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Quantitative methods in process improvement — Six Sigma —

Part 2:
Tools and techniques

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

Partie 2: Outils et techniques

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Foreword

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ISO 13053-2 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 7, *Applications 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

Six Sigma[1)] is an approach developed for businesses and organizations seeking to gain a competitive advantage. Six Sigma practices are designed to be instrumental in

- driving process improvement and making statistically based decisions,
- measuring business results with a level of reliance,
- provisioning for uncertainty and error,
- combining high returns and benefits in the short, medium and long run, and
- removing the waste from any process.

The sigma score (written Z_{value}) is an indicator of process quality that expresses process performance in terms of an ability to provide a product or a service that meets customer and third party specifications and expectations. It is directly related to either

a) the proportion of good or positive outputs (yield) provided by a process, or

b) the proportion of poor or negative outputs [%, ppm or defects per million opportunities (DPMO)] from a process.

The following table translates the Z_{value} as the proportion of defects that might be expected.

Table 1 — 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 ISO 13053-1:2011, Annex A.

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

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

Quantitative methods in process improvement — Six Sigma —

Part 2:
Tools and techniques

1 Scope

This part of ISO 13053 describes the tools and techniques, illustrated by factsheets, to be used at each phase of the DMAIC approach.

The methodology set out in Part 1 of ISO 13053 is generic and remains independent of any individual industrial or economic sector. This makes the tools and techniques described in this part applicable to any sector of activity and any size business seeking to gain a competitive advantage.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
benchmarking
method for comparing the performance of the leading organizations in a market segment

2.2
brainstorming
group creativity technique designed to generate a large number of ideas

2.3
cause and effect diagram
Ishikawa diagram
fishbone diagram
visual tool often used with brainstorming for the logical organization of potential causes of a problem

2.4
common cause
source of process variation that is inherent in a process over time

2.5
confidence interval
interval within which a parameter to be estimated can be expected to lie with a probability of $\geq 1 - \alpha$, e.g. generally 95 % or 99 %

2.6
continuous data
data that have been measured on a scale and that can be subdivided

2.7
critical-to-quality
CTQ
critical characteristics, the quality performance requirements which must be met to satisfy the customer

2.8
customer
organization or person that receives a product

NOTE The customer can be internal or external to the organization.

[ISO 9000:2005, 3.3.5]

2.9
defect
non-fulfilment of a requirement related to an intended or specified use

[ISO 9000:2005, 3.6.3]

2.10
defect opportunity
any measurable event creating a possible defect

2.11
defective unit
unit with one or more defects

[ISO 3534-2:2006, 1.2.16]

2.12
design of experiments
DOE
systematic methodology for collecting information to guide improvement of any process

NOTE 1 Statistical models are developed to represent the process under analysis.

NOTE 2 Simulation tools and optimization can be applied to test and confirm specific improvements.

2.13
discrete data
data that can be classified, but not subdivided

NOTE 1 Continuous data, by grouping or otherwise classifying, can be regarded as discrete.

NOTE 2 Data classified according to different attributes are discrete and are called “attribute data”.

NOTE 3 Discrete data come from nominal or ordinal scales.

2.14
environmental aspect
activity, product or service that could possibly interact with the environment

2.15
gate review
project review led by a sponsor each time a DMAIC stage is completed in order to validate the conclusions of that stage

2.16
input
resources or data, or both, required to execute a process

2.17
Kano model
quality management tool used to prioritize customer requirements

2.18
measurement system analysis
MSA
series of studies that explains how a measurement system performs

NOTE Validating measurement systems makes it possible to ensure data consistency and data stability.

2.19
mistake proofing
poka yoke
prevention method designed as a simple technique to prevent either

- anyone from making unplanned or unwanted changes to a system, or
- any errors from negatively impacting on a system

2.20
objective
target value of a process, determined by the customer

2.21
operational definition
clear, concise description of a measurement and the process used to derive it

2.22
output
products or services generated through a process

2.23
Pareto analysis
methodology used to drill into discrete data to assess the frequency of defects by classification factors

2.24
process
set of interrelated or interacting activities that transforms inputs into outputs

2.25
process map
graphical display of a process

2.26
project charter
document that states the problem to be solved, the improvement goals, the project scope, the project milestones and the project roles and responsibilities

2.27
quality function deployment
QFD
method to translate customer requirements into design characteristics and, ultimately, into process control requirements

NOTE The “house of quality” is a tool used by this method.

2.28
sampling plan
plan that describes how samples are to be selected

2.29
scorecard
customer-specified evaluation device used to track performance in satisfying customer requirements

2.30
special causes
sources of process variation other than inherent process variation

NOTE Special causes are due to known or exceptional factors, sometimes called assignable causes.

2.31
third party
person or body concerned or impacted by the performance issue in question

2.32
top Y
primary CTQ for both customer and organization

2.33
unit
item produced or handled

2.34
voice of the customer
VOC
information from the customer that expresses his expectations

NOTE This can require the customer concerned to state targets he needs and will assist the producer to know the customer's position and to understand his or her expectations.

3 Symbols and abbreviated terms

3.1 Symbols

b_0 intercept in a regression equation

b_1 coefficient in a regression equation

C criticality number used in FMEA

c number of defects (nonconformities)

D detection ranking used in FMEA

d accuracy (associated with confidence interval)

L lower specification limit

N population size

n sample size

n_{CTQC} number of critical to quality characteristics

O occurrence ranking used in FMEA

p proportion

r correlation coefficient

Σ summation

$\hat{\sigma}$ estimated population standard deviation

S severity ranking used in FMEA

s sample standard deviation

U upper specification limit

X random variable (independent)

$\bar{X}$ mean value of X

Y random variable (dependent)

$\bar{Y}$ mean value of Y

$\hat{Y}$ predicted value of Y

Y_{DPMO} calculated value of DPMO

Y_{ppm} calculated value of ppm

Z_{value} sigma score or value

3.2 Abbreviated terms

ANOVA analysis of variance

COQ cost of quality

COPQ cost of poor quality

CTQ critical to quality

CTQC critical to quality characteristics

DMAIC define, measure, analyse, improve and control

NOTE 1 The DMAIC method for improving an existing process and its output has five phases: define, measure, analyse, improve and control.

DPMO defects per million opportunities

NOTE 2 DPMO can be used to determine the sigma score.

FMEA failure mode and effects analysis

FMECA failure mode, effects and criticality analysis

GRR gauge repeatability and reproducibility study

ppm parts per million

RACI responsible, accountable, consulted, informed

ROI return on investment

RPN risk priority number

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

4 DMAIC process sequence

4.1 Define phase

4.1.1 Objectives

The objectives of this step are to

a) identify the requirements and expectations of the stakeholders,

b) identify the voice of the customer and third parties (CTQC, etc.),

c) select the project team,

d) develop a process map (SIPOC), visualize the data (Pareto), and

e) create a project charter.

4.1.2 Steps

4.1.2.1 Define: Step 1

Identify the customers and the third parties, understand their demands and translate them into measurable requirements. Set improvement objectives.

Techniques	Factsheet or International Standard
Customer claims, market feedback, surveys	Factsheet 04, ISO 9001 or other management standards
Third party expectations, ethics surveys	Factsheet 04, ISO 14001 or other management standards
ROI, costs and accountability	Factsheet 01
Six Sigma indicators	Factsheet 20
Affinity diagram	Factsheet 02
Kano model	Factsheet 03
CTQ requirements	Factsheet 04
House of quality	Factsheet 05
Benchmarking	Factsheet 06

4.1.2.2 Define: Step 2

Define and set down the team objectives for the project: deadlines, stakes, constraints, risks, return on investment, competencies and scope of the project.

Techniques	Factsheet or International Standard
Project charter	Factsheet 07
Project planning tool: Gantt chart, project schedule	Factsheet 08
RACI competencies matrix	Factsheet 28
ROI, costs and accountability	Factsheet 01
Project risk analysis (in Project charter)	Factsheet 07

4.1.2.3 Define: Step 3

Characterize the activity or the process.

Techniques	Factsheet or International Standard
SIPOC	Factsheet 09
Process mapping and process data	Factsheet 10

4.2 Measure phase

4.2.1 Objectives

The objectives are

a) to visualize the data (by means of a trend chart, histogram, etc.), and

b) to assess baseline performance for the current process in order to reinforce the project objective.

4.2.2 Steps

4.2.2.1 Measure: Step 1

Take the measurable requirements (Y) and select one or more critical variables (X) to improve.

Techniques	Factsheet or International Standard
Voice of the customer (house of quality, etc.)	Factsheet 05
Voice of third parties (environment, social responsibility, sustainability)	Factsheet 05
CTQ tree diagram	Factsheet 04

4.2.2.2 Measure: Step 2

Define the data to be collected in order to pinpoint the process variation drivers (X).

Techniques	Factsheet or International Standard
Prioritization matrices	Factsheet 11
Cause and effect diagram	Factsheet 12
Brainstorming	Factsheet 13
FMEA (Failure Mode & Effect Analysis)	Factsheet 14

4.2.2.3 Measure: Step 3

Double-check the fitness of the metrics selected.

Techniques	Factsheet or International Standard
MSA (Measurement system analysis)	Factsheet 15

4.2.2.4 Measure: Step 4

Develop a stratified data collection (X and Y) plan.

Techniques	Factsheet or International Standard
Data collection plan	Factsheet 16
Determination of sample size	Factsheet 17

4.2.2.5 Measure: Step 5

Understand and validate the data.

Techniques	Factsheet or International Standard
Normally tests and transformation of non-normal distributions	Factsheet 18
Visual display of data: histogram; box plot (box-and-whisker plot); Pareto chart; run chart	Factsheet 19
Control chart	Factsheet 30

4.2.2.6 Measure: Step 6

Measure process performance and/or process capability.

Techniques	Factsheet or International Standard
Indicators: P_p, P_{pk}, C_p, C_{pk}, ppm, DPMO, Z_{value}	Factsheet 20

4.2.2.7 Measure: Step 7

Confirm or readjust the improvement objectives.

Techniques	Factsheet or International Standard
Compare initial objectives with indicators (Project charter)	Factsheet 07

4.3 Analyse phase

4.3.1 Objectives

The objectives are

a) to identify wastes,

b) to identify environmental and socially negative impacts,

c) to select and rank the key process variables (X),

d) to establish relationships between X and Y,

e) to validate the root cause (X) that affects Y,

f) to estimate the weak points of the current design.

4.3.2 Steps

4.3.2.1 Analyse: Step 1

Analyse the process to pinpoint non value-adding activities or activities that need improvement.

Techniques	Factsheet or International Standard
Cause and effect analysis	Factsheet 12
Waste analysis	Factsheet 21
Value-stream analysis	Factsheet 22
Services delivery modelling (service process analysis)	Factsheet 23
Process mapping	Factsheet 10

4.3.2.2 Analyse: Step 2

Chart potential links between X and Y.

Techniques	Factsheet or International Standard
Scatter diagrams, Pareto and scatter plots	Factsheet 19
Run chart	Factsheet 19

4.3.2.3 Analyse: Step 3

Quantify the impact of key process variables X and their potential interactions.

Techniques	Factsheet or International Standard
Hypothesis testing	Factsheet 24
Regression analysis	Factsheet 25
Correlation	Factsheet 25

4.3.2.4 Analyse: Step 4

Further refine the assessed impact of key process variables by employing an experimental approach to find new factors.

Techniques	Factsheet or International Standard
Design of experiments	Factsheet 26
Regression analysis	Factsheet 25
Hypothesis testing	Factsheet 24

4.4 Improve phase

4.4.1 Objectives

The objectives are

a) to identify solutions (selection),

b) to plan and develop a pilot test (e.g. usage of DOE),

c) to develop a robust solution (FMEA update),

d) to implement the selected solutions.

4.4.2 Steps

4.4.2.1 Improve: Step 1

Determine the target process.

Techniques	Factsheet or International Standard
Descriptive statistics visualization	Factsheet 19

4.4.2.2 Improve: Step 2

Generate solution ideas/redesign.

Techniques	Factsheet or International Standard
Brainstorming and other creativity tools	Factsheet 13
Design of experiments	Factsheet 26

4.4.2.3 Improve: Step 3

Test.

Techniques	Factsheet or International Standard
Reliability	Factsheet 27

4.4.2.4 Improve: Step 4

Assess the risks.

Techniques	Factsheet or International Standard
FMEA (failure mode & effect analysis)	Factsheet 14

4.4.2.5 Improve: Step 5

Select.

Techniques	Factsheet or International Standard
Prioritization matrices and other decision-making methods	Factsheet 11

4.4.2.6 Improve: Step 6

Organize solution deployment.

Techniques	Factsheet or International Standard
Project planning tools: • Gantt chart; • Project schedule	Factsheet 08
Resource management tools (RACI matrix, etc.)	Factsheet 28

4.4.2.7 Improve: Step 7

Implement.

4.5 Control phase

4.5.1 Objectives

The objectives are

a) to review, verify and validate the improvements (control plan),

b) to preserve the benefits (e.g. deployment of TPM),

c) to institutionalize the improvements (e.g. 5S, ongoing capability),

d) to provide feedback and teamwork recognition.

4.5.2 Steps

4.5.2.1 Control: Step 1

Update the control plan.

Techniques	Factsheet or International Standard
FMEA update	Factsheet 14
Control plan (documented)	Factsheet 29

4.5.2.2 Control: Step 2

Document the best-practice activities.

Techniques	Factsheet or International Standard
Drafting process procedures	ISO 9001, ISO 14001, or other management standards
Training	ISO 9001, or other management standards

4.5.2.3 Control: Step 3

Implement solution monitoring.

Techniques	Factsheet or International Standard
Control charts	Factsheet 30

4.5.2.4 Control: Step 4

Double-check the improvement is effective and efficient.

Techniques	Factsheet or International Standard
Statistical testing, graphical representation	Factsheets 04, 19 and 24
Calculation of gains achieved	Factsheet 01, ISO 9001, ISO 14001 or other management standards
Process capability	Factsheet 20
Satisfaction survey	ISO 9001 or other management standards
Benchmark (update)	Factsheet 06

4.5.2.5 Control: Step 5

Capitalize on the lessons learned.

Techniques	Factsheet or International Standard
Project review and feedback on experience	Factsheet 31
Reporting the achievements: on an intranet, the Internet, etc.	Factsheet 07

4.5.2.6 Control: Step 6

Institutionalization.

Techniques	Factsheet or standard
Assess potential gains and risks across other business applications	Factsheet 07 ISO 9001 or other management standards

4.5.2.7 Control: Step 7

Project closure and celebrate completion.

Annex A
(informative)

Factsheets

See Factsheets 01 to 31.

Factsheet 01 — ROI, costs and accountability

WHAT DOES IT INVOLVE?

A Six Sigma project aims at improving operating profit or revenue or both. It is important to manage this programme as any business task with

a) operating and financials objectives (ROI and costs),

b) an accounting model that illustrates the expenses and incomes of the project, and

c) a budgeting process to help manage the Six Sigma project on a medium term time scale.

WHAT ROLE DOES IT PLAY?

ROI and cost accounting provide the proof that a Six Sigma project will deliver financial results.

ROI techniques, combined with an appropriate accounting model, help to manage the progress of a project and verify that each milestone is within the scope of the financial target.

WHAT NEEDS TO BE DONE?

There are three steps :

1. Build a cost accounting model for the Six Sigma project.

   A Six Sigma project is driven by a process principle: the value of it is the difference between the value of the outputs of the activities and their costs. Each activity produces revenues (linked to the outputs) but also generates some costs. The cost accounting is a breakdown of the general accounting with some specific accounts for the cost and revenue of a process activity.

   The cost accounting offers an identical vision for both the finance and the operational departments about the revenues and the costs of a process. It is important that the financial and the operation departments use the same accounting model for business performance.

   As a result, cost accounting is able

   to give the cost and revenue of each unit from a process, and

   to build the accounting process for the value chain.

2. Establish the ROI for the project.

   The main objective of this step is to provide a recommendation to fund the project, or not.

   The ROI calculation must be understandable in the cost accounting model built in Step 1.

3. Build the budget and manage the project.

   For a medium or a long term Six Sigma project, the timing of the improvement effort, and the timing of the anticipated benefit, will be different, and most probably expenditure will start before any benefits are accrued. A budget is a tool that allows the scheduling of both income and expenditure.

GUIDELINES

ROI and cost accounting is an ongoing process that supports all activities and processes.

TO FIND OUT MORE:

Factsheet 02 — Affinity diagram

WHAT DOES IT INVOLVE?

The "affinity diagram", sometimes referred to as the "KJ method", was devised by Jiro Kawakita.

The method involves gathering all the ideas, opinions and reactions raised by subjects or specific questions and then organising and sorting them to facilitate more structured analysis and discussion.

This method generally follows on from a brainstorming session (see Factsheet 13).

WHAT ROLE DOES IT PLAY?

The affinity diagram provides a straightforward approach for handling subjective ideas, affective impressions or highly personal perceptions. The tool generates important clues for identifying real causes.

The affinity diagram is useful to promote the involvement of a group of people in addressing issues and concerns by getting people to organize their data into a structure that is natural to the participants.

WHAT NEEDS TO BE DONE?

Through topic-based group work, each participant airs their ideas, concerns and feelings in response to the subject raised.

Each idea is recorded onto a note card or a "sticky note". The moderator clarifies the ideas aired where appropriate, and asks the participants to classify inter-related ideas into categories. One idea may be classified under more than one different category.

Sticky notes carrying "loner" ideas that do not seem to fit are put back with the so-far unsorted notes.

The group reviews the pattern of categories and may choose to produce new sub-categories or groupings.

When, and only when, all the sticky notes have been satisfactorily classified, the focus group selects a heading for each category.

The final pattern of inter-category relationships can be reviewed to highlight and then analyse the causes of the problem.

GUIDELINES

This tool can be used alongside other, more fact-based and more measure-based tools.

Associations between ideas need to be intuitive. A single category can contain only one idea note card.

Keeping the classification process as short as possible will let the categories emerge naturally, using the right side of the brain, leaving no time for rational explanations and reasoned advocacy.

TO FIND OUT MORE:

See Brassard [32] and Rochet [45].

Factsheet 03 — Kano model

WHAT DOES IT INVOLVE?

The Kano model distinguishes six types of product quality:

1. ‘attractive’ quality (or exciting). A quality characteristic is not expected by the customer but has a high impact on his or her buying decision. This is the 'plus', the 'innovative' quality characteristic, liable to win the buyer's decision (to have a product that stands out from the crowd, attractive or win-over expectations).
2. ‘1-dimensional’ quality (or desired). If the characteristic is not fulfilled, the customer will notice it and be dissatisfied. On the contrary, if it is fulfilled, the customer will notice it and therefore be in a satisfied mood.
3. 'must-be' quality, as found in all the products available on the market. This is a minimum requirement, since customers may refuse products without this must-be quality (bottom line expectations).
4. 'offered' quality, in tune with market mood. Customer preferences will often be driven by economic criteria (promotional offer). A more or less sophisticated technology can sway the decision (performance expectations).
5. ‘indifferent’. Quality characteristics that have no effect, nor influence, on customer satisfaction.
6. ‘sceptical’. Characteristics that may badly influence the customer who could turn away from the offer.

WHAT ROLE DOES IT PLAY?

The Kano model helps developers determine what functions, performance level, or features will create excitement, offer increasing (or decreasing) satisfaction, merely meet basic expectations, or will be met with indifference. In a way, the Kano model captures latent customer needs for a better understanding of the voice of the customer. Kano survey responses can help identify hidden market segmentation.

The model has two main roles:

1. to identify how queried functions, performance levels, or features create customer satisfaction or dissatisfaction: customers are polled with specific inverse-paired questions; and
2. to tie product functions, performance levels and features to strategic criteria.

WHAT NEEDS TO BE DONE?

There are 5 phases:

1. draft the Kano questionnaire;
2. identify the people who will be polled through the questionnaire;
3. prepare the setting in which the questionnaire will be administered;
4. test the questionnaire; and
5. process the responses.

GUIDELINES

Deploy the quality function deployment system (QFD).

Use the Kano questionnaire.

TO FIND OUT MORE:

See Fiorentino [37] , Kano [39] and Vigier [48].

Factsheet 04 — CTQ tree diagram

WHAT DOES IT INVOLVE?

CTQ (critical to quality) is a visual tool depicted as a horizontal tree where the branches represent information expressed through customer focus groups or through processes for gathering stated or unstated customer expectations.

WHAT ROLE DOES IT PLAY?

The CTQ tree is able to transform broad customer needs into a more focused, sometimes even higher-level-perception customer needs, while at the same time determining the customer's expectations in terms of critical-to-quality characteristics.

The CTQ is employed at step 1 of the “define” phase and step 4 of the “control” phase of the DMAIC method.

WHAT NEEDS TO BE DONE?

A group works with a flip chart to determine the customer's key need. The group then identifies the first tier of requirements from the customer's initial need continuing down with more tiers as new requirements are deduced and new quality-critical characteristics appear.

For example:

a. core need: “fully conforming deliveries”;

b. first tier requirement: “delivery deadlines”, “deliveries in good condition”; and

c. critical characteristics: “carrier”, “delivery date”, “goods packaging”, “full order”, etc.

GUIDELINES

The key point is not to make assumptions on customer expectations but to always double-check them with the customer.

Do not go further than three tiers in the tree structure.

Using this tool often makes it possible to highlight “quick fix” defects that can be eliminated immediately.

TO FIND OUT MORE:

See ISO 9001 [8], ISO 14001 [14] and other management standards.

Factsheet 05 — House of quality

WHAT DOES IT INVOLVE?

The “house of quality” is a matrix tool for identifying and formulating relationships between:

1. customer expectations or the objectives targeted; and
2. the solutions put forward or regular practices (functional specifications).

The house of quality belongs to the quality function deployment (QFD) process that embraces the entire cycle of the product life, from customer expectations to the product / service delivery, maintenance and retrieval.

WHAT ROLE DOES IT PLAY?

The tool is designed to formulate different decision criteria and cross-check solutions against customer expectations. The tables produced make it possible to draw together a focus group's opinions and thereby facilitate decision making.

The method also makes it possible to integrate design engineering considerations and nurture a customer-centric viewpoint.

House of Quality

Functional Specifications (FS)

Customer Expectations (CE)

	FS1	FS2	FS3	FS4	FS5	FS6	FS7
CE1							
CE2							
CE3							
CE4							
CE5							

WHAT NEEDS TO BE DONE?

The tool works in four steps:

1. identify the solutions (functional specifications) put forward and the targeted objectives (customer expectations, for example);
2. define internal relationships:
   a. relationships and design constraints between the solutions offered (functional specifications), and
   b. relationships and design constraints between the objectives targeted (customer expectations);
3. assess how the solutions offered fit the objectives targeted; and
4. “weigh-up” the suggested solutions and the objectives targeted.

GUIDELINES

Pre-requisites for deploying this tool include

i. capture the “voice of the customer”, document the objectives targeted, candidate solutions, etc., and
ii. a cross-functional focus group.

TO FIND OUT MORE:

See Fiorentino [37], Mizuno [41], Vigier [48] and Yoji [49].

Factsheet 06 — Benchmarking

WHAT DOES IT INVOLVE?

Benchmarking is a performance improvement tool that measures the performance of different companies and identifies the best practices. It involves some techniques that aim to compare the performance of a given company to the performance of a group of the best known companies in the same market.

WHAT ROLE DOES IT PLAY?

In a quality or a continuous improvement process, benchmarking is an important step that scores the level of performance of the process management of an organization. The purpose is to compare its own practices with the practices of a group of companies acting in the same market.

Different types of benchmarking can be produced:

a. internal;

b. competitive; and

c. functional (e.g. human resources, procurement, R&D…).

WHAT NEEDS TO BE DONE?

There are two main phases.

1. Planning phase

As a first step, plan how to collect the data about performance and organization. Then select the companies that will represent the benchmark and establish a first evaluation of their levels.

2. Analysis and improvement phase

Establish the measures and the analysis in order to identify the gap of performance between the target company and the companies of the benchmark. Once the gaps have been evaluated, implement the best practices to reach the new level of performance.

GUIDELINES

Benchmarking is an efficient way to introduce best practices in an organization.

Start with an internal benchmark. Set up an internal score for the main departments of the company. Then, continue with the competitive benchmark.

TO FIND OUT MORE:

Subscribe to a benchmarking network and exchange information about improvement practices.

Factsheet 07 — Project charter

WHAT DOES IT INVOLVE?
A project charter is a contract that is established between the Project Sponsor and the project team.
WHAT ROLE DOES IT PLAY?
1. Clearly sets out the project team's roles and goals. 2. Keeps the project team focussed on the priorities of the business. 3. Transfers the project from project sponsor to project team.
WHAT NEEDS TO BE DONE?
Draft an official document stating: a. the title of the target problem; b. the problem statement; c. the project challenges and benefits expected; d. the goals to be achieved; e. the project scope; f. the project risk analysis; g. the role of the project team; h. the key steps, milestones and results expected; i. a cost-estimate for the project; j. the resources and means necessary; and k. validation of the project at the first project “gate” review.
GUIDELINES
The project charter formalizes the group's deadlines and deliverables commitments. The project charter shall be drafted in collaboration with the project leader and the sponsor. The project charter shall be validated and signed by the sponsor, the owner of the processes involved, the project leader, and general management. Changes may be made to the charter while the project is underway, in which case the same people will need to validate the updated version.
TO FIND OUT MORE:
See Pillet [44].

Factsheet 08 — Gantt chart

WHAT DOES IT INVOLVE?
A Gantt chart is a planning tool that displays the time scale of all activities of a project on a single calendar.
WHAT ROLE DOES IT PLAY?
A Gantt chart is one of the essential planning tools of a project manager. By stating the start and end dates of the activities that can be processed in parallel, the project manager has visibility of the time schedule.
WHAT NEEDS TO BE DONE?
Establish an exhaustive list of all the activities (or tasks) of the project. On the Gantt chart, each row is a different activity. For each activity, give estimated starting and ending dates. The columns describe the calendar (days, weeks, years). Connect the different activities with an arrow where the output of one is the input of another. During the execution of a task, indicate on the chart the percentage of activity completed. Repeat it for all the activities of the project, with a sequential order between the activities indicated by the arrows.
GUIDELINES
Determine the critical path which represents the sequence of the essential tasks to be performed. Use a Gantt chart to communicate the progression of the project over time.
Every important step of the project should be formalized by a milestone.
TO FIND OUT MORE:
See Minana [40] and Sinit [46].

Factsheet 09 — SIPOC

WHAT DOES IT INVOLVE?

Mapping the entire process and establishing the process flowchart.

WHAT ROLE DOES IT PLAY?

A SIPOC is a visual representation of a process that prompts teams to explicitly state all five 'SIPOC' entities and thereby understand the entire process.

We have:

Suppliers: the process supplier has to be identified,

Inputs: the inputs need to be described,

Process: a concise outline of the transformation achieved through the process,

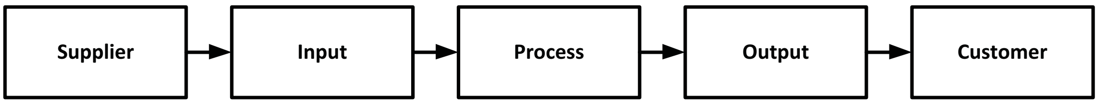
Outputs: the outcome (output) of the process has to be identified,

Customers: the process customer has to be identified.

WHAT NEEDS TO BE DONE?

All five SIPOC items shall be written into a table in diagram form, thus ensuring that no item can be left out, and offering a visual display of the interactions between sequences involved.

SIPOC diagram



Example in the food industry:

GUIDELINES

The SIPOC diagram is to be employed in the “define” phase of the DMAIC process for continuous improvement.

TO FIND OUT MORE:

See the literature on the Six Sigma method.

Factsheet 10 — Process mapping and process data

WHAT DOES IT INVOLVE?

Process flow mapping is a visual display tool for representing and analysing a process flow.

The process map is a formalized representation of a flow. Process mapping yields a single map featuring all the processes and their interactions. The business process map is used to analyse the interactions between many processes. Any individual process may include a number of flows, but not every business flow is contained in this process. There is no one-to-one relationship between processes and flows, for several reasons:

a. some flows are left out as the process does not describe all the real-world flows involved in the activity or the process may be poorly formalized;

b. there are many flows that do not need to be formalized (filing into cabinets, moving between workshops, etc.), the process should only map out significant flows (otherwise it would be impossible to navigate through them); and

c. at any given moment in time, the process will cover the main flows, but changes in practices combined with the constant drive towards improvement will mean that some flows get phased out while new flows get created, and there is no reason for these new flows to be contained in a single process.

WHAT ROLE DOES IT PLAY?

Gives an in-depth display of process activities for a flow.

WHAT NEEDS TO BE DONE?

Symbolic representation designed to establish:

1. movements;
2. process steps (transforming or assembling) that are value-added for the customer;
3. “non-value-added” process steps;
4. waiting time (including work in progress stocks); and
5. the value-added ratio.

GUIDELINES

Training for users.

Use a symbols library.

TO FIND OUT MORE:

See Biteau [30] and Crouhy [34].

Factsheet 11 — Prioritization matrix

WHAT DOES IT INVOLVE?

1. Classify root cause/solutions, etc. according to their impact on the target problem.
2. Highlight basic disagreements so that they can be quickly resolved.
3. Focus on the best things to do, not everything can be done.
4. Highlight step-by-step criteria as compulsory control points in the process chain.

WHAT ROLE DOES IT PLAY?

1. Aids a decision when a group cannot come to a consensus on a possible solution, certain solutions will be given priority over others.
2. To be performed each time a set of identified causes, solutions and effects has to be ranked, in order to give a better focus on decision-making given guiding priorities.
3. Cut down the number of possible solutions by ranking them according to clearly stated criteria.

WHAT NEEDS TO BE DONE?

1. Chose a final objective.

   All members of the group must agree on the objectives. The given purpose will greatly impact the choice of the criteria.

2. Create the list of criteria.

   This list can be created from brainstorming or from older documents (budget reporting, objectives commitment, etc.). The most important point is that the group reaches a consensus about the final criteria and their meaning.

3. Balance the criteria.

   First, create a table where the causes/solutions and the identified criteria are given.
   Then, each member of the group scores each criterion according to the level of importance.
   For example:

Very important criterion	9 pts
Important criterion	3 pts
Standard criterion	1 pts
Without any importance	0 pts

   See the example below.

4. Use the results.

   In order to find out which are the most important causes/solutions, add up the points for each criterion. The total indicates which causes/solutions should be considered first.

EXAMPLE Prioritization Matrix

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Total	Rank
Cause A	9		9	1	19	1
Cause B					0	5
Cause C	3	9	1	3	16	2
Cause D		1	3		4	4
Cause E	1	3		9	13	3

NOTE The main cause identified is Cause A, which scored 19 points.

GUIDELINES

If there is no consensus between several competing causes, then the criteria values can be multiplied instead of totalled in order to differentiate according to the weight of the impact.

TO FIND OUT MORE:

See the literature on Six Sigma methods.

Factsheet 12 — Cause and effect diagram

WHAT DOES IT INVOLVE?

A cause and effect diagram visually displays possible causes for a problem. It is also known as an “Ishikawa diagram” or “fishbone diagram”.

WHAT ROLE DOES IT PLAY?

1. Identifies the cause and effect relationship (instead of switching straight from problem to solution).
2. Stimulates ideas through brainstorming of potential root causes.
3. Categorizes and visually displays the causes triggering an effect.

WHAT NEEDS TO BE DONE?

1. Clearly state the effect targeted.
2. Brainstorm the potential causes.
3. Sort the causes into the most widely-used categories, corresponding to the 5Ms+E: Machine, Materials, Manpower, Method, Measurement and mother nature (the Environment).
4. Sketch out a fishbone diagram, placing the effect at the head, with the corresponding categories as the bones; the bones can be further branched out where necessary.
5. Break the causes down into categories and subcategories.

GUIDELINES

Additional brainstorming can identify other causes within the categories where few causes had thus far been identified.

The diagram shows the potential causes. Once the diagram has been completed, the next step is to verify the causes.

It is useful to highlight the potential causes acting as the main drivers of the effect or whose impact on the effect needs to be verified. In this way, the priorities can be easily displayed.

TO FIND OUT MORE:

See Ishikawa [38] and ISO/IEC 31010:2009 [23].

Factsheet 13 — Brainstorming

WHAT DOES IT INVOLVE?

Brainstorming is a group creativity technique for problem-solving and creating a large number of ideas in a very short space of time.

A flip-chart is used to note down and record all the ideas aired.

Different sets of brainstorming procedures are used for different contexts and target outcomes:

1. highly freeform brainstorming, used to stimulate maximum creativity: an example from advertising would be “find a new brand name”; or
2. more directed brainstorming, used when there is less space for creativity: example from a technical setting: “find a solution meeting specific criteria”.

WHAT ROLE DOES IT PLAY?

Brainstorming is a disciplined yet relaxed way of prompting group members to search for new ideas, creating a setting that challenges the prevailing hypotheses and paradigms.

The brainstorming is employed at step 2 of the “measure” phase and step 2 of the “innovate / improve” phase of DMAIC.

Brainstorming can be used at any time there is a need to “generate ideas”.

WHAT NEEDS TO BE DONE?

a. Recap the step and the workgroup objective, set the target outcome for the brainstorming session.

b. Set a timeframe.

c. Agree on a problem statement or questions to be worked on through the brainstorming session; write the target problem out clearly, at the top of the flip-chart.

d. Recap on the ground rules:

   i. no criticizing the ideas generated;

   ii. no judgements on the ideas generated;

   iii. encourage “out-of-the-box” ideas;

   iv. build on other people's ideas; and

   v. all ideas will be recorded.

e. Start work with the group, and make sure everyone in the group can easily read all the ideas generated and listed.

f. Make sure every participant gets to freely provide their input. Don't let one individual “chatterbox” dominate the session.

g. Keep going round the table to keep the pace up; participants “pass” when they do not have an immediate idea.

h. The moderator shall not cut short or interpret the ideas generated; the moderator's role is to record all the ideas on the flip-chart just as they were issued.

i. Once a significant body of ideas has been generated, certain points may need clarifying, as not everyone will necessarily grasp all the ideas.

j. Once the brainstorming session is over, other analytical techniques step in, such as cause and effect analysis, pair-wise comparisons, etc.

GUIDELINES

Use a flip-chart with easily detachable sheets, good marker pens, and something for fixing the sheets to a wall.

The moderator remains standing up throughout the session, so that ideas can be written down properly.

TO FIND OUT MORE:

See Caplen [33].

Factsheet 14 — Failure mode and effects analysis (FMEA)

WHAT DOES IT INVOLVE?

Both FMEA and FMECA (failure mode, effects and criticality analysis) play a useful role in quality assurance and a pivotal role in reliability assurance. Both methods can be applied to a broad panel of potential problems in technical systems. They can be expanded or readjusted to varying degrees according to the objective targeted. The analysis can be deployed during the planning and definition phases of a project, and is widely used in a range of system design and implementation processes. FMEA is an inductive method for carrying out low-level to high-level qualitative analysis on system safety or reliability.

Functional reliability diagrams (function and sub-function reliability graphs) and status graphs (description of the structure between two transformations) that are plotted based on system structure are closely tied to FMEA. Separate diagrams will be required according to

1. the way the different criteria for defining system failure are determined,
2. the severity of the functional failure or the negative effect on the guaranteed level of system function,
3. the safety factor, and
4. other process function phases.

Other applications of FMEA and FMECA include:

a. for evaluating the effects and sequence of events triggered by each failure mode identified in the system – regardless of origin – at different functional levels within that system;
b. for determining the severity or the criticality of each failure mode in terms of its impact on normal system function or on system performance level, and for evaluating the impact on the reliability or safety of the function targeted;
c. for categorizing known failure modes according to how easily they can be detected, diagnosed, simulated, how easily a component can be changed, and according to the resources mobilized to counter the failure mode and keep the system up and running (repair, maintenance and logistics, etc.), as well as any other relevant parameters;
d. for establishing failure probability and impact rating, as long as the necessary input data are available; and
e. for increasing process availability.

FMEA has three main fields of application: the system, product and process levels. In all three cases, the FMEA method can help anticipate risks and prioritize the most-at-risk points according to an indicator called criticality.

WHAT ROLE DOES IT PLAY?

The aim is to lower the risks of failure of reliability, maintainability, availability and safety. System, product or process analysis helps fine-tune the technical specifications and boosts efforts to make improvements the customer can see.

WHAT NEEDS TO BE DONE?

The method consists of (using a rating scale of 1 to 10):

a. listing potential failures and scoring the potential consequences of this failure, S;
b. determining the occurrence of these causes of the potential failures, O;
c. assessing the failure detection modes, D.

Criticality (C) is also known as the risk priority number (RPN): $C = S \times O \times D$

A high criticality number indicates a major risk.

In most cases, the focus group will look for workaround solutions for items with an unacceptable criticality score. These items will then be re-scored according to the solutions available.

GUIDELINES

FMEA (FMECA) analysis requires the following:

a. a dedicated, cross-functional focus group;
b. significant preparation; and
c. the tracking of remedial actions with follow-up on the real results of these actions on criticality.

TO FIND OUT MORE:

See AIAG's FMEA [28]. BS EN 60812:2006 [26], and ISO/IEC 31010:2009, B.13 [23].

Factsheet 15 — Measurement system analysis (MSA)

WHAT DOES IT INVOLVE?

The following list gives the main causes of measurement uncertainty, in the case of continuous variables.

1. **Resolution**: the smallest increment of the measurement variable that a device is capable of detecting.
2. **Measurement accuracy (bias)**: the difference between what a measurement system 'reads' and what the true value is.
3. **Linearity error**: measurement bias across the usable range of the measuring system.
4. **Stability**: variability in the results given by a measurement system measuring the same characteristic and the same product over an extended period of time.
5. **Repeatability**: the difference between results of successive measurements on the same measurand (with all measurements carried out under identical measurement conditions: same measurement procedure; same observer, same measuring instrument, used under the same operating conditions, same location, the repetition over a short period of time).
6. **Reproducibility**: the difference between results of measurements on the same measurand (with measurements carried out under different measurement conditions).

In the case of categorical variables (often encountered in transactional processes), the main causes of measurement errors are due to differences in training and in expertise of the agents of the processes.

WHAT ROLE DOES IT PLAY?

Identifying measurement uncertainty for continuous variables is an important step towards validating a measurement instrument in relation to the tolerances of the process or product characteristics to be measured. The most widely used is the GRR test.

This test compares the measurement uncertainty with the tolerance interval of the process or product characteristic to be measured, which is expressed as a percentage, to determine the acceptability of the measurement instrument.

The usual decision criteria are:

i. GRR< 10 %: the measurement system is **acceptable**;

ii. 10 %<GRR< 30 %: the measurement system **needs improvement**

iii. GRR> 30 %: the measurement system is **unsuitable**.

Assessing the level of agreement amongst various agents of the processes in making specific decisions is an important step in identifying measurement uncertainty for attribute data.

WHAT NEEDS TO BE DONE?

1. Select which components need to be measured.
2. Have several operators make repeated measurements (for example, 10 components each measured three times by three operators).
3. Analyse the results with a spreadsheet or through specialized statistical software (calculation and graphical display).
4. Interpret.
5. Decide whether the measurement system is acceptable.

GUIDELINES

Specialized software should be used to run the calculations and format the results. Measurements that are outliers must be excluded or re-measured. However, the cause of these outliers should be studied in order to prevent them from reoccurring.

When the outcome is unacceptable, it may be necessary to conduct a brainstorming to identify possible factors that influence the measurement uncertainty and then reduce or remove them.

TO FIND OUT MORE:

See ISO/TR 12888 [12], ISO 22514-3 [20], AFNOR [27] and AIAG's MSA [29].

Factsheet 16 — Data collection plan

WHAT DOES IT INVOLVE?

To produce the media needed to record an adequate dataset of key information in a predetermined format.

To specify what data and how much data are to be collected and over what time period.

To provide operational definitions of measured data and categorical data.

NOTE Even the best data processing methods will produce ambiguous (and dangerous) results if the data they use are poorly defined or if they are not recorded properly.

WHAT ROLE DOES IT PLAY?

To give the most faithful picture possible of the status of various organizational, technical, environmental and commercial processes, at any given time, and to provide data on product characteristics at different stages of their development.

It is through data (either raw or processed), sometimes in an indicator format, that decision-makers keep themselves informed. The data can be used to cross-check against specifications, to run through the improvements cycle, and to build databases and a corporate memory.

WHAT NEEDS TO BE DONE?

There is no mathematical formula for setting which information needs to be gathered.

When establishing a data collection form, it would seem logical to draw on several sources:

1. forms currently in use, that can be adapted;
2. information required by the (internal or external) customer, auditors, or various different managers;
3. operator experience, that should be coordinated and the key points documented; and
4. standards.

The data collection form is drafted according to objectives that need to be well-defined; there is the form and the content.

Content-wise, the main points are:

a. parameters identifying the item concerned;

b. parameters relating to the data collection environment - place, date, operator, etc.;

c. target characteristics; and

d. process operating conditions and process environment conditions at the time the record is made.

Form-wise, the options are:

i. binary response: “yes”-“no”;

ii. qualitative– plaintext (with or without a repertoire of words) or coded; and

iii. quantitative (units to be measured).

If the data are collected directly into a computer, they will almost certainly meet form-format conditions.

It may be necessary to design a validation step for certain datasets.

GUIDELINES

Always clearly define what needs to be done and why it needs to be done.

Make sure that everyone is clear on the way the information is to be formulated.

TO FIND OUT MORE:

See Ishikawa [38] and ISO/IEC 19795-1:2006, Clause 7, *Data collection* [18].

Factsheet 17 — Determination of sample size

WHAT DOES IT INVOLVE?

Determining the number of samples to be taken from a population of individuals to characterize the population.

Increasingly large sample sizes will yield progressively more accurate estimates. However, measurement operational costs increase with the number of individuals, n. The aim is therefore to use an optimal sample size.

WHAT ROLE DOES IT PLAY?

Determining and minimizing the number of individuals to be sampled from a population of (known or unknown) size N in order to find out population characteristics (mean, standard deviation, relative frequency) at a given level of confidence.

1 If the focus is on a continuous characteristic of the population (for example the size of individuals in the French population), the mean (size characteristic) and the standard deviation (dispersion characteristic) can be used to describe the population. The mean and standard deviation of a sample of size n are estimators of the mean and standard deviation of the population of (known or unknown) size N.

EXAMPLE 1 How many people need to be measured before the average size of the French population can be calculated to an accuracy of ±1 mm?

2 If the focus is on an individual attribute (eye colour, for example), the relative frequency of blue-eyed people in a sample of n individuals taken from the population is an estimator of the relative frequency of blue-eyed people in the population of (known or unknown) size N.

EXAMPLE 2 How many people need to be observed before the average percentage of blue-eyed people in the French population can be calculated to an accuracy of ±1 %?

WHAT NEEDS TO BE DONE?

There are widely-used formulae for calculating sample size.

EXAMPLE 1 To estimate the mean, the sample size required to give a 95 % chance of obtaining a mean that falls within a confidence interval of ± d, is approximately $n \approx \left(2s/d\right)^2$ (where s is the standard deviation of the n sample values).

EXAMPLE 2 To estimate the relative frequency, the sample size required to give a 95 % chance of obtaining a relative frequency that falls within a confidence interval of ± d is $n = p(1-p)(2/d)^2$ (where p is the proportion of individuals in the sample who carry the attribute).

GUIDELINES

To improve the estimates of mean or relative frequency, it is necessary to increase the size of the sample. Doubling the sample size divides the accuracy d of the result by $\sqrt{2}$.

TO FIND OUT MORE:

See BS 600 [24] and ISO/TR 18532 [17].

Factsheet 18 — Normality testing

WHAT DOES IT INVOLVE?

A large number of continuous characteristics follow the normal, or Gaussian, distribution. Methods of statistical analysis are easy to apply when the distribution studied follows such a distribution.

Testing whether a characteristic follows a normal distribution makes it possible to detect anomalies and learn whether the properties of the normal distribution apply.

If the data do not follow a normal distribution, it may be that

1. the characteristic is unstable – the presence of special causes (trends, drift, outliers, etc.), or
2. the characteristic naturally follows a different distribution.

WHAT ROLE DOES IT PLAY?

It highlights, via a statistical test, if the data do not follow a normal distribution.

If the data do not follow the normal distribution, it may be possible to transform the data so that they become normal.

Using a normal distribution makes it possible to forecast the number of defects or the proportion of outputs that are outside a specification.

WHAT NEEDS TO BE DONE?

a. Produce a probability plot of the data to indicate if the data follow a normal distribution.
b. Conduct an Anderson-Darling test of the data for non-normality.
c. Calculate skewness and kurtosis of the data.

GUIDELINES

The probability plot indicates non-normality if it deviates from a straight line when the scale used to plot against is from the normal distribution.

The Anderson-Darling test determines the degree of departure from normality of a set of data. There is usually an associated probability value (p-value) given with it. If this p-value is less than 0,05 most practitioners will interpret this to mean a normal distribution cannot be assumed for the data.

Standard algorithms exist to transform data to the normal. The most common are the Box-Cox transformation and the Johnson transformation. A transformation algorithm will not be able to transform an unstable characteristic (presence of special causes) and sometimes a transformation will not work. In the latter case, the user should consult a professional statistician.

TO FIND OUT MORE:

See ISO 5479 [5] and ISO 16269-4:2010, 4.3.5 [15].

Factsheet 19 — Descriptive statistics visualization tools

WHAT DOES IT INVOLVE?

Summarizing, both graphically and numerically, the statistics for sets of data.

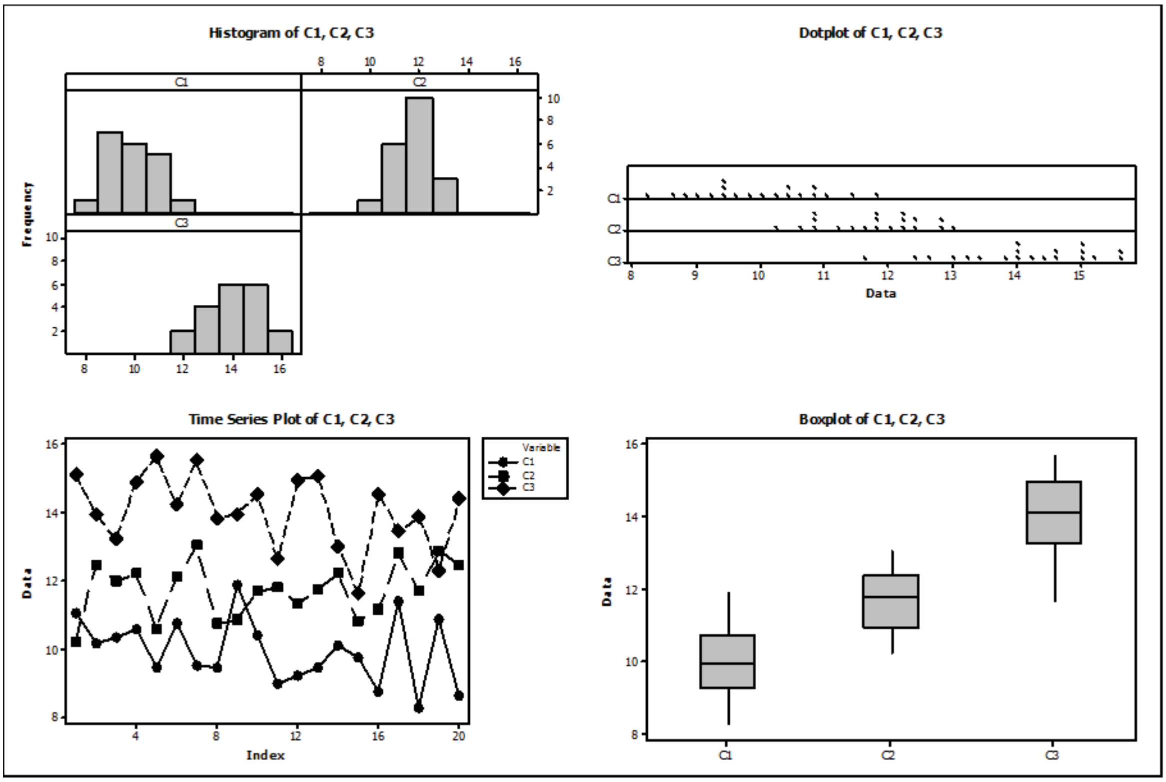
WHAT ROLE DOES IT PLAY?

The objective of this analysis is to understand the variation of factors (X). This may involve stratifying by levels of a factor (X).

WHAT NEEDS TO BE DONE?

The data are analysed by grouping (stratifying) the data into the different levels, if appropriate.

EXAMPLE The main graphic shown below displays highlight stratification (C1, C2 and C3 are the three levels of variation of a factor X).



GUIDELINES

The graphical display makes it possible to detect the potential influences of a factor on a characteristic. Run statistical tests to confirm whether the influence is true.

TO FIND OUT MORE:

See Ishikawa [38].

Factsheet 20 — Indicators

WHAT DOES IT INVOLVE?

An indicator is a measure designed to track changes, at predefined intervals, of an important quantity. The most likely focus of an indicator is one associated with some performance criterion. Under a Six Sigma approach, the most widely used indicators are:

1. indicators of the proportion of negative-effect (or defective) output data or input data generated by a process: % (percentage), ppm (parts per million) or DPMO (defects per million opportunities); or
2. process capability indices or process performance ratios: C_p, C_{pk}, P_p, P_{pk} or z, the number of process standard deviations.

Other business indicators are used in practice such as product return rate, on-time delivery, or number of customer complaints, along with an overall measure of quality called COQ (cost of quality) or COPQ (cost of poor quality).

WHAT ROLE DOES IT PLAY?

1. It provides information over time to a Six Sigma team on how a process is performing.
2. It is used to express the level of CTQC (critical to quality characteristic).

WHAT NEEDS TO BE DONE?

1. Calculate parts per million: ppm

$$Y_{\text{ppm}} = \frac{c}{n} \times 1\,000\,000$$

2. Calculate the number of defects per million opportunities (or non-conformity: DPMO)

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

3. Calculate a process capability index or a process capability ratio: C_p

$$C_p = \frac{U - L}{6\hat{\sigma}}$$

GUIDELINES

1. Given that processes are being constantly improved, their performance levels regularly improve, to a point that using % units (e.g. 0,001 5 %) becomes wholly impractical, thus prompting a switch towards ppm that provides more useful values.
2. Illustrative examples are
   a. a process yielding 11 % of defective bricks, i.e. 110 000 ppm, or
   b. a 0,001 5 % deadline overrun, i.e. 15 ppm.
3. Any process can have several different defect types. The calculation DPMO takes account of this fact.
4. Illustrative examples of a pizza delivery process: three defect types (late delivery, cold pizza and pizza nonconforming to order), 36 total defects, 50 000 deliveries:

$$Y_{\text{DPMO}} = \frac{c}{n_{\text{units}} \times n_{\text{CTQC}}} \times 1\,000\,000 = \frac{36}{50\,000 \times 3} \times 1\,000\,000 = 240$$

5. Make sure the team is fully conversant with the statistical principles underpinning how C_p and z are calculated.
6. Before calculating C_p or z, check that the data are normally distributed because the calculation is different when the distribution is not normal.

TO FIND OUT MORE:

See ISO/TR 22514-4 [21].

Factsheet 21 — Waste analysis

WHAT DOES IT INVOLVE?

The “7 wastes” originally described by Taiichi Ohno at Toyota are activities that do not create added value but that add additional costs.

Although they generally feature in production settings, these “7 wastes” can easily be described in services, businesses and in private- or public-sector administrative functions.

1. **Waste stemming from overproduction**: the most dangerous of all, as it drives the other forms of waste by producing more than is necessary or by producing items earlier than planned, *e.g. advertising materials, items finished ahead of schedule, etc.*
2. **Waste stemming from waiting time:** time spent waiting for something to happen, *e.g. waiting for repairs, running out of raw materials, unproductive meetings, etc.*
3. **Waste generated by unnecessary conveyance operations:** includes any movement of equipment or parts that does not bring added value, *e.g. using special carrier services to ship a part due to behind-schedule part manufacture.*
4. **Waste due to over processing**: heavy, cumbersome procedures due to over-complicated process designs that do not match actual needs, *e.g. bureaucratic red tape.*
5. **Waste due to excess inventory:** more stock than is necessary, *e.g. when large quantities are bought in an attempt to benefit from volume discounts.*
6. **Waste stemming from motion:** unnecessary movements due to poorly-designed layout, *e.g. stocking finished goods a significant distance from the shipping berth.*
7. **Waste stemming from product defects:** producing products rejected at quality control, or unsatisfactory services, *e.g. customer returns.*

WHAT ROLE DOES IT PLAY?

Highlighting these “7 wastes” makes it possible to start eliminating almost all “waste”-generating factors, significantly cut costs, and increase workforce efficiency.

WHAT NEEDS TO BE DONE?

Waste needs to be detected, dealt with, eliminated, and regularly double-checked in order to prevent unwanted recurrence.

a. Map the processes.

b. Form a taskforce to identify which process steps has waste.

c. Determine the annual costs.

d. Prioritize the actions to be introduced.

e. Re-engineer the processes, this time eliminating sources of waste.

GUIDELINES

“7 wastes” tools should be handled thoughtfully and with care, since waste is often down to long-standing practices and sometimes even to the prevailing organizational setup in place.

“7 wastes” tools are a key component in lean management or just-in-time approaches.

TO FIND OUT MORE:

Look up information on the Toyota Production System (TPS), e.g. Ohno [42].

Factsheet 22 — Value stream analysis (VSM)

WHAT DOES IT INVOLVE?

It is a workplace system for obtaining – at least cost – only those necessary product or service functions while at the same time generating improvements in the factors that govern their quality, safety, sustainability and design.

WHAT ROLE DOES IT PLAY?

1. Value stream analysis is a key economic tool for any business.
2. Cutting manufacturing costs to a minimum by only producing what is strictly necessary.
3. Developing new concepts as part of a drive to cut manufacturing costs to better meet customer needs.

WHAT NEEDS TO BE DONE?

Value-added analysis is conducted according to 'job plan' scheduling in the following seven phases:

a. orientation of 'value' engineering actions;
b. information-gathering;
c. analysis of functions and costs – validation of needs and objectives;
d. generation of ideas and potential solution paths;
e. solutions testing and assessment;
f. forecasts – presentation of the selected solutions – decision-making; and
g. implementation.

GUIDELINES

i. This is a method that should be employed as soon as a product or service appears to become outdated, insufficiently competitive, overloaded or – more generally – out-of-step with customer or market needs.
ii. It applies to every level of the production process: from design through to sales and to production.

TO FIND OUT MORE:

See Boulet [31] and Petitdemange [43].

Factsheet 23 — Services delivery modelling

WHAT DOES IT INVOLVE?

Services delivery is the process required for a business to produce the service it is marketing.

Modelling services delivery highlights three core process strands:

1. the “customer role”, that can vary between a high degree of participation, in which the customer is described as active, and a low degree of involvement, where the customer is 'dominated';
2. the “customer interface role”, that can vary between high and low involvement; and
3. the “physical media”, that work to the requirements of both “service experience” performance: the styling and sensations involved, and 'functional' performance designed to facilitate service delivery in material terms.

The service is identified by an entity that can be enumerated and evaluated according to some quality and performance criteria. For example, travelling from one country to another is one service entity conducted by an agency. This “service entity” can be of good or bad quality and has a cost. This service entity is activated by the customer, by some interaction with an “interface” and supported by some physical media.

e-marketing and web services are online tools for the production of services.

WHAT ROLE DOES IT PLAY?

Service delivery models, like any process map, can be used to detail all service delivery flows and determine CTQs based on the three strands highlighted.

Building service delivery models for each individual service is an effective method for gaining insight into how a service should be organized, with the view on the customer's perspective.

Service delivery modelling is employed at step 3 of the “define” phase and step 1 of the “analyse” phase.

WHAT NEEDS TO BE DONE?

Establish the path (route, travel, visit…) of the customer and fix the key points where some choices are made.

Then, on this path, describe the different contact points with their interface roles. At the end, indicate the main physical supports used along the path. This gives the service delivery model.

GUIDELINES

Use this approach for service activities such as tourism, travelling, leisure, entertainment, where cost management and customer satisfaction CTQ) are the key issues.

TO FIND OUT MORE:

See Eiglier [36].

Factsheet 24 — Hypothesis testing

WHAT DOES IT INVOLVE?

Performing statistical tests on the values or equality of statistical parameters such as

a. the mean,

b. the variance or standard deviation, or

c. the proportion of one or more properties in the data (e.g. “good” or “bad”).

WHAT ROLE DOES IT PLAY?

1. Statistical tests comparing one or more data samples are used to answer the following two classic situations.

   a. For a given sample representing a candidate solution: does this solution enable us to achieve the objective or target value we are looking for?

   b. Between two samples, each representing a different solution: does one of these solutions yield significantly different results to the other or, put a different way, is one of these solutions significantly better or worse than the other?

2. This means that these tests can be used to

   a. check whether a solution will yield the expected results, or

   b. compare results between different candidate solutions.

WHAT NEEDS TO BE DONE?

The table below highlights the most common statistical tests that are used.

Parameter	**Comparison to a target value or an objective**	**Comparison between two values**
Mean	t-test	t-test or ANOVA
Variance or standard deviation	Chi-squared test	F-test LEVENE's test SNEDECOR's test
Proportion or frequency	Binomial test Poisson test Normal distribution approximation test	Normal distribution approximation test

GUIDELINES

TO FIND OUT MORE:

See ISO 2854 [1] and ISO 11453 [10].

Factsheet 25 — Regression and correlation

WHAT DOES IT INVOLVE?

1. Collect "'paired" data (X and Y).
2. Produce a scatter plot of the data.
3. Calculate a line of "best fit" through the plotted points.
4. Measure how well X predicts the values of Y.

WHAT ROLE DOES IT PLAY?

To check and/or prove a quantified relationship between two variables.

EXAMPLE length of a person's feet = f(height of the person) + f(length as a newborn child)

WHAT NEEDS TO BE DONE?

1. Gather "paired" data (X and Y).
2. Produce a scatter plot of the data and check for any relationship. If a linear relationship appears reasonable, proceed. Otherwise, seek specialist help.
3. Calculate a best line using the following model:

$$\hat{Y} = b_0 + b_1 X$$

where b_0 and b_1 are calculated from the data using the following equations:

$$b_1 = \frac{\sum\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sum\left(X_i - \overline{X}\right)^2} \text{ and } b_0 = \overline{Y} - b_1\overline{X}$$

4. Calculate the correlation coefficient using the following equation:

$$r = \frac{\sum\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sqrt{\sum\left(X_i - \overline{X}\right)^2\left(Y_i - \overline{Y}\right)^2}}$$

GUIDELINES

It is recommended to produce a graphical display of the scatter plot (X_i, Y_i) to assess whether the first-degree model is legitimate, since it is possible for r to be > r_{crit} without this first-degree model actually being the best.

Correlation measures the degree of the linear relationship between two or more random variables. In order to prove a quantified relationship between two variables X and Y, the significance of the coefficient of correlation r characterizing the degree of dependence between the two variables X and Y must be established. The interpretation is as follows:

$r = 0$: there is no linear relationship between X and Y.

$r = -1$ or $+1$: there is a perfect linear relationship: all the points (X_i, Y_i) are either negatively or positively aligned

$0 < r < 1$: this means we can state, with a given risk (α) of being wrong, that r is significantly different from zero if the absolute value for 'r' is greater than an r_{crit} given in the table below:

Critical values for the correlation coefficient (r_{crit}) where $\alpha = 5$ %

$n-2$	2	5	7	10	15	20	30	50	100
r_{crit}	0,950	0,755	0,666	0,576	0,482	0,423	0,349	0,273	0,195

EXAMPLE

$n = 12$, i.e. 12 pairs (X_i, Y_i), which gives $r = 0{,}65$

For $\alpha = 5$ %, reading off the table for $n - 2 = 10$ gives $r_{crit} = 0{,}576$

$r = 0{,}65 > r_{crit} = 0{,}576$: the relationship is significant.

TO FIND OUT MORE:

See ISO 3534-1 [2].

Factsheet 26 — Design of experiments (DOE)

WHAT DOES IT INVOLVE?

1. Decide which response (Y) is to be observed and which factors (X) are to be used.
2. Determine how many levels each factor is to be held at during the experiment.
3. The selection of an experimental layout and determining how many runs and replicates are needed.
4. Run the experiment and collect the data.
5. Analyse the results.
6. Perform a confirmation run to verify the findings.

WHAT ROLE DOES IT PLAY?

1. Design of experiments is a tool for modelling effects such as measurable observables (like the results of a process or an activity) so that they can be analysed and understood. The aim is generally to gain a better understanding of these effects, and to resolve any problems they may be causing.
2. Gather as much information as possible (study as many causes as possible) through as few trials as possible.
3. Save time and increase efficiency.
4. Find solutions on quantified items.
5. Prove, quantify and model the influence of causes (parameters or factors and interactions).

WHAT NEEDS TO BE DONE?

1. State the problem.
2. Determine the objectives and transform the objectives into measurable responses.
3. Select the factors and the levels at which they operate.
4. Identify any potential interactions.
5. Build the design of experiments, using standardized test tables, e.g. classical or Taguchi arrays.
6. Run the trials set out in the design of experiments.
7. Process the results.
8. Draw graphs of the factor and interaction effects.
9. Determine the significant factors and interactions (analysis of variance).
10. Conduct a confirmation run using the indicated preferred settings for the factors determined from the experiment and verify the original findings.

GUIDELINES

1. Express the effect with a measurable 'Y' (process output) for the response.
2. Make sure that the causes, parameters or factors are controllable and independent.
3. Build a problem analysis team with experience in the effect to be studied.
4. Take measures to ensure that all test equipment will remain operationally available throughout the tests.
5. Opt to use limited ranges of variation in causes, parameters or factors.
6. Methodically run the trials set out in the design of experiments.
7. Be on the lookout for cultural bottlenecks and natural resistance inherent to the design of experiments and which can potentially introduce variation on several factors at the same time.

TO FIND OUT MORE

See ISO 3534-3 [4], ISO/TR 13195 [13], ISO/TR 12845 [11] and ISO/TR 29901 [22].

Factsheet 27 — Reliability

WHAT DOES IT INVOLVE?

Reliability is a characteristic of an item, component, sub-assembly, process, system or network that indicates the ability of the item to perform its purpose for a given period of time and under a given set of conditions. Non-repairable items means zero failures from the time they are commissioned into operation.

Since repairable equipment may require preventive or corrective maintenance, reliability is expressed as availability, the ratio of time in a state of able readiness to the total amount of time the item is called upon.

Equipment that is held on standby (such as safety equipment) or stock and that needs to be fully operational as soon as required tends to have to be designed to meet specific reliability features.

Software reliability is managed through particular field-specific methods.

WHAT ROLE DOES IT PLAY?

Reliability gives confidence. Not only is reliability a strong selling point, it is also pivotal information to how equipment usage is organized: forecasting uninterrupted periods of operational activity, with its impact on productivity, implementing support by scheduling maintenance plans (frequencies, levels, resources employed), assessing unit quantities of spare parts and equipment stocks.

WHAT NEEDS TO BE DONE?

Reliability is determined on failure periods.

The indicators of on-line or off-line (testing) reliability are MTTF (mean time to failure) and MTBF (mean time between failures). The first is the average time an item remains operational before it fails for the first time. The indicator for repairable items is MTBF, the mean time between two consecutive failures.

The probability distribution of failure according to time is obtained by adjusting the failure time data to fit statistical distributions – the negative exponential distribution for electronic systems, and the Weibull distribution for mechanical systems.

The reliability indicator for a fleet of equipment is the proportion of equipment ready for service at a given point in time or on average over a given timeframe.

Reliability prediction is an approach employed upstream of the new product development phase, or before making changes, i.e. when specifications are drafted or as part of the design phase. Depending on available input, the approach draws on feedback on previous products or similar products, on databases, and on expert opinion, since experts can provide *a priori* knowledge.

In order to maintain reliability over a long period of time, the deployment of a TPM (total productive maintenance) plan is recommended.

GUIDELINES

Reliability hinges on consistent data collection, including records of incidents and technical events, through every stage of the product life cycle.

For repairable equipment, opt for the RCM (reliability-centred maintenance) method.

TO FIND OUT MORE:

See Crowder [35] and for details, BS 5760 [25].

Factsheet 28 — RACI competencies matrix

WHAT DOES IT INVOLVE?

RACI is the acronym for responsible, accountable, consulted, informed. RACI is a competency management method that assigns roles and responsibilities when delivering a business change.

The descriptions break down as follows:

Responsible: the person tasked with ensuring the process runs properly;

Accountable: the person giving approval that the process is running correctly;

Consulted: the person or persons consulted for their opinions on the running of the process;

Informed: the person or persons who need to be kept up-to-date on the results.

WHAT ROLE DOES IT PLAY?

The rationale is that a change to a process cannot occur on its own, and that people therefore have to be assigned specific activities in order to carry the change through. The aim is to make sure that all activities are covered and to clarify that roles and responsibilities are appropriately assigned.

WHAT NEEDS TO BE DONE?

The most straightforward method is to produce a matrix where the activities impacted by the change are in the rows and the people (roles) are in the columns. The intersection cells will be given one of the four letters from the acronym RACI so as to determine each person's responsibility (in the column) in relation to their activity (row). The diagram can be referred to as a roles and responsibilities matrix.

	Project leader	**Consultant**	**Legal advisor**	**Director**
Process 1	R	I	I	A
Process 2	I	R	I	A
Process 3	I	A	R	I

GUIDELINES

If there is overlap, the inconsistency needs to be resolved to reach an acceptable scheme (repeated Rs need to be redistributed). If there are unoccupied responsibilities (no R or no A for a process), a person needs to be appointed to fulfil the role.

TO FIND OUT MORE:

See Tonnelé [50].

Factsheet 29 — Monitoring / control plan

WHAT DOES IT INVOLVE?

1. A control (monitoring) plan is a quality plan covering a process and its resulting product outputs; it is a document specifying the procedures (a clearly-stated way to perform an activity) and associated resources to be employed, when, and by whom, for a product and its process. The plan covers each activity in the process, setting out the measures planned
   a. in terms of quality monitoring and measurements on both product and process, and
   b. in terms of safeguarding means / resources and / or maintaining the skills of the personnel involved.
2. The control plan is a written description of the processes and systems required in order to fully control product quality.

WHAT ROLE DOES IT PLAY?

The plan, by compiling and summarizing the monitoring and measurement solutions implemented in order to manage each individual process, can have dual objectives:

a. to guarantee the quality of the product output of the process;
b. to give confidence to the customers of the process (some of whom require a quality monitoring plan): customers of the process know what is being monitored on the product designed for them and in its associated process.

WHAT NEEDS TO BE DONE?

1. Identify the in-process activities.
2. Initiate a 5S if necessary.
3. For each activity, list the monitoring and measurement solutions that are either desirable or necessary in order to fully control the process, with particular focus on
   a. customer requirements (through a QFD matrix, for example),
   b. the objectives, and
   c. the risks in the process and its activities.
4. For each monitoring and measurement solution, describe
   a. the method and its associated monitoring and measurement (or control) system,
   b. the level of control: level 1, level 2 or level 3,
   c. the poka-yoke techniques deployed,
   d. the control schedule, and
   e. the type of recordings employed to keep records.

EXAMPLE 1 Monitoring plan (model 1) — Process: “Giving our customers training on our products”.

Monitoring and measures (product, process)	**Activities**
1 Percent of ongoing design a. Method, monitoring and measurement : design review b. Level: 1 and 2 (trainer and manager) c. Frequency: identical to the reviews. d. Type of recording : design review reports 2 (duration of starting activities) / (total duration of training)	1 Establish the plan 2 Design the training units

EXAMPLE 2 Monitoring plan (model 2) — Process: “Giving our customers training on our products”

It is relevant, or even strongly recommended for tangible products, to differentiate the monitoring and measurement actions performed directly on the product from those performed on the process (the 5Ms). This is in order to prove that the process is fully controlled, as a key to scaling down the product monitoring and measurement obligation. The monitoring plan can then take the following format:

Product	**Process**		
Monitoring and measures	**Activities**	**Monitoring and measures**	**Maintenance / Support**
	Activities (n) …		

GUIDELINES

Make the clearest possible distinction between the product (process output) and the process itself.

TO FIND OUT MORE

See ISO/TS 16949:2009 [16] and management standards.

Factsheet 30 — Control charts

WHAT DOES IT INVOLVE?

Control charts involve selecting a product characteristic or a parameter from a process and sampling it over time. The data are plotted onto a control chart. The chart has lines drawn on it that indicate the mean value and statistical limits. Statistically based rules are used to determine if the plotted characteristic is in control or out of control.

WHAT ROLE DOES IT PLAY?

The plan, by compiling and summarizing the monitoring and measurement solutions implemented in order to manage each individual process, can have dual objectives:

1. Control charts are tools that are used to monitor, control and improve a process performance over time.
2. Establishing whether a process is under control.
3. Displays process variations.
4. Helps to detect and indicate where actions should be taken to protect against further causes of malfunction in the process.

WHAT NEEDS TO BE DONE?

1. Select the process to be charted.
2. Establish the sampling method.
   a. Define the sampling frequency and the sample size.
   b. Collect around 25 samples in order to establish the statistics and the control limits.
3. Start collecting the data.
   a. Gather the samples without any modifications to the process.
   b. Record the data on the control chart.
4. Calculate the appropriate statistic.

   Appropriate statistics include means, standard deviations, ranges, number of nonconformities, number of nonconforming units…, etc.
5. Calculate the upper control limit and the lower control limit.
6. Build up the control chart.

   Plot the control limits and the mean value of the statistic onto the chart.

GUIDELINES

The following situations would indicate a process that is out-of-control. Should they occur, these would be handled via specific, pre-defined actions (equipment adjustments, bringing in technicians, etc.):

1. one or more points outside of the control lines;
2. a pattern of 7 consecutive points all falling on the same side of the central line;
3. a series of 7 consecutive intervals all increasing or all decreasing;
4. 14 consecutive points alternately increasing then decreasing (“zigzagging”).

It is possible to add further rules to determine whether a process is out-of-control by defining a number of zones within the boundaries of the control lines (zones A, B and C).

TO FIND OUT MORE

See ISO 7870-1 [6].

Factsheet 31 — Project review

WHAT DOES IT INVOLVE?

1. Check the results achieved by comparison against the expectations pinpointed in the define phase.
2. Gather feedback on the points of project roll-out that need improvement.
3. Identify the (non-project) actions to be wrapped up.
4. Define who is responsible for follow-up actions.
5. Communicate on project close-out and give feedback on the changes implemented (new process defined, etc.).

WHAT ROLE DOES IT PLAY?

The project review step is where project closure is documented and the project team is disbanded, and it offers the opportunity to communicate on the project record.

WHAT NEEDS TO BE DONE?

1. The project team gives its feedback, in response to the following questions.
   a. What went well?
   b. What didn't go well?
   c. What needs to be changed, and how?
   d. What are the lessons to be learned, and what are the success factors?
   e. Who does this feedback need to be shared with?
2. Draft a satisfaction survey and forward it to the “customers”.
3. Draft a project review report setting out the actions implemented over the five DMAIC project phases and stating the results of the project. Ideally, this document shall be signed by the members of the project team, the project leader and the sponsor.

   This document may cover the following points.

   Project recap, initial objectives, project team, methodology and tools deployed, feedback, gains made, actions remaining and actions taken to secure the project for the longer term, future gains and opportunities, etc.
4. Communicate. Several different communication media may be suitable, such as an article in the in-house bulletin, a memo on the intranet, a specific project close-out meeting, a temporary on-site posting, etc.

GUIDELINES

The essential baseline agenda is to run a feedback session with all the actors involved.

TO FIND OUT MORE:

Refer to the large body of project management materials published.

Consult project management standards.

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