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ABSTRACT

This paper describes a new Statistical Process Control technique to better manage the engineering Information Technology life cycle process. This includes the identification of the activities in the engineering IT support lifecycle initiation, reproduction, analysis and resolution phases. The performance of these lifecycle activities are analyzed using a highly modified Chart of Individuals, Statistical Process Control approach. This new type of SPC system can help engineering IT management to determine whether or not a support incident is in control. Out of control support incidents can then be investigated for special causes so that corrective action may be taken.

INTRODUCTION

Customer satisfaction has always been one of the most important criteria and driving force for the engineering industry. Customers of an engineering company must be satisfied with the schedule, budget, and technical performance of work. With the dependence on computer hardware and software, information technology (IT) is playing an increasing important role in achieving successful performance with respect to these factors. This importance is evident from both the projected increase in U.S Government IT spending from $36.4 billion in 2001 to $60.3 billion in 2006 and the estimated overall IT spending from $200 billion in 2001 to $220 billion in 2002 [Paulson, 2002).

Unfortunately, engineering IT support does not always receive the attention that it deserves. At the beginning of many projects, management may minimize or even ignore the importance of engineering IT support. However, once the project begins, its success can depend heavily on engineering IT support for the timely and effective deployment of project software, training, customizing and corrective maintenance of data.

IT support issues in the engineering industry are far more complex than common, general IT support issues. Some more common IT support issues in the engineering industry include engineering software not working as designed, calculation results not conforming to specifications, software not properly functioning with particular operating systems, and software installations corrupting the operating system. These situations must be resolved in order for the support incident to be considered a success.

RESEARCH OBJECTIVE

The objective of this research is to determine critical incidents in the engineering IT support life cycle and to create a Statistical Process Control (SPC) system to identify when the engineering IT support process goes out of statistical control. This capability will enable the engineering IT support management to more rapidly investigate and correct the causes of out of control situations. By more effectively managing the engineering IT support process, the engineering organization can help avoid cost overrun and revenue losses.

RELEVANT LITRATURE

A literature review was conducted in order to identify past efforts related to the use of quality related tools such as statistical process control techniques for engineering information technology lifecycle activities. The resulting search identified significant activity in the areas of IT support in engineering, IT support for collaboration and coordination, IT support responsible for success in industry, and IT support for product development and maintenance. Research efforts involving quality related tools applied to information technology activities are more limited. Some effort has been made to apply quality functional deployment approaches to IT activities (Eyob, 1998). Other techniques include the examination of different organizational designs and the involvement of end users on software engineering quality and reliability (Nance, 1997). Lastly, the service quality of IT systems has also been examined using survey type instruments (Whitten, 2004). However, the use of Statistical Process Control techniques in the IT field is far more limited. In 1990, the possibility of using SPC tools to improve a decision support system was examined (Gilbert et al, 1990). The use of statistical process control techniques for defects in operating system software has also been investigated (Weller, 1995; Weller 2000). In 2000, the use of SPC was also suggested for the entire software development process (Radice, 2000). Lastly, the specific use of SPC tools in software quality control processes for reviews and testing has also been explored (Gardiner and Montgomery, 1987; Jalote and Saxena, 2002). While limited existing work has been identified in the use of SPC in the IT field, these efforts concentrate on operating systems, generic software applications, and the software development lifecycle. No relevant literature was identified specifically addressing the use of SPC techniques for engineering IT support and the engineering IT support lifecycle.

PROBLEM STATEMENT

Engineering IT support incident lifecycle activities are usually complex. Inadequate knowledge of the engineering IT support lifecycle results in ineffective responses and unnecessary expense. This situation is aggravated by the fact that there no specific tools available to systematically help to monitor and statistically control the various engineering IT support lifecycle activities.

In order to properly manage engineering IT support lifecycle activities, the life cycle activities themselves must first be determined and then these activities must be systematically controlled. By developing a Statistical Process Control system to monitor these activities, engineering IT support management can more effectively determine when a support failure is occurring. The nature and cause of the failures can then be investigated and hopefully be corrected in time. This will help an engineering company to allocate a proper budget for its IT support department and use this information in their early quotations and planning to avoid cost overrun and revenue losses.

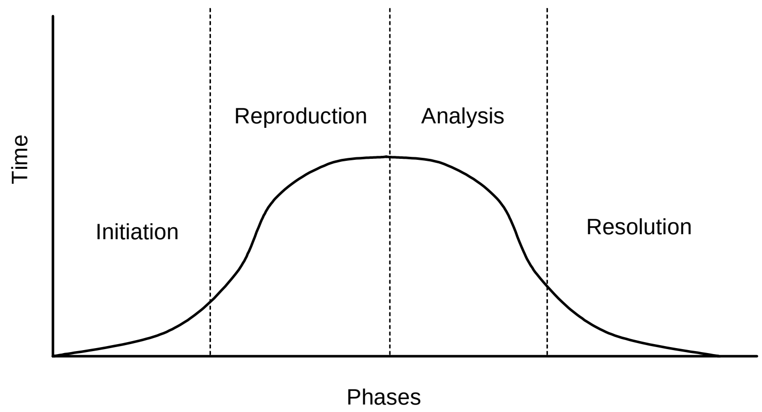
METHODOLOGY

The research methodology for this effort involved identifying common engineering IT support lifecycle activities, engineering IT support data collection and transformation, developing the Statistical Process Control chart system, and lastly validating the SPC chart approach.

Identifying engineering IT Support Lifecycle Activities

The typical project lifecycle includes conceptual, planning, execution, and termination phases. The engineering IT support lifecycle differs significantly in that these types of activities occur in what would traditionally be considered in the termination phase of a generic project. In the termination phase of a typical project, the organization typically arranges for a variety of support or maintenance oriented activities. To help identify the specific engineering IT support lifecycle activities, a number of different engineering companies were observed. These observational efforts were augmented with personal interviews with engineering IT support managers. This process indicated that engineering IT support issues can be broadly divided into four different lifecycle phases. These include initiation, reproduction, analysis, and resolution phases.

Figure 1: Engineering IT Support lifecycle.



- **<u>Initiation:</u>** This is first phase of the lifecycle. Problem initiation starts when any user of an engineering organization finds a problem/bug in the software or work processes. The user has to initiate the process of conveying the problem to the engineering IT support group. This process includes lifecycle phase elements of 1.1 opening the support worksheet, 1.2 product verification, 1.3 analyst assignment, 1.4 attempting contact with the customer, and 1.5 actually establishing contact with the customer.

- **<u>Reproduction:</u>** This is the second phase of the lifecycle. Once the problem is initiated, it needs to be understood fully and reproduced by the engineering IT support personnel. This is a very important phase as most of the time, once understood by the analyst, a simple clarification help resolve the issue but if the problem can not be reproduced at the IT support level, it is impossible to resolve the issue. This process includes lifecycle phase elements of 2.1 clarifying the problem, 2.2 searching existing knowledge databases for possible solutions, 2.3 consulting with support peers, and 2.4 attempting to reproduce the problem.

- **<u>Analysis:</u>** This is the third phase of the lifecycle. Once the problem can be reproduced, it goes into analysis phase, where it is further examined. This process consists of lifecycle phase elements for 3.1 determining the criticality of the problem, 3.2 investigating possible workarounds, 3.3 determining the impact of suggested or needed changes, and 3.4 determining the costs of the solution. If the problem affects the production and deadline, it gets elevated to the highest level of criticality. If the problem requires the changes in the work processes more departments and managers become involved.

- **<u>Resolution:</u>** This is the fourth phase of the lifecycle. In this final phase is the resolution of the problem that is mostly a discussion and delivery phase between the engineering IT support analyst and the user. This includes the life cycle phase elements of 4.1 attempting to contact the customer, 4.2 actually establishing contact, 4.3 conveying the decisions from the analysis phase, 4.4 discussing the solution with the customer including closing out the support request. In this phase, it is also determined whether the customer is satisfied with overall resolution or not. Closure of the ticket or service request only takes place with the agreement between the support analyst and the user.

Engineering IT Support Data Collection and Transformation

With the identification of the engineering IT support lifecycle phases, data was collected on the processing times for each individual element in each life cycle phase. Input data was collected from a variety of engineering companies and engineering support vendor companies. This included the engineering IT support lifecycle activities for a total of forty-seven independent projects. The processing time data for each element in each phase of the lifecycle for the individual support projects was extracted from the incident support logs and analyzed.

A few ticket or service requests took either an exceptionally long time or a very short time with no explanation given. In the case of short time incidents, the problem was discussed on phone and resolved during the first contact. Very long time incidents occurred due to several reasons. In some situations, the support analyst or the customer were out on travel. There were also some requests where the user failed to reestablished contact after opening the service request. In these situations, the requests were not properly closed. Incidents with these types of abnormalities were removed from the data set.

Another type of data was whether the support process was considered a success or a failure. A support process was considered to be a failure if the support issue could have, but did not properly conclude. Another type of failure was when the solution provided by the support analyst did not satisfy the customer. A variation of this type of failure was when a correct solution was provided, but the customer did not concur with the solution.

Statistical Process Control Chart System Development

This section includes a brief discussion of basic SPC concepts, the use of the chart of individuals approach, and the validation of the charts. More a more comprehensive discussion of the various types of SPC charts, readers are directed to any one of a number of references.

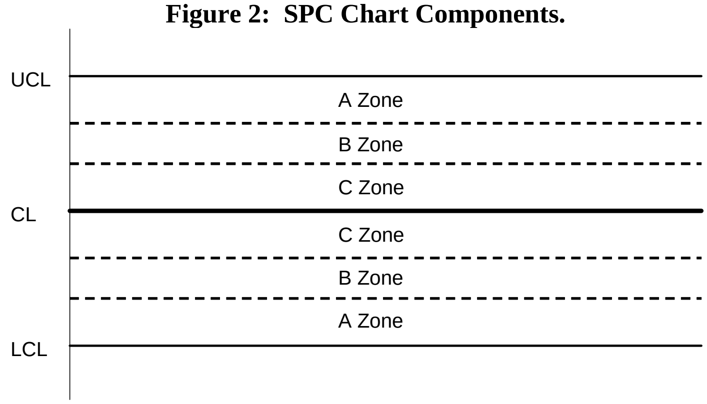
Basic SPC Concepts

The concept of the Statistical Process Control chart was developed by Walter Shewhart in 1924. The general process for utilizing a SPC system is to create a chart from historical data, plot current data, and observe the data for patterns. The basic idea is that for a stable process, a measured parameter will vary around some historical mean value. Any variation from the mean value with an in control system is attributable to normal variation in the process. A process with these characteristics is known as being in control. However, should the process exhibit unusual patterns such as a shift away from the mean value or an increase in variance, then it is considered out of control. Should the process goes out of control, the cause of the variance should be immediately investigated and corrected. Once the process is back in control, the system continues to be monitored.

SPC Chart Components

There are many types of SPC charts. Most of these charts share similar components. The typical SPC chart consists of a central line, an upper control limit, a lower control limit, and six zones. The central line is usually associated with the mean value of the parameter being measured. The upper control limit line (UCL) is generally based on the central line value plus three standard deviations. Similarly, the lower control limit is generally based on the central line value, but minus three standard deviations. Three of the zones are located between the central line and the UCL. The zone lines are based on the central line plus one and plus two standard deviations. Likewise, there are three lower zones between the central line and the LCL. The lower zone lines are the central line minus one and two standard deviations. A generic SPC chart is illustrated below.

Figure 2: SPC Chart Components.



SPC Chart Run Rules

After the chart is created, data from the process is plotted on the chart and observed for unusually patterns. If the plots exhibit any of the following patterns, then there is statistical reason for investigating the process for possible problems.

- One point beyond the A zone.
- Eight successive points on the same side of the central line.
- Six successive points that increase or decrease.
- Two out of three points beyond the B zone.
- Four out of five points beyond the C zone.
- Fourteen or more consecutive points oscillating above or below the previous point.

Figure 3 illustrates a system which is out of control. The sixth and eighth points are in the A zone. This means that the pattern contains two out of three points are beyond the B zone. The process should be immediately examined at this point to determine if there are specific causes as to why the plotted values have increased in value. If the processes are not examined, it is likely that future data points will follow the same increasing trend. Soon the process will begin to produce unusable product.

Figure 3: SPC Chart Components.

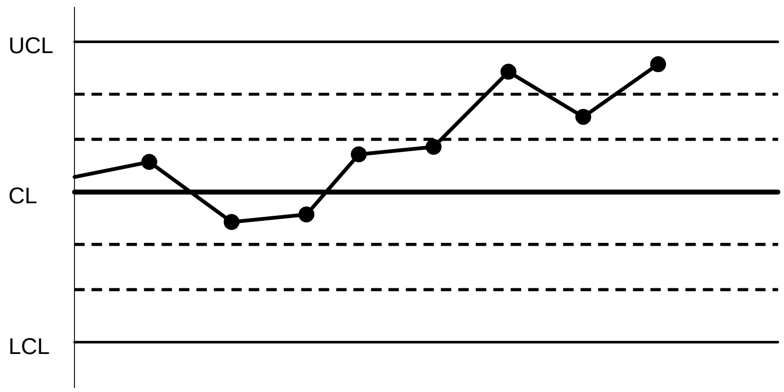


Chart of Individuals Approach

There are actually a large number of different types of SPC charts. The most common of these are the X bar chart which measures the deviation around the mean for a sample of data and the R range chart which measures the range of values for the same data. By definition, these common types of SPC charts require the ability to take a sample of data for each time observed period. Unfortunately, this is not possible with engineering IT support life cycle activities. At any given point in time, only one elapsed time observation can be made for each incident. This inherent limitation requires the use of a less common SPC approach. The chart of individuals approach utilizes the same chart components as previous described. However, the chart of individuals bases all of the chart components on individual observations rather than sample observations (Montgomery and Runger, 1999).

Calculating the Chart of Individuals Chart Components

Once the historical data was collected and properly investigated, the data was used to calculate the chart of individuals chart components. Data from twenty successful support incidents were arranged in a tabular form.

$\overline{X}$ was calculated for each elements from the collected data and s of X_i was calculated,

where,

$\overline{X}$ = Mean of the data and calculated as

$$\overline{X} = \frac{\left(\sum X\right)}{n} \tag{1}$$

and

s = Standard deviation and calculated as

$$s = \sqrt{\frac{\sum\left(X - \overline{X}\right)^2}{n-1}} \tag{2}$$

Various zones were calculated with the help of $\overline{X}$ and s as follows:

Upper limit for upper zone A, $UCL = \overline{X} + 3s$, (3)

Lower limit for lower zone A, $LCL = \overline{X} - 3s$, (4)

Upper limit for upper zone B = $\overline{X} + 2s$, (5)

Lower limit for lower zone B = $\overline{X} - 2s$, (6)

Upper limit for upper zone C = $\overline{X} + s$, (7)

Lower limit for lower zone C = $\overline{X} - s$. (8)

Run Rule Modifications for Engineering IT Support Process

The general SPC run rule patterns must be modified for analyzing out of control engineering IT support life cycle activities. This is because some of the normal run patterns that would indicate a problem situation actually have no practical significance to data that is based on cumulative time values. Following are the run rule modifications for engineering IT support process keeping in view the nature of this process:

- Negative Values: Negative data points of elements of engineering IT support has no actual significance as time taken are always a positive value.

- Below the centerline: Data points of engineering IT support below the centerline do not present a significance problem because this means that the support incident is expeditiously being resolved.

Data Transformation

The wide variance in the duration of the various engineering lifecycle elements requires that the raw data undergo significant data transformation. The first transformation is that the actual time spent on each lifecycle element for each support incident must be extracted from the raw data. This is necessary in order to calculate the summary statistics for the length of time it takes each particular lifecycle element to be completed. This means that the control chart will have as many x axis points as there are lifecycle elements. As previously discussed, there are five elements in the initiation phase, four elements in the reproduction phase, four elements in the analysis phase, and four elements in the resolution phase. Thus, there are a total of seventeen points to be plotted on the x axis. These are represented as points 1.1 through 1.5, 2.1 through 2.4, 3.1 through 3.4, and 4.1 through 4.4.

Work on an IT support issue or a service request is also not continuously active. This means that attempts to plot the actual time spent on individual lifecycle activity elements will result in unacceptably noisy plots. For this reason, it is necessary to plot cumulative time values versus absolute time values along the x axis of the control chart as the incident progresses through the support lifecycle phases (Bauch and Chung, 2001). To calculate the cumulative time for each lifecycle element, the current elapsed time is simply the previous cumulative time plus the absolute time spent on the current lifecycle element.

Another type of data transformation involves the discarding of unusual raw data. This usually occurs when some unusual activity disrupts the support lifecycle. The most common type of disruption is when either the analyst or the customer becomes unavailable for a period of time due to professional or personal reasons. This has the effect of artificially increasing the length of time for a particular lifecycle element. Because the non-typical data can adversely affect the chart parameter values it is necessary to discard this type of data.

The final type of data treatment involves determining whether each support incident was a success or failure. Only incidents that are considered successes can be used as historical data for calculating the chart parameters. This enables the statistical comparison of all future support incidents to the performance of the historically successful support incidents.

Statistical Process Control Chart Development

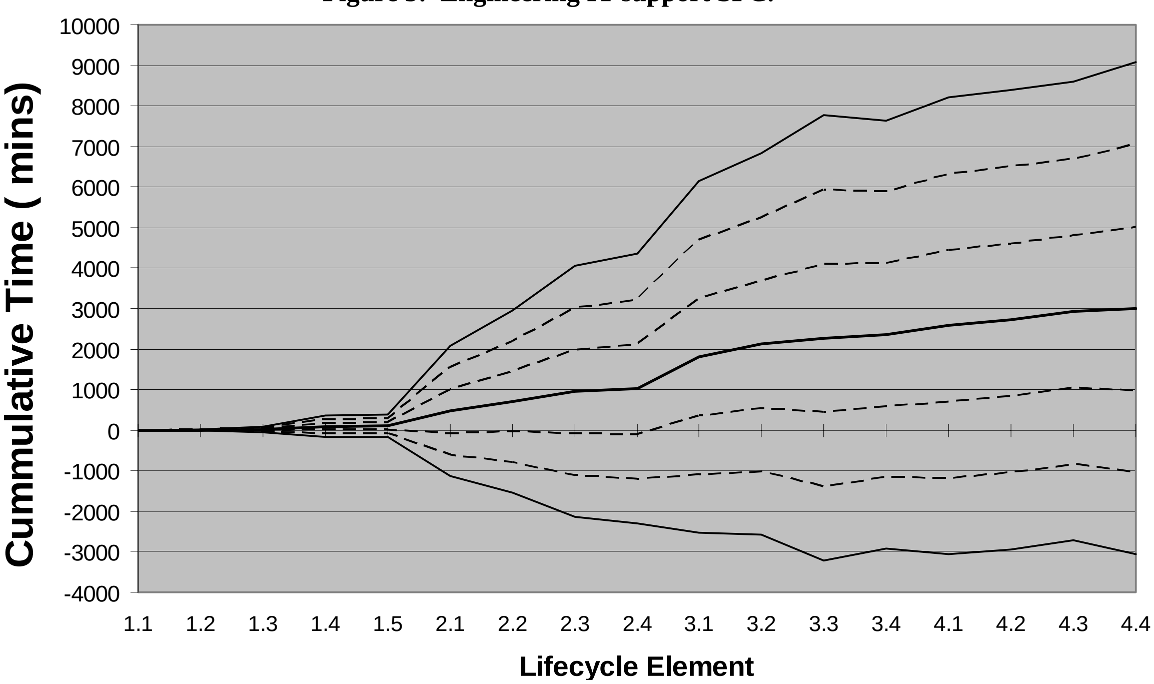
The $\overline{X}$ and S were calculated from the transformed raw data. These summary statistical values were used to calculate the chart parameters as previously described in the chart of individuals section. Figure 4 shows the values of the resulting chart parameters. Figure 5 shows the developed engineering IT support statistical process control chart.

Figure 4: SPC Chart Parameters.

	Initiation					Reproduction				Analysis				Resolution			
SN	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4
XBAR	0	2	13	97	97	472	708	951	1017	1805	2122	2277	2360	2577	2729	2934	3006
XBAR+S	0	7	35	188	189	1007	1456	1984	2127	3249	3690	4106	4122	4457	4618	4820	5029
XBAR+2S	0	12	58	280	281	1543	2203	3017	3236	4693	5257	5935	5883	6337	6506	6706	7052
XBAR+3S	0	17	80	372	372	2079	2951	4049	4346	6137	6825	7764	7644	8218	8395	8593	9074
XBAR-S	0	-3	-9	5	5	-64	-40	-82	-92	361	554	447	599	697	841	1047	984
XBAR-2S	0	-7	-32	-87	-87	-600	-787	-1115	-1202	-1083	-1014	-1382	-1163	-1183	-1048	-839	-1039
XBAR-3S	0	-12	-54	-178	-178	-1136	-1535	-2148	-2311	-2527	-2582	-3211	-2924	-3063	-2936	-2726	-3061

As previously discussed negative values have no significance as time is always a positive value. Similarly, the zone boundaries below the central line are also of less importance as activity in this area means that the incident is performing well with respect to other incidents.

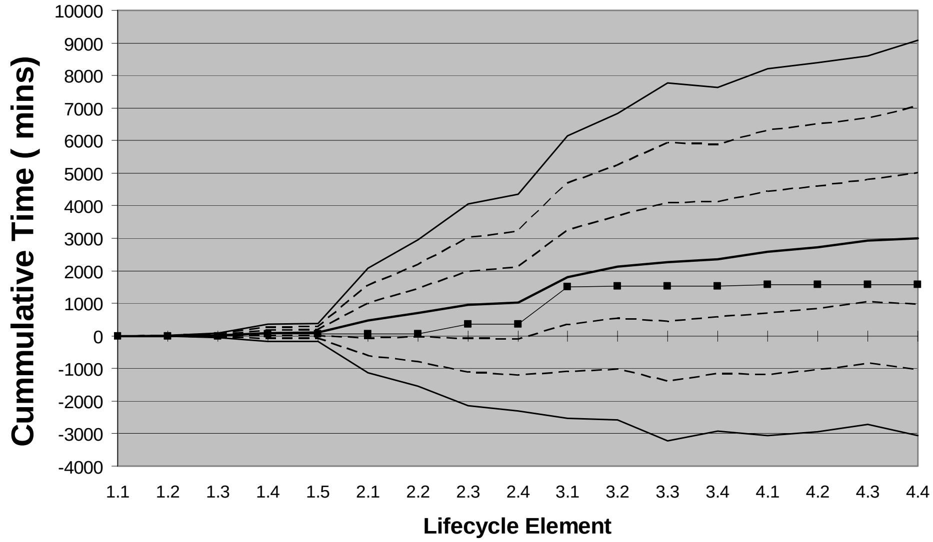
Figure 5: Engineering IT support SPC.



Statistical Process Control Application and Validation

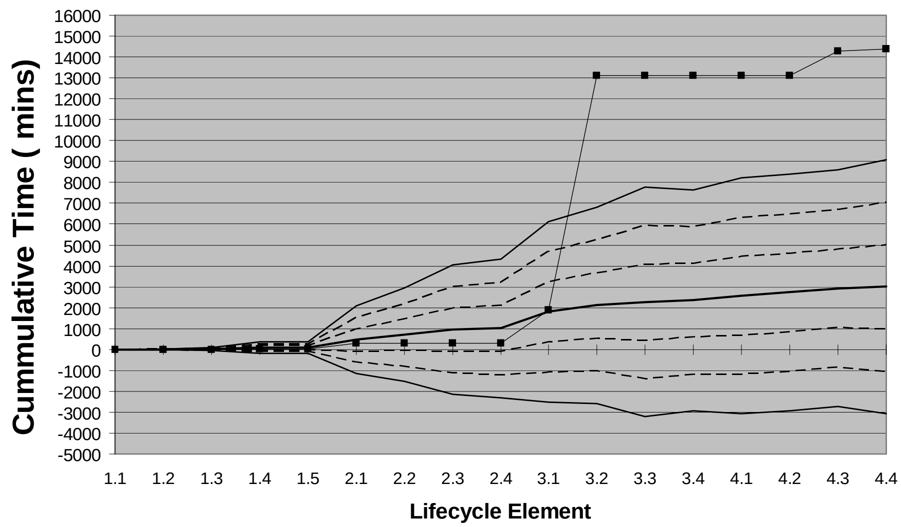
Both successful and unsuccessful support incident data sets were examined using Engineering IT Support chart to determine the validity of the chart methodology. To be valid, the chart must indicate that successful projects remain in control while unsuccessful projects are out of control. Figure 6 illustrates a representative successful project which is in control throughout the lifecycle.

Figure 6: Successful Engineering IT Support Incident.



Conversely figure 7 illustrates a representative unsuccessful project which goes out of control. At lifecycle element 3.2, the duration of the element is outside of the UCL. This indicates a catastrophic failure in the support process.

Figure 7: Unsuccessful Engineering IT Support Incident.



Limitations and Assumptions

This study analyzed the IT support in an engineering company under some constraints, which may not involve all aspects of IT support and all conditions of engineering companies. It does not necessary resolve IT and project budgeting issues that may not be directly related to engineering IT support. Assumptions were also made that during whole support process the support communications such as e-mail, Internet and other means were always available and not down for any significant working time.

SUMMARY AND CONCLUSIONS

The result of this research was very encouraging and clearly indicates that engineering IT support issue can be very well managed using statistical process control charts. This research covered mainly two important aspects, elements of engineering IT support and integrating those elements with the unique SPC chart of individuals.

With the use of these control charts engineering IT support managers can determine where the process is getting out of control and quickly determine remedial steps. They can utilize manpower effectively once they know where they have to put more effort. Thus, this work will help an engineering company to allocate a proper spending budget for their IT support department and avoid schedule delays, cost overruns and revenue losses.

FUTURE RESEARCH

The plan for future research includes further investigating and modifying current engineering IT support processes. This future research should be based on mostly implementing this work in the current work processes to help increase the effectiveness of the IT support group as in general.

Most of major engineering companies have some processes already in place for resolving their day to day IT related issues. The emphasis until now was to examine the number of issues open and closed. There was no control over the resolution process itself. By slightly modifying their existing systems, management will have a better handle on most of the major issues in the engineering IT support process.

With these future research activities and minor changes in the current work processes, the engineering IT support management will not only know the elements of interests but will be able to effectively manage both internal man power and the clients.

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