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Improving Patients Discharge Process in Hospitals by using Six Sigma Approach

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***Abstract*—**The need to increase the efficiency of health care systems is becoming an obligation, and one of area of improvement is the discharge process. The objective of this work is to minimize the patients discharge time (for insured patients) to be less than 50 minutes by using six sigma approach, this improvement will also: lead to an increase in customer satisfaction, increase the number of admissions and turnover on the rooms, increase hospital profitability.Three different departments were considered in this study: Female, Male, and Paediatrics. Six Sigma approach coupled with simulation has been applied to reduce the patients discharge time for pediatrics, female, and male departments at hospital. Upon applying these recommendations at hospital: 60%, 80%, and 22% of insured female, male, and pediatrics patients respectively will have discharge time less than the upper specification time i.e. 50 min.

***Keywords*—**Discharge Time, Healthcare, Hospitals, Patients, Process Improvement, Six Sigma, Simulation

I. Introduction

IN year 2012 humanity is witnessing a degree of development that had never been reached before, this development levered up the human quality of life and its importance. In the core of quality of life is *healthcare*, by which it is most of the time measured by life expectancy. For that assuring to keep this measure high and increasing, a continuous effort is needed endlessly to increase the quality of healthcare and make it affordable for more people.

Taking a look on the statistical data of the Organization for Economic Co-operation and Development in relation to expenditure on healthcare since 1960 till 2009, we can see that with no exception all developed country had increased its expenditure by value and percentage of Gross Domestic Product (GDP) year after year. At 2009 17.4% of the US GDP was expended on healthcare ($7960) per capita, which means 2.8 trillion US dollars just in the US, one hundred times the expenditure in 1960. This indicates the importance and size of the healthcare industry today. Basic industrial engineering skills such as process redesign, quality control, layout optimization, and forecasting had helped in organizing the healthcare resources to reach better outcomes. The industrial engineering had proven their importance in increasing the healthcare quality and reducing its costs. For this reason a large number of industrial engineers work today in this branch, and the Institute of Industrial Engineers had a big society related to it called the Society of Health Systems.

More sophisticated industrial engineering tools and techniques developed in factories had been applied in the healthcare sector in the last decades.

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Simulation, operations research, total quality management and other proved to be very useful and essential in improving the quality of healthcare as it did in manufacturing. Simulation for example was useful to understand queuing models, impact of policy changes, and access and availability population models. Operations research studied for example optimal pricing and costing models, scheduling and workforce planning, and optimal dosing models.Six Sigma is a technique developed after Deming in Japan factories; Motorola in the beginning. Six Sigma studies the process variability aiming to improve quality by finding the root cause solutions that increases yield which normally is ($\pm 3\sigma$) to perfection ($\pm 6\sigma$). Usually Six Sigma looks for improving procedures, such examples in healthcare are surgery procedures, clinical tests, and room cleaning. It is worthily to mention that one of the best hospitals in applying Six Sigma is Valley Baptist Medical Center in Harlingen in Texas. Visiting their website you can see the number of awards they gained in the last years, and how the Six Sigma approach made them rank first in whole Nation for Heart Failure by Centers for Medicaid & Medicare Services (CMS) for the years 2007 and 2008 consecutively.

II. Literature review

Healthcare providers like any other service industry face many challenges, like reducing costs and keeping abreast of technological changes while meeting regulatory guidelines, exacerbated by the problem of a scarce qualified labor force.

Pexton [1] agrees that today's healthcare environment is complex. She states that medical care error and variability reduce confidence in the medical community providing safe and effective patient care.

Since Six Sigma programs strive to reduce variability and defects within processes, implementing a breakthrough strategy is a logical solution for improving patient care. Note that defects in patient care processes can run the spectrum from minor dietary issues to patient morbidity and fatality.

Harry and Schroeder [2] define a breakthrough strategy as a 'disciplined method of using extremely rigorous data-gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them'.

Measurement of errors is necessary for design of a quality improvement strategy. Pexton [1] cites the Institute of Medicine's definition of errors as: 'the failure of a planned action to be completed as intended (i.e. error of execution) or the use of a wrong plan to achieve an aim'. Medication errors are examples of a common problem in many hospitals (i.e. error of planning).

She also emphasizes the importance of defining 'quality' in the health care industry. Again, she cites the Institute of Medicine's definition of quality: 'Quality is the extent to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge'.

Long [3] describes healthcare industry measures of operating in a higher sigma level environment (i.e. lower defect rate) as: patient satisfaction, physician satisfaction, reduced overtime, reduced patient wait times, increased revenues, and enhanced quality of life. Stahl *et al*. [4] posit that the measurable response variables (metrics) in health care can be classified into four categories: service level (e.g. access to care, wait time, service time); service cost (e.g. cost per unit of service, labor productivity); customer satisfaction (e.g. patient or family, referring physician, employee); and clinical excellence (e.g. guidelines for medication or treatment, standard procedures for patient monitoring).

Tucci [5] states that some potential barriers to implementation of Six Sigma programs in hospitals include:

1. Nursing shortage: 'moving' Registered Nurses (RNs) to full-time quality program positions, e.g. training to be Black Belts.
2. Governmental regulations.
3. Costs: start-up and maintenance—initial costs of executive education, employee orientation, and investment in intensive training of Black Belts and Green Belts (prior to actual realization of benefits) can begin at 1/2 million dollars in the first year.
4. Long-standing functional walls and professional group 'silos' of physicians not actually 'employed' by the hospital—research has indicated that to earn their support for the implementation of Six Sigma quality initiatives, the physicians need to be introduced to data which support benefits in the areas of work environment procedures, patient satisfaction, correlation between higher quality and lower cost.
5. Difficulty in obtaining base-line data on process performance.
6. Long project ramp-up times—typically 6 or more months.
7. Risk of Six Sigma programs in health care being marginally implemented to only easily measured non patient care processes, i.e. 'low touch' processes.

He also states that some potential benefits of implementation of Six Sigma in hospitals include:

1. Measurement of health care performance requirements on the basis of common standards—through use of statistical analysis and hypothesis testing, Six Sigma mirrors the medical fields' life-threatening situation and high risk decision-making processes;
2. Creation of shared accountability for continuous quality improvement—requires development of common definitions of how an error is defined;
3. Health care employee surveys indicate that the employees consider their work to be important and they want to improve the quality of patient care, but interestingly these same employees feel under-appreciated and left out of quality improvement programs;
4. Implementing Six Sigma with emphasis on improving customers' lives could engage more health care professionals and support personnel in the quality improvement process.

Ashby et al [6] report the challenges of taking an existing facility's inpatient volumes and procedures and projecting them into a replacement facility with differently sized units, overall scale, and layout. Discrete event simulation is used to examine the impacts of this transition as well as the operational impacts of capacity changes, process redesign, and process improvements. This effort to optimize patient flow throughout the inpatient units is done while modeling and observing the impacts on other interdependent parts of the hospital such as the Emergency Department, and Operating Rooms.

The rest of the paper is organized as follows: Model; which describes how to implement six sigma methodologies into certain steps in service industry, results and discussions; in this section demonstration is given of how to implement our model by using real life case study, and finally summary of the outcomes is embedded in conclusions.

III. Model

A frame work for implementing improvements in service industry is essential and critical for reserving and continuing them. In this paper, Six Sigma and simulation model are used as the basic tools in the proposed framework. The proposed framework, which is valid for any service or manufacturing processes, Fig. 1, is summarized in following steps:

1. Construction of the flow chart for the process: this step will help in understanding how the entity (material, customer, patient) flows through the process, and what's the role of each activity is.

2. Identification of metric(s): clear, measurable, and distinct output(s) (i.e. time, cost, yield…) should be identified.

3. Collection of observation: this stage is used to collect real life data for the output specified in the previous stage.

4. Performing statistical analysis: in this stage statistical analysis such as outlier's detection, distributions fitting, statistical quality control charts, and calculation of sigma quality level is performed. These calculations will establish the reference base for the current performance of the process.

5. Building simulation model: Simulation model is used to mimic the behavior of the process and will allow performing the analysis and verification step before actual application on the real process.

6. Perform design of experiments: the significant factors with their appropriate levels are determined by using design of experiment method. The design of experiment runs are performed on the simulation model not on the actual process, which will save both time and money.

7. Verification of results on the simulation model: the optimum solution results from the design of experiment step is verified on simulation model, the sigma quality level for the metric is calculated and compared with the base value. If a decrease happens in the sigma quality level, it means deterioration on the process performance occurs, and a searching for new factors is required.

On the other hand, if there is an increase in this value, it means that there is an enhancement of the process occurs upon application of the new settings of the factors. The increment of the sigma quality level i.e. enhancement of the process is determined by the amount of time and money available by the improvement team of course, higher sigma quality level requires more time and money.

8. Implementing solutions on real process: if the amount of increment on the sigma quality level is acceptable, the factors levels are tuned to the proposed level captured from the simulation model.

9. Collection of observations: Second set of observations are collected for the output specified in the early stage.

10. Performing statistical analysis: Statistical analysis such as outliers' detection, distributions fitting, statistical quality control charts, and calculation of sigma quality level is performed on the new set of observations.

11. Termination of the improvement process: if the new sigma quality level obtained from applying the setting is acceptable, the improvement process is terminated.

12. Monitoring the sigma quality level: observations should be collected from the process, and the sigma quality should be monitored to avoid its degradation.

IV. Results

The case study was conducted in the Specialty Hospital which has become one of the prestigious medical centers in Jordan and the region. To sustain this good reputation, the management tries every effort to provide a high quality health care, and to guarantee customer satisfaction. But one of the major issues that affect the hospital's performance level and profitability was the time consumed for a discharge to take place and to be done. The interest to solve this problem was extremely high, because strictly speaking, this process reduces the turnover rate on the rooms and consequently, reduces profitability.

A. Case Study

The case study was performed in one of the most important service sectors, which is the health care. The reason for choosing it due to: It's one of the largest industries in 2008; health care provides 13.4 million jobs for wage and salary workers, ten of the twenty fastest growing occupations are health care related, health care will generate 3.2 million new wage and salary jobs between 2008 and 2018, more than any other industry, largely in response to rapid growth in the elderly population, most workers have jobs that require less than 4 years of college education, but health diagnosing and treating practitioners are highly educated.

The purpose of this paper is to minimize the percentage of insured patients who's discharge time from hospital above 50 minutes. This improvement project is supposed to: lead to an increase in customer satisfaction, increase in the number of admissions and turnover on the rooms, and increase hospital profitability.

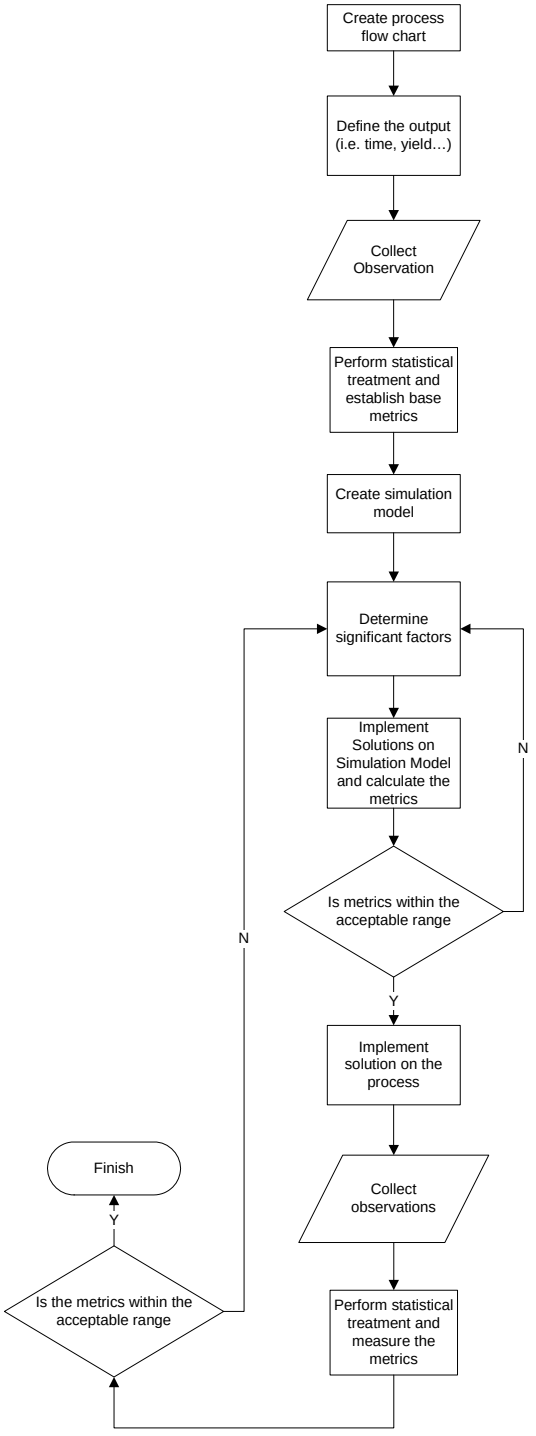

Fig. 1 Flow Chart for Improvement Process

The hospital has 250 beds and it has on occupancy rate of 100%. Unfortunately, the patient's discharge process takes a long while to be done, which decreases the turnover on the rooms, hence reducing profitability. Consequently, an improvement is needed to lower the discharge time. The suggested methodology is to implement a Six Sigma approach.

The improvement methodology was adopted to reduce the percentage of insured patients who's their discharge time from hospital above 50 minutes.

The improvement methodology consists of the following steps:

1) Step One

Construction of the flow chart for the process: this step will help in understanding how the entity (material, customer, patient) flows through the process, and what's the role of each activity is. The insured patient's discharge process goes through the following events, Fig. 2:

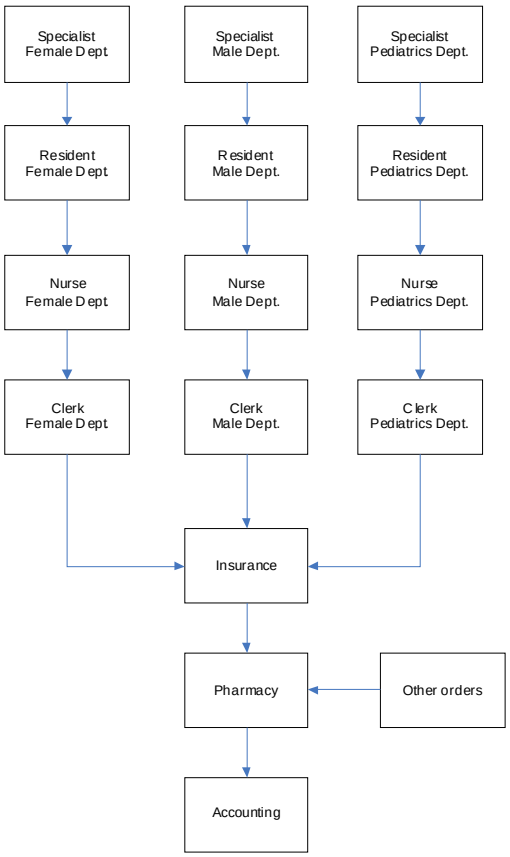

Fig. 2 Flow chart of patients discharge process

Specialist's signature for discharge order, resident's report as well as writing the medication prescription, nursing report, clerk entering the discharged patient's data into the hospital system, prescription delivered to pharmacy in order to get the required medicines, pharmacy entering all dispensed medicine data as well as finalizing the patient's receipt, porter taking the file to the accounting department, patients and/or their families going to the accounting department to do the actual payment.

Concerning the last step in the discharge process, it relies entirely on the patient and his family. Based on this fact, we decided to eliminate it from the flow chart because we can't control the time by which the patient along with his family actually go to the accounting department.

In this paper, we will use the pediatrics department data to illustrate our methodology.

2) Step Two

Identification of metric: discharge time for the insured patients, starts when the specialist signs for discharge order and end when file reaches with the porter to the accounting department.

3) Step Three

Collection of observation: this stage is used to collect real life data for discharge time for the insured patients, those data points were collected for a period of 5 weeks. Sample data from the discharge time process at the hospital is shown in Table II.

4) Step Four

Performing statistical analysis: in this stage statistical analysis such as outliers' detection, distributions fitting, statistical quality control charts, and calculation of sigma quality level is performed. These calculations will establish the reference base for the current performance of the process.

a) Outlier detection

As a first step, we have to calculate the cycle time of the discharge process (i.e. the summation of all the time periods taken for each step of each discharge). The cycle time in this case is defined as both, the service time and the waiting time. Since we needed to test for each department on its own in order to be able to clarify what are the main factors affecting each department in its discharge process, we have taken the cycle time for each department separately. Table III shows the cycle time present at each department.

Box plot method –using Minitab software - was used to remove the outliers from pediatrics discharge time observations, Fig. 3. Brushing outliers is performed from the original box plot, and a second box plot is created, repeating this step until no outliers are present**,** Fig. 4. Twenty seven observations (27 data) remained to be used in our analysis.

TABLE II
SAMPLE DATA COLLECTED AT HOSPITAL, SHOWING THE TIME CONSUMED IN EACH ACTIVITY FOR DIFFERENT DEPARTMENTS

Patient's ID	Department	Specialist's Signature	Resident's Report	Nursing Report	Clerk	Insurance	Pharmacy Closing Receipt	Porter Going to Accounting
1	Pediatrics	10:15	10:15 - 10:22	10:22 - 10:42	10:44 - 10:46	10:30 - 10:37	10:46 – 11:05	11:05 – 11:09
4	Pediatrics	10:13	10:13 - 10:17	10:17 - 10:21	10:21 - 10:24	10:23 - 10:33	10:33-10:55	10:35 – 10:37
5	Pediatrics	11:20	11:20 - 11:25	11:25 - 11:28	11:28 - 11:31	11:21 - 11:24	11:24 – 11:38	11:38 – 11:44
8	Female	10:35	10:45 - 10:49	10:35 - 10:40	10:56 - 11:00	10:47 - 11:07	11:07 – 11:18	11:24 – 11:27
9	Female	9:50	09:50 - 09:53	09:53 - 09:57	09:57 - 09:59	09:57 - 09:59	09:59 – 10:28	10:28 – 10:37
11	Female	11:55	11:55 - 11:59	11:59 - 12:02	12:05 - 12:22	11:58 - 12:03	12:03 – 12:45	12:45 – 12:49
14	Male	9:30	10:30 - 10:33	10:33 - 10:34	10:34 - 10:38	10:34 - 10:38	10:38 – 10:44	10:45 – 10:47
15	Male	10:30	10:46 - 10:59	10:32 - 10:36	11:02 - 11:08	11:02 - 11:13	11:13 – 11:21	11:23 – 11:25
16	Male	9:55	10:20 - 10:24	10:09 - 10:12	10:34 - 10:38	10:30 - 10:33	10:38 – 11:14	11:14 – 11:15

b) Distributions fitting

The objective of this step is to find the closest distribution for the observations. Goodness of fit test is used to determine the appropriate distribution by using Anderson-Darling Statistic (A^2). The Anderson-Darling statistic is a measure of how far the plot points fall from the fitted line in a probability plot. The statistic is a weighted squared distance from the plot points to the fitted line with larger weights in the tails of the distribution. A smaller Anderson-Darling statistic indicates that the distribution fits the data better.

$$A^2 = -n - \left(\frac{1}{n}\right)\sum_{i=1}^{n}\begin{bmatrix}(2i-1)\log Z_i \\ +(2n+1-2i)\log(1-Z_i)\end{bmatrix} \quad (1)$$

Where Z = F(X), where F(X) is the cumulative distribution function. Suppose that a sample X_1, .., X_n gives values Z_i = $F(X_i)$, i=1,.., n. Rearrange Z_i in ascending order, $Z_1 < Z_2 <...<Z_n$.

Table IV shows the Anderson-Darling Statistic (A^2) values for different distributions (i.e. Normal, Exponential, Weibull, and Gamma). The smallest value obtained for A^2 is for the normal distribution.

TABLE III
CYCLE TIME FOR PEDIATRICS, FEMALE, AND MALE DEPARTMENT

Pediatrics Department			Female Department	Male Department
54	98	74	52	77
23	76	52	47	55
17	59	98	54	80
24	66	69	54	49
24	65	68	44	82
38	65	117	32	70
38	65		54	52
75	50		59	146
74	122		79	170
66	122		77	73
66	71			179

To emphasize the obtained results, probability plot is also used to identify the appropriate distribution. The probability plots for the Normal, Exponential, Weibull, and Gamma distributions are shown in Fig. 5. It can be seen from the probability plots, that the normality distribution is the best one among the four, since all data are falls within the 95% confidence interval.

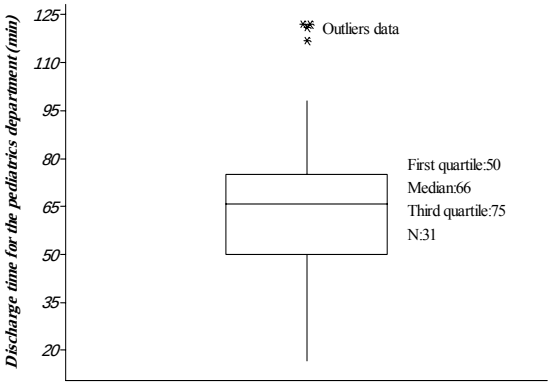

Fig. 3 Box plot of the discharge time for the pediatrics department, with outliers

c) Quality Control Charts

After removing the outliers, finding the appropriate distribution that fits the data, the following step is to determine if the process is in control or not.

TABLE IV
ANDERSON–DARLING STATISTICS A^2 FOR PAEDIATRICS DEPARTMENT

Distribution	A^2
Normal	0.778
Exponential	5.146
Weibull	0.880
Gamma	1.307

This check is performed by using the quality control chart method. The appropriate chart to use for the patient discharge time (the metric in our case) is Individuals-Moving Range (I-MR) chart. The (I-MR) chart for the discharge time is shown in Fig. 6.

The Individuals chart is drawn in the upper half; the Moving Range chart in the lower half. Seeing both charts together allow tracking both the process level and processing variation at the same time, as well as detecting the presence of special causes.

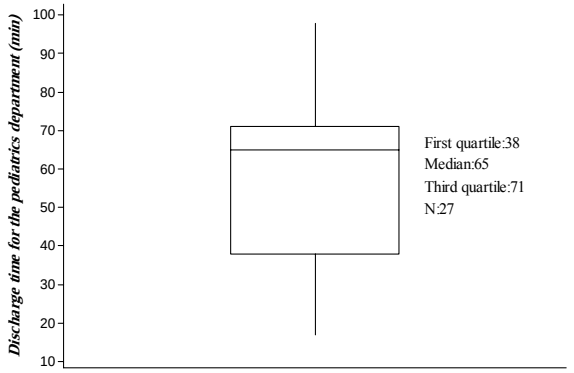

Fig. 4 Box plot of the discharge time for the pediatrics department, no outliers

In order to construct I-MR charts, average moving range ($\overline{MR}$) is calculated as follows:

$$\overline{MR} = \frac{R_w + ... + R_n}{(n - w + 1)} \quad (2)$$

Where

w = the number of observations used in the moving range. The default is $w = 2$.

R_i = the i^{th} moving range = max [x_i, ..., x_{i-w+1}] - min [x_i, ..., x_{i-w+1}], for i = w, ..., n

By default, I-MR chart estimates the process variations (σ), with the following equation:

$$\sigma = \frac{\overline{MR}}{d_2} \quad (3)$$

Where

$\overline{MR}$: The average of the moving range

d_2: is unbiased constant that varies according to the sample size, the moving range is of width 2 (i.e. w=2), since consecutive values have the greatest chance of being alike (d_2=1.128)

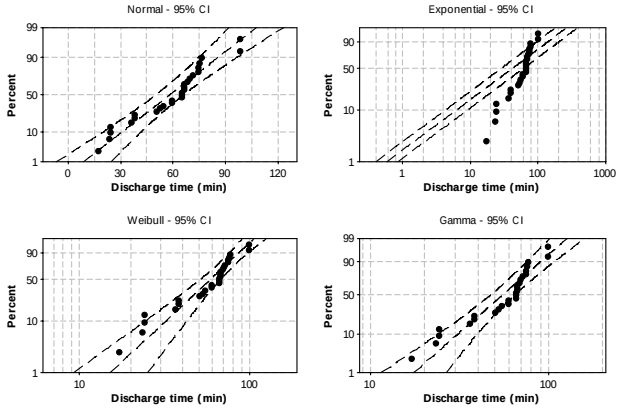

Fig. 5 Probability plot for the discharge time (min) for the pediatrics department

For the individual chart, the upper control limit (UCL), center line ($\overline{X}$), and lower control limit (LCL) are calculated from:

$$\overline{X} = \sum_{i=1}^{n} \frac{x_i}{n} \quad (4)$$

$$UCL = \overline{X} + k\sigma \quad (5)$$

$$LCL = \overline{X} - k\sigma \quad (6)$$

Where

x_i: i^{th} observation (i.e. discharge time), for i = *1*, ..., *n*

n: sample size, in our case n=27

k: constant, in our case k=3

For the moving range chart, the upper control limit (UCL), center line ($\overline{MR}$), and lower control limit (LCL) is calculated from:

$\overline{MR}$ is calculated from (2).

$$UCL = d_2\sigma + d_3 k\sigma \quad (7)$$

$$LCL = d_2\sigma - d_3 k\sigma \quad (8)$$

Where:

d_2 is unbiased constant that varies according to the sample size, the moving range is of width 2 (i.e. w=2), since consecutive values have the greatest chance of being alike (d_2=1.128, look up table value)

d_3 is a constant used to calculate control limits for ranges (look up table value)

k: constant, in our case k=3

If the lower control limit falls below zero, then it will reset to zero. (i.e. if LCL < 0 then LCL = 0)

Examining the quality control charts, reveals that there are three observations (points 4, 13, and 25) out of control for the individual chart and one observation (point 25) for the moving range chart; one point more than three standard deviations from center line. These three points investigated again, and unusual reasons (i.e. doesn't belong to the process itself) were found to be responsible for these points (i.e. physician made a phone call, or something like that).

d) Sigma Quality Level (or sigma level)

Six Sigma is an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates. Six Sigma focuses on establishing world-class business-performance benchmarks and on providing an organizational structure and road-map by which these can be realized. It indicates a level of performance equating to 3.4 nonconformities per million opportunities, a level which some regard as being 'world-class performance'.

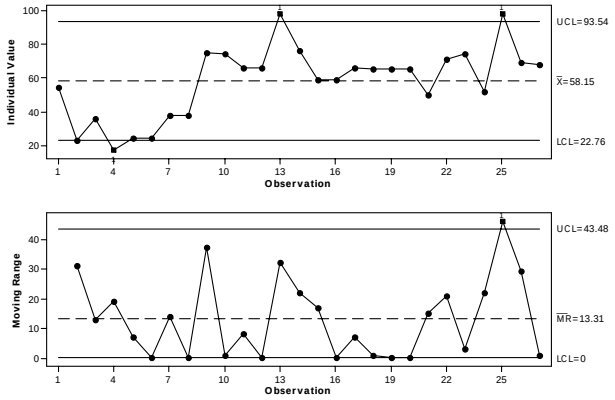

Fig. 6 Individual moving range (I-MR) of the discharge time for the pediatrics department

Sigma quality level (SQL) or sigma level is a quality metric that is calculated by some to describe the capability of a process to meet specification. A six sigma quality level is said to have a 3.4 part per million (ppm) rate. Breyfogle [7] prefers to distinguish between sigma as a measure of spread and sigma used in sigma quality level.

(1) Sigma quality level calculations

In order to calculate the Sigma quality level (SQL), a systemic way is presented by Staudter [8], Fig. 8. A continuous normal data is the assumption for this model; this assumption is checked before in the distribution fitting step; the discharge time observations were found to follow normal distribution, as shown in Fig. 9.

The standardize Z value is calculated by:

$$Z = \frac{USL - \overline{X}}{s} \quad (9)$$

Where

USL: upper specification level

$\overline{X}$:sample mean

s: sample standard deviation

The long term sigma quality level, $SQL_{LT}=|Z|$

The short term sigma quality level, $SQL_{ST}=|Z|+1.5$

Using the following parameters for the discharge time: USL= 50 min, $\overline{X}$:58.15 min, *s*=21.19 min, then:

Z=-0.385, SQL_{LT} = -0.385, SQL_{ST} =1.115 which correspond to part per million (ppm)=650,000

That's means that 65% from patients discharge time above 50 min.

5) Step Five

The Oxford American dictionary [9] defined simulation as a way "to reproduce the conditions of a situation, as by means of a model, for study or testing or training, etc.". For our purposes we are interested in reproducing the operational behavior of dynamic systems. The model that we will be using is a computer model. Simulation in this context can be defined as the imitation of a dynamic system using a computer model in order to evaluate and improve system performance.

According to Schriber [10], Simulation is "the modeling of a process or system in such a way that the model mimics the response of the actual system to events that take place over time." By studying the behavior of the model, we can gain insights about the behavior of the actual system.

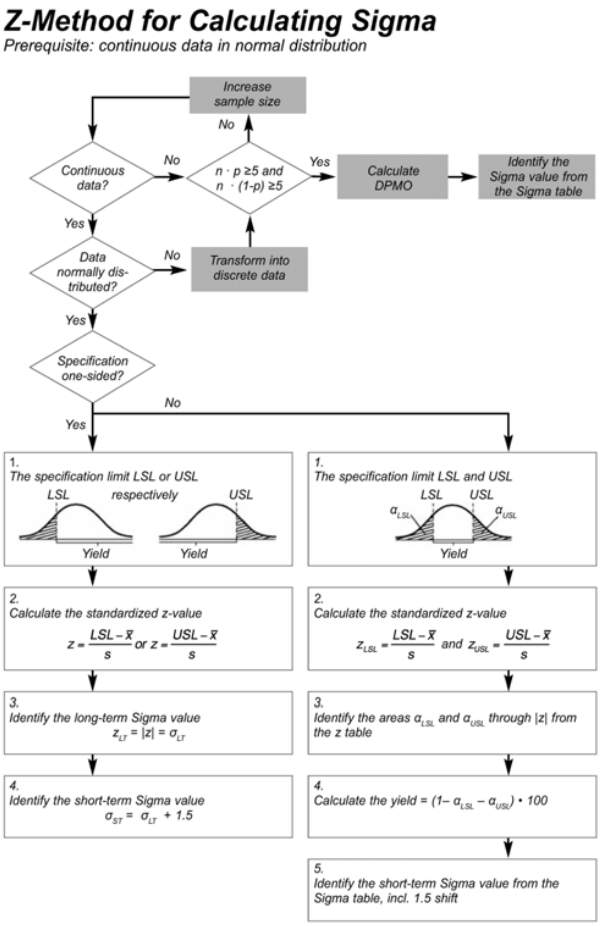

Fig. 8 Z Method for Calculating Sigma Quality Level

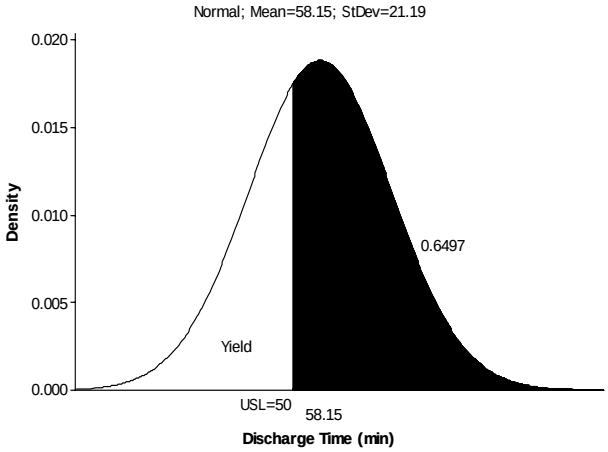

Fig. 9 Probability distribution for patient discharge time

In practice, simulation is usually performed using commercial simulation software (ProModel is used in this research). ProModel is used for modeling constructs specifically designed for capturing the dynamic behavior of systems. Performance statistics are gathered during the simulation and automatically summarized for analysis.Our primary focus is on discrete-event simulation, which models the effects of the events in a system as they occur over time. Discrete-event simulation employs statistical methods for generating random behavior and estimating model performance. These methods are sometimes referred to as Monte Carlo methods because of their similarity to the probabilistic outcomes found in games of chance, and because Monte Carlo, a tourists resort on Monaco, was such a popular center for gambling. Rather than leave design decisions to chance, simulation provides a way to validate whether or not the best decisions are being made. Simulation avoids the expensive, time-consuming, and disruptive nature of traditional trial-and-error techniques. The power of simulation lies in the fact that it provides a method of analysis that is not only formal and predictive, but is capable of accurately predicting the performance of even the most complex systems. By simulating alternative production schedules, operating policies, staffing levels, job priorities, decision rules, and the like, a manager can more accurately predict outcomes and therefore make more informed and effective management decisions.

By using a computer to model a system before it is built or to test operating policies before they are actually implemented, many of the pitfalls that are often encountered in the start-up of a new system or the modification of an existing system can be avoided. Improvements that traditionally took months and even years of fine tuning to achieve can be attained in a matter of days or even hours. Because simulation runs in compressed time, weeks of system operation can be simulated in only a few minutes or even seconds.

6) Step six

The objective of this step is to reveal the main reasons for the delay in discharge time, this stage is considered the most important step in the model, usually it requires several iterations to perform the task, and it consist from two steps: cause and effect diagram (fish bone), followed by design of experiments.

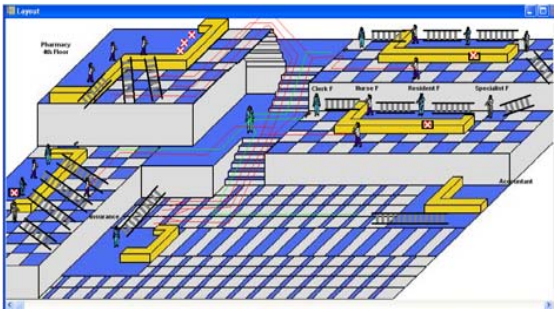

Fig. 9 Simulation model layout for the patient discharge time process

a) Cause and Effect Diagram (Fish Bone)

To be able to reduce the discharge time, the main reasons for delay need to be specified. A brain storming session is carried out by which the causes thought to be the main reasons for delay are stated with the type of delay related to each cause. The results of the brain storming session are projected on fish bone skeleton.

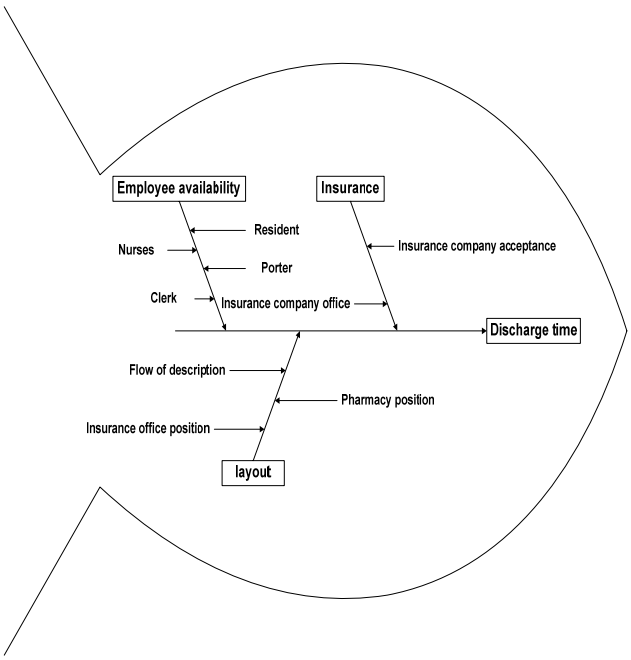

Fig. 10 Cause and Effect/ Fish Bone diagram for the patients discharge time process

Fig. 10 shows the cause and effect diagram for the discharge time process, where the effect i.e. discharge time is placed at the front (fish head) and the causes (i.e. insurance, employee availability, and layout) are placed on the branches, and for each branch sub causes are listed.

But this diagram has two shortcomings; first, there are no validation that the suggested causes are really responsible the output, second, if it happens that the suggested causes are the real one, there are no discriminations among these causes (the rank of these causes on the output), and the causes sensitivity at the output. Fortunately, these shortcomings will be overcome be using Design of Experiments.

a) Design of Experiments

Design of experiments is a statistical analysis technique used to reveal the causes (i.e. factors) affecting the process output. The brain storming session occurred in the effect and cause diagram stage produce candidates for the design of the experiment stage. These candidates, called factors in the DOE scheme, can be classified as controllable and uncontrollable factors i.e. noise factors. The difference between controllable and the uncontrollable factors, is that the second one cannot be controlled in the real life application although it can be controlled in the lab.

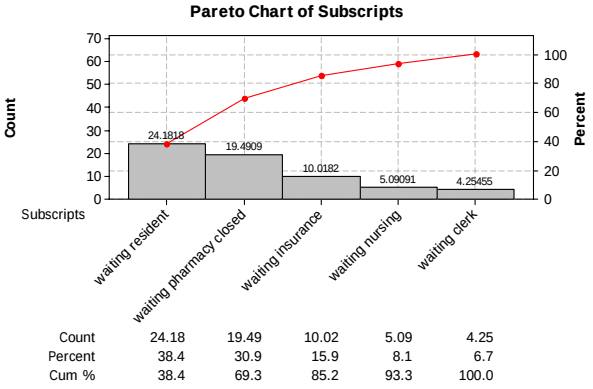

Fig. 11 Pareto chart for the patients waiting time

Based on the cause and effect diagram and the Pareto chart, Fig.11, four factors were considered in this study, Table V; resident's availability, pharmacy dispensing prescription and finalizing patient's receipt, getting insurance company approval, time needed for porter to get the file and take it down to accounting.

TABLE V
CANDIDATES FACTORS RESULTED FROM THE CAUSE AND EFFECT DIAGRAM AT PEDIATRICS DEPARTMENT

Factor	Low level (-1)	High level (+1)
x_1:Resident availability time (min)	5	23
x_2:Porter Service Time (min)	0.05	5
x_3:Insurance Service Time (min)	5	7.2
x_4:Number of pharmacist	3	4

Sixteen runs were performed using two level full factorial experiments (i.e. 2^4=16) in order to determine the significant factors, Table VI, the output of each run is the sigma quality level, which has been calculated from the mean and the standard deviation, as mentioned in the sigma quality calculations section.

Two important issues need to be mentioned regarding DOE table. First; the result for each run was obtained from the simulation model. Second, considering the sigma quality level (SQL) is the output of DOE runs; reduce the number of runs required (i.e. instead of constructing two DOE, one to reveal the factors affecting the mean, and the other to reveal the factors affecting the variability).

It can be seen from Table VII that the significant factors are: x_2: porter service time, x_3: insurance service time and x_4: number of pharmacist, since their p-values are less than 0.05. The regression equation that correlates the sigma quality level value with the significant factor is:

$$SQL = 0.7312 - 0.2437\,x_2 - 0.1937\,x_3 + 0.1062\,x_4 + 0.1063\,x_1x_2 + 0.0563\,x_1x_3 - 0.1188\,x_3x_4 \quad (10)$$

S = 0.075 PRESS = 0.288

R-Sq = 98.76%, R-Sq(predicted) = 87.34%, R-Sq(adjusted) = 96.29%

TABLE VI
DESIGN OF EXPERIMENT RUNS FOR PEDIATRICS DISCHARGE

Run	x_1	x_2	x_3	x_4	Mean	STD	% of Defective	PPM	SQL
1	-1	-1	-1	-1	53.55	10.42	0.6332	633279	1.1
2	1	-1	-1	-1	71.44	28.25	0.7760	776002	0.7
3	-1	1	-1	-1	61.77	11.48	0.8473	847325	0.5
4	1	1	-1	-1	79.73	30.21	0.8374	837434	0.5
5	-1	-1	1	-1	58.85	13.12	0.7499	749969	0.8
6	1	-1	1	-1	70.87	27.72	0.7741	774180	0.7
7	-1	1	1	-1	67.08	14.28	0.8840	884051	0.3
8	1	1	1	-1	78.58	26.29	0.8614	861424	0.4
9	-1	-1	-1	1	48.84	9.207	0.4498	449871	1.6
10	1	-1	-1	1	70.25	62.28	0.6274	627462	1.2
11	-1	1	-1	1	57.14	10.42	0.7533	753309	0.8
12	1	1	-1	1	78.54	59.74	0.6835	683578	1.0
13	-1	-1	1	1	54.22	7.725	0.7075	707548	0.9
14	1	-1	1	1	68.50	27.03	0.7530	753070	0.8
15	-1	1	1	1	62.46	6.879	0.9649	964954	0.0
16	1	1	1	1	76.66	23.75	0.8690	869092	0.4

In order to check the validity of the regression model, residuals normality plot, residuals frequency diagram (histogram), and residuals versus the fitted, observations order, were plotted as shown in Fig. 12. It can be seen that model assumption are all satisfied i.e. residual observations follow normal distribution, and trends associated in the fitted or observed order residuals.

Substituting x_1= -1, x_2= -1, x_3= -1, and x_4= +1, results in SQL=1.43 which correspond to ppm=528,000.

That's mean that around 53% from patients discharge time will be above 50 min (it was before 70.2%)

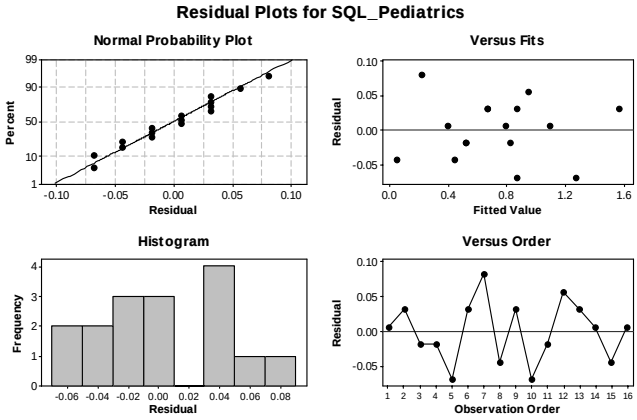

Fig. 12 Residuals normality plot, residuals versus fitted value and observations order, and histogram

V. CONCLUSIONS

Health care is unique from any other type of industry in that health care professionals are highly dependent on each other to provide and coordinate services of high value for human beings. The need to increase the efficiency of health care systems is becoming an obligation, and one of area of improvement is the discharge process.

Patients admitted to the hospital fear the experience of hospitalization and losing their independence, they want to leave as soon as possible and every effort should be made to help to do so.

The objective of this work is to minimize the patients discharge time to be less than 50 minutes by using six sigma approach, this improvement will also: lead to an increase in customer satisfaction, increase the number of admissions and turnover on the rooms, and increase hospital profitability.

Three different departments were considered in this study: Female, Male, and Paediatrics. Real life data were collected for the discharge time of patients for the three departments for one month, those date were used to build the simulation model, and to measure the current performance (i.e. the actual discharge time for patients). Cause and effect diagram with Design of Experiment (DOE) technique were used to determine the important factors that affect the discharge process, and to build the optimization model.

Six Sigma approach coupled with simulation has been applied to reduce the patients discharge time for pediatrics, female, and male departments at hospital. Upon applying these recommendations at hospital: 60%, 80%, and 22% of insured female, male, and pediatrics patients respectively have discharge time less than the upper specification time.

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