# IMPACT OF SIX SIGMA ON CONSTRUCTION PERFORMANCE

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This research proposes that to implement a continuous improvement type process in construction the following requirements must be met: create a performance based environment which differentiates performance and value, run a performance based process where the risk is minimized by high performance contractors instead of the client's professional representative, and use a non-technical performance information process. Six Sigma is a rigorous process to minimize risk and deviation. The core of Six Sigma is DMAIC, define, measure, analyse, improve, and control. The result of Six Sigma will be an increased efficiency, improvement in performance, and the control of performance problems (not on time, on budget, and meeting quality expectations). Efforts in the construction industry to apply concepts of Six Sigma have been inconsequential due to a price based environment. This paper defines a performance or value based environment which processes such as Six Sigma can be implemented successfully. This is currently being tested in the United States by the Federal Aviation Administration's (FAA). The implementation of Six Sigma concepts has been difficult due to the institutionalisation of technical management, control, and inspection concepts which are not performance based.

Keywords: continuous improvement, delivery process, non-performance, performance-based, six sigma.

#### INTRODUCTION

The construction industry has attempted to solve the issues of non-performance and value for the past ten years. Previous research has identified the following:

- 1. Construction has primarily been delivered as a price based commodity and performance issues have been identified (Rylander 2001).
- 2. Solutions such as partnering, lean construction, business process reengineering, continuous improvement, and supply chain studies have not had an overall impact on the performance and value of construction (Green 2001).

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Kashiwagi, D, Chong, N, Costilla, M, McMenimen, F and Egbu, C (2004) Impact of six sigma on construction performance. *In:* Khosrowshahi, F (Ed.), *20th Annual ARCOM Conference*, 1-3 September 2004, Heriot Watt University. Association of Researchers in Construction Management, Vol. 1, 13-23.

- 3. There has been very few documented tests run using an information based best value process and information environment which competes both performance and price, where the results are measured for improvement, being completed on time, minimizing contractor cost generating change orders, and meeting the client's expectations.
- 4. When performance or best value processes are used, a performance based environment is created where the client's construction management, inspection, and control are minimized (State of Hawaii 2002).

The results of this research lead to the following possible conclusions which will be developed in this paper:

- 1. Construction risk (not being on time, not being on budget, and not meeting the client's expectations) is minimized by the client's designer, construction manager, quantity surveyor, or inspector in the price based environment.
- 2. Construction risk is minimized by the best value contractor in the performance based environment. There is very little need for construction managers or technical professionals representing the client's interest in an optimal best value environment where the performing contractor is acting in the client's best interest.
- 3. The performance based environment is process based, and the process uses non-technical information, which results in an information environment (risk assignment is clearly understood by everyone).
- 4. The performance information environment will therefore minimize the risk by assigning risk to entities that can minimize risk, and will motivate those who are not at risk to minimize their decision making, management, and control due to the assignment of risk minimization to the high performance contractor.

The hypothesis of this paper is that a Six Sigma process which minimizes risk and deviation through the measurement of performance information, may be implemented on the delivery of construction in a performance based environment. The methodology of the research includes the following steps:

- 1. Identifying the price based environment as one that requires the client to minimize the risk by use of technical expertise.
- 2. Identifying that the performance based environment requires the client to use a non-technical information based process.
- 3. Identifying that PIPS has run successfully in the performance based environment.
- 4. Defining the relationship and application of Six Sigma and the DMAIC process on PIPS.
- 5. Identifying that PIPS is a Six Sigma based process which defines, measures, analyzes, improves, and controls deviation and risk.
- 6. Proposing a methodology where construction risk and deviation can be controlled by measurements of performance and the DMAIC philosophy.

The paper introduces the following new potential concepts:

- 1. Although construction is built at the site and each project is unique, construction risk can be minimized by treating the delivery of construction with an "information worker" using a non-technical process rather than with technical professionals.
- 2. Because the delivery of construction is a process based solution, solutions using Six Sigma concepts of minimizing deviation and risk using non-technical information can be successfully implemented.
- 3. The Six Sigma concepts not only pertain to the selection of the contractor, but the method of minimizing technical management of the contractor during construction.

## PRICE-BASED ENVIRONMENT

The construction industry has been in the price-based, commodity sector for the past twenty years. Designers and engineers use technical specifications, minimum requirements, and standards to define the commodity. The combination of the lowest price and minimum standards increases the risk of construction and has resulted in the need for technically oriented construction and project managers to minimize the risk by managing, controlling, and inspecting. Another reason for the need of client's construction management is the construction industry's treatment of each construction project as being unique, with different environmental conditions, requirements, types of construction, clients, contractors, time, and cost. This rationale is reflected in the federal organizations' usage of past performance information only as a prequalification instead of a relative predictor of future performance (Brams, Schaengold, and Grandon 1999, Contractor Performance System 2001).

Characteristics of the price based environment include: an adversarial environment, low profit margins, a lack of trained personnel, a high turnover rate, and poor performance (60 - 70% on time, on budget, and meeting customer expectations and 6/7 performance ratings out of a maximum of 10) (CIB 2000, Egan 1998, Why do Contractors Fail 2003, Post 1998, Warseck 2002, Advice 2003). Some of the alternate project delivery methods which minimize the characteristics of the price based environment have been more successful (Konchar and Sanvido 1998). In 2003, the Federal Aviation Administration, US Coast Guard, and the US Army Medical Command requested a new delivery process and environment with a minimized need for management, control, and inspection than that which is required in the price based environment.

### PERFORMANCE BASED ENVIRONMENT

In Quadrant II (Figure 1), construction risk is minimized by using a non-technical process to hire and allow the best performing contractors to do the construction. In the performance based environment, the high performing contractor minimizes the risk. This goes along with the following concepts:

- 1. High performing contractors do quality control.
- 2. High performing contractors minimize the risk of non-performance with expertise.
- 3. Highly skilled contractors do not need to be managed and inspected.



Figure 1: Optimization of Construction Performance

A performance based environment motivates continuous improvement (Best Value 1998). Selection in Quadrant II is based on high performance and competition, and not relationships or low price. When competition is maximized, performance is maximized. The use of client's decision making and technical expertise (subjective decision making) are functions that are minimized in Quadrant II. Deductive logic (Kashiwagi Solution Model (KSM)) explains why a Quadrant II performance based procurement system must be a process based solution (Figure 2) (Kashiwagi 2002).



Figure 2: KSM Deductive Model of Related Information Characteristics

The deductive KSM uses the extremes of applying information to identify characteristics of a Type A (information based, predictive) and Type C (lower information usage, reactive) entity. A Type A person (Figure 2) perceiving and using information will more likely use the non-technical performance information before the construction event, selecting the best performer (competitive), influencing rather than managing, controlling, and directing the contractor (efficient), and influencing the best value contractor to measure themselves before and after the project. Deductive logic identifies the most efficient contractor as the most competitive contractor, and also a contractor who will think in the owner's best interest and deliver best value. This is a process of selection using non-technical performance information rather than using technical information to manage the contractor.

The biggest difference between the price based and performance based environments is who minimizes the client's risk. If movement is made from the price based to the performance based environment, the following actions are required:

- 1. Utilizing a method to measure the past performance and capability of contractors to minimize risk on the future project.
- 2. Utilizing a method to identify value (performance and price).
- 3. Moving the risk to the contractor and making the performing contractor minimize the risk of construction as much as possible before constructing.

#### PERFORMANCE INFORMATION PROCUREMENT SYSTEM (PIPS)

PIPS has been developed and tested over the last ten years on 380 tests of construction (\$230M). PIPS is a selection process which selects the best value contractor based on past performance, ability to identify and minimize risk before construction, and price. PIPS has been very successful (98% on time, no contractor generated cost change orders, and meeting the customer's expectations). Statistical studies have shown that PIPS has been rated approximately 40% more successful than low bid (99% confidence limits) by clients who have used both processes (Parmar 2004). PIPS was tested by private industry clients as well as federal and state government clients. The importance of the PIPS tests includes the following factors:

- 1. PIPS does not use technical information in the selection of the best value contractor.
- 2. PIPS does not require the project manager to have a technical background.
- 3. PIPS allows the client to participate with the client's professional representative.
- 4. There are no technical submittals by the contractors in the selection process.
- 5. There is no need for prequalification.
- 6. It is a process that identifies who can best minimize the risk in terms of the client's understanding (cost, time, and expectation).

It is a process based solution. It uses an information environment to identify relative non-performing contractors, which results in the non-performers being noncompetitive. It minimizes risk by making the performers more competitive.

The following conclusions can be made:

- 1. PIPS is a non-technical process based solution to construction risk.
- 2. PIPS has been run in a performance based environment.
- 3. A performance based environment can be created.
- 4. A nontechnical process based solution can be used in the performance based environment.

# SIX SIGMA DMAIC

Six Sigma is traditionally known as a standard deviation, which is the average distance or deviation from the optimal or expected. "The roots of Six Sigma as a measurement standard can be traced back to Carl Frederick Gauss (1777-1855) who introduced the concept of the normal curve. Six Sigma as a measurement standard in product variation can be traced back to the 1920's when Walter Shewhart showed that three sigma from the mean is the point where a process requires correction... Many measurement standards (Cpk, Zero Defects, etc.) later came on the scene but credit for coining the term "Six Sigma" goes to a Motorola engineer named Bill Smith...In the early and mid-1980s with Chairman Bob Galvin at the helm, Motorola engineers decided that the traditional quality levels -- measuring defects in thousands of opportunities -- didn't provide enough granularity. Instead, they wanted to measure the defects per million opportunities. Motorola developed this new standard and created the methodology and needed cultural change associated with it" (http://www.isixsigma.com/library/content/c020815a.asp).

"Six Sigma is a rigorous and disciplined methodology that uses data and statistical analysis to measure and improve a company's operational performance by identifying and eliminating 'defects' in manufacturing and service-related processes. Commonly defined as 3.4 defects per million opportunities, Six Sigma can be defined and understood at three distinct levels: metric, methodology and philosophy..." (www.isixsigma.com). Six Sigma's rigorous process (metrics, methodology, and philosophy) of minimizing the number of defects can be applied to any process based solution (Elliot 2003). DMAIC, is a Six Sigma process to define, measure, analyze, improve, and control (Pande, Neuman, and Cavanagh 2000). Six Sigma is being used to optimize processes and minimize waste, bring innovation, and changing behaviour (http://www.6sigma.com/WhatWeDo.htm). Six Sigma uses the philosophy that if you can measure the number of defects, you can next identify what causes it and eliminate the cause by changing the process.

To apply DMAIC, a process must be defined, measured (in terms of deviation and risk), analyzed to identify the cause of risk, improved, and controlled. Control means "An 'in statistical control' process...that is free of assignable/special causes of variation. Such a condition is most often evidence on a control chart which displays an absence of non-random variation" (http:// www.isixsigma.com / dictionary / Control-48.htm).

# PIPS AND DMAIC

PIPS was created and tested in 1992, and continually tested and modified from 1994 to the present (Kashiwagi 2004). PIPS will first be analyzed to identify if it meets the requirements of DMAIC, to show the influence of DMAIC on PIPS, and to identify if the DMAIC explanation can be used to explain the results of PIPS. The major components of the PIPS process can be defined as:

- 1. Measurement of past performance (metrics).
- 2. Selection of the best value contractor using performance information (methodology).
- 3. Construction.

4. Integration of construction performance measurement on the unique project on the contractor's future competitive performance measurement.

Measurement occurs in:

- 1. Past performance information.
- 2. The ability to identify, prioritize, and minimize risk.
- 3. The relative value when considering general ability to perform and the ability to perform on the current unique project.
- 4. The contractor's ability to manage the risk of their project by proper documentation.
- 5. The contractor's performance after the project is completed.
- 6. Modification of the contractor's past performance rating.

Modifications to PIPS were influenced by the philosophy of DMAIC. The first step after considering DMAIC was to explain PIPS in terms of DMAIC. Figure 3 was created to visualize the process in terms of DMAIC.



Figure 3: Definition of PIPS Process

The measurement aspect of PIPS was made more important. Contractors and critical elements were requested to identify their identity based on measurements. They were given the responsibility for measuring their own performance. The measurement of value was simplified in terms of the best value, and the deviation from the best value in terms of risk for the project.

The process was analyzed in terms of defects resulting from the process. The low number of defects or projects which had large risk verified that we had selected the right measurements, in the right order, with the proper granularity. It was realized that the process could be modified to fit client's requirements without increasing the number of defects. When PIPS was first tested, the Information Measurement Theory concepts of minimizing bias were strictly enforced. With the understanding of risk and defects, steps which did not substantially increase risk were implemented in order to permit more clients to use PIPS without increasing risk or defects. This allowed the process to be more efficient (use less resources). The improvement in the process came with the understanding of what caused risk. Changes included:

- 1. The contractors were given the task of contacting their own references.
- 2. The contractors' references were not checked until the selection of the best value, and then only a few references checked of the best value contractor.
- 3. A subjective decision was inserted into the process, allowing an override of the best value selection based on additional information not in the process.
- 4. The documentation of risk was moved from the client's representative to the contractor.
- 5. The contractor was given the responsibility to manage the project by risk identification and minimization.
- 6. Another important addition influenced by DMAIC was the measurement of the contractor's performance during the project by measuring the number of times the contractor submits the risk assessment in a timely fashion, and the times the report is accurate.

The PIPS process is self regulated and controlled. For example, if a contractor exhibits higher risk on a project based on their performance measurements, the client directs the contractor to minimize the risk in greater detail during the pre-award period. The only way to override the control of the process is for the client's representative to ignore the performance information and start managing, controlling, and directing the contractor. The risk documentation by the contractor is implemented to identify any trend or external source of variation that may lead to risk of the contractor. These factors can then be considered to not penalize the contractor for risk caused outside of their control.

# FACILITY MANAGEMENT PERFORMANCE INFORMATION SYSTEM (FMPIS)

Preliminary results show PIPS as a process that minimizes variation and the risk of construction risk (State of Hawaii report 2002, Parmar 2004). DMAIC also identifies that risk can come from sources outside the control of the process. The client and client's representative have already been identified as a source of risk to the contractor's performance. Although the documentation of the risk protects the contractor by identifying the sources of variation, DMAIC is also used to identify a possible structure to minimize the variation of performance in the client's organization.

Using the placement of minimal risk information, it is proposed that the same information environment which minimizes variation in the contractors' performance can be used to minimize the risk of technical decision making in the client's organization. Figure 4 shows a proposed Facility Management Performance Information System (FMPIS) on a three tiered client's organization. The structure requires the following:

Contractor risk information is sent to a central database by an attachment to an email. The attachment is removed and put into a database that sorts the project based on the risk information. The database will perform two functions:

- 1. Identify to the facility manager (FM) the performance line of the entire organization in terms of number of projects, total cost, change order rate, on time percentage.
- 2. Identify which projects are at risk with the accompanying contractor and project manager.



Figure 4: FM Information System

This information system puts the project or branch managers at risk. Because this information does not require any actions internally, project managers will react by minimizing the risk of being identified as non-performers by either hiring better performing contractors or giving more attention to the non-performers.

The objective of FMPIS is to have project managers measure their performance, minimize their decision making, hire the best contractors, facilitate performance, and minimize their risk by identifying which contractors are low performers. The project managers will take on the appearance of leaders who influence instead of manage and direct (Maxwell 1998). In this way, the entire FM organization performance can be measured. Each component of the client's and contractor's organization will measure performance, minimize risk by deferring to the expert, and minimize decision making and management.

### CONCLUSION

PIPS, a performance based process, has been successfully tested. The performance based environment has been identified. The solution is a process based solution. PIPS is a process based solution (instead of a technical based solution.) PIPS fits the definition of a process that uses the DMAIC solution. PIPS has been improved by the DMAIC philosophy and process. The DMAIC solution also adds a new component to the process (FMPIS.) Current research projects with the FAA and USAMC are testing the application of the FMPIS. The objective of the process is to motivate the FM's personnel to move from a technical solution to a process solution, and allow the performing contractors to minimize risk. Unless the measurement of performance, the analysis of the measurements, and the improvement shown by measurements, are identified, it will not be possible to identify construction value. DMAIC processes cannot be successfully implemented in the price based environment because measurements and continuous improvement and minimum standards are not compatible. For DMAIC to be successfully implemented, a performance based environment must be created using repeatable processes using performance measurements.

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