Proceedings of the 2010 Industrial Engineering Research Conference
A. Johnson and J. Miller, eds.

The Value of Industrial Engineers in Lean Six Sigma Organizations

Dr. Erick C. Jones
University of Nebraska-Lincoln
Lincoln, Nebraska

Dr. Michael W. Riley
University of Nebraska-Lincoln
Lincoln, Nebraska

Trevor Battieste
Vought Aircraft Industries, Inc.
Dallas, Texas

Abstract

Many organizations utilize Lean Six Sigma (LSS) Organizational deployment strategies to drive business success. LSS techniques are focused on creating bottom-line business results using data driven solutions. Industrial Engineering has always been a discipline that has trained engineers to seek solutions using 1) data collection techniques, 2) statistical data evaluations, and 3) economic impact evaluations. The Industrial Engineer's (IEs) education in time study and work measurement, multivariate statistics and probability, and engineering economy has provided the groundwork for this knowledge. This transcript describes a framework for how Industrial Engineering can support the many traditional (Champion, sponsor, Master Black Belt, Black Belt, and Green Belt) and nontraditional roles (financial representative, statistician, change agent, and activity-based accountant) within Six Sigma Organizations as well as the linkages between these roles. This research provides the IE and the organization a guide to further utilize IEs as a resource that supports bottom line business results.

Keywords
Lean Six Sigma, Industrial Engineering discipline, DMIAC, DFSS, data collection, statistical evaluation, economic impact evaluation

1. Introduction
Lean Six Sigma (LSS) is a methodology that allows organizations to "maximize shareholder value by the fastest rate of improvement in customer satisfaction, cost, quality, process, speed, and invested capital" [1]. There are several approaches that can be utilized by LSS such as DMAIC, DMADV, or IDOV. The Define Measure, Analyze, Improve, and Control (DMAIC) methodology utilized by Six Sigma is employed to reduce the resources wasted within existing processes [2]. To design a new product to be Six Sigma quality, the Design for Six Sigma (DFSS) approach is needed; this process operates on either the Define, Measure, Analyze, Design and Verify (DMADV) or IDOV (identify, design, optimize and validate) methodology.

2. Background
The standard improvement model of the Lean Six Sigma is DMAIC. The *define* phase establishes the project goal and defines the resources needed for the project. In the *measure* phase, the details of the process are measured. In the *analyze* phase, various root causes for the problem are identified and statistical data analyses are conducted to find the most important root causes of the problem. The root causes identified in the *analyze* phase are then improved upon in the *improve* phase. During the *improve* phase, it must be determined through the use of facts and data whether the solution found is viable. An organization utilizing Six Sigma makes changes in the process to attain the goal that was identified during the *define* phase. During the *improve* phase, the solutions are implemented to prevent the problems from reoccurring. During the various phases, a variety of tools including statistical evaluations are utilized [3]. These tools and how to use them are taught in various courses in Industrial Engineering (IE) curriculum. The knowledge and skills taught in the IE curriculum enables the Industrial Engineers to play a variety of roles in

Six Sigma. The purpose of this paper is to describe the relationship between the IE academic curriculum, the variety of roles played by the Industrial Engineers in Six Sigma organization, and the variety of engineering analysis tools used.

3. Aspects of Lean Six Sigma

There are three important aspects of an LSS project: data collection, statistical analysis and evaluations of data collected, and the statistical evaluations. Data collection is an important aspect of any type of research study. There are two types of data collection techniques: quantitative and qualitative. Quantitative data collection utilizes numerical and statistical processes to answer specific questions [3]. Statistical data analysis can result in descriptive measures (mean, mode, median, range, and standard deviation) or inferential measures where numerous hypotheses can be tested. Statistics can be used in a variety of ways to support inquiries or program assessments/evaluations. Data can be collected in a variety of ways such as through experimentation. Qualitative data is obtained through methods such as interviews, on-site observations, and focus groups that are in narrative rather than numerical form [4-7] and is then analyzed by searching for themes and patterns. The second feature of a LSS project is performing statistical evaluations on the data collected to predict the results. Some of the tools used in the statistical evaluations are regression analysis, control charts, scatter plots, and ANOVA. The final aspect of an LSS project is to provide results of the statistical evaluation. In this phase, the important causes of the problems, the economic impact of these issues, and the methods to reduce and control these issues are provided. The Industrial Engineering discipline trains Engineers in all these aspects through the various courses throughout a typical undergraduate degree program.

4. Roles in Lean Six Sigma

The different roles in a Six Sigma project are shown in the Figure 1. The Executive Leadership role is fulfilled by a person who sets a vision and direction for the project. In most cases, this role is filled by a top level executive or manager. Champions are the leaders of the implementation of the project. This role can be filled by a district manager or senior manager. The financial backing required by the project is provided by the sponsors. The Master Black Belt is the person who can teach, consult or lead the technical aspects of a Six Sigma project. Black belts and Green belts are typically the ones who lead or support the project.

Figure 1: Role in Six Sigma Projects.

5. Academic Discipline

5.1 Aspects of the Lean Six Sigma

The courses offered in the Industrial Engineering discipline enables the Engineers to handle the three aspects of LSS. First, IE's are prepared for data collection by the education in time study and work management. Furthermore, the procedure to setup the experiments is aided by the study of Design of Experiments. Second, IE's are educated on the statistical evaluation tools through multivariate statistics and probability courses. Third, senior capstone courses prepare the IE to make recommendations based on project assessment.

5.2 Roles in Lean Six Sigma

The traditional roles (project manager, data analyst, continuous improvement engineer, etc.) of an Industrial Engineer are the same roles that the Six Sigma organizations assign to the Black Belt, Master Black Belt, or Champions. The academic education of an Industrial Engineer provides a sufficient background to enable them to perform these roles. Some additional education may be helpful to prepare Engineers to play the roles as champions, statistical evaluator, and economic justifier.

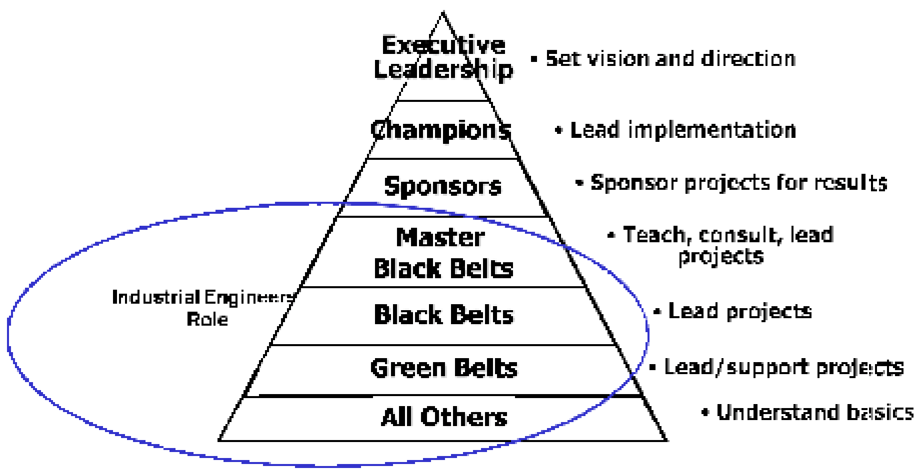

Figure 2: Role of Industrial Engineers in Six Sigma Projects

6. Industrial Roles

Industrial Engineers (IE) are also trained in basic engineering and additional courses which enable them to act as a change agent. The various tools used in LSS are part of the IE curriculum. Many IEs suggest that LSS is nothing more than using IE tools to focus on financial performance instead of efficiency improvement. The versatile nature of the Industrial Engineers helps them to perform in any part of the LSS projects. Also many tools used in the Six Sigma like flowcharts or cause and effect diagrams are included in most IE academic curriculum.

7. Six Sigma/Industrial Engineering Interface Framework

In this paper, we introduce a Six Sigma/Industrial Engineering Interface Framework (SS/IE IF). The framework describes three components that relate Six Sigma initiatives with Industrial Engineering. The components include:

1. Six Sigma Industry Interface
2. Six Sigma Industrial Engineering Academic Interface
3. Six Sigma Industrial Engineering Specialized Knowledge Interface

We describe those components and demonstrate how the framework can reveal the value of using IEs in all of the Six Sigma roles. **The Six Sigma Interface** shows the DMAIC process and the specific tools that are utilized in those steps. These tools have been envisioned to support the successful implementation of Six Sigma projects. Most of the tools described are taught in an IE undergraduate program and most IE and Engineering Management (EM) curriculums. Table 1 shows the tools typical taught to IE's that allow an industry to execute Six Sigma DMAIC. Typically, the Lean aspects of Six Sigma or the Lean in Lean Six Sigma are demonstrated in the *control* phase. Specifically, the Lean tools include 5-S, TPM, Mistake Proofing, Visual Systems, and Value Stream Mapping.

Table 1: Six Sigma Industry Interface

DEFINE	MEASURE	ANALYZE	IMPROVE	CONTROL
Interview Process	Hypothesis Testing	Process Capability Analysis	Factorial Design of Experiments	Control Plans
Language Processing	Analysis of Variance	x-y Map	Fractional Factorials	Visual Systems
Prioritization Matrix	Quality Function Deployment	FMEA	Data Mining	5-S
System Map	Flow down	Multi-Vari Chart	Blocking	TPM
Stakeholder Analysis	Measurement System Analysis	Chi- Square	Response Surface Methodology	Mistake-Proofing
Though Process Map	Graphical Methods	Regression	Multiple Response Methodology	SPC/APC
Value Stream Mapping	Process Behavior Charts	Buffered Tolerance Limits	Theory of Constraints	

The **Six Sigma Industrial Engineering Academic Interface** describes the general academic classes that cover the topics and theory that support the CORRECT use of the Six Sigma Tools. The premise is that to correctly use tools such as regression, multi-variable analysis, and statistical process control (SPC), it is important to have foundational knowledge of calculus based statistics. Classes such as engineering statistics (descriptive, hypothesis testing, inferential), applied statistics (ANOVA, Regression, Design of Experiments), and statistical quality control allow for mastery of these tools. Industrial Quality Control focuses on capability ratios whereas Applied Statistics and Quality Control focuses more on control charts. Oftentimes many pundits who criticize Six Sigma identify that most statistical components are not correctly used or understood, minimizing the effectiveness of these tools. Utilizing IEs in the execution of these tools would provide a higher probability of using these tools correctly and better results for Six Sigma projects and initiatives. Table 2 shows the interface between the Industrial Engineering Academic curricula and the Six Sigma process. The course names used in this study are typical course names and are used to represent courses that are typically available in IE undergraduate and graduate programs. Additionally, some courses such as project management and advanced classes in Engineering Economics may be provided as a graduate class in IE departments. These courses would teach the student how to perform a stakeholder analysis which is commonly used in the *define* phase.

Table 2: Six Sigma Industrial Engineering Academic Interface

DEFINE/ ACADEMIC DISCIPLINE	MEASURE/ ACADEMIC DISCIPLINE	ANALYZE/ ACADEMIC DISCIPLINE	IMPROVE/ ACADEMIC DISCIPLINE	CONTROL/ ACADEMIC DISCIPLINE
Project Management, Engineering Management, Industrial Quality Control, Engineering Economy	Applied Statistics and Quality Control, Engineering Statistics and Data Analysis,	Industrial Quality Control, Engineering Statistics and Data Analysis, Applied Statistics and Quality Control	Quality Engineering: Use of Experimental Design and Other Techniques, Engineering Statistics and Data Analysis	Industrial Quality Control, Applied Statistics and Quality Control

The **Six Sigma Industrial Engineering Specialized Knowledge Interface** as shown in Table 3 highlights the special knowledge of the Industrial Engineer. IEs can also participate in Six Sigma in specialized roles that can support SS initiatives. Some Six Sigma organizations create specialized positions that assist them in successfully implementing Six Sigma. Some of these positions include statistics specialist, Lean specialist, and leadership liaison (or change agent). Separating these roles from traditional Six Sigma roles provides an organization the ability to supplement their Six Sigma process. An additional role not shown is Economist, which is a role in which the specialist evaluates and verifies the earnings or savings for the project. This role would typically work in close partnership with accounting.

Table 3: Six Sigma Industrial Engineering Specialized Knowledge

SPECIAL KNOWLEDGE	INDUSTRIAL TOOLS	ACADEMIC COURSES
Statistics	Multi-Vari Chart, Chi- Square, Regression, Factorial Design of Experiments, Measurement System Analysis. [3]	Applied Statistics and Quality Control, Engineering Statistics and Data Analysis,
Lean	5-S, TPM, Mistake-Proofing. [3]	Industry Quality Control, Applied Statistics and Quality Control
Leadership	Value Stream Mapping, Though Process Map, Stakeholder Analysis, System Map, Interview Process, Prioritization Matrix. [3]	Project management, Engineering Management, Industry Quality Control, Engineering Economy

The **integration of the job functions and opportunities for IEs in Six Sigma** is not included in our framework, but it is an important component for Industrial Engineering visibility in Six Sigma organizations. This integration is shown in Table 4. Six Sigma is based upon the Plan Do Check Act (PDCA) premise. We show how different job functions are identified under both PDCA and Six Sigma steps to show the flexibility of the frameworks use for non-Six Sigma organizations. Overlaying this table with the other tables describes how the IE who seeks these positions can identify the skills they learned and can utilize them in those job functions. For example, if an IE works as a CEO, he/she will use skills learned in engineering management. This table also suggests that those skills will allow one to effectively perform the stakeholder analysis that is aligned in the *define* phase when executing Six Sigma events.

Table 4: Job Functions of Industrial Engineering in Six Sigma Industry

PLAN	**DO/CHECK**	**ACT**
DEFINE	MEASURE/ANALZE/IMPROVE	CONTROL
CEO, COO, Plant Manager, Project manager, Operations Manager	Project manager, Engineer, Consultant, Programmer	IE Consultant, Safety Engineer, Ergonomist

8. Implementation of the framework

We demonstrate examples of how to use the framework. For example, a CEO (Table 4) who represents the Six Sigma role of executive leader (Figure 1) would use project management (Table 2) knowledge in the *define* stage (Table 3) as seen in Figure 3. In addition, the leader may use an interview process (Table 3) as special knowledge for leadership. A specific example is the CEO leading an executive round table using interview process.

CEO	⇒	Define	⇒	Project Management	⇒	Leadership
Table 4		Table 1		Table 2		Table 3

Figure 3: Example 1 of how to use the framework

An another example is that IE Consultant (Table 4) using their industrial quality control (Table 3) knowledge to perform as a Lean Trainer (Table 1) in *control* phase of the Six Sigma project as seen in Figure 4.

IE Consultant	⇒	Control	⇒	Industry Quality control	⇒	Lean
Table 4		Table 1		Table 2		Table 3

Figure 4: Example 2 of how to use the framework

9. Proposed Study

A test instrument will be utilized to test the validity of this framework. The questionnaire will be used to quantify what roles an IE has at the SS Company, which tools they utilize, and which job function or title they have at the company. The test population will include personnel who work at Six Sigma companies and participate in one of the active roles described in the paper. Additionally, a second instrument will be utilized to verify the IE curriculum and body of knowledge outlined in this paper. A sample set of IE programs will be evaluated by their posted curriculum and interviews from various faculty and department heads of IE departments. At the conclusion of the analysis, the framework will be updated so that it provides an accurate depiction of IE/SS interface.

10. Conclusion

Many courses in the Industrial Engineering discipline provide the foundation for various roles in Six Sigma initiatives that are implemented in many companies. This paper describes how the foundational knowledge that is important in Six Sigma is supported by the coursework provided in most IE curriculums. We also describe how typical role and or jobs that are associated with Six Sigma are related to IE curricula or IE body of knowledge. We provided an Industrial Engineering/Six Sigma Interface Framework that shows how the Six Sigma roles utilize the IE body of knowledge in order to use the standard Six Sigma tools. This paper also provides a path forward for organizations that seek to extend Six Sigma with DFSS and move towards new process and product development using the IE body of knowledge.

This paper shows how the IE field has provided a critical foundation to Six Sigma. It can be implied that the IE body of knowledge has been reorganized and marketed to create Six Sigma given that Six Sigma foundation is based upon Plan, Do, Check, and Act principles popularized in the IE field. All IEs should be able to utilize this document to demonstrate that IEs can play a critical part to successful Six Sigma initiatives at most companies. The framework shows that IEs can play all Six Sigma roles and additional roles such as statistician, Lean leader, Economic auditor and consultant. This framework should be used to ensure that IEs can market and demonstrate the skill set during Six Sigma initiatives.

References

1. Geroge, M.L. 2002, Lean Six Sigma: combining Six Sigma quality with lean speed, McGraw-Hill Companies, Inc.
2. Yang, K., Haik, B.E., 2009, Design for Six Sigma: A Roadmap for Product Development, 2nd edition, McGraw-Hill Companies, Inc.
3. Pyzdek, T., Kellere, P., 2009, The Six Sigma Handbook, 3rd edition, McGraw-Hill Companies, Inc.
4. Steckler, A., McLeroy, K.R., Goodman, R.M., Bird, S.T., McCormick, L., 1992, Toward Integrating Qualitative and Quantitative Methods: An Introduction, Health Education Quarterly, 19, 1-8.
5. Patton, M.Q., 1990, Qualitative Evaluation and Research Methods, 2nd ed, Sage Publications, Newbury Park, USA.
6. Maxwell, J., 1996, Qualitative research design: An interactive approach, Sage, Thousand Oaks, CA.
7. Patton, M., 2002, Qualitative research & evaluation methods, 3rd edition, Sage, Thousand Oaks, CA.