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Benefits, obstacles, and future of six sigma approach

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Abstract

Understanding the key features, obstacles, and shortcomings of the six sigma method allows organizations to better support their strategic directions, and increasing needs for coaching, mentoring, and training. It also provides opportunities to better implement six sigma projects. This paper examines the evolution, benefits, and challenges of six sigma practices and identifies the key factors influencing successful six sigma project implementations. It integrates the lessons learned from successful six sigma projects and considers further improvements to the six sigma approach. Effective six sigma principles and practices will succeed by refining the organizational culture continuously. Cultural changes require time and commitment before they are strongly implanted into the organization.
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1. Introduction

The six sigma method is a project-driven management approach to improve the organization's products, services, and processes by continually reducing defects in the organization. It is a business strategy that focuses on improving customer requirements understanding, business systems, productivity, and financial performance. Dating back to the mid 1980s, applications of the six sigma methods allowed many organizations to sustain their competitive advantage by integrating their knowledge of the process with statistics, engineering, and project management (Anbari, 2002). Numerous books and articles provide the basic concepts and benefits of the six sigma method (Harry and Schroeder, 2000) (Hoerl, 1998, 2001). The challenges and realities in implementing the six sigma method successfully are immense. However, the benefits of applying the six sigma method to technology-driven, project-driven organizations are equally great.

The objective of this paper is to review and examine the evolution, benefits, and challenges of six sigma practices and identify the key factors influencing successful six sigma project implementation. The paper also integrates the lessons learned from successful six sigma projects and their potential applications in managing traditional projects, and considers further improvements to the methodologies used for managing six sigma projects. Wider applications of six sigma principles to the organization will succeed through senior management involvement, organizational commitment, cultural change, and effective project management.

2. Two perspectives of six sigma processes

2.1. Statistical viewpoint

Six sigma method has two major perspectives. The origin of six sigma comes from statistics and statisticians. Hahn et al. (1999), Hoerl and Snee (2002), and Montgomery (2001) discuss the six sigma method from a statistical, probabilistic, and quantitative point of view. From the statistical point of view, the term six sigma is defined as having less

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than 3.4 defects per million opportunities or a success rate of 99.9997% where sigma is a term used to represent the variation about the process average (Antony and Banuelas, 2002). If an organization is operating at three sigma level for quality control, this is interpreted as achieving a success rate of 93% or 66,800 defects per million opportunities. Therefore, the six sigma method is a very rigorous quality control concept where many organizations still performs at three sigma level (McClusky, 2000).

2.2. Business viewpoint

In the business world, six sigma is defined as a 'business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customer's needs and expectations (Antony and Banuelas, 2001). The six sigma approach was first applied in manufacturing operations and rapidly expanded to different functional areas such as marketing, engineering, purchasing, servicing, and administrative support, once organizations realized the benefits. Particularly, the widespread applications of six sigma were possible due to the fact that organizations were able to articulate the benefits of six sigma presented in financial returns by linking process improvement with cost savings.

3. Understanding six sigma

3.1. Six sigma strategies, tools, techniques, and principles

Six sigma is a systematic, data-driven approach using the define, measure, analysis, improve, and control (DMAIC) process and utilizing design for six sigma method (DFSS) (GE 2004). The fundamental principle of six sigma is to 'take an organization to an improved level of sigma capability through the rigorous application of statistical tools and techniques' (Antony et al., 2003). It generally applies to problems common to production. Table 1 summarizes six sigma business strategies, tools, techniques, and principles.

Table 1
Six sigma strategies, principles tools, and techniques (adapted from Antony et al., 2003)

Six sigma business strategies and principles	Six sigma tools and techniques
Project management	Statistical process control
Data-based decision making	Process capability analysis
Knowledge discovery	Measurement system analysis
Process control planning	Design of experiments
Data collection tools and techniques	Robust design
Variability reduction	Quality function deployment
Belt system (Master, Black, Green, Yellow)	Failure mode and effects analysis
DMAIC process	Regression analysis
Change management tools	Analysis of means and variances
	Hypothesis testing
	Root cause analysis
	Process mapping

3.2. Six sigma strategies, tools, techniques, and principles

Anbari (2002) pointed out that six sigma is more comprehensive than prior quality initiatives such as Total Quality Management (TQM) and Continuous Quality Improvement (CQI). The six sigma method includes measured and reported financial results, uses additional, more advanced data analysis tools, focuses on customer concerns, and uses project management tools and methodology. He summarized the six sigma management method as follows:

$$\text{Six Sigma} = \text{TQM (or CQI)} + \text{Stronger Customer Focus} + \text{Additional Data Analysis Tools} + \text{Financial Results} + \text{Project Management}$$

3.3. DMAIC process

DMAIC is a closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applies technology for continuous improvement. Table 2 presents the key steps of six sigma using DMAIC process.

3.4. DFSS methodology

DFSS is a systematic methodology utilizing tools, training and measurements to enable the organization to design products and processes that meet customer expectations and can be produced at Six Sigma quality levels (Mader, 2002). The goal of DFSS is to achieve minimum defect rates, six sigma level, and maximize positive impact

Table 2
Key steps of six sigma using DMAIC process (Adapted from McClusky, 2000)

Six sigma steps	Key processes
Define	Define the requirements and expectations of the customer
	Define the project boundaries
	Define the process by mapping the business flow
Measure	Measure the process to satisfy customer's needs
	Develop a data collection plan
	Collect and compare data to determine issues and shortfalls
Analyze	Analyze the causes of defects and sources of variation
	Determine the variations in the process
	Prioritize opportunities for future improvement
Improve	Improve the process to eliminate variations
	Develop creative alternatives and implement enhanced plan
Control	Control process variations to meet customer requirements
	Develop a strategy to monitor and control the improved process
	Implement the improvements of systems and structures

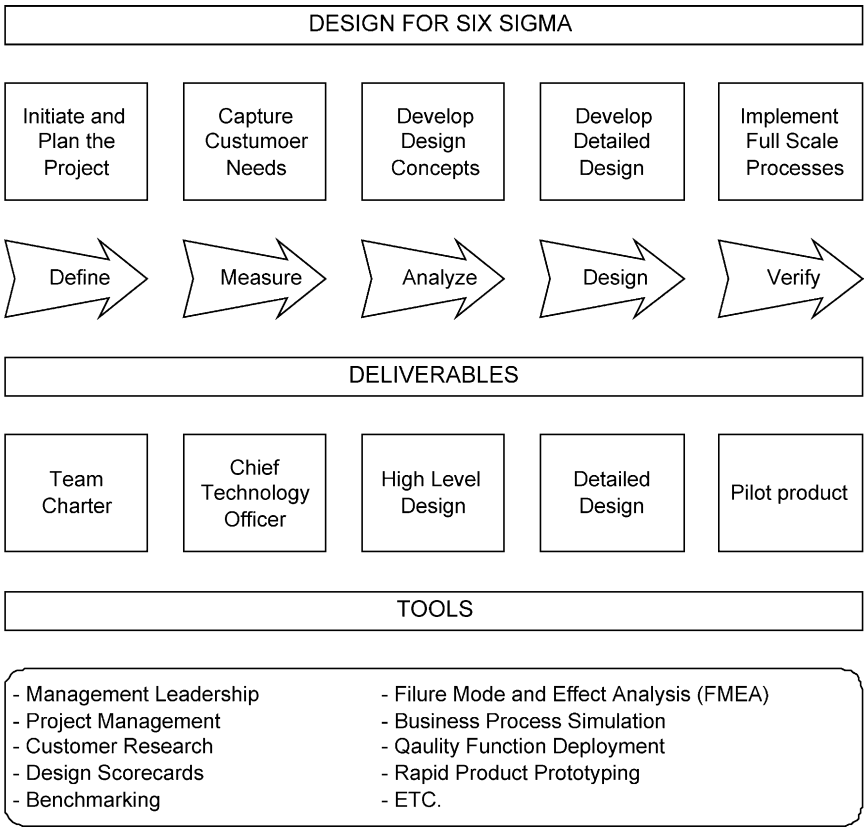

Fig. 1. Five Step DFSS process (adapted from de Feo and Bar-El, 2002).

during the development stage of the products. It is used to develop new products or services with a six sigma criteria, capability, and performance (Tennant, 2002). It utilizes variety of quality oriented tools and techniques to meet customer requirements and has shown an increase in life cycle profits. As Treichler et al. (2002) noted the essence of DFSS is 'predicting design quality up front and driving quality measurement and predictability improvement during the early design phases.' Essentially, the DFSS process is focused on new or innovative designs that yield a higher level of performance. De Feo and Bar-El (2002) summarize seven elements of DFSS as follows.

- Drives the customer-oriented design process with six sigma capability
- Predicts design quality at the outset
- Matches top–down requirements flow down with capability flow up
- Integrates cross-functional design involvement
- Drives quality measurement and predictability improvement in early design phases
- Uses process capabilities in making final decisions
- Monitors process variances to verify that customer requirements are met

DFSS has been used and proven successful at Dow Chemical (Buss and Ivey, 2001), W.R. Grace, (Rajagopalan et al., 2004), Delphi Automotive (Treichler et al., 2002), NCR Corporation (McClusky, 2000), General Electric (Weiner, 2004), and other process oriented industries. Fig. 1 depicts the five step DFSS process (Table 2).

4. Reported benefits of implementing six sigma

4.1. Manufacturing sector

Motorola was the first organization to use the term six sigma in the 1980s as part of its quality performance measurement and improvement program. Six sigma has since been successfully applied in other manufacturing organizations such as General Electric, Boeing, DuPont, Toshiba, Seagate, Allied Signal, Kodak, Honeywell, Texas Instruments, Sony, etc. The reported benefits and savings are composed and presented from investigating various literatures in six sigma (Weiner, 2004; de Feo and Bar-El, 2002; Antony and Banuelas, 2002; Buss and Ivey, 2001; McClusky, 2000). Table 3 summarizes the organizations, projects, benefits, improvements, and savings by implementing the six sigma process.

4.2. Financial sector

In recent years, finance and credit department are pressured to reduce cash collection cycle time and variation

Table 3
Reported benefits and savings from six sigma in manufacturing sector

Company/project	Metric/measures	Benefit/savings
Motorola (1992)	In-process defect levels	150 times reduction
Raytheon/aircraft integration systems	Depot maintenance inspection time	Reduced 88% as measured in days
GE/Railcar leasing business	Turnaround time at repair shops	62% reduction
Allied signal (Honeywell)/laminates plant in South Carolina	Capacity Cycle time Inventory On-time delivery	Up 50% Down 50% Down 50% Increased to near 100%
Allied signal (Honeywell)/bendix IQ brake pads	Concept-to-shipment cycle time	Reduced from 18 months to 8 months
Hughes aircraft's missiles systems group/wave soldering operations	Quality/productivity	Improved 1,000%/improved 500%
General electric	Financial	$2 billion in 1999
Motorola (1999)	Financial	$15 billion over 11 years
Dow chemical/rail delivery project	Financial	Savings of $2.45 million in capital expenditures
DuPont/Yerkes plant in New York (2000)	Financial	Savings of more than $25 million
Telefonica de espana (2001)	Financial	Savings and increases in revenue 30 million euro in the first 10 months
Texas instruments	Financial	$ 600 million
Johnson and Johnson	Financial	$ 500 million
Honeywell	Financial	$1.2 billion

(Sources: Weiner, 2004; de Feo and Bar-El, 2002; Antony and Banuelas, 2002; Buss and Ivey, 2001; McClusky, 2000).

in collection performance to remain competitive. Typical six sigma projects in financial institutions include improving accuracy of allocation of cash to reduce bank charges, automatic payments, improving accuracy of reporting, reducing documentary credits defects, reducing check collection defects, and reducing variation in collector performance (Doran, 2003).

Bank of America (BOA) is one of the pioneers in adopting and implementing six sigma concepts to streamline operations, attract and retain customers, and create competitiveness over credit unions. It has hundreds of six sigma projects in areas of cross-selling, deposits, and problem resolution. BOA reported a 10.4% increase in customer satisfaction and 24% decrease in customer problems after implementing six sigma (Roberts, 2004). American Express applied six sigma principles to improve external vendor processes, and eliminate non-received renewal credit cards. The result showed an improved sigma level of 0.3 in each case (Bolt et al., 2000). Other financial institutions including, GE Capital Corp., JP Morgan Chase, and SunTrust Banks are using six sigma to focus on and improve customer requirements and satisfaction (Roberts, 2004).

4.3. Healthcare sector

Six sigma principles and the healthcare sector are very well matched because of the healthcare nature of zero tolerance for mistakes and potential for reducing medical errors. Some of the successfully implemented six sigma projects include improving timely and accurate claims reimbursement (Lazarus and Butler, 2001), streamlining the process of healthcare delivery (Ettinger, 2001), and reducing the inventory of surgical equipment and related costs (Revere and Black, 2003).

The radiology film library at the University of Texas MD Anderson Cancer Center also adopted six sigma and improved service activities greatly (Benedetto, 2003). Also in the same institution's outpatient CT exam lab, patient preparation times were reduced from 45 min to less than 5 min in many cases and there was a 45% increase in examinations with no additional machines or shifts (Elsberry, 2000).

4.4. Engineering and construction sector

In 2002, Bechtel Corporation, one of the largest engineering and construction companies in the world, reported savings of $200 million with an investment of $30 million in its six sigma program to identify and prevent rework and defects in everything from design to construction to on-time delivery of employee payroll (Eckhouse 2004). For example, six sigma was implemented to streamline the process of neutralizing chemical agents, and in a national telecommunications project to help optimize the management of cost and schedules (Moreton, 2003).

4.5. Research and development sector

The objectives of implementing six sigma in R&D organizations are to reduce cost, increase speed to market, and improve R&D processes. To measure the effectiveness of six sigma, organizations need to focus on data-driven reviews, improved project success rate, and integration of R&D into regular work processes. One survey noted that as of 2003 only 37% of the respondents had formally implemented six sigma principles in their R&D organization (Johnson and Swisher, 2003). Rajagopalan et al. (2004) reported that the development

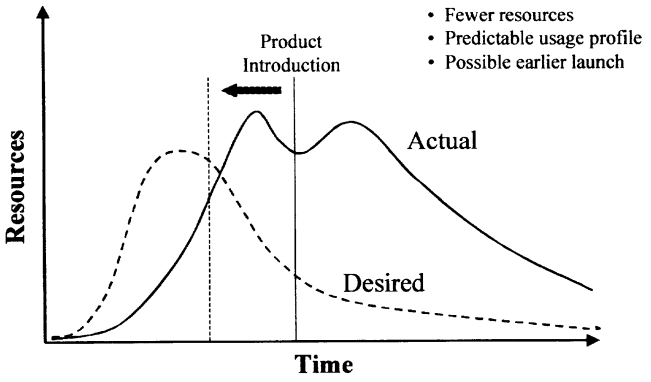

Fig. 2. Advantages of applying six sigma in R&D projects (adopted from Johnson and Swisher, 2003).

and manufacturing of the new prototype at W.R. Grace (Refining Industry) was cut to 8–9 months from 11–12 months by implementing the DFSS process. Fig. 2 shows the conceptual benefits and improvement of implementing six sigma in R&D projects.

5. Key factors for implementing a successful six sigma program

Antony and Banuelas (2002) and Banuelas Coronado and Antony (2002) presented the key ingredients for the effective introduction and implementation of six sigma in UK manufacturing and services organizations as the following.

- Management commitment and involvement.
- Understanding of six sigma methodology, tools, and techniques.
- Linking six sigma to business strategy.
- Linking six sigma to customers.
- Project selection, reviews and tracking.
- Organizational infrastructure.
- Cultural change.
- Project management skills.
- Liking six sigma to suppliers.
- Training.
- Linking six sigma to human resources (Wyper and Harrison, 2000).

Johnson and Swisher (2003) provided useful implementation tips for successful six sigma applications as:

- Sustained and visible management commitment.
- Continuing Education and training of managers and participants.
- Setting clear expectations and selecting project leaders carefully for leadership skills.
- Picking and selecting strategically important projects.

Starbird (2002) argued that six sigma process is part of a management system to achieve business excellence in organizations and presented keys to six sigma success as:

- Start process management: identify core processes, customer needs, and measures.
- Drive performance through reporting: Leaders must maintain and report opportunity lists, status of active projects/resources, and results from finished projects.
- Integrate championing of active projects: Select and charter projects and require updates during existing staff meetings.

Based on various literature reviews and discussions with six sigma leaders in organizations that adopted the six sigma method, the authors identified four key elements of successful six sigma applications.

5.1. Management involvement and organizational commitment

Six sigma requires top management dedication and contribution to resources and effort. A good example is General Electric's former CEO Jack Welch's involvement (Henderson and Evans, 2000). He was charismatic and influential enough to restructure the business and change the attitudes of the employees toward six sigma (Hendricks and Kelbaugh, 1998). The organizations' CEOs are often involved in the successful implementation of six sigma. Organizational infrastructure needs to be established with well trained individuals ready for action. Implementation of six sigma projects means commitment of resources, time, money, and effort from entire the organization.

5.2. Project selection, management, and control skills

Six sigma projects have to be carefully reviewed, planned, and selected to maximize the benefits of implementation. The project has to be feasible, organizationally and financially beneficial, and customer oriented. There has to be a clear set of measures and metrics to incorporate customer requirements. The project has to be reviewed periodically to evaluate the status of the project as well as the performance of six sigma tools and techniques being implemented. The project should be well documented to track project constraints, mainly cost, schedule, and scope. There should also be a lessons learned mechanism to capture the key issues of previous projects.

5.3. Encouraging and accepting cultural change

People facing cultural change and challenges due to the implementation of six sigma must understand the change first. This requires having a clear communication plan

and channels, motivating individuals to overcome resistance, and educating senior managers, employees, and customers on the benefits of six sigma. Announcing the results of six sigma projects including successes, obstacles, and challenges will help future projects to avoid making similar mistakes and adopt only the very best practices.

5.4. Continuous education and training

Education and training give a clear sense for people to better understand the fundamentals, tools, and techniques of six sigma. Training is part of the communication techniques to make sure that managers and employees apply and implement the complex six sigma techniques effectively. There is usually a ranking of expertise identified by the belt system (Hoerl, 2001). Four different Belt levels (Master, Black, Green, Yellow) make sure that establishment and execution of six sigma projects are done seamlessly. The curriculum is customized and needs to be provided by identifying key roles and responsibilities of individuals implementing six sigma projects (Antony and Banuelas, 2002). Organizations need to continuously learn and adapt the latest trends and techniques that are outside the six sigma domain that might be useful to complement the six sigma approach. The authors found that selection of knowledgeable, well-respected employees for Black Belt assignments was a critical success factor for six sigma projects.

6. Obstacles and challenges of six sigma method

6.1. Issues in strategy

Hammer and Goding (2001) argued that six sigma has been the target of criticism and controversy in the quality community characterizing it as 'Total Quality Management on Steroid'. One of the main criticisms is that six sigma is nothing new and simply repackages traditional principles and techniques related to quality (Catherwood, 2002). Organizations must realize that six sigma is not the universal answer to all business issues, and it may not be the most important management strategy that an organizations feels a sense of urgency to understand and implement six sigma. To ensure the long-term sustainability of the six sigma method, organizations need to analyze and accept its strengths and weaknesses and properly utilize six sigma principles, concepts, and tools.

6.2. Issues in organizational culture

Quality concepts need to be embedded into the process of designing rather than just monitoring the quality at the manufacturing level (McClusky, 2000). The more important issue is the change in organizational culture that puts quality into planning. Addressing the problems and issues that are easy to correct and claiming that the six sigma method is a big success is simply deceiving. Organizations without a complete understanding of real obstacles of six sigma projects or a comprehensive change management plan are likely to fail. Senior management's strong commitment, support, and leadership are essential to dealing with any cultural issues or differences related to six sigma implementation. If the commitment and support of utilizing various resources do not exist, organization should probably not consider adopting six sigma.

6.3. Issues in training (Belt Program)

Training is a key success factor in implementing six sigma projects successfully and should be part of an integrated approach. The belt program should start from the top and be applied to the entire organization. The curriculum of the belt program should reflect the organization's needs and requirements. It has to be customized to incorporate economical and managerial benefits. Training should also cover both qualitative and quantitative measures and metrics, leadership, and project management practices and skills. It is important to note that formal training is part of the development plan of producing different belt level experts. Participants need to be well informed of the latest trends, tools, and techniques of six sigma, and communicate with actual data analysis. The authors found that selection of less-capable employees for Black Belt assignments was associated with challenges to six sigma projects.

7. Future of six sigma

Six sigma is likely to remain as one of the key initiatives to improve the management process than just being remembered as one of the fads (Johnson and Swisher, 2003). The primary focus should be on improving overall management performance, not just pinpointing and counting defects. Researchers and practitioners are trying to integrate six sigma with other existing innovative management practices that have been around to make six sigma method even more attractive to different organizations that might have not started or fully implemented the six sigma method. Integrating and comparing principles and characteristics of six sigma with Total Quality Management (Revere and Black, 2003), (Hammer and Goding, 2001), Human Resource Functions (Wyper and Harrison, 2000), Lean Production (Antony et al., 2003), ISO 9000 (Catherwood, 2002), ISO 9001 (Dalgleish, 2003), and the capability maturity model (Murugappan and Keeni, 2003) are all part of the quality

community's effort to maximize the positive effect of the six sigma method.

8. Conclusions

Successful implementation and growing organizational interest in six sigma method have been exploding in the last few years. It is rapidly becoming a major driving force for many technology-driven, project-driven organizations. Factors influencing successful six sigma projects include management involvement and organizational commitment, project management and control skills, cultural change, and continuous training. Understanding the key features, obstacles, and shortcomings of six sigma provides opportunities to practitioners for better implement six sigma projects. It allows them to better support their organizations' strategic direction, and increasing needs for coaching, mentoring, and training.

The statistical aspects of six sigma must complement business perspectives and challenges to the organization to implement six sigma projects successfully. Various approaches to six sigma have been applied to increase the overall performance of different business sectors. However, integrating the data-driven, structured six sigma processes into organizations still has room for improvement. Cultural changes require time and commitment before they are strongly implanted into the organization. Effective six sigma principles and practices are more likely to succeed by refining the organizational culture continuously.

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