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# The Impact of Inspection on the Quality Assurance and Reliability of Projects, Manufacturing, Operations and Maintenance

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**Author's contribution**

*This whole work was carried out by the author.*

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## ABSTRACT

A Review of the Impact of Inspection on the Quality Assurance and Reliability of Project, Manufacturing, Operations and Maintenance is reported. The types of inspections and methods of establishing the frequency of inspection have been identified. It has been revealed that too little inspection leads to greater rejects (out-of-limit works) and too much inspection leads to loss of revenue due to the cost of excess inspections. A compromise has therefore been established between cost of out-of-limit work and cost of inspections. This eventually led to the formulation of the optimal value for the Change Multiple in frequency of inspection of projects, manufacturing, operations and maintenance. This optimal value of frequency of inspection yielded the optimal value added to Quality Assurance and reliability of projects, manufacturing, operations and maintenance.

**Keywords:** *Inspection; Quality assurance; FDP; "change multiple" in frequency of inspections.*

## 1. INTRODUCTION

In order to investigate the impact of Inspection on Quality Assurance and Reliability of Projects, the definition of projects and their importance will need to be understood. Also the definition of Quality, Assurance and Reliability will be essential. In a similar vein, the need for

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quality projects will be identified. Of further interest will be the definition of inspection and the importance of inspection on projects. The thrust of this work will be to establish an empirical frame work that will satisfy the "Inspection Frequency" for each major equipment (bridges, buildings, roads, pipelines, machines etc), once the required peculiar data of such equipment are imputed into the empirical relationship. Methods for establishing the frequency of inspection as well as types of inspections will be reviewed. Consequent on the foregoing, the review will assess how inspections drive projects to Success.

## **2. DEFINITION OF PROJECTS AND THEIR IMORTANCE**

A Project [1] can be defined as a temporary endeavor undertaken to create a unique product or service. In the same vein, Project [2] has been defined as a planned piece of work that has a specific purpose and that usually requires a lot of time. Project [3] has also been described as an individual or collaborative enterprise planned to achieve a particular aim. On the other hand, Project [4] has been represented as something that is contemplated, devised or planned; plan; scheme, a large or major undertaking, especially one involving considerable money, personnel and equipment. A Project [5] is also seen as a plan or proposal; a scheme, an undertaking requiring concerted effort. Project [6] is also viewed as a planned piece of work that has a particular aim, especially one that is organized by a government, company or other organization. A Project is seen as planned set of interrelated tasks to be executed over a fixed period and within certain cost and other limitations [7,8,9]. Why do we embark on projects?; of what significance and importance are projects to the society, communities, organizations and the environment?. Concise answers to the preceding questions are that projects help in lifting societal and organizational developments from a lower level to a higher one [10,11,12,13]. In other words, projects add value to the society; as such every successfully executed project adds some amount of improvement to the society.

## **3. DEFINITION OF QUALITY, ASSURANCE AND RELIABILITY**

Quality in manufacturing is defined as a measure of excellence or a state of being free from defects, deficiencies and significant variations [14]. It is brought about by strict and consistent commitment to certain standards that achieve uniformity of a product in order to satisfy specific customer or user requirements. Quality is also defined as: a peculiar and essential character; how good or bad something is; a characteristic or feature that someone or something has; something that can be noticed as a part of a person or thing; a high level of value or excellence [15]. Accordingly, Quality means fitness for use; Quality is inversely proportional to variability [16]. Quality is a perceptual conditional and somewhat subjective attribute and may be understood differently by different people. Consumers may focus on the specification quality of a product or service, or how it compares to competitors in the market place. Producers might measure the conformance quality or degree to which the product/service was produced correctly. Support personnel may measure quality in the degree that a product is reliable, maintainable or sustainable. Simply put, a quality item (an item that has quality) has the ability to perform satisfactorily in service and is suitable for its intended purpose. Emphasis laid on Juran's "fitness for intended use" basically says that quality is "meeting or exceeding customer's expectations" [17]. In a similar vein, Quality is defined as: an inherent or distinguishing characteristic; a property; a personal trait, especially a character trait; superiority of kind or degree or grade of excellence [18]. Quality is also seen as the standard of something as measured against other things of a similar kind; the degree

of excellence of something [19]. Quality can be viewed as essential characteristic, property or attribute of something [20].

In retrospect, Assurance [21] is seen as: a positive declaration intended to give confidence, a promise; confidence or certainty in one's own abilities or certainty about something. Assurance [22] is also viewed as a statement or indication that inspires confidence; a guarantee or pledge that a plan would succeed; freedom from doubt; certainty. In similar vein, Assurance [23] is viewed as coverage of an event that is certain to happen while a corroborative view of Assurance [24] are: the state of being sure or certain about something; a strong feeling of confidence about yourself or about being right; or a strong and definite statement that something will happen or that something is true.

On the other hand, Reliability [25] is: the quality or state of being reliable or the extent to which an experiment, test or measuring procedure yields the same results on repeated trials. Synonyms of Reliability [25] include: dependability, dependableness, reliableness, responsibility, solidity, solidness, sureness, trustability and trustworthiness. Furthermore, Reliability [26] is defined as the ability to be relied on or depended on, as for accuracy, honesty or achievement. In a similar vein, Reliability [27] is the probability that an item will perform a required function without failure under stated conditions for a stated period of time. Reliability methods could be divided into:

- i) System Reliability (Reliability Prediction) – here probability methods are used to determine system reliability using knowledge of system architecture and part reliability;
- ii) Part Reliability (Reliability Estimation) – statistical methods are used to determine part reliability using part failure data (reliability data). A part is an item that is assumed to be indivisible for the purpose of determining its reliability;
- iii) Repairable System Reliability – use of reliability figures of merit that require some knowledge of system repair activity and
- iv) Non-Repairable System Reliability – use of reliability figures of merit that do not require knowledge of repair activity. On the other hand, Reliability [28] is seen as: capable of being relied on, dependable; yielding the same or compatible results in different clinical experiments or statistical trials.

#### **4. WHY THE NEED FOR QUALITY PROJECTS?**

Quality [29] projects offer complete project management, construction management and principle agent services. This is to ensure successful completion of specific project goals and objectives. In the same vein, the goal of the office of Air Quality Planning and Standards (OAQPS) [30] is to preserve and improve the quality of the air that we breathe. Towards this end, OAQPS is involved in various projects dealing with the assessment and regulation of air pollution. In similar vein, commercial results are improved by focusing on wind projects quality and safety in Power-Generation [31]. On the other hand, Project Quality Plan [32] is seen as a set of activities planned at the beginning of the project that helps achieve quality in the project being executed. The purpose of the project quality plan is to define these activities or tasks that intends to deliver products while focusing on achieving customer's quality expectations. These activities/tasks are defined on the basis of the quality standards set by the organization delivering the product. Furthermore, in simple home-remodeling projects or constructing a high-rise building, pouring a driveway or building highways, quality in construction projects ensures that the work represents the highest standards and lasts as long as possible generally, quality-related decisions take place during the planning and

design phase of the project [33]. The main reason for evaluating quality of conformance in construction projects is to ensure that the design specifications are met. Any method that purports to measure Project Quality must consider at least two aspects:

- i) Technical Quality as measured by Defect Counts and Positive Counts or Indicators and
- ii) Perception of Quality, a subjective factor that can be measured by such indicators as Customer Involvement and Stakeholder Satisfaction [34].

In the Input: Process: Output model as the basic building block of Quality Measurement, the individual project work package or activity assignment are:

- i) Assuring proper inputs: selecting appropriate talent for each assignment, then using effective delegation with information about how the results will be evaluated;
- ii) Specifying Quality Processes, then monitoring the results, and correcting the processes that produce defects and
- iii) Reviewing the Outputs or results, using appropriate review levels and participants.
- iv) Monitoring review outcomes and correcting the inputs and processes as needed [34].

Projects can be “hard products” (that is tangible projects) or “soft products” (that is less tangible projects). For these project types, measures are used where available, and indicators where measures are not available. A key measure is Defect Count or more appropriately, Planned versus Actual Defect Count [34]. Indicators of Quality (for particularly very early in projects when defect counts may not be available and as seen from subjective and perception side of Project Quality) are:

- i) Engagement measures: internal customer involvement in key project activities; expected versus actual;
- ii) Planned versus Actual Cumulative Review Count and
- iii) Assessment Measures: customer satisfaction surveys; stakeholder expectations evaluation.

Effective Reviews should also follow these guidelines:

- a) Assure Proper Preparation
  - b) Review the results, not the performer
  - c) Find the problems, not the solutions to them and
  - d) Assure follow-up on open items [34].
- e) Factors that must be in place in order to produce Quality results include:
- i) Producing realistic plans;
  - ii) Involving customers and clearly understanding needs;
  - iii) Using repeatable and repeated processes;
  - iv) Engaging competent team members;
  - v) Assuring team member ownership;
  - vi) Demonstrating effective informative delegation;
  - vii) Planning and staffing appropriate Reviews and
  - viii) Assuring proper testing, documentation and training [34].

Quality characteristics are often evaluated relative to specifications. A value of a measurement that corresponds to the desired value for that Quality characteristic is called the nominal or target value for that characteristics. These target values are usually bounded by a range of values that most typically and sufficiently close to the target so as to not impact the value [35]. Tools and Techniques for improving Quality are:

- i) Histograms and Bar Charts;
- ii) Pareto chart;
- iii) Scatter Diagrams;
- iv) Cause-and-Effect Diagrams;
- v) Process Flow Diagrams;
- vi) Control Charts;
- vii) Design of Experiments (DOX)
- viii) Data Snooping;
- ix) Quality Loss Function (QLF);
- x) Three-Sigma ( $\mu \pm 3\sigma$ );
- xi) Six-Sigma ( $\mu \pm 6\sigma$ )(see Fig.1 in appendix);
- xii) Process Capability Ratio and
- xiii) Process Capability Index [35].

The Process Capability Ratio (also known as Potential Capability Index) =  $C_p = (U - L)/6\sigma$  (1)

The Process Capability Index (also known as Actual Capability Index) =  $C_{pk} = [(\mu-L)/3\sigma, (U-\mu)/3\sigma]$  (2)

Where U is the upper limit of specification and L is the lower limit of specification,  $\mu$  is the mean value and  $\sigma$  is the standard deviation of specification. When  $C_p$  equals  $C_{pk}$ , the process is centred between the upper and lower specifications limits and hence the mean of the process distribution is centred on the nominal value of the design specifications, that is at the midpoint of the specification range [35].

$C_p$  is used at the process design stage. If  $C_p = 1.0$ , process is just potentially capable of meeting specification.

If  $C_p < 1.0$ , Process is potentially incapable of meeting the specification.

If  $C_p > 1.0$ , Process is potentially capable of meeting the specification.

If  $C_{pk} > 1.0$ , the Process is meeting the specification.

If  $C_{pk} < 1.0$ , the Process is not meeting the specification.

However,  $C_{pk}$  has the advantages over  $C_p$  that it can detect a shift in the mean value X from the target value  $X_0$ .  $C_p$  cannot detect this shift and is therefore not suitable for measuring actual process capability [35].

Additional tools in Six-Sigma are:

- i) Design for Six-Sigma (DFSS);
- ii) Voice of the Customer (VOC);
- iii) Define, Measure, Analyze, Design and Verify (DMADV) and
- iv) Define, Measure, Analyze, Improve and Control (DMAIC) [35]. (See the details of these tools in Table 1 and Table. 3 in Appendix).

In recent years, two sets have become identified with Six-Sigma, namely Lean systems and Design for Six-Sigma (DFSS). Lean systems are designed to eliminate waste, that is unnecessary long cycle times, or waiting times between value-added work activities. Waste can also include rework (doing something over again to eliminate defects introduced the first time) or scrap. Rework and scrap are often the result of excess variability, so there is an obvious connection between Six-Sigma and Lean (see Table. 2 in Appendix) [35]. On the other hand, DMAIC is a structured problem-solving procedure widely used in quality and process improvement (See the details of the DMAIC Problem Solving Process in Table 1 and Table. 3 in Appendix). It is often associated with Six-Sigma activities and almost all implementations of Six-Sigma use the DMAIC problem solving process for Project Management and Completion [35].

## **5. DEFINITION OF INSPECTION**

Inspection is defined as: an official process of checking that things are in the correct condition or that people are doing what they should; an action of looking at something carefully, especially in order to check that it is satisfactory [36]. For the Inspections to be done, an Inspection and Test Plan must be done. Inspection and Test Plan is a document made by Manufacturer/Subcontractor or Contractor to describe the minimum requirements of the Quality Control activities, Inspection and Test Items during fabrication and /or construction phase, reference documents, required acceptance criteria certifying or verifying documents, and Inspection parties involved; it also assure that the product will be built in accordance with project specification, codes and standard requirements, and meet local government regulations[37]. In engineering activities, inspection involves the measurements, tests, and gauges applied to certain characteristics in regard to an object or activity. The results are usually compared to specified requirements for determining whether the item or activity is in line with these targets. Inspections are usually non-destructive. In the same vein, Inspection is seen as the act of looking at something closely in order to learn more about it, to find problems, et cetera; the act of inspecting something [38]. Also, Inspection means the act of inspecting or viewing, especially carefully or critically; formal or official viewing or examination [39]. Alternatively, Inspection [40] is viewed basically as an organized examination or a formal evaluation exercise. An inspection involves the measurements, tests, and gauges applied to certain characteristics in regard to an object or an activity. Inspection [41] can also be seen as careful examination or scrutiny while some school of thought view Inspection[42] as the critical appraisal involving examination, measurement, testing, gauging and comparison of materials or items. An inspection determines if the material or item is in proper quantity and condition, and if it conforms to the applicable or specified requirements. On the other hand, Inspection [43] can be seen as the examination of a part to determine if it conforms to specifications. Inspection traditionally follows the completion of a part. In other words, Inspection [44] is close examination of something, especially for faults or errors; an official check or examination of something for safety or quality. In the same vein, Inspection [45] is described as a visual examination of a facility and/or equipment to identify, report and eliminate or control hazards that could cause accidents before they result in loss. Inspections should target all exposures to property and members of the public.

## **6. WHY CARRY OUT INSPECTION ON PROJECTS?**

The necessity of Inspection [46] arises as: i) the need to reduce losses, ii) the need to maintain a safe environment, iii) changing environment implies changing risks. Formal

Inspections [47] can take different forms and you and your representatives will need to agree on the best methods for your work place. Some of the ways that inspection can take place are: safety tours; safety sampling; safety surveys and incident inspections. Site inspections [48] are an important process of ensuring your work meets building regulation standards which ensure that project will be safe, fire resistant, energy efficient and sustainable. After April 6th 2013, when you submit a building Regulation Application, you are likely to be provided with an inspection service plan before you start work detailing the stages of work they would like to inspect [48]. This will vary depending on the size and complexity of your project, age of your home, the construction type, ground conditions and your builder's experience [48]. The regular inspection [49] of civil engineering structures extends the service life of those structures. As the operator, you can use the results of such inspections to identify any required renovations in time and implement repairs cost-effectively. Benefits of inspection are that it enable you to: recognize repair needs in time and save money as a result; enhance the safety of your structures through monitoring; receive assistance by obtaining quality assurance of construction materials used in repair and take advantage of our many years of experience in construction [49]. The same basic consent and inspection process applies whether building a new home, commercial building or structure, or for renovations, additions, alterations or demolitions [50]. Requirements [50] that apply to all but exempt to building work are: building consent, inspections and code compliance certificate. Additional requirements that apply to buildings with specified systems (which are mainly commercial, public, or multi-units residential buildings) are: compliance schedule and building warrant of fitness. The purpose of the law is to ensure that building work is safe, durable, and does not endanger health, both for the current users of the building and to protect those who may buy and use the property in the future [50]. Building without a building consent [50] where one is required is an offence in New Zealand that could result in fines and possibly the removal of the building work. It may also make it difficult to sell the building or even to get insurance. Building consent and inspection checklist [50] is as detailed below:

- a) Find out about the site before making a detailed building consent application. Consider making an application for a project information memorandum (PIM). A PIM identifies:
  - i) Whether a resource consent is required;
  - ii) Whether other laws affect the site, for example, heritage requirements, territorial authority bylaws;
  - iii) Whether the land has special features, for example erosion, or is affected by hazardous materials;
  - iv) Details of surface water and waste water and whether a development contribution fee is required.
- b) Prepare the building consent application and accompanying plans and specifications. If restricted building work is involved the applications must include certain documentation from a licensed building practitioner with an appropriate design license.
- c) Notify the building consent authority when work begins on a project.
- d) Organize inspections and ensure they are occurring as required.
- e) At the end of the project, organize for a final inspection for a Code Compliance Certificate (CCC).
- f) Owners of commercial, public or most multi-unit residential buildings have ongoing requirements through the Building Warrant of Fitness (BWOFF) regime. On

completion of your project, the Building Consent Authority will issue a compliance schedule covering the maintenance, inspection and reporting requirements for the specified systems in the building. The building owner is responsible for ensuring that the requirements of the Compliance Schedule are met. On the anniversary of the Compliance Schedule, building owners will need to supply the territorial authority with a BWOFF.

## **7. HOW DO WE ESTABLISH THE FREQUENCY OF INSPECTION?**

Frequency of inspections [51] for Routine, Under-water, Fracture critical member and Damage, in-depth is stipulated as follows:

- a) Routine inspections
  - i) Inspect each bridge at regular intervals not to exceed twenty-four months.
  - ii) Certain bridges require inspection at less than twenty-four month intervals. Establish criteria to determine the level and frequency to which these bridges are inspected considering such factors as age, traffic characteristics and known deficiencies.
  - iii) Certain bridges maybe inspected at greater than twenty-four month intervals, but not to exceed forty-eight-months, with written FHWA approval. This may be appropriate when past inspection findings and analysis justifies the increased inspection interval.
- b) Under-water inspections
  - i) Inspect under-water structural elements (for example bridge struts, columns, pilings and slabs) at regular intervals not to exceed sixty months.
  - ii) Certain under-water structural elements require inspections at less than sixty months intervals. Establish criteria to determine the level and frequency to which these members are inspected considering such factors as construction materials, environment, age, scour characteristics, condition rating from past inspections and known deficiencies.
  - iii) Certain under-water structural elements may be inspected at greater than sixty-month intervals, not to exceed seventy-two months, with written FHWA approval. This may be appropriate when past inspection findings and analysis justifies the increased inspection interval.
- c) Fracture critical member (FCM) inspections
  - i) Inspect FCMs at intervals not to exceed twenty-four months.
  - ii) Certain FCMs require inspection at less than twenty-four month intervals. Establish criteria to determine the level and frequency to which these members are inspected considering such factors as age, traffic characteristics and known deficiencies.
- d) Damage, in-depth and special inspections.

Establish criteria to determine the level and frequency of these inspections.



On the other hand, the criteria for establishing control plan sample size and inspection depends on the process, the process control, the capability and frequency of special causes [52]. There is no accurate way to determine this without that information as there is no magic equation that you can plug and chug to get a valid answer. General rule of thumb: 5 data points between any expected adjustment [52]. On how to decide frequencies of preventive maintenance (PM) inspection, the failure developing period (FDP) (called pf curve by some) is defined as the time difference between the failure and the breakdown of an equipment [53]. The theoretical answer as to the frequency of inspection is that:

$$\text{The Inspection Frequency (should roughly be)} = \text{FDP}/2 \text{ [53]} \quad (3)$$

The real problem is that we do not know what the FDP is [53]. There is no standard, no documentation and most plants do not have any history on FDP [51]. The FDP change when we have access to better tools and that the only reason we buy inspection tools is to extend the FDP with more accuracy [53]. In reality, the ability to detect a failure during the FDP also depends on the person's ability to do the inspection, environment (lighting, temperature, indoor versus outdoor, etc), and operational parameters at the time of inspections, equipment design and accessibility [53]. In a nutshell, inspection frequencies are based on FDP, not criticality or component life and that FDP for all failure modes is quite unfeasible and impractical to predict, but that a pretty good guess could be made as to what it is [53]. On the other hand, the Hazard Analysis and Critical Control Point based inspection (HACCP) could be used [54].

Food safety is the primary focus of an HACCP approach inspection. One lesson learned was that good communication skills on the part of the person conducting an inspection are essential [54]. With any maintenance task, there must be a balance between the cost of the task and the machine's criticality [55]. The best way to start is to decide whether the machine merits monitoring. The identified criteria to be taken into consideration among others are:

- i) Machine safety;
- ii) Risks upon failure;
- iii) Mission criticality;
- iv) Repair costs and down time costs;
- v) As well as other factors that may be specific to the process or facility [55].

Other crucial criteria in the determination of the frequency of inspection, is the "Change Multiple" in Frequency of Inspection ( $\Delta f$ ) [56]. Briefly this is expressed as follows:

Let  $S$  = Initial cost of out-of-limit work (defective work) say per month at present frequency of inspection.

$I$  = Initial cost of inspection over the same period including overheads.

$$\Delta f = \text{"Change Multiple"} \text{ in frequency of inspection, that is, new frequency } f_2 = (\Delta f)f_1; \quad (4)$$

where  $f_1$  is the initial frequency.  
 Cost of Out-of-limit work =  $S/ \Delta f$ .  
 Cost of inspection =  $I \Delta f$ .

$$\text{Therefore, Total Cost, } C = I \Delta f + S/ \Delta f. \quad (5)$$

$$\partial C/\partial(\Delta f) = 1 - S/(\Delta f)^2.$$

At minimum cost,  $\partial C/\partial(\Delta f) = 0$ .

$$\text{That is, } 1 - S/(\Delta f)^2 = 0. \quad (6)$$

$$\text{Therefore, } \Delta f = (S/1)^{1/2} \text{ [56]}. \quad (7)$$

## 8. TYPES OF INSPECTIONS

Inspections can be announced or unannounced, targeted or general, in-depth, general or one-off (also called rapid), scheduled or occasional [57]. Inspection can be classified into:

Catch Problems Early:

- i) Pre-production inspection 5%; - this tells the buyer which kind of raw materials/or components will be used. Factories are often suspected of lowering their costs by purchasing substandard materials. The pre-production inspection can also focus on the process to be followed as production starts.
- ii) During production inspection 30%; - allows the buyer to have an idea of average product quality, early in the production cycle. It is the most useful and the most under-rated tool at the disposal of importers, who only rely on final inspections.
- iii) Final random inspection 80% (verify quality before shipment); - also called "pre-shipment inspection" is by far the most common type of QC checks. It takes place once 100% of shipment quantity is finished and at least 80% is packed so it can be a real random inspection. It puts pressure on the suppliers and gives power to buyers. Its objective is really to confirm a shipment's quality, rather than catching issues early; and.
- iv) Container loading inspection (shipment). Like the pre-production inspection, it is seldom used. But it can be a worthwhile option in some specific cases [58].

On the other hand, Inspection can also be classified into Residential, Commercial or pools [59]. In the same vein, classifications for recurring inspections for batch materials are regarded as:

- i) Inspections triggered by the release of orders and
- ii) Inspections for repetitive manufacturing [60].

Types of inspection that have been found useful for many companies are:

- i) Continuous inspections – as in continuous casting in Steel and Aluminum Billet Mills.
- ii) General inspections – that involving all the departments and facilities;
- iii) Special inspections – as in Fire Equipment, Elevators, Lifts inspections, Environmental inspections among others;
- iv) Operator inspections – normally performed by the operator of the unit or device, but can also be performed on critical parts of stationary equipment;
- v) Inspections performed as a part of preventive maintenance and
- vi) Motor vehicle inspections [61].

Three factors primarily dictate what type of inspections will be required, namely:

- i) The premises, equipment, vehicles, processes and materials used;
- ii) Past incident/accident history;

- iii) Occupational Safety and Health Administration (OSHA) and other regulatory requirements [61].

In the same vein, Construction inspections have been classified into: electrical, mechanical, heating and cooling units, ventilation, kitchen equipment and refrigeration systems [62]. Plumbing inspectors check piping systems. Elevator inspectors verify elevators, amusement park rides, escalators and moving sidewalks; public works inspectors check the bridges, dams and streets in addition to the highway, water and sewer systems of all levels of government for statutory compliance [62].

## **9. HOW DO INSPECTIONS DRIVE PROJECTS TO SUCCESS?**

Inspections in manufacturing have positive impact as it:

- i) Reduces end-line defects;
- ii) Saves time and efforts of final inspection;
- iii) Helps to fix the problems at the outset, and prevents common mistakes being made repeatedly and
- iv) Helps to ensure quality of the products of a production line [63].

You cannot manage what you cannot measure. With the proliferation of web based tools, measuring, managing and improving with data has become easier and much more efficient. Return on investment improves with a six sigma program in place versus benchmark [64]. In a nutshell, we note that Success will not lower its standard to us rather we must raise our standard to Success [65]. The efficient, effective and enabling tool to raise our standard to Success in projects, maintenance, manufacturing and operations is Inspection.

## **10. DISCUSSION**

From the foregoing, Project has been defined as a one-off programme whose critical attributes are hinged on Objective, Budget and Schedule. That a project is conceived, planned and executed with the view of achieving an objective subject to the constraints of budget (cost) and schedule (time). From this view point therefore, a successful project adds value to the system/society/economy. Thus the objective to be achieved or realized must be specified in terms of Quality Standard. This Quality (standard) is a measure of excellence or a state of being free from defects, deficiencies and significant variations. For this product, of the specified quality to find in-road to consumer's hearts, the producer must be in a position to declare with burning desire his confidence or certainty level or trust on his product, which in turn inspires the customer or consumer. The producer must also demonstrate the consistency and trustworthiness of the product in terms of reliability. Quality projects are executed so as to satisfy existing niches in order to raise the level of societal development. One major tool for the evaluation of the status of a project is Inspection. Inspection is defined as an official process of checking that things are in the correct condition in order to check that it is satisfactory. In other words, inspection is close examination of something, especially for faults or errors; an official check or examination of something for safety or quality. But the nagging Question is how much inspection is needed or necessary for a specific project, maintenance or operation?. Many of the authors are of the view that there is no magic equation to manipulate in order to arrive at the number or frequency of inspection. Other authors specify calculated guess. Perhaps the near accurate approach suggested is the Failure Developing Period (FDP) approach. The FDP approach is likely to approximate value

for the frequency of inspection. It is expected that the “change Multiple” in the frequency of inspection approach will smoothen the FDP value as the “change multiple” value has been achieved through optimization process. Hence Inspection (using the “Change Multiple” in frequency of inspection) of projects, operations and maintenance will enhance or optimize their quality assurance and reliability in the sense that cost of inspection and cost of rejects (out-of-limit works) will be minimized.

## 11. CONCLUSION

Identified realistic frequency of inspection approaches for projects, manufacturing, operations and maintenance are: i) Hazard Analysis and Control Point (HACCP); ii) Failure Developing Period (FDP) and iii) “Change Multiple” in frequency of inspection. The most realistic optimization-based frequency of inspection tool is the “Change Multiple” in frequency of inspection. This “Change Multiple” in frequency of inspection will optimally drive projects, manufacturing, operations and maintenance into achieving high level of quality assurance and reliability.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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**APPENDIX 1**

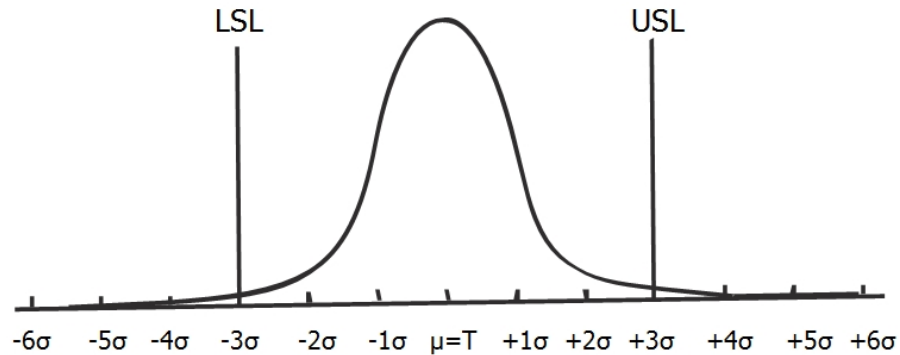
**Table 1. Tools used in dmaic**

<b>Tool</b>	<b>Define</b>	<b>Measure</b>	<b>Analyze</b>	<b>Improve</b>	<b>Control</b>
Project Charter	*				
Process Maps & Flow Charts		*			
Cause –and-Effects Analysis		*			
Process Capability Analysis		*			
Hypothesis Tests, Confidence Intervals			*		
Regression Analysis, Other Multivariate Methods			*		
Gauge R&R	*				
Failure Mode & Effects Analysis		*			
Designed Experiments		*	*		
SPC and Process Control Plans		*	*		

Source: Gupta (2012)[64]

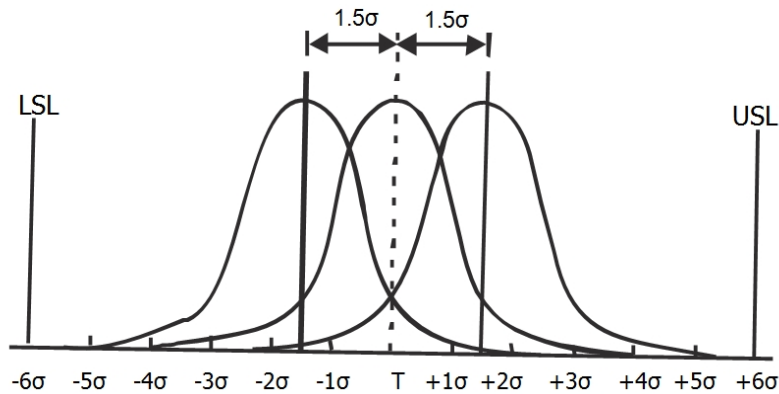


**APPENDIX 2**



Spec. limits	Percent inside specs	ppm Defective
±1 Sigma	68.27	317300
±2 Sigma	95.45	45500
±3 Sigma	99.73	2700
±4 Sigma	99.9937	63
±5 Sigma	99.999943	0.57
±6 Sigma	99.999998	0.002

(a) Normal Distribution Centred at the Target (T): GUPTA [35]



Spec. limits	Percent inside specs	ppm Defective
±1 Sigma	30.23	697700
±2 Sigma	69.13	608700
±3 Sigma	93.32	66810
±4 Sigma	99.3790	6210
±5 Sigma	99.97670	233
±6 Sigma	99.999660	3.4

(b) Normal Distribution with the Mean Shifted by ± 1.5σ from the Target.

**Fig. 1. The Motorola Six-Sigma Concept [35]**

Source: Gupta [35]

**APPENDIX 3**

**The Process Improvement Triad: DFSS, Lean and Six-Sigma/DMAIC Overall Programs**

**Table 2. Six-Sigma/DMAIC, Lean and DFSS: How They Fit Together (Source: Gupta [35])**

<b>DFSS</b>	<b>Lean</b>	<b>Six-Sigma/DMAIC*</b>
Design predictive quality into products	Eliminate waste, improve cycle time	Eliminate variability
<b>Robust Design for Six-Sigma</b>	<b>Lead-time Lean</b>	<b>Six-Sigma/DMAIC* Variation reduction</b>
Requirement allocation	Flow mapping	Predictability
Capability assessment	Waste elimination	Feasibility
Robust design	Cycle time	Efficiency
Predictable product quality	Work-in-progress reduction Operations and design.	Capability Accuracy

*\*The "I" in DMAIC may become DFSS.*

**Table 3. The DMAIC Problem Solving Process (Source: Gupta [35])**

<b>DEFINE</b> →	<b>MEASURE</b> →	<b>ANALYZE</b> →	<b>IMPROVE</b> →	<b>CONTROL</b> →
Define Opportunities	Measure Performance	Analyze Opportunities	Improve Performance	Control Performance
<b>Objectives</b>	<b>Objectives</b>	<b>Objectives</b>	<b>Objectives</b>	<b>Objectives</b>
Identify and/or validate the business improvement opportunity.	Determine what to measure.	Analyze data to understand reason for variation and identify potential root causes.	Generate and quantify potential solutions.	Develop ongoing process management plans.
Define critical customer requirements.	Manage measurement data collection	Determine process capability throughout cycle time.	Evaluate and select final solution.	Mistake-proof process
Document (map) processes.	Develop and validate measurement systems	Formulate, Investigate and verify root cause hypotheses.	Verify and gain approval for final solution.	Monitor and control critical process characteristics
Establish project charter, build team.	Determine sigma performance level.			Develop out of control action plans

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