations, *IISE Transactions on Healthcare Systems Engineering*, pp. 1-15.

[9] Hamid, M., Hamid, M., Nasiri, M., and Ebrahimnia, M. (2018). Improvement of operating room performance using a multi-objective mathematical model and data envelopment analysis: A case study", *International Journal of Industrial Engineering & Production Research*, vol. 29, no. 2, pp. 117-132.

[10] Feng, L.I., Luo, L., and Gong, R. (2015). Application of classification methods to elective surgical cases cancellation detection, *International Conference on Engineering Management, Engineering Education and Information Technology*. Guangzhou, China: Atlantis Press.

[11] He, L., Madathil, S.C., Oberoi, A., Servis, G., and Khasawneh, M.T. (2019). A systematic review of research design and modeling techniques in inpatient bed management, *Computers & Industrial Engineering*, vol. 127, pp. 451-466.

[12] Roland, B., Di Martinelly, C., Riane, F., and Pochet, Y. (2010). Scheduling an operating theatre under human resource constraints, *Computers & Industrial Engineering*, vol. 58, no. 2, pp. 212-220.

[13] Abdelrasol, Z.Y., Harraz, N., and Eltawil, A. (2013). A proposed solution framework for the operating room scheduling problems, *Proceedings of the world congress on engineering and computer science*, vol. 2, pp. 23-25.

[14] Mabry, C.D., Kalkwarf, K.J., Betzold, R.D., Spencer, H.J., Robertson, R.D., Sutherland, M.J., and Maxson, R.T. (2015). Determining the Hospital Trauma Financial Impact in a Statewide Trauma System, *Journal of the American College of Surgeons*, vol. 220, pp. 446-458.

[15] Kirkpatrick, J.R., Marks, S., Slane, M., Kim, D., Cohen, L., Cortelli, M., Plate, J., Perryman, R., and Zapas, J. (2015). Using Value-Based Analysis to Influence Outcomes in Complex Surgical Systems, *Journal of the American College of Surgeons*, vol. 220, pp. 461-468.

[16] R. Revetria, A. Catania, L. Cassettari, et al., Revetria, R., Catania, A., Cassettari, L., Guizzi, G., Romano, E., Murino, T., Improta, G., and Fujita, H. (2012). Improving healthcare using cognitive computing-based software: An application in emergency situation, *International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems*, pp. 477-490.

[17] Hammer, M. (1990) Reengineering work: Don't automate, obliterate, *Harvard Business Review*, vol. 68, no.4, July/August, pp. 104-112.

[18] Motta, M., and Lega, F. (1997). Process re-engineering for the health care organisations: an introduction, *Mecosan*, vol. 6, no. 23, pp. 163-165.

[19] Patrone, C., Cassettari, L., Damiani, L., Mosca, R., and Revetria, R. (2017). Optimization of Lean Surgical Route through POCT Acquisition, *Lecture Notes in Engineering and Computer Science*, 2228, pp.828-832.

[20] Pannella, M., Marchisio, S., and Di Stanislao, F. (2003). Reducing clinical variations with clinical pathways: do pathways work?, *Int J Qual Health Care*, vol. 15, pp. 509-521.

[21] Cassettari, L., Mosca, R., Orfeo, A., Revetria, R., Rolando, F., and Morrison, F., J. (2013). A System Dynamics Study of an Emergency Department Impact on the Management of Hospital's Surgery Activities, *Proceedings of the 3rd International Conference on Simulation and Modeling Methodologies, Technologies and Applications (HA-2013)*, pag. 597-604.

[22] Dhupar, R., Evankovich, J., Klune, J.R., Vargas, L.G., and Hughes, S. (2011). Delayed operating room availability significantly impacts the total hospital costs of an urgent surgical procedure, *Surgery*, vol. 150, pp. 299-305.

[23] Smith, C.D., Spackman, T., Brommer, K., Stewart, M.W., Vizzini, M., Frye, J., and Rupp, W. (2013). Re-Engineering the Operating Room Using Variability Methodology to Improve Health Care Value, *Journal of the American College of Surgeons*, vol. 216, pp. 559-568.

[24] Pandit, J.J, Abbott, T., Pandit, M., Kapila, A., and Abraham, R. (2012). Is 'starting on time' useful (or useless) as a surrogate measure for 'surgical theatre efficiency'?, *Anaesthesia*, vol. 67, pp. 823–832.

[25] Heslin, M.J., Doster, B.E., Daily, S.L., Waldrum, M.R., Boudreaux, A.M., Smith, A.B., Peters, G., Ragan, D.B., Buchalter, S., Bland, K.I., and Rue, L.W. (2008). Durable Improvements in Efficiency, Safety, and Satisfaction in the Operating Room, *Journal of the American College of Surgeons*, vol. 206, pp. 1083-1089.

[26] Kimbrough, C.W., McMasters, K.M., Canary, J., Jackson, L., Farah, I., Boswell, M.V., Kim, D., and Scoggins, C.R. (2015). Improved Operating Room Efficiency via Constraint Management: Experience of a Tertiary-Care Academic Medical Center, *Journal of the Amerian College of Surgeons*, vol. 221, no. 1, pp. 154-162.

[27] Correll, D.J., Bader, A.M., Hull, M.W., Hsu, C., Tsen, L.C., and Hepner, D.L. (2006). Value of Preoperative Clinic Visits in Identifying Issues with Potential Impact on Operating Room Efficiency, *Anesthesiology*, vol. 105, pp. 1254-1259.

[28] Harders, M., Malangoni, M.A., Weight, S., and Sidhu, T. (2006). Improving operating room efficiency through process redesign, *Surgery*, vol. 140, pp. 509-516.

[29] Guinet, A., and Chaabane, S. (2003). Operating theatre planning, *Int. J. Production Economics*, vol. 85, pp. 69-81.

[30] Jebali, A., Hadj Alouane, A.B., and Ladet, P. (2006). Operating rooms scheduling, *Int. J. Production Economics*, vol. 99, pp. 52-62.

[31] Marcon, E., Kharraja, S., and Simonnet, G. (2003). The operating theatre planning by the follow-up of the risk of no realization, *Int. J. Production Economics*, vol. 85, pp. 83-90.

[32] Fei, H., Meskens, N., and Chu, C.A. (2010). A planning and scheduling problem for an operating theatre using an open scheduling strategy, *Computers & Industrial Engineering*, vol. 58, pp. 221-230.

[33] Augusto, V., Xie, X., and Perdomo, V. (2010). Operating theatre scheduling with patient recovery in both operating rooms and recovery beds, *Computers & Industrial Engineering*, vol. 58, pp. 231-238.

[34] Min, D., and Yih, Y. (2010). An elective surgery scheduling problem considering patient priority, *Computers & Operations Research*, vol. 37, pp. 1091-1099.

[35] Lamiri, M., Xie, X., Dolgui, A., and Grimaud, F. (2008). A stochastic model for operating room planning with elective and emergency demand for surgery, *European Journal of Operational Research*, vol. 185, pp. 1026-1037.

[36] Lamiri, M., Grimaud, F., and Xie, X. (2009). Optimization methods for a stochastic surgery planning problem, *Int. J. Production Economics*, 120: 400-410.

[37] Cardoen, B., Demeulemeester, E., and Beliën, J. (2010). Operating room planning and scheduling: A literature review, *European Journal of Operational Research*, vol. 201, pp. 921-932.

[38] Cima, R.R., Brown, M.J., Hebl, J.R., Moore, R., Rogers, J.C., Kollengode, A., Amstutz, G.J., Weisbrod, C.A., Narr, B.J., Deschamps, C., and Surgical Process Improvement Team, Mayo Clinic, Rochester. (2011). Use of Lean and Six Sigma Methodology to Improve Operating Room Efficiency in a High-Volume Tertiary-Care Academic Medical Center, *Journal of the American College of Surgeons*, vol. 213, pp. 83-92.