A Review of DFSS: Methodology, Implementation and Future Research

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Abstract- Design for Six Sigma(DFSS) is a data-driven quality strategy for designing or re-design a product or service from the ground up. DFSS is an approach that improves quality by redesign the product or developed the product as per voice of customer or customer requirement. In recent years there has been a significant increase in the use and development of the DFSS methodology in manufacturing industry and others. It is high time to have a review on the DFSS approach. This paper reviews some related literatures to describe methodology, implementation, obstacles and future researches. The given paper consists of the basic of six sigma and DFSS and its related features. Then, some sectors that benefit from the implementation of DFSS are listed out. At last, some topics for future research are presented.

Keyword—Six sigma, Design for six sigma, DMADV, DIDOV, IDOV.

I. INTRODUCTION

The traditional quality management approaches, including Statistical Quality Control (SQC), Zero Defects and Total Quality Management (TQM), have been key players for many years, while Six Sigma is one of the more recent quality improvement initiatives to gain popularity and acceptance in many industries across the globe. Since its initiation at Motorola in the 1980s, many companies including GE, Honeywell, Sony, Caterpillar, and Johnson Controls have adopted Six Sigma and obtained substantial benefits. Six Sigma is a long-term commitment. It won't work well without full commitment from upper management. Six Sigma changes the way a company thinks by teaching fact-based decision making to all levels.

As defined by Creveling, Design for Six Sigma (DFSS) is a proactive approach to building Six Sigma performance into the upfront design of a new product, service or process. It is a systematic methodology for designing new Six Sigma quality products to exceed customer expectations through the use of engineering tools and training in the product development life cycle.

Six Sigma is a business process methodology developed at Motorola in the early 1980s that enhances customer satisfaction from products or services by improving manufacturing processes. A subset of Six Sigma, Design for Six Sigma (DFSS) applies Six Sigma principles to the new product development (NPD) process, emphasizing that decisions made in the early phases of designing and engineering could have a profound effect on subsequent activities to build and deliver new products. At the center of DFSS approach, is a five-step process, DMADV, which is an acronym- Define, Measure, Analyze, Design, and Verify. The DFSS approach is taught in General Electric Company' Black Belt Customer Training Program and is heavily promoted in popular Six Sigma books, e.g., [19]. Many companies such as General Electric, Allied Signal, Raytheon, and Delphi A

DFSS is a methodology to make the introduction of new products and Services more efficient, reliable, and capable of meeting customer expectations or requirements. DFSS is driven by "Critical to Quality" (or CTQ) Factors, the quality characteristics critical to the customer. Six Sigma refers to a business initiative that improves the financial performance of a business through the improvement of quality and the elimination of waste

II. METHODOLOGY OF DFSS

Design for Six Sigma (DFSS) is a systematic methodology utilizing tools, training and measurements to design products and processes that meet customer expectations at Six Sigma quality levels. Six Sigma has been defined as the statistical unit of measurement, a Sigma that measures the capability of the process to achieve a defect free performance. Six Sigma has the ability to produce products and services with only 3.4 defects per million, which is a world-class performance. Six Sigma has also been described as a high performance data driven approach in analyzing the root causes of business problems and solving them.

Following table shows the problem solving cycle for design for six sigma and 10 approaches that are used worldwide.(Dr. Swen Günther 2012)

DFSS-Cycle	Hits of Google*	Phases					
DMADV	59.000	Define	Measure	Analyse	Design		Verify
IDOV	13.400		Identify		Design	Optimize	Verify
DMADOV	3.060	Define	Measure	Analyse	Design	Optimize	Verify
DMEDI	2.680	Define	Measure	Explore	Develop	*Implement*	
CDOV	1.730			Concept	Design	Optimize	Verify
DCCDI	1.350	Define	Customer	Concept	Design	*Implement*	
DCOV	1.350	Define		Characterize		Optimize	Verify
DIDOV	473	Define	Identify		Design	Optimize	Verify
DMADIC	76	Define	Measure	Analyse	Design	*Implement*	Control
DMCDOV	38	Define	Measure	Characterize	Design	Optimize	Verify

Table 1.Various Method of DFSS

From above table the first one DMADV is common methodology used in most sectores

2.1. DMADV

- Define. The Design step engages the program planning process to establish what is the product concept? The design management team begins a project by developing a business case for capitalizing on an opportunity that is presented from its technology portfolio or its product line plan. They must determine through customer and market research how this opportunity can address commercial needs of the marketplace. The initial assessment of the product concept and its commercial viability is presented in the business case along with the projected budget and a multi-generational product line plan that identifies how features and concepts will be sequenced for introduction into the market (as new pr ompletion of the initial conceptual design review the product bu a pment team is assigned to staff the project.

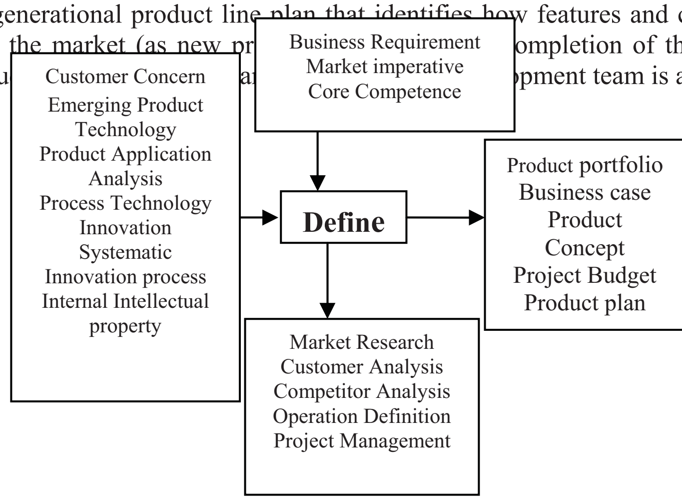

Figure1. Define map

- Measure. The Measure step evaluates the market requirements for both the product concept and the potential market demand for the product. During this step research is planned to determine customer needs and competitive performance as well as to identify those features and options that are differentiators of the product. The team seeks to identify those design elements that are critical-to-quality for the product in that they deliver satisfaction for identified customer requirements. This step in the design process is documented using Quality Function Deployment (QFD) matrices as well as design scorecards which are used to record the progress of the project. Design control is managed through tollgate reviews of checklists for critical activities to assure that adequate progress is made toward the planned product launch date.

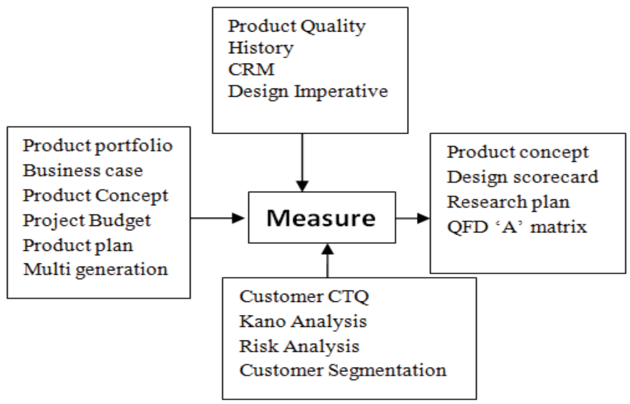

Figure2. Measure map

- Analyze. The Analyze step completes characterization of the product and includes the following key activities: functional analysis of the features and their capability to address the identified customer requirements, benchmarking of performance for these features, conceptual design of the product, process maps of both the production and service delivery processes, and a design requirement specification. The milestone or tollgate review that completes the Analyze step evaluates the design scorecard along with a comparison of the design requirements against the business plan to authorize the detailed product design.

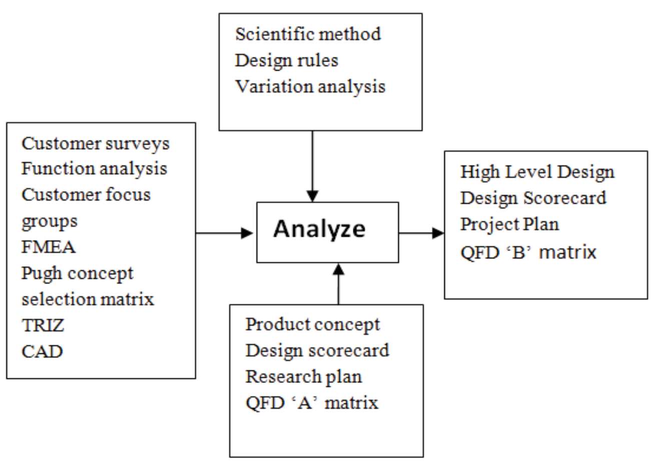

Figure3. Analyze map

- Design. In the Design step detailed process maps are created for the production facility layout, along with the engineering detail of the product specification. All the critical process parameters are identified; failure analysis is conducted to determine the potential risks; capability analysis is conducted to determine design robustness, and statistical analysis is used to establish tolerances for critical parameters. Value analysis is conducted to assure that the product value proposition is optimized. In this step reliability testing of prototypes is conducted to demonstrate growth in the stability of the design as well as its readiness for the commercial marketplace.

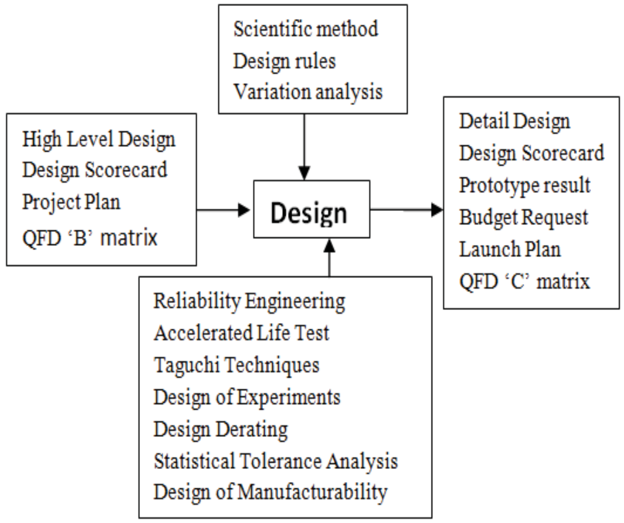

Figure4. Design map

- Verify. The Verify step engages the customer in product testing through pilot tests that demonstrate the marketability of the product as well as its production readiness. Pilot tests are used to verify the details for transition to full production as well as the implementation of the control procedures for routine production after ramp-up to the full forecast volume is achieved. The control plan for the product is embedded in its assembly procedures, test procedures and acceptance criteria. The product completes development and transitions to full production upon completion of the Verify step that is marked by an official product launch.

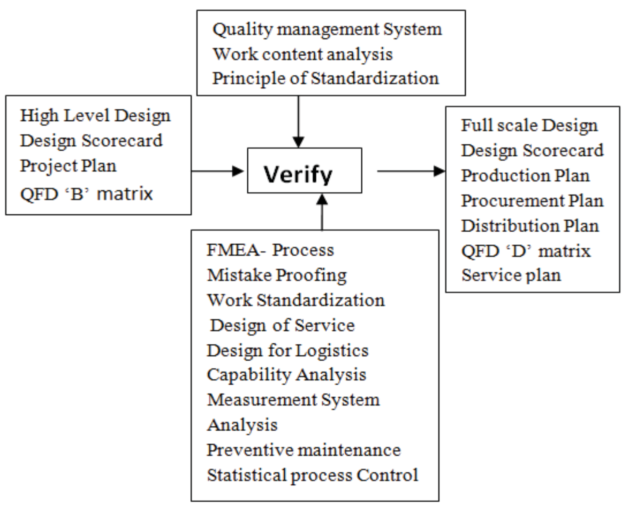

Figure5. Verify map

2.2. IDOV

The IDOV methodology is analogous to the DMADV methodology. The first step of IDOV, the Identify stage is equivalent to the first two stages (Define and Measure) of DMADV. This stage is driven by the "Voice of the Customer", identifying customer requirements and performing a competitive analysis to establish the business case for the new product. CTQs are developed in this stage to identify technical requirements and specifications using tools such as benchmarking, Quality Functional Deployment (QFD) and target costing. The design stage emphasizes "CTQ Deployment", identifying functional requirements and developing and evaluating alternative concepts and ultimately selecting the "best fit" concept. This stage is equivalent to the analysis stage of DMADV. In the optimize stage (equivalent to DMADV's design stage), the design is optimized. In the verify stage, as in the V of DMADV, the design is tested and validated. Our goal in this research was to observe these stages in process and see how it affects the NPD process.[1]

2.3. DIDOV

The DIDOV development model divides the product creation process into the steps of Define, Identify, Design, Optimize and Verify. These steps are briefly explained in the next section. A more elaborate discussion can be found in literature [1], [2].

Define: The first step of the process focuses on identifying the business need and ascertaining commitment and resources. In other words define the project goal, make a plan to reach that goal, and arrange for the necessary time, budget and people. A feasibility study can be part of the define stage.

Identify: This step translates the business goal into measurable engineering data. An important step is to identify the customer needs: What does the customer value in the product? What would be an incentive to buy this product, rather than another? What would discourage a customer from buying the product? After this inventory these "soft" qualifiers and disqualifiers are translated into measurable quantities, the so-called "Central-to-quality" (CTQ) parameters.

Design: In the DFSS view, the design is the contents of the black box between the inputs to the outputs. The relation between the inputs and outputs is called the transfer function. A first design choice is made to obtain a group of solution directions that seems most likely to result in an optimal transfer function. Next, the design is worked out in more detail and parameters are identified in the transfer function. Mathematically speaking, the objective of the design phase is to construct the transfer function between the inputs and the outputs, including the relevant parameters.

Optimize: The optimize phase focuses upon finding the parameter setting to fill the business and the customer needs as reflected in the CTQs. In traditional six sigma, the optimize phase is heavily focused on mathematical and statistical exercises to locate an optimum and minimize the number of defects as a result of parts variation.

Verify: This phase focuses on verifying the final design. Typically this involves producing a sufficiently large sample of products and verifying if the CTQs and the defect level target are met.

Summarizing, the DIDOV - DFSS method phases are:

1. Define the goal, get commitment and plan the resources
2. Identify the relevant inputs and outputs and CTQs
3. Design the product. This determines the so-called transfer function that relates the inputs to the outputs. Identify parameters.
4. Optimize the design; find the parameter settings that best fill the CTQs.
5. Verify the design: ascertain that the design, with the optimized parameter settings, results in the desired outputs and meets the CTQs to a certain defect level.

The DIDOV method has a fractal nature: At every level and in every phase it is possible to delve deeper and do a lower level whole or partial DIDOV cycle. On the highest business level the different DIDOV phases are separated in content matter, and phases are executed at different locations and levels in the organization.[3]

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III. DESIGN FOR SIX SIGMA IMPLEMENTATION

Design For Six Sigma implementation can be divided into types of sectors: manufacturing and non-manufacturing, described as follows.

A. Manufacturing sector

Cases of successful companies that have adopted Design for Six Sigma are presented in many papers. The authors describe how the respective companies' implement Design for Six Sigma, giving insights into issues of perceived best practices. Motorola was the first organization to use the term Six Sigma in the 1988s as part of its quality performance measurement and improvement program. Design for Six Sigma has been successfully applied in other manufacturing organizations such as General Electric, Allied Signal, Raytheon, and Delphi A, etc. Very few papers have been found regarding successful implementation strategies for whole businesses in other parts of the world. Therefore, academic research outside USA could be a good area of future study to determine any comparative differences in implementation issues, such as those caused by cultural issues. Some showed that product Quality & Manufacturability can be improved effectively by Design For Six Sigma method and experiments proved the roller burnishing size with quality assurance method improved as much as 71 to 79 % comparing with conventional cutting condition. As a matter of fact, the parameters optimization by DFSS method is offering an effective tool to control the roller burnishing size in machining [13].

3.1. Non-manufacturing sector

1) Healthcare sector

Healthcare services are one of the major active nonmanufacturing contexts in which Design for Six Sigma has been adopted, with the majority of papers studying implementation issues in USA. Design for 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 papers explain how Six Sigma improves healthcare service quality by reducing medical errors and increasing patient safety.

2) Financial services sector

In recent years, finance and credit department are pressured to reduce cash collection cycle time and variation 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 [19]. Bank of America 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. Bank of America reported a 10.4% increase in customer satisfaction and 24% decrease in customer problems after implementing Six Sigma [20].

3) Other Sectors

Application of Design for Six Sigma also possible in Third Party Intensive Programs The uniqueness of this approach is instead of forcing third parties to adopt DFSS methods we can help them better manage and influence the development of our requirements into more robust designs. Some papers have presented a novel approach to achieve variability reduction, synchronization, and therefore delivery performance improvement in supply chain networks. Our approach exploits connections between design tolerancing in mechanical assemblies and lead time compression in supply chain networks [16]. Some paper has demonstrated how the DFSS methodology can be implemented to supply chain design to identify the VOC then translate it into CCR's showing that demand management is one of the major CCRs for a supply chain which can then be optimized and validated. Design for Six Sigma is not limited to tangible products but can be a useful and flexible methodology for dealing with the complexity and variability of supply chain design [12].

IV. FUTURE TRENDS OF DESIGN FOR SIX SIGMA

Although Design for Six Sigma originated in manufacturing industry, it has been successfully adopted by many other public or private sectors, from financial services to health care delivery and management, from information technology to knowledge management. These ideas can be integrated with other productivity improvement methods, for example the recent focus on Lean Six Sigma. These methods will continue to show their endurance in the global business environment. Some research is proposed for applying DFSS to different supply chain processes and from various positions within a supply chain.

V.CONCLUSION

Successful implementation of DFSS quality management at an organization leads to process variations, quality and productivity improvement, bottom line results improvement & competitive position of the industry. The organization also needs to consider certain quality ingredients for implementing a successful DFSS program as described in this paper. DFSS presents a proactive systems design approach where the focus is placed on spending more efforts in collecting and translating VOC into product. Design for Six Sigma DAMDV methodologies is beneficial to improve productivity and quality of the organization. The DAMDV methodology is applicable in both, manufacturing and non-manufacturing sectors. DFSS is a new strategic paradigm of management invention for an organization to survive in this 21st century. DFSS is perhaps the most successful business improvement strategy developed in last fifty years. Its relevance extends even beyond manufacturing to services, government & the public sectors to service, healthcare & nonprofit organizations.

REFERENCES

[1] Richard M. Franza, Satya S. Chakravorty "Design for Six Sigma (DFSS): A Case Study" PICMET 2007 Proceedings, 5-9 August, Portland, Oregon - USA © 2007 PICMET
[2] Ir. G. A. (Wendy) Luiten "Thermal Design in the Design for Six Sigma – DIDOV Framework" 27th IEEE SEMI-THERM Symposium
[3] Andrew D. Sleeper "Andrew D. Sleeper" McGraw-Hill
[4] Thomas pyzdek "The Six SigmaHandbook" McGraw-Hill
[5] Megan Florent Tchidi, Zhen He "The Requirements Engineering Process Model Based on Design for SixSigma" 978-1-4244-5265-©2010 IEEE
[6] Subir Chowdhury, "Design For Six Sigma", PEARSON EDUCATION LIMITED
[7] *Dr Jju Antony and Ricardo Banuelas Coronado "*Design for Six Sigma" manufacturing engineer february 2002
[8] Lawrence I. Goldman and Crystal Campbell "CRYSTAL BALL® AND DESIGN FOR SIX SIGMA" Proceedings of the 2004 Winter Simulation Conference R .G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, eds.
[9] Koji Shimoyama and Akira Oyama and Kozo Fujii " New Efficient and Useful Robust Optimization Approach- Design for Multi-Objective Six Sigma" 0-7803-9363-©2005 IEEE.
[10] Mihály Janóczki, Balázs Illés "Cost Effective Design for Six Sigma in Component Placement" 1-4244-0551-©2006 IEEE
[11] Yousef Amer, Lee Luong, Sang-Heon Lee, William Y C Wang, Muhammad Azeem Ashraf and Zahid Qureshi "Implementing Design for Six Sigma to Supply Chain Design" 1-4244-1529-©2007 IEEE
[12] Hari Narayanan, Soo Beng Khoh,and Penang Design Centre "Managing Change Towards Design for Six Sigma" 978-1-4244-6567- ©2010 IEEE.
[13] J. J. Wu ,Y. z. Wang, w. s. Cai, "Improving Quality & Manufacturability by Design For Six Sigma" 978-1-4244-6932 ©2010 IEEE.
[14] Kai Xu, " Six Sigma Roles in Innovation" 1-4244-0148- 2006 IEEE.
[15] Subramanyam Ranganathan, Cvetan Redzic, Ph.D, "Application of Design for Six Sigma in Third Party Intensive Programs" 978-0-7695-3266-© 2008 IEEE.
[16] Dinesh Garg ' Y. Narahari N. Viswanadham,Design of Six Sigma Supply Chains" 0-7803-7736-2003 IEEE.
[17] Jack Welch, "What is design for six sigma".
[18] Chantal Baril, Soumaya Yacout, Bernard Clément, "Design for Six Sigma through collaborative multiobjective optimization" Computers & Industrial Engineering 60 (2011) 43–55.
[19] Gregory H Watsons,"The Element Of Design of Six Sigma" ETM-5111, pp 2-16,2003
[20] Qianmei Feng, Kailash C. Kapur, "New to Six Sigma? An Introduction to Six Sigma for Students and New Quality Practitioners" December 11, 2007