Operating Rooms Efficiency Project

Submitted to:

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Six Sigma Program

Prepared by:

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Executive Summary

In late April of 2009, the President of one of Michigan's largest health care providers told us that they wanted to eliminate the waste in their process and improve the processing rate, or throughput, of the operating rooms. The Vice President of operations, who championed and led this project, requested to initiate a Six Sigma project with the ultimate objective of improving throughput rate. We immediately began to examine the process and determined that the actual daily throughput rate was 26 surgeries in the morning and six surgeries in the afternoon shift.

We immediately told the management team that we would examine the process closely and identify the key performance variables related to this output. Next, we formed a team to determine the cause of the problem and implement a solution. Our team used the Six Sigma Strategy to examine the processes in the operating room and identify ways to optimize these processes.

Following the Six Sigma Strategy, we determined that delays are the major cause of variation in the operating rooms. Preliminary results show delays on 57 percent of the surgeries or 1 in 2 surgeries. The other major causes of variations we identified are forecasting the duration of surgeries and the time to turnover a room (i.e., the time to get the room ready for the next operation). In addition, we determined that, on average, 520 minutes (13.5 percent of the total available time in a day) is spent on just getting the operating rooms ready for the next surgery.

Performance metrics show that the average length of a delay is 26 minutes with a standard deviation of 29 minutes. In the morning shift, the average total length of delays in one operating room is 50 minutes with a standard deviation of 40 minutes. Also, the average time to turnover a room is 23 minutes with a standard deviation of 8.9 minutes. We were unable to determine accuracy of forecasting system because there are not historical data readily available.

Statistical Process Control (SPC) analysis shows that this process in unstable and statistically out-of-control. This is an indication that variability in the system is large and not in control. It was thought at the beginning of this project that the bottle-neck of this process was the Operating Room, but process performance metrics showed that this system has extra capacity.

Data analyses show that current Utilization for the morning and afternoon shift is 69% and 36%, respectively. The method used to calculate this metric has a significant impact on the results. The method used in this report was to subtract time to turnover a room from available time, which provides higher Utilization than when not subtracting this variable.

We determined that the key performance input variables (KPIVs) that are directly linked to improving processing rate or throughput of the operating rooms are:

a. Patient in Room Time or Cycle Time (T)
b. Scheduled Number of Surgeries (I)
c. Utilization (U)
d. Time to Turnover a Room (C)
e. Total Delays (D), and
f. Surgery Duration Forecast Accuracy (F)

The above variables were used as inputs to generate a mathematical model which explains how improvements or changes in any of these variables will impact throughput rate.

The daily average processing rate, or Throughput (TH) per Operating Room (OR), is explained by the following model.

Throughput (TH) = 2.59 - 0.0623 + Total Patient in Room Duration + 26.7 x OR Utilization

For a single operating room, the Throughput per Operating Room is

TH = 2.59 – 0.0623 (285.13) + 26.7 (0.69) = **3.2 surgeries**

This result shows that with an average utilization of 69 % and a total daily average Cycle time of 285.13 minutes, we should expect one operating room to generate 3.2 surgeries in a day during the morning shift.

To improve process performance and increase the processing rate, or throughput rate, in the operating rooms we considered the following alternatives:

1. A Kaizen event to reduce Cycle Time (T) of surgeries and Time to Turnover a Room (C).
2. Create a department (or entity) to track, analyze and report process performance and to reduce or eliminate delays in the system.
3. Create standardized work manuals for every job.
4. Training on standardization of work for supervisors and OR personnel.
5. Assign teams to OR following FIFO
6. Change scheduling pattern for surgeries with long history of delays.

We are confident that these recommendations will bring stability and capability to the current system, resulting in lower variability, and increased process performance and throughput.

1.0 Improvement Opportunity: Define Phase
1.1 Problem and Process Description

The executive management team is dissatisfied with the process performance of the operating rooms. They sustain that due to the low processing rate of its OR, the system is operating below its designed capacity. The system is plagued with systemic delays, lower-than-planned utilization and an inaccurate forecasting system responsible for most of the variability in the system.

Delays are the major cause of variation in the Operating Rooms. Preliminary results show delays on 57 percent of the surgeries, or 1 in 2 surgeries.   Figure 1 shows the distribution of delays in percentage.
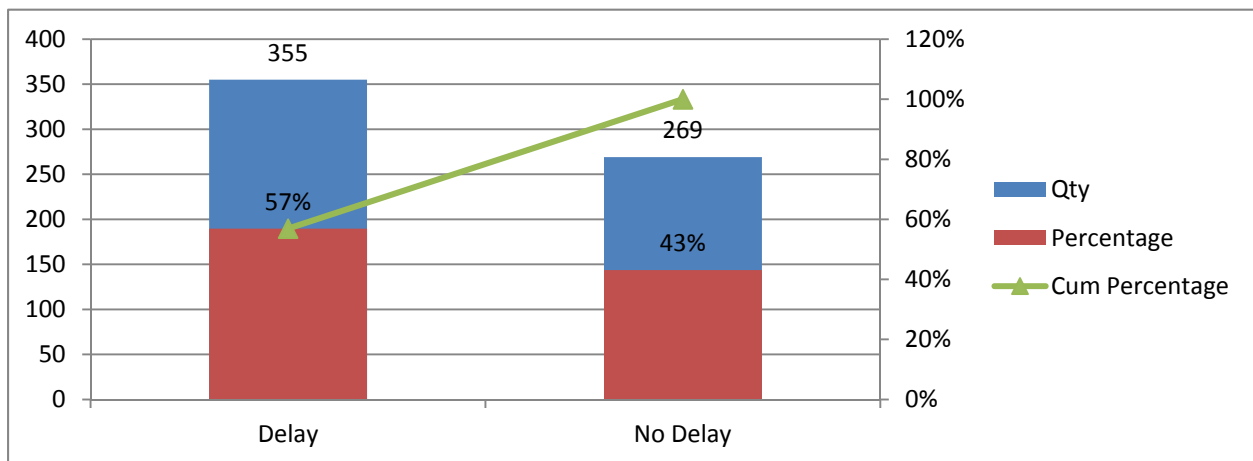

Figure 1. Bar graph showing delays in the operating rooms by quantity and as a percentage of the total delay time.

The second major cause of variation for this system is the fact that each surgery is unique in its own right and the duration of each operation has to be forecasted. A member of the efficiency team contends that forecasting the duration of surgeries should be accurate eighty percent of the time.

Another cause of variation is the time it takes to turnover a room (i.e., get the room ready for the next operation). According to OR administrators, it takes an average of 20 minutes to turnover a room and there are approximately twenty six surgeries each day, which means that on average 520 minutes (13.5 percent of the total available time) are spent each day just getting the operating rooms ready for the next surgery.

Not directly a cause of variation, but a concern during this study, was the accuracy of the data that is input in the computer system and the time it takes for vital information to be processed and provided to managers and supervisors for tracking purposes and to follow-up on key process

performance. A preliminary study performed on delays by each surgeon was judged by a member of the efficiency team, as having bias in the way the delays were allocated by the analysts. We could not confirm or reject these allegations.

1.2 Key Measures for Evaluating Project Success
The goals for the Six Sigma problem-solving project may be turned into four key performance metrics:
1. Reduce and/or eliminate defects.
2. Illustrate the possible cause(s) of the problem.
3. Improve the Operating room process.
4. Provide recommendations to improve this process.

From the perspective of the management team, a key issue is to improve the processing rate, or throughput, as well as the overall performance of the operating rooms. The health care provider recognizes the value of quality of care and services, and would like to find opportunities to reduce the total health care costs while improving customer satisfaction and quality in its operation rooms by means of eliminating waste and finding more efficient ways to care for its patients.

1.3 Project Scope
The Six Sigma team focused its analysis on improving the processing rate, or throughput, in the operating rooms (OR). The team hopes to ultimately use the results of this study to support company-wide changes at other locations.

2.0 Current State: Measure Phase
One of the first steps in the investigation was to identify the key performance output variables (KPOVs) and key performance input variables (KPIVs) of the process. The single KPOV is Processing Rate or throughput (R).

The KPIVs of the process are Patient in Room Duration or Cycle Time (T), Scheduled Number of Surgeries (I), Utilization (U), Time to Turnover a Room (C), Total Delay (D), and Forecast Accuracy (F), i.e., the accuracy of the time forecasted to perform the surgeries.

During this phase, a preliminary study was done aimed at getting a snap shot of the surgery scheduling pattern and for this purpose four months worth of data (2515 data points), were evaluated (See Appendix A). It is interesting to note that 20.6% of the surgeries that occur in the course of a day start at 7:00 AM.

2.1 Current Process Performance Level

The current daily throughput for the morning shift is an average of 26 surgeries and a standard deviation of +/- 4. The daily throughput for the afternoon shift is an average of 6 surgeries, with a standard deviation of +/- 2.

To evaluate the efficiency of current process performance, we first established criteria for a defect. A defect was defined as a surgery with a delay taking longer than 20 minutes. Therefore, there is one defect per opportunity. The 20 minute threshold used to measure current process performance is not an arbitrary number used to evaluate input variable Total Delay (D). This number represents the maximum allowable wait to perform a surgery without penalizing Utilization (U).

Delays have been identified as the major source of variation in the system. This is one of the reasons why the team wants to evaluate this variable in more detail.

It is understood that, in addition to evaluating total delay in the system, it is important to quantify and identify each of the components of this time separately because it would help the team when developing corrective and improvement actions.
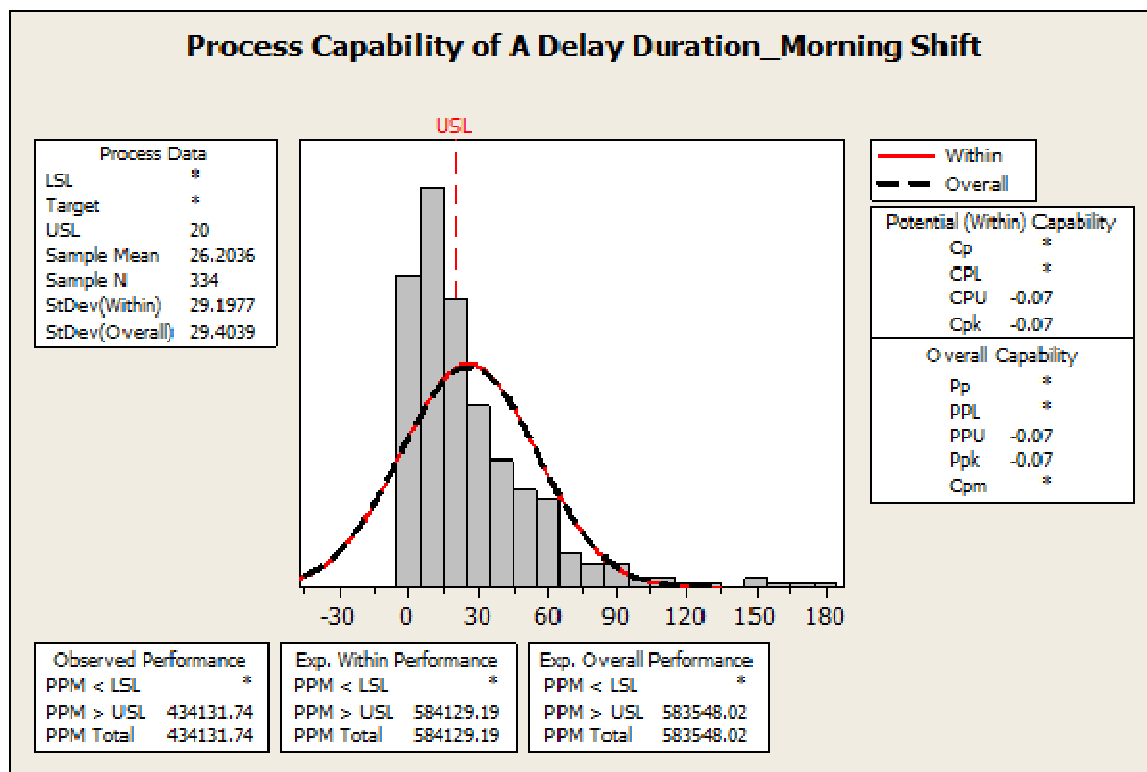

Figure 2. Process capability chart of total delay duration, showing the process capability indices and expected overall performance.

The results in Figure 2 above show that the OR current process has an expected delay failure rate of 583,548 defects per million opportunities (DPM). It also shows that average length of one delay in the system is 26 minutes with a standard deviation of 29 minutes. As observed by the

high value of the standard deviation relatively to the average or mean, this system shows a high degree of variability.

It should be noted that only delays greater than 20 minutes are regarded as defects, which explains the reason why this process capability chart is one-sided, or with only an upper limit. The capability index Ppk has a negative value (-0.07) which is an indication that the mean of this process is outside specification limits. Also note that, regardless of the chosen threshold value (e.g., 20, 30, 40, etc.), the mean and the standard deviation of the Total Delay remains unchanged.
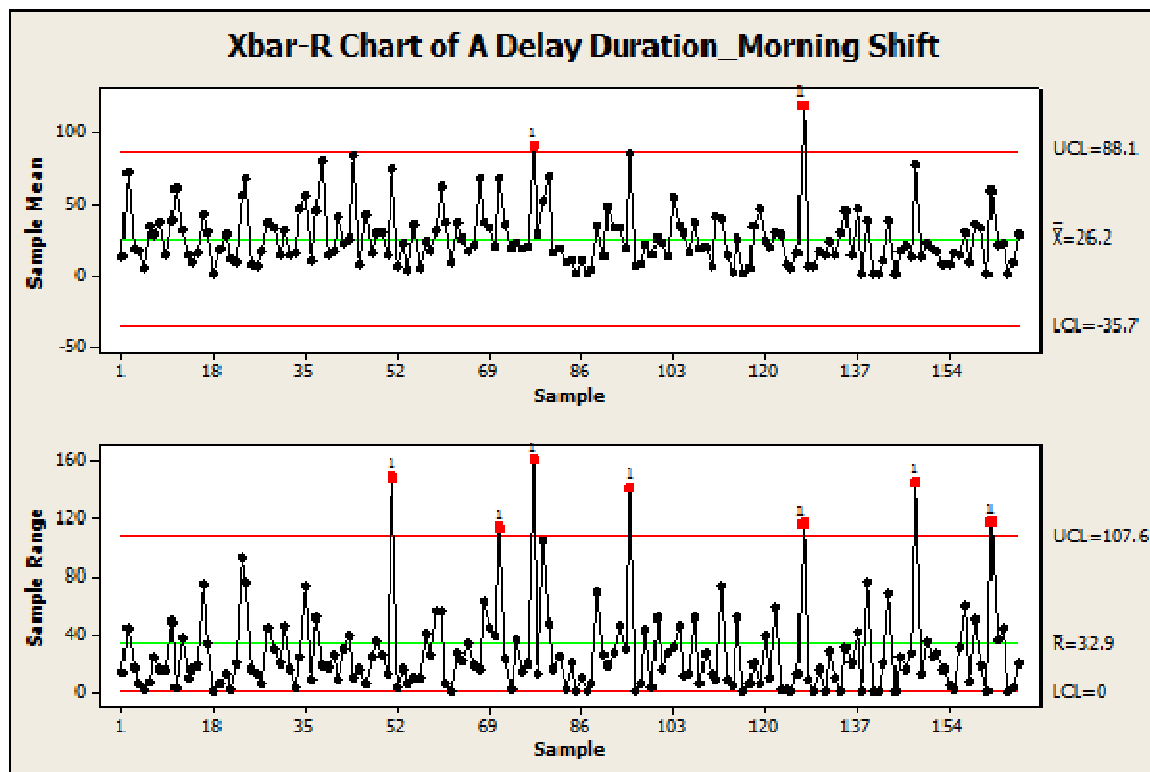

Figure 3. Xbar-R-Chart of total delay duration, showing status of the process stability

The mean and dispersion of input variable Total Delay for the morning shift are statistically out-of-control as shown in the control charts in Figure 3. These control charts also validate the notion of the high degree of variability in the system.

2.2 Data Collection
To validate and support our findings, the Six Sigma team decided to conduct two different studies as describe below.

Study 1

This step is targeted to measure the accuracy of the electronic data. How accurate are your data? To determine the answer to this question, we performed Accuracy studies.   The team gathered historical data from the computer system (measurement system) and compared these outputs with calculated data. We then performed statistical testing of the hypotheses to determine if there are statistically significant differences.

One of the objectives of this study is to verify the capability of the computer system to distinguish variation in the system from gage or measurement variation.

Study 2

This step compiled historical data for the two main shifts: the morning shift, which operates from 7:00 AM to 3:00 PM and the afternoon shift, which operates from 3:00 to 7:00 PM. The sample size for each of the shifts is based on 20 days of full process recording. Data were collected for all eight of the operating rooms available and operational during the morning shift and all five of the operation rooms available during the afternoon shift. Depending on the day and the types of surgeries occurring, the number of surgeries varies among operating rooms. In the morning shift, an operating room holds three to five surgeries and in the afternoon shift, there are two to three surgeries. Because of this variation in number of surgeries completed in one room during one shift, the team had to choose the highest number of surgeries common to each room per shift. Therefore, the data were compiled into subgroups of three and subgroups of two for the morning and afternoon shifts, respectively.

Another characteristic of these sampled data is that they were collected not only differentiating morning from afternoon surgeries, but also by the day of the week (Monday through Friday). One of the reasons the data were collected in this way was to allow the team to assess the process performance in greater detail.

The Six Sigma team used these data to evaluate overall process performance and to validate the actual amount of time that it takes to turnover a room.

Based on preliminary studies and feedback from the efficiency team, the Six Sigma team decided to focus its attention to delays in the system and forecasting the duration of surgeries as being the most plausible root causes of the problem.

2.3 Current OR Process Map
This process has three major areas: Pre Operation (Pre Op), Operating Rooms (OR) and Post Operation (Post Op). The process begins when the patient arrives two hours before surgery to the hospital and checks in at the front desk. In this step, personal data, health insurance and past health history is gathered and checked prior to allowing the patient into Pre Op. Once this step is completed, and if everything is in order, the patient waits until a nurse comes to the waiting area, locates the patient, and brings the patient into the Pre Op area.

Pre Op
In this step, a nurse pulls the patient's record and follows through according to the type of surgeries and directions indicated in the patient's record. Once the patient completes all of the Pre Op requirements and the Operating room is available and ready, the patient is brought into the Operating room.

Operating Room (OR)
The patient completes the final phase of the surgery preparation, and anesthesia is administered if applicable, and the operation begins. Once surgery is completed and the patient recovers, the patient is moved to the Post Op rooms.

Post Op
The patient is brought to this area until consciousness is regained and later released, if applicable, or moved as directed by the surgeon.

For a complete step-by- step description of the process map, please see Appendix B.

2.4 Operating Rooms (OR) Process Description
The morning shift operates from 7:00 AM until 3:00 PM. During this shift, there are 10 operating rooms available for surgeries, but two of them are dedicated to treat very specific medical conditions and are not considered in this study. Every morning at the beginning of the shift, a technician and Registered Nurse (RN) are assigned to a specific room and take care of all surgeries scheduled for that specific room.

The afternoon shift operates with five operating rooms staffed similarly to the morning shift.

3.0 Analyze Phase
3.1 Qualitative and Quantitative Process Analysis
This study begins with the testing and validation of the electronic data gathered to serve as the building blocks to assess current process performance. One of the objectives of the data validation is to assess the accuracy and capability of the system to provide a reliable account of the events that are taking place in the process.

This analysis continues with the study and evaluation of the KPIVs and KPOVs for the operating rooms. This step also explores their relationships and how changes in any of the input variables affect the overall process.

3.2 System Data Validation
To assess the accuracy of the output data we compared historical data for February and April and compared these results to a duplicate sample of calculated measurements of the same variables. The calculated samples of data used for data validation were Total delays and Utilization.

Throughout this study, calculated data are used to verify and/or validate information provided by the system output, and to determine vital information otherwise not directly provided in the

sampled data. The calculated data used throughout this study include utilization, room turnover time, total delays and throughput.

Table 1. Two-Sample T-Test to determine if any difference between the system output and calculated value is statistically significant.

Two-Sample T-Test and CI: Single Delay Duration_System Output, Single Delay Duration_Calculated

```
Two-sample T for a Single Delay Duration_System Output vs a Single Delay
Duration_Calculated

                                N  Mean  StDev  SE Mean
Single Delay Duration_System  334  26.2   29.4      1.6
Single Delay Duration_Calcula 334  24.0   24.0      1.3


Difference = mu (Single Delay Duration_System Output) - mu (Single Delay
    Duration_Calculated)
Estimate for difference:  2.23
95% CI for difference:  (-1.84, 6.31)
T-Test of difference = 0 (vs not =): T-Value = 1.08  P-Value = 0.282  DF = 639
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The average single delay according to the system output is 26.2 minutes and the average calculated single delay is 24 minutes. Based on a p-value of 0.282 (Table 1), which is greater than Alpha 0.05, the alternative hypothesis is rejected and we conclude that there is no significant difference between the system output average (26.2 minutes) and calculated average (24 minutes). The team also conducted a two-sample T-Test (table not shown) with the input variable Utilization, and again found no significant difference between the averages. In other words, when assessing process performance, either the system outputs or calculated data are equally valid.

Another tool used to assess the statistical significance between two data sets is a Box-plot chart (Figure 4). Figure 4 shows the location of the mean and the dispersion of these two data sets. It is evident in this box-plot that both the mean and the dispersion of the two data sets are very similar and support the result of the above T-Test.
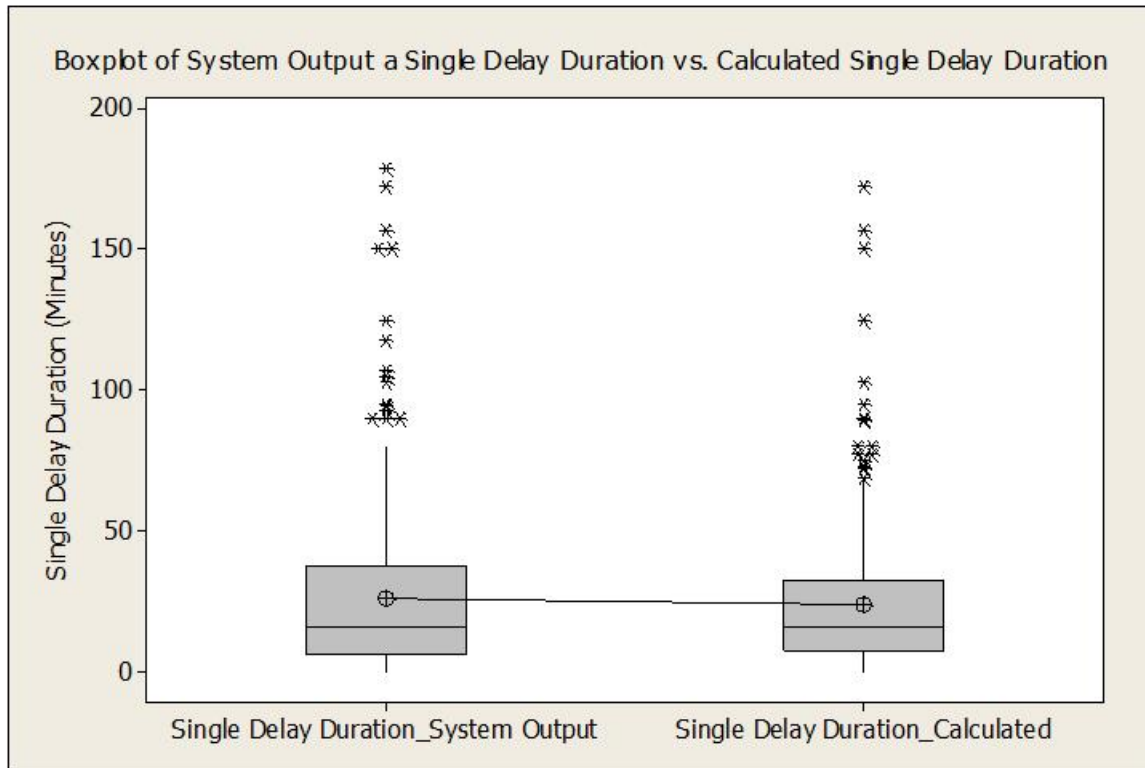
Figure 4. Boxplot chart of single delay duration, comparing the mean and dispersion of the system data output versus calculated data.

3.3 Process Performance Analysis
The Six Sigma team identified the following as the key performance input variables (KPIVs) related to the processing rate, or throughput, of the operating rooms:
   a. Patient in Room Time or Cycle Time (T)
   b. Scheduled Number of Surgeries (I)
   c. Utilization (U)
   d. Time to Turnover a Room (C)
   e. Total Delays (D), and
   f. Surgery Duration Forecast Accuracy (F)

This study begins by analyzing each of these input variables individually and assessing their interactions to determine whether correlation exists among the input variables or between the input and output variables.

Patient in Room Time or Cycle Time (T)
This variable measures the average time it takes to perform a surgery. Cycle Time begins when the patient is brought into the Operating Room (OR) and ends when the patient is taken out of the room. Cycle Time has three important components: one that measures the time starting when the patient is brought into the OR until the surgery starts, the second measures the duration of the time of surgery, and the third component measures the time from the end of surgery until the

patient is out of the OR. These components of Cycle Time will be denoted T1, T2, and T3, respectively. The Six Sigma team measured and evaluated each of these times with the purpose of identifying where the major opportunities for improvement are (Table 2).

Table 2. Descriptive Statistics showing the mean and standard deviation of Cycle Time key input variables time before surgery (T1), time of surgery (T2), and time post surgery (T3).

Descriptive Statistics: Time Before Surgery, Time of Surgery, Time Post Surgery

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median
Time Before Surgery	623	0	24.539	0.438	10.938	3.000	18.000	23.000
Time of Surgery	623	0	57.21	1.86	46.48	1.00	24.00	41.00
Time Post Surgery	623	0	7.319	0.205	5.108	-8.000	4.000	6.000

According to the Minitab output in Table 2, the mean for T1, T2 and T3 are 24.5, 57.21 and 7.31 minutes with a standard deviation of 10.9, 46.48 and 5.1 minutes, respectively. The average "Patient in Room Time" or Cycle Time (i.e., T1 + T2 + T3) is 89.04 minutes with a standard deviation or variability of 62.5 minutes. It should be noted that the standard deviation for Time of Surgery (T2) is almost as large as the mean; this can be explained by the fact that the time to perform surgeries varies greatly from case to case.

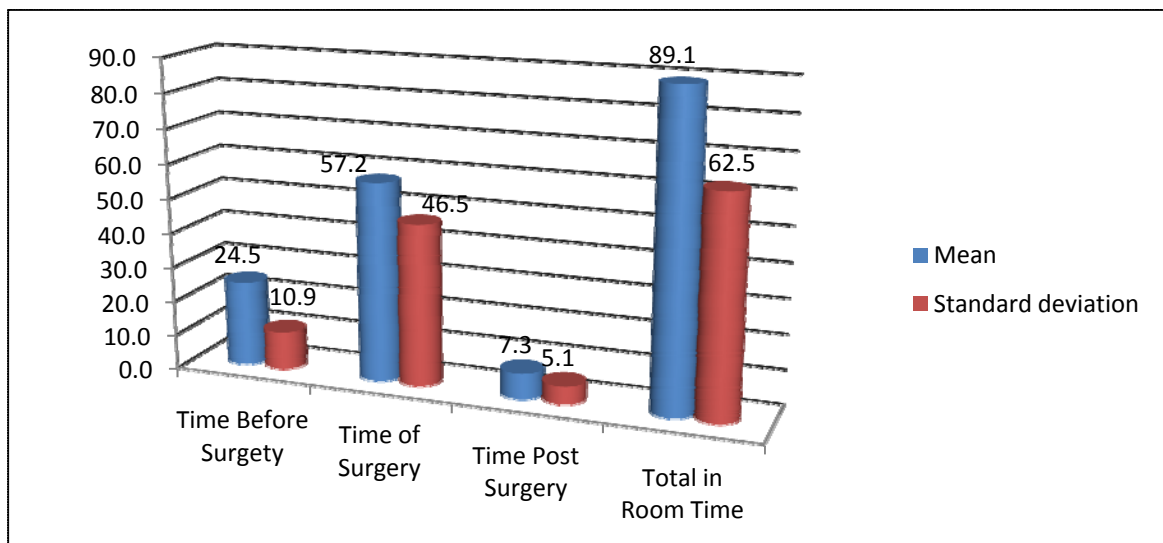Another way to visualize the information provided in Table 2 is shown below in Figure 5.

Figure 5. Bar chart of the total time a patient spends in the Operating Room, showing the mean and standard deviation of the total and each of the components of Cycle Time.

Utilization (U) and Time to Turnover a Room (C)
Utilization and Time to Turnover a Room are key input variables the team analyzed in order to understand their interaction and relationship and how changes in any of these two will impact the processing rate (throughput) and overall process performance.

Utilization reflects the proportion of the time that an available resource is occupied or the proportion between the time the resource is occupied and available time. In this study, the Time to Turnover a Room (20 minutes for each surgery during a shift) was subtracted from available time to calculate the utilization for the Operating Rooms.

When the team analyzed Utilization, the data from the morning shift (7:00 AM to 3:00 PM) and afternoon shift (3:00 to 7:00 PM) was evaluated separately.

The variable Time to Turnover a Room (C) measures the time that it takes to prepare the room for the next surgery. The team acknowledges the importance of this variable in the evaluation of Utilization and process performance and wanted to determine if the actual control limits of the process fall around the specified 20 minutes. The system output does not provide data for this measurement and as a result it had to be calculated. To calculate this time, we excluded instances when consecutive surgeries were scheduled greater than 20 minutes apart from each other. For example, when a surgery ends and the next one does not start until 45 minutes later, the hospital staff doesn't need to start turning over the room right away and therefore if the team included these instances, the value would be skewed.

To evaluate the process capability of the OR, it was assumed that it takes an interval between 15 and 20 minutes to turnover a room, instead of just 20 minutes for the purpose of determining if the time was lower than 20 minutes (Figure 6).
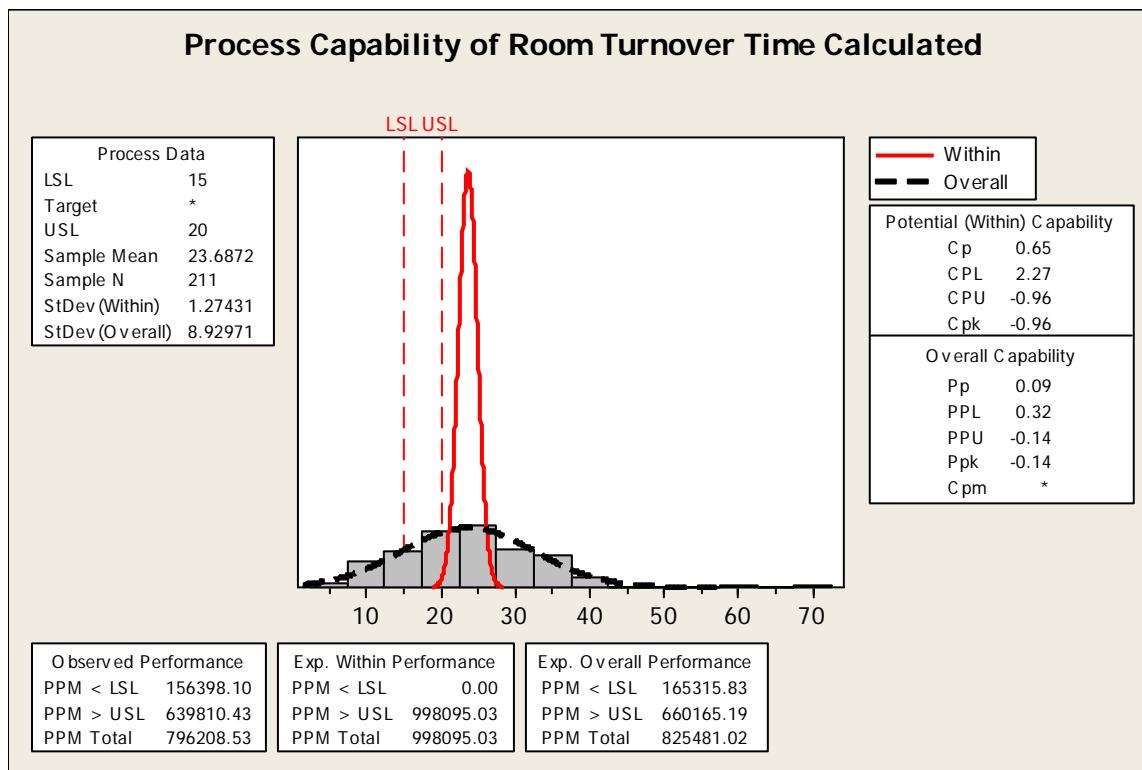

Figure 6. Process capability chart of the time to turn over the operating room, showing the mean and standard deviation and process capabilities indexes.

An important aspect shown by Figure 6 is that the mean is slightly above the 20 minute assumed time. The above Minitab output shows that the average time to turnover a room is 23.6 minutes with a standard deviation, or variability, of 8.9 minutes. The process capability indices show a Pp value of 0.09, which is much smaller than Cp = 0.65; this is an indication of a mean shift and special-cause variation. Special-cause variation is characterized by new, outside the historical experience, unanticipated, emergent or previously neglected phenomena within the system. Another inherent characteristic is that always arrives as a surprise.

Two of the most important ways that time to turnover a room affects the process performance in the OR, are:

1. The lost time or waste created when taking approximately 23.6 minutes to get the room ready for the next surgery, and
2. The positive and negative results caused in the actual Utilization of the OR, when excluding and including the time to turnover a room in the calculations.

The current processing rate or throughput for the morning shift is an average of 26 surgeries with a standard deviation of +/- 4. This means that daily throughput is between 22 and 30 surgeries. Therefore, during each morning shift, there are between 519 and 718 minutes spent (wasted) on just getting the rooms ready for the next operation. The Six Sigma team wanted to raise the following question: how many surgeries could have been completed in a month if the turnover time could be reduced by half? The answer is between 62 and 86 surgeries.

To address point number two above, the team calculated the actual Utilization of the OR during the morning shift both when excluding (or subtracting the 20 minutes from net available time) and including in the time to turnover a room (Figures 7 and 8).
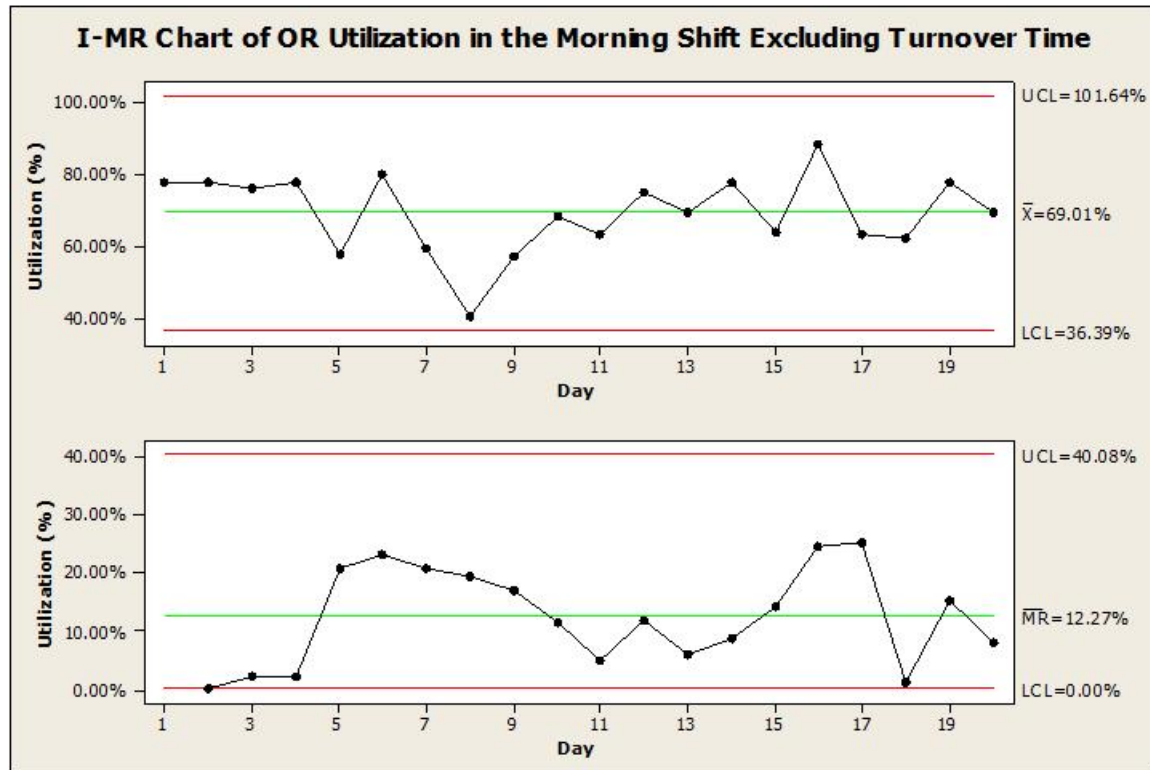
Figure 7. I-MR Chart of Utilization in the OR during the morning shift calculated by excluding the time to turnover a room from the total available time.   The average utilization is 69.01% and the range of dispersion is 12.27%.

According to the control charts shown in Figure 7, when excluding the room turnover time from the available time, the Utilization of the Operating Rooms (OR) during the morning shift has an overall mean of 69%. During the observed period (20 days), Utilization fluctuated between 90% and 48%.
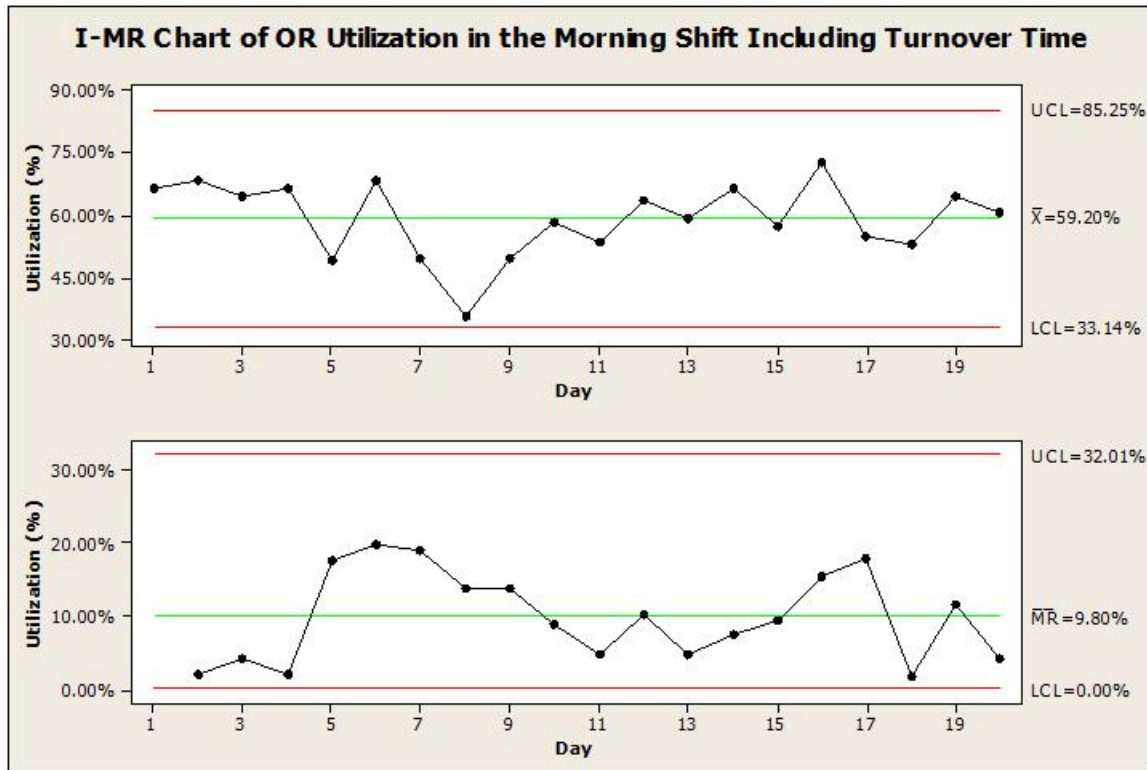
Figure 8. I-MR Chart of Utilization in the OR during the morning shift calculated by including the time to turnover a room in the total available time.   The average utilization is 59.20% and the range of dispersion is 9.80%.

According to control charts shown in Figure 8, when including the turnover time as a part of the total available time, the Utilization of the Operating Rooms (OR) for the morning shift has an overall mean of 59 percent. During the observed period (20 days), Utilization fluctuated between 75 and 43 percent.

The Utilization for the afternoon shift was calculated by excluding the time to turnover a room (Figure 9). The average Utilization for the afternoon shift is 36%. This low utilization is a major concern and a threat to improving processing rate in the system.
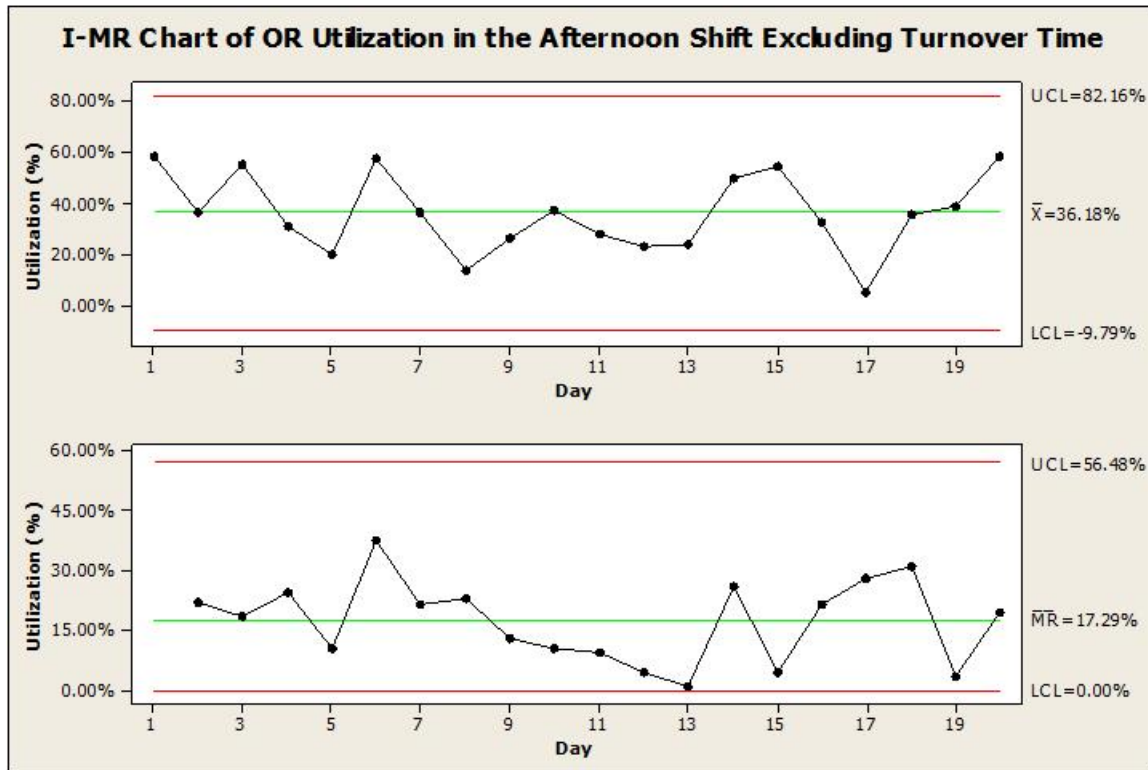
Figure 9. I-MR Chart of Utilization in the OR during the afternoon shift calculated by excluding the time to turnover a room from the total available time. The average utilization is 36.18% and the range of dispersion is 17.29%.

Total Delays (D)
Delays have been identified as one of the major cause of variations in the system, and a key element to improving the processing rate or throughput of the system. This key input variable measures the total delays in one operating room per shift.

A process capability analysis of Total Delay shows that in the morning shift there is an average Total Delay of 50 minutes with a standard deviation of 40 minutes, per Operating Room (Figure 10). The high value of the standard deviation relative to the average is an indication that this system has a high degree of variability.
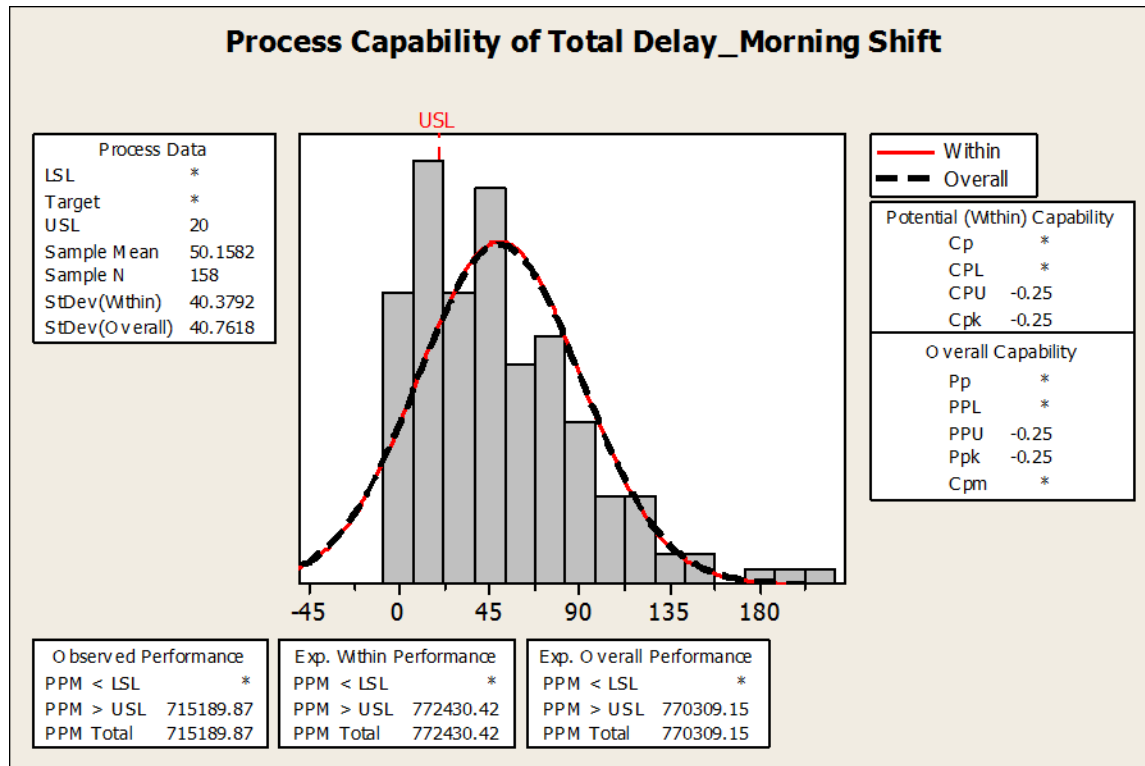
Process Capability of Total Delay_Morning Shift

Process Data	
LSL	*
Target	*
USL	20
Sample Mean	50.1582
Sample N	158
StDev(Within)	40.3792
StDev(Overall)	40.7618

— Within
- - Overall

Potential (Within) Capability	
Cp	*
CPL	*
CPU	-0.25
Cpk	-0.25

Overall Capability	
Pp	*
PPL	*
PPU	-0.25
Ppk	-0.25
Cpm	*

Observed Performance		Exp. Within Performance		Exp. Overall Performance	
PPM < LSL	*	PPM < LSL	*	PPM < LSL	*
PPM > USL	715189.87	PPM > USL	772430.42	PPM > USL	770309.15
PPM Total	715189.87	PPM Total	772430.42	PPM Total	770309.15

Figure 10. Process capability chart of Total Delay duration in an operating room in the morning shift, showing the process capability indices and expected overall performance.

The team wants to measure the magnitude of each of the components of Total Delay to better understand this problem and use this knowledge when developing corrective actions. The team analyzed all types of delays that were recorded in the system during four moths (January through April) and categorized all of the delays by reason code (Figure 11). The top three reasons for delay are "Previous Case Ran Late," "Surgeon Delay" and "Patient Delay." It should be noted that "Previous Case Ran Late" alone accounts for almost 57 percent of all the delays recorded in the system during the specified period of time. The reason codes "Previous Case Ran Late" and "Surgeon Delay" together account for almost 80 percent of the delays.
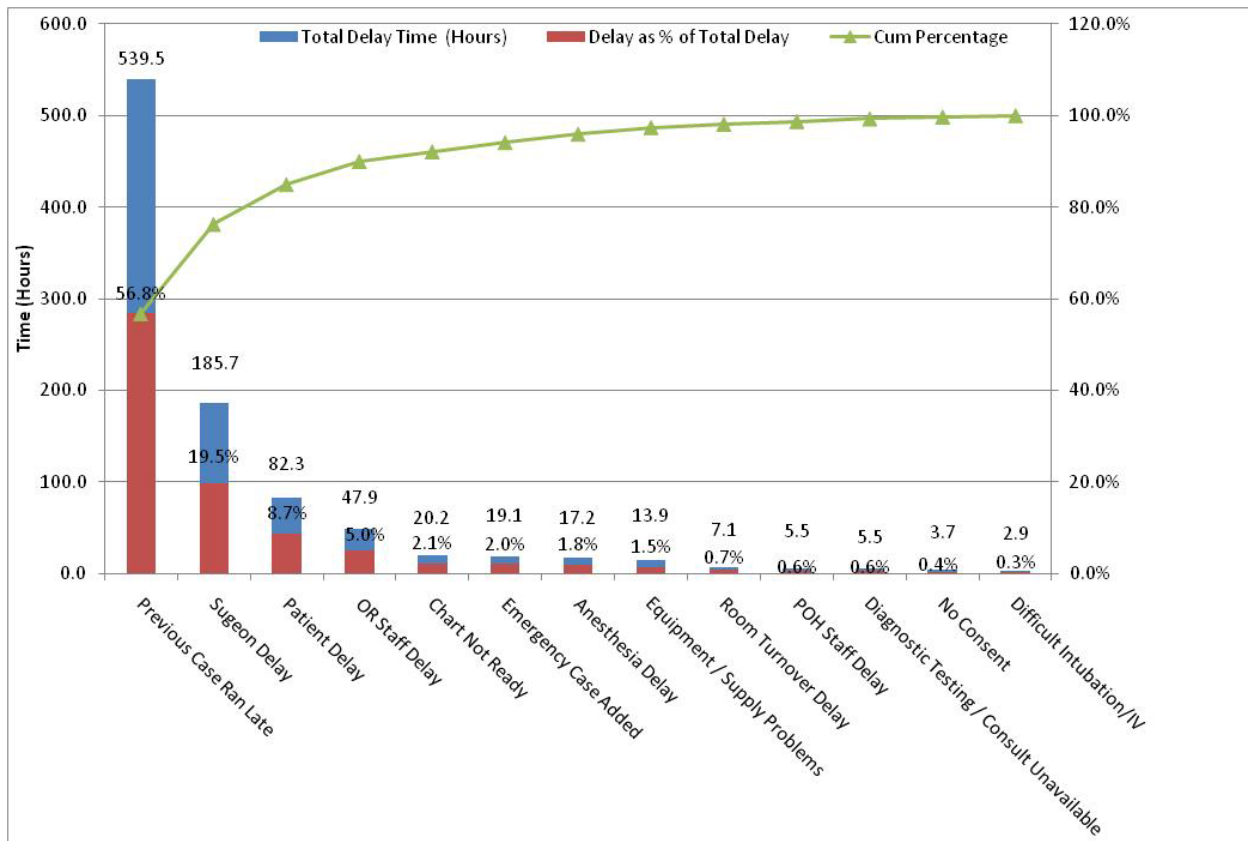
Figure 11. Bar graph showing the delay in the operating rooms by reason codes. For each reason code, the delay is shown in hours and as a percentage of the total delay.

In this study, it was observed that the reason code "Previous Case Ran Late" is being used not only to describe situations where the previous case ran late, but also when the duration of surgery was longer than originally predicted. We should note that in cases where surgery took longer than predicted, it is more an issue of forecasting accuracy than a delay itself. The Six Sigma team wants to highlight the following scenarios that could happen when coding delays in the system.

1. When there are three surgeries in a row and during the first surgery there was a "Surgeon Delay" of 50 minutes, for example, the subsequent surgeries are going to start late because of the Surgeon Delay during the first surgery but are currently being coded as "Previous Case Ran Late." In some cases, the reason code "Previous Case Ran Late" was used to identify cases where surgeries took longer than predicted. This can explain the high percentage of cases under this coding (Figure 11).

2. We would also like to bring up the cascading effect of delays at the beginning of the shift. Using the same example, if the first surgery is late, the result is that surgery two and three would be also late. If the delay would have happened during the last surgery there would be only one delay. This cascade is adding to the high percentage of cases under this coding.

Forecast Accuracy_ Surgery duration (F)
This is a key input variable which measures the accuracy of the forecasting system. The computer system does not provide this information, even though this is a key component to improve process performance and reduce variability in the system. The evaluation team did not find an effective and accurate way to measure this metric from the current data output. As a result, we strongly encourage the management team to initiate a Six Sigma project to measure and evaluate this variable.

Overall Process performance_ Throughput
Up to this point we have defined and analyzed each of the key input variables related to the output variable processing rate or throughput. We have seen the important aspects of each of these input variables and how they function individually. We would now like to evaluate the overall process performance when considering all related input variables.

We aim to generate a mathematical model that creates a direct link between the process input and output variables. To find this mathematical model we will perform Stepwise and Multiple regression analysis to identify which variables are directly connected, or correlated, with the response (Throughput) and which are insensitive, or robust, to changes. This model will also provide insight on how to achieve our targets.

It is important to note that Cycle time (T), Total delays (D), and Utilization (U) are the only input variables that will be used in the multiple regression analysis. The reasons for this are that: 1) data are not provided for some of the key input variables described previously (Time to Turnover a Room (C) and Surgery Duration Forcast Accuracy (F)) and 2) some variables are not independent of each other (Table 3).

The data used to generate the mathematical model or regression equation are those from the morning shift only.

Table 3. Multiple Regression Analysis, evaluating correlation between throughput and key input variables Total Delay, Total Patient Time and Utilization.

Regression Analysis: Throughput versus Total Delay, Total Patient in Room Time

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The regression equation is
Throughput = 2.59 - 0.000174 x Total Delay
            - 0.0623 x Total Patient in Room Time + 26.7 x OR Utilization


Predictor                           Coef    SE Coef       T      P
Constant                          2.5893     0.1233   21.01  0.000
Total Delay                    -0.0001741  0.0008196   -0.21  0.832
Total Patient in Room Time      -0.062341   0.001817  -34.32  0.000
OR Utilization                   26.7213     0.7358   36.32  0.000


S = 0.402871   R-Sq = 89.9%   R-Sq(adj) = 89.8%
```

In regression analysis, a value for R-square equal to or greater than 70% is judged to be strong. Among these variables, only those with a P-value equal to or smaller than 0.05 are considered as correlated with the response. According to output from Minitab (Table 3), the KPIVs which have a strong correlation with the processing rate or throughput (KPOV) are Total Patient in Room Time (or Cycle Time) and Utilization.

These results validate the fact that two of the major factors related to improving processing rate or throughput are Cycle time (Total Time Patients spend in the OR) and Utilization. According to the regression analysis, key input variable Total Delay does not have a strong correlation with the processing rate or throughput in the system, and as a result was eliminated from the above equation.

Table 3 provides the mathematical model or equation which links key input variables Total Patient in Room (Cycle Time) and Utilization with key output variable Throughput . After eliminating the variable with a P-value greater than 0.05, the regression equation shown in Table 3 becomes the model shown below.

Throughput = 2.59 - 0.0623 Total Patient in Room Operation + 26.7 OR Utilization

It is important to note that the processing rate achieved by this equation is that of one Operating Room in a day of operation (daily rate per room/ shift).

The following example will showcase an application of this equation. We have already determined the average total cycle time (285.13 minutes) and average utilization (69%) for this system. With this information, then, we can find answers to the following questions:

1. What is the current average throughput of an Operating Room?
2. How many Operating Rooms do we need if we want to perform a particular number of surgeries in one shift?

As already identified in Figure 7, the current average utilization of the OR is 69%. The average total cycle time of an operating room during the morning shift is 285.13 minutes. Using these data as inputs we can answer question one:

The daily average processing rate or Throughput per Operating Room (OR) can be calculated as follows.
OR = 2.59 – 0.0623 (285.13) + 26.7 (0.69) = **3.2 surgeries**

The Total processing rate or Throughput for the eight ORs available during the morning shift as predicted by the model above is 25.6 (e.g., 8 x 3.2) surgeries. The actual average number of surgeries in the morning shift is 26.

Given the predicted throughput for one operating room (3.2 surgeries), we can predict how many Ors we need in order to perform a specific number of surgeries. For example, if only 8 surgeries are scheduled in a shift, we need only $8 \div 3.2$, or 2.5 rooms. This means, two rooms would operate the entire shift, and a third room would only be needed for approximately four hours.

Figure 8 provides a graphical representation of what would happen to the OR process performance if we increase or decrease utilization, assuming everything else remains constant. We can see from the graph that throughput per operating room increases from 3.2 to 7.3 when we increase utilization from the current state of 69% to 84%. The Six Sigma team believes that the optimal Utilization target for this process should be 85%.
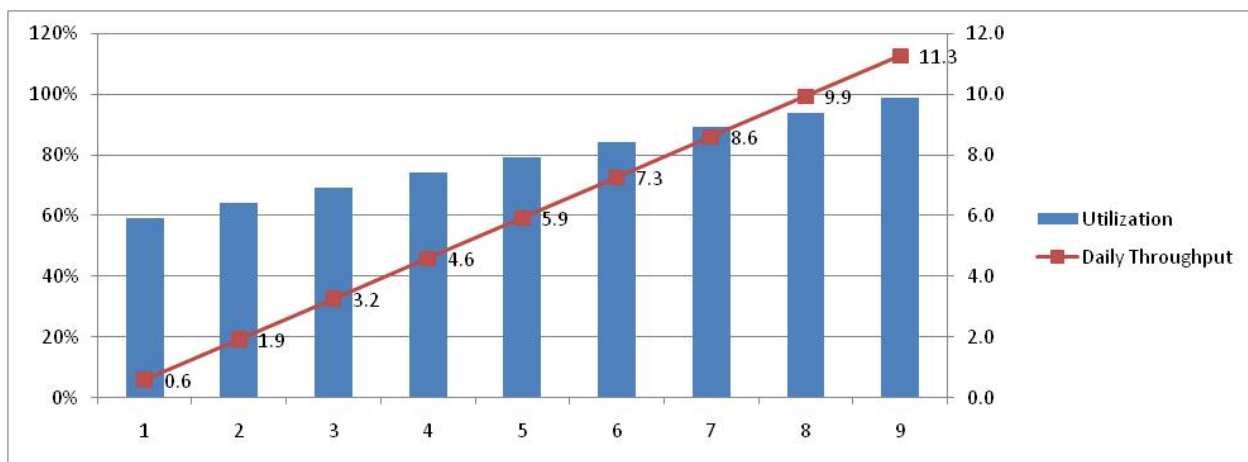

Figure 8. Bar graph showing the relationship between Utilization and Throughput. Current throughput is 3.2 surgeries per operating room with a utilization of 69%.

4.0 Recommendations: Improve Phase

Several recommendations were developed from this analysis. The first set of recommendations relates to reducing variability in the system. The second set relates to improving processing rate or throughput, and the third set relates to the quality and accuracy of the reported information.

Reducing Variability
One of the major challenges in improving processing rate of the ORs is variation. One of the reasons the team included the standard deviation of every performance measure studied in this analysis was to raise awareness of the degree of variability embedded in the system.

The major contributors to variability in the system are delays, forecasting the duration of surgeries and lack of standardized work manuals. To cope with these challenges, we will need not only an accurate forecasting system, precise and accurate tracking of the events, but also a quick and timely process to track, manage and control delays.
To reduce delays, we recommend creating a Process Performance Department which tracks, analyzes, identifies, reports and eliminates root causes of delays in the system. This department would report directly to the VP of operations.

Another recommendation in reducing delays is to schedule types of surgeries with a history of delays at the end, and never at the beginning of the shift, in order to prevent the cascading effect that delays have on the subsequent surgeries. These typically delayed surgeries could also be scheduled on a Friday, which has historically been demonstrated to have a lower demand than any other day of week.

We have said during the analysis phase that the current system output does not provide historical data related to forecasting transactions; under this condition is near impossible to provide an accurate assessment. Thus, to understand, analyze and improve the forecasting of surgeries, we recommend beginning a Six Sigma project geared to defining, measuring, analyzing, improving and controlling the forecasting system.

To reduce variability in the operational process we recommend creating and implementing standardized work manuals. These manuals should explain the most efficient step-by-step activities needed (as agreed by the team) at every job to perform surgeries. In addition to creating these manuals, we recommend providing training and management support to team leaders and supervisors to begin this initiative.

In manufacturing, standardized work implementation begins with providing the appropriate training, tools and support to supervisors and team leaders. They will then take the lead making sure that everyone under his or her team gets the training and help needed to perform his/her job the best way possible.   This common manufacturing practice can also be implemented in the hospital setting.

Improving Processing Rate or Throughput in OR

This study has already identified and validated the two major components related to improving throughput in the system: Patient in Room time (or Cycle Time) and Utilization. A variable directly linked to Utilization is the Time to Turnover a room. The Six Sigma team is convinced that by improving these variables, processing rate will increase significantly.

Utilization is a calculated relationship between the time the resource is occupied or busy and the available time; as a result, we will only address Cycle Time and Time to Turnover a room.

Patient in Room Time or Cycle Time
The three components of this variable are: Time before Surgery (T1), Time or duration of Surgery (T2) and Time after Surgery (T3). To improve this variable we recommend a "Kaizen" event. This event should include the key players in these operations, which will meet and focus on finding the best solutions to reducing this time.

During the measuring phase, we witnessed instances which should be reduced and/or eliminated. For example, a nurse had to leave the operation room to retrieve a surgical tool in order to proceed with the surgery, or a patient had to wait for the anesthesiologist or surgeon. These instances need to be reduced and/or eliminated and a Kaizen event can address these issues.

Time to Turnover a Room
We also recommend including this variable in the Kaizen event. In addition to Kaizen, we recommend changing the actual method which assigns or dedicates a team to a specific room during a shift. Instead of this method, we propose assigning teams to the next operation room that becomes available for service. It should resemble a bank, where cashiers serve the next customer in line, in the order they arrived.

Quality and Accuracy of Information
The third recommendation is to improve the quality and accuracy of the recorded information. In this regard, we recommend training and creating awareness of the importance of recording the events as they happen in order to manage and control the efficiency of the operating rooms.

In the current state of the process, once the patient is brought into the Pre Operating room, this step is not recorded until a series of routine steps have been performed. We recommend as the first step to log the patient information into the system to let everyone downstream know that the patient has been admitted into this area and then proceed with next required steps.

During the analysis phase the Six Sigma team did not find historical data for delays caused when the time to perform a surgery took longer or less than the predicted time. We recommend creating a reason code to specify that the surgery took longer than predicted. The naming of the variable could be, for instance "Overrun or Underrun Time of Surgery."

Special attention should be paid when creating reports of the process performance, and more specifically, of delays, to avoid double dipping. For instance, if there were two consecutive

surgeries and the first one had a 25 minute delay and the second one was delayed 40 minutes, the total delay in the system is 25 + (40 – 25), or 45 minutes.

5.0 Recommendations: Control Phase

We recommend developing Score Cards that measure Quality, Cost, Delivery, Safety and Moral. These metrics will evaluate and quantify the process performance and would help the hospital administrators to keep track of recent and actual performance.

Score cards should be supported with team building and quality meetings. Team building meetings should be held every day at the beginning of the shift and Quality meetings should be held once a week or as often as needed. The length of these meetings should be short and the content concise. The topics covered in these meetings should include the five described metrics and any other important events regarding work-related issues.

We recommend providing management, supervisors, team leaders, etc., with weekly "Process performance" reports, instead of monthly as in current practice. These reports need to be easy to read and comprehend. Reports must include the following information: Delays, utilization, average time to turnover a room, etc. Delays should be broken-down by reason codes and sorted from top-down. Utilization and Time to Turnover a room need to be broken-down by shifts for easier and faster reporting.

Another important point in this topic is to identify the root causes of each of the top delays and they should be discussed at the weekly meeting. The message should be clear that we are tracking with the purpose of helping you to do your job easier and more efficiently. Also, by eliminating root causes, we guarantee to reduce the frequency and severity of these events in the future.