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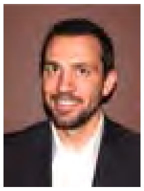

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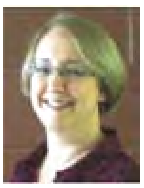

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Abstract

The purpose of this paper was to research the timeliness of completing Lean Six Sigma Green Belt DMAIC projects. The purpose of this study was based on a descriptive study of internal company data of Lean Six Sigma projects. The results of this study revealed that the actual duration was significantly longer than the planned duration. The DMAIC phases of projects differ significantly by planned versus actual duration. The study was limited to a single location of a large manufacturing company that has started Lean Six Sigma. As a result, the sample size at the time of the study is fairly small. Only Lean Six Sigma projects where accredited Green Belts were involved in the study. Improved project management practices ought to improve initial project planning and portfolio management of Lean Six Sigma projects. Recognition of the unique outcomes required by individual phases for timely completion of Lean Six Sigma project is recommended. More study of Lean Six Sigma effectiveness based upon company data would be valued by the Lean Six Sigma community. This study adds to the limited published literature of Six Sigma Green Belts: a crucial area of Lean Six Sigma deployment within industry.

Lean Six Sigma Green Belt Projects Planned versus Actual Duration

Since its introduction at Motorola, companies around the world have adopted Six Sigma as a way of achieving process excellence. Six Sigma is now practiced widely within 82 of the 100 largest companies in the United States (Bloomberg, 2007). Six Sigma is now deployed across a wide variety of functions and companies such as manufacturing, procurement, nursing, engineering, medical laboratories, and warehouses. A typical description of Six Sigma is a disciplined and quantitative approach involving systems and process improvement for manufacturing or services with an overall statistical approach of selecting the right projects based on an organizational goals for dramatic results (Sharma & Chetiya, 2010; Linderman, Schroeder, Zaheer, & Choo, 2003). Encompassing the Six Sigma approach is a framework called Process Excellence (Montgomery, 2010).

Within the Process Excellence framework, this research focused on a large manufacturing company implementing Six Sigma. This company locates Six Sigma within the organization's Process Excellence goal to identify specific issues that prevent the organization from increasing overall customer satisfaction through target areas of quality, delivery, and cost. Use of Process Excellence supports identification of specific opportunities of improvement that contribute to better process understanding. In turn, implementation of improvement projects was conducted at the company business location level. To enhance these goals, the company includes Lean principles within the Process Excellence framework for an integrated Lean Six Sigma strategy, a practice adopted by many large organizations (Tjahjono, Ball, Vitanov, Scorzafave, Norgueira, Calleja, Minguet, Narasimha, Rivas, Srivastava, & Yadav, 2010). After an initial deployment of Lean Six Sigma, the purpose of this paper was to determine Lean Six Sigma implementation at this location. Since the Process Excellence framework included substantial Green Belt focus, this study focused on Green Belt Lean Six Sigma project efficiency. This efficiency was defined by the timely completion of Green Belt projects.

Research Question

At this business location, Process Excellence follows four overall areas including process basics, process control, process flow, and zero defects (Large manufacturing company, 2011). Lean Six Sigma is central to this framework where the number of improvement projects is predicted to grow substantially in the future. This predicted growth requires the company's Lean Six Sigma approach to operate more efficiently. The focus of this research was to answer the following questions:

RQ1: How long do Lean Six Sigma Green Belt projects take as compared to original project plans?
RQ2: Do DMAIC project phases differ significantly with regard to timeliness?

The Lean Six Sigma timeliness problem is significant because the full speed of return is not realized (George, Rowlands, & Kastle, 2003). At the time of this study, the percentage of Lean Six Sigma Green Belt projects completed based upon the company's definition of timeliness of three to six months is currently 36 percent at this location (Large manufacturing company, 2011). The key focus for this location is to gain a greater understanding of the business costs and improve customer satisfaction through better project completion (Large manufacturing company, 2011).

Literature Review

Six Sigma

Six Sigma may be described as a methodology for pursuing continuous improvement in customer satisfaction and profit that goes beyond defect reduction, and which emphasizes business process improvement (Schroeder, Linderman, Liedtke, & Choo, 2007; Breyfogle, 2003).

The strategy involves a concentrated level of measurement on the health of business processes through identification and reduction of variation for improvement (Schroeder et al., 2007). All business functions may be included resulting in common areas of cost reduction, lower cycle times, and improved levels in product and process quality (Breyfogle, 2003). Six Sigma (SS) has changed over time from a quality engineering function to an overall business improvement methodology (Snee, 2004). Areas within SS include statistical techniques, operations management, and change culture (Tjahjono et al., 2010). SS benefits include improved levels of product and process quality through a focused process approach (Mehrjerdi, 2011). SS focuses on customers through active leadership for overall organizational improvement (Zhang, Hill, and Gilbreath, 2011). SS's origins in manufacturing supported production goals of higher quality products through lowering the possible number of defects (Mehrjerdi, 2011). Academics and practitioners now put SS in the larger concept of Process Excellence with a solid foundation upon quality and Lean principles (Montgomery, 2010).

Lean Six Sigma

The company under study has combined Lean and SS principles under a single methodology of Process Excellence. Lean Six Sigma combines the goals of variation reduction and improving value in one holistic approach (Arnheiter & Maleyeff, 2005; Bendell, 2006; Salah, Rahim, & Carretero, 2010; Corbett, 2011). Taiichi Ohno, Shigeo Shingo and Eiji Toyoda developed the Toyota Production System (TPS) between 1948 and 1975 (Strategos, 2012). TPS emphasizes the identification of waste (often reoccurring) following specific ideas and techniques to eliminate it (Strategos, 2012). Lean has been adapted from TPS to increase value by reduction of seven typical wastes sources (Breyfogle, 2003). Elimination of waste has many forms such as transportation, inventory, motion, waiting, overproduction, overprocessing, and defects (Womack, Daniel, & Jones, 1990). Lean thinking is centered on preserving value and focusing on the customer (Womack, et al., 1990). Together, Lean Six Sigma operate under one methodology: Define, Measure, Analyze, Improve, Control (DMAIC).

DMAIC

The Lean Six Sigma projects conducted by the company Green Belts follow the DMAIC methodology. DMAIC is inspired by Deming's Plan-Do-Check-Act Cycle (Breyfogle, 2003). DMAIC is composed of five stages and serves different motives, depending upon the phase (Brady & Allen, 2006). DMAIC is utilized for existing products and processes, and is recommended when the cause of the problem is unknown or unclear (DeFeo & Barnard, 2005). The DMAIC methodology demands rigorous empirical studies as the primary way to establish Lean Six Sigma effectiveness (Zhang, Hill, & Gilbreath, 2011). Crucial to Lean Six Sigma success is the ability to link business strategy to continuous improvement projects.

Critical Success Factors

To operate a Lean Six Sigma strategy, managing according to critical success factors (CSF) is recommended. The company in question manages Process Excellence and, subsequently, Lean Six Sigma efforts to its own CSFs. Critical success factors were first described by Daniel (1961) as a set of environmental conditions necessary for an initiative to succeed. A strategy for first identifying critical success was further described by Rockart (1979) as business requirements required before strategic implementation of new processes. Linking of critical success factors to overall business strategy is abundant in the literature (Leidecker & Bruno 1984; Devlin, 1989; Ketelhohn, 1998). CSFs have been applied to successful Lean Six Sigma implementation efforts to guide strategic efforts (McAdam & Evans, 2004). CSFs may be utilized at both the strategic and operational levels (Revere, Kadipasaoglu & Zalila, 2006). CSFs serve as an important framework for Six Sigma implementation (Laureani & Antony, 2012) A summary of CSFs are shown in Table (1) below.

TABLE (1): CSFs for Lean Six Sigma Implementation. Summary of Reference for Literature Review

Critical Success Factors	Reference
Leadership commitment and participation	Antony & Banuelas (2002); Sandholm & Sorqvist (2002); Pande, Neuman, & Cavanaugh (2000); Snee & Hoerl (2003); Desai, Antony, & Patel (2012); Dobbins (1995); Coronado & Antony (2002); Breyfogle, (2003); Mehrjerdi (2011); Zhang, Hill & Gilbreath (2011); Jacobsen (2008)
Projects align to business plans & VOC	Harry & Schroeder (2006); Antony & Banuelas (2002); Desai et al. (2012); Coronado & Antony (2002); Mehrjerdi (2011); Zhang et al. (2011); Jacobsen (2008); Sharma & Chetiya (2010); Pande et al (2000)
Six Sigma Framework	Antony & Banuelas (2002); Snee & Hoerl (2003); Desai et al. (2012); Breyfogle, 2003; Zhang et al. (2011); Sharma & Chetiya (2010)
Project management / execution	Harry & Schroeder (2006); Antony and Banuelas (2002); Pande et al. (2000); Snee & Hoerl (2003); Coronado & Antony (2002); Bisgaard (2007)
Utilization of Six Sigma tools	Pande et al. (2000); Antony & Banuelas (2002); Desai et al. (2012); Coronado & Antony (2002); Breyfogle (2003); Jacobsen (2008); Sharma & Chetiya (2010)
Six Sigma Training	Sandholm & Sorqvist (2002); Harry & Schroeder (2006); Antony & Banuelas (2002); Snee & Hoerl (2003); Coronado & Antony (2002)
Project Selection	Sandholm & Sorqvist (2002); Desai et al. (2012); Coronado & Antony, 2002; Breyfogle, (2003); Jacobsen (2008); Sharma & Chetiya (2010); Ramu (2007); Pande et al. (2000)

Project Performance

The success of Lean Six Sigma implementation is based upon project success (DeRuntz & Meier, 2010; Lynch, Bertolino, & Cloutier, 2003). Without evidence, Lean Six Sigma effectiveness is open to subjective interpretation (Linderman, et al., 2003). Defining project performance empirically may lead to a lack of Lean Six Sigma on bottom-line savings, a key characteristic of Lean Six Sigma (Antony, 2004a). Lean Six Sigma project performance is also defined by timely completion (Snee & Hoerl, 2003). Typically, projects should be completed within four to six months (Breyfogle, Cupello, and Meadows, 2001).

Identifying and evaluating projects up front is done to prevent subsequent project problems where a comprehensive evaluation is conducted to meet organizational goals (Padhy, & Sahu, 2011). Thus, Lean Six Sigma efforts falter by lack of applying CSFs, such as those identified in Table 1 (Yang, K., Yeh, Pai, & Yang, C., 2008). Jacobsen (2008) further describes barriers to Lean Six Sigma success through a CSF view: a lack of leadership commitment and communication, poor project selection and definition, insufficient project management, and inadequate human resources. These challenges may be summarized as a lack of theoretical understanding by practitioners (Aboelmaged, 2009; Antony, 2004b).

Six Sigma Green Belts

Successful Lean Six Sigma implementation requires practitioners at multiple levels where individual roles vary according to organizational size, goals, and strategy. (Green, Barbee, Cox, & Rowlett, 2006). The most fundamental role in Lean Six Sigma is the Black Belt that serves as the manager of DMAIC projects and full-time change agent (Schroeder et al., 2007). Supporting Lean Six Sigma exclusively through Black Belts may be unsustainable, so Green Belts fill in an important role of expanding Lean Six Sigma across the organization locally (Pzydek & Keller, 2009). Green Belts work as part-time DMAIC managers, support Black Belt efforts, answer to a functional manager, and expand Lean Six Sigma efforts to make a significant organizational impact (Green, Barbee, Cox, & Rowlett, 2006). Green Belts typically conduct projects locally, utilizing more fundamental lean techniques (Green, 2006). Green Belt dedication to Lean Six Sigma projects is typically two to five percent of their time (Pzydek & Keller, 2009). To support successful Lean Six Sigma adoption, Green Belt efforts are increasingly required (Green et al., 2006).

Methods

The company in question is a large multi-national manufacturing company that operates an overall Process Excellence program worldwide. The Process Excellence program's primary goal is to support specific issues that prevent the company from increasing overall customer satisfaction. Within process excellence, Lean Six Sigma is utilized where full-time Black Belts conduct DMAIC projects. Green Belts at this company conduct Lean Six Sigma projects locally, on a part-time basis, within their functional areas. Both Black Belts and Green Belts may become certified inside the corporation.

This study used internal company data to answer the research question of planned versus actual duration of Lean Six Sigma Green Belt completed projects. An operational definition of the measurement of project duration was created to communicate the research question consistently. The operational definition of 'planned duration time' was found in the project charter at Lean Six Sigma project launch. Operational definitions are repeatable descriptions of how a measurement is to be made that ensures consistency in understanding and in determining the values for the measurements (Deming, 2000). After launch, the planned project duration time is the number of calendar days from the date of successful completion of the *Define* gate review to the planned date of the *Contro*l gate review as agreed by the Green Belt and the Process Excellence team made up of subject matter experts (SMEs). The operational definition of 'actual project duration' is the number of calendar days from successful completion of the *Define* gate review to the successful completion of the *Control* gate review. Actual project duration in the sample was collected from the following sources: a) use of a company Process Excellence database that serves as Lean Six Sigma project repository containing gate reviews, overall project reviews, signatures of completion, and potential financial benefits, and b) individual project history files located at the company location where the study occurred.

The internal project database is utilized for continuous improvement. This database is utilized to track SS projects and, for this study, provided the duration information. From the database and records, time between gate reviews was collected within projects. Gate reviews represent significant milestones in any project, and were collected in the database and individual review of project files. The statistical analysis was done using regression analysis and median test of project data, a nonparametric equivalent to ANOVA.

Assumptions

Project duration in this study from the company's database is accurate. Actual project duration ended at the *Contro*l gate review conducted by the Process Excellence team and Green Belt at project closure.

Limitations

This study contains data from one location of this large multi-national manufacturing company. Only the initial Lean Six Sigma projects, where the Green Belt was certified successfully, were studied. The study occurred within three years of initial adoption of the latest Lean Six Sigma

Green Belt requirements; therefore, the sample size of projects at the time of the study is 18. These limitations must be taken into consideration with regard to applicability of findings over longer periods of time and different types of Lean Six Sigma projects.

Delimitations

The sample size and related historical data of these projects is consistent with current Lean Six Sigma Green Belt certification requirements at this company. Green Belt projects are DMAIC in methodology. Each completed project was conducted by one individual in Green Belt training.

There are two research questions studied in this paper:

RQ1: How long do Lean Six Sigma Green Belt projects take as compared to original project plans?

RQ2: Do DMAIC project phases differ significantly with regard to timeliness?

To answer the first question, the first step is a statistical analysis of the relationship of planned duration to actual duration.

Results

In this study, data were collected to determine the planned duration and actual duration of initial Green Belt projects. The actual project duration and planned duration data were collected from the 38 projects in the company's historical database that met the following conditions: a) completed Green Belt certification projects, b) in the specific unit of the company and coached by Process Excellence team members, and c) started after June 2009 to correspond with date of the latest and current Green Belt requirements.

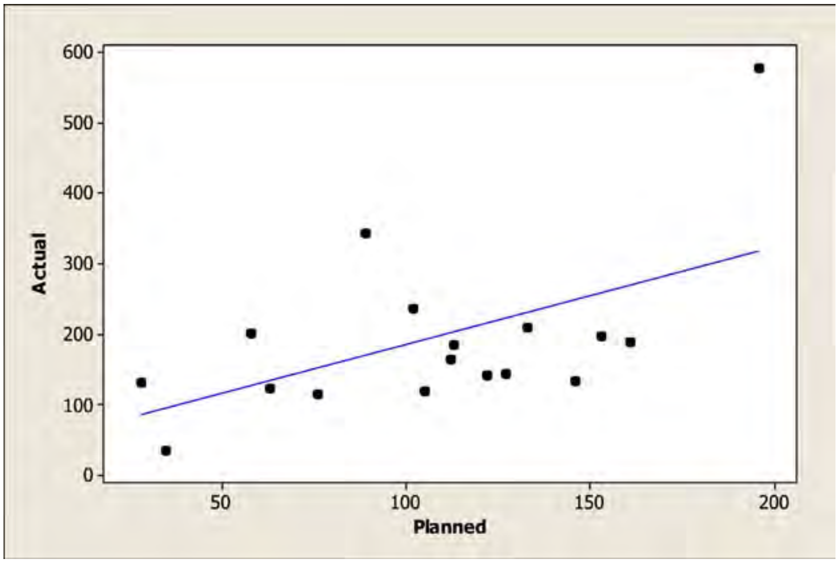
Based upon these criteria, 18 projects were selected from the total. To determine the planned duration, each of the 18 project charters were examined. The project charter is a document that lists the problem statement, business impact, goals, scope, timeline and defined team (George, Rowlands, Price, & Maxey, 2005). Lean Six Sigma project charters require agreement from the following: the sponsor, Green Belt , Green Belt's functional manager, team members, and mentor (Black Belt or Master Black Belt). For this study, the project start date for planned and actual duration is the completion of the *Define* gate review. While the start of a Lean Six Sigma Green Belt project usually consists of a kick-off meeting, these were not recorded. Therefore, the research team based the project start date for the measurement of actual project duration upon the completion of the *Define* gate review. For actual duration, each DMAIC phase was recorded from documented gate reviews as measured in days between gate reviews. For example, the duration of the *Measure* phase is the number of days from the *Define* gate review to the *Measure* gate review. The planned project duration is found by counting the number of days between the actual *Define* gate review and the planned *Control* gate review. The actual project duration is found by counting the number of days between *Define* gate review and *Control* gate review. Using these two operational definitions, a consistent measurement of durations was possible and easily determined by collecting data from the records of completed Green Belt projects.

For each of the 18 projects, the initial project planned duration, the actual project duration, and the difference between actual and planned (timeliness) was collected from company project records. Project timeliness is defined as:

$$\textit{Timeliness} = |\textit{Actual project days} - \textit{Planned project days}| \qquad (1)$$

An evaluation of timeliness begins with understanding the significance of the problem. While Lean Six Sigma projects were planned based upon a number of factors, the issue of duration is a key indicator of project success (P. Cada, personal communication, May 6, 2014). For Lean Six Sigma, this is done, in large part, on the SME's defining project duration (planned days). All analyses were conducted with Minitab Release 17 statistical software. An initial analysis of project duration performance was done by regression analysis and shown in Figure (1) below.

FIGURE (1): Planned days vs. Actual days of Green Belt Lean Six Sigma Project Timeliness



This figure illustrates no significant relationship

Planned project duration was deficient to predict actual project duration due to poor predictive power. From Figure 1, there was no significant relationship between planned days and actual days of initial Green Belt Lean Six Sigma projects (*R-Sq (adj) = 24.9%*) and expressed in the formula (*Actual = 47.7 + 1.38 Planned*) at a *p* value of (*alpha=0.05*). An apparent outlier is present in Figure 1. The data for the outlier was investigated and the data point was found to be correct without assignable cause and, therefore, retained in the analysis. Based on this data, the method of estimating the duration of Green Belt DMAIC projects was not helpful. The estimation of project duration by SMEs and the Green Belts considers a number of factors: the scope of the project; the number of stakeholders involved; the perceived change complexity; the experience level and competing commitments of the Green Belt; the level of local knowledge of the project subject; and finally, the type of project (P. Cada, personal communication, May 6, 2014). Despite these efforts, there was minimal predictive ability based upon the lack of a statistically significant relationship between the planned and actual duration done at the planning stages of Lean Six Sigma projects.

Green Belt project timeliness was significantly skewed. An Anderson-Darling test of normality of the projects' timeliness demonstrated that the data did not follow a normal distribution (*alpha=0.05*) with $p<0.005$ with considerable right skew in the distribution. Timeliness of projects was a median of 56 days, and the lower and upper bounds of the 95% confidence interval for the median was 24 and 118 days. Practically speaking, this means that 50 percent of the projects were 56 days longer than planned. Without intervention, the company could expect Green Belt Lean Six Sigma projects to last from approximately three weeks to four months longer, a considerable range. Practically, 50 percent of projects not being completed on time represent very low process excellence. Statistically, the results were significant as well.

Because overall project performance, as defined by duration (timeliness of project completion) was found lacking, further in-depth analysis was done by project phase. Green Belt Lean Six Sigma projects at this location follow the DMAIC methodology. DMAIC has different goals utilizing varying techniques, following a stage-gate process for each phase (Pzdek & Keller, 2009). Since the company under study practices a stage-gate review strategy for Lean Six Sigma Green Belt projects, project duration was planned, by phase, through the Process Excellence team. By recording each stage gate review, the project duration was analyzed utilizing the same formula of timeliness described above, leading to the second research question: Do DMAIC phases significantly different by timeliness?

FIGURE (2): Moods Median Test for Significance by DMAIC Phase Timeliness

```
Chi-Square = 14.67    DF = 4    P = 0.005

                                  Individual 95.0% CIs
C8  N<=  N>  Median  Q3-Q1  +---------+---------+---------+------
D    15   3       1      4  *
M    11   7      14     44   (--*-------)
A     8  10      42     51          (---*---)
I     5  13      79    113            (-----------*-------------)
C     6  12      56    118         (--------*----------------)
                            +---------+---------+---------+------
                            0        35        70       105

Overall median = 37
```

This figure indicates that timeliness by DMAIC phase was statistically significant

Due to the non-normal nature of the data, a nonparametric analysis utilizes a Mood's Median test as a nonparametric equivalent of ANOVA (Gibbons & Dickinson, 1997; Mood, 1954). Figure 2 above indicates that timeliness by DMAIC phase was statistically significant. As the Lean Six Sigma projects proceed through DMAIC, the timeliness becomes substantially larger. Projects tend to adhere more closely to the planned duration in the earlier phases but become widely dispersed as the project proceeds through the implementation phases (*Improve* and *Control*). The confidence intervals (95%) are statistical significance as shown in figure 2 (Box, Hunter, W., & Hunter, J., 1978). The *Define* phase differs significantly from all other phases (MAIC). The implementation phases, known as *Improve* and *Control*, exhibit the least practical timeliness where planned versus actual time increases but are statistically similar.

Conclusions

This study provides empirical evidence supporting anecdotal beliefs that initial Green Belt Lean Six Sigma projects take longer to complete than planned. Furthermore, Green Belt projects get more off track as projects proceed from beginning to end. While the sample size of the study is low (n=18), these projects represent all of the successfully completed Lean Six Sigma Green Belt projects during the time frame for this analysis. Even before projects are initiated, planning for success is arbitrary due to the nature of how projects are planned with regard to time. As shown above, the subject matter expertise model that is utilized displays no predictive power. While there are a number of factors that are tacitly utilized when planning for project duration, how these elements are utilized in a model that is transparent is unknown. For practice, it is recommended that the organization adopt a more readily identifiable project selection model that incorporates these factors, including timelines, in planning Green Belt projects before kickoff. Highlighting this critical success factor, in addition to the critical success factors of project management and execution should bring greater upfront emphasis to project success, utilizing crucial inputs, that include project duration. Project selection models display more reliability and consistency and, while incorporating subject matter expertise, bring a more balanced approach to the project planning process (Kumar, Antony, & Cho, 2009).

Projects tend to '*go off the rails*' as time proceeds, confounding the issue of project management and the nature of DMAIC. As demonstrated above, the *Define* phase is significantly timelier than all other phases (MAIC). In this study, the *Define* gate review is done after project kickoff, attended to closely by stakeholders, with limited competing commitments by Green Belts. As projects proceed, the timeliness slips. While Lean Six Sigma success relies upon Green Belt and Black Belt training as a critical success factor, there is less attention to the importance of other stakeholders involved in Lean Six Sigma implementation, especially in Green Belt projects. While Green Belts are trained in Lean Six Sigma project techniques, these personnel often reside locally, within their existing role and function, answering to a local manager. These elements are not as comprehensive or as substantial as the supporting mechanisms that Black Belts typically receive (Tjahjono et al., 2010). While it is unknown how local managers operate in this case, more emphasis on, and education about, the sponsor role is worthy of attention (Bryde, 2008). In particular, this could include project sponsor assurance that their role is clearly defined and communicated, mirroring the Green Belt distinction of splitting time between Lean Six Sigma and regular activities (Bryde, 2008).

Lean Six Sigma projects change in nature as they proceed through the DMAIC methodology. DMAIC phases utilize different skills for different objectives. The *Define, Measure,* and *Analyze* phases represent problem investigation where the majority of work is located within a team's control. In *Improve* and *Control*, a team moves from largely observational study to testing and experimentation. The *Improve* and *Control* phases also necessarily include more personnel beyond the DMAIC team as well. In this study, *Define* was statistically significant from the rest of MAIC. Practically, *Measure* and *Analyze* were clustered together and away from a cluster of *Improve* and *Control* phases. A limitation of this study was sample size due to the study goals. With more projects coming to completion, a clearer statistical result may occur. A future area of research could include project success, DMAIC goals, and team control. Other results go beyond how DMAIC projects proceed based upon team commitment and control.

While results here are preliminary, there is evidence that better project management practices be implemented. While better sponsor training and resource management of Green Belt competing commitments are recommended, better communication among stakeholders is recommended to keep projects on track. Regular updates represented by face-to-face interaction between Green Belts, their sponsors and, if not identical, with functional managers are recommended to minimize project barriers that may be due, in part, to team dependency upon those outside of the Lean Six Sigma team as it moves into *Improve* and *Control* phases. These concerns are heightened due to the Green Belt functional focus where concentrated effort, after Lean Six Sigma projects launch, wane over time.

Project management is a critical skill for every business, function and individual, and this is true also for Lean Six Sigma projects. Coronado and Antony (2002) state that Green Belts need to consider the fundamental project elements of time, cost, and quality. Green Belts and mentors need to consider the basic project management elements noted in these reviews (Coronado & Antony, 2002). In this study, the planned durations found in Lean Six Sigma project charters are based upon previous work and do not include other fundamental project management scheduling approaches such as sufficient slack time (Lambrechts, Demeulemeester & Herroelen, 2011). Lean Six Sigma delivers the tools to run a project; project management delivers the discipline to manage the project (Ramu, 2007).

Another perspective on the importance of project management is understanding the type of Lean Six Sigma projects through project classification. Six Sigma projects typically are designed for project durations based upon a generally accepted four to six months, based upon SME evaluation (Pzydek & Keller, 2006). However, the SME approach here did not produce a practical predictive model for actual duration based on planned duration. There may be too much reliance on subject matter experts to properly scope Green Belt projects based upon one project duration requirement. Classification of DMAIC projects should include the nature of the project, a focus on clear objectives, and a project timeline (Green, 2006).

Summary

From this research, an initial study of the timeliness of Lean Six Sigma Green Belt projects is lacking. While initial Lean Six Sigma Green Belt projects are planned to be completed within 180 days at this manufacturing location, over 50 percent of projects extended 56 days past that deadline. This lack of timeliness is greatest within DMAIC projects where considerable differences between the problem investigation (*Define; Measure; Analyze*) and the implementation (*Improve; Control*) phases. While the sample size is small, this study represents all of the Green Belt Lean Six Sigma projects completed during the study timeframe at this major, global manufacturing location. While specific barriers are lacking due to a paucity of gathered evidence, a review and comparison of CSFs in the literature as compared to this business critical success factor framework shows a significant difference in project management and execution. Improving the project management focus, including moving to critical success factor framework for project factors (project selection; project management; project classification) beyond strategy in managing Lean Six Sigma projects may improve the timeliness of these functional area Green Belt projects.

To improve the study reproducibility, the continued gathering of project data specifically and generally, more detailed information of project factors of Lean Six Sigma Green Belt projects at other organizations would enhance results. This internal data is often difficult to obtain, but more detailed information of DMAIC projects from a functional area of responsibility perspective is needed if Lean Six Sigma efforts are to be sustainable in the business enterprise. Future studies could further examine this strategic to project relationship of critical success factors and the perceived impact on project timeliness as a definition of project success.

References

Aboelmaged, M. (2009). Six sigma quality: a structured review and implications for future research. *International Journal of Quality Reliability Management, 27*(3), 269-318.

Antony, J. (2004a). Six sigma in the UK service organizations: results from a pilot survey. *Managerial Auditing Journal, 19*(8), 1006-1013.

Antony, J. (2004b). Some pros and cons of six sigma: an academic perspective. *The TQM Magazine, 16*(4), 303-306.

Antony. J., & Banuelas, R. (2002). Key ingredients for the effective implementation of Six Sigma program. *Measuring Business Excellence*, *6*(4), 20 – 27.

Arnheiter, E., & Maleyeff, J. (2005). The integration of lean management and six sigma. *The TQM Magazine, 17*(1), 5-18.

Bendell, T. (2006). A review and comparison of six sigma and the lean organizations. *The TQM Magazine, 18*(3), 255-262.

Bisgaard, S. (2007). What's missing in six sigma: project management - individually and collectively. *ASQ Six Sigma Forum Magazine*, 38-39.

Bloomberg. (2007, June). *Six Sigma: So Yesterday*. Retrieved from: http://www.businessweek.com/magazine/content/07_24/b4038409.htm

Box, G., Hunter, W., & Hunter, J. (1978). *Statistics for Experimenters: an Introduction to Design, Data Analysis, and Model Building.* New York: John Wiley & Sons.

Brady, J., & Allen, T. (2006). Six sigma literature: a review and agenda for future research. *Quality and Reliability Engineering International, 22*(3), 335-367.

Bryde, D. (2008). Perceptions of the impact of project sponsorship practices on project success. *International Journal of Project Management*. 26, 800–809.

Breyfogle, F. (2003). *Implementing Six Sigma*. Hoboken, New Jersey: John Wiley & Sons.

Breyfogle, F., Cupello, J., & Meadows, B. (2001). *Managing Six Sigma*. New York: John Wiley & Sons.

Corbett, L., (2011). LSS: the contribution to business success. *International Journal of Lean Six Sigma, 2*(2), 118-13.

Coronado, R., & Antony, J. (2002). Critical success factors for the successful implementation of six sigma projects in organizations. *The TQM Magazine, 14*(2), 92–99.

Daniel, D. (1961). Management information crisis. *Harvard Business Review, 39*, 111–121.

Deming, W. (2000). *Out of the Crisis*. MIT press. Cambridge, MA, USA.

DeRuntz B., & Meier R. (2010). An Evaluative Approach to Successfully Implementing Six Sigma. *Technology Interface Journal.* Retrieved from: http://technologyinterface.nmsu.edu/Spring10/Spring10/013.pdf

Desai, D., Antony, J., & Patel, M. (2012). An assessment of the critical success factors for Six Sigma implementation in Indian industries. *International Journal of Productivity and Performance Management*, 61(4), 426-444.

Devlin, G. (1989). How to implement a winning strategy. *European Management Journal, 7*(3), 377–83.

Dobbins, R. (1995). A failure of methods, not philosophy. *Quality Progress*, July, 31-33.

DeFeo, J., & Barnard, W. (2005). *JURAN Institute's Six Sigma Breakthrough and Beyond Quality Performance Breakthrough Methods*. New York: Tata McGraw-Hill.

George, M., Rowlands, D., & Kastle, B. (2003). *What is Lean Six Sigma*, New York: McGraw-Hill.

George, M., Rowlands, D., Price, M., & Maxey, J. (2005). *The Lean Six Sigma Pocket Toolbook*. New York: McGraw Hill.

Gibbons, J. & Dickinson, J. (1997). *Nonparametric Methods for Quantitative Analysis* (3rd ed.). New York: American Science Press.

Green, F. (2006). Six sigma and the green belt perspective: a study in five companies. *International Journal of Six Sigma and Competitive Advantage*, 2(3), 291-300.

Green, F., Barbee, J., Cox, S. & Rowlett, C. (2006). Green belt six sigma at a small company. *International Journal International Journal of Six Sigma and Competitive Advantage*, 2(2), 179-189.

Harry, M., & Schroeder, R. (2006). *Six sigma: the breakthrough management strategy revolutionizing the world's top corporations*. New York: Crown Business.

Jacobsen, J. (2008). Avoiding the mistakes of the past: Lessons learned on what makes or breaks quality initiatives. *Journal for Quality and Participation*, 4-8.

Ketelhohn, W. (1998). What is a key success factor. *European Management Journal*, 16(3):335-40.

Kumar, M., Antony, J., & Cho, B. (2009). Project selection and its impact on Six Sigma. *Business Process Management Journal*, 15(5), 669-686.

Lambrechts, O., Demeulemeester, E., & Herroelen, W. (2011). Time slack-based techniques for robust project scheduling subject to resource uncertainty. *Annals of Operations Research*, 186(1), 443-464.

Large manufacturing company. (2011). Conducting Improvement Activity. Retrieved November 21, 2011, from Large manufacturing company Quality Management System: http://www.infocentre.large manufacturing company.com.

Laureani, A., & Antony, J. (2012). Critical success factors for the effective implementation of lean sigma: results from an empirical study and agenda for future research. *International Journal of Lean Six Sigma*, 3(4), 274-283.

Leidecker, J., & Bruno, A. (1984). Identifying and using critical success factors. *Long Range Planning*, 17(1), 23-32.

Linderman, K., Schroeder, R., Zaheer, S., & Choo, A. (2003). Six sigma: a goal theoretic perspective. *Journal of Operations Management*, 21, 193-203.

Lynch, D., Bertolino, S., & Cloutier, E. (2003). How to Scope DMAIC Projects. *Quality Progress*, 37-41.

Mandel, P. (2012). Improving process improvement: executing the analyze and improve phases of DMAIC better. *International Journal of Lean Six Sigma*, 3(3), 231-250.

McAdam, R., & Evans, A. (2004). The organizational contextual factors affecting the implementation of six-sigma in a high technology mass-manufacturing environment. *International Journal of Six Sigma and Competitive Advantage*, 1(1): 29-43.

Mehrjerdi, Y. (2011). Six Sigma: methodology, tools, and its future. *Emerald Insight*, 79-88.

Montgomery, D. (2010). A modern framework for achieving enterprise excellence *International Journal of Lean Six Sigma*, 1(1), 56-65.

Mood, A. (1954). On the asymptotic efficiency of certain nonparametric two-sample tests. *The Annals of Mathematical Statistics*, 25(3), 514-522.

Pande, P., Neuman, R., & Cavanaugh, R. (2000). *The Six Sigma Way: How GE, Motorola and other top companies are honing their performance*. New York: McGraw-Hill.

Padhy, R., & Sahu, S. (2011). A real option based Six Sigma project evaluation and selection model. *International Journal of Project Management,* 29(8), 1091-1102.

Pzydek, T. & Keller, P. (2009). The Six Sigma Handbook: A complete guide for green belts, black belts, and managers at all levels (3rd ed.). New York: McGraw-Hill.

Ramu, G. (2007). Six Sigma project assignment: know your black belts. *Six Sigma Forum Magazine*, 26-30.

Rockart, J. (1979). Chief executives define their own data needs. *Harvard Business Review*, March-April, 81-93.

Revere, L, Kadipasaoglu, R., & Zalila, F. (2006). An empirical investigation into six sigma critical success factors. *International Journal of Productivity and Quality Management*, 1(3), 224-252.

Salah, S., Rahim, A., & Carretero, J. (2010). The integration of six sigma and lean management. *International Journal of Lean Six Sigma*, 1(3), 249-274.

Sandholm, L. & Sorqvist, L., (2002). 12 requirements for six sigma success. *Six Sigma Forum Magazine*, November, 17-22.

Schroeder, R., Linderman, K., Liedtke, C., & Choo, A. (2007). Six Sigma: definition and underlying theory. *Journal of Operations Management*, doi: 10.1016/j.jom.2007.06.007.

Sharma, S., & Chetiya, A. (2010). Six Sigma project selection: an analysis of responsible factors. *International Journal of Six Sigma*, 280-292.

Snee, R., & Hoerl, R. (2003). *Leading Six Sigma: a step-by-step guide based on experience with GE and other Six Sigma companies*. New York: Ft Press.

Snee, R. (2004). Six sigma: the evolution of 100 years of business improvement methodology. *International Journal of Six Sigma and Competitive Advantage*, 1(1), 4-20.

Strategos. (2012, April). Retrieved from: http://www.strategosinc.com/toyota_production htm.

Tjahjono, B., Ball, P., Vitanov, V., Scorzafave, J., Norgueira, J., Calleja, M., Minguet, L., Narasimha A., Rivas, A., Srivastava, S., & Yadav, A. (2010). Six sigma, a literature review. *International Journal of Lean Six Sigma*, 1(3), 216-233.

Womack, J., & Daniel, T., & Jones, D. (1990). *The Machine That Changed the World*. New York: Harper Perennial.

Yang, K., Yeh, T., Pai, F., & Yang, C. (2008). The analysis of the implementation status of six sigma: an empirical study in Taiwan. *International Journal of Six Sigma and Competitive Advantage*, 4(1), 60-80.

Zhang, W., Hill, A., & Gilbreath, G. (2011). A research agenda for six sigma research. *The Quality Management Journal*, 39-53.