Developing an instrument for measuring Six Sigma implementation

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Abstract: The purpose of this paper is to develop an instrument for measuring Six Sigma implementation. We develop eight constructs for measuring Six Sigma implementation utilising the PDCA cycle (plan-do-check-act). The instrument captures different aspects of Six Sigma implementation in organisations such as the role of black belts, financial responsibility and executive support. In addition, we show that there is significant difference in Six Sigma implementation among organisations, where those employing PDCA cycle for their Six Sigma initiatives achieve higher level of performance. We believe the proposed instrument can be used for measuring Six Sigma implementation in organisations. Implications for managers and future research have been provided.

Keywords: Six-Sigma; plan-do-check-act; PDCA; process improvement; quality management.

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1 Introduction

The emergence of Six Sigma as a robust process improvement methodology has gained momentum in recent years. Six Sigma has been identified as a powerful tool that dramatically improves performance, enhances process capability, and produces bottom line results for organisations (Dasgupta, 2003; Linderman et al., 2003; Pantano et al., 2006; Anand et al., 2007; Kumar et al.; 2008, 2009). Having been developed from quality management philosophy (Goeke and Offodile, 2005), Six Sigma has attracted academic research attention in recent years (Raisinghani et al., 2005). According to Hammer (2002), Six Sigma is a project based methodology that attempts to solve a specific performance problem recognised by an organisation. It is a concept that concentrates on the customer rather than the product (Douglas and Erwin, 2000).

The influence and effect of Six Sigma initiatives on organisational performance and profitability are numerous. According to Hoerl (1998) GE's operating margins increased from 13.8% to 14.5%, which is worth about \$600 million, stemmed from Six Sigma quality initiatives. In 2002, at least 25% of Fortune 200 companies claimed they had Six Sigma programme (Hammer, 2002). Organisations are looking toward Six Sigma not only as a way to gain competitive edge and to reduce cost possible, but also to keep their customer base returning for additional business opportunities. Six Sigma methodology has been effective in process simplification by reducing the number of stages in a process resulting in higher customer satisfaction (Behara et al., 1995).

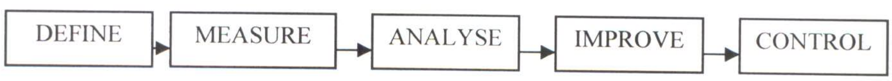
As organisations look toward Six Sigma programmes, there is a need to address effective implementation of Six Sigma projects. In an attempt to do so, this paper focuses on the development of an instrument to measure Six Sigma implementation. We define Six Sigma methodology using DMAIC or DMADV, the popular frameworks for Six Sigma projects (Breyfogle, 2003; Pyzdek, 2003). We operationalise Six Sigma implementation using the PDCA cycle (plan-do-check-act). Developing appropriate instruments to assist in understanding Six Sigma implementation has been recommended in the literature (Harry, 1998; Blakeslee, 1999; Goh et al., 2003). However, few empirical studies have been conducted on effective Six Sigma implementation. We believe that developing an instrument for effective implementation of Six Sigma will help scholars and practitioners to gain better insight on Six Sigma implementation. It also helps organisations to effectively utilise their resources so that they can benefit from their Six Sigma initiatives.

2 Six Sigma: background and literature review

According to Feld and Stone (2002) Six Sigma is a data-driven philosophy used to drive management decisions and actions across an organisation. Caulcutt (2001) indicates that Six Sigma reduces waste, increases customer satisfaction, and improves processes with a considerable focus on financially measurable results (Gowen et al., 2008; Matson and Stauffer, 2009). For the purpose of this paper, Six Sigma is defined as a set of methodologies and techniques used to improve quality and reduce cost utilising a structured and disciplined methodology for solving business problems. Our definition is consistent with Hammer (2002).

A popular framework for implementing a Six Sigma methodology is the DMAIC process. DMAIC, or define, measure, analyse, improve, and control are the key processes of a standard framework for a Six Sigma approach and is shown in Figure 1.

Figure 1 DMAIC framework



According to Jing and Li (2004) the psychology of this approach is that key process input variables are narrowed down to a vital few with the idea that having control of the vital few will allow for control of the whole process. DMAIC is widely used when a product or process is already in existence but performing inadequately. DMAIC focuses on eliminating unproductive steps, developing and applying new metrics, and using technology to drive improvement (De Feo and Barnard, 2004). Another popular approach associated with Six Sigma projects, DMADV or define, measure, analyse, design, and verify is used for developing new products/services (Figure 2). While the focus of

DMAIC is on eliminating waste and improving an existing process, DMADV is primarily utilised to develop new products/services.

Figure 2 DMADV framework

Six Sigma has a strategic component aimed at not only developing commitment to it, but also active involvement of higher management (Snee, 2000). That strategic component is the responsibility of management to identify the key processes of their organisation, measure their effectiveness and efficiency, and initiate improvements to the worst performing processes. It is suggested that firms should implement their Six Sigma initiatives via integrating it with their business strategy (Cheng, 2007). Combining Six Sigma with other quality improvement programmes (e.g., Lean systems) improves the likelihood of effective implementation of Six Sigma (Shah et al., 2008).

2.1 Literature review

As evidenced by Linderman et al. (2003) academic research in Six Sigma is lagging behind its practice in the industry. While academic research is needed to fill the gap between the theory and practice of Six Sigma, few empirical studies have been carried out to understand the effective implementation of Six Sigma projects. Six Sigma appears to be a transnational concept where there is little variation in the way it has been perceived across nations (van Iwaarden et al., 2008).

Most research on Six Sigma has been primarily focused on anecdotal evidence and case studies. Academic research on Six Sigma has been accelerated in recent years (Linderman et al., 2003; McAdam and Lafferty, 2004). McAdam and Lafferty (2004) argue that successful implementation of Six Sigma requires attention to both process perspective (methodology) and people perspective (behaviour). While early research on Six Sigma has been focused on the technical side of Six Sigma in terms of tools, techniques and methodologies, recent studies have paid attention to the psychological, contextual and human side of Six Sigma such as reward systems for Six Sigma (Buch and Tolentino, 2006), goal setting (Linderman et al., 2006), organisational context (Choo et al., 2007a), and psychological safety (Choo et al., 2007b). Six Sigma has been traditionally focused on cost reduction and efficiency; however recent studies show that it could be used as a methodology to increase profitability (Sodhi and Sodhi, 2005), and it could drive creativity (Biedry, 2001), enhance organisational learning (Wiklund and Wiklund, 2002), and facilitate innovation (Byrne et al., 2007). Through improvement in organisational processes Six Sigma projects enable organisations to more effectively meet the needs of their customers (Matson and Stauffer, 2009). In terms of performance variation, the human side of Six Sigma exhibits the highest level of variation between different groups in a company (Fleming et al., 2005). Empirical evidence suggests that human resource management practices significantly affect Six Sigma implementation (Zu and Fredenall, 2009). Effective Six Sigma implementation requires top management commitment, highly disciplined approach, and training (Hahn et al., 2000).

2.2 *Six Sigma implementation*

Different theoretical frameworks have been used to understand Six Sigma implementation. Building upon goal theory literature, Linderman et al. (2003) address the role of specifying challenging goals for Six Sigma projects, where Six Sigma projects with challenging goals result in a greater magnitude of performance. They also indicate that the use of a structured method (in Six Sigma projects) increases performance. In another study, Linderman et al. (2006) empirically show that goals can be effective when Six Sigma projects employ Six Sigma tools and methods. However, specifying unrealistic and very challenging goals are counterproductive, resulting in frustration and lack of motivation for team members.

From a knowledge management perspective, Choo et al. (2007a) develop a knowledge-based framework for Six Sigma projects. By focusing on two complementary sources of knowledge creation in Six Sigma projects – prescribed methodology and organisational context – they argue that Six Sigma projects that can make a balance between the effective implementation of prescribed methodology (e.g., tools and techniques such as quality control) and context (e.g., leadership, organisational culture, and black belt roles) can generate higher level of knowledge. To the extent that firms can manage such a balance, a sustainable quality advantage will be maintained.

With reference to Six Sigma implementation as a structured and systematic process improvement methodology, little has been said on the design and structure of Six Sigma projects as a unified methodology. While companies implement Six Sigma in a variety of ways, it is important to determine how much of those efforts are done in a systematic and structured way. According to Mader (2002) structured application of tools and techniques increases the rate of success in process improvement. Foster (2006) has also emphasised the importance of consistency and standardisation in quality improvement projects. Standardisation of methodologies reduces variability in the processes so it is crucial for companies to implement Six Sigma in a structured and systematic way so that they can benefit the most from their efforts (Choo et al., 2007a). It is important to note that the success of any quality improvement project (including Six Sigma) requires the co-existence of both attention to the details and innovation (Naveh and Erez, 2007). While a structured method (such as PDCA) facilitates attention to the details, contextual variables such as the role of black belt and executive commitment are the key in providing a culture of innovation.

Previous research on Six Sigma has paid little attention to the role of black belts in Six Sigma projects and how they can facilitate successful implementation of Six Sigma. Linderman et al. (2003) argue that improvement specialist such as black belts serve as role models for Six Sigma improvement projects where it increases the success of Six Sigma project. More recently Nonthaleerak and Hendry (2008) explored areas of weakness in Six Sigma implementation. Their findings suggested that Six Sigma is more appropriate for high risk and cross functional projects, and Six Sigma projects should be aligned to the organisational goals. In addition, they emphasised the role of black belts (their time and availability) for the success of Six Sigma projects. In another study, Gowen et al. (2008) showed that knowledge management practices would enhance implementation of Six Sigma programmes.

To address the above shortcomings in the literature, we have employed the PDCA framework to relate Six Sigma implementation to process improvement. The steps in Six Sigma projects (DMAIC or DMADV) are similar to PDCA (Shewhart, 1931, 1939; Choo et al., 2007a). The PDCA cycle is a well established framework for process improvement where it focuses on continuous learning and knowledge creation (Deming, 1993), which is the key in the success of any quality improvement initiative (Wiklund and Karlsson, 1997; Wiklund and Wiklund, 2002). While organisations may use different terminologies for their Six Sigma projects, by adhering to a unified and well established framework such as PDCA we attempt to integrate all Six Sigma projects under the PDCA cycle. We believe framing Six Sigma project within a PDCA cycle provides a more comprehensive view of Six Sigma implementation in organisations.

3 Construct development

Eight constructs have been defined for Six Sigma implementation. The constructs have been developed based on the review of the literature (Breyfogle, 2003; Pyzdek, 2003) along with other constructs developed by the researchers after observing several Six Sigma organisations. These constructs investigate variations in implementing Six Sigma. A study on improvement projects shows that the quality of such projects is affected by both methods and psychological variables (Choo et al., 2007a). In another study the effect of contextual variables on Six Sigma implementation has been addressed (Choo et al., 2007b). The proposed instrument addresses both the methods aspect of Six Sigma as well as the financial and organisational aspect. The following is a list with a brief description of the eight constructs evaluated:

1 *Black belt roles:* Black belts are used differently across organisations. The purpose of this construct is to measure the degree to which the roles of black belts are dedicated to Six Sigma or if they have to split their time between their Six Sigma responsibilities and other day to day management activities. The role of black belts in effective implementation of Six Sigma projects has been addressed in previous studies (Hammer, 2002; Linderman et al., 2003; Choo et al., 2007a; Shroeder et al., 2007). Black belts bridge the gap between the top management and Six Sigma project team (Schroeder et al., 2008).

2 *DMAIC v. DMADV:* These two Six Sigma processes are designed to be used for specific types of projects. The purpose of this construct is to measure if they are used according to their intended use according to the guidelines provided by Breyfogle (2003).

3 *Plan:* Deming (1986) describes how quality projects are managed in the following process; plan, do, check, act. It is sometimes referred to as a PDCA cycle (Arveson, 1998). For both DMAIC and DMADV, this is the 'define' step. This construct contains the first steps to start a project such as project selection, project planning, and project scope and metrics. The purpose of this construct is to compare how organisations actually start projects with how DMAIC and DMADV recommend starting projects (Pyzdek, 2003; Breyfogle, 2003).

4 *Do:* The purpose of this construct is to measure how organisations perform the second step in the PDCA cycle. For both DMAIC and DMAVD this is the 'measure' stage in the Six Sigma process. Experiments and tests are performed to evaluate current performance and improvements on a project. Examples of these tools are

design of experiments (DOE) and failure modes and effect analysis (FMEA) (Breyfogle, 2003).

5 *Check:* The purpose of this construct is to measure the third step in the PDCA cycle to see if the new ideas will perform as expected. Both DMAIC and DMADV have 'analyse' as the third step. The purpose of this construct is to determine if the organisations check the data with statistical tools to determine which sources of variation are critical to the process. Another purpose is to determine if judgments are made on the data before the statistical analyses are performed.

6 *Act:* The purpose of this construct is to measure the last step in the PDCA cycle which encompasses the last two steps in the Six Sigma processes. Although they are different in nature the last two steps are used to set and implement plans to make sure that the changes or new ideas are successful.

7 *Financial responsibility*: The purpose of this construct is to measure how leaders of the project are held accountable for the reported benefits as well as the benefits to the leaders when the project goes well. Recent studies have addressed the need for monitoring and assessing the financial performance of Six Sigma project during its implementation process (Schroeder et al., 2008).

8 *Executive support:* The purpose of this construct is to measure how involved the executives are with the projects. The role of executive in supporting Six Sigma projects has been addressed in the literature (Linderman et al., 2006; Byrne et al., 2007; Schroeder et al., 2008). Executives not only need to support Six Sigma projects in terms of providing resources and their commitment but they also need to make a balance between Six Sigma projects and operational activities of the firm. It is believed that the balance between innovation projects (such as Six Sigma) and the operational activities of company is the key to the success of the firm (Gottfredson and Aspinall, 2005).

The above constructs capture both the methodological elements (e.g., PDCA) and the contextual element (e.g., executive commitment) of Six Sigma projects. From the knowledge-based view of quality improvement, creation of knowledge in Six Sigma projects requires the co-existence of both methodological and context elements (Choo et al., 2007a). Accordingly, we believe the instrument is cable of addressing both aspects of knowledge creation in Six Sigma projects.

In addition, we are interested in investigating the similarities and differences in Six Sigma implementation between companies. While companies such as GE report millions of dollars savings from Six Sigma projects, Six Sigma projects do not provide the desired benefit to all organisations. There have been strong criticism on the effect of improvement projects (such as Six Sigma) where it is believed that many quality-based interventions fail and do not provide the desired results (Stebbins and Shani, 2002). While elements such as vision, skills, resources, action plans, and incentives are necessary in effective Six Sigma implementation (Larson, 2003), the collective effect of both methodological and contextual variables are the key in successful Six Sigma implementation (Choo et al., 2007a). In other words, to benefit from Six Sigma projects, companies need to follow the methodological aspect of Six Sigma (e.g., PDCA) while addressing the contextual variables (e.g., leadership commitment). In that regard, we expect to see differences in the implementation of Six Sigma projects. Organisations which excel in Six Sigma projects adhere more to the methodological and contextual variables of Six Sigma implementation. Accordingly, we hypothesise that

H1 There is significant difference among organisations regarding Six Sigma implementation. Organisations that follow a structured methodology for Six Sigma (e.g., PDCA) outperform organisations that do not follow a structured methodology.

4 Methodology

The first major step was to identify a group of organisations for the purpose of conducting an in depth study of their Six Sigma practices. It was also important to have good access to financial data. Another consideration was the size of company used. The following describes how the companies were selected for this research.

4.1 Procedure

The Fortune 500® provides a list of the top 500 companies sorted by gross income. We initially decided to utilise this list for several reasons. The first is that most of the companies have been around prior to the advent of Six Sigma. This is beneficial for comparing aspects before and after a Six Sigma implementation. Second, larger corporations have a broad range of businesses and so corporate initiatives are better publicised and have a large impact on company performance whereas smaller companies may be more impacted by specific customer demand for a specific product or business unit.

The next step was to compile a list of Fortune 500® companies that have implemented Six Sigma. The website (http://www.sissigmacompanies.com) annually reports a list of these companies. In 2005 the site reported 180 companies. From this list of 180 companies, 20 companies were chosen randomly for an evaluation of their stock performance and further investigation of their Six Sigma implementation. From the final list of 20 companies, two companies have been selected.

These two corporations were the only two companies that volunteered for this research. They did under the condition of anonymity so they will be referred to as 'Company A' and 'Company B.' Further analysis revealed the fact that Company A's performance (in terms of stock performance) has been significantly improved after 3.5 years while Company B's performance has declined from the time it launched Six Sigma projects. Both companies had negative performance before implementing Six Sigma projects (for 3.5 years) and they had similar patterns for their stock performance. Figure 3 shows the stock performance of Company A and Company B over time. The vertical column shows companies relative stock performance (RSP) which is calculated by this formula:

$$\delta_t = \frac{D_t}{D_0}$$

$$RSP = \frac{P_t}{P_0 \delta_t}$$

where:

D_t = Dow Jones Industrial Average (DJIA) at time t

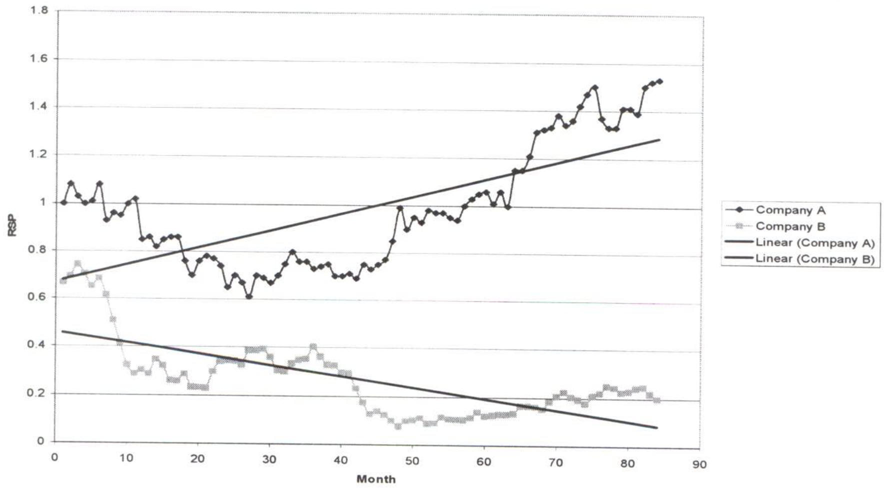
D_0 = initial DJIA

P_t = stock price at time t

P_0 = initial stock price.

Regression analysis was used to determine the significance of the patterns before and after Six Sigma implementation for both companies. Note that zero in Figure 3 represents the time both companies initiated their Six Sigma efforts. ANOVA analysis showed that both companies had a significant negative and linear trend before Six Sigma implementation. However, the regression for Company A after implementing Six Sigma was positive and linear while the trend for Company B was negative.

Figure 3 Stock performance for Company A and B over time (see online version for colours)



4.2 Data collection

A five point Likert scale was used to gather information from the managers for this study. All of the measures were developed by the researchers. In each company, contacts with managers and Six Sigma project managers were made to identify potential Six Sigma projects. A total number of 29 project managers were identified. These were managers who specifically worked on Six Sigma projects and had great knowledge and understanding of Six Sigma implementation in their company. A copy of the initial instrument and the final instrument has been provided in the appendices.

4.3 Reliability

The Cronbach's alpha is used to measure the internal consistency (reliability) of the instrument. Reliability of an instrument shows the degree of consistency or repeatability of the measurement (Streiner, 2003).

4.3.1 Black belt roles

Despite the standardisation of Six Sigma implementation, there are different ways to deploy black belts in an organisation. Breyfogle (2003) recommends a black belt's only job is to be a black belt. They provide leadership for Six Sigma projects (Wiklund and Wiklund, 2002). Part of his definition of a black belt is that a black belt's time should not be split between black belt roles and managing a production line, troubleshooting, design work, and other duties that are associated with management or ownership of the product or service the organisation provides (for example, line management at a factory or sales manager). However, some companies do not use this strict definition. Using this definition of black belt roles, six questions were developed by the researchers to determine if a company forces black belts to split time between 'regular duties' and black belt duties such as coaching and guiding Six Sigma projects (see Appendix). Pyzdek (2003) refers to black belts not as project managers but as change agents. His vision of a black belt is someone who has extensive training in statistics and Six Sigma methodologies and helps guide multiple teams through Six Sigma projects.

The initial Cronbach's alpha was 0.146, which is considerably below the target of 0.5 for new constructs. Therefore a stepwise reduction of questions was used to increase the internal reliability of the construct. The reductions removed one question per step from the construct if eliminating a question raised the Cronbach's alpha and no more than half of the original questions have been removed. While it is believed that new scales often result in lower alphas (Carmines and Zeller, 1978) that was not the case with black belt roles. Table 1 shows the final Cronbach's alpha.

Table 1 Cronbach's alpha for black belt roles

Final Cronbach alpha	*Number of items*
.391	3

4.3.2 DMAIC vs. DMADV

The purpose of the DMAIC v. DMADV construct was intended to measure the usage of these two common Six Sigma processes. Questions were asked to determine if companies were using DMAIC and DMADV according to Simon's (2000) definitions. DMAIC is used to improve current processes or product whereas DMADV is used to develop new processes or products. Table 2 shows the reduction summary.

Table 2 DMAIC vs. DMADV summary of reductions

Step	*Initial alpha*	*Question to eliminate*	*New alpha*
1	0.324	13	0.377
2	0.377	15	0.43
3	0.43	12	0.523
4	0.523	14	0.587
5	0.587	16	0.676

The final Cronbach's alpha was 0.676 which is considered marginally acceptable. After reviewing the questions it was noticed that all of the questions asked negatively were causing serious problems to the reliability of the construct. Some of the questions asked if current processes or products were improved using DMADV steps and the others asked if new processes or products were improved using DMAIC steps, which is the opposite of how Simon (2000) recommend using DMAIC and DMADV. The responses tended to show inconsistent responses within companies. This could indicate that some practitioner noticed the difference in the use of DMAIC and DMADV and others did not.

4.3.3 Plan

The next set of questions focused the planning stage of projects. Pyzdek (2003) and Breyfogle (2003) both recommend that meetings are held with executives, accountants guide financial reasoning, executive direction takes precedent over manager's interests, metrics are clearly defined, and the scope of the project is narrowed for both DMAIC and DMADV. Table 3 shows the Cronbach's alpha reduction. The final alpha calculated was 0.640. This indicated marginal acceptability for this construct.

Table 3 Cronbach's alpha for plan

Step	*Initial alpha*	*Question to eliminate*	*New alpha*
1	0.296	23	0.408
2	0.408	25	0.459
3	0.459	24	0.524
4	0.524	22	0.588
5	0.588	19	0.64

4.3.4 Do

The 'do' step of the PDCA cycle is considered as the measure stage in both DMAIC and DMADV terminology. This is where key process input variables (KPIV), key process output variables (KPOV), current performance, and other aspects of a product or process are measured (Breyfogle, 2003). Table 4 shows the final Cronbach's alpha. This construct tested to be marginally acceptable with a final Cronbach's alpha of 0.610.

Table 4 Final Cronbach's alpha for do

Step	*Initial alpha*	*Question to eliminate*	*New alpha*
1	0.178	35	0.399
2	0.399	34	0.464
3	0.464	32	0.478
4	0.478	30	0.548
5	0.548	33	0.610

4.3.5 Check

The 'check' stage of the PDCA cycle is seen in both DMAIC and DMADV as analyse. This is the step where all the data taken from the measure phase is analysed and inferences are made from the data. The questions used in this construct are to measure whether this stage is performed properly by the organisation or not. The Cronbach's alpha reduction summary is shown in Table 5. Check's internal reliability tested to be marginally acceptable with a final Cronbach's alpha of 0.681.

Table 5 Cronbach's alpha for check

Step	*Initial alpha*	*Question to eliminate*	*New alpha*
1	0.532	44	0.586
2	0.586	43	0.603
3	0.603	45	0.633
4	0.633	38	0.638
5	0.638	41	0.681

4.3.6 Act

The last step of the PDCA cycle is 'act'. The implementation or deployment of a project occurs in this phase. This construct was intended to measure what companies do in this phase. Table 6 shows the reduction of questions. This construct tested to be marginally acceptable with a final Cronbach's alpha of 0.640.

Table 6 Cronbach's alpha for act

Step	*Initial alpha*	*Question to eliminate*	*New alpha*
1	–0.011	56	0.421
2	0.421	55	0.53
3	0.53	54	0.567
4	0.567	53	0.61
5	0.61	52	0.64

4.3.7 Financial responsibility

Six Sigma has many aspects outside of its process methodologies. One aspect not mentioned often in literature is how the financial impacts of projects are reported and audited. Some companies have internal audits to determine if the project actually met its predicted savings while other companies do not. This construct is not specific to Six Sigma and can be used on non-Six Sigma companies as well. Table 7 shows the reductions and additional reductions only showed marginal improvement. Financial responsibility was considered internally reliable with a final Cronbach's alpha of 0.843.

Table 7 Cronbach's alpha for financial responsibility

Step	*Initial alpha*	*Question to eliminate*	*New alpha*
1	0.7	59	0.783
2	0.783	63	0.811
3	0.811	66	0.832
4	0.832	64	0.842

4.3.8 Executive support

Executive support is deemed critical to the success of any programme regardless if it is Six Sigma related or not. Table 8 shows the reductions. Executive support was considered internally reliable with a final Cronbach's alpha of 0.851.

Table 8 Cronbach's alpha for executive support

Step	*Initial alpha*	*Question to eliminate*	*New alpha*
1	0.544	76	0.751
2	0.751	70	0.795
3	0.795	72	0.838
4	0.838	74	0.851

4.3.9 Final reduced questionnaire

By using Cronbach's alpha to validate each construct, a master list of questions that can be used for future research has been developed. Table 9 shows the remaining final Cronbach's alpha for each construct.

Table 9 Final questionnaire summary

Construct	*Cronbach alpha*
Black belt role	0.391
DMAIC vs. DMADV	0.676
Plan	0.640
Do	0.610
Check	0.681
Act	0.640
Financial responsibility	0.843
Executive commitment	0.851

5 Results

The eight constructs tested were intended to evaluate different aspects of Six Sigma implementation. After the iterative reductions, all but one of the constructs tested to be at least marginally reliable. With further refinement, the questionnaire developed could be used to determine characteristic differences between Six Sigma implementations of companies. For newly developed constructs a reliability value of 0.5 seems satisfactory. Overall, with the exception of the black belt roles, all other constructs meet the threshold of the reliability. Therefore, we can conclude that the proposed instrument has an acceptable reliability.

5.1 Comparing Six Sigma performance between Company A and B

To test if there is difference between two companies (Company A and Company B) in terms of Six Sigma implementation, a mean comparison has been conducted. Table 10 shows that there were differences between the two companies. A Walsh test was then conducted on the differences between the companies to determine if the companies responded the same to the questionnaire (Siegel, 1956). The Walsh test showed the companies responded significantly different at an alpha of 0.036. This rejects the null hypothesis of H_1 that there is no difference in Six Sigma implementations between the two companies.

The construct with the biggest difference was black belt roles. The results show that Company B splits up black belts time between black belt roles and other responsibilities. Another construct that showed a difference was financial responsibility. Company A appears to hold its employees more accountable for their financial reports than Company B. Finally, it appears that Company A uses DMAIC and DMADV much closer to how it is recommended by Pyzdek (2003) and Breyfogle (2003) than Company B.

Table 10 Comparison of Company A and B

Construct	*Company A*	*Company B*	*Difference*
Black belt roles	3.52	2.47	1.06
Financial responsibility	3.67	2.70	0.97
DMAIC vs. DMADV	4.37	3.68	0.69
Executive commitment	3.48	2.97	0.50
Act	4.27	3.88	0.39
Plan	3.53	3.32	0.21
Do	3.68	3.58	0.10
Check	4.14	4.44	–0.30

Even though the black belt roles construct did not have a high internal reliability it is clear that there are major differences in how the two companies use black belts within their organisations. In discussions with Company A, they stated employees are pulled from management or engineering and given a two-year rotation in a black belt position. During this time they are removed from their previous roles and given the responsibility to coach and lead Six Sigma projects within their division. One of the questions in the questionnaire tested for this by asking, "A black belt must split their time between black belt roles and department or area management." In discussions with Company B, they stated black belts are trained then encouraged to implement Six Sigma into their day to day management responsibilities.

The financial responsibility construct had the next largest difference between companies. This could indicate Company A holds their leaders more responsible for their financial reporting. Company A's responses indicated that there are audits that check the financial reports and that leaders are held responsible if a project did not realise its financial benefits. DMAIC vs. DMADV also had differences between the companies' responses. After looking at the raw data, it could be interpreted that Company A uses the two processes more closely to Simon's (2000) recommendations. The last construct that showed a difference between the companies is executive support. The primary questions that showed differences involved the speed in which messages were returned by executives and the active involvement with executive management.

With reference to Table 10, practices such as black belt roles, financial responsibility, and DMAIC vs. DMADV exhibit the most significant difference between Company A and Company B. These are practices that are specifically associated with Six Sigma programmes. This suggests that the effectiveness of Six Sigma programmes is not solely determined by utilising a structured methodology such as PDCA. The success of Six Sigma is greatly influenced by the role of black belts, making them accountable and responsible for the performance (financial responsibility), and following the appropriate Six Sigma implementation process (DMAIC vs. DMADV).

This questionnaire showed the differences in the companies' respective Six Sigma programmes. This was the original purpose of the questionnaire. Therefore, the questionnaire may need to be re-worded before used again, but the premise of the constructs and questions did show measurable differences between the two companies.

6 Summary and findings

One of the objectives of this research was to determine how the company performances relate to the responses given by Six Sigma practitioners. Unfortunately only two companies volunteered for this study; therefore a complete analysis could not be performed on the data relating the questionnaire responses to the success metric. Nevertheless, there were noticeable differences in the responses from the two companies.

Without more companies to participate it is not possible to mathematically show relationships between these differences in the constructs and the success metric. However, the data suggested there are differences in how Six Sigma is practiced and there were differences in success after the Six Sigma implementations. This could lead to finding relationships between implementation techniques and performance.

In conclusion, Company A and Company B had differences in their success and had differences in how they implemented Six Sigma. The differences found in their Six Sigma programmes may affect their performance. Assuming the differences in the constructs are contributing to the performance differences, companies should have dedicated black belts, hold project leaders responsible for their financial reporting, and use DMAIC and DMADV according to their intended use.

Assuming the implementations of Six Sigma caused the changes in performances and that the differences in implementations caused the differences in performance, several recommendations can be made.

1 Black belts should be dedicated to the Six Sigma programme and not forced to split their time between their Six Sigma responsibilities and other management responsibilities.

2 Employees should be held responsible for their financial impacts by either positive or negative reinforcement.

3 Companies should use DMAIC and DMADV according to Simon (2000) who indicated that DMAIC should be used for improving and DMADV should be used for developing.

4 Executives should be actively involved with projects.

7 Limitations

There are some critical assumptions that need to be mentioned. The assumption of validity when comparing the responses to the questionnaire may have been violated. Only three of the constructs had a final Cronbach's alpha higher than the necessary 0.7 to be considered valid. Four of the constructs are considered marginally valid because their final Cronbach's alpha was above 0.6. One construct was not considered valid because it was well below 0.6. While for new constructs (such as the constructs in this study) a Cronbach's alpha of 0.5 is suggested, small sample size might be a factor. Therefore, further studies with larger sample size are recommended.

In addition to marginal validity, most of the questions eliminated were asked negatively. This indicates that the questions asked in the negative either did not have the intended opposite meaning, were too confusing, or otherwise constructed in a way that invalidated the questions.

This research has many useful concepts even though it had several limitations. We proposed a new survey instrument for measuring the implementation of Six Sigma projects. In addition, this research related the methodological aspect of Six Sigma (DMAIC or DMADV) to quality and process improvement (PDCA cycle). We also made a link between the organisational variables and methodological variables for effective implementation of Six Sigma projects.

The lower than needed internal reliability of the constructs indicates the questionnaire needs further refinement. However on face value, three of the constructs have differences between the two companies and two of the constructs show similarities. This indicates that there are variations between the characteristics of the two programmes and they could be related to the success metric. With the addition of several other companies and the elimination of less meaningful or unreliable constructs, the methodology provided in this research could show where companies can improve in their Six Sigma programme.

8 Implications for managers

The implications of this research are that it is possible to measure the inputs and outputs of a Six Sigma implementation. For researchers, this methodology of measuring the implementation techniques and relating them to company performance could be applied to other types of management methodologies such as Lean, Kaizen, or total quality management. If future results show relationships between implementation patterns and performance, it could help practitioners implement Six Sigma with a higher likelihood of company success.

9 Future research

This research built foundation for future study of Six Sigma. Future research should include refinement of the questionnaire, particularly with the roles of black belts within companies. In addition, with the participation of more companies there is the possibility to find relationships between the performance of the companies and how they implemented Six Sigma. Evidence from the industry shows that Six Sigma can be implemented to improve the performance of supply chain projects (Yang et al., 2007). Future research needs to address the implementation of Six Sigma in a supply chain environment. Finally, the implementation of other quality programmes (such as lean manufacturing) may have a positive effect in the successful implementation of Six Sigma project (Jain and Lyons, 2009). Therefore, future research should consider the co-existence of other management initiatives on successful implementations of Six Sigma projects.

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Appendix A Questionnaire

Role of black belts

- black belts only lead Six Sigma projects
- black belts are process owners
- a black belt's only responsibility in the company is to manage projects
- black belts are area managers
- a black belt's role in the company is to lead Six Sigma projects
- a black belt must split his time between his black belt role and management of his department or area.

DMAIC vs. DMADV

- existing products or processes are improved with a DMAIC methodology
- new products or processes are developed with a DMADV methodology
- the M in DMAIC measures current performance
- the A in DMADV determines if the customer needs will be met
- the C in DMAIC is when the control plan is carried out
- existing products or processes are improved with a DMADV methodology
- a new product or process is developed with a DMAIC methodology
- the M in DMADV measures current performance
- the A in DMADV determines the root causes
- the C in DMAIC is when the customer's needs are verified.

Plan

- meetings are held with executives to determine the type of projects to work on
- accountants are involved with project selection
- project selection is based mostly on executive direction

- metrics are clearly defined during the planning
- the scope of the project is narrowed during the Define stage
- managers decide on the types of projects to work on
- accountants are involved only after the projects are selected
- project selection involves mostly financial impact, regardless of executive direction
- metrics are defined after measuring current process or products
- the scope of the project is left broad during the define stage.

Do

- process input variables are developed using tools in the measure phase
- a measurement systems analysis (MSA) is performed during the measure phase
- the KPIV's and KPOV's are determined in the measure phase
- measuring devices must have precision of at least ten times the specification tolerance
- the number of samples taken is calculated using estimated variance and a confidence interval
- process input variables are known in the define phase
- measurement devices are assumed to be accurate if the calibration date has not expired
- the KPIV's and KPOV's are determined in the analyse phase
- measuring devices must have a precision of at least two times the specification tolerance
- the number of samples taken assumed from an experienced manager.

Check

- statistical tests are performed to determine if samples are statistically different
- root causes or critical customer requirements are determined in the analysis phase
- quantifying gaps or opportunities is a deliverable of the analysis phase
- attention is focused on the 'vital few' sources of variation
- a normality check is built into an ANOVA summary
- if the samples are separate by more then 10% of the mean, they are considered different
- root causes or critical customer requirements are needed before an analysis can begin
- gaps and opportunities are identified in the measure phase

- all sources of variation need to be lowered
- when using ANOVA it is not necessary to check for normality of the data.

Act

- control charts are used to monitor the source of the variation in a process or product after a project is completed
- control charts are used to monitor the output of the process or product after a project is completed
- there is a standard in place to instruct teams on how to transfer ownership of the project back to the process owner
- new process steps are integrated into the standard operating procedure
- a response plan is made for corrective action following all projects
- after fixing the source of the variation, it is not necessary to track it's properties after the project is completed
- after improving the process or product it is not necessary to track it's properties after the project is completed
- it is up to the project leader to decide on how to transfer the ownership of the project back to the process owner
- new process steps are to be continued until it appears the root causes have disappeared
- no response plan is made following a project.

Financial responsibility

- accountants are used during projects to verify cost justification
- audits are conducted to determine if the cost justification was realised after a project is completed
- promotions, bonuses, or performance ratings are directly related to projected financial benefits from projects
- project leaders are held responsible if financial benefit is not realised after completion
- accountants are held responsible if financial benefits are not realised
- cost justification is conducted by team member's best recollection of costs
- cost justifications are not looked at after a project is complete
- promotions, bonuses, or performance ratings are directly tied to actual savings verified through audits
- project leaders are held responsible if a project did not meet its' financial benefit

- accountants are not held responsible if a project did not meet it's financial benefit.

Executive commitment

- messages to executives are returned promptly
- responses from the executive leadership take a while
- executives are actively involved in team projects
- executives interact with teams mainly by request of a team
- executives are easy to contact during a project
- executives are difficult to contact during a project
- when budget is needed for a project an executive helps lobby for funds
- when budget is needed for a project the executive leadership is not involved
- the executive leadership openly shows support for the project
- the executive leadership often questions the true benefit of a project with team members.

Appendix B Final questionnaire

Role of black belts

- black belts are process owners
- a black belt's only responsibility in the company is to manage projects
- a black belt's role in the company is to lead Six Sigma projects.

DMAIC vs. DMADV

- existing products or processes are improved with a DMAIC methodology
- the M in DMAIC measures current performance
- the C in DMAIC is when the control plan is carried out.

Plan

- meetings are held with executives to determine the type of projects to work on
- accountants are involved with project selection
- metrics are clearly defined during the planning
- the scope of the project is narrowed during the define stage
- the scope of the project is left broad during the define stage.

Do

- process input variables are developed using tools in the measure phase
- the KPIV's and KPOV's are determined in the measure phase
- the number of samples taken is calculated using estimated variance and a confidence interval.

Check

- attention is focused on the 'vital few' sources of variation
- if the samples are separate by more than 10% of the mean, they are considered different
- all sources of variation need to be lowered
- when using ANOVA it is not necessary to check for normality of the data.

Act

- control charts are used to monitor the output of the process or product after a project is completed
- new process steps are integrated into the standard operating procedure
- a response plan is made for corrective action following all projects.

Financial responsibility

- accountants are used during projects to verify cost justification
- audits are conducted to determine if the cost justification was realised after a project is completed
- project leaders are held responsible if financial benefit is not realised after completion
- accountants are held responsible if financial benefits are not realised
- cost justification is conducted by team member's best recollection of costs
- project leaders are held responsible if a project did not meet its' financial benefit.

Executive commitment

- messages to executives are returned promptly
- responses from the executive leadership take a while
- executives are actively involved in team projects
- executives are easy to contact during a project
- when budget is needed for a project an executive helps lobby for funds
- the executive leadership openly shows support for the project.