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Quantitative methods in process improvement — Six Sigma —

Part 1: DMAIC methodology

Méthodes quantitatives dans l'amélioration de processus — Six Sigma —

Partie 1: Méthodologie DMAIC

Reference number
ISO 13053-1:2011(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13053-1 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 7, *Application of statistical and related techniques for the implementation of Six Sigma*.

ISO 13053 consists of the following parts, under the general title *Quantitative methods in process improvement — Six Sigma*:

— *Part 1: DMAIC methodology*

— *Part 2: Tools and techniques*

Introduction

The purpose of Six Sigma[1)] is to bring about improved business and quality performance and to deliver improved profit by addressing serious business issues that may have existed for a long time. The driving force behind the approach is for organizations to be competitive and to eliminate errors and waste. A number of Six Sigma projects are about the reduction of losses. Some organizations require their staff to engage with Six Sigma and demand that their suppliers do as well. The approach is project based and focuses on strategic business aims.

There is little that is new within Six Sigma from the point of view of the tools and techniques utilized. The method uses statistical tools, among others, and therefore deals with uncertain events in order to provide decisions that are based on uncertainty. Consequently, it is considered to be good practice that a Six Sigma general program is synchronized with risk management plans and defect prevention activities.

A difference, from what may have gone before with quality initiatives, is every project, before it can begin, must have a sound business case. Six Sigma speaks the language of business (value measurement throughout the project), and its philosophy is to improve customer satisfaction by the elimination and prevention of defects and, as a result, to increase business profitability.

Another difference is the infrastructure. The creation of roles, and the responsibilities that go with them, gives the method an infrastructure that is robust. The demand that all projects require a proper business case, the common manner by which all projects become vetted, the clearly defined methodology (DMAIC) that all projects follow, provides further elements of the infrastructure.

The scope of this part of ISO 13053 limits the document to only cover the improvement of existing processes. It does not go into the realm of Design for Six Sigma (DFSS) or the re-engineering of a process where the DMAIC methodology is not fully suitable, nor does it cover the issue of certification. There will also be situations where any further work on an existing process is not possible, either technically, or in a financially justifiable sense. Other standards dealing with these circumstances are yet to be developed, but when they have been published, ISO 13053 together with those future documents will form a cohesive set of standards ranging from improving existing processes to the development of new ones to deliver Six Sigma levels of performance, and beyond.

1) Six Sigma is a trade mark of Motorola, Inc.

Quantitative methods in process improvement — Six Sigma —

Part 1: **DMAIC methodology**

1 Scope

This part of ISO 13053 describes a methodology for the business improvement methodology known as Six Sigma. The methodology typically comprises five phases: define, measure, analyse, improve and control (DMAIC).

This part of ISO 13053 recommends the preferred or best practice for each of the phases of the DMAIC methodology used during the execution of a Six Sigma project. It also recommends how Six Sigma projects should be managed and describes the roles, expertise and training of the personnel involved in such projects. It is applicable to organizations using manufacturing processes as well as service and transactional processes.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13053-2, *Quantitative methods in process improvement — Six Sigma — Part 2: Tools and techniques*

3 Symbols and abbreviated terms

3.1 Symbols

c number of defects (nonconformities)

μ location of the process; population mean value

μ^* “off-set” location of the process; “off-set” population mean value

n_{CTQC} number of critical to quality characteristics

n_{units} number of units surveyed

p proportion of nonconforming items

R sample range value

R_{moving} moving range value usually calculated between successive observations

σ population standard deviation

u number of defects (nonconformities) per item

X value

$\bar{X}$ sample arithmetic mean value

Y_{DPMO} calculated number of defects per million opportunities

z standardized normal distribution deviate

Z_{value} Sigma score or value

3.2 Abbreviated terms

5S acronym meaning sort, set, shine, standardize and sustain as used in the “visual factory”/“visual workplace” approach

5-Why method for finding the potential root cause of a problem

8D eight disciplines problem-solving method

ANOVA analysis of variance

C&E cause and effect

COPQ cost of poor quality

COQ cost of quality

CTC critical to cost

CTQ critical to quality

CTQC critical to quality characteristic

DMAIC define, measure, analyse, improve, control

DOE design of experiments

DPMO defects per million opportunities

EVOP evolutionary operation

FMEA failure mode and effects analysis

FTA fault tree analysis

KPI key performance indicator

KPIV key process input variable

KPOV key process output variable

MCA multiple correspondence analysis

MSA measurement system analysis

NPR number of problem reports

OTD on-time delivery

ppm parts per million

QFD quality function deployment

RACI responsible, accountable, consulted, informed

RR return rate

RTY rolled throughput yield

SIPOC flowchart showing (S)upplier, (I)nputs, (P)rocess, (O)utputs, (C)ustomer relationships

SOP standard operating procedure

SPC statistical process control

TPM total productive maintenance

4 Fundamentals of Six Sigma projects within organizations

4.1 General

The main purpose of a Six Sigma project is to solve a given problem in order to contribute to an organization's business goals. Six Sigma projects should be undertaken only when the solution to a problem is not known.

The specific activities of a Six Sigma project can be summarized as

a) gather data,

b) extract information from the data through analysis,

c) design a solution, and

d) ensure the desired results are obtained.

A practical approach should always be favoured when applying the above activities as shown in Table 1 below.

Table 1 — Fundamentals of Six Sigma

Question	Six Sigma phase	Description
What is the issue?	Define	Define a strategic issue to work on
Where is the process now?	Measure	Measure the current performance of the process to be improved
What is causing this?	Analyse	Analyse the process to establish the main root cause of poor performance
What can be done about it?	Improve	Improve the process through testing and studying potential solutions to establish a robust improved process
How can it be kept there?	Control	Control the improved process by establishing a standardized process capable of being operated and continually improved to maintain performance over time

4.2 Voice of the customer

The “voice of the customer” should provide a permanent feedback loop for the duration of a Six Sigma project. In the context of a Six Sigma project, this might be the Project Sponsor, an internal customer, or an external customer. It is important that every Six Sigma project start with the customers' needs and expectations. Subsequently, the ongoing activities of the project should be checked, at each phase, to confirm that they have not departed from the original customer expectations.

4.3 Accountability

The Six Sigma improvement methodology should be targeted on financial efficiency but should also take into consideration safety and customer satisfaction.

In all cases, an accounting model should be established, as a first step, so that the financial performance of a process is properly evaluated. Subsequently, both the financial department and operations department can look at one set of data and should be able to forecast similar outcomes.

The performance of the project under investigation should be assessed in terms of effectiveness and adaptability for the customer or the efficiency for the business. This should be reviewed regularly with the sponsor of the project.

4.4 Maturity of processes of an organization

Continual improvement comprises a set of actions which improve the performance of an organization. The concept of maturity has been introduced in order to evaluate different levels of performance of an organization and to give a road map for continual improvement projects. Usually, five levels are used:

— Initial (Level 1) – no description of any process in the organization;

— Managed (Level 2) – reactive only on customer demand, the process to respond to the customer has been formalized;

— Defined (Level 3) – the processes of the whole organization are defined;

— Quantitatively Managed (Level 4) – all the processes of Level 3 are quantitatively managed with indicators; and

— Optimized (Level 5) – the processes can be optimized with the use of indicators.

In a Six Sigma organization, the levels of maturity will change gradually. The different stages of progress will provide a general road map of the continual improvement programme and the level of maturity. The levels are shown in Figure 1.

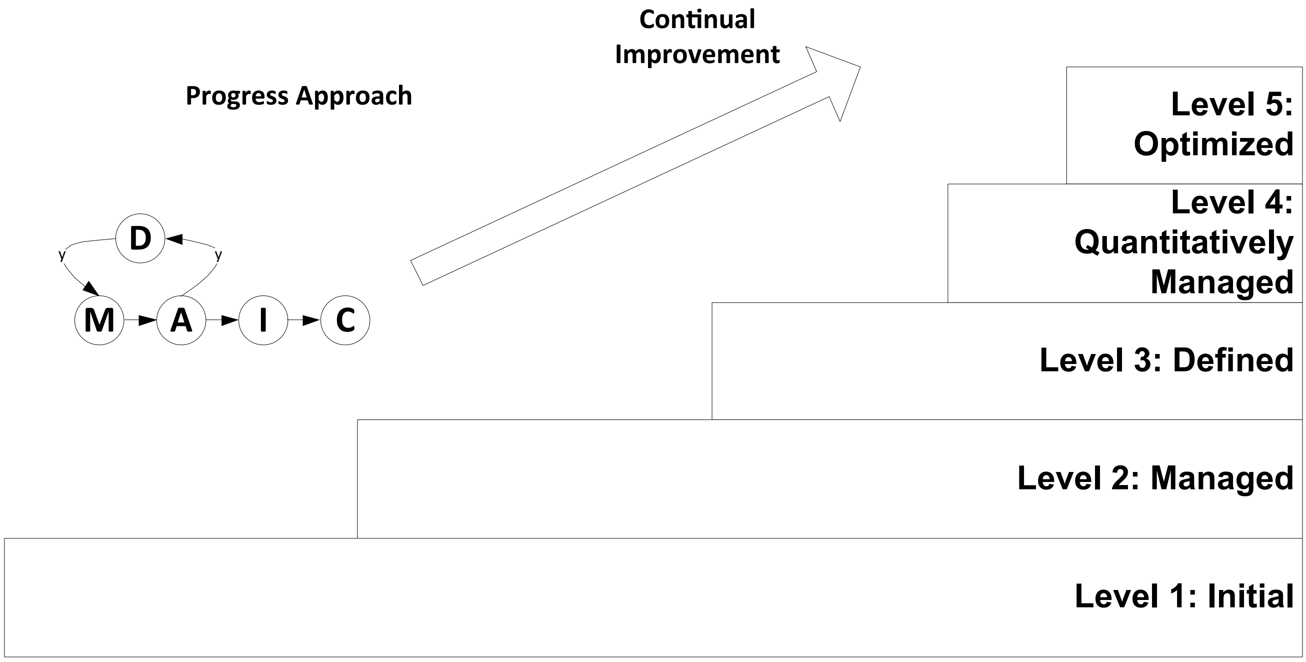

Figure 1 — Continual improvement and maturity level

4.5 Relationship with quality management standard ISO 9001

The quality principles outlined in the quality management system standards ISO 9000 and ISO 9001 call for a factual approach to decision making, a process approach to achieving quality and the practice of continual improvement.

Six Sigma methods are powerful tools for top performance in each of these areas.

Quality comes out of an enterprise's system. Quality methods such as Six Sigma operate more effectively when they are integrated into an enterprise's operating system and processes, from market research to quality planning to process control and through to life cycle management.

An enterprise introducing Six Sigma should examine its operating systems to understand where existing processes need to be modified. The introduction of a range of methods, based on the use of data and problem-solving methods (such as DMAIC), could help improve the enterprise's operating systems. This can also help the enterprise improve the existing system continually, which is also a requirement of ISO 9001. Companies which follow this route tend to achieve greater productivity, customer satisfaction and a sustainable competitive position in their market place.

Members of an enterprise benefit from the training, learning and application of Six Sigma methods. They become more competent and knowledgeable in statistical thinking, understanding process variability and the resulting application within a quality management system.

Another very important benefit of integration of the Six Sigma methods in the quality management system is the opportunity to collect and store core knowledge on each project and process. This knowledge (on customer satisfaction, design for manufacture, process capability and in-service data on reliability) will be passed on to subsequent project teams, thereby embedding in the enterprise core knowledge which business sustainability needs to survive in the long term and avoiding the loss of knowledge when key people leave or retire.

Customers and stakeholders are the ultimate beneficiaries of Six Sigma integration into a quality management system giving a superior product, lower costs and better consistency from the delivered products.

5 Six Sigma measures

5.1 Purpose

The purpose of measures in a Six Sigma project is to be able to quantify the performance of a process. This enables comparisons, analysis and insights into the causes of performance to be gained. Various business measures can be applied to quantify a problem targeted for resolution by one or several Six Sigma projects. Several measures can be used to quantify the problem during the execution of a Six Sigma project. The following subclauses identify the chief measures that can be used. The choice of measure will depend on the project. Three of these measures often used to stimulate activities for improvement are: “product return rate”, “number of problem reports”, and “on-time delivery”. Continuous measures of these characteristics will tell us more about “by how much” the characteristics need to be improved. A further measure groups most of these as an overall measure – the cost of poor quality.

5.2 Defects per million opportunities (DPMO)

DPMO should be calculated using the following formula:

$$Y_{\text{DPMO}} = \frac{c}{n_{\text{units}} \times n_{\text{CTQC}}} \times 1\,000\,000$$

The potential number of CTQC defects (nonconformities) is counted from the n_{units} surveyed. It measures the achieved quality performance and it is expressed as a rate per million of all such CTQC defects. The value can then be later used to estimate a “sigma score” (or Z_{value}). See Table 2.

Table 2 — Sigma scores

Calculated value of DPMO (Y_{DPMO})	Sigma score (Z_{value})
308 538,0	2
66 807,0	3
6 210,0	4
233,0	5
3,4	6

NOTE 1 A full table of sigma scores can be found in Annex A.

NOTE 2 Calculations are based on a 1,5 sigma shift of the mean.

The benchmark used to rank the quality or performance is the sigma score. World class performance has become synonymous with a sigma score of 6, i.e. a performance level of 3,4 DPMO. Thus, a continuous process with a sigma score of 6 has a specification limit that is actually 4,5 standard deviations from the mean value.

As an illustration of how the above calculation can be applied, consider a product that has 1 000 CTQCs associated with it. If all of the characteristics had a performance of 3,4 DPMO, then the probability that the unit will be “defect-free” is $1 - (0{,}000\,003\,4)^{1\,000}$, or 0,996 606. If a batch of 150 units were produced, the probability that there will be no defects in the batch is $0{,}996\,606^{150}$, or 0,60. In other words, even though each CTQC has a sigma score of 6, the probability that there is at least one defect amongst a batch of 150 such products will be 0,40. Thus, for such products, the level of DPMO performance for the CTQCs needs to be much higher than a sigma score of 6. A sigma score of 6 is very much the initial threshold level.

5.3 Sigma score

The sigma score is derived from the normal distribution, but with a 1,5 standard deviation “off-set”, chosen historically from custom and practice. See Figure 2. This offset of 1,5 (= 6 − 4,5) is called the shift (value).

NOTE The shift of 1,5 sigma captures the estimate of the variation of the process mean between short- and long-term periods.

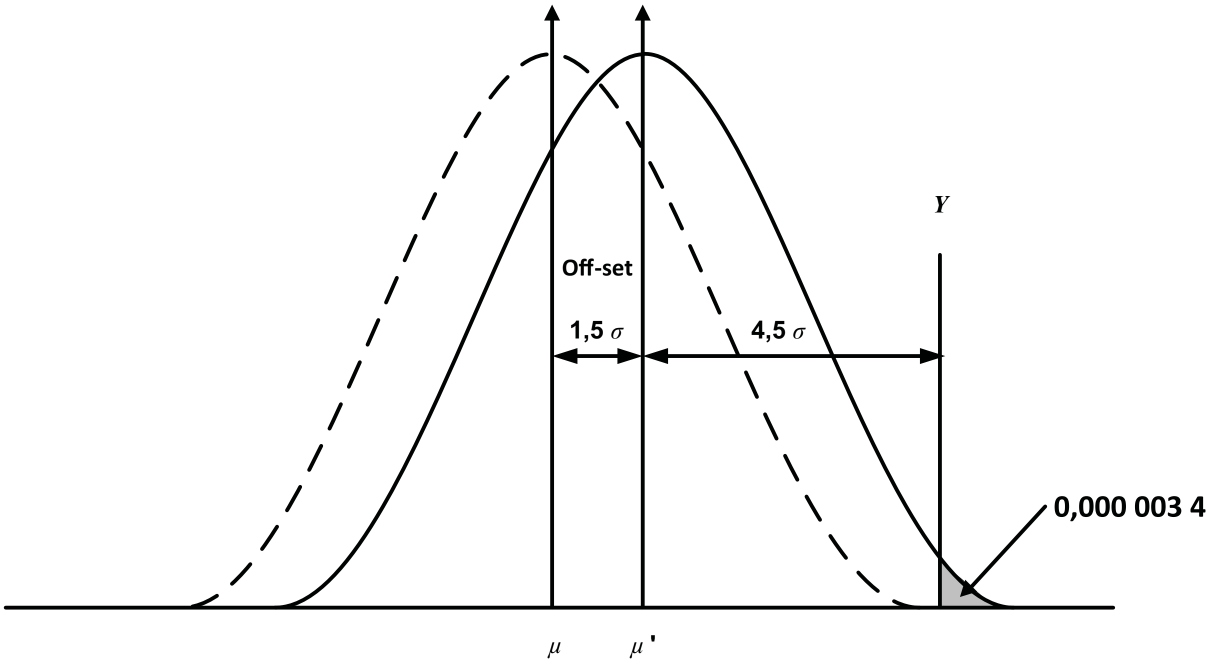

Figure 2 — Derivation of the sigma scores

A sigma score of 6 is actually 4,5 standard deviations from the mean value. Therefore, to determine the proportion of the distribution remaining in the tail of the distribution, z is 4,5, using a standardized normal distribution. Table 2 was constructed in this manner. Further values can be read from Table A.1, which has been prepared in the same way.

Naturally, caution is required here since the normal distribution may not always be an appropriate model to use.

5.4 Rolled throughput yield (RTY)

RTY is the probability that a single unit can pass through a series of process steps free of defects.

In the case of multi-stage processes RTY is calculated by multiplying the “first time through yield” for each process step. The “first time through yield” does not include any rework, repair, additional adjustment, delay for down time, etc. It is also called “non-adjusted rate” or “go-through rate”. See the example in Figure 3.

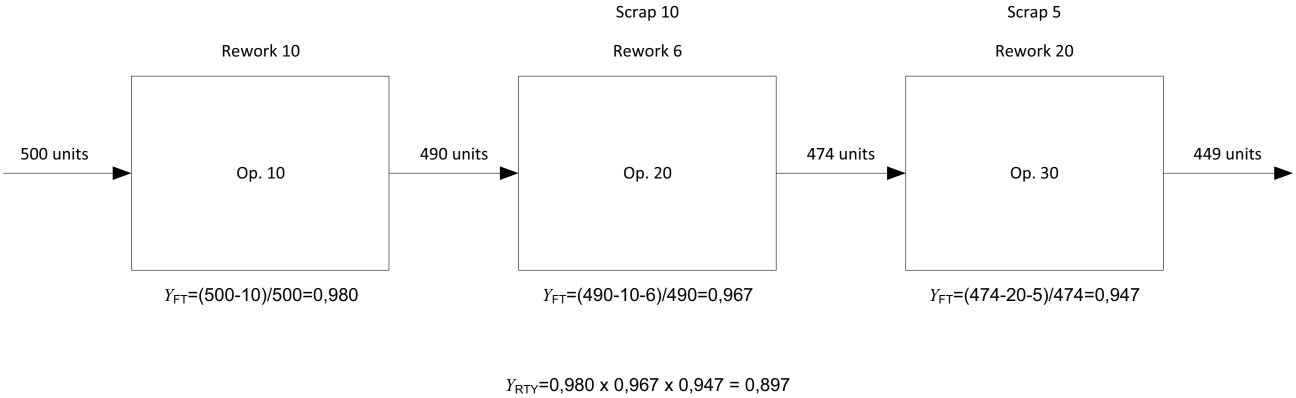

Figure 3 — Rolled throughput yield example

The RTY calculation is a more appropriate measure of the process' performance rather than the more “naïve” calculation after Op. 30 of 485 divided by 500, i.e. 0,970, that overstates the process' real performance of 0,897.

NOTE RTY assumes that the process steps are independent.

5.5 Return rate (RR)

RR is defined as the number of returns – or request for returns – of a given product in a specified period, such as a month, divided by a measure of shipments. Shipments can be determined over the same specified period as the number of returns or can be a “normalized” measure of shipments such as a smoothed average over a year.

5.6 Number of problem reports (NPR)

NPR is defined as the number of customer-originated problem reports during a specified period such as a month, where the reports relate to the quality of a product. A product can either be a piece of hardware, a software release, a system installed at a customer site, or a service provided to a customer.

Reports are sometimes broken into three categories according to their severity: critical, major and minor. In such cases, NPR is split into three different measures, one for each level of severity.

5.7 On-time delivery (OTD)

OTD measures the timeliness of deliveries to customers. It is defined as the percentage of orders that are delivered at the customers' sites according to the scheduling requirements of the customers per specified period of time.

5.8 Cost of poor quality (COPQ)

The traditional cost of quality (COQ) captures costs across the entire company using the categories of prevention, appraisal, internal failure, and external failure. An often large part of COQ relates to the cost of poor quality or COPQ that is incurred by producing and fixing defects either as internal failure or as external failure. This cost covers all efforts to ship the defective product or its replacement, diagnose the root cause for the defects, repair the defective product or scrap it, retest it, repackage the new product, etc. It does not include any loss to the customer nor the cost incurred from lack of customer satisfaction with the product.

6 Six Sigma personnel and their roles

6.1 General

An organization seeking to implement Six Sigma should consider the following roles and whether they are applicable to its implementation. Some roles may need to be assigned full time occupation depending upon the size of the organization and the complexity of the projects (see Clause 14, Tables 8, 9 and 10). A schematic representation of what the interrelationships can be is shown in Figure 4.

Figure 4 — Example of Six Sigma roles and their interrelationships

6.2 Champion

This individual is likely to be a senior member of the organization, e.g. director or a vice president of quality, and one who carries a large degree of influence within the organization. The person will

a) determine the strategy for the deployment of Six Sigma throughout the organization, and

b) be responsible for setting and promoting business objectives with regards to the Six Sigma initiative.

6.3 Deployment Manager

To oversee and to manage the deployment of Six Sigma, every organization will require a Deployment Manager. Depending upon the size of the organization, this might be a full time occupation. The roles of the Deployment Manager will be the following:

a) to promote the Six Sigma initiative;

b) to determine, along with senior management, the nature of the expansion of Six Sigma within the company, the size of the populations of Master Black Belts, Black Belts, Green Belts, etc., and the duration of the secondments for these personnel;

c) to liaise with and report to senior management about the progress of any Six Sigma initiative;

d) to involve new Project Sponsors and recruit new Master Black Belts and Black Belt candidates for the purpose of Six Sigma;

e) to negotiate with the different areas of the company for the secondment, and later the redeployment, of the candidate Black Belts;

f) to manage any facility that is provided for the pursuit of Six Sigma, e.g. a Six Sigma centre, for the use of the Master Black Belts and the Black Belts;

g) to seek potential projects; and

h) to participate in “major” gate reviews, as necessary.

6.4 Project Sponsor

The Project Sponsor is vitally important to the successful outcome of a Six Sigma project. This person may be the process owner within which a Six Sigma project is to be undertaken. The Project Sponsor's duties will be linked to the (1) success of the project, (2) importance and effective use of gate reviews, (3) institutionalization of any problem solution, (4) the removal of old ways of doing business after a new solution is in-place, and (5) the satisfaction of any training needs.

The principal roles of the Project Sponsor are the following:

a) to champion the Six Sigma methodology with peers and with others higher in the organization;

b) to support the nominated Six Sigma project;

c) to provide resources requested by the Black Belt and required for the Six Sigma project;

d) to remove any “road blocks” encountered by the Black Belt in discharging the project;

e) to participate in all gate reviews directly and to sign-off on the phase when the work has been done properly;

f) to ensure the full implementation of all recommendations of the Six Sigma project;

g) to ensure that improvements identified within the nominated projects are realized and maintained; and

h) to ensure that completed projects are evaluated for potential application across other businesses or elsewhere within the same business.

6.5 Master Black Belt

The role of the Master Black Belt is to support the Black Belts in the application of the DMAIC methodology and the selection and use of the tools and techniques required. In particular, the Master Black Belt will

a) coach and mentor the Black Belts in the application of the DMAIC methodology and the selection and use of the tools and techniques required,

b) provide support so that improvements identified within the nominated projects are realized and maintained,

c) provide “internal” consultancy in advanced statistics,

d) assist in the identification of suitable improvement projects,

e) assist in the determination of the scope of the selected improvement project,

f) assist in periodic reviews of the improvement projects,

g) provide training in the tools and techniques associated with Six Sigma to Black and Green Belts as required,

h) determine if any training activities are appropriate and effective, and

i) lead improvement projects as required.

NOTE Depending on its size, a company might use consultancy services to provide the Master Black Belt function when a Master Black Belt cannot be grown within the company since Master Black Belts usually require experience drawn from many companies and a wide business knowledge (they are often former senior managers within a company).

6.6 Black Belt

The Black Belt is expected to deliver the agreed benefits of a Six Sigma project to the organization. In so doing, the Black Belt will

a) work with others to identify and quantify opportunities for improvement,

b) organize multidisciplinary teams (process organization), where necessary, and manage improvement projects,

c) lead improvement projects or facilitate Green Belt Projects using the DMAIC methodology,

d) train, coach and mentor Green Belts on DMAIC methodology and associated process improvement techniques, and

e) participate in all gate reviews directly through prepared presentations of the work accomplished to-date with an emphasis on the accomplishments in the phase being reviewed.

6.7 Green Belt

The Green Belt is expected to deliver the agreed benefits of a Six Sigma project to the organization. These improvement activities will often be within the Green Belt's usual field of employment and operation. In so doing, the Green Belt will

a) work with the local “line management” to identify and quantify opportunities for improvement within the local environment,

b) be required to work under the direction of a Black Belt as a member of a larger Six Sigma project led by the Black Belt,

c) be required to lead a smaller Six Sigma project under the direction of a Black Belt, and

d) possibly coach process operators (Yellow Belts) on process improvement methods and activities.

6.8 Yellow Belt

A Yellow Belt is usually a process operator, either in a manufacturing sense or an office (transactional) sense. The Yellow Belt is expected to participate in Six Sigma project teams when a Six Sigma project is concerned with a process within which the Yellow Belt operates.

In so doing, the Yellow Belt will

a) work with the local Green Belt to identify and quantify opportunities for improvement within the local environment,

b) be required to work under the direction of a Black Belt or a Green Belt as a member of a larger Six Sigma project led by the Black Belt, and

c) be required to participate in a smaller Six Sigma project under the direction of a Green Belt.

7 Minimum competencies required

The recommended minimum competencies required of the Six Sigma personnel identified in Clause 6 are shown in Table 3. The table indicates the minimum level of competency for each skill/role combination. A numerical value has been assigned to each skill ranging from 0, where no competency is considered necessary for a particular role, to 3, where the particular skill is considered highly necessary for a particular role.

Table 3 — Minimum competency requirements to fulfil a given role

Skill	Master Black Belt	Black Belt	Green Belt	Yellow Belt
Business perception	3	2	1	1
Computer literacy	3	3	1	1
Customer focus	3	3	3	3
Interpersonal skills	3	3	2	1
Motivational skills	3	3	2	1
Numeracy	3	2	1	1
Practical problem solving skills	3	2	3	1
Presentation skills	3	3	2	0
Process improvement experience	3	2	1	0
Process management skills	3	3	2	0
Project management skills	3	3	2	0
Results driven	3	3	2	2
Six Sigma tools knowledge	3	2	1	1
Statistical skills	3	2	1	0
Statistical software use	3	3	1	0
Training skills	3	3	1	0
Coaching skills	3	2	2	0

Level 0 - Not needed; Level 1 - Basic competence; Level 2 - Proficient user; Level 3 - Highest level of ability.

NOTE A value of 0 in the table indicates that, to fulfil the given role, a certain skill may not be needed. It does not mean that the individual in the role has no knowledge of that particular skill.

8 Minimum Six Sigma training requirements

8.1 Recommended training

Training can be provided in a number of ways, either as formal classroom style courses or through other training media such as e-Learning or similar distance learning courses. The recommended training requirements, expressed in days, are shown in Table 4 for each of the Six Sigma personnel described in Clause 6.

Table 4 — Recommended minimum course durations

Category	Champion[a] / Deployment Manager	Sponsor	Master Black Belt[b]	Black Belt	Green Belt	Yellow Belt
Instruction[c] (days)	3	1	10	20	5	1
Tutorials (days)	-	-	2	5	1	0
Number of qualifying Six Sigma projects	-	-	2	2	1	0

[a] To become a Champion, it is not enough to just complete the Champion Training.

[b] A Master Black Belt will have previously completed Black Belt training and performed this role for at least two years and will consequently have completed a number of Six Sigma projects.

[c] The instruction given is assumed to be delivered in a classroom. Some companies substitute some of this time with distance "e-learning".

The Master Black Belt training is usually split into two weeks separated by a short interval of time, e.g. two weeks.

The Black Belt training is usually divided into five four-day durations, or some other suitable division e.g. four five-day durations, each separated by about three to four weeks.

8.2 Training requirements for Champions / Deployment Manager

The purpose of this training is to familiarize the Champion and the Deployment Manager with the DMAIC methodology and to understand and appreciate the tools that support it. In this way, they will be well prepared to receive reports from Six Sigma teams about progress and findings of projects.

This training should have the same content as that for Green Belts but with more emphasis on project selection, project scoping and implementation of recommendations. (The typical content of a Green Belt training programme can be seen in Table B.2.)

8.3 Training requirements for Sponsors

The purpose of this training is to familiarize the Sponsor with the DMAIC methodology and to understand and appreciate the tools that support it. In this way, the Sponsor will be prepared to receive reports from Six Sigma teams about progress and findings of projects and to be able to fully participate in "gate reviews", as well as to be able to "institutionalize" the Six Sigma approach to business improvement.

The content for Sponsor training might vary according to the business application but will concentrate on the assessment of the deliverables and how to evaluate them at the completion of each Six Sigma phase.

8.4 Training requirements for Master Black Belts

A candidate Master Black Belt should have already been accredited as a Black Belt and will therefore have already received the necessary training for a Black Belt. If this is not the case, the Master Black Belt should take further training that is recommended to extend the Master Black Belt's knowledge of statistical methods, other related mathematical techniques and management organizational techniques. The precise training agenda shall be tailored to the specific individuals and to the area(s) of application (manufacturing or transactional) which the MMB is intended to support.

8.5 Training requirements for Black Belts

A candidate Black Belt should either have received training and been accredited as a Green Belt or, have the equivalent level of experience and knowledge. The typical content of a Black Belt training programme is shown in Table B.1.

The candidate Black Belt's knowledge should be confirmed by means of either a written or a multiple-choice assessment. The assessment may be internal or may be run by an external organization.

In addition to attending the training programme, each candidate Black Belt should complete at least two Six Sigma projects that have been certified by a certifying authority. This may be either an internal or external certification. The projects provide the candidate Black Belts the opportunity to demonstrate their knowledge and ability to apply the Six Sigma tools. The projects should be assessed by Master Black Belt(s). The assessment should include an oral examination which may be seen as part of mentoring during projects undertaken as part of training and certification process.

Additional Six Sigma projects might be undertaken if the candidate Black Belt is, due to the nature of the first two projects, unable to demonstrate their full knowledge of the Six Sigma tools.

8.6 Training requirements for Green Belts

A typical content of a Green Belt training programme is given in Table B.2. The candidate Green Belt's knowledge should be confirmed by means of either a written or a multiple-choice assessment. The assessment may be internal or may be run by an external organization.

In addition to attending the training programme, each candidate Green Belt should complete one Six Sigma project approved by a certifying authority. This may be either an internal or external certification. This project provides the candidate Green Belt the opportunity to demonstrate his/her knowledge and ability to apply the Six Sigma tools appropriate for Green Belt level.

The project should be assessed by an independent Black Belt and will be from the area where the candidate Green Belt works. The assessment should include an oral examination.

8.7 Training requirements for Yellow Belts

The training programme for candidate Yellow Belts should take the form of a one-day Six Sigma awareness seminar where the purpose of Six Sigma and the Six Sigma methodology (DMAIC) should be explained. Detailed descriptions of the Six Sigma tools should be kept to a minimum.

The training should, preferably, be given by a Black Belt, but Green Belts can also perform this function.

Yellow Belts, when engaged with a Six Sigma project team, should receive “on-the-job” training in the application of those Six Sigma tools that are appropriate to the project. This training should be given by Green or Black Belts who are running the project.

An organization implementing a Six Sigma initiative should consider whether it would be beneficial to the successful implementation of the programme, to train all of its employees to at least Yellow Belt level.

9 Six Sigma project prioritization and selection

9.1 General considerations

Projects should be selected to meet clear organizational objectives. Only projects where the solution is not known in advance may be considered for Six Sigma projects.

The outcome of each project should contribute to the overall improvement of the profitability of an organization. Organizations should keep lists of potential Six Sigma projects, ranked according to some measure of potential profit, in order to assist in such a selection process. Some projects might appear easier to do than others and this should be taken into account when the choices are made.

9.2 Project prioritization

There are several different ways of assessing the relative merits of competing potential Six Sigma projects.

The graph, shown in Figure 5, is an example of one approach. Competing Six Sigma projects are rated for their degree of difficulty in their execution and for their potential profit. These values represent co-ordinates that are then plotted onto the graph.

Projects that lie in the box labelled “Priority 1” are those that should be done before others since they represent projects that have a large profit potential and carry a low level of difficulty in their execution. It can be a matter of debate whether some projects laying in Priority 3 should be done before some of those lying in Priority 2. Those lying in Priority 4 might never be selected unless an important customer of the organization requires a Priority 4 project to be executed.

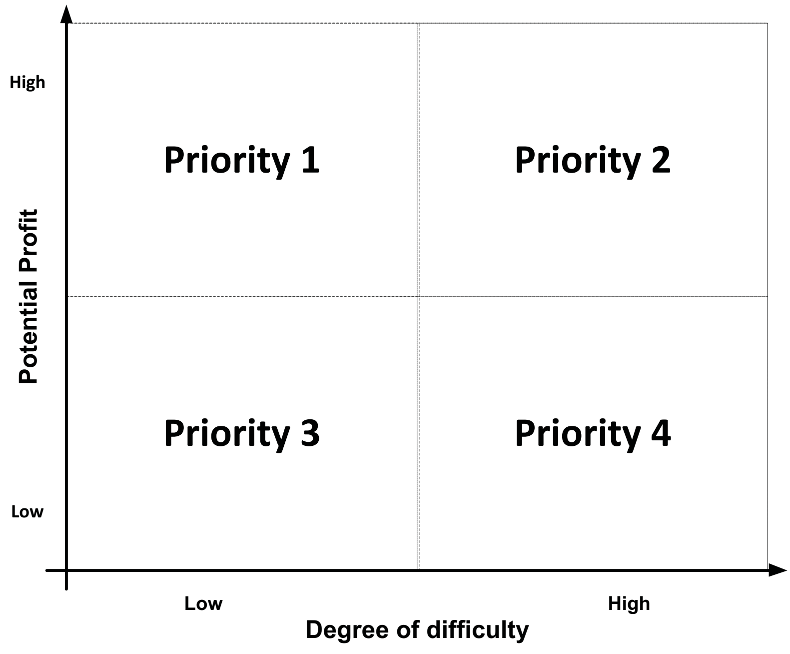

Figure 5 — Project selection graph

Another, more objective, approach is to use a table or matrix similar to that shown in Table 5. This is sometimes called a “project hopper”. The table columns contain rank numbers assigned to project outcomes against set criteria. Each project priority number is calculated by multiplying together each of the individual rank numbers of columns A to E – the greater the project priority number, the more important the project.

The table can be constructed and values calculated with the use of a spreadsheet or similar computer software.

Table 5 — Example of potential project prioritization

Project title	(A) Customer importance	(B) Expected total project cost	(C) Likelihood of project success	(D) Expected contribution to profit	(E) Applicability to other areas	(F) Project priority number	(G) Project order
Invoice error investigation	8	2	9	5	4	2 880	2
Low yield on XXX line	6	5	7	8	8	13 440	1
Etc.							

NOTE 1 The ranks are on a 1 to 10 scale with 1 being the worst and 10 the best.

NOTE 2 The value in column (F) is the product of the ranks in columns (A) to (E).

NOTE 3 The project order in column (G) is the ranking of the values in column (F).

9.3 Project selection

9.3.1 General checklist

The Six Sigma DMAIC method is best suited for resolving chronic problems. Acute problems are better dealt with by other purpose problem-solving methods such as 8D or methods described in ISO 9004:2009, Annex B will also be useful depending on the problem.

The following list, although not exhaustive, indicates the criteria that should be used to measure potential Six Sigma projects against.

a) Does the potential project have recurring events?

b) Do measures exist? If “no”, can measures be established in an appropriate amount of time?

c) Do you have the ability to control, i.e. manipulate, the process?

d) Will the potential project improve customer satisfaction?

e) Is the potential project aligned to at least one of the business measures (indicators)?

f) Will the potential project deliver savings?

g) Will the potential project have a high probability of being completed through the application of DMAIC within 6 months from its start?

h) Is it possible to set “success” criteria for the project?

If the answers to the above questions are “yes”, the potential project should be regarded as appropriate to execute.

At the gate review, the Project Sponsor can decide whether the project is appropriate. This involves a decision about whether or not the proposed project is meaningful (to the business strategy), measurable (measures can be developed for the process) and manageable (the proposed project scope is appropriate).

9.3.2 Process oriented problems

The performance of each process should be assessed by examining the business measure that is appropriate for the process, e.g. delivery performance against schedule over time. If possible, the performance of the process should also be expressed as a monetary value.

Projects suitable for selection are of processes that appear to be under-performing with regards to their requirements.

9.3.3 Product- or service-oriented problems

Where a known problem exists with either a product or service, e.g. address errors on invoices, the possible causes and the nature of the problem should be investigated.

Each particular problem is the product of an errant system (or process). The frequency and magnitude of the problem should be monitored to determine whether it is constant or sporadic, increasing in magnitude or decreasing, etc.

9.3.4 Project scoping

Care should be taken to ensure that the scope of the Six Sigma project is not too wide. The project should be subdivided into a series of simpler projects which can be managed within a reasonable time period by a small project team.

The recommended approach to use is the method of "$Y = \mathrm{f}(X)$". The rationale of the method is illustrated schematically in Figure 6.

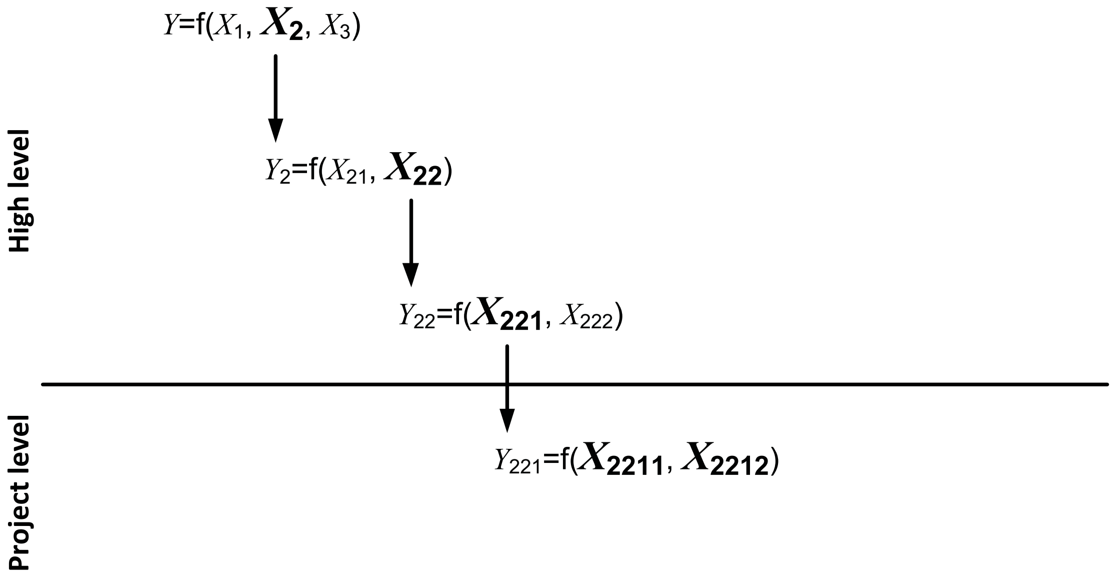

Figure 6 — Schematic example of the $Y = \mathrm{f}(X)$ cascade method for scoping Six Sigma projects

Y is the KPOV for each level. At each level, the process or problem should be analysed to determine which of the KPIVs (the X) is the most significant. This value of X should be used as the KPOV (Y) for the next level. The values of the KPIVs (X) should preferably be established from appropriate data. However, other techniques such as FMEA, or occasionally judgement, can be used depending on the specific type of project.

The process of refinement should continue until it is not possible to differentiate between the significance of the different KPIVs (X). This is the level at which the scope should be set for the project. An example showing the cascade for the problem of non-value added time in a machine shop is given in Figure 7.

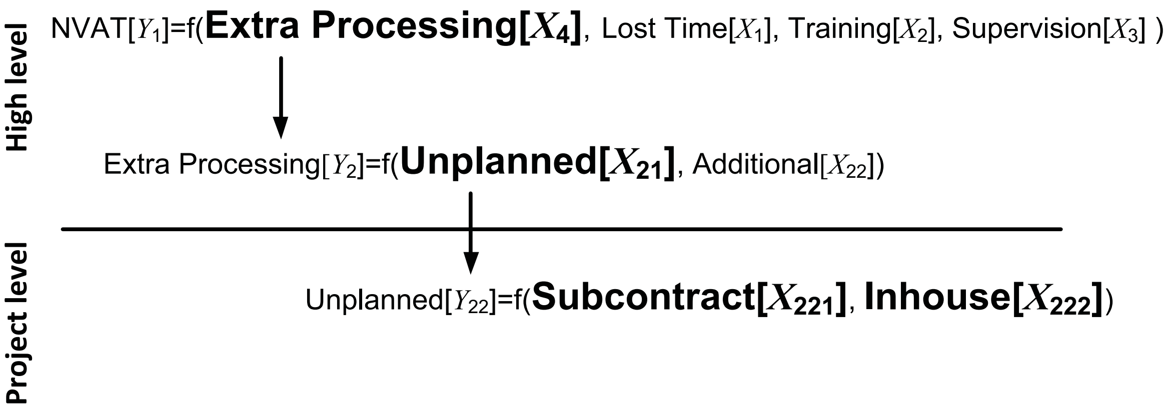

Figure 7 — Example cascade for non-value added time in a machine shop

10 Six Sigma project DMAIC methodology

10.1 Introduction

A Six Sigma project is usually executed by the DMAIC process illustrated in Figure 8.

Each phase of the methodology should be followed in the sequence define, measure, analyse, improve and control. However, once data have been gathered and analysed the project should be reviewed and, if necessary, re-defined, re-measured and re-analysed. The first three phases should be repeated until the project definition agrees with the information derived from the data. The methodology should only proceed to the final two phases once the project definition is stable.

Regular reports (see Clause 12) should be submitted to the Project Sponsor at all phases. Regular gate reviews should be held with the Project Sponsor at each phase of the DMAIC process.

Refer to ISO 13053-2 for further information on the tools and techniques identified in the following subclauses.

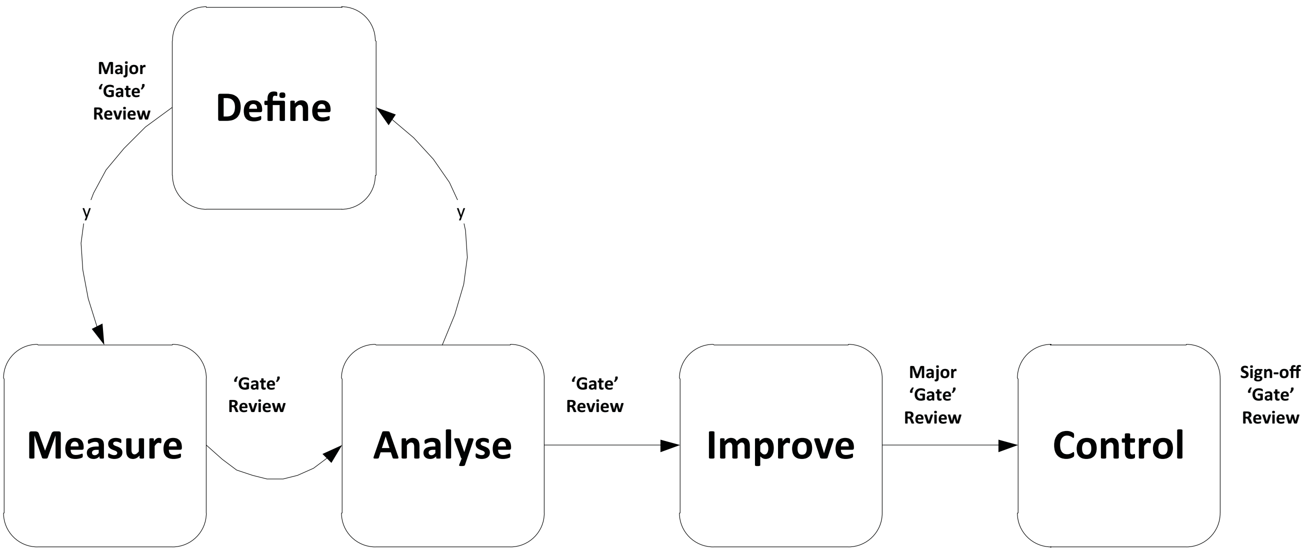

Figure 8 — Example of Six Sigma DMAIC sequence

10.2 Define phase

The outcome of this phase is a project charter that lists what is observed to be wrong. The project charter should state the description of the problem and include data about the size of the problem and its financial impact on profit. The scope of the project, together with the objectives that should be realized at the end of the project, should be clearly defined in both operational (including safety matters if appropriate) and financial terms.

The outputs from the phase, as appropriate, may include the following:

a) a project charter including risk analysis (see ISO 13053-2 for an example);

b) Six Sigma indicators;

c) SIPOC diagrams;

d) flowcharts;

e) Pareto diagrams;

f) a list of CTQCs;

g) financial result costing (profit estimation); and

h) project review.

10.3 Measure phase

The purpose of the measure phase is to develop a data collection plan, to collect the data, to evaluate the data, and to create a baseline of recent process performance.

The “measure” phase is the phase where all the data about the variables that are believed to influence the problem should be collected. Before starting to collect data, however, an assessment should be made of the efficacy of the measurement processes that the project will depend on. All measurement systems to be used should be capable of providing data to the required level of accuracy and repeatability. This includes measurement processes that result in discrete “attribute” type data. If there is any doubt about the quality of the data, any statistical analysis that is subsequently undertaken might be invalid.

The outputs from the phase, as appropriate, may include the following:

a) measurement systems analyses of all measurement processes used in the project, including attribute data agreement where necessary, and for all CTQC measures;

b) data collection plan;

c) sample size determination;

d) DPMO;

e) probability distribution tests;

f) trend charts;

g) control charts;

h) histograms;

i) capability and/or performance analyses of affected processes; and

j) project review.

10.4 Analyse phase

The purpose of the analyse phase is to identify the gaps between baseline performance and targets, to understand the root sources of variation, and to prioritize improvement opportunities.

The data obtained during the measure phase above should be analysed in detail, using statistical techniques as appropriate, to identify, prove or verify the significant KPIVs.

As stated above (see 10.1), the findings from the analyse phase might alter the understanding of the problem and lead to a re-definition of the project.

The first three phases should be repeated until the project definition is stable.

The outputs from the phase, as appropriate, should include the following:

a) cause and effect diagrams;

b) process FMEAs;

c) FTAs;

d) 5-Why analyses;

e) further MSA;

f) sample size determination;

g) probability distribution tests;

h) hypothesis tests;

i) ANOVA;

j) regression and correlation analyses;

k) DOEs;

l) a list of significant KPIVs;

m) value/non value add analysis/ wastes identification; and

n) project review.

10.5 Improve phase

The purpose of this phase is to establish a robust improvement to the process. The activities to be considered range from the practical, such as mistake-proofing certain operations, to using optimization techniques and making processes robust against noise variables though DOEs, as appropriate. During this phase, identify any “road blocks” that will prevent the selected solution from being implemented, and overcome them. Ways to overcome any potential “road blocks” should be identified before the process modification is implemented.

Tools such as “solution selection matrices” should be used in situations where more than one solution exists and the choice is unclear.

The outputs from the phase, as appropriate, should include the following:

a) solution selection matrix;

b) mistake proofing;

c) sample size determination;

d) response surface DOEs;

e) parameter design DOEs;

f) updated process FMEAs;

g) initial process studies' capability and/or performance indices; and

h) process map of what the process should now be;

i) an updated list of CTQCs;

j) Six Sigma indicators; and

k) project review.

10.6 Control phase

The effectiveness of the solution should be confirmed by collecting and analysing fresh data. A forward plan for the ongoing “control” of the process should be prepared for use in the area in which the process exists.

The improved process should be handed over to the Project Sponsor, and to the area in which the process exists, after the required process improvement has been confirmed. A process audit should be carried out and its findings reviewed approximately six months on from the end of the project. A date for the process audit should be determined prior to “hand over”.

Any details, facts or other information learnt during the execution of the project should be recorded and passed on to other areas where they can be applied.

The Black Belt should document any open points in the project or forward plans which the process owner and other involved persons may need to take for the improved process to become properly embedded. Such a project transition action plan would include the planned date for the process audit.

A final report should be written and circulated to interested parties. The report should be filed for ready access by others. All reports should be formatted in a standard way and should be indexed by key-words. The report should indicate the lessons learnt to be passed onto future Six Sigma project teams.

The outputs from the phase, as appropriate, should include the following:

a) process control plans;

b) an updated list of CTQCs;

c) further MSA;

d) control charts;

e) on-going capability;

f) 5S;

g) TPM;

h) financial costing (actual versus expected); and

i) a summary, project review, in a generic benefits analysis, that should reference the agreed objectives in the project charter.

11 Six Sigma project methodology — Typical tools employed

The following table summarizes many of the tools that are typically used within a Six Sigma project. Further information on some of the tools listed can be found in ISO 13053-2.

Table 6 — Typical Six Sigma tools and techniques

Tool (technique)	Factsheet number[a]	Define	Measure	Analyse	Improve	Control
Capability / performance	20	R	R	R	R	R
CTQC	04	M	M		M	M
Customer focus group	05	S				
Descriptive statistics	19	S	S	S	S	S
Financial justification	01	M				R
Gantt chart	08	R				
Kano model	03	S				
Non-conformance opportunities identification	04	R				
Pareto diagram	19	S	S	S	S	
Prioritization matrix	11	R			R	
Process flow chart	10	R		S	R	
Project charter	07	M				
Project review	31	M	M	M	M	M
Project risk analysis	07	M				
QFD	05	R		R	R	
RACI matrix	28	R			R	
Service delivery modelling	23	S	S		S	S
SIPOC	09	R			S	
Six Sigma indicators	20	M			M	
Value stream analysis	22	R				
Waste analysis	21	R	R	R		
Benchmarking	06		R		R	
Data collection plan	16		M			
MSA	15		M	M		M
Probability distribution (e.g. normality) tests	18		M (for continuous data) R (for others)	M (for continuous data) R (for others)		
Sample size determination	17		M	M	M	
SPC	30		R	R		R
Trend chart	19		S			S

Table 6 (*continued*)

Tool (technique)	Factsheet number[a]	Define	Measure	Analyse	Improve	Control
Affinity diagram	02			S		
ANOVA	24, 26			R	R	
C&E diagram	12			R		
DOE	26			R	R	
Hypothesis tests	24			R	R	
Process FMEA	14			R	M	
Regression and correlation	25			R	R	
Reliability	27			R	R	
5-why analysis	—			S		
Brainstorming	13				S	
MCA	—				S	
Mistake proofing (poka yoke)	29				R	R
Solution selection	11				R	
TPM	27				S	S
5S	29				S	S
Control plan	29					M

[a] Factsheets are given in ISO 13053-2.

NOTE M – Mandatory; R – Recommended; S – Suggested.

12 Monitoring a Six Sigma project

12.1 General

The Six Sigma project should be regularly monitored in order to know if it is running to schedule and whether other measures of viability of project are satisfactory.

Regular reports should be submitted to the Project Sponsor.

12.2 Gate reviews

A gate review should be conducted when a project is deemed to have finished one phase and about to move onto the next. A review panel comprising the Deployment Manager (depending on the project), Project Sponsor, Master Black Belt, the Black (or Green) Belt who is running the project and any other interested manager, as an observer, should be convened to conduct the review. A copy of all the relevant data and analysis and reports should be circulated to the panel in advance of the meeting.

The “belt” who is running the project should give a short presentation of the work to date and respond to all questions from the other members of the panel.

The Project Sponsor shall initial the gate review when the panel are agreed that the work has been done properly and the analyses and the conclusions are correct. The project may then proceed to the next phase.

12.3 Project management

A Gantt chart should be prepared and regularly updated so that any time slippage can be identified and corrective action taken to bring the project back onto schedule. It is recommended that all existing international standards on project management tools be considered for use, where appropriate.

The overall duration of a Six Sigma project is difficult to predict accurately, although most organizations hope they can be completed within a six-month period. Allowances should be made for unforeseen delays when planning the project timetable. These could range from the absence of data and the need to set up data collection systems in the early phases to delays in the acquisition of new equipment or tooling during the later phases.

12.4 Weekly mentoring sessions with a Master Black Belt

Routine weekly reviews between the Black Belt and the corresponding Master Black Belt should be instigated as a method of tracking progress. The meetings should be used to escalate issues, identify problems with project resources and identify “road blocks”. Road blocks should be forwarded to the Project Sponsor for action and resolution.

The review meeting should take about one hour and the Master Black Belt should deal with the detail of the project, give guidance to the Black Belt and assist in any technical way.

More frequent and/or longer sessions may be required when mentoring candidate Black Belts through a project undertaken within the training and certification process.

13 Critical to success factors for Six Sigma projects

Two items critical to a successful outcome of a Six Sigma project are the existence of well-defined and maintained stakeholder management plans and that the project should be data driven.

The project should be reviewed to confirm that a stakeholder management plan exists and is up-to-date.

The factors listed in Table 7 should be considered in turn and any that are not data driven should be identified and corrected.

Table 7 — Factors that can make a Six Sigma project a success or a failure

Success factor (Data driven …)	Failure factor (Absence of data …)
Linked to an organization's business objective	Objectives are too vague
Associated with a KPI	Not associated with any KPI, more of a “pet project” pushed by a senior member of the organization
Linked to CTQ or CTC	No proper link to any CTQ and crosses over the boundaries of other projects
Project Sponsor is a senior member of the organization with sufficient influence	No Project Sponsor or the chosen Project Sponsor is too engaged elsewhere and lacks sufficient influence
The objective for the project will be to deliver a significant impact on the organization	Unclear deliverables
Project completed promptly and within its notional timescale	Timescale slippage not addressed, lack of project reviews
Resourced to the required levels	Lack of time and resources
Has a process with clearly identifiable KPIVs and KPOVs	Ill-defined process
Ready availability of reliable data	Lack of data, lack of a system to extract or collect data, poor operational definitions, poor measurement systems

Ensure there are

a) well-defined and maintained stakeholder management plans, and

b) data-driven projects.

14 Six Sigma infrastructures within an organization

14.1 General information

The type of infrastructure chosen by any organization will depend on several factors and there are neither “right” nor “wrong” arrangements. What works for one organization may not work for another. The ratios of the roles are to provide a critical mass, which can be adjusted for any industry or service, for the successful deployment and ongoing function of the Six Sigma initiative.

The factors tend to be the following:

a) the overarching structure imposed by a central facility;

b) the number of employees at the site; and

c) the nature of the business.

14.2 Large - Over 1 000 employees at a site

The recommended infrastructure for sites having a large population is shown in Table 8. A special location should be set aside for the Master Black Belts and the Black Belts to reside in for their secondment and they should have the Deployment Manager as their line manager.

Table 8 — Typical Six Sigma infrastructure for large site populations

Role	Number	Comments
Deployment Manager	1	Permanent role
Project Sponsor	Variable	Variable according to the number and types of projects
Master Black Belts	1 per 5 Black Belts	Full time
Black Belts	1 per 5 Green Belts	Full time Often seconded to the role for a two year period and then re-absorbed back into the business
Green Belts	1 per 30 employees	Part time Seconded to projects according to needs
Yellow Belts	All employees	Part time Seconded to projects according to needs
NOTE The numbers referred to in this table are not always suitable for every Six Sigma application and the actual numbers may be different in each case.		

14.3 Medium – 250 to 1 000 employees at a site

The recommended infrastructure for sites having a medium population is shown in Table 9. It is not usual for a special location to be set aside for the Master Black Belts and the Black Belts to reside in. Their line manager should be their normal "operational" manager.

Table 9 — Typical Six Sigma infrastructure for medium site populations

Role	Number	Comments
Deployment Manager	1	Part time
Project Sponsors	Variable	Variable according to the number and types of projects
Master Black Belts	1 per 5 Black Belts	Full time Often only found in organizations of over 500 employees
Black Belts	1 per 5 Green Belts	A mixture of full and part time Usually resident within their usual area of work
Green Belts	1 per 30 employees	Part time Seconded to projects according to needs
Yellow Belts	All employees	Part time Seconded to projects according to needs
NOTE The numbers referred to in this table are not always suitable for every Six Sigma application and the actual numbers may be different in each case.		

14.4 Small – Less than 250 employees at a site

The recommended infrastructure for sites having a small population is shown in Table 10.

Table 10 — Typical Six Sigma infrastructure for small site populations

Role	Number	Comments
Deployment Manager	0	Duties taken by an existing senior manager
Project Sponsors	Variable	Variable according to the number and types of projects
Master Black Belts	0	Not usually found employed on site, but an organization should use external resource instead
Black Belts	1 per 5 Green Belts	Part time Operational within their usual area of work
Green Belts	1 per 30 employees	Part time Seconded to projects according to needs
Yellow Belts	All employees	Part time Seconded to projects according to needs
NOTE The numbers referred to in this table are not always suitable for every Six Sigma application and the actual numbers may be different in each case.		

14.5 Multiple sites

Multi-site organizations seeking to deploy a common approach would typically follow a “Large” or “Medium” approach but would likely have Master Black Belts operating over a nominated group of sites, e.g. regionally, and Black Belts selected strategically from locations having the greatest perceived opportunity to benefit from the projects. Black Belts may be able to help other sites directly or through projects that Green Belts undertake or participate in.

Annex A
(informative)

Sigma scores

See Table A.1.

Table A.1 — Sigma scores

Sigma	0,00	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09
6,0	3,4									
5,9	5,4	5,2	4,9	4,7	4,5	4,3	4,1	3,9	3,7	3,6
5,8	8,5	8,2	7,8	7,5	7,1	6,8	6,5	6,2	5,9	5,7
5,7	13	13	12	12	11	11	10	9,8	9,3	8,9
5,6	21	20	19	18	17	17	16	15	15	14
5,5	32	30	29	28	27	26	25	24	23	22
5,4	48	46	44	42	41	39	37	36	34	33
5,3	72	69	67	64	62	59	57	54	52	50
5,2	108	104	100	96	92	88	85	82	78	75
5,1	159	153	147	142	136	131	126	121	117	112
5,0	233	224	216	208	200	193	185	178	172	165
4,9	337	325	313	302	291	280	270	260	251	242
4,8	483	466	450	434	419	404	390	376	362	349
4,7	687	664	641	619	598	577	557	538	519	501
4,6	968	935	904	874	845	816	789	762	736	711
4,5	1350	1306	1264	1223	1183	1144	1107	1070	1035	1001
4,4	1866	1807	1750	1695	1641	1589	1538	1489	1441	1395
4,3	2555	2477	2401	2327	2256	2186	2118	2052	1988	1926
4,2	3467	3364	3264	3167	3072	2980	2890	2803	2718	2635
4,1	4661	4527	4396	4269	4145	4025	3907	3793	3681	3573
4,0	6210	6037	5868	5703	5543	5386	5234	5085	4940	4799
3,9	8198	7976	7760	7549	7344	7143	6947	6756	6569	6387
3,8	10724	10444	10170	9903	9642	9387	9137	8894	8656	8424
3,7	13903	13553	13209	12874	12545	12224	11911	11604	11304	11011
3,6	17864	17429	17003	16586	16177	15778	15386	15003	14629	14262
3,5	22750	22216	21692	21178	20675	20182	19699	19226	18763	18309
3,4	28717	28067	27429	26803	26190	25588	24998	24419	23852	23295
3,3	35930	35148	34380	33625	32884	32157	31443	30742	30054	29379
3,2	44565	43633	42716	41815	40930	40059	39204	38364	37538	36727
3,1	54799	53699	52616	51551	50503	49471	48457	47460	46479	45514
3,0	66807	65522	64255	63008	61780	60571	59380	58208	57053	55917

Table A.1 (*continued*)

Sigma	0,00	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09
2,9	80757	79270	77804	76359	74934	73529	72145	70781	69437	68112
2,8	96800	95098	93418	91759	90123	88508	86915	85343	83793	82264
2,7	115070	113139	111232	109349	107488	105650	103835	102042	100273	98525
2,6	135666	133500	131357	129238	127143	125072	123024	121000	119000	117023
2,5	158655	156248	153864	151505	149170	146859	144572	142310	140071	137857
2,4	184060	181411	178786	176186	173609	171056	168528	166023	163543	161087
2,3	211855	208970	206108	203269	200454	197663	194895	192150	189430	186733
2,2	241964	238852	235762	232695	229650	226627	223627	220650	217695	214764
2,1	274253	270931	267629	264347	261086	257846	254627	251429	248252	245097
2,0	308538	305026	301532	298056	294599	291160	287740	284339	280957	277595
1,9	344578	340903	337243	333598	329969	326355	322758	319178	315614	312067
1,8	382089	378280	374484	370700	366928	363169	359424	355691	351973	348268
1,7	420740	416834	412936	409046	405165	401294	397432	393580	389739	385908
1,6	460172	456205	452242	448283	444330	440382	436441	432505	428576	424655
1,5	500000	496011	492022	488034	484047	480061	476078	472097	468119	464144
1,4	539828	535856	531881	527903	523922	519939	515953	511966	507978	503989
1,3	579260	575345	571424	567495	563559	559618	555670	551717	547758	543795
1,2	617911	614092	610261	606420	602568	598706	594835	590954	587064	583166
1,1	655422	651732	648027	644309	640576	636831	633072	629300	625516	621720
1,0	691462	687933	684386	680822	677242	673645	670031	666402	662757	659097
0,9	725747	722405	719043	715661	712260	708840	705401	701944	698468	694974
0,8	758036	754903	751748	748571	745373	742154	738914	735653	732371	729069
0,7	788145	785236	782305	779350	776373	773373	770350	767305	764238	761148
0,6	815940	813267	810570	807850	805105	802337	799546	796731	793892	791030
0,5	841345	838913	836457	833977	831472	828944	826391	823814	821214	818589
0,4	864334	862143	859929	857690	855428	853141	850830	848495	846136	843752
0,3	884930	882977	881000	879000	876976	874928	872857	870762	868643	866500
0,2	903200	901475	899727	897958	896165	894350	892512	890651	888768	886861
0,1	919243	917736	916207	914657	913085	911492	909877	908241	906582	904902
0,0	933193	931888	930563	929219	927855	926471	925066	923641	922196	920730

NOTE 1 The values in the table are DPMO. To find a sigma score, find the nearest DPMO and read off a sigma score.

NOTE 2 Calculations are based on a 1,5 sigma shift of the mean.

Annex B
(informative)

Training

B.1 Typical Black Belt training agenda

See Table B.1.

Table B.1 — Typical Black Belt training agenda

Day	Week 1 (Define)	Week 2 (Measure)	Week 3 (Analyse)	Week 4 (Improve)	Week 5 (Control)
Day 1	Cost of poor quality models; business measures; benchmarking; project financials	Scales of measurement; data types; definition of opportunities; interpreting variation	Basic tools; hidden factories; short and long term capability; standardized Normal distribution; confidence intervals	Full factorial experiments	Mistake proofing
Day 2	Identification of waste; concept of value; opportunities; Six Sigma measures; project selection	Process variation; process FMEA	Hypothesis testing; power and sample size calculations; distributions; ANOVA; multi-variate analysis	Fractional factorial experiments	SPC for attribute data
Day 3	Problem definition; identifying customers; process mapping; characteristic selection matrices; cause and effect diagrams	MSA for measurements; MSA for attributes	Linear regression and correlation; residual analysis; non-parametric hypothesis tests	EVOP; multiple regression analysis	SPC for measured data
Day 4	Team building; personality style profiling; project charter; project management; Gantt charts	Sampling strategies; data collection tools; basic statistical tools; process performance; process capability	Weibull analysis; 5-Why analysis	Process robustness; response surface experiments; force field analysis	Control plans; 5S; TPM; process audits; success criteria

B.2 Typical Green Belt training agenda

See Table B.2.

Table B.2 — Typical Green Belt training agenda

Day 1 (Define)	**Day 2 (Measure)**	**Day 3 (Analyse)**	**Day 4 (Improve)**	**Day 5 (Control)**
Project selection	Concept of variation	Capability analysis	Improvement - Alternative idea generation	Error proofing
DMAIC methodology	FMEA	Pareto analysis	“Should be” process map	Long-term MSA plan
Identifying CTQCs	Types of data	Box plots	Conducting an FMEA	p charts
Process mapping	Data collection plans	Histograms	Pilot improvements	u charts
Refining project scope	MSA	Scatter plots	Validate improvements	$\overline{X}$ and R charts
Cause and effect matrices		Run charts		X and R_{moving} charts
Waste and value analysis		Cause and effect diagrams		SOP's and training plans

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