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On the optimal selection of process alternatives in a Six Sigma implementation

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Abstract

Six Sigma is at the top of the agenda for many companies that try to reduce cost and improve productivity. Many of the top manufacturing companies implement thousands of Six Sigma projects every year and this implementation demands a significant investment of capital that requires a careful analysis to make sure that the benefits obtained are much higher than the actual investment. This cost benefit analysis is crucial, especially for companies whose products have a small profit margin. In this paper, two optimization models that will assist management to choose process improvement opportunities are presented. These models consider a multi-stage, asynchronous manufacturing process with the opportunity to improve quality (scrap and rework rates) at each of the stages. The first model is to maximizing the sigma quality level of a process under cost constraint while the selection of Six Sigma alternatives to maximize process returns is considered by the second model. Process quality improvement usually results in costs associated with the purchase of new technology, modification of existing equipment, training employees, hiring new employees and investment in information technology infrastructure. The proposed models recognize that a company competes for funds and that benefits can result in either improved revenue or reduction in costs. An example illustrates the application of the optimization models developed and results show that in some scenarios implementing Six Sigma may not be financially beneficial.

Keywords: Mathematical programming; Optimal allocation; Process improvement; Six Sigma

1. Introduction

Six Sigma, a trademark of Motorola, was introduced more than 20 years back as a method to reduce manufacturing defects. The concept behind this method was developed by William Smith to deal with the high failure rate experienced by the systems produced. Smith proposed Six Sigma as a tool to improve the reliability and the quality of products and thus, focused it at reducing defects by improving manufacturing processes. Initially developed as an operational strategy, Six Sigma has evolved into a competitive corporate strategy used extensively throughout the corporate world. Even

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Nomenclature

i	ith stage of process, $i = 1, \ldots, n$
Y	Process yield
j	jth defect type for each stage, $j = 1,2$. (1 = scrap, 2 = rework)
k	kth Six Sigma implementation alternative, $k = 1, \ldots, q_i$
f_{ij}	Rate of defect type j at state i
r_{ijk}	Rate of defect type j for alternative k in state i
δ_{ik}	Decision variable related to the kth process alternative for the ith stage
I_i	Number of units that are processed at the ith stage
U	Unit selling price
c_i^m	Marginal production cost of an item at the ith stage
Q_{ik}	Implementation cost for the kth process alternative for the ith stage
S	Raw material available at the first stage
D	Process demand
B	Budget available for Six Sigma alternatives
K_i	Production capacity for the ith production stage
R_i	Amount of rework resulting from the ith stage
c_i^R	Rework cost at the ith stage
c_i^X	Scrap cost at the ith stage
Z^+	Set of positive integers

traditional companies that adhere to conventional management frameworks have started embracing Six Sigma as a method of substance with the potential to increase market share and profitability (Harry, 1998). The benefits of implementing Six Sigma programs have been extensively reported in the literature (Hendricks and Kelbaugh, 1998; Hahn et al., 1999; Lanyon, 2003; Robinson, 2005) and range from the simple reduction in the number of manufacturing defects to the improvement of the market share and the competitive advantage of a company. In this sense, Anon (2003) conducted a study of 13 high profile corporate houses in the US from a wide variety of industries and reported that Six Sigma programs returned more than double the investment.

However, as discussed by Deleryd (1999), with the increasing number of organizations using process capability studies, warnings have been launched that imprudent use of numerical measures of capability, might lead the user to make erroneous decisions. In this respect, recently there have been many cases reported in the literature where Six Sigma has failed to deliver the desired results. Zimmerman and Weiss (2005), quote a survey conducted by *Aviation Week* magazine among major aerospace companies, which reported that less than 50% of the companies expressed satisfaction with results from Six Sigma projects, nearly 20% were somewhat satisfied and around 30% were dissatisfied. Even at these levels of satisfaction, Six Sigma has been accounted to do better than many other process improvement techniques. Zimmerman and Weiss (2005) also point that 60% of the companies in the survey selected opportunities for improvement on an ad-hoc basis and only 31% relied on portfolio approach. It is interesting to note that companies that used a portfolio approach gained better results.

As illustrated in Table 1, Six Sigma is the process management tool that has yielded the greatest results (Dusharme, 2006). Moreover, the fact that in this table Six Sigma is ranked much higher than other process improvement techniques, illustrates the effect of concurrently implementing various process improvement techniques given that most of these techniques constitute the Six Sigma toolbox. This fact is important because none of the remaining quality improvement initiatives have much application outside manufacturing industry.

Although Six Sigma was originally conceived to reduce waste due to process deficiencies in

Table 1
Rating of process improvement techniques (Dusharme, 2006)

Process improvement tool	Impact (%)
Six Sigma	53.60
Process mapping	35.30
Root cause analysis	33.50
Cause and effect analysis	31.30
ISO 9001	21.00
Statistical process control	20.10
Total quality management	10.30
Malcolm Baldridge criteria	9.80
Knowledge management	5.80