

# A Quality Control Application in Healthcare Management

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## Abstract

Healthcare productivity can be improved through scientific management tools for quality analysis. This problem has been recognized and a lot of research has been dedicated to overcome related problems in hospital management. However, most of the research lacks scientific procedures. This paper presents a surgery-related management problem that has not been considered before. A model is developed to determine significant factors affecting surgery delays in hospitals and surgery clinics. An experiment was designed and a regression model was developed to find a relation between surgery delays and selected factors. Results show that factors such as medical staff and missing information significantly delay surgery compared to other factors such as admission time (from hospital admission to surgery). Results can be used to control important factors to reduce delays, risks to patients, and hospital costs.

**Keywords:** Healthcare management; Quality control; Quality assurance; Design of experiments

## Introduction

Quality Assurance and Quality Control are very critical issues in Hospital Management. Over the past several years, this problem has been recognized and a lot of research has been dedicated to overcome quality related problems in hospital management. The goal is generally to increase efficiency as well as productivity in all areas of health care industry, including emergency and regular clinical operations.

Shaw [1] and Ovretveit [2] have applied Quality Assurance and Total Quality Management to improve healthcare systems under consideration. Several researchers, such as Birnbaum [3], Benneyan and Kaminsky [4], Buchanan and Wilson [5], and FranCois et al. [6], have presented and demonstrated effective methods to improve quality and safety in healthcare. Several practitioners and managers, such as Ovretveit and Gustafsson [7] and Catsambas [8] believe that quality related actions should be taken; but are unsure how to proceed, especially within resource constraints. Quality and safety improvement can be achieved through different approaches and strategies. Each hospital needs to be analysed with respect to its own

operational policies and procedures in order to determine the most appropriate and cost effective strategies. Grimshaw [9] showed that continuous quality improvement approaches could be effective. One of the main problems is that most of the researches carried out in this area are not well-designed and they do not include scientific procedures with statistically proven results. Some research, such as Dodwad [10] is based on sound experience, but little is based on scientific procedures. Some other management tools, as shown by Robinson [11], have been proposed and used to improve general healthcare operations and quality in general. Ovretveit and Staines [12] have presented a study, in which they show how quality improvement is achieved through an independent case study of the Jönköping Quality Program.

Recently several researchers, such as Fischman [13] and Poksinska [14], have considered lean implementation and six sigma in health care. DelliFraine et al. [15] have done a literature review related to the applications of six sigma and lean implementation in health care. They analysed 177 articles on the subject over the past 10 years. They indicate that only 34 articles reported any outcomes with such applications and only one-third of these included statistical tests for the significance of the results. They conclude that there are significant gaps in the six sigma and lean health care quality improvement literature and very weak evidence that six sigma and lean improve health care quality. However, many of the papers are case oriented and problem specific. Therefore, more research is needed for assessing quality improvement strategy effectiveness that can be used to answer quality-related questions. The general indication is that each healthcare system needs to be studied in detail and problem areas identified so that appropriate quality improvement procedures can be implemented.

One of the major shortcomings in research carried out in this direction is that scientific methods and statistical procedures are not used appropriately. Any investigation carried out related to quality and productivity improvement should be quantified, and appropriate scientific tools should be utilized in order to justify the results as well as to see the significance of the analysis carried out. In a recent research paper "A Quality Control Application in Healthcare Management Using DOE" by Savsar and Al-Ajmi [16], the authors have considered the surgery operations in an international hospital clinic and tried to investigate system performance with respect to surgery delays,

which were affected by various factors. The objective was to determine the significant factors that affect the surgery delays and to suggest a control procedure by which surgery delays could minimize. In this paper, a summary and a commentary of this paper is presented.

## Systems Analysis and Problem Description

Operational activities in any industrial or service organization need to be scrutinized and necessary analysis need to be carried out in order to see major factors that affect the performance of activities. This is an essential step in improving efficiency and productivity. Quality assurance and management is actually a three-stage process. First, it is necessary to analyse the system or the operation under consideration and to identify critical factors that affect the final output or system performance. Second, the critical factors should be further studied and investigated at different levels to determine the exact effect on system performance at different levels. Finally, a control procedure should be implemented in order to keep these factors under control and within optimum limits based on the investigation results.

In order to understand the problem under consideration, it may be useful to describe the surgery department studied, which is divided into four specialties: plastic surgery; orthopaedics; ophthalmology; and dental. There are three wards comprising 80 beds. The general surgery unit offers laparoscopy, morbid obesity, anorectic, breast, thyroid gland surgeries and biopsies and gastro-intestinal endoscopies. Operating theatre (OT) surgical procedure is studied in detail with respect to all activities taking place before the operation. Delays due to incomplete information, tests and preparations were critical. Surgery department lost time due to these delays, which resulted in higher hospital costs. The administration and responsible staff were not aware of this fact. In particular, pre-anesthesia, patient consent, and lab/radiology related information were causing excessive delays. After a detailed analysis using the cause and effect diagram and preliminary data collection, it was realized that three important steps must be completed and related information presented to the surgeon to initiate surgery: A signed consent form; a completed pre-anesthesia procedure before moving the patient to the OT; and completed laboratory and radiology requirements before surgery. Doctors give a letter to the patient or the guardian about surgical side effects and disadvantages, and the letter has to be signed by the patient or his/her guardian.

The hospital anesthetic department staff administers pre-anesthesia and anesthesia by topical application, injection, and inhalation or by combination of them. Sedation is used to facilitate the gastroenterologists and other physicians to undertake diagnostic endoscopies without subjecting the patient to general anesthesia. Sometimes the patient is moved into the surgery department without the required procedure or with incomplete anesthesia. In some cases, laboratory diagnostic testing results may be incomplete. Radiology and medical imaging results, ultrasound, CT scanning, MRI, mammography and dental x-rays, etc. is necessary for surgery. Incomplete results, forgotten procedures and missing

information, which occur at one or more steps, cause delays in surgery. Hospital statistics indicated that missing pre-anesthesia information is the major problem (45%) owing to queuing and late arrivals for test appointments. The next highest percentage (29%) is missing lab/radiology results, followed by missing patient consent forms (26%), all of which must be scrutinized in order to reduce surgery delays. A systematic procedure is needed to determine the most significant delay factors and to quantify their significance.

After realizing the fact that surgical delays in the hospital were causing problems and affecting system productivity, quality, and effectiveness, it was decided to determine the factors that affect such delays. Based on observation and further analysis of the surgery system, it was found that types of doctors, elapsed time after admitting the patients, and missing or incomplete information on tests and preparations were major factors. These factors were then further analysed and an experimental design was set up to research and see how and at what degree they had effects on surgical delays.

## Research Methodology and Experimental Design

After identifying the factors affecting surgical delays, the next step was to set up a factorial design of experiment to analyse the statistical significance of the effects of these factors on system performance. System performance was the surgical delays in this case. A general factorial design was used to run the experiment. Data was collected on delays for combination of all three factors at different levels. In this experiment, "doctor's type" factor had 2 levels; "elapsed time since patient admission" factor had 4 levels; and "missing information" factor had 7 levels as follows:

1. Doctor (I: In-house Doctor or V: Visiting Doctor).
2. Time elapsed since hospital admission (<5; 5-10; 10-15; and 15-20 hours).
3. Missing information (patient consent (A); pre-anaesthesia (B); lab/radiology results (C); and any combinations of these factors (AB, AC, BC, and ABC).

Based on the numbers of levels of each factor,  $2 \times 4 \times 7 = 56$  combinations of factors were identified and the response data was collected at each combination. In order to reduce the effects of experimental errors on the results, two replications were done for each combination, which resulted in 112 experiments. The response was surgical delays in minutes. A fixed effect model was considered with three factors and their interactions resulting the equation:

$$\text{Fixed Effects Model: } Y_{ijkl} = \mu + \alpha_i + \beta_j + \lambda_k + (\alpha\beta)_{ij} + (\alpha\lambda)_{ik} + (\beta\lambda)_{jk} + (\alpha\beta\lambda)_{ijk} + \epsilon_{ijkl}$$

Here  $\mu$  is mean expected response value if there were no effects of the factors.  $\alpha_i$  are the effects of "doctor factor" at level  $i$ ;  $\beta_j$  are the effects of "elapsed admission duration factor" at level  $j$ ; and  $\lambda_k$  are the effects of "missing information factor" at level  $k$ . The remaining terms are the interaction effects, while the  $\epsilon_{ijkl}$  term represents the residual error value, which cannot

be explained by any effects. It is assumed that experimental errors are normally and independently distributed with mean 0 and variance  $\sigma^2$ . A normal probability plot showing no obvious pattern in the residuals histogram validated this assumption and a time sequence plot confirmed that residual patterns had no structure and were independent. Using the collected data, an Analysis of Variance (AOV) was performed to determine the factors that had the most significant effects on response, which was the surgery delay time. Thus, main objective of the study was to estimate and analyse surgery delays to figure out which factors affect them and to come up with a clear recommendation regarding to the most favourable factor level settings that minimizes surgical delays.

## Results and Discussions

Experimental methods play an important role in process development and quality improvement. An experiment is a test

in which some purposeful changes are made to a process or variables so that we may observe and identify the reasons for changes in outputs. In the hospital system's case, various factors affecting surgery delays are considered for investigation. The dependent variable in the model was the surgery delay and the independent variables were doctors, time elapsed since the patient was admitted to the hospital, and missing information. A form was prepared and the experiment was conducted to collect the response variable (surgery delays). The delay data was then categorized as a function of the selected factors and their combinations. Delay time for each patient was computed based on the difference between the time patient was transferred to OT and time a call was received to transfer the patient. Response variable (delay time in minutes) for each factor combination was then recorded as shown in Table 1. Two samples were taken for each combination.

**Table 1:** Surgery delays (minutes) at different combinations of various factors considered.

	Elapsed Admission Time (hours)							
	<5		05-Oct		Oct-15		>15	
	Doctor*		Doctor		Doctor		Doctor	
Missing Information	In	Visit	In	Visit	In	Visit	In	Visit
A	13.02	14.95	13.95	14.82	7.96	12.2	9.81	13.97
	10.15	13.09	11.13	12.5	9.6	10.46	7.7	9.8
B	19.5	22.33	12.61	18.4	10.7	16.71	10.75	15.58
	16.71	18.36	15.84	16.99	11.6	19.65	13.3	20.6
C	103.67	133.67	98.9	102.7	146.65	178.44	118.81	119.55
	138.33	144.89	99.13	113.24	75	128.2	65	98.5
AB	18.45	26	32.81	30.6	31.08	38	22.24	26.29
	23.76	33.42	26.7	26.9	17.7	31.7	19.2	30.6
AC	110.51	156.04	105	116.87	90.96	106.06	91.24	178.63
	106.6	124.37	103.4	123.6	102.3	120.8	102.5	109.8
BC	100.89	184.48	96.65	126.55	87.32	89.57	162.48	175.44
	165.33	199.63	94.5	97.2	107.34	95.8	195.4	198.47
ABC	92.29	188.34	127.46	147.43	103.7	106.06	170.35	194.43
	136.32	189.5	190.3	173.5	160.4	212.34	90	134.76

Analysis of variance (ANOVA) was carried out on all factors at fixed levels, resulting in 56 combinations. Table 2 shows the analysis of variance results as obtained by the Minitab program. Sums of squares (SS), mean squares (MS), F value and p values are shown for each factor. From p-values in the ANOVA table, it was concluded that doctor type and missing information significantly affected delays ( $p\text{-value} < \alpha = 0.05$ ). There was no evidence that elapsed admission time affected delays since the 0.075 p-value for elapsed admission time was larger than the

0.05 critical test value. There was a significant interaction between elapsed admission time and missing information since the  $p\text{-value}=0.004 < \alpha=0.05$ . This means that missing information affected delay when it interacted with admission time.

If the average surgical delay data are plotted with respect to types of doctors, it could be easily seen that surgery delays are significantly higher for visiting doctors than in-house doctors.

This was probably because in-house doctors had more control over the situation; they follow and enforce hospital procedures.

**Table 2:** ANOVA table for surgery delay time.

Source of Variation	DF	SS	MS	F	P-value
Doctor (I)	1	7855.4	7855.4	15.27	0
Admission time (II)	3	3750.4	1250.1	2.43	0.075
Missing information (III)	6	356781	59463.5	115.58	0
Doctor * Admission Time	3	1659.5	553.2	1.08	0.367
Doctor * Missing Info.	6	3723.9	620.7	1.21	0.317
Admission time * missing info.	18	23731.2	1318.4	2.56	0.004
Doctor * admission time* missing information	18	4747	263.7	0.51	0.941
Experimental error	56	28810.5	514.5		
Total	111	431058.8			

Similar relations between surgical delays and elapsed admission time show that when elapsed admission time increases, delay decreases because the patient will have more time to provide the required information. However, when elapsed admission time exceeds 15 hours, delay also increases, which does not support the conclusion that increasing elapsed admission time reduces surgery delays after a certain level. Therefore, ANOVA results do not show elapsed admission time significantly affecting delays. Missing information's effect on delays is found significant in the ANOVA table. Among the missing information, factor C (lab/radiology) and its interactions with other missing information, such as patient consent-A and pre-anaesthesia-B were significant. Furthermore, the results of analysis showed that there was no significant interaction between doctors and elapsed admission time and between doctors and missing information factors. Finally, some interaction between elapsed admission time and missing information was observed, which made sense since this the period patients have been in the hospital before surgery. As this time increases, missing information will be less because patients have more time in hospital to take tests and complete pre-surgery procedures. The model correlation coefficient,  $R^2$  is 0.93, which shows the variability portion explained by the model. The  $R^2$  high value shows that experimental error is small and not significant.

Experimental factors can be either quantitative, such as temperature, or qualitative, such as operators. Typically qualitative factors could not be ranked numerically. In the hospital case, all factors and their levels are qualitative, such as in-house doctors, visiting doctors, missing information, etc. ANOVA was repeated with selected significant regression factors. Model F-value was found to be 29.85. It indicated that variation in the dependent variable or the delay time was significantly affected by the variation in the significant independent variables or the factors considered and not just by randomness. A regression equation, which related the response variable (Surgery Delay Time) to coded independent variables, was obtained by coding the independent variables as follows:

$\alpha_i$  = Doctor type i (=0 or 1)

$\beta_j$  = Elapsed Admission Time j (=0 or 1)

$\lambda_k$  = Missing information k (=0 or 1)

$$\begin{aligned} & \text{Surgery Delay Time} = \\ & 82.04 + 8.38 \\ & \alpha_1 + 7.41\beta_1 - 5.26\beta_2 - 6.02\beta_3 - 70.47\lambda_1 - 65.80\lambda_2 + 34.51\lambda_3 - 54.82\lambda_4 + 33. \\ & 51\lambda_5 + 54.03\lambda_6 - 6.18\beta_1\lambda_1 + 6.79\beta_2\lambda_1 + 4.51\beta_3\lambda_1 - 4.43\beta_1\lambda_2 + 4.98\beta_2\lambda_2 + 4. \\ & 45\beta_3\lambda_2 + 6.18\beta_1\lambda_3 - 7.79\beta_2\lambda_3 + 21.55\beta_3\lambda_3 - 9.22\beta_1\lambda_4 + 7.30\beta_2\lambda_4 + 8.43\beta_3 \\ & \lambda_4 + 1.42\beta_1\lambda_5 + 1.93\beta_2\lambda_5 - 4.49\beta_3\lambda_5 - 19.10\beta_1\lambda_6 - 27.08\beta_2\lambda_6 - 35.03\beta_3\lambda_6 \end{aligned}$$

The regression equation is a prediction equation for the delay time in coded factors. Based on our results, it is possible to optimize the model and find the optimum solution corresponding to the factor combinations that minimize surgery delays. The optimal solution, which corresponds to minimum mean delay time, occurs for in-house doctors, admission time, or hospital stay of less than 15 hours prior to surgery and only the consent information missing. The maximum mean delay time (191.32 hours) is associated with visiting doctors, admission time more than 15 hours and missing information related to pre-anesthesia and lab/radiology. It appears that the longer the patient is in the hospital the delay is worse, which suggests that inpatient or related personnel ignore or forget surgery requirements. Also, visiting doctors, who are not continuously in the hospital and involved with surgery preparation, encounter delays.

## Conclusions

Hospital productivity can be improved by healthcare quality management. Strategies that are most appropriate and cost effective for a particular hospital need to be investigated. In this paper, an experimental design and a regression model are developed to determine significant factors that affect surgery delays in an international hospital. Delays, which affect hospital productivity and costs, are unavoidable. The statistical models indicate that doctor type affects delays. In particular, visiting

medical staff encounters more delays than in-house doctors. The results also show that missing information depend on elapsed admission time. As elapsed admission time increases, missing information decreases, which significantly affects delay. Missing lab/radiology information causes most delay, mainly because related tests and X-rays take time to complete. Missing pre-anesthesia information was the greatest percentage (45%), which is high compared to the consent and lab/radiology information problems. Some measures that could improve healthcare systems and minimize surgery delays include establishing:

1. A computerized system to record consent, pre-anaesthesia and lab/radiology procedures to make sure patients with missing information are not scheduled for surgery.
2. A policy to enforce procedures for completing preliminary requirements for surgery and to ensure patients are in hospital sufficiently long enough to complete all pre-surgery tests.
3. A surgery schedule for each doctor along with a linked, advanced checking mechanism to be made on missing information before surgery.
4. A special checking mechanism for operations assigned to visiting doctors.

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