An Analysis of Predictor Variables for Operational Excellence through Six Sigma

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Abstract

Managers at the operations level use Six Sigma to improve operational parameters like reducing cycle time, increasing throughput yield, reducing defects and process variation, eliminating the hidden factory and bringing about smoothness in workflow through undertaking various stages of the DMAIC (Define Measure Analyse Improve Control) methodology. The paper aims to study the key factors that can lead to improvement in operational performance through Six Sigma projects, by using a multiple regression model. Based on a literature survey, six key factors that impact operational performance are identified. To study the factors identified through the literature review and analyze the impact factors of operational performance, ten manufacturing companies were selected for a pilot survey. The average percentage benefit post- implementation of Six Sigma on nine operational parameters was then evaluated in these ten organizations. To establish predictor variables for percentage improvement in operational parameters, a multiple regression analysis was carried out. Using this analysis, four regressor variables were found to significantly impact operational performance through Six Sigma implementation. The study has resulted in providing an effective strategic focus and direction for action plan using six sigma approach in companies to eliminate or mitigate operational inefficiencies and pitfalls that often mar their business performance.

Keywords
Six sigma, operational parameters, defects, six sigma tools, six sigma projects,

1. Introduction
Every organization's functioning can be broken down at three basic levels, the highest level is the business level, the second level is the operations level and the third level is the process level (Harry and Schroeder, 2005). While the Six Sigma methodology is applied at each level, the results achieved at each level are different though complementary. This paper studies Six Sigma application at the operations level. Managers at the operations level use Six Sigma approach to improve operational parameters like reducing cycle time, increasing throughput yield, reducing defects and variation, eliminating the hidden factory and improving smoothness and workflow through various stages of the DMAIC (Define Measure Analyze Improve Control) methodology. For example, during the Define phase, the operational goals like reducing cycle time are set up. During the Analyze and Improve phases, the focus of managers at the operations level may be on Black Belt training, project selection and use of appropriate statistical tools.

Although critical success factors of the Six Sigma methodology have been researched by various authors [Anthony2004a, Anthony2004b, Anthony et. al. 2005, Chau et. al. 2009, Cheng 2007, Revere et. al. 2006, Yang et. al. 2008], concrete analysis of factors that influence operational excellence through Six Sigma practices is lacking. The paper aims to study the key factors that can lead to improvement in operational performance through Six Sigma projects by using a multiple regression model.

2. Key Factors for Operational Excellence

In Six Sigma, operational performance may be a product of a combination of many underlying factors. Often, the solution to an operational issue is masked by an underlying support system which can blind companies to operational issues that are persistent and predictable (Harry and Schroeder 2005). Some operational benefits, that can be realized when Six Sigma process is applied, are decreased work–in-progress, improved process flow, increased productivity, improved inventory turns and reduced cycle time (Dedhia 2005). Through a literature study, critical characteristics for success at the operational level are identified.

Six Sigma projects often focus on resolving operational issues. For example, a study of Six Sigma implementation in a public sector electronics enterprise in India (Sharma and Chetiya 2010b) indicated that most deliverables of Six Sigma projects in the organization were operational parameters (Table 1).

Table1: Deliverables in Six Sigma projects in an Indian public sector unit

Deliverables	**Number of projects**
Defect Reduction	23
Customer satisfaction	3
Quality Improvement	20
Cycle time reduction	25
Cost Improvement	5
System Improvement	11
Yield Improvement	9

At the operational level, selecting the right projects becomes a key issue. At Samsung Electronics Company (SEC) for example, Six Sigma projects have contributed to an average of 50 % reduction in defects between 1999 and 2001 (Yun et. al. 2002). Tata Motors in India reported operational results like less rejection, less rework, smoother process flows and less cycle time by applying Six Sigma projects. Authors like Revere et. al. (2006), Banuelas et. al. (2006), Shanmugam (2007), Snee (2009) and, Sharma & Chetiya (2010a) have discussed the importance of the project selection process in the context of Six Sigma.

Application of the right tool mix has been discussed by many authors with respect to Six Sigma success. The authors have shown with the help of case examples how a combination of basic Six Sigma tools and more complex Shainin tools were successfully used to address the root cause of quality problems in an auto component manufacturing organization in India. Anthony & Banuelas (2002) in a study of Six Sigma success factors in organizations in UK concluded that tools and techniques is the second most important key ingredient after management commitment. A study of Six Sigma implementation in 106 firms by Lee (2002) also established statistical tool usage as important. Other authors who have discussed the importance of tools and techniques are Hahn & Doganaksoy (2006), Swanson (2007), Nicholas (2008) and Stefanko (2009).

While Six Sigma has a number of individuals trained in the five standardized belt ranked system viz. the champions, master black belts (MBBs), black belts (BBs), green belts (GBs) and white belts (WBs), the bulk of implementation of the Six Sigma projects rests on the black belts. Black belts can help do such things as reduce labor, material, cycle time and inventory and these improvements can be then accounted to validate the extent of Six Sigma returns (Harry and Schroeder 2005). According to Adams et. al. (2003) ,black belts are the best and brightest in an organization and hence the black belt selection process should be considered as a very important activity.

The measurement and improvement of processes is essential to achieve operational excellence. Process capability impacts quality and a poorly performing process can impact operational factors like cycle time, operational costs and work flow. Measuring the capability of each process that offers operational leverage would ensure that the company knows the capability of the process and hence the capability of the business. Process problems are often interconnected to operational issues, which in turn are tied to support systems that are ultimately linked to issues like customer satisfaction, profitability and shareholder value (Harry and Schroeder 2005). Process capability studies can improve all aspects of operations like cycle time, process variation and Rolled Throughput Yield (RTY). It can help determine if new equipment is capable of meeting the requirements and can also compare the capabilities of alternative equipment or machines. Motorola was the first company to recognize the importance of using process capability as a metric of operational performance with their extremely successful Six-Sigma program. Process capability studies can be used to successfully streamline a manufacturing process without any major capital expenditure.

Based on the above review, six key factors that impact operational performance are identified as:

(i) Project Selection.
(ii) Use of basic Six Sigma tools.
(iii) The black belt selection process.
(iv) Use of intermediate Six Sigma tools.
(v) Continuous process monitoring through process capability analysis.
(vi) Use of advanced Six Sigma tools.

3. Regression Model: Analysis of Predictor Variables for Operational Excellence

To study the factors identified through the literature review and analyse the impact factors of operational performance, ten manufacturing companies with the following criteria were selected for a pilot survey. The selected organizations have at least three years of experience in implementing Six Sigma and are operating at a minimum level of 2 to 3 sigma. In addition these organizations have executives trained as Green Belts and Black Belts. All the organizations have a Quality Management System (QMS) like ISO 9000 in place. And finally, the selected organizations have had significant awareness and education about Six Sigma practices among its workforce.

The ten organizations were evaluated in terms of average percentage benefit post implementation of Six Sigma on nine operational parameters. These parameters are:

(i) Reduction in Process Cycle Time
(ii) Improvement in Rolled Throughput Yield (RTY)
(iii) Reduction in operational costs
(iv) Reduction in need for inspection and supervision
(v) Reduction in rework and scrap
(vi) Reduction in set-up costs
(vii) Degree of improvement in smoothness in work flow
(viii) Increase in ROI
(ix) Reduction in Cost of Poor Quality (COPQ).

The average percentage benefit in the operational parameters as reported by the selected 10 companies in all the above parameters is shown in table 2.

Table 2: Percentage Improvement in Operational Parameters

Company Code	Average % of improvement in Operational Parameters
Comp 1	79
Comp 2	14
Comp 3	5
Comp 4	10
Comp 5	26
Comp 6	9
Comp 7	35
Comp 8	10
Comp 9	58
Comp 10	25

The companies also responded to the six factors identified through a literature study as having an impact on operational excellence.

To establish predictor variables for percentage improvement in operational parameters, a multiple regression analysis was carried out. The response variable considered is percentage improvement in operational parameters. Six regressor variables are considered to have possible impact on the response variable. These are project selection, use of basic six sigma tools, the black belt selection process, use of intermediate tools, continuous process monitoring through process capability analysis and use of advanced tools.

Table 3: Summary of Multiple Regression Model

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.991	.982	.945	5.69356

The multiple regression analysis was carried out on SPSS Version 16. The first output obtained (table 3) gives a summary of the overall model.

The summary of the multiple regression model indicates a strong association between operational benefits and the six independent variables with the correlation being a high 0.991. The Coefficient of Multiple Determination (R^2) value is approximately 98%. This implies that 98 % of the total variation in operational benefit is explained by the six independent variables selected for the study. Some prefer the value of R Square adjusted for degrees of freedom to the unadjusted value but there seems to be little advantage in doing so (Draper and Smith 1998).

The next table in the output is the ANOVA table (Table 4) for the entire model to test the acceptability of the model from a statistical perspective. To examine whether the overall regression is significant or not, we now analyse the ANOVA table. The decision to accept or reject the null hypothesis (regression is not significant) is based on the 'p' value under the column 'Sig.'. Since $p = 0.011 < 0.05$, the null hypothesis is rejected and it may be concluded that the overall regression is significant and the probability of getting these results due to chance alone is less than 0.011.

Table 4: ANOVA for significance of regression

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5191.650	6	865.275	26.692	.011[a]
	Residual	97.250	3	32.417		
	Total	5288.900	9			
a. Predictors: (Constant), Advanced Tools, Black Belt Selection, Project Selection, Basic Tools, Process Capability Analysis, Intermediate Tools						
b. Dependent Variable: Operational Benefit						

Table 5, separately examines each term in the fitted linear model:
The 'B' column in table 6 gives the intercept and the estimated coefficients of each independent variable. The remaining columns test the significance of each regressor variable in the model. The 'p' – values for project selection (0.005), basic tools (0.038), black belt selection (0.026) and continuous monitoring through process capability analysis (0.012) are less than 0.05 and these variables may therefore be considered as significant predictors of operational improvement. The 'p'-values for intermediate tools (0.09) and advanced tools (0.81) were not found to be significant.

Table 5: Analysis of Coefficients of Multiple Regression Model

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-12.000	6.973		-1.721	.184
	Project Selection	46.250	6.366	.985	7.266	.005
	Basic Tools	28.500	8.052	.607	3.540	.038
	Black Belt Selection	23.500	5.694	.409	4.127	.026
	Intermediate Tools	-22.750	9.442	-.485	-2.410	.095
	Process Capability Analysis	44.000	8.052	.957	5.465	.012
	Advanced Tools	3.250	12.409	.069	.262	.810
a. Dependent Variable: Operational Benefit						

Therefore, it may be concluded that although all the variables collectively can explain 98% of the variation in operational benefit, focusing on project selection, use of basic tools, black belt selection and continuous monitoring of processes through process capability analysis can ensure significant improvement in operational benefit.

The final output in the analysis is a normal probability (P-P) plot of the standardized residual values shown in Figure 1.

Normal P-P Plot of Regression Standardized Residual

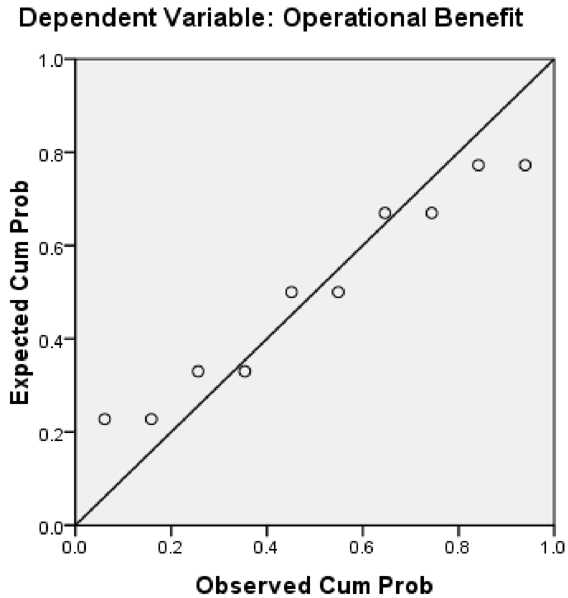

Figure 1: Plot of residuals from the model

A model that fits the data well would produce residuals that fall along a straight line (Pyzdek 2003). Since all the residuals are lying along the straight line and there are no outliers, it may be concluded that the fit of the regression model to the data is adequate.

4. Conclusion

Process related problems are hierarchical in nature and operational issues at the process level may affect business issues like profitability, market share and customer satisfaction. The model hopes to provide a more effective focus for companies to mitigate or reduce operational issues that often affect business performance. To summarize, it suggests identifying and selecting Six Sigma projects for implementation that focus on resolving operational issues which can impact profitability, utilizing the inherent power of basic statistical tools, proper selection of black belts to better leverage the knowledge of the workforce and consistent and accurate process monitoring that can be achieved through regular process capability analysis. Overall, it would be a balanced approach to include these factors to bring about excellence in operations in any manufacturing enterprise.

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Biography

Anuradha R Chetiya is Assistant Professor in the Department of Statistics, Ramjas College, University of Delhi. She completed her PhD from the Faculty of Management Studies, University of Delhi. She has presented papers at a number of conferences on six sigma methodology and implementation on which most of her research is based. She has published a number of papers in referred national and international journals. She has also authored two books in the area of quantitative techniques in management.

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