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Construction analysis based on total quality management and six sigma methodologies

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This paper focuses on comprehensive study that analyses the total quality management (TQM) practices in connection with the relationship between organization strategy and its performance. By analyzing TQM in the context of organization strategy around a number of important factors, this paper seeks to advance the understanding of TQM and six sigma in general context which highlights the causes of quality problem and building quality into the production process. It is also notable here that the six sigma is pivotal in enhancing the management process. As an outcome, it can be deduced from this study that the important factors of TQM are those basic elements that greatly lead to good performance. It is also shown that the total quality management is affected by the quality leader's contribution.

Key words: Quality control, total quality management, construction, quality assurance, six sigma.

INTRODUCTION

Total Quality Management (TQM) is a management concept, according to Edwards Deming. Management is mostly linked `with the development, deployment and improvement of organizational systems that are important for different business processes. Total Quality Management (TQM) is collected organizational effort formulated to enhance quality at each level. TQM philosophy has great impact on organizations and on your life. Total Quality management (TQM) is different from the old concept of quality because its focus is on facilitating customers, finding the causes of quality problems and building quality into the production process. The importance of total quality management (TQM) has increased each level. According to the literature the TQM elements may be grouped into two directions: the management system and technical system. It has always been a big problem in the construction industry to achieve acceptable levels of quality.

Huge resources have been drained each year because of lack of quality management procedures. The manufacturing industry has developed Total Quality Management (TQM) concept. It was first applied in Japan and in recent years used in the United States; this has enhanced productivity, minimized product cost and improved reliability. Such concepts are also applicable to the construction industry. Although construction is a creative, one time effort, the Japanese construction industry accepted the TQM concepts that could only be applied to large production. TQM is a continued effort that involves every organization in the industry to improve performance of business activities. It is present in every aspect of a company and makes quality a strategic objective. It is also achieved through an integrated effort among personnel at all levels to enhance customer satisfaction by continuously improving performance. TQM focuses on process improvement, customer and supplier involvement, teamwork, training and education in an effort to achieve customer satisfaction, cost effectiveness and defect free work. TQM provides the culture and climate essential for innovation and technology advancement.

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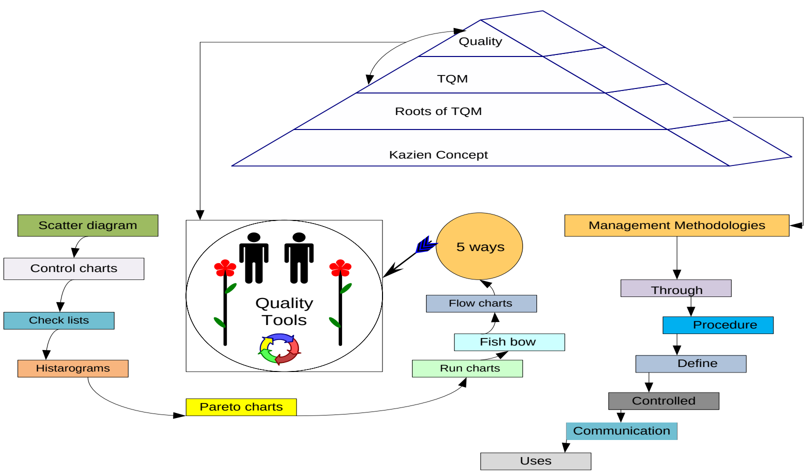

Figure 1. Schematics of quality management.

Quality management

Quality means the strong meeting the legal, aesthetic and functional requirement of any project. The production line quality is important for quality products delivery. It means that quality must be on an equal level with project scope, time and cost. Design professionals, therefore, believe that quality is calculated by the aesthetics of the facilities they design. In the building construction industry, quality can be defined as fulfilling the requirements of the designer, constructor, and regulatory agencies as well as the owner. In terms of function, a high quality building project can be described by such terms as ease in understanding drawings, level of agreement in drawings and specifications, economics of construction, ease of operation, ease of maintenance and energy efficiency. Schematics of quality management is shown in Figure 1.

In advance scope, quality management has four main components: (i) quality planning, (ii) quality control, (iii) quality assurance and (iv) quality improvement (Rose, 2005). Quality management is focused not only on product/service quality, but also the means to achieve it. Quality management, therefore, uses quality assurance and control of processes as well as products to achieve more consistent quality. Quality management is implemented by many organizations. Serious problems can still be found in construction site (CIRC, 2001). The purpose of project quality management is to ensure that the project meets its requirements (Schwalbe, 2006). Quality management plays a major role in construction companies (Mccaffer, 2004).

Origin of TQM

It is the early 1920s' production quality control ideas and notably the concept was developed beginning in the late 1940s and 1950s; it was pioneered by Americans Feigenbum, Juran and Deming. The quality management history, from mere 'inspection' to Total Quality management and its modern 'branded interpretations such as "Six Sigma" has led to the development of essential processes, ideas, theories and tools that are central to organizational development, change management and the performance improvements that are generally desired for individuals, teams and organizations. Quality management resulted mainly from the work of the quality think tanks and their theories. The American think tanks that featured in the 1950s in Japan were Joseph Juran, Edwards Deming and Armand Feigenbum; the Japanese quality think tanks who developed and extended the early American quality ideas and models were Kaoru Ishikawa, Genichi Taguchi and Shigeo Shingo; and the 1970 to 1980s' American Western gurus, notably Philip Crosby and Tom Peters, who further extended the Quality management concepts after the Japanese successes. A wide range of tools and techniques is used for identifying, measuring, prioritizing and improving processes which are critical to quality. Again, these ideas and methods feature prominently in modern interpretations of total quality management methodology, such as six sigma. These process improvement tools and techniques include: define, review, identify, verify, execute, (DRIVE) process mapping, flow charting, force field analysis, cause and effect, brainstorming, Pareto analysis, statistical process control (SPC), control charts, bar charts, 'dot plot' and tally charts, check sheets, scatter diagrams, matrix analysis, histograms.

Kaizen concept in TQM era

A very important concept of Kaizen within quality management deserves specific explanation. Kaizen is a way of thinking, working and behaving, embedded in the philosophy and values of the organization. In the business

Table 1. Main quality tools.

5 Whys	**Asking 'Why' at least five times to uncover root cause of a problem**
Flowcharts	Boxes and arrows method of examining activities, potentially used in brainstorming, also found in business process modeling
Fishbone/Ishikawa diagrams	Fishbone structured diagram for identifying cause/effect patterns, in which primary categories are generally pre-determined according to context. See fishbone diagram and usage example for project management
Run charts	A graph which plots data/change along a timeline
Pareto charts	A line and bar graph displaying cause/effect ratios, especially biggest relative cause, based on pare to theory
Histograms	A bar graph displaying data in simple categories which together account for a total
Check sheets	Pre-formatted lists for noting incidence, frequency, etc., according to known useful criteria
Check lists	There are under an operational condition which ensure all important action are been taken into account before decision making
Control/Shewhart charts	A standard pattern of performance/time for a given process, often in Run chart format, which acts as a template to check conformance and deviation
Scatter diagram/scatter plot	A graph which plots points (Typically very many individual instances) according to two variables, which produces a useful visual indication of the relationship between the two variables

words, the word kaizen has been utilized by the Japanese to characterize a business strategy that involves every-one in an organization working together to make improve-ments 'without large capital investments (Adams et al., 2003). Kaizen is a core principle of quality management generally and specifically within the methods of Total quality management and 'lean manufacturing'. Originally developed and applied by Japanese industry and manufacturing in the 1950s and 60s, Kaizen continues to be a successful philosophical and practical aspect of some of the best known Japanese corporations and has for many years been interpreted and adopted by 'western' organizations all over the world. The Japanese process of continuous improvement uses problem solving and analysis techniques that may include the use of fishbone diagrams, control charts, affinity diagrams and other tools (Masaaki, 1986). A Japanese management philosophy is typically translated as "continuous improvement."

Using this concept, employees are given the authority and resources to solve problems to make improvements (Tozawa Bunji, 1995). In the Japanese words, kai and zen, kai means change and zen means good. The popular meaning is continuous improvement in all areas of a company; not just quality (JW, 2000). It is an organi-zational attitude, approach and philosophy in doing business. It is the key thrust for maintaining or achieving competitive advantage through a well managed, dynamic change process (USA, 1981). In relation to a social system as an industrial process, kaizen is at the heart of the quality philosophy and involves the use of quality circles or small teams of workers to analyze and make suggestions for improving their own work tasks (Drew et al., 2004). Continuous incremental improvement of an activity is to eliminate waste (Gemba Research LLC, 2009): Japanese for 'change for the better' or 'improvement'. It is a business philosophy of continuous cost reduction; reduction of quality problems and delivery time reduction through rapid, team based improvement activity (Ferguson and Clayton, 1988). The philosophy of con-tinual improvement is that every process can and should be continually evaluated and improved in terms of time required, resources used, resultant quality, and aspects relevant to the process (Juran, 1988).

Tools for determining quality

Quality tool means tools and techniques used in support of Kaizen and other quality improvement or quality management programmes and philosophies. Based mainly on statistical and manufacturing process quality tools are used at all levels of an organization typically in 'quality circles' or Kaizen work teams to analyze and review activities and uncover inefficiencies. Main quality tools are expressed in Table 1.

Some quality tools, like flowcharts and checklists, have become part of mainstream management. Others tools such as the fishbone diagram has stayed quite specific to the engineering and manufacturing disciplines, which traditionally have a strong focus and expertise in Kaizen. 'Lean' management and other quality management

Table 2. Quality management methodologies.

Thorough	Procedures should cover all aspects of work where conformity and standards are required to achieve the desired quality levels. For example, one might decide to control formal program testing, but leave the preliminary testing of a prototype to the programmer's discretion.
Procedures	Any recurring aspect of work could merit regulation. The style and depth of the description will vary according to needs and preferences, provided it is sufficiently clear to be followed.
Defined	A major tenet is that the defined procedures are good and will lead to the desired levels of quality. Considerable thought, consultation and trialing should be applied in order to define appropriate procedures. Procedures will often also require defined forms or software tools.
Controlled	As with any good quality management, the procedures should properly controlled in terms of accessibility, version control, update authorities etc.
Communication	All participants need to know about the defined procedures that they exist, where to find them, what they cover. Quality reviewers are likely to check that team members understand about the procedures.
Used	The defined procedures should be followed. Checks will be made to ensure this is the case. A corrective action procedure will be applied to deal with shortcomings. Typically the corrective action would either be to learn the lesson for next time, or to re-work the item if it is sufficiently important.

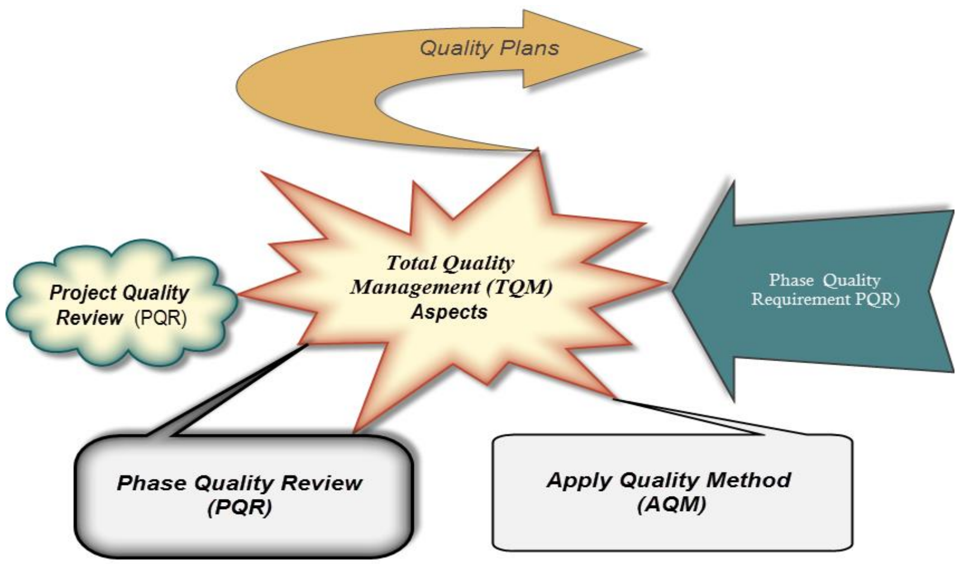

Figure 2. Aspects of quality management.

methodologies are shown in Table 2.

Quality management aspects

The followings are the various aspects of Quality Management (Figure 2). Different organizations will interpret differently these concepts and may package them into other activities. This description follows the logical requirements (Table 3).

Dependence of quality and work scope

Quality methods will depend on the type of project- the team, application, technology, participants, environment, etc. That will also be affected by strategic decisions about the investment in quality exemplified as follows,

1. All requirements should be prototyped iteratively in collaboration with the responsible user manager.
2. Designers are expected to consider any reasonable

Table 3. Aspects of quality management.

Aspect	Summary
Quality plan	Define and agree the needs for quality and the specific approaches to meet them.
Phase quality requirements	For each phase, what specific things will be done and what specific deliverable will be produced.
Apply quality methods	Throughout the work the defined approach to quality will be followed. Work or deliverable falling short of the standards will need be reworked to achieve an acceptable standard.
Phase quality review	Before each phase can be closed, a review is performed to ensure that acceptable quality standards have been achieved.
Project quality review	Before the project can be completed, the overall conformance to Quality Methods and requirements should be assessed and approved.

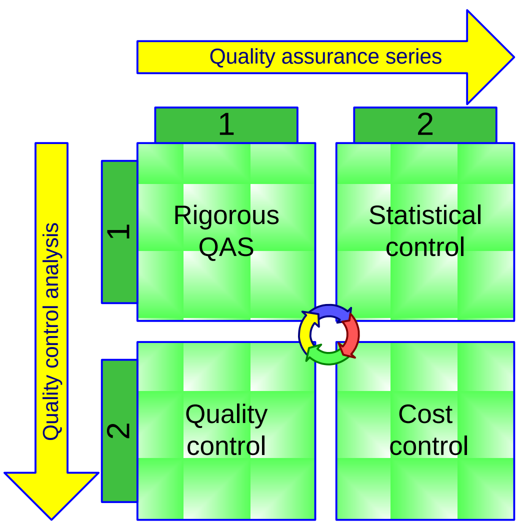

Figure 3. Quality assurance series.

alternative approaches and discuss them with the responsible user manager before creating a detailed design.
3. Any anticipated impact on time scales, resourcing, deliverables or benefits should be communicated to the project manager as soon as possible and before any revised action is taken.
4. All documents should include control information such as version numbers, issue dates, status, authors and reviewers.
5. All designs should be reviewed by a different sub-team and by the overall solution architect.
6. Any aspect of a deliverable which could impact upon another deliverable should be noted in the issues of management system.

Quality assurance series

Quality assurance (QA) is a program which covers activities necessary to provide quality in the work to meet the project requirements (Ferguson and Clayton, 1988).

The assurance is provided from evidence of the objective (Juran, 1988) but the type of evidence differs widely according to the persons requiring the assurance and the nature of the product. QA includes regulation of the quality of raw materials, assemblies, products and components; services related to production; and management, production and inspection processes. QA is more than just testing the quality aspects of a product, service or facility. It analyzes the quality to make sure it conforms to specific requirements and complies with established plans. Previously, the extensive division of labor and mechanization results from the Industrial Revolution. It was possible for workers to control the quality of their own products. Quality control by inspection in the 1920s and 1930s led to the growth of quality inspection functions, separately organized from production and big enough to be headed by superintendents. The systematic approach to quality started in manufacturing industries during the 1930s, mostly in USA, when some attention was given to the cost of scrap and rework. Quality assurance series is depicted in Figure 3.

Quality assurance process

1. Test previous articles
2. Plan to improve
3. Design to include improvements and requirements
4. Manufacture with improvements
5. Review new item and improvements
6. Test new item

The process for Quality Assurance is very rigorous and requires a lot of testing and planning. Also, one of the primary devices of QA is metrics, or measurability. The team or firm has to comply with previous requirements, implement new requirements and improve the old item. Other than following requirements, the team or firm has

Table 4. Quality control parameters.

Skill	Description
Fit for purpose and right first time	The product should be suitable for the intended purpose and mistakes should be eliminated.
JIS	The Japanese Industrial Standards define quality control as a system for the economical production of goods and services that meet the demands of the consumers**.**
QCC	Quality control concepts, techniques, and practices were developed around assumptions of the inevitability of error and made no room for a defect-free situation.
QCD	Quality control is development of a project quality control plan. Presently, testing and inspection requirements are scattered throughout the contract specifications.

to comply with consumers' needs.

Analysis of Quality control

Quality Assurance (QA) is a program covering activities necessary to provide quality in the work to meet the project requirements. QA includes policies related to Quality control, procedures, standards, training, guide-lines, and system necessary to produce quality. The design professional and constructor are responsible for developing an appropriate program for each project. Quality Control (QA) is the specific implementation of the QA program and related activities. Effective QC reduces the possibility of changes, mistakes and omissions, which in turn result in fewer conflicts and disputes (Juran, 1988). In the 1950s and 1960s, owners became increasingly concerned with cost and schedule, areas where design professionals were not providing good control (Brien, 1989). One way in which more attention will be given to quality control is development of a project quality control plan. Presently, testing and inspection requirements are scattered throughout the contract specifications. Quality control is the specific implementation of the quality assurance program and related activities.

The term "quality control" has had a short history. Early in the twentieth century, it began to be used as a synonym for defect prevention. However, during the 1940s and 1950s, there was a wave of enthusiasm for the use of statistical methods in quality control (Juran, 1988). The proponents of this movement coined the phrase "statistical quality control" and publicized it so widely that many managers gained the impression that quality control consisted of the use of statistical methods in industry. As a consequence, the statistical quality control movement weakened the use of quality control as an accepted term for the regulatory process. The Japanese Industrial Standards define quality control as a system for the economical production of goods and services that meet the demands of the consumers (Masaaki, 1986). Quality control concepts, techniques and practices were developed around assumptions of the inevitability of error and made no room for a defect free situation (Crosby, 1967). The terms quality assurance and quality control are frequently used interchangeably because quality control is a part of quality assurance (Ferguson and Clayton, 1988).

Statistical control

Most of the organizations use statistical process control to bring the organization to six sigma levels of quality; in other words, so that the likelihood of an unexpected failure is confined to six standard deviations on the normal distribution. This probability is less than forty one million. Items controlled often include clerical tasks such as order entry as well as conventional manufacturing tasks (Antony and Banuelas, 2002; Robert, 2004). Traditional statistical process controls in manufacturing operations usually proceed by randomly sampling and testing a fraction of the output. Variances in critical tolerances are continuously tracked and where necessary corrected bad parts are produced (Anbari, 2002; Thareja et al., 2007).

Cost control

Using a linear extrapolation of costs, the forecast total cost, CF, is,

$$Cf = Ct/Pt$$

Where Ct is the cost incurred to time t and pt is the proportion of the activity completed at time t. Alternatively, the use of measured unit cost amounts can be used for forecasting total cost. The basic formula for forecasting cost from unit costs is:

$$Cf = Wct$$

Where Cf is the forecast total cost, W is the total units of work and ct is the average cost per unit of work experienced up to time t. Quality control parameters are given in Table 4.

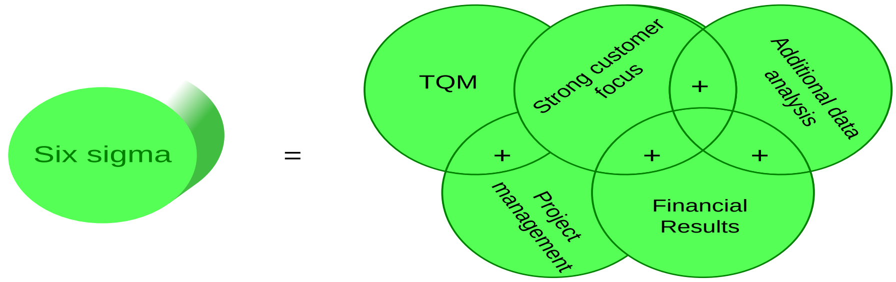

Figure 4. Application of six sigma**.**

Six sigma

The term “sig sigma” is a measurement standard in defining a normal curve of statistical data. The Greek letter “Ϭ” or sigma is a mathematical term that represents a measure of standard deviation, or variability within a given population around the mean. Many researchers have studied sig sigma programs and identified many critical decisions of these programs. For example, see the previous research of Antony and Banuelas (2002), Coronado and Antony (2002), Lakhavani (2003), Lynch et al. (2003), Mcadam and Evans (2004), Gijo and Rao (2005), Szeto and Tsang (2005), Ladani et al. (2006), Savolainen and Haikonen (2007) and Davison and Al-Shaghana (2007). Recently, Zu et al. (2008) studied the evolving theory of quality management and the role of six sigma. Literature is reviewed that develops relevant information on the history, development, application and effectiveness of the TQM and six sigma high-profile management systems. Management involves in performing many six sigma functions, such as selecting improvement specialists, identifying project selection and facilitating six sigma implementation (Gitlow and Levine, 2005; Hoerl and Snee, 2002; Antony et al., 2007). While the high-profile management systems of greatest relevance to the study which this literature review will support are TQM and Six Sigma; other high-profile management systems also are reviewed.

The main responsibility is to provide technical expertise and leadership in facilitating a specific six sigma implementation. Pyzdek (2003) and Keller (2005) point out six sigma programs have performance metrics and measurements based on cost, quality, and schedules. Six sigma implementation uses a systematic procedure: a five-step DMAIC (Define, Measure, Analyze, Improve and Control) methodology. A detailed description of DMAIC methodology can be found in Pyzdek (2003) and Keller (2005). The system must be incorporated into the organizational structure. Control procedures must be established at every stage of the production process (Ryan, 2005). Imagine the issue is the end product of a building construction process and that the function of the facility is either direct production or materials handling. A specific desired outcome for the facility class must be defined (De Feo and Bar-El, 2002).

From the statistical point of view, the term six sigma is defined as having less than 3.4 defects per million opportunities or a success rate of 10% where sigma is a term used to represent the variation about the process average (Antony and Banuelas, 2002). Actually, six sigma is an organization system that tries to appreciate and eradicate the negative effect of variation in processes. It was shorthand for people to understand that if you can control the variation, you can achieve remarkable results (Robert, 2004). Dating back to mid 1980s, application of six sigma method allowed many organizations to sustain their competitive advantage by integrating their knowledge of the process with statistics, engineering and project management. Anbari (2002) and 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 measures and reports financial results. It uses more advanced data analysis tools, focuses on customer concerns and uses project management tools and methodologies (Bechtel Corporation, 2008) (Figure 4).

Six sigma methods have 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. If an organization is operating at three sigma levels for quality control, it is interpreted as achieving a success rate of 95.5% or 66900 defects per million opportunities. Therefore, the six sigma method is a very rigorous quality control concept where many organizations still perform at three sigma level (McClusky, 2000).

Six sigma methodologies

A strong feature of six sigma is the creation of an infrastructure to assure that performance improvement activities have the necessary resources. Creating a successful six sigma infrastructure is an ongoing process whose aim

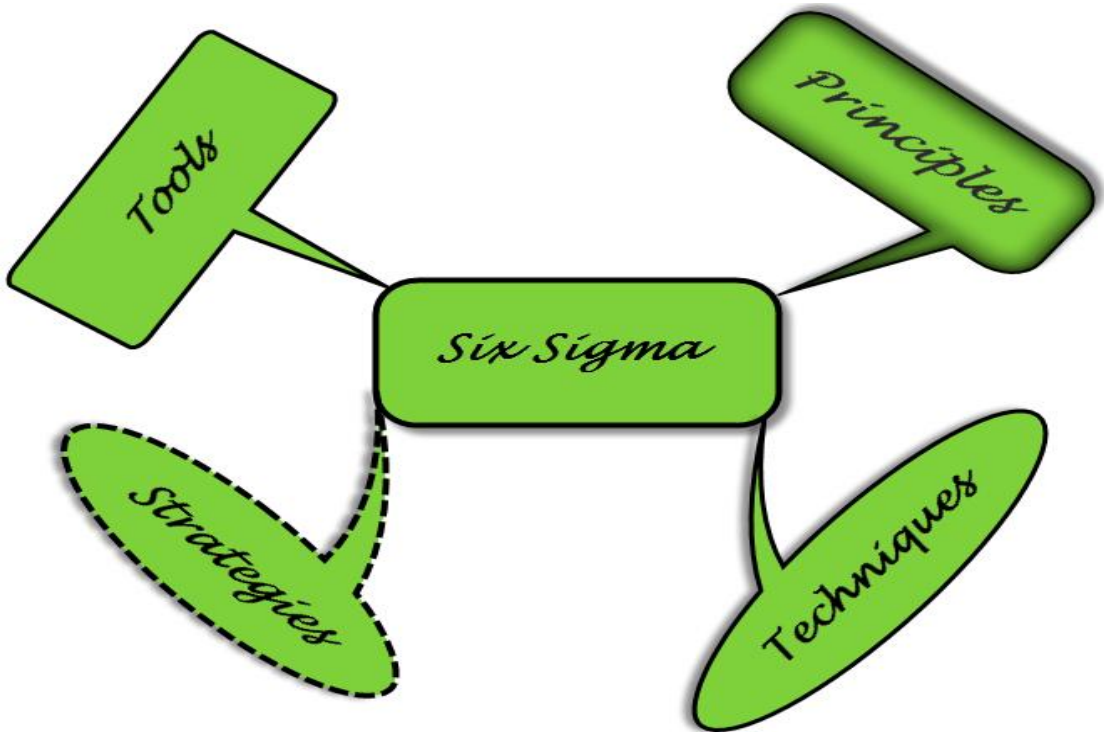

Figure 5. Six sigma strategies, constriction principles tools and techniques.

is to infuse an awareness of quality into the way all employees approach their everyday work. Six sigma projects of continuous process improvement are led from concept to completion through five project management steps or phases named DMAIC (Define, Measure, Analyze, Improve and Control). Six sigma applies a structured approach to managing improvement activities which is represented by Define- Measure- Analyze-Design-Verify (DMADV) used in product/service design improvement (Linderman et al., 2003). Motorola engineers expanded on the term in the 1980s when they decided that the traditional quality levels (measuring defects in thousands of opportunities) were inadequate. Instead they wanted to measure the defects per million opportunities. By using statistical analysis to minimize variation, six sigma enables data based process improvements. Mathematically six sigma refers to the population that falls within plus or minus six standard deviations. Many characterize six sigma programs as the latest management fad of improvement tools and techniques (Watson, 2006).

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) (General, 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, 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 and Banuelas, 2002), ISO 9000 (Cather, 2002), ISO 9001 (Dalgleish and Feo, 2002) and the capability of 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. Six sigma strategies constriction principles tools and techniques are illustrated in Figure 5 and Table 5.

CONCLUSION

One concludes that the 'quality' and its concepts are important for the construction industry. In real sense the construction plan development is very much analogous to the development of a good facility design, as many critiscms have been directed to construction industry (not only product that faces criticism but the process, the labour and the raw material are all under pressure for better quality in construction). In order to undertake the role of quality various aspects of quality tools and techniques are also described in here. Every planner must weigh the costs and reliability of different insuring technical feasibility. In the manufacturing industries focus is on process quality where TQM and its principles are always taken into account. Design, construction and

Table 5. Six sigma strategies, constriction principles tools and techniques.

Six sigma constriction strategies and principles	Six sigma tools and techniques
Project Management	Statistical Constriction 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

operation phases are essential to enhance competitiveness, efficiency and flexibility in quality measurement surroundings to focus on meeting customer needs and organizational objectives. TQM is a corporate culture that is characterized by increased customer satisfaction through continuous improvement, involving all employees in the organization. We suggest that TQM and six sigma play an important role for better understanding in construction community (employees, units, departments within an organization).

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