J Med Syst (2016) 40: 220
DOI 10.1007/s10916-016-0577-3

SYSTEMS-LEVEL QUALITY IMPROVEMENT

Use of Six Sigma Methodology to Reduce Appointment Lead-Time in Obstetrics Outpatient Department

Miguel A. Ortiz Barrios[1] · **Heriberto Felizzola Jiménez**[2]

Received: 5 March 2016 / Accepted: 18 August 2016 / Published online: 31 August 2016

Abstract This paper focuses on the issue of longer appointment lead-time in the obstetrics outpatient department of a maternal-child hospital in Colombia. Because of extended appointment lead-time, women with high-risk pregnancy could develop severe complications in their health status and put their babies at risk. This problem was detected through a project selection process explained in this article and to solve it, Six Sigma methodology has been used. First, the process was defined through a SIPOC diagram to identify its input and output variables. Second, six sigma performance indicators were calculated to establish the process baseline. Then, a fishbone diagram was used to determine the possible causes of the problem. These causes were validated with the aid of correlation analysis and other statistical tools. Later, improvement strategies were designed to reduce appointment lead-time in this department. Project results evidenced that average appointment lead-time reduced from 6,89 days to 4,08 days and the deviation standard dropped from 1,57 days to 1,24 days. In this way, the hospital will serve pregnant women faster, which represents a risk reduction of perinatal and maternal mortality.

This article is part of the Topical Collection on *Systems-Level Quality Improvement*

✉ Miguel A. Ortiz Barrios
mortiz1@cuc.edu.co

Heriberto Felizzola Jiménez
healfelizzola@unisalle.edu.co

[1] Department of Industrial Engineering, Universidad de la Costa CUC, Barranquilla, Colombia

[2] Department of Industrial Engineering, Universidad de la Salle, Bogotá, Colombia

Keywords Healthcare · Six Sigma · Outpatient Obstetrics

Introduction

With basis on the forecasts of global population growth for the next 30 years, the increased longevity of people and the government's intention to extend the coverage of health services, it can be said that healthcare industry is one of the sectors with the highest growth potential in the coming years [1, 2]. This creates a number of new challenges and opportunities for both health insurance companies and medical centers since, the demand for health services will continue to rise and it will be required to have medical procedures with high quality and safety standards, shorter service times and the suppression of non-value added activities in the process, which will increase the operational capacity and drive down service costs [3].

At present, Six Sigma has turned out to be a response to those organizations that face a considerable growth in demand of their products and service. This demand must be satisfied with greater efficiency and effectiveness [4]. For this reason, many health insurance companies have implemented Six Sigma as a business strategy to diminish medical errors, reduce service times in both administrative and clinical processes, improve the supply of drugs and diagnostic services, and shrink the investments in cost-intensive treatments. This has allowed these organizations are sustainable both financially and operationally without adversely affecting the quality of their services [5].

The appointment lead-time, defined as time since appointment request until patient care, is one of the critical to satisfaction (CTS) in healthcare sector since patients want to have shorter waiting times since their health

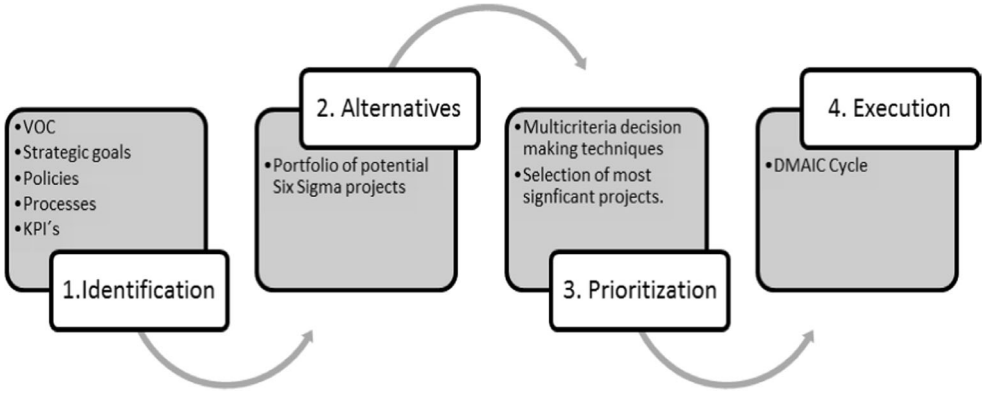

Fig 1 Proposed methodology for a successful implementation of Six Sigma programs (Source: Author)

problems affect their quality of life. Therefore, this paper presents the methodology and results of a Six Sigma project that was implemented in a maternal-child hospital, whose primary aim was to reduce the appointment lead-time in its obstetrics outpatient department (OOD). The results show the effectiveness of Six Sigma to achieve significant improvements in service processes.

The remainder of this paper is organized as follows: "Six Sigma and its applications on healthcare industry" Section presents a recent literature review on six sigma applications in healthcare; in "Methodology" Section, methodology is described; "Results and discussion: Improvement of appointment lead-time in an obstetrics outpatient department of hospital sector" Section shows and discusses the results of the case study. Finally, "Conclusions" Section presents the conclusions.

Six Sigma and its Applications on Healthcare Industry

The first applications of Six Sigma took place in manufacturing enterprises. However, because of its effectiveness in solving quality and efficiency problems, its scope was extended to cover several sectors, inter alia: services, healthcare and education. The first specific implementation of Six Sigma in healthcare sector occurred in 1998 at Commonwealth Health Corporation. Some of the results include 33 % increase in throughput, 21.5 % reduction of operational costs in Radiology Department and US$2.5 million in savings [6].

As regards the quality of healthcare services, Six Sigma can deal with various aspects such as: patient safety, effectiveness, patient satisfaction, appointment lead-time, efficiency and equity [7]. In the particular case of appointment lead-time and

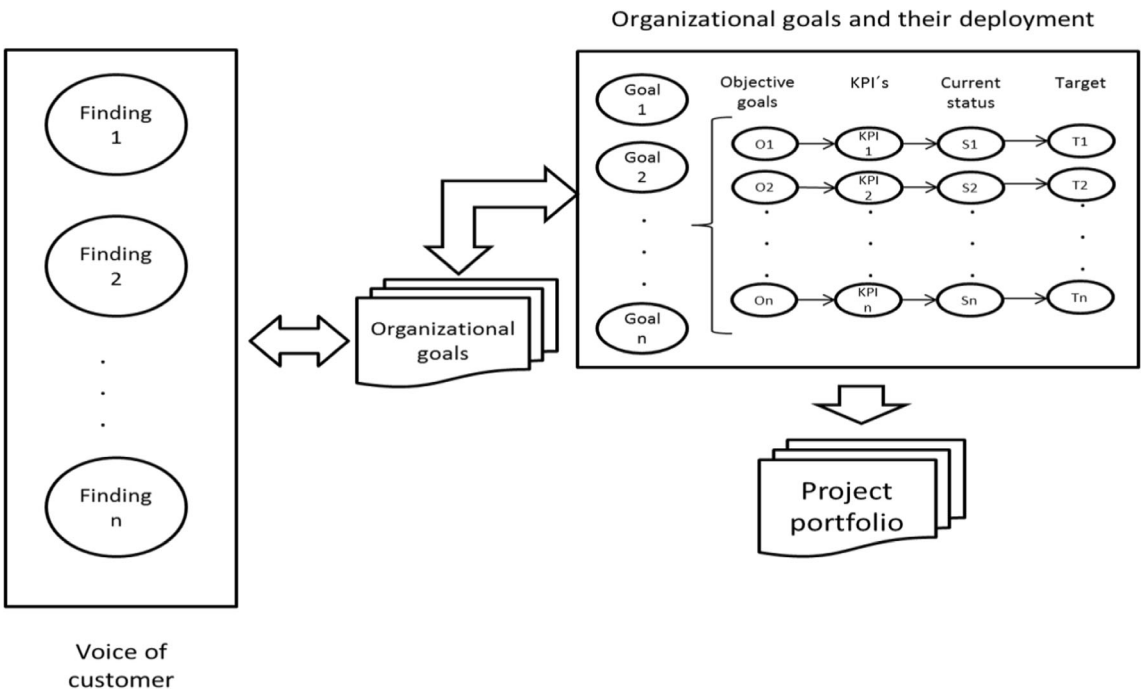

Fig 2 Creation process of Six Sigma project portfolio

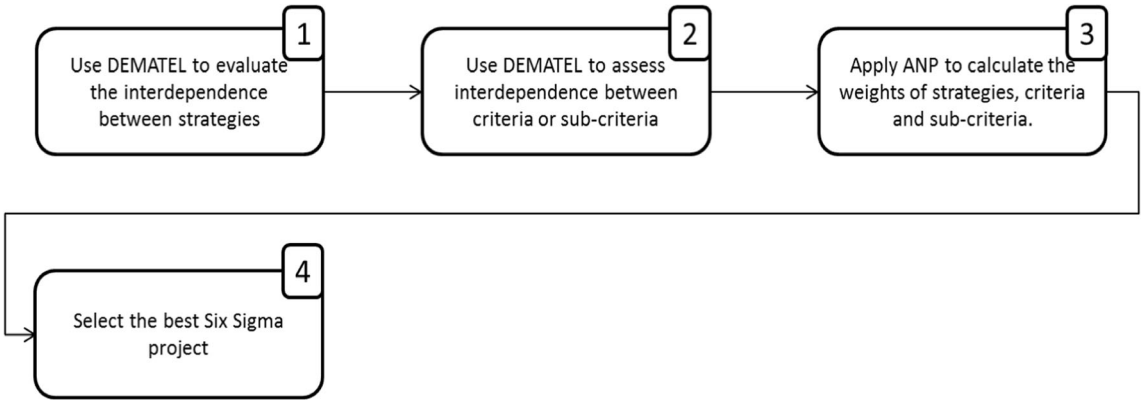

Fig 3 Decision-making scheme for Six-Sigma project selection process

efficiency, some relevant works can be referenced. For instance, Bhat & Jnanesh [8] used Six Sigma in a rural hospital achieving a reduction of 97 % for time spent in face-to-face patient care and 91 % in patient waiting time. Gijo & Antony [9] implemented Lean Six Sigma in an outpatient department. In this case, the average waiting time was reduced from 57 min to 24.5 min and standard deviation dropped from 31.35 min to 9.27 min. Furthermore, Lin, Jin & Chia [10] used Lean Six Sigma-based simulation in the ophthalmology department of a clinic. Through this methodology, a redesign of the appointment system was presented with 23.7 % reduction in patients' waiting time. Another case study is exposed by Lin et al. [11] who applied Lean Six Sigma in Otorhinolaryngology department and as a result of this, patient's waiting time decreased by 24 %, time spent in face-to-face patient care improved by 34 % and the distance traveled by patients and hospital staff fell by 34 %. Mandahawi et al. [12] also worked on this area to improve its efficiency and reduce its average stay length. Their intervention achieved a 48 % decrease in these performance indicators. On the other hand, Fischman [13] used Lean Six Sigma in the Internal Medicine area of an Emergency Department with the purpose of improving patient flow by decreasing patient waiting time between triage and medical care. Another case study was presented by Huddle et al. [14] who implemented Lean Six Sigma in an audiology clinic. This application improved the

Table 1 VOC format to evaluate critical to satisfaction of Financial Management Department

Client department Critical to satisfaction – Financial Management Department	General Management	Administrative Management	Internal Control	Disciplinary supervision	Quality	Human resource Management
Lead-time in financial reporting	E	E	G	G	G	G
Veracity of financial information	A	A	A	G	G	U

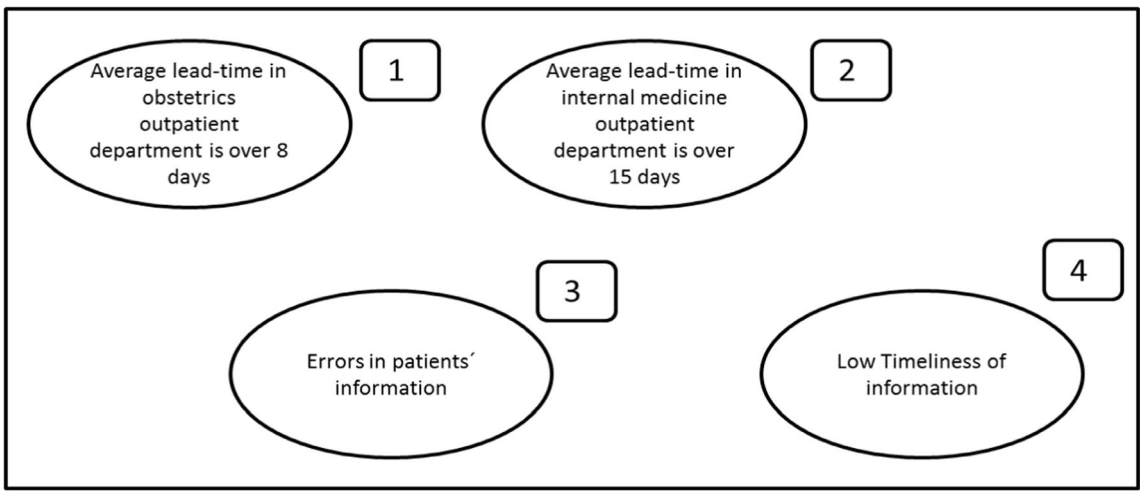

Fig 4 Findings in Voice of Customer analysis

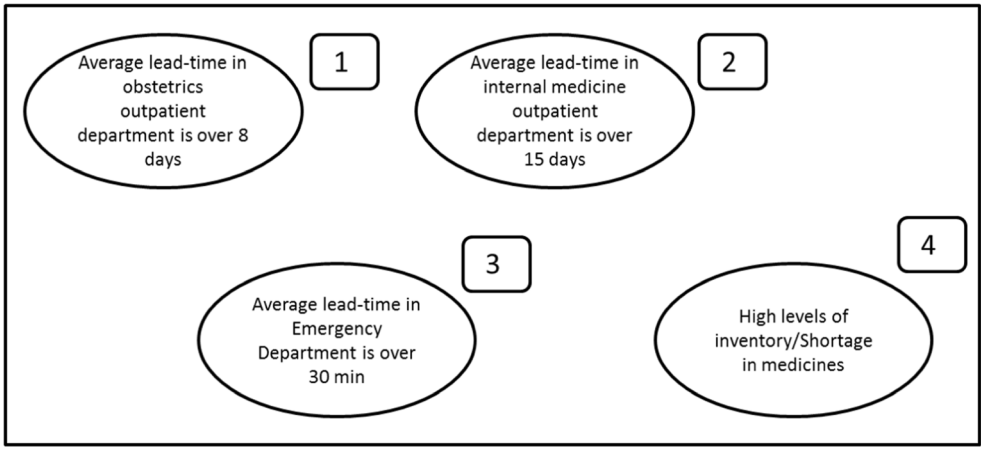

Fig 5 Findings in KPI's analysis

utilization percentage of time blocks from 77 % to 90 %, increased the number of scheduled appointments and reduced the waiting time from 29 days to 24 days.

Several applications can be also referenced in specific healthcare services like chemotherapy, pathology, sample analysis, medical recording and phlebotomy. One of these applications was implemented by Bhat, Gijo & Jnanesh [15], who applied Lean Six Sigma to reduce the turn-around-time (TAT) of the medical reporting process. TAT dropped from 18 min to 9 min which represents a 50 % decrease; moreover, the inventory level and the number of required staff were also reduced. Furthermore, Lamm et al. [16] used an adaptation of DMAIC methodology to improve the efficiency of chemotherapy process for adults. On the other hand, Kim et al. [17] applied Six Sigma to reduce patient's waiting time in phlebotomy process. Jiju, Jose & Johny [18] employed Six Sigma to reduce the sampling time in the pathology department of a clinic affiliated with a manufacturing company.

One of the commonest applications of Lean Six Sigma in healthcare is provided by surgery departments since quality, appointment lead-time, efficiency and costs are critical aspects for any healthcare provider. Bender et al. [19] used DMAIC methodology of Six Sigma aiming to improve the efficiency of a surgery department. With this implementation, resource utilization and incomings were increased; while set-up times, operational costs and over-time were reduced. Sedlack [20] implemented Six Sigma and Statistical Process Control (SPC) to improve the efficiency of colon surgery process (recovery, set-up and billing). Finally, Cima et al. [21] developed a comprehensive project that involves all the surgical specialties. With this project, process efficiency (from service approval to patient outflow) was improved with focus on operational downtimes, information management and patient flow.

As can be observed in the previous literature review, Lean Six Sigma can be applied in any medical specialty or clinical service offered by a healthcare provider; thus, its implementation has been increased exponentially over the past few years. In this case, the contribution of the present paper consists about presenting the implementation of Six Sigma in ginecobstetrics department, including previous phases such as the identification of opportunities and project selection through multicriteria decision making (MCDM) techniques which is a critical aspect to ensure the project's success and reduce risks.

Table 2 Articulation between findings and organizational goals

Goal Number 1: Ensure an on-time, efficient and effective service with the commitment of internal, social and public agents.		
Goal Number 2: Increase the supply capacity according to the service portfolio, service needs and biodiversity conservation through the protection and sustainable use of ecosystems.		
Goal Number 3: Harmonize the healthcare services with a financial stability that ensures their sustainability.		
Finding number.	Description of the finding	Attached goals
1	Average lead-time in obstetrics outpatient department is over 8 days	1,2,3
2	Average lead-time in internal medicine department is over 15 days	1,2,3
3	Errors in patient's information	1,2,3
4	High levels of inventory/shortage in medicines	1,2,3
5	Average lead-time in Emergency department is over 30 min	1,2,3
6	Low timeliness of information	1,2,3

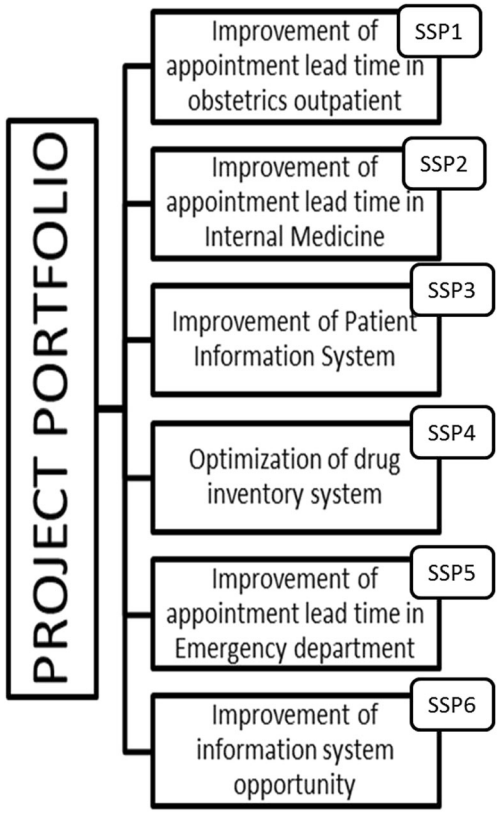

Fig 6 Project Portfolio defined for a specific maternal–child hospital

Methodology

To develop a successful Six Sigma implementation, it is necessary to carry out a series of support activities to ensure compliance with the next aspects: First, the problem must be addressed in line with strategic objectives. Second, the solution to the problem creates a significant impact on service quality and causes a substantial reduction of costs. Finally, it must contribute to improving patient satisfaction with regard to the quality, safety and efficiency of the healthcare services [22–24]. Thus, prior to developing the project, a four-phase methodology was designed (See Fig. 1):

Phase I - Identification To identify key improvement areas is necessary to analyze three aspects in an organization: First, customer voice; Second, strategic goals and organization policies and third, the processes and their key performance indicators (KPI's). The Voice of Customer analysis (VOC) is done by identifying the critical to satisfaction (CTS). For this, a survey for healthcare providers was carried out in order to determine the quality characteristics with the highest relevance in medical care. Once the customer perceptions have been obtained, the organizational policies, goals and KPI's are defined. KPI's should be specified in terms of current condition and a target with the aim of assessing the effectiveness of the Six Sigma projects that will be finally selected for their application.

Phase II – Alternatives The creation of potential Six Sigma projects is done by linking each organizational goal with several points for improvement that are previously detected by VOC analysis. In this way, a Six Sigma project portfolio is deployed with measurements and coherently towards the organizational vision and current market. A scheme used to articulate organizational goals with VOC is presented in Fig. 2 [25]:

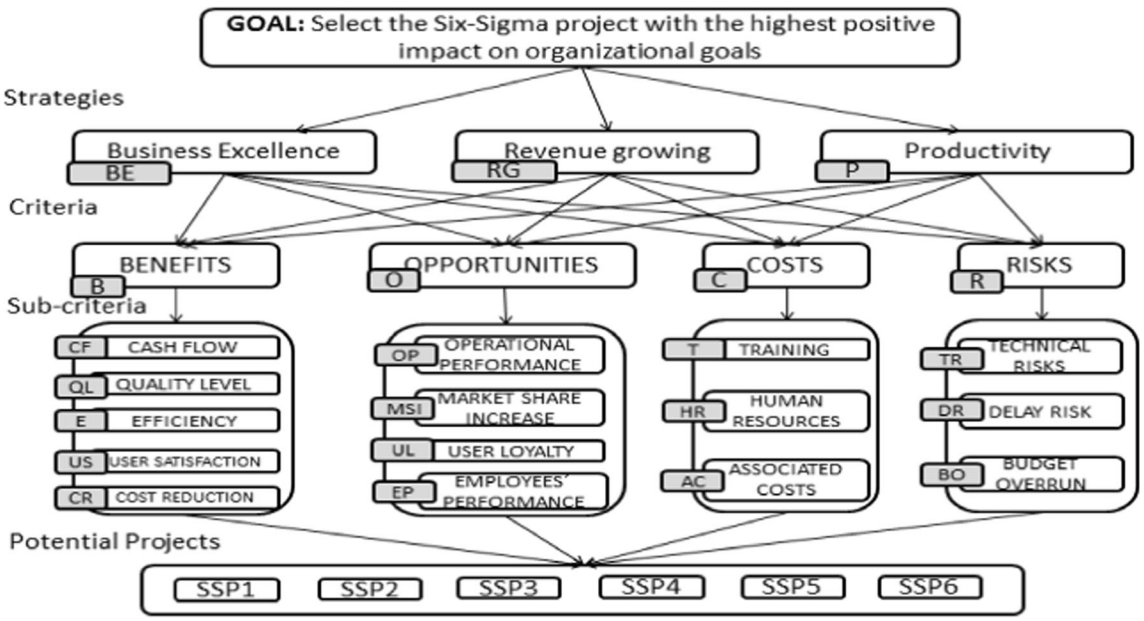

Fig 7 MCDM model to select the most suitable Six-Sigma project for the hospital - Adapted from [31]

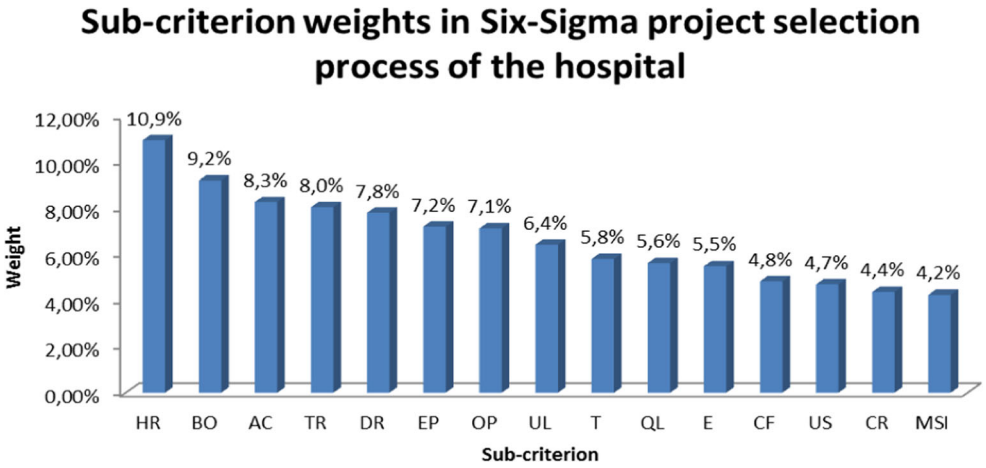

Fig 8 Weights of sub-criteria

Phase III – Prioritization The selection process of Six Sigma projects is to evaluate a project portfolio with a view to achieving organizational goals by implementing some of them [26, 27]. It is one of the most critical stages of a Six Sigma process afforded by the fact that defines much of the success in the deployment and implementation of the program [28, 29]. Therefore, it is important to ensure that the projects are selected in line with the organizational goals and objectives of healthcare providers [30]. In the evaluation process, four criteria were defined: OPPORTUNITIES, BENEFITS, RISKS and COSTS. Each of them was divided into sub-criteria for a total of 15 sub-criteria in the decision making model. Three strategic goals were also defined: BUSINESS EXCELLENCE, REVENUE GROWING and PRODUCTIVITY. Besides, it is proposed to combine two MCDM techniques: ANP (Analytic Network Process) and DEMATEL (Decision Making Trial and Evaluation Laboratory). Both techniques have been successfully used in project selection and are based on pairwise comparisons related to the influence and importance of decision factors and sub-factors [31]. These comparisons have to be made by a Six-Sigma team whose participants must be chosen according to their experience and their position in the company related to the project. A decision- making scheme is presented in Fig. 3 to illustrate the steps of Six-Sigma project selection process.

Phase IV. Execution Finally, the selected project is developed by using DMAIC cycle which consists of five steps: DEFINE, MEASURE, ANALYZE, IMPROVE and CONTROL. DEFINE involves defining the problem, indicating how it affects the customer and what benefits could be achieved with the project implementation. MEASURE is to determine the current status of the process through the calculation of KPI's. ANALYZE comprises identifying the causes of the problem through the use of statistical tools. IMPROVE consists of evaluating and implementing solutions to ensure the fulfillment of strategic goals. As final step, CONTROL is to

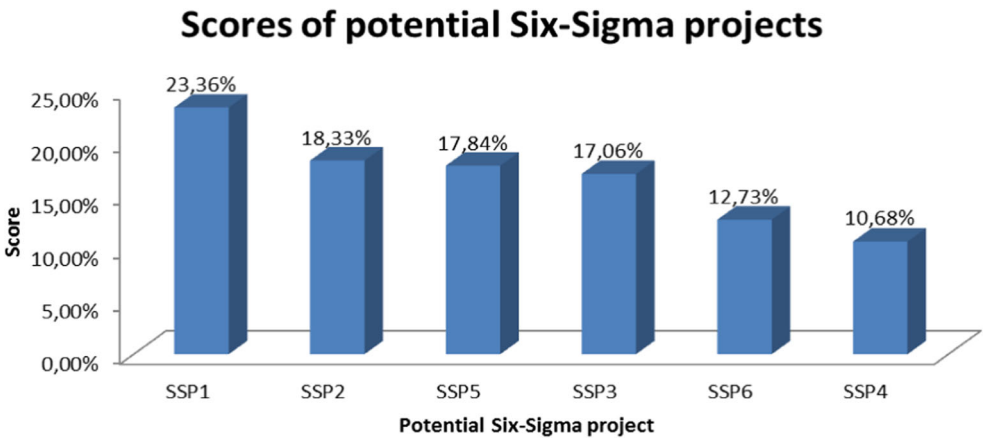

Fig 9 Global scores of Six-Sigma projects

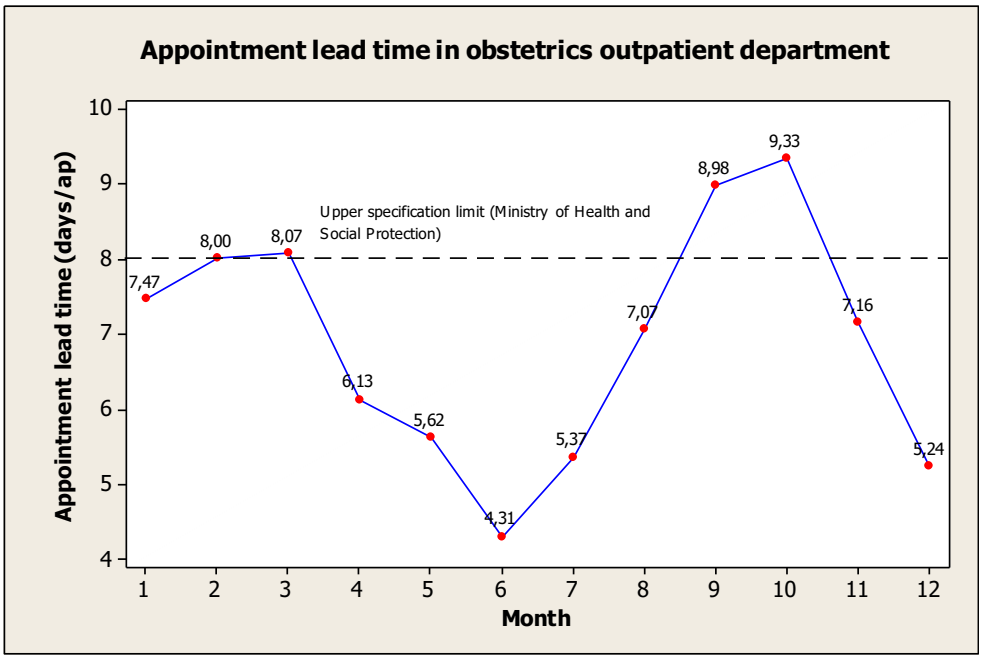

Fig 10 Current status of appointment lead-time in obstetrics outpatient department

design a system to maintain the improvements already achieved.

A case study with the implementation of the proposed methodology in a maternal-child hospital is presented in "Results and discussion: Improvement of appointment lead-time in an obstetrics outpatient department of hospital sector" Section to prove its validity and effectiveness. First, the hospital identified a set of needs based on VOC and KPI's analysis. Then, with the support of a Six-Sigma team, it created a Six-Sigma project portfolio and selected the most prioritized project (Improvement of appointment lead-time in an obstetrics outpatient department) according to a multi-criteria decision making (MCDM) model and a hybrid MCDM technique between ANP and DEMATEL [32]. Finally, the selected project was executed using DMAIC cycle and the results evidenced the suitability of the suggested methodology.

Results and discussion: improvement of appointment lead-time in an obstetrics outpatient department of hospital sector

Phase I. Identification

The case study presented in this paper is part of a research project implemented in the obstetrics outpatient department of a maternal-child hospital during 2014. This hospital is one of the most traditional healthcare organizations in public sector

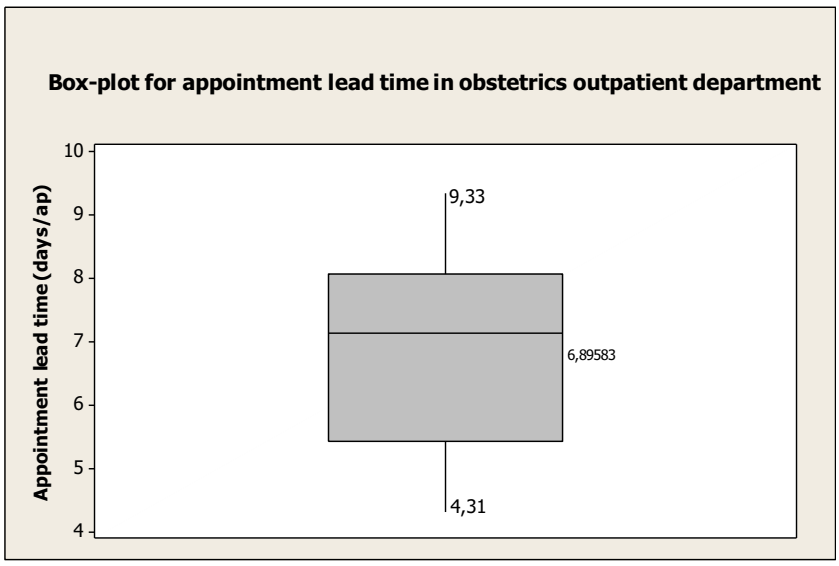

Fig 11 Box-plot for appointment lead-time in obstetrics outpatient department

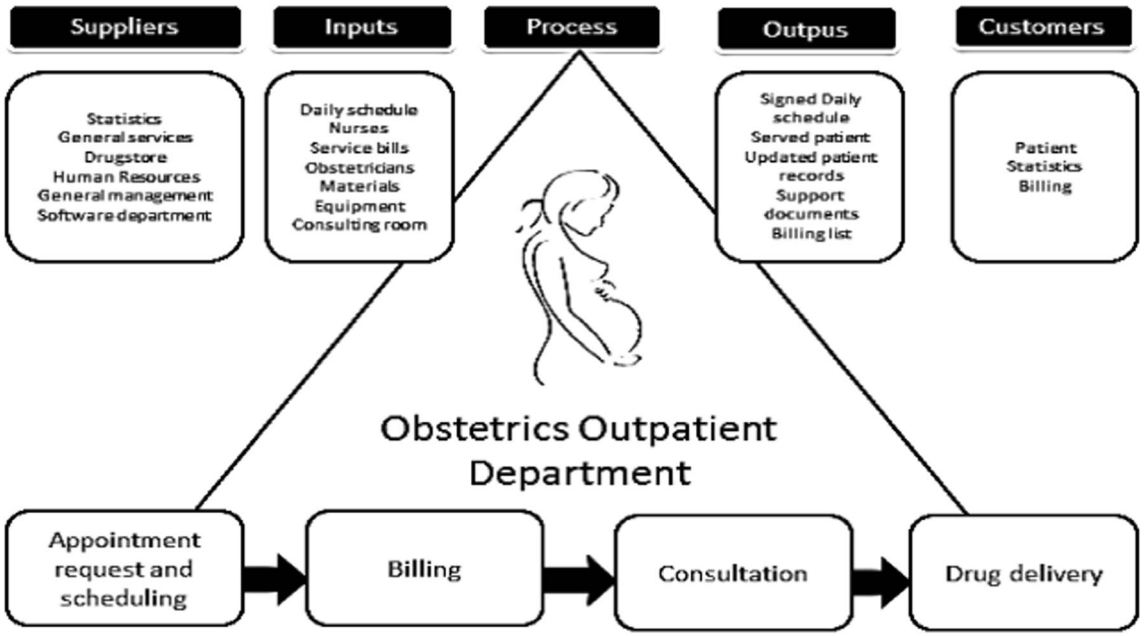

Fig 12 SIPOC diagram for obstetrics outpatient department in study

of Colombia and provides high-complexity services to 18,362 patients per year approximately. Its main goals are focused on promoting efficient resource utilization and patient satisfaction. However, the hospital lacked an efficient way to deploy these organizational goals to potential projects. In this sense, any Six-Sigma project could be selected without establishing whether it had the highest positive impact on the company; reason why it was possible to choose a non-significant project for the organization. To avoid this, it was necessary to previously identify the primary weaknesses of the hospital by evaluating patient's perception and KPI's (Key performance indexes). For this, a VOC (Voice of Customer) study and an analysis of indicators were carried out.

An example of a VOC format used in this study is shown in Table 1. In this, each hospital department is evaluated by its clients/users in terms of its critical to satisfaction. Each critical can be assessed as: E (Excellent), G (Good), A (Acceptable) or U (Unacceptable). Those critical with "A" or "U" grades in more than 50 % of the clients, were categorized as "VOC findings" The results, in terms of VOC findings, are summarized in Fig. 4:

On the other hand, KPI's were statistically studied taking into account the separation between their current performance and govern targets. In this respect, a set of findings were established. Some of them coincided with the findings described in VOC analysis (See Fig. 5)

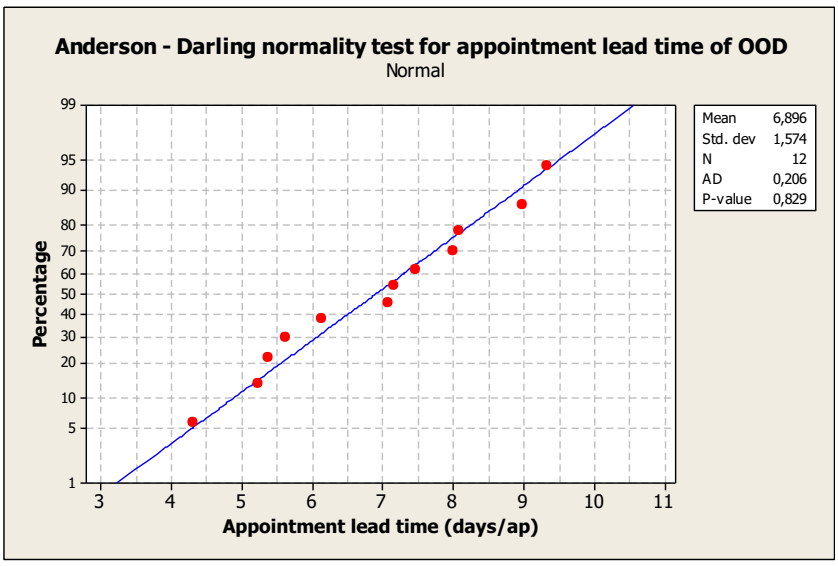

Fig 13 Anderson – Darling normality test for appointment lead time of obstetrics outpatient department

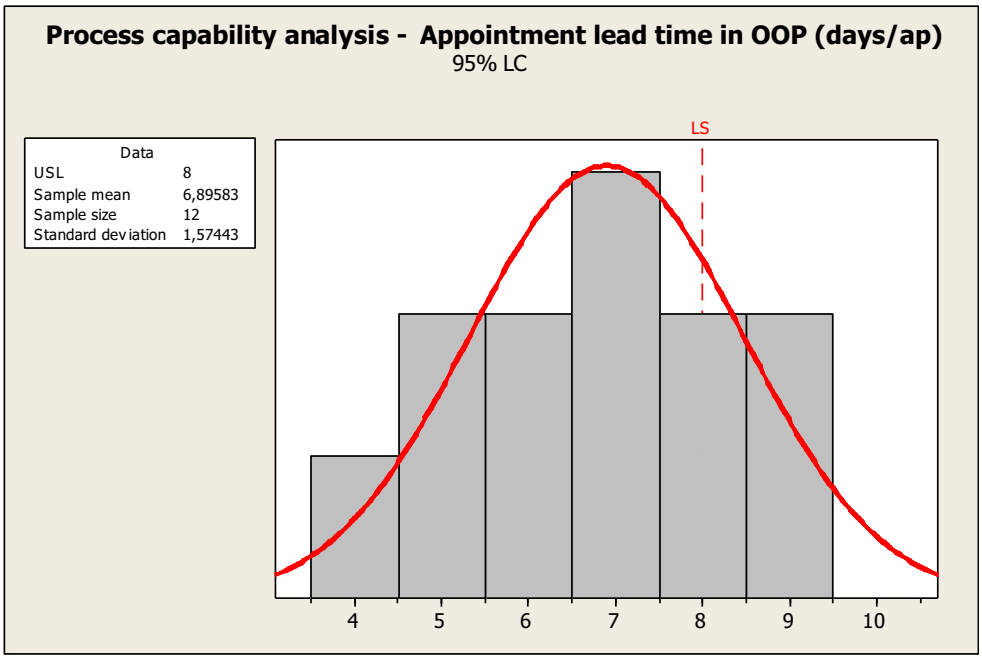

Fig 14 Process capability analysis – Appointment lead time in obstetrics outpatient department

Phase II. Alternatives

To establish a project portfolio, it is necessary to articulate findings from KPI's and VOC analysis with organizational goals. To support this activity, six professionals from Quality Department (2), Financial Department (2), General Management (1) and User Service Department (1) were selected to be part of the Six-Sigma team. Each of these participants had more than 17 years of experience in healthcare sector and had a broad knowledge of all the processes associated with the hospital under study. After creating the Six-Sigma team, organizational goals were identified and linked to each of the findings (See Table 2).

With basis on the information provided in Table 2, the next step consisted about defining a set of Six-Sigma projects responding to the findings described above. The results (See Fig. 6) were discussed with the Six-Sigma team and the hospital director. Both agreed with the resulting project portfolio.

Phase III. Prioritization

After selecting a portfolio with 6 projects, a total of 3 strategies, 4 criteria and 15 sub-criteria were identified with the support of the Six-Sigma team and the pertinent literature. Based on this, a MCDM model was designed to select the project with the highest positive impact for the hospital (See Fig. 7).

To evaluate the project portfolio, a combined ANP-DEMATEL technique was used as explained in Fig. 3 of "Methodology" Section. In this stage, the Six-Sigma team made the pairwise comparisons for both DEMATEL and ANP methods according to the decision-making model described in Fig. 5. As a result of this process, the weights of criteria, sub-criteria and strategies were calculated. It was determined that each strategy contributed equally to the goal (33.3 %) as well as each criteria (25 %). The weights of sub-criteria have been illustrated in Fig. 8.

Furthermore, DEMATEL results evidenced strong dependence in each of the clusters described in the decision-making

Table 3 Six Sigma indicators for the OOD in study

Upper specification limit (USL) Mean	8 days/app 6.89 days/app	PPM	322,800
Standard deviation (σ) Upper control limit (UCL)	1.574 days/app 11.61 days/app	Short-term Sigma level	0.72
Zu P (error)	0.71 24.03 %	Cps	0.235
Efficiency	65.97 %		

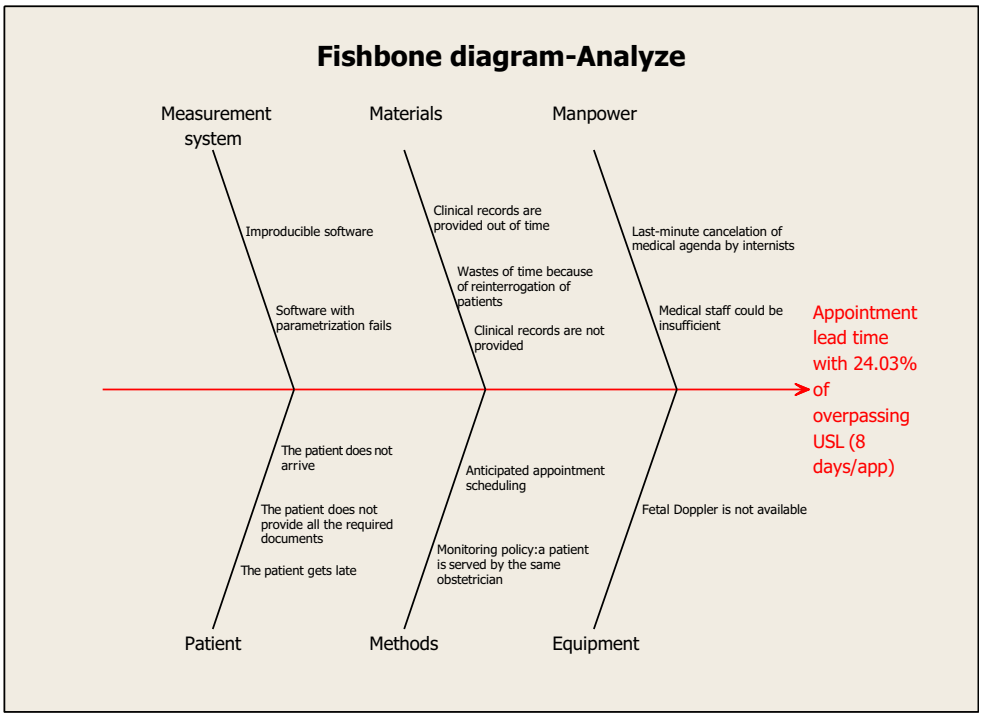

Fig 15 Fishbone diagram – Analyze

model. In STRATEGIES cluster, REVENUE GROWING was categorized as a "receiver" (it is influenced by the other strategies). In BENEFITS cluster, EFFICIENCY, USER SATISFACTION and OPERATIONAL COST were qualified as "dispatchers" (sub-criteria that influence on the receivers). In OPPORTUNITY cluster, MARKET SHARE INCREASE was considered as the only receiver in that group. In COST cluster, TRAINING was categorized as a dispatcher, ASSOCIATED COSTS as a receiver and HUMAN RESOURCE was not classified in any of the categories. Finally, in RISK cluster, BUDGET OVERRUN was considered as the only receiver.

Given the above, the potential Six-Sigma projects were evaluated. The scores obtained by each project are shown in Fig. 9. It can be observed that project SSP1 (Improvement of appointment lead time in obstetrics outpatient) obtained the highest score (23.36 %).

Phase IV. Execution

Define

Understanding the importance of providing great clarity in defining the problem of the obstetrics outpatient department,

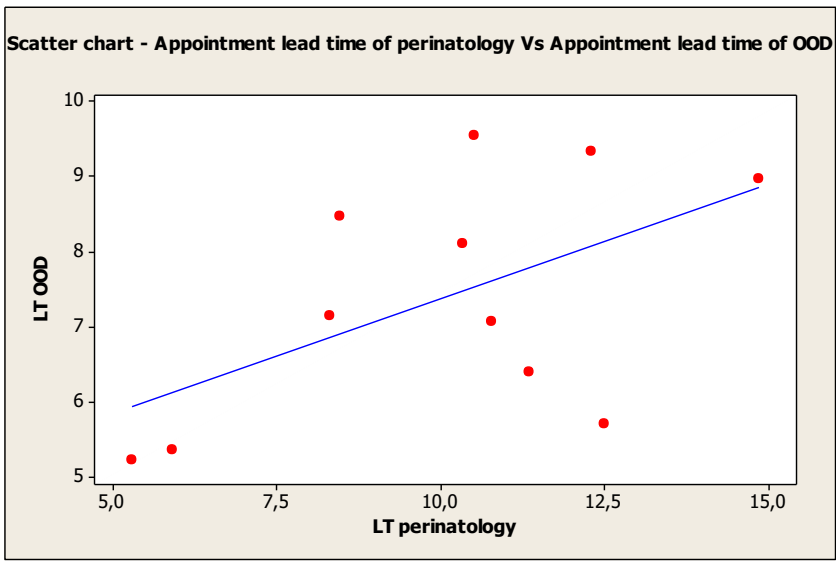

Fig 16 Scatter chart – Appointment lead time of perinatology Vs. Appointment lead time of OOD

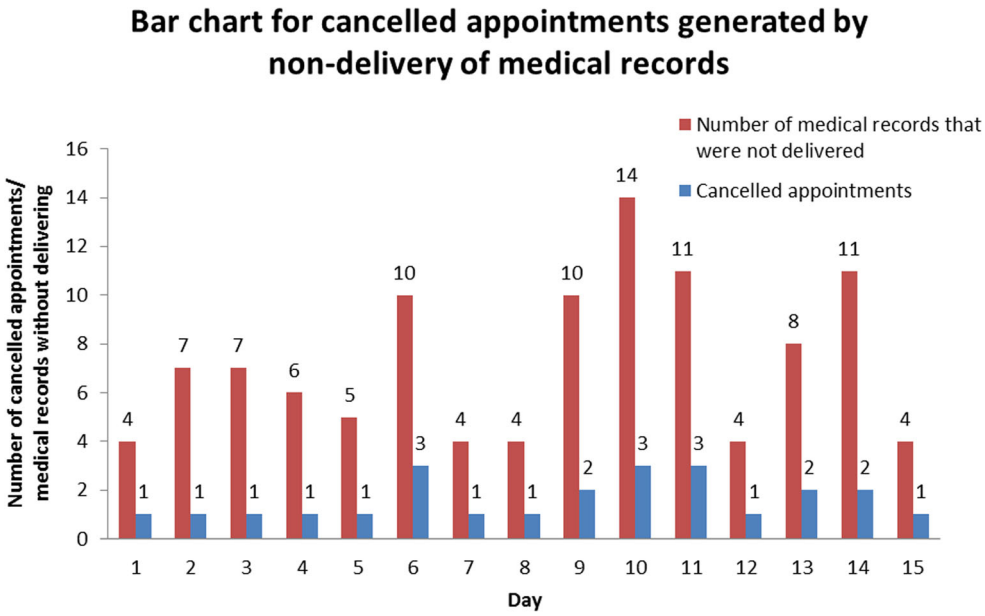

Fig 17 Bar chart for cancelled appointments and their relations with non-delivery of medical records

a Six Sigma team has been set up with different workers supplied by the maternal-child hospital in study. This team was composed by six members: Director of patient services, Quality Assurance Director, QMS Director, Director of outpatient services, Chief Financial Officer and two external consultants. In turn, this workgroup was headed by two industrial engineers with expertise on the implementation of Six Sigma programs.

To define the current status of the obstetrics outpatient department, appointment lead time was studied and diagramed using a line chart with the aid of MINITAB software. It should be noted that the upper specification limit has been established by the Ministry of Social Protection and Health (8 days/appointment on average).

At the moment of assessing the process, average appointment lead-time is equal to 6.89 days with a deviation standard of 1.57 days. Figure 10 evidences that this department has overpassed the upper specification limit in months 3, 9 and 10 (March, September and October). This can be represented with a 24.03 % chance of overpassing this target. The higher value (9.33 days/appointment) took place in October since the number of pregnant women use to be bigger in this period of the year. A box-plot (See Fig. 11) has also graphed to evidence the variation of the process and with whiskers limited by 4.31 days/app and 9.33 days/app, the process needs a serious intervention since this is reflected in longer waiting times for pregnant women who could develop severe complications and put their babies at risk.

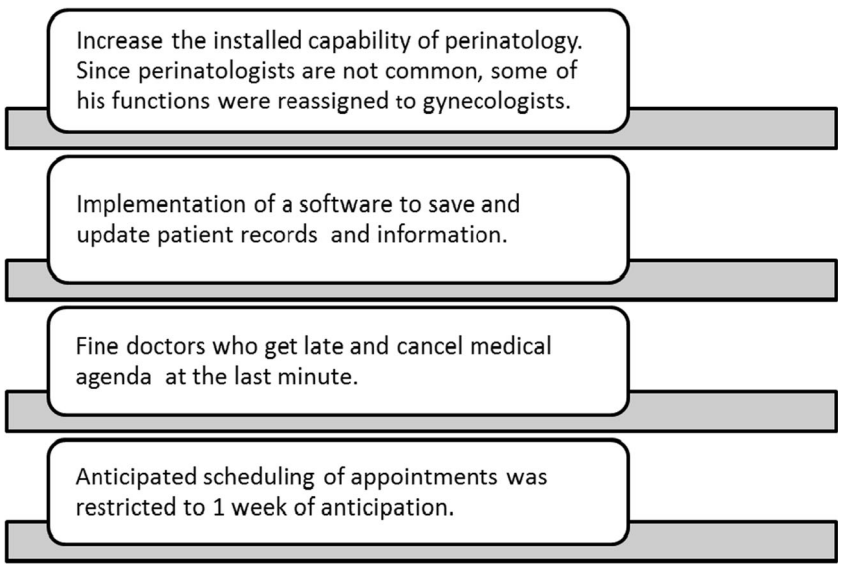

Fig 18 Improvement strategies for OOD in study

Table 4 Six Sigma indicators for the OOD in study – After intervention

Upper specification limit (USL)	8 days/app	PPM	46,500
Mean	4.08 days/app		
Standard deviation (σ)	1.24 days/app	Short-term Sigma level	3.16
Upper control limit (UCL)	7.8 days/app		
Zu	3.16	Cps	1.054
P (error)	4.65 %		
Efficiency	95.35 %		

With this information, a project charter was designed setting out two metrics (operational cost, appointment lead time), project duration of 6 months, the scope of the project (obstetrics outpatient department), potential benefits for all the stakeholders (patients, hospital director, government, employees) and a brief outline of the problem.

To learn more about the process, a SIPOC (Supplier, Inputs, Process, Outputs and Customers) diagram has been designed (See Fig. 12). This lets us to assess the impact of the different factors that affect the process and the existing relations between themselves. In this case, it can be observed that STATISTICS department play an important role in the process because it is distinguished as both SUPPLIER and CUSTOMER of the obstetrics outpatient department. Inputs and outputs of the process are also noticed and will be under careful considerations in next steps.

Measure

As next stage, Six-sigma team proceeds with assessing the current state of the OOD. For this, data and information about appointment lead time were gathered with the aid of Software Department of the hospital. These data were extracted from the database of the hospital where all the appointments ($n = 4020$) corresponding to its last operational year were listed together with their request and consultation dates. As next step, with the support of Minitab Software ®, appointment lead-times were calculated. Then, an Anderson – Darling normality test was performed to establish whether this data have a normal distribution (See Fig. 13).

With a p-value of 0.829, there is sufficient evidence to conclude that this data is normally distributed and also potential atypical points are not illustrated in the graph. On the basis of this conclusion, the use of non-parametric techniques is discarded.

Furthermore, a process capability analysis (See Fig. 14) is also performed to determine how capable the process is to fulfill the requirements, in this case, upper specification limit established by the Ministry of Health and Social Protection (USL = 8 days/appointment).

Table 3 summarizes all Six Sigma indicators. It can be observed that with a Cps of 0.235, the process is not capable to ensure the compliance of government target with regard to obstetrics outpatient. With this result, the process is categorized with the worst grade (Class 4), which means that serious changes are required. This is also confirmed by the short-term sigma level (0.72) which is very low upon considering "0" as the lowest value. This sigma level is equivalent to 322,800 PPM (Parts per million defective), meaning that out of every million appointments, 322,800 will have an appointment lead

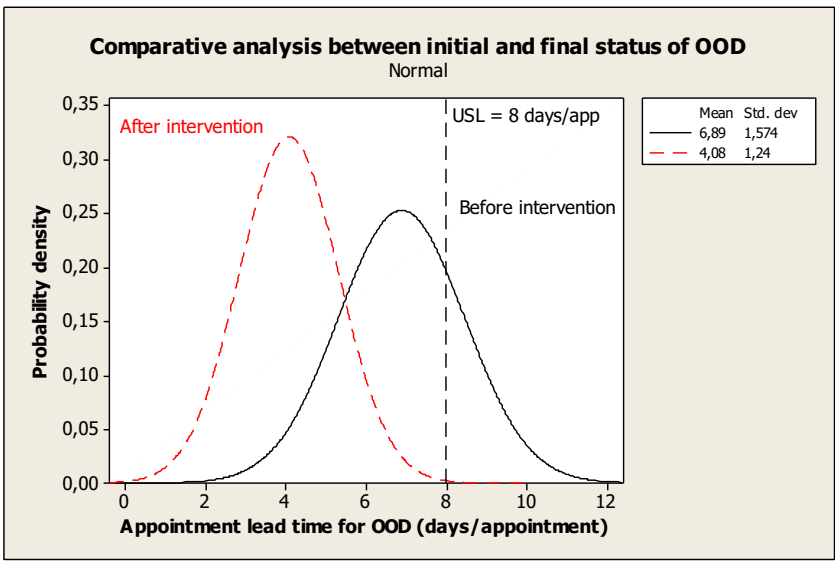

Fig 19 Comparative analysis between initial and final status of OOD

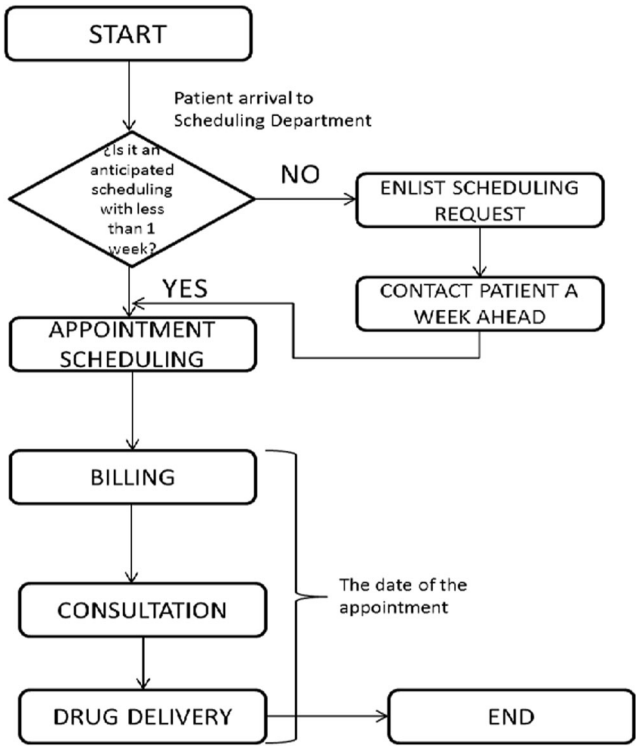

Fig 20 Flowchart of obstetrics outpatient department after improvement

time over 8 days. It should be highlighted that the measurement system integrated by the servers of APPOINTMENT SCHEDULING DEPARTMENT and DSS (Decision Support Software) of the hospital was qualified as valid to provide reliable data; which is very important to ensure a high confidence level in decision making.

Analyze

It has been concluded that appointment lead time of OOD is not satisfactory and requires serious interventions. For this reason, it is necessary to explore the potential causes of the problem through a fishbone diagram (See Fig. 15). These causes were identified by the Six-Sigma team members according to their experience and opinions provided by patients (patient satisfaction surveys), doctors and support staff in a 4-h session.

The so-called *cause and effect diagram* provided meaningful findings and guided Six Sigma team towards the creation of more precise improvement strategies. Upon analyzing each possible cause, the team determined that last-minute cancellation affected the appointment lead time of the department. To establish this, cancelled appointments were collected together with their request, scheduling and re-scheduling dates in order to calculate the average rate of increase for the lead-time. Results evidenced that patients with cancelled appointments tended to wait for 8.12 days more which has negative implications on their health status. Furthermore, a sub-specialty called *perinatology* was affecting with a correlation coefficient of 54.59 % (See Fig. 16), being highlighted as the main variation source of appointment lead time in OOD. To determine this, appointment lead-times for *perinatology* were obtained and correlated with appointment lead-time in OOD. This is also linked to the fact that 35.13 % of the cancelled appointments are related to this sub-specialty.

A more in-depth analysis evidenced that there was only one perinatologist who served patients from 8 am to 12 m, 2 days in a week. The rest of his schedule was distributed among different functions that could be assumed by a gynecologist. In some cases, lead time of a perinatology appointment overpassed 21 days which is very risky for women with high-risk pregnancy. On the other hand, anticipated programming of appointments and late deliveries of medical records were also significant on appointment lead time of OOD but with minor effects. To measure non-delivery of medical records, a format was designed to establish the number of records that were provided to the physicians per day and then relate it to the amount of records that had to be delivered in that time. With these data, effectiveness of this activity could be quantified (See Fig. 17). As it can be observed, the number of cancelled appointments is highly minor regards to the number of medical records that were not delivered.

On the other hand, appointments with anticipated scheduling were filtered from the database of the hospital. Normally, these patients preferred requesting their next appointments on the same day of consultation. This policy was affecting appointment lead-time with a correlation coefficient of 23.4 %. The rest of the causes were proved as non-significant for OOD lead-time.

Improve

Six Sigma team of this hospital constituted a fundamental contribution at the moment of designing strategies for the process enhancement. As a result, four improvements were defined (See Fig. 18) and implemented with considerable outputs (See Table 4).

The resulting data were also extracted from the database of the hospital where the appointments corresponding to 3 months after intervention ($n = 1005$) were collected together with their request and consultation dates. As a next step, with the support of Minitab Software ®, appointment lead-times were calculated. Results evidence OOD increased its sigma level by 2.45 which represented a new sigma level of 3.16. This means that out of 1'000.000 appointments, 46,500 will be scheduled with a lead time greater than 8 days/appointment. Efficiency rate consequently improved by 27.63 % and probability of overpassing USL decreased up to 4.65 % which is low. Cps also increased up to 1.054 which means that involved processes in OOD are partially adequate to comply with governmental standards. Finally, a comparative analysis

between initial and final status of OOD with regard to appointment lead time is shown to prove the effectiveness of the proposed approach (See Fig. 19). The flowchart of obstetrics outpatient department after improvement can be observed in Fig. 20. An inspection stage has been added to avoid anticipating scheduling with more than 1 week ahead.

Control

Maintaining the improvements already achieved is a really challenging step due to the existence of different barriers in hospital personnel (Resistance to change). However, some Six Sigma projects fail due to poor control plans [22]. For this reason, it is required to create effective strategies to ensure a correct quality control and monitoring of the process. In this case, an individual control chart was designed to check the performance of appointment lead time in OOD with the purpose of detecting and preventing potential falloffs in the process. Furthermore, implemented improvements were documented in Quality Management System of the hospital where they can be consulted online by the employees. Finally, results were presented to the steering committee of the hospital which expressed its full satisfaction with the improvements achieved.

Conclusions

Healthcare industry is currently addressing with the increased pressure of reducing operational costs and enhancing high-quality levels of care. Six-Sigma provides an understandable framework to achieve these goals and its benefits have been widely proved in multiple healthcare scenarios. Particularly, this paper concentrated on implementing Six Sigma in obstetrics outpatient department of a maternal-child hospital through a four-phase methodology that starts with the identification of improvement opportunities and finishes with the application of DMAIC cycle.

Results evidence the effectiveness of the proposed approach. Specifically, the average appointment lead time of this department reduced from 6,89 days to 4,08 days and the deviation standard dropped from 1,57 days to 1,24 days which represents that out of 1.000.000 appointments, 46,500 will be scheduled with a lead time greater than 8 days. In this way, women with high-risk pregnancy will have shorter waiting times before consultation, meaning that there is a minor risk of developing complications that could result in perinatal and/or maternal mortality.

This approach will guide practitioners and decision makers in healthcare services to achieve a better performance in obstetrics outpatient services. For future work, it is recommended to integrate financial models into the proposed framework with the purpose of assessing the economic affectations of the project.

Acknowledgments Authors thank the support of Marco Antonio Bolaño, Janeth Rebolledo Rudas, Margarita Manjarrez, Fidel Borge Salazar, José Turizzo Rodelo, Juan Alvarado Socarrás, Ivan Egea Borge and Liliana Castro Castillo who formed part of the Six-Sigma team.

References

1. Dellifraine, J. L., Langabeer, J. R., and Nembhard, I. M., Assessing the Evidence of Six Sigma and Lean in the Health Care Industry. *Qual. Manag. Health Care* 19:211–225, 2010. doi:10.1097/qmh.0b013e3181eb140e.
2. Cabello, J. J., Garcia, D., Sagastume, A., Priego, R., Hens, L., and Vandecasteele, C., An approach to sustainable development: the case of Cuba. *Environ. Develop. Sustain.* 14(4):573–591, 2012.
3. Taner, M. T., Sezen, B., and Antony, J., An overview of six sigma applications in healthcare industry. *Int. J. Health Care Qual. Assur. Int. J Health Care QA* 20:329–340, 2007. doi:10.1108/09526860710754398.
4. Antony, J., Antony, F. J., Kumar, M., and Cho, B. R., Six sigma in service organisations. Int J Qual & Reliability Mgmt International Journal of Quality &amp. *Reliab. Manag.* 24:294–311, 2007. doi:10.1108/02656710710730889.
5. Sehwail, L., and Deyong, C., Six Sigma in health care. *Leadersh. Health Serv.* 16:1–5, 2003. doi:10.1108/13660750310500030.
6. Lopez, L., *Six Sigma in healthcare: a case study with Commonwealth Health Corporation*. Real World Examples of Success, World Class Applications of Six Sigma, 1997. doi:10.1016/B978-0-7506-6459-2.50011-1.
7. Taner, M. T., Sezen, B., & Antony, J. An overview of six sigma applications in healthcare industry. 2013. doi: 10.1108/09526860710754398.
8. S. Bhat and N. A. Jnanesh. Application of Lean Six Sigma methodology to reduce the cycle time of out-patient department service in a rural hospital. 14(3); 222–237, 2014. doi:10.1504/IJHTM.2014.064257.
9. Gijo, E. V., and Antony, J., Reducing Patient Waiting Time in Outpatient Department Using Lean Six Sigma Methodology. *Qual. Reliab. Eng. Int.* 30(8):1481–1491, 2014. doi:10.1002/qre.1552.
10. W. D. Lin, X. Jin, and S. Y. Chia, "Simulation based lean six sigma approach to reduce patients waiting time in an outpatient eye clinic," in 2014 I.E. International Conference on Industrial Engineering and Engineering Management. 394–398, 2014. 10.1109/IEEM.2014.7058667.
11. S. Y. Lin, D. Gavney, S. L. Ishman, and J. Cady-Reh. Use of lean sigma principles in a tertiary care otolaryngology clinic to improve efficiency. 123(11); 2643–2648, 2013. doi:10.1002/lary.24110.
12. Mandahawi, N., Al-Araidah, O., Boran, A., and Khasawneh, M., Application of Lean Six Sigma tools to minimise length of stay for ophthalmology day case surgery. *Int. J. Six Sigma Compet. Advant.* 2011. doi:10.1504/IJSSCA.2011.039716.
13. Fischman, D., Applying lean six sigma methodologies to improve efficiency, timeliness of care, and quality of care in an internal medicine residency clinic. *Qual. Manag. Healthcare* 19(3):201–210, 2010. doi:10.1097/QMH.0b013e3181eece6e.
14. M. G. Huddle, A. Tirabassi, L. Turner, E. Lee, K. Ries, and S. Y. Lin. Application of Lean Sigma to the Audiology Clinic at a Large Academic Center. 154(4); 715–719, 2015. doi:10.1177/0194599815627774.

15. Bhat, S., Gijo, E. V., and Jnanesh, N. A., Productivity and performance improvement in the medical records department of a hospital. *Int. J. Product. Perform. Manag.* 2015. doi:10.1108/IJPPM-04-2014-0063.
16. Lamm, M. H., Eckel, S., Daniels, R., and Amerine, L. B., Using lean principles to improve outpatient adult infusion clinic chemotherapy preparation turnaround times. *Am J Heal. Pharm.* 72(13): 1138–1146, 2015. doi:10.2146/ajhp140453.
17. Kim, Y. K., Song, K. E., Lee, W.-K., Harry, M., Schroeder, R., Westgard, J., Klee, G., Burtis, C., Ashwood, E., Gras, J., Philippe, M., Riebling, N., Tria, L., Nevalainen, D., Berte, L., Kraft, C., Leigh, E., Picaso, L., Morgan, T., Westgard, J., Westgard, S., Simmons, J., Riebling, N., Tria, L., Jackson, J., and Woeste, L., Reducing Patient Waiting Time for the Outpatient Phlebotomy Service Using Six Sigma. *Korean J. Lab. Med.* 29(2):171, 2009. doi:10.3343/kjlm.2009.29.2.171.
18. Gijo, E. V., Jiju, A., Jose, H., and Johny, S., Reducing patient waiting time in a pathology department using the Six Sigma methodology. *Leadersh. Heal. Serv.* 26(4):253–267, 2014. doi:10.1108/LHS-02-2012-0004.
19. J. S. Bender, T. O. Nicolescu, S. B. Hollingsworth, K. Murer, K. R. Wallace, and W. J. Ertl. Improving operating room efficiency via an interprofessional approach. 209(3); 447–450, 2015. doi: 10.1016/j.amjsurg.2014.12.007.
20. Sedlack, J. D., The Utilization of Six Sigma and Statistical Process Control Techniques in Surgical Quality Improvement. *J. Healthc. Qual.* 32(6):18–26, 2010. doi:10.1111/j.1945-1474.2010.00102.x.
21. 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., and Deschamps, C., Use of Lean and Six Sigma Methodology to Improve Operating Room Efficiency in a High-Volume Tertiary-Care Academic Medical Center. *J. Am. Coll. Surg.* 213(1):83–92, 2011. doi:10.1016/j.jamcollsurg.2011.02.009.
22. Coronado, R. B., and Antony, J., Critical success factors for the successful implementation of six sigma projects in organisations. *TQM Mag.* 14:92–99, 2002. doi:10.1108/09544780210416702.
23. Jiménez, H. F., and Amaya, C. L., Lean Six Sigma en pequeñas y medianas empresas: un enfoque metodológico. *Ing. Rev. Chil. Ing. Ing. Rev. Chil. Ing.* 22:263–277, 2014. doi:10.4067/s0718-33052014000200012.
24. Sharma, S., and Chetiya, A. R., An analysis of critical success factors for Six Sigma implementation. *Asian J. Qual.* 13:294–308, 2012. doi:10.1108/15982681211287810.
25. Su, C. T., and Chou, C. J., A systematic methodology for the creation of Six Sigma projects: A case study of semiconductor foundry. *Expert. Syst. Appl.* 34(4):2693–2703, 2008. doi:10.1016/j.eswa.2007.05.014.
26. Ortíz, M. A., Felizzola, H. A., and Isaza, S., A contrast between DEMATEL-ANP and ANP methods for six sigma project selection: a case study in healthcare industry. *BMC Med Inform Decis Mak BMC Med. Info. Dec. Making*, 2015. doi:10.1186/1472-6947-15-s3-s3.
27. Su, C., and Chou, C., A systematic methodology for the creation of Six Sigma projects: A case study of semiconductor foundry. *Exp. Syst. Appl.* 34(4):2693–2703, 2008. doi:10.1016/j.eswa.2007.05.014.
28. Kwak, Y. H., and Anbari, F. T., Benefits, obstacles, and future of six sigma approach. *Technovation* 26(5):708–715, 2006. doi:10.1016/j.technovation.2004.10.003.
29. Snee, R. D., and Rodebaugh, W. F., Frontiers of Quality: The project selection process. *Qual. Prog.* 35(9):78–80, 2002.
30. Gijo, E. V., and Rao, T. S., Six Sigma implementation – Hurdles and more hurdles. *Tot. Qual. Manag. Bus. Excel.* 2005. doi:10.1080/14783360500077542.
31. Büyüközkan, G., and Öztürkcan, D., An integrated analytic approach for Six Sigma project selection. *Exp. Syst. Appl.* 37(8): 5835–5847, 2010. doi:10.1016/j.eswa.2010.02.022.
32. Ortíz, M. A., Cómbita, J. P., De la Hoz, A., Felice, F. D., and Petrillo, A., An integrated approach of AHP-DEMATEL methods applied for the selection of allied hospitals in outpatient service. *Int. J. Med. Eng. Info.* 8(2):87–107, 2016. doi:10.1504/IJMEI.2016.075760.