Six Sigma

Methods and Tools for Process Improvement

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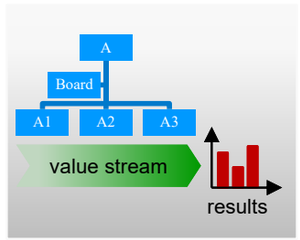
Six Sigma is a concept with several meanings – it links practice with methods and statistics

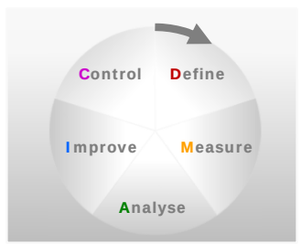
1. Improvement Program: increase customer satisfaction and reduce costs

- Problems of corporate products & services offer potentials for the improvement of processes
- These improvement potentials are identified by customer, by the management and by employees
- Potentials are defined as Six Sigma projects and then supervised by *Sponsors* from management
- Projects are implemented by Green-/ Black-Belts, according to the method and tools of the DMAIC cycle



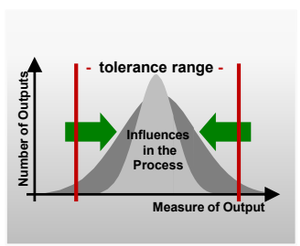
2. Methodical Approach: chronologically linked tools for the implementation of the project

- The DMAIC-Cycle is a problem-solving approach in five phases for the implementation of projects
- The approach is based on an open box of chronologically linked rational-logical and statistical tools
- The tools serve to define problems, analyze causes, develop solutions and control their success
- Additional tools serve to prepare the business case and to manage the project



3. Statistical Basis: process capability, process control, problem-cause relations, improvements

- The sigma level is a performance measure of the process capability, i.e. the excellence of the outputs
- At a level of 6 sigma (6σ), only 3.4 errors are expected in 1 million outputs (Motorola's short-term-sigma)
- Control charts indicate the variation of the process performance, i.e. variation of the output over time
- Statistical tests identify the main problems, the relationships to their causes and degree of improvement



… to analyse and realize potentials and to verify improvements

Introduction

Improvement Program & Method & Statistics

The quality of a Six Sigma program is determined by the management, …

Success factors for Six Sigma Programs:
- Involvement of the management via policy deployment and target agreement
- Specific career options for successful Green and Black Belts

Number of projects implemented per Green Belt:
- In successful programs: 1.6 projects per year (Mean)
- In terminated programs: 1.2 projects in the lifespan of the Six Sigma program (Mean)

Unsuccessful Six Sigma Programs:
- Termination after 5.7 years (Mean)
- Reasons for termination:
  - new management appointed, e.g. after reengineering of the company or mergers
  - no more suitable improvement topics identified, conviction that nothing more can be improved

Leyendecker, B., Schindewolf, S., Hutwelker, R., Weigel, H.: Erfolgsfaktoren für die Etablierung von Six Sigma (QZ 7/ 2011)

… career options for Belts and the continuous identification of suitable project topics

The sustainability of a Six Sigma corporate program is ensured by the continuous ...

Sources of improvement potentials

Management
- Targets for important key figures
- Deficiencies in key figures
- Process efficiency and effectiveness

Customer
- Ratings
- Complaints
- Purchases and cancellations

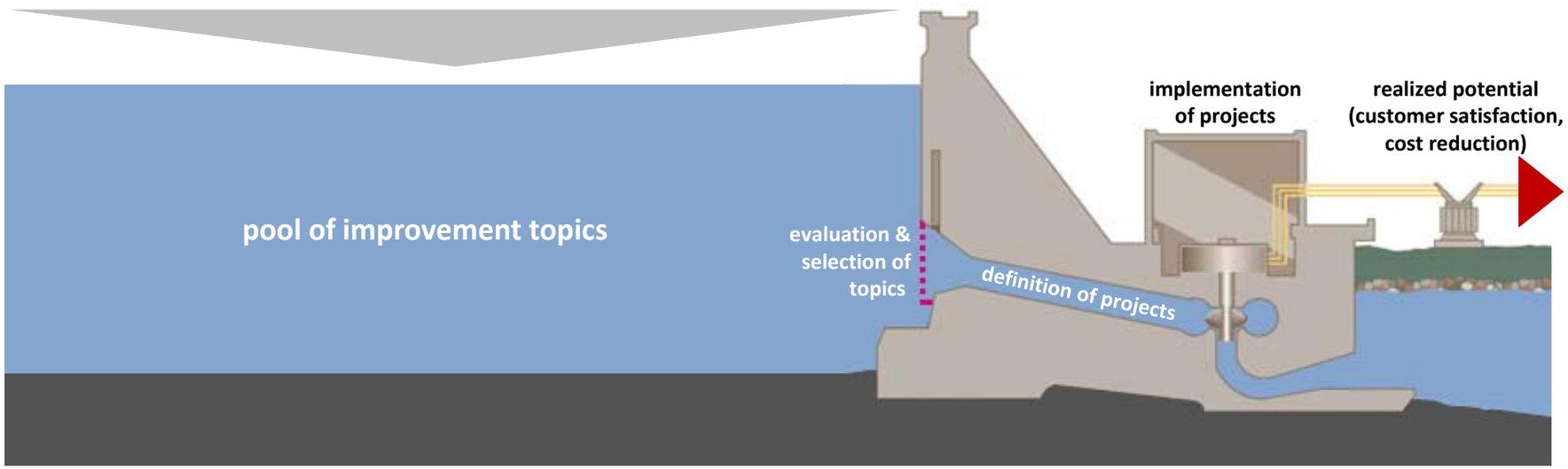
Analyses
- Suggestions scheme
- Value stream analysis
- 5S/ 5A

Employees
- Clarifications on inputs
- Negative influences on the process
- Deficiencies in outputs

Realization of improvement potentials

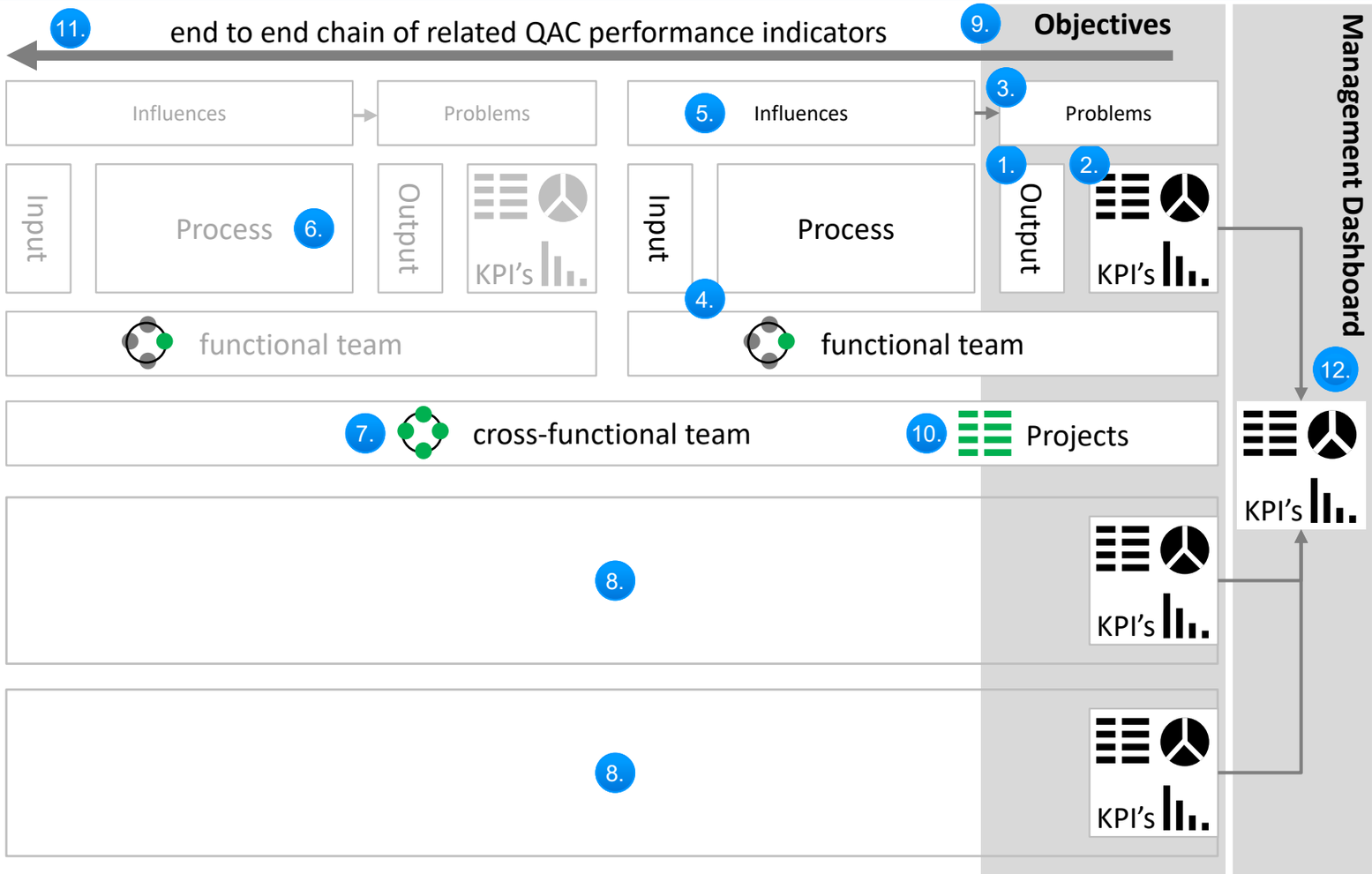
Steering Board
- Management
- Process owner (as potential sponsors)
- Master Black Belt

Project Team
- Sponsor
- Green/Black Belt
- Subject Matter Experts



… identification of improvement topics and their implementation in projects

An improvement program for operational excellence should be developed and ...



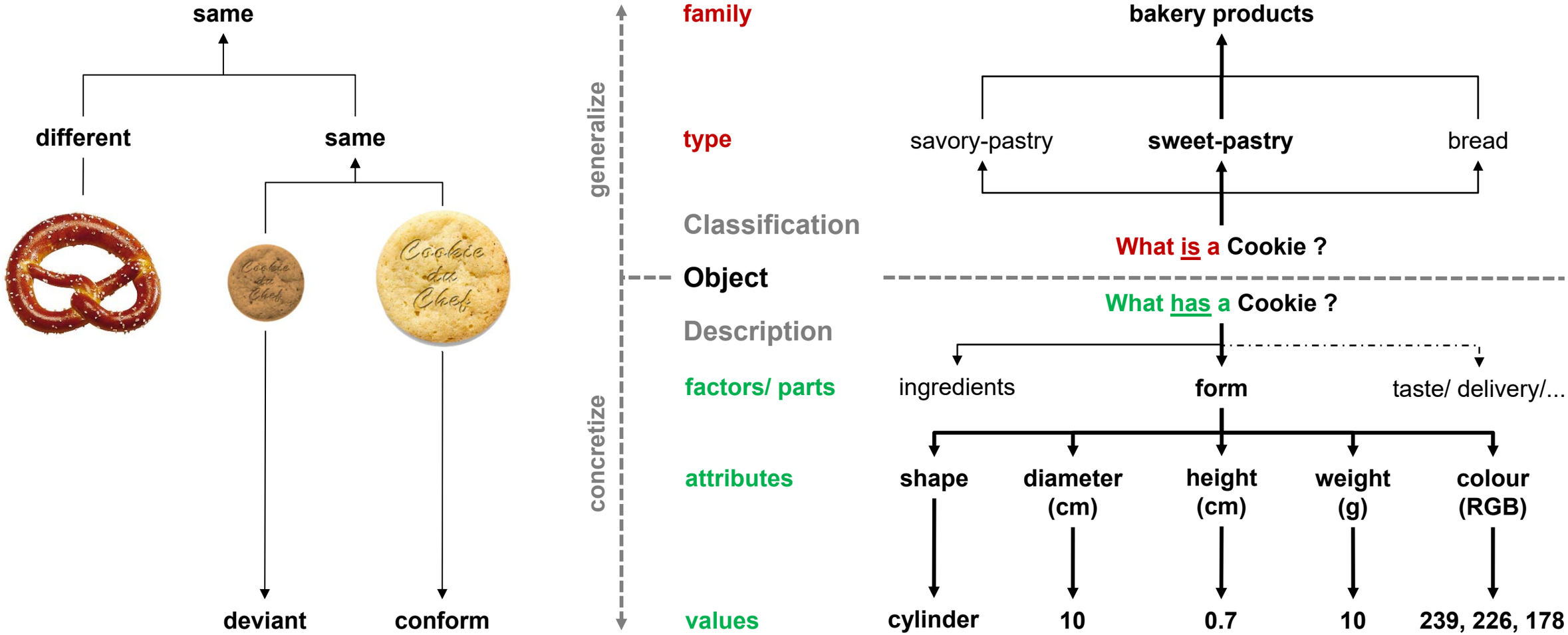
1. Identify important outputs/ customer touch points
2. Analyse data on quality, availability, and consumption (QAC), leading to the process costs
3. Pre-define obvious deviations of the outputs as problems
4. Identify the associated process, its key inputs, and the team members
5. Pre-define obvious influences that trigger the problems
6. Structure the upstream process up to the first relevant (external) input
7. Create a cross-functional team consisting of Lean Six Sigma Green Belt candidates
8. Structure further important processes from the last output to the first relevant input
9. Determine objectives for important outputs (touch points)
10. Identify, evaluate and select improvement topics, assign teams, implement projects
11. Derive QAC performance indicators, and target values for intermediate outputs along the process
12. Integrate KPI's to a management dashboard
13. Collect data continuously and adapt initial KPI's,
14. Continuously improve and/ or define further projects to achieve the objectives/ operational excellence
15. Review project results, acknowledge achievements

... organized along cores processes, evaluated by KPI's - with improvements triggered by deviations from requirements

Introduction

Improvement Program & Method & Statistics

Observe by asking questions – Classify to generalize and Describe to concretize



Each of these assignments means: modelling and measuring the reality

Observations in the bakery assigned to the: Problems → Output – Attribute – Deviation

problem type	descriptors	primarily affected
Quality	- false, defective, insufficient, missing or unreliable	(internal) Customer
	- not or only partially suitable for the targeted purpose	
	- risky for safety and security	
Availability	- not available in the required quantity (too much/ too few)	(internal) Customer
	- not available at the required time (too early/ too late)	
	- not available at the required location	
Consumption	- time consuming in preparation or waiting times in between	Management
	- wasteful in consumption of input or resources (active)	
	- losses of input or resources during creation (passive)	

Problems (Y) of Outputs

Object	Attribute	Deviation	
Cookie	taste	bad	Q
Cookie	diameter	> 10 cm	Q
Cookie	delivery	1 week early	A
Cookie	ingredients	> 50g waste	C
Cookie	energy	waste	C

Description of Problems (Y)

- **Outputs are material/ immaterial objects, e.g.**
  - cookie / video / decision
- **Objects are characterised by attributes, e.g.**
  - taste / audience-retention / alternative
- **Attributes deviate from required state or value**
  - bad / discontinued / false alarm

Classification of Problems (Y)

- **Problems are output attribute deviations in the categories:**
  - **Q**uality (in a given or required attribute)
  - **A**vailability (right quantity, time, and location)
  - **C**onsumption (losses or waste of inputs or resources)

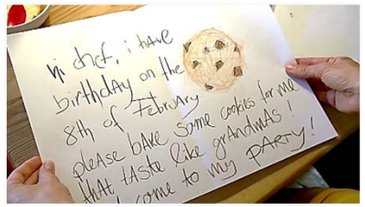
Problems can be classified into the Categories of: Quality, Availability and Consumption

Observations in the bakery assigned to the: Causes (x), …

Causes (x) in the Process	
Order specification on taste ambiguous	i
Ingredients individually determined	m
Chocolate nibbled from ingredients	a
Timer setup wrong	r
Cookies shaped variably	m
Date on calendar wrong	r
Oven extremely preheated	r

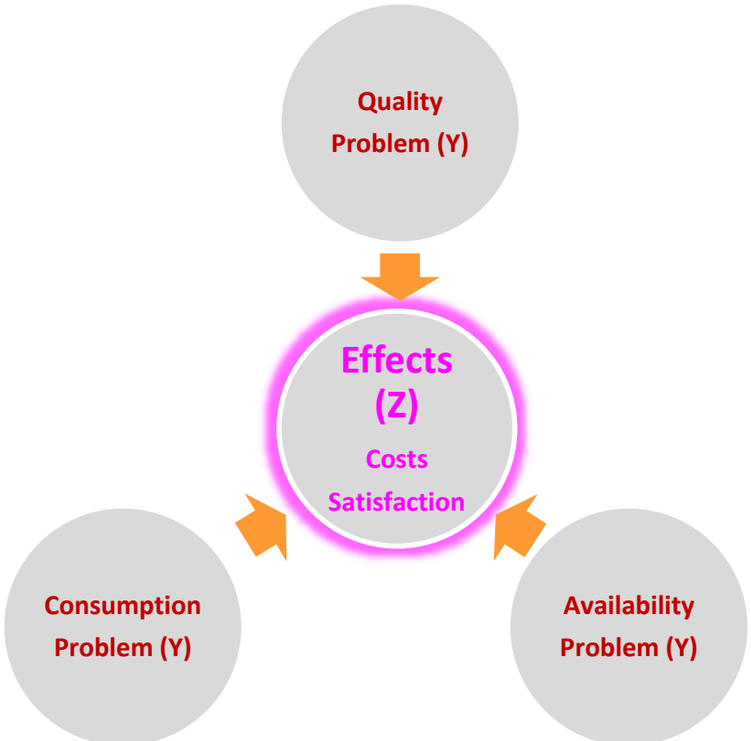
Classification of Causes (x)

- **Negative influences from**:
  - **I**nputs (xi),
  - **M**ethods (xm),
  - **R**esources (xr) and/ or
  - **A**ctivities (xa)
- **trigger and/ or amplify problems**



… and classified into the Categories of: Input, Method, Resources and Activity

Observations in the bakery assigned to the: Effects (Z), …



We solve problems to decrease costs …

NOT

Decrease costs to solve problems

Effects (Z) on Customer & Company

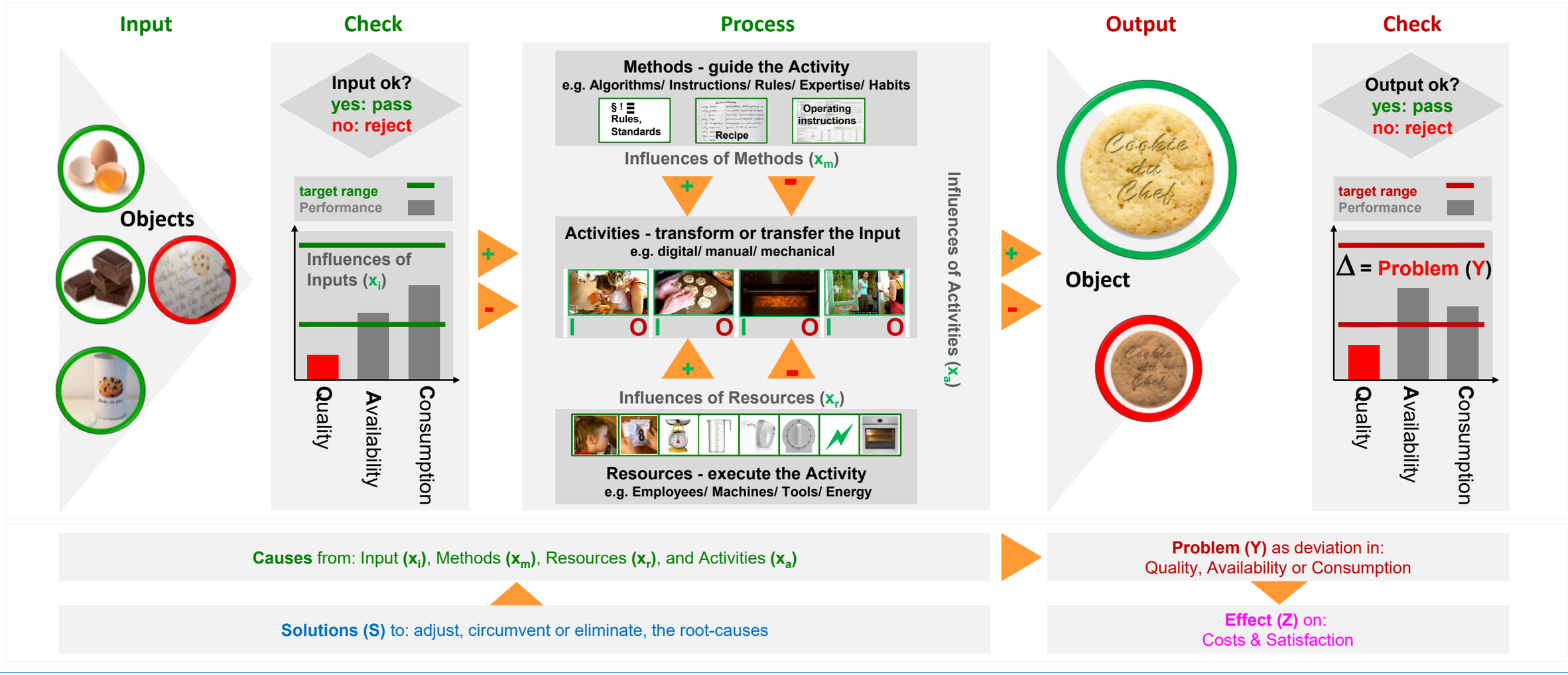
Customer dissatisfied	S
Customer compensation claims	C
Company quality costs increased	C
Company revenue losses	C

Classification of Effects (Z)

- **Problems lead to effects in the categories:**
  - **C**osts (e.g. by inspection, rework, scrap, lost revenue)
  - **S**atisfaction (e.g. by ratings, claims, migration)
- **and determine the financial potential of a project**

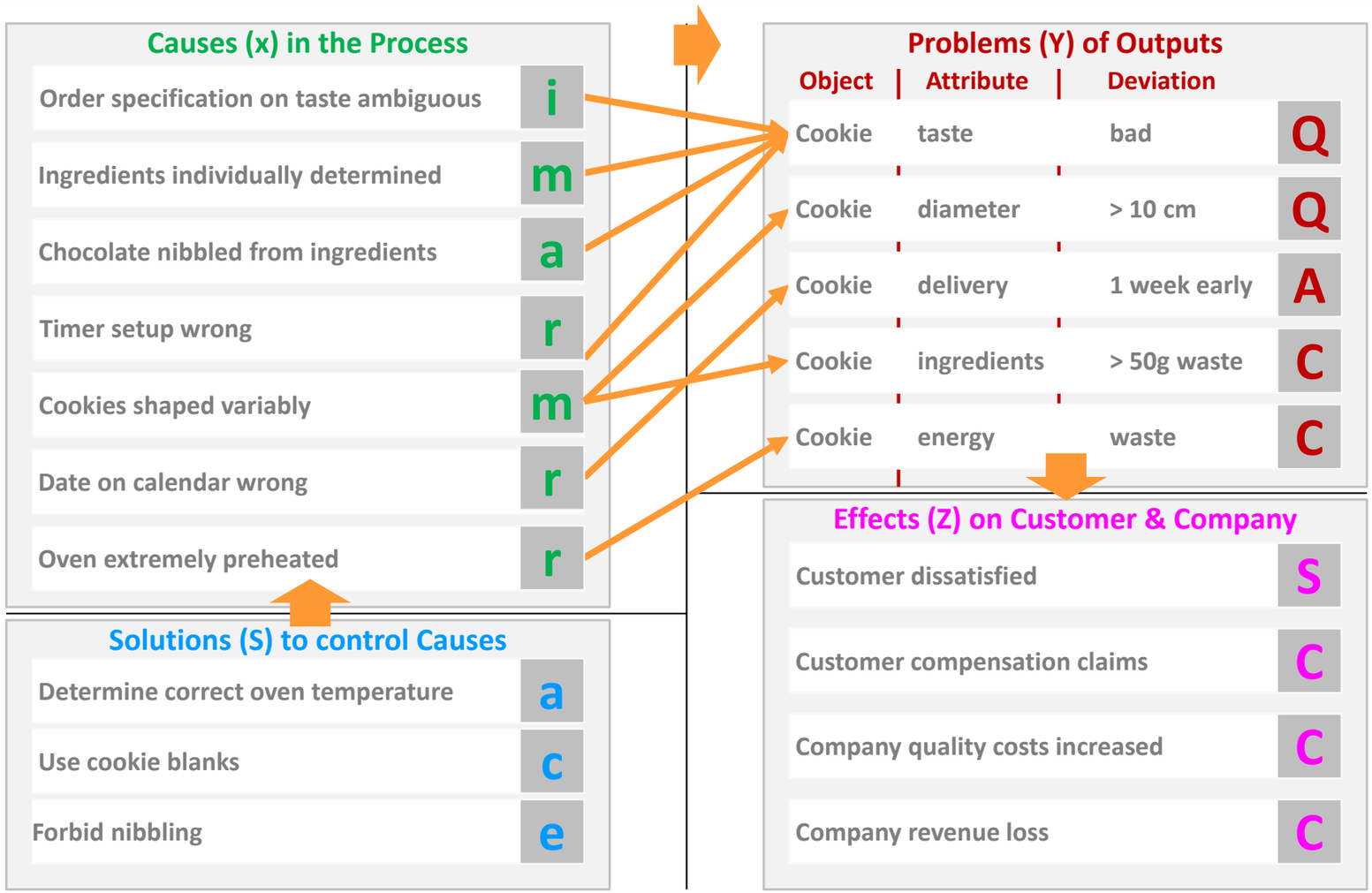
… and classified into the Categories of: Costs and Satisfaction

The Process-Problem-Solving Model …



… links a Problem and its Effects, its Causes and its Solution to the underlying Process and its Outputs

Observations in the bakery assigned to the categories: Solutions (S), Causes (x), Problems (Y) and Effects (Z) and …



Classification of Problems (Y)

- **Problems are deviations in:**
  - **Q**uality (in a given or required attribute)
  - **A**vailability (right quantity, time, and location)
  - **C**onsumption (losses or waste of inputs or resources)
- **of** (intermediate) **outputs**

Classification of Causes (x)

- **Negative influences in the upstream process from**:
  - **I**nputs (xi),
  - **M**ethods (xm),
  - **R**esources (xr) and/ or
  - **A**ctivities (xa)
- **trigger and/ or amplify problems**

Classification of Effects (Z)

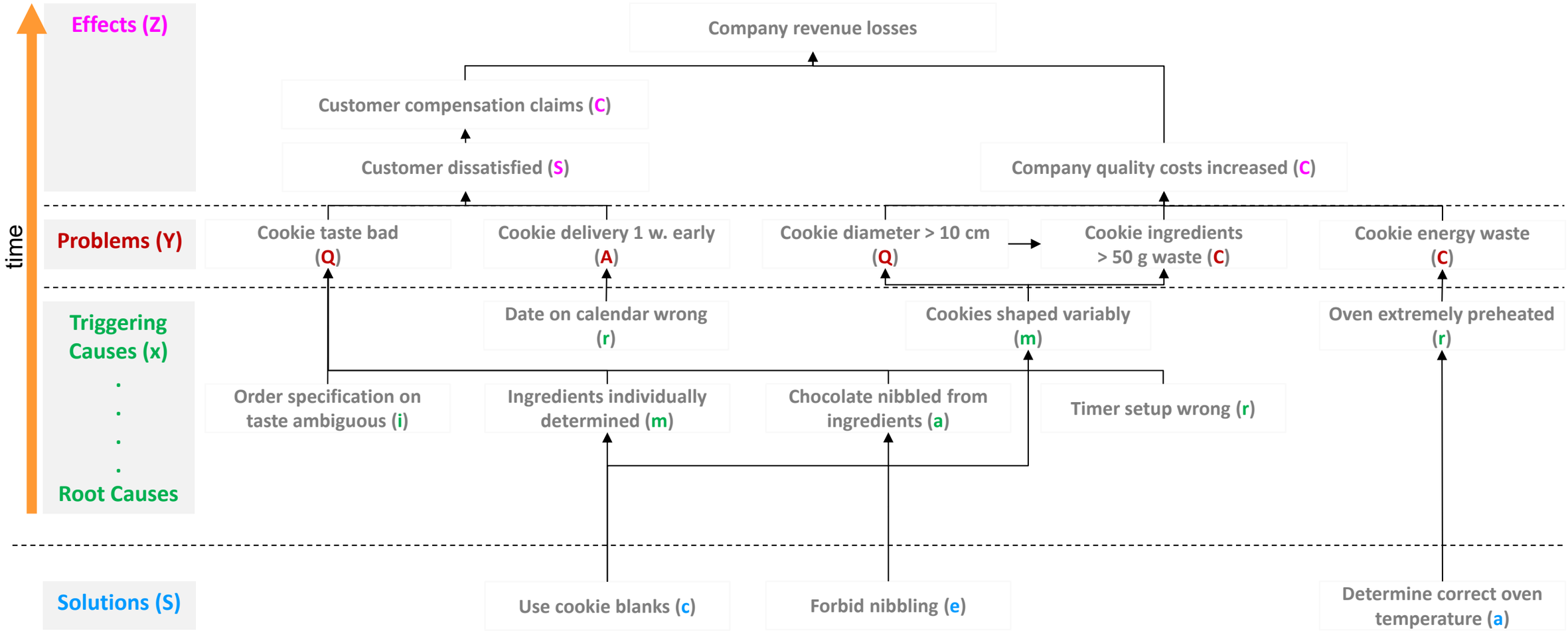
- **Problems lead to effects in the categories:**
  - **C**osts (e.g. by inspection, rework, scrap, lost revenue)
  - **S**atisfaction (e.g. by ratings, claims, migration)
- **and determine the financial potential of a project**

Classification of Solutions (S)

- **Solutions aim to**:
  - **a**djust,
  - **c**ircumvent or
  - **e**liminate
- **causes (negative influences) of the problem**

… within these categories further classified

Effects (Z), Problems (Y), Causes (x) and Solutions (S) hierarchically structured in a fault-tree



This modelled problem twin will be specified and statistically analysed to focus solutions on the important root causes

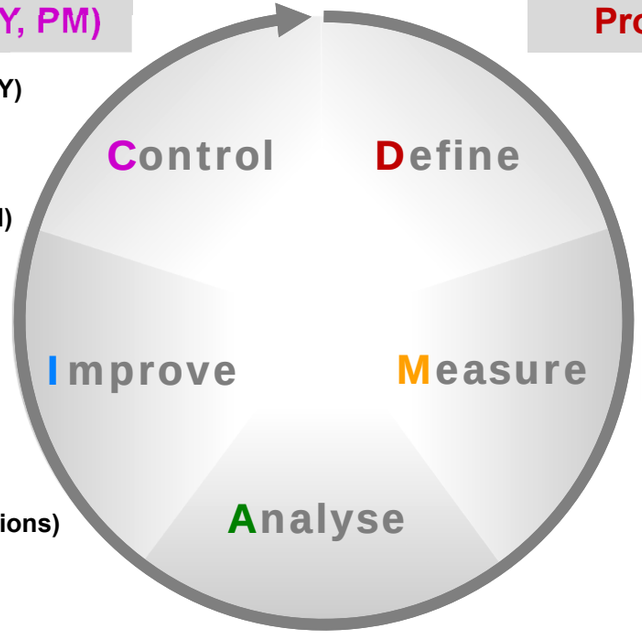
The DMAIC is a chronological guideline for problem solving …

Effects (Z) and Sustainability (Y, PM)

- Process Performance **(of critical Y)**
- Test of Improvements **(Y_{t1} vs. Y_{t2})**
- Financial/ other Benefits **(Z)**
- Process-Management-Plan **(PM)**

Problems (Y), their Effects (Z) and Project Mngmt (PM)

- Project-Topic & -Definition **(Problems Y, Effects Z)**
- SIPOC **(project field, from first influence x to last problem Y)**
- Voice-to-Criticals **(identify critical problems Y)**
- Project-Charter **(organize project, PM)**
- Stakeholder Communication **(reduce resistance, PM)**



Solutions (S)

- Solutions **(eliminate root causes x')**
- FMEA **(reduce risks of solutions)**
- Action-Plan **(adapt and specify solutions)**
- Implement the Measures

Influences (x) and their Relations to Problems (Y)

- Input-Analysis **(identify influences x)**
- Process-Mapping/ Analysis **(identify influences x)**
- C&E Matrix **(assumptions about x-Y relationships)**
- Data-Collection-Plan **(units, scale levels, sampling plan for x, Y)**
- Hypotheses **(formalized assumptions for risky x-Y-pairs)**

Root Causes (x') of Influences (x) of Problems (Y)

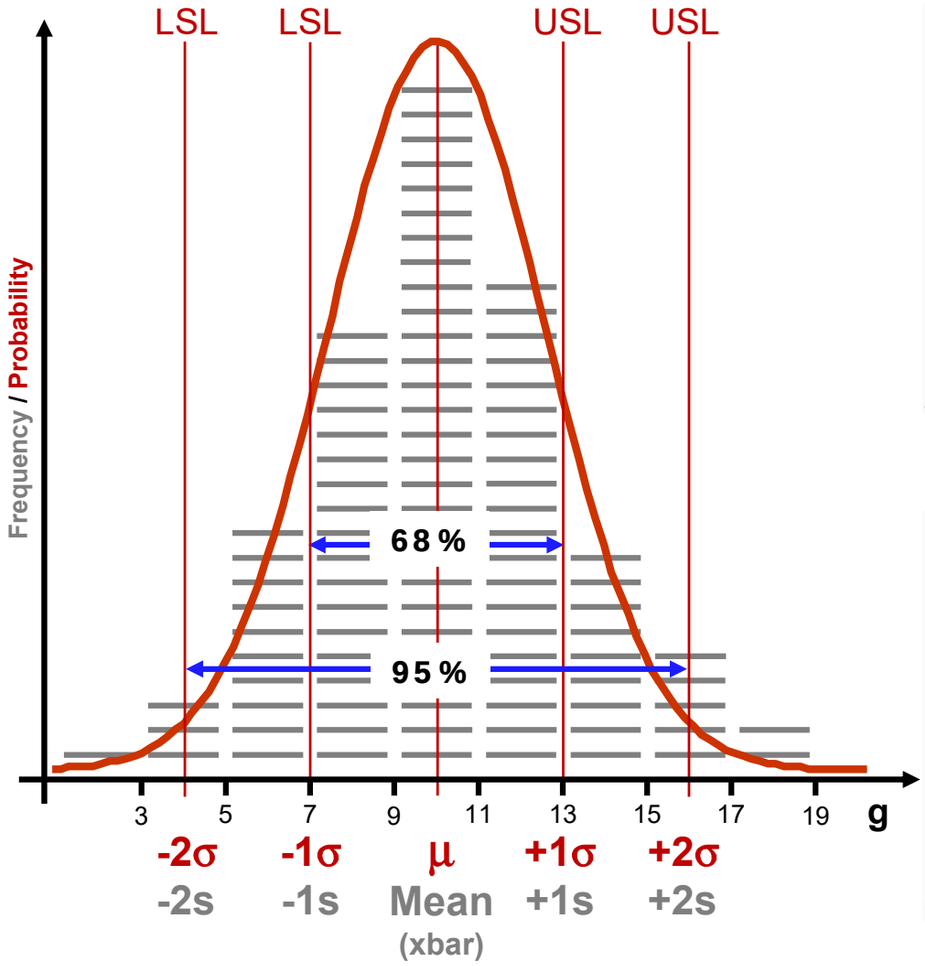
- Data Evaluation **(data inspection and charts for x, Y)**
- Process Performance **(control over time & capability of Y)**
- Test of Hypotheses **(test relationships between influences x and problems Y)**
- Root-Cause-Analysis **(identify root causes x' of influences x on problems Y)**

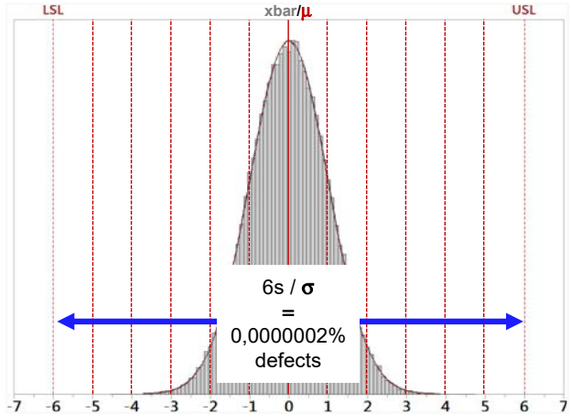
… including a sequence of rational and statistical tools for Six Sigma projects

Introduction

Improvement Program & Method & Statistics

Output requirements are specified by a tolerance range for each important attribute (LSL-USL)

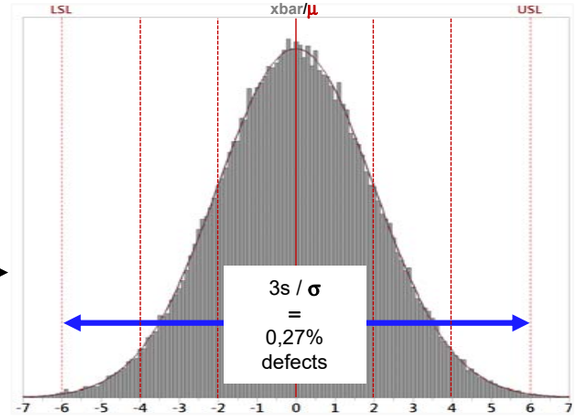




Process Capability: 6 sigma
(z-values from standard normal distribution)

xbar = 0
s = 1
LSL = - 6
USL = 6
Sigma-Level= 6

There are 6 standard deviations distance from the mean to each specification limit



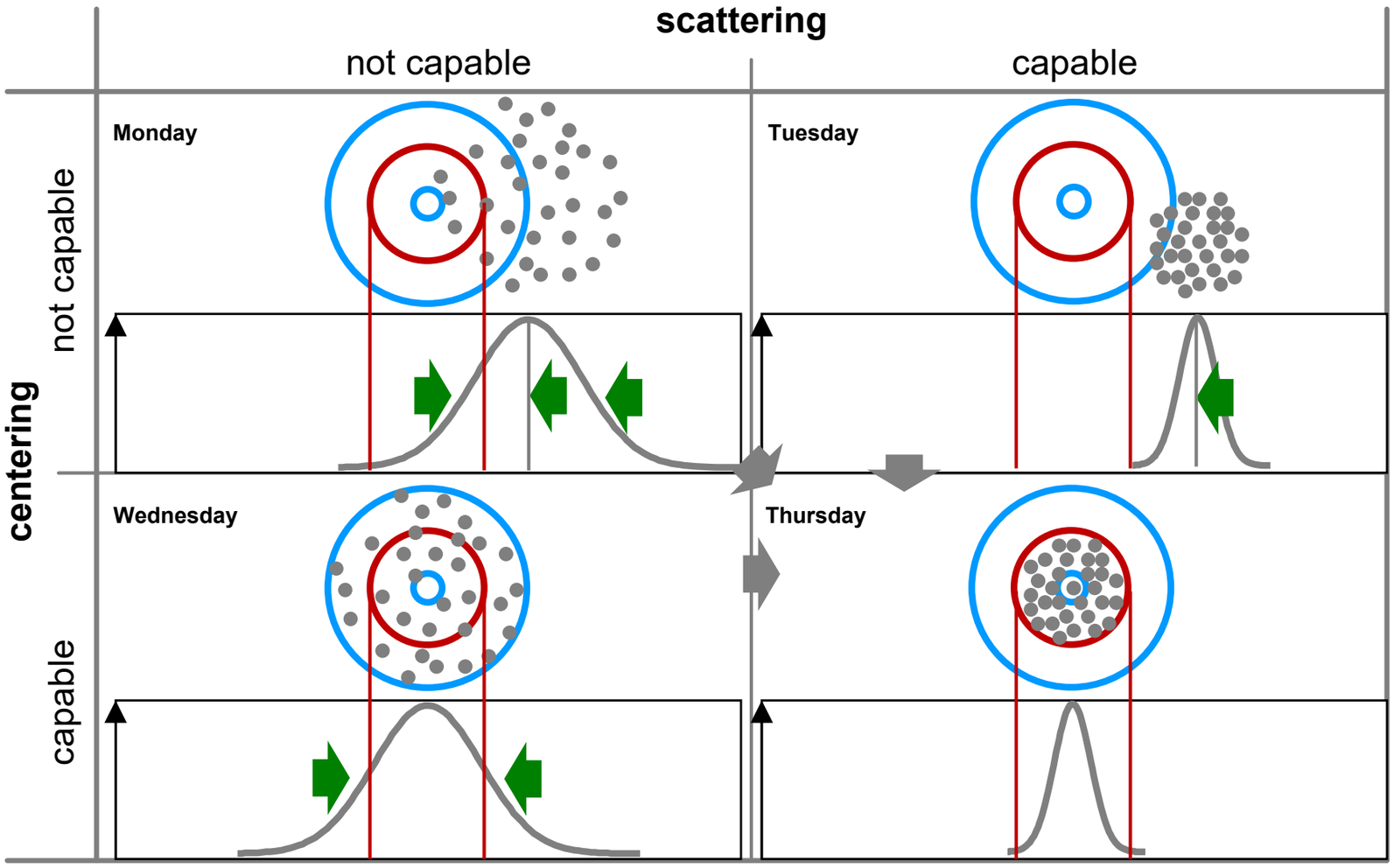
Process Capability: 3 sigma
(z-values from standard normal distribution)

xbar = 0
s = 2
LSL = - 6
USL = 6
Sigma-Level= 3

There are 3 standard deviations distance from the mean to each specification limit

The more outputs are within the Lower (LSL) and Upper Specification Limits (USL), the more capable the process is

Six Sigma's goal is to align performance indicators of products and services …



… to the center and to minimize their variability, according to customer requirements

Percentages and sigma levels can be transformed into each other

examples from everyday life	99% yield *would* mean:	in reality happend:	Yield (%) short-term / long-term	Sigma Level (short-term)	Sigma Level (long-term)
Air traffic safety	11 crashes of aircraft daily arriving and departing Munich Airport	37.6 million flights with 4 fatal accidents (2015, worldwide)	99,9999894%	(6,69)	5,19
U-train victims of violence	1 victim/ 100 passengers	139 victims/ 349 million passengers (Germany)	99,9999602%	(6,44)	4,94
Reference: Errors in typical paperback (300 words/page; 300 pages/book)	**3 errors per page; 900 errors per book**	**6 sigma performance corresponds to: 1 error per 3,27 books**	**99,9996600%**	**6** [1)]	**4,5** [2)]
Work safety	10,000 industrial accidents/ 1 million working hours	14,76 industrial accidents/ 1 million working hours (Germany)	99,9985240%	(5,68)	4,18
Counterfeit money	10,000 counterfeit notes/ 1 million bank notes	50 counterfeit notes/ 1 million bank notes (Europe)	99,9950000%	(5,39)	3,89
Error in hospital treatment resulting in death	190,000 errors resulting death/ 19 million hospital treatments	19,000 errors resulting death/ 19 million hospital treatments (Germany)	99,9000000%	(4,59)	3,09
Driving licences revoked for alcohol	62000 revoked licenses / 6.2 million visitors	158 revoked licenses/ 6.2 million visitors on Oktoberfest 2017	99,9974516%	4,05	(2,55)
Executed death penalty on innocent people	1 innocent/ 100 executed	4 innocent/ 100 executed (USA)	96,0000000%	(3,25)	1,75

1) Sigma Level is based on z-values of the standard normal distribution +/- 1,5s as adjustment for time-dependent performance drifts, according to Mikel J. Harry (Motorola)**
2) Sigma Level is based on z-values of the standard normal distribution according to Carl Friedrich Gauss

… and they should be compared with data measured in:

Data were measured in:	short-term interval	long-term interval
short-term interval	no adjustment necessary	adjustment: short-term-data - 1,5s
long-term interval	adjustment: long-term-data + 1,5s	no adjustment necessary

The appropriate target for a desired performance level varies depending on the industry, the process, the requirements of management and the specification of customers.

Naturally, an automated process in production can achieve a higher yield than the sales process in a car dealership. 99% yield can therefore be excellent in one process and alarming in another.

Each yield should thus be evaluated within meaningful and appropriate specification limits.

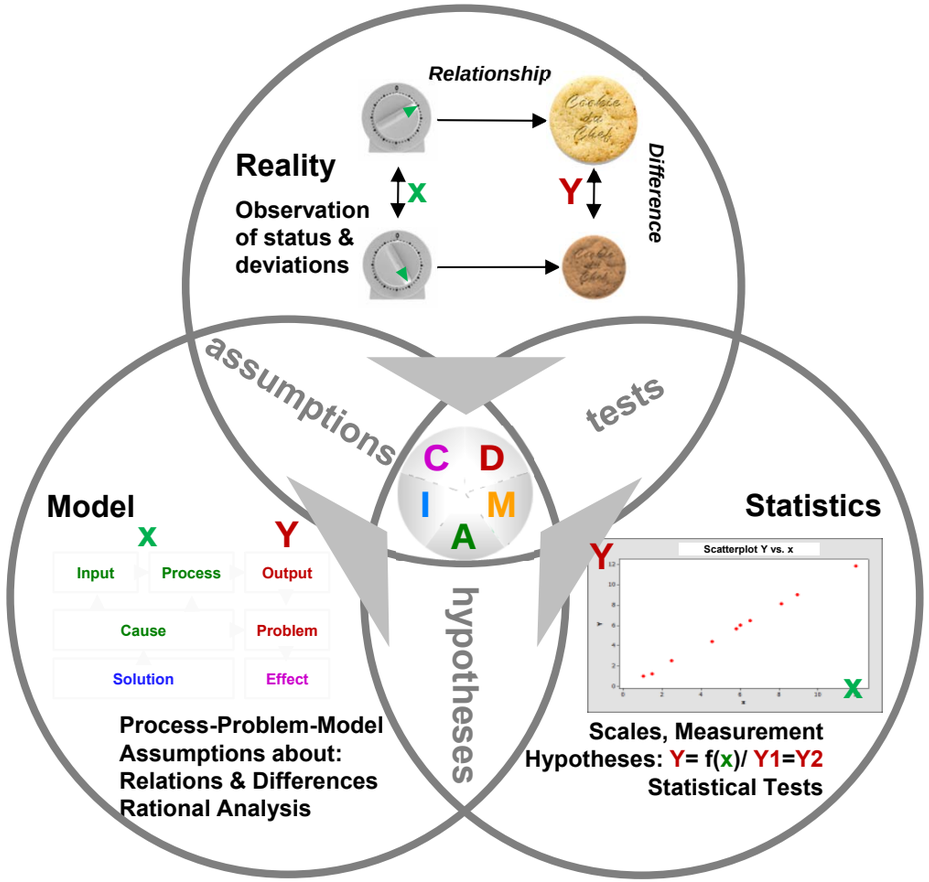
** Harry, M. J. (1988): The Nature of Six Sigma Quality; Motorola University Press

Examples of performance levels in everyday life, given in yield rates and sigma levels

Introduction

Linking Reality, Method & Statistics

Six Sigma projects follow a scientific approach …



assumptions
+ hypotheses
+ tests

allow to
- describe,
- explain and
- predict the reality

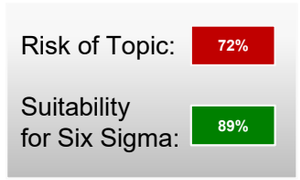
This scientific approach
is realized in the phases
DEFINE, MEASURE and ANALYSE
of the DMAIC cycle

… to solve the equation: Y= f(x) – the problem is a function of its negative influences

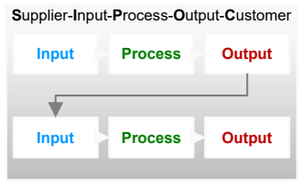
DEFINE

DEFINE: From the identification of problems (Y) to the Project-Charter

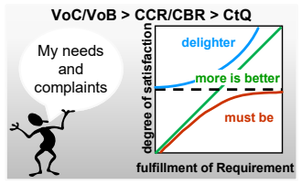
- **Identify and define a new Six Sigma project (Project-Topic & Project-Definition)**
  - Identify a weakness in a process and/ or a deviation in a product/ service, evaluate the relevance for the company and check the suitability for Six Sigma (Project-Topic)
  - Specify the problems with the product/ service and the underlying process, evaluate the effects of the problems on the customer and on the business (Project-Definition)



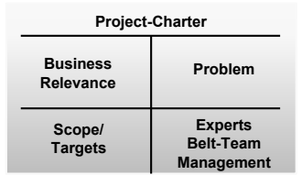
- **Delimitate and structure the application area of the project (SIPOC)**
  - Delimitate the area of the project by determining the first Input and the last output of the process
  - Identify all important intermediate outputs of the process within the determined area
  - Identify the underlying core process steps and their important inputs
  - Identify the related internal/external supplier of the inputs and the internal/external customer of the outputs



- **Listen to the customer and manager (VoC/VoB), filter their complaints and requirements (CCR/ CBR), prioritize the problems (KANO) and identify the Critical to Quality (CtQ) (Voice to Critical)**
  - Interview customer and manager about their needs and complaints on the (intermediate) outputs (VoC / VoB)
  - Translate complaints into requirements of customer and manager for the attributes of these outputs (CCR / CBR)
  - Assign required attributes to the categories: Quality, Availability and Consumption (type of problem)
  - Evaluate the importance of the requirements (KANO-Model) and determine the degree of their fulfillment (CtQ)



- **Define the scope, define the targets, build the team and agree these conditions (Project-Charter)**
  - Summarize the relevance of the project for the customer and the company (business case)
  - Summarize information about the process, its important outputs and their problems
  - Agree on the targets for the important requirements (CtQ´s) and on the scope of the project
  - Assemble the team with Sponsor, process owner, Black/ Green Belts, subject matter experts and controlling



Summary DEFINE: Important Problems (Y) are defined and a contract on the targets, scope and team of the project is agreed.

Outlook MEASURE: Identify the Influences (x) on the Problems (Y), develop related Hypothesis and a Data Collection Plan

DEFINE

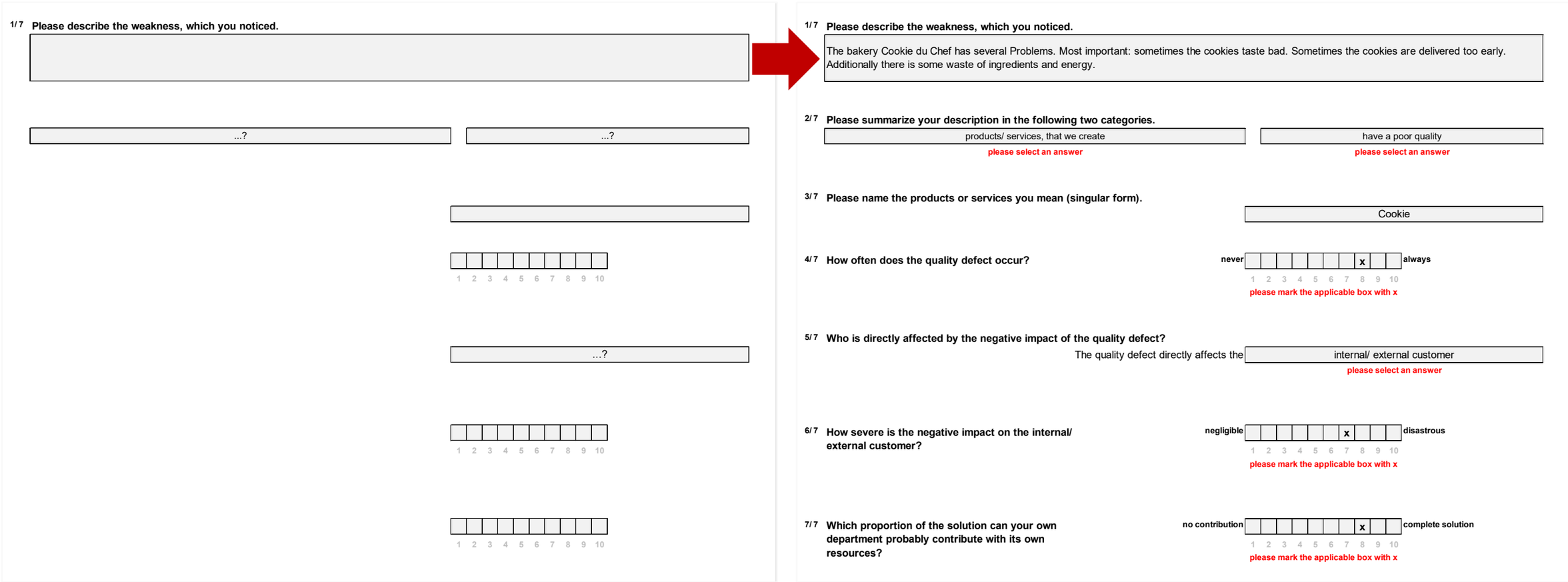
Identification and Definition of a Six Sigma Project

sigmaGuide: content

Phase	Tool	Purpose
	Summary	Summary of the purpose of the tools in sigmaGuide
Define	**Part 1**	**Identify a topic for a Six Sigma Project**
	Project-Topic	Identify Problems of the daily work as a potential for Improvement
	Part 2	**Define a Six Sigma Project**
	Process & Output	Describe the Process and its Output
	Problem	Describe the Problem
	Effect	Describe the Effect of the Problem
	Solution	Outline Solution-Ideas - if already available
	Project-Definition	Summary: Process, Output, Problem and Effect
Define	**Part 3**	**Implement a Six Sigma Project**
	SIPOC	Structure the Process in its important steps, with related Supplier, Inputs and Outputs and Customer
	Voice to Critical	Identify Voice of Business/ Customer (VoC/ VoB), Critical Business/ Customer Requirements (CCR/ CBR), Problems and CtQ´s
	Voice to Critical (Summary)	Summary: VoC, VoB, CCR, CBR, Problems and CtQ´s
	Chart: Y CtQs Bar-Chart	Problems and their Severity
	Chart: Y CtQs Kano-Chart	Fulfillment of requirements resulting satisfaction according to Kano-characteristics
	Project-Charter	Complete and sign the Project-Charter
	Stakeholder-Communication	Identify the Stakeholder and develop a Communication-Plan
Measure	Input-Analysis	Describe Inputs (xI) of the Process, Requirements on the Inputs and Deficiencies
	Chart: Influence of xI	Display: Strength of negative Influences of the Inputs (xI) on the Outputs (Y)
	Process-Mapping and -Analysis	Describe Activities of the Process (xP), related Inputs (xI) and Outputs (Y) and negative Influences
	Chart: Influence of xP	Display: Strength of negative Influences of the Activities (xP) on the Outputs (Y)
	C&E Matrix xY	Evaluate relationships between negative Influences of the Inputs (xI) and the Activities of the Process (xP) on the Outputs (Y)
	Chart: C&E Heatmap	Display: Risks of the Influences from Inputs (xI) and Activities (xP) on the Outputs (Y)
	Data-Collection-Plan	Operationalise Measurands of Inputs (xI), Activities (xP) and Outputs (Y); Recommendation for appropriate: Charts, Parameter, Process-Capability-Indices, Control-Charts, One-Sample-Tests
	Hypothesis	Overview of all automatically generated Hypothesis, prioritized by their Risk; Recommendation for appropriate statistical Tests
Analyse	Process-Capability	Calculate Process-Capability (Yield, DPMO, Pp/ Ppk, Sigma-Level, …)
Improve	Solution-Ideas	Develop Solution-Ideas to eliminate the Root-Causes
	Chart: Solution-Selection	Overview to Efforts, Benefits and Effect of Solutions
	Action-Plan	Specify Measures to implement the Solution-Ideas
	FMEA	Analyse the Risks of Measures (FMEA:= Failure Mode and Effects Analysis)
Control	Process-Capability	Calculate Process-Capability (Yield, DPMO, Pp/ Ppk, Sigma-Level, …)
	Process-Management-Plan	Define measures to sustainably maintain the process-improvements
	Summary and benefits	Summarize the results of the phases and demonstrate the financial and other benefits of the project

Please select the marked tool

The identification of a Project-Topic is the first step to a Six Sigma project



The video: Cookie du Chef shows, that there are improvement potentials in this bakery

Every employee is able to describe observed weaknesses in the work environment

The Project-Topic summarizes the given information in statements and evaluations

Please check the summary of our dialogue.

Summary:

The bakery Cookie du Chef has several Problems. Most important: sometimes the cookies taste bad. Sometimes the cookies are delivered too early. Additionally there is some waste of ingredients and energy.

Cookies - i.e. Products/ services, that we create - have a poor quality. The quality defect occurs very often and has a strong impact on the internal/ external customer. The problem can be solved with a very big contribution by the own department.

Relevance of the topic:	35%
Suitability for method:	Six Sigma
Solvable by own department up to:	80%

If this summary of answers does not seem to make sense to you, please correct your answers.

If this summary seems to make sense to you, then please go to section: **Process & Output**

or send this File to:

Please check the summary of our controlled dialogue which shows your answers in context.
If the content of this or subsequent summaries is incorrect or pointless, then please change your given answers.

Based on this summary, the management can decide whether further investigations are necessary

Criteria for Lean Six Sigma Project-Topics

Focus: Problem of the Output

Type of problem: Deviation in Quality, Availability and Consumption

Effect of the problem on: (internal) Customer and Business

Measurability:

x (influences of Input/ Method/ Resources)	Y (required attributes of the Output): measurable	Y (required attributes of the Output): not measurable
measurable	Six Sigma	really?
not measurable	Lean/ Kaizen	Basic Improvement or Actionism

Statistical tests: Sample size > 30 xY value pairs collectable within a month

Project benefit: 20 - 60k€ for a Green Belt and > 100k€ for a Black Belt project

Implementation time: Not longer than half a year (typically)

Persons to be involved:
- Customer for interviews
- Experts for workshops **(Process-Mapping; Root-Cause-Analysis & Solutions)**
- Employees to implement the developed measures

For the Lean Six Sigma certification you must solve a Quality, Availability and Consumption Problem

Project-Definition: Summary of all collected information about the topic, process and output, problems, …

Project-Definition

The bakery Cookie du Chef has several Problems. Most important: sometimes the cookies taste bad. Sometimes the cookies are delivered too early. Additionally there is some waste of ingredients and energy.

COOKIE - i.e. products/ services, that we create - have a poor quality. The quality defect occurs very often and has a strong impact on the internal/ external customer. The problem can be solved with a very big contribution by the own department.

Relevance of the topic:	35%
Suitability for method:	Six Sigma
Solvable by own department up to:	80%

Section 1: Process and Output

Summary:

The Product COOKIE is a tangible final Output for external Customers and is in the Creation Process BAKE COOKIES within a year 13 - 52 times generated. Important Input of the Process to generate the Product COOKIE is: BUTTER, SUGAR, FLOUR, CHOCOLATE.

Section 2: Problem

Summary:

1. Problem: COOKIE TASTE BAD. COOKIE fulfills the requirement on Quality (is error-free) in 30%.

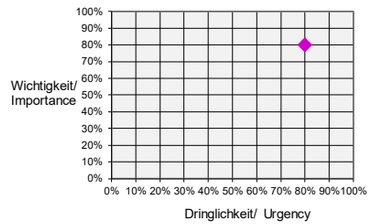
2. Problem: COOKIE DELIVERY TOO EARLY. COOKIE fulfills the requirement on Availability (just in time) in 70%.

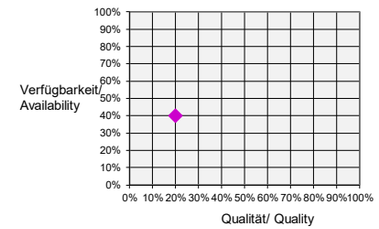
3. Problem: COOKIE INGREDIENTS WASTED. COOKIE fulfills the requirement on efficient utilisation of means (no waste of Input, Resources) in 50%.

Section 3: Effect

Summary: Voice of Business

The satisfaction of the process-owners with the Consumption in the Creation Process of the COOKIE is: 40%.
The total costs of the specified 3 problems are estimated by 100€ / year.
They are primarily the result of quality costs due to scrap and additional expenditure.
The solution of the problems is rated as:
- major URGENT (80%-Level)
- major IMPORTANT (80%-Level)





Summary: Voice of Customer

The satisfaction of the external customers with the:
- Quality of COOKIE is: 20%.
- Availability of COOKIE is: 40%.

Section 4: Solution

Solution Idea to 1. Problem

more sugar in the mix

Solution Idea to 2. Problem

Solution Idea to 3. Problem

additional Information

Your additional comments, advices, feedback … are very appreciated.

Personal Data

First Name	Reiner	Surname	Hutwelker
Unit	Cookies	Location	Munich
Telephone	123456789	eMail	reiner.hutwelker@sigmaLogic.de

effects, available solution ideas and some details about the author – ready for evaluation by the Six Sigma Board

DEFINE

SIPOC, Voice-to-Criticals, Project-Charter, Stakeholder Communication

Specify the project limits by the output with the last problem and the first influential input …

SIPOC					
Process-Step	**Supplier**	**Input (xI)**	**Process (xMR)**	**Output (Y)**	**Customer**
1	Customer (Child)	Request (cookie-type & delivery-date)	check Disposability	Order (cookie-type; delivery-date)	Logistic & Procurement Service
2		Order (cookie-type; delivery-date)	determine necessary & missing Ingredients	Shopping-List	Logistic & Procurement Service
3	Supermarket	Ingredients	assemble Ingredients	Ingredients (complete)	Logistic & Procurement Service
4		Start-Signal	prepare Workspace	Workspace (clean)	Production Support
5		Ingredients (complete)	weigh Ingredients	Ingredients (weighed)	Production Support
6		Ingredients (weighed)	knead Ingredients	Dough (ball)	Chef du Cookie
7		Dough (ball)	roll out Dough	Dough (sheet)	Chef du Cookie
8		Dough (sheet)	cut out Cookies	Cookies (raw)	Chef du Cookie
9		Cookies (raw)	bake Cookies	Cookies (baked)	Chef du Cookie
10	Tin Factory	Tin	pack Cookies in Tin	Cookies (boxed)	Production Support
11		Cookies (boxed)	deliver Cookies	Cookies (delivered)	Logistic & Procurement Service
12					

SIPOC

The SIPOC is a table of the project-field. Its purpose is to:

- define the limits of the project, from the first Input to the last Output. The last Output should be the Output with the chronological last Problem from the Problem-Statement of the Project-Definition. Select the first Input such that the area between the first Input and the last Output covers all triggers of the last Problem.
- structure the project-field from the first Input (top left) to the last Output (bottom right) line by line with the important Input-Process-Output steps.

Practice Tips:

- Indicate the subsequent development stages of the objects in Input and Output by adding the respective latest characteristic attribute of the object in brackets, e.g.: Cookies (baked).
- Typical number of (core) Process-Steps in a SIPOC: 8 – 12
- To shift an entry: never use cut & paste – instead use: copy & paste and delete unnecessary cells
- If an Output in one step serves as an Input in a subsequent step, then copy the Output and paste it as new Input
- If more than one object enters the process as Input, then only enter the new external object as Input
- Describe the Activities of the Process with a verb, followed by a noun, e.g.: bake Cookies

… and structure the process-field row by row by the important process-steps (Supplier - Input - Process - Output - Customer)

Instructions

1. Start with the Output

   Outputs are the results of Activities in the Process-Steps. They can be material Objects (e.g. Cookie) or immaterial (e.g. Order, Decision).

   Sometimes for the immaterial Outputs it is not immediately clear, how the Output can be identified and discriminated from the Activity of the Process-Step. The following guidelines might be helpful.

   In the area of Process-Improvement its necessary to work with specific examples to get a realistic idea of the situation.

   So at first develop an idea of the Output from a concrete example or even better: take a photo or a screenshot. If you only have a general idea of the Output in mind (e.g. Management, Information) you might also not be able to specify its Requirements and Problems.

   If you visualize at least one concrete example of the Output, you will be able to describe the Output with just one single noun (e.g. Order) or a composite noun (e.g. Shopping-List). This is important, because now you are able to:

   - identify a given class of Outputs (e.g. the class of Shopping-Lists, the class of Orders, the class of Cookies),
   - specify the variation of the Outputs within their class (e.g. Cookie salty vs. Cookie sweet) and
   - count Outputs (one, two, … Cookies).

   This is a prerequisite, to later measure the attributes of the Outputs (see below).

   In the different development steps of the Process sometimes the same noun is used for the different intermediate Outputs. In this case it is helpful to specify the status in brackets to discriminate its development steps (e.g. Cookie (raw), Cookie (baked), Cookie (boxed), Cookie (delivered)).

   Please specify all intermediate Outputs, between the first Input and the final Output of the Project, order them chronologically and enter them into the Output-Column of your SIPOC.

2. Specify the Process-Steps

   Start with the last Output (bottom right) and identify the upstream Process-Step that leads to this Output.

   Please take care, to describe the activity of the Process-Step by using a precise verb (e.g. weigh Ingredients). This will assure that you do can differentiate it from another Output or an Input.

   It is not necessary here to describe the details of the Process. This will be done later in the Process-Mapping-Analysis. Purpose of the SIPOC is to structure the field of the Project and to identify the most important Inputs, Activities and Outputs.

3. Specify the Input

   Each Input of a Process-Step is an Output of an upstream Process-Step. For this please describe the Inputs also with just one single noun (e.g. Tin).

   If an intermediate Output becomes the Input of a downstream Process-Step within the SIPOC, you should again write it down to show the flow of the Process.

   If several Inputs come into the Process, then try to combine them in just one noun (e.g. Ingredients).

   In the Input-Analysis (see below) the Inputs, which result as Outputs from within the SIPOC, will be shown in [brackets] to indicate, that they do not need to be evaluated.

4. Specify Supplier and Customer

   Identify the Customer of those Outputs, which are delivered outside the SIPOC - at least the Customer of the Output in the bottom right corner.
   Identify the Supplier of those Inputs, which are supplied from outside into the SIPOC - at least the Supplier of the Output in the upper left corner.

(Extract from sigmaGuide)

Voice to Critical leads from the Voice of the Customer (VoC)/ Voice of Business (VoB) via the …

Voice/ statements of customer and manager (VoC/ VoB)
about their wishes and complaints on an output

↓

Derivation of output attributes
underlying the wishes and complaints

↓

Definition of Critical Requirements of Customer (CCR)
and Business, i.e. manager (CBR)

↓

Definition of the critical deviation of the output attribute as problem

↓

Determination of the problem type (Quality; Availability; Consumption)

↓

Determination of the Kano-category of the problem
(*must-be; more-/ less-is-better; delighter*)

↓

Estimation of the frequency with which the requirements are met

↓

Calculation of the severity of the problem and their prioritization
leads to the problems that are critical to quality (CtQ)

Managers often complain about a **lack of process transparency** and expect more insight from the project.

This is not a problem - but is one of the standard tasks of a Six Sigma project due to the MEASURE- and ANALYSE- and CONTROL-phase.

It makes sense to ask for more precise ideas about exactly what is to be made transparent and take it into account in the Process-Management-Plan.

Managers sometimes express **requests for specific solutions** already in the DEFINE phase.

Please note that determining a solution in this phase contradicts the idea of DMAIC and a precise analysis of the problems. Ask them to postpone the solution ideas until the IMPROVE phase.

An exception are **quick wins** with guaranteed success, which can be implemented immediately.

… Critical Requirements of Customers and Business (CCR/ CBR) to the critical problems (CtQ)

Procedure of the Voice-to-Criticals

Procedure to collect the necessary information, e.g. in interviews:

1. Select a relevant source and collect answers at least to the following questions:
2. Which of these SIPOC outputs is causing you trouble?
3. What do you require from this output?
4. What complaints do you have about these outputs?
5. Which quality of output does your request and complaint relate to?
6. How should this property be pronounced in the best case?
7. How is this characteristic pronounced in the worst cases?
8. What is their satisfaction if your expectations are fully met?
9. What is their satisfaction if your expectations are not met?
10. What percentage of the outputs received meets your requirements?

Sources to collect the Voice of Customer (VoC):

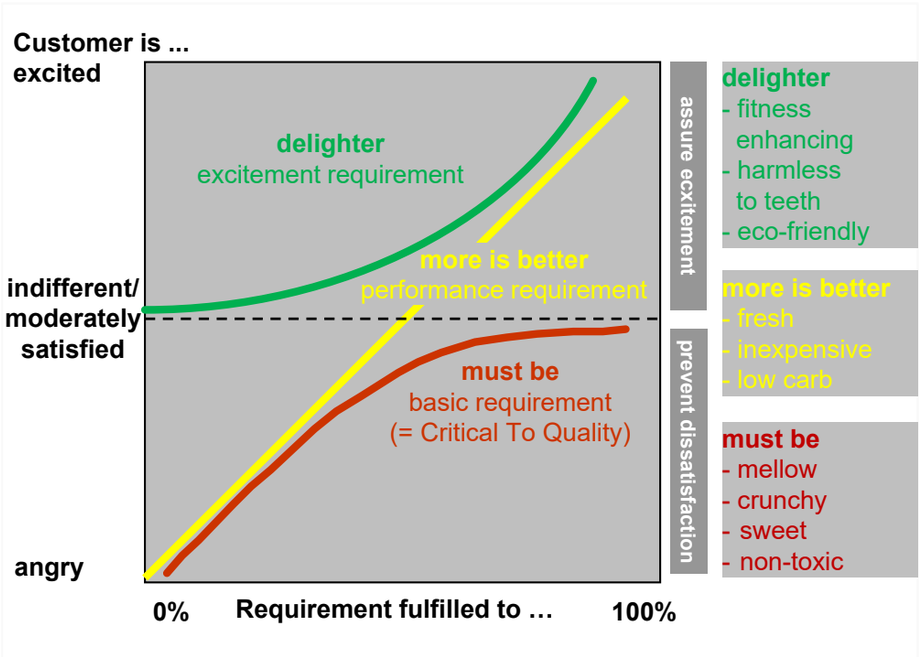
1. Internal/ external customer
2. Internal quality control,
3. Complaints (sales/ customer care),
4. Warranty cases,
5. Dealers,
6. Customer satisfaction surveys,
7. Social media and
8. Own experiences and experiences of friends/ colleagues

Sources to collect the Voice of Business (VoB):

- Personal interviews with:
  - Process owner
  - Sponsor (if not the same)

Use as many information sources that are available to you – interviews are preferred

Identify the critical Requirements of the Customer and the Business (CtQ‘s), …



The **KANO-Model** serves to:
- Classify the requirements of the Customer (CCR) and Business (CBR) and
- Identify the critical requirements (CTQ´s= Critical to Quality), i.e. severity of the output problems.

There are three categories, specified by their characteristics:
1. **must be:** These are the basic requirements of the customer/ business which have to be fulfilled to prevent dissatisfaction.
2. **more/ less is better:** These are the performance requirements of the customer/ business which should be fulfilled either as high/ as low as possible or straight to a certain value within a specific range.
3. **delighter**: These are the excitement requirements, important for marketing but unimportant for Six Sigma, because they are not necessarily expect, but lead to excitement if given.

Focus is on the **must be´s**. These attributes determine the CTQ´s of your product/ service, because they cannot be compensated by other attributes of your product/ service.

… from the Severity of the must-be Problems of the Outputs

Please answer the questions and check the summary

Y_01		
Whose Requirement do you want to specify?	**Customer**	Source of Requirement: Customer
	Please select an answer.	
Which Output does the the Customer want to evaluate?	**Cookies (baked)**	Output: Cookies (baked)
	Please select an answer.	
What does the Customer require from COOKIES (BAKED)? COOKIES (BAKED) should …	**Cookies taste like those from Grandma**	Voice of Customer (VoC): Demand
	Please quote the statement of the Customer.	
Which deviation of COOKIES (BAKED) from the Requirement is problematic for the Customer ?	**Cookies taste of nothing**	Voice of Customer (VoC): Complaint
	Please quote the statement of the Customer.	
Which attribute of COOKIES (BAKED) is addressed in this Demand and Complaint?	**taste**	Attribute of COOKIES (BAKED): TASTE
	Please enter just one Noun.	
How should TASTE be according to the Requirement of the Customer?	**mellow-crunchy-sweet**	Critical Customer Requirement (CCR): COOKIES (BAKED) TASTE MELLOW-CRUNCHY-SWEET
	Please enter just one adjective.	
Which deviation of TASTE is problematic?	**crumbly-bland**	Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND
	Please enter just one adjective.	
To which category does the Requirement TASTE MELLOW-CRUNCHY-SWEET vs. CRUMBLY-BLAND belong?	**Quality (Faultlessness/ Fulfilment of Purpose)**	Requirement-Category of TASTE: Quality
	Please select an answer.	
Which relevance does the Requirement COOKIES (BAKED) TASTE MELLOW-CRUNCHY-SWEET have according to the Kano-Model?	**Must-Be**	Kano-Category of TASTE: Must-Be
	Please select an answer.	
To what extend is the Requirement on TASTE of COOKIES (BAKED) actually fulfilled?	**20%**	Requirement for TASTE of COOKIES (BAKED) is fulfilled to: 20%
	Please enter a value between: 0% - 100%.	
Y_01: Output: Cookies (baked) | Voice of Customer (VoC): Demand: Cookies taste like those from Grandma; Complaint: Cookies taste of nothing | Critical Customer Requirement (CCR): COOKIES (BAKED) TASTE MELLOW-CRUNCHY-SWEET | Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND | Requirement-Category of TASTE: Quality | Kano-Category of TASTE: Must-Be | Requirement for TASTE of COOKIES (BAKED) is fulfilled to: 20% | The Severity of being unsatisfied with TASTE of COOKIES (BAKED) is: 92% (Rank 1/ 5).		

If the statements in the summary are pointless or cumbersome, please adapt the answers

Summary and details of VoC/ VoB, Critical Requirements, CTQ´s for all Y´s

Summary: Voice of Customer (VoC), Voice of Business (VoB), Critical Requirements (CCR/ CBR), Problems, Severity, KANO and CtQ-Rank							
Y	**Voice**	**of ...**	**Critical Business Requirement (CBR) or Critical Customer Requirement (CCR)**	**Problem**	**Kano-Category**	**Severity**	**Critical to Quality (CtQ) Rank**
Y_01	Cookies (baked) Cookies taste of nothing	Customer	CCR: Cookies (baked) taste mellow-crunchy-sweet	Cookies (baked) taste crumbly-bland	**Must-Be**	**92%**	**1**
Y_02	Cookies (delivered) delivered too early	Customer	CCR: Cookies (delivered) delivery in time	Cookies (delivered) delivery > 1 hour too early/ late	**More/Less-Is-Better**	**60%**	**2**
Y_03	Cookies (boxed) waste of energy	Management	CBR: Cookies (boxed) energy-consumption minimal	Cookies (boxed) energy-consumption > 10% waste	**More/Less-Is-Better**	**30%**	**3**
Y_05	Cookies (baked) Cookies are too big	Management	CBR: Cookies (baked) diameter > 9cm and < 10 cm	Cookies (baked) diameter > 10 cm	**More/Less-Is-Better**	**30%**	**3**
Y_04	Cookies (boxed) waste of ingredients	Management	CBR: Cookies (boxed) ingredient-consumption minimal	Cookies (boxed) ingredient-consumption > 10% waste	**More/Less-Is-Better**	**20%**	**5**
Y_06							

Details: Voice of Customer (VoC), Voice of Business (VoB), Critical Requirements (CCR/ CBR), Problems, Severity, KANO and CtQ-Rank
Y_01: Output: Cookies (baked) | Voice of Customer (VoC): Demand: Cookies taste like those from Grandma; Complaint: Cookies taste of nothing | Critical Customer Requirement (CCR): COOKIES (BAKED) TASTE MELLOW-CRUNCHY-SWEET | Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND | Requirement-Category of TASTE: Quality | Kano-Category of TASTE: Must-Be | Requirement for TASTE of COOKIES (BAKED) is fulfilled to: 20% | The Severity of being unsatisfied with TASTE of COOKIES (BAKED) is: 92% (Rank 1/ 5).
Y_02: Output: Cookies (delivered) | Voice of Customer (VoC): Demand: Cookie delivery on requested time; Complaint: delivered too early | Critical Customer Requirement (CCR): COOKIES (DELIVERED) DELIVERY IN TIME | Problem: COOKIES (DELIVERED) DELIVERY > 1 HOUR TOO EARLY/ LATE | Requirement-Category of DELIVERY: Availability | Kano-Category of DELIVERY: More/Less-Is-Better | Requirement for DELIVERY of COOKIES (DELIVERED) is fulfilled to: 40% | The Severity of being unsatisfied with DELIVERY of COOKIES (DELIVERED) is: 60% (Rank 2/ 5).
Y_03: Output: Cookies (boxed) | Voice of Business (VoB): Demand: low energy consumption; Complaint: waste of energy | Critical Business Requirement (CBR): COOKIES (BOXED) ENERGY-CONSUMPTION MINIMAL | Problem: COOKIES (BOXED) ENERGY-CONSUMPTION > 10% WASTE | Requirement-Category of ENERGY-CONSUMPTION: Consumption | Kano-Category of ENERGY-CONSUMPTION: More/Less-Is-Better | Requirement for ENERGY-CONSUMPTION of COOKIES (BOXED) is fulfilled to: 70% | The Severity of being unsatisfied with ENERGY-CONSUMPTION of COOKIES (BOXED) is: 30% (Rank 3/ 5).
Y_04: Output: Cookies (boxed) | Voice of Business (VoB): Demand: low consumption of ingredients; Complaint: waste of ingredients | Critical Business Requirement (CBR): COOKIES (BOXED) INGREDIENT-CONSUMPTION MINIMAL | Problem: COOKIES (BOXED) INGREDIENT-CONSUMPTION > 10% WASTE | Requirement-Category of INGREDIENT-CONSUMPTION: Consumption | Kano-Category of INGREDIENT-CONSUMPTION: More/Less-Is-Better | Requirement for INGREDIENT-CONSUMPTION of COOKIES (BOXED) is fulfilled to: 80% | The Severity of being unsatisfied with INGREDIENT-CONSUMPTION of COOKIES (BOXED) is: 20% (Rank 5/ 5).
Y_05: Output: Cookies (baked) | Voice of Business (VoB): Demand: Cookies fit exactly into the tin; Complaint: Cookies are too big | Critical Business Requirement (CBR): COOKIES (BAKED) DIAMETER > 9CM AND < 10 CM | Problem: COOKIES (BAKED) DIAMETER > 10 CM | Requirement-Category of DIAMETER: Quality | Kano-Category of DIAMETER: More/Less-Is-Better | Requirement for DIAMETER of COOKIES (BAKED) is fulfilled to: 70% | The Severity of being unsatisfied with DIAMETER of COOKIES (BAKED) is: 30% (Rank 3/ 5).

Summary & Details: Voice of Customer (VoC), Voice of Business (VoB), Critical Requirements (CCR/ CBR), Problems, Severity, KANO and CtQ-Rank

The summary of the "Voice to Criticals" lists the important results of this tool in a table.

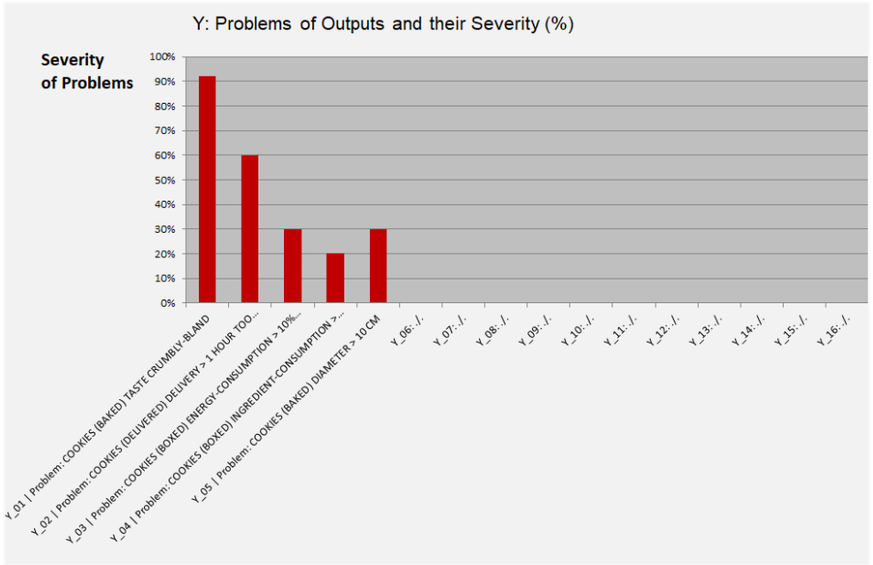
The details of the "Voice to Criticals" lists all given information for each Y of this tool also in a table.

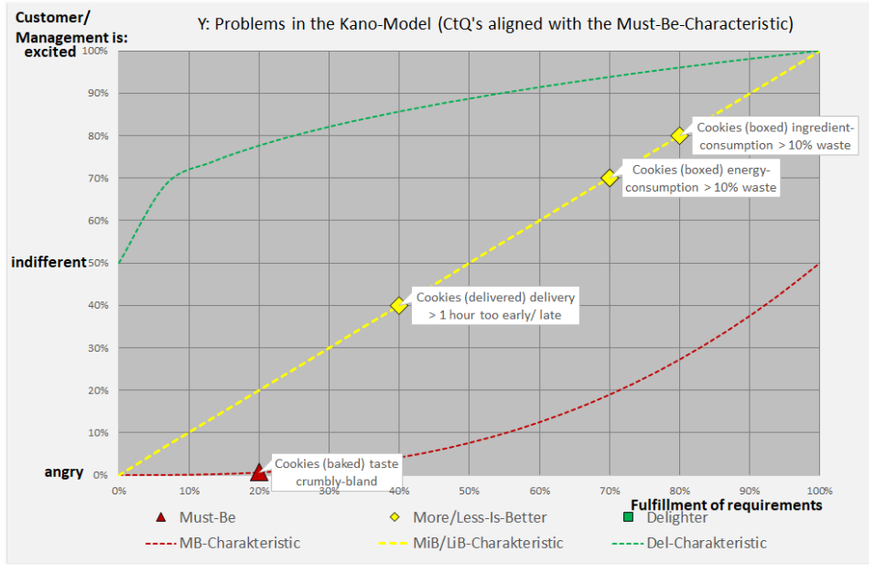
Both tables can be included in the Project-Story-Book.

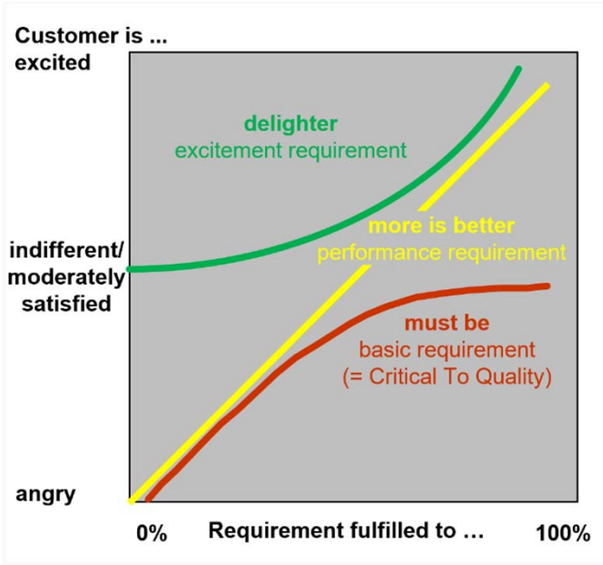
Please sort the table: Summary with: Ctrl Shift S

This information about Y is the anchor of your project

Bar-Chart with the Severity of the Problems (Y) …







The bar-chart: Y CtQ shows
the Problems and the Severity of their impacts
on the Customer and on the Business

The Kano-Chart: Y CtQ aligns the Problems to the modified Kano characteristics of *Must-Be*, *More/ Less is Better* and *Delighter*.

The basis for the calculation is the:
- fulfillment of requirements and the
- inverted Severity of the problems (= Satisfaction)

Original characteristics
of the Kano model

… and adapted Kano-Chart with the fulfillment of requirements and calculated satisfaction

The contract for your project with business-base, VoC/ VoB and solution-ideas

Project-Charter

Project-Name

Improve the performance of Cookie production

Business-Case

The Product COOKIE is a tangible final Output for external Customers and is in the Creation Process BAKE COOKIES within a year 13 - 52 times generated. Important Input of the Process to generate the Product COOKIE is: BUTTER, SUGAR, FLOUR, CHOCOLATE.

Process & Output

Product/ Service:	**Cookie**
Process:	**bake cookies**

Voice of Customer (VoC)

The satisfaction of the external customers with the:

- Quality of COOKIE is: 20%.
- Availability of COOKIE is: 40%.

Problems

Y_01 | Cookies (baked) taste crumbly-bland

Y_02 | Cookies (delivered) delivery > 1 hour too early/ late

Y_03 | Cookies (boxed) energy-consumption > 10% waste

Voice of Business (VoB)

The satisfaction of the process-owners with the Consumption in the Creation Process of the COOKIE is: 40%.

The total costs of the specified 3 problems are estimated by 100€ / year.

They are primarily the result of quality costs due to scrap and additional expenditure.

The solution of the problems is rated as:

- major URGENT (80%-Level) / - major IMPORTANT (80%-Level)

Solution-Ideas

more sugar in the mix

Comment

Comment

In Scope		**Out of Scope**	
in:	Vanilla Cookies	out:	Chips
in:	Chocolate Cookies	out:	Bread
in:		out:	
in:		out:	

Management

Sponsor	Mr. B. Aking	**Supplier**	Supermarket
A_ccountable	Chef du Cookie	**Customer**	Charlotte
Controlling	Mrs M. Oney	**Customer**	Lili
...?		**...?**	

Targets		**Timeline**
Y_01	Improve taste of Cookies (grade of 1,5 in customer rating)	30 October 20xx
Y_02	Deliver ordered Cookies on time (+/- 1h)	30 October 20xx
Y_03	Reduce consumption of energy (- 20%)	30 October 20xx
Y_04	Reduce consumption of ingredients (- 20%)	30 October 20xx

Experts

Black-Belt	Mr B. B. Elt	**Master-Black-Belt**	Reiner
Green-Belt	Y. Ou	**...?**	
Expert	Mrs D. Ough	**...?**	
Expert	Mr E. Quipment	**...?**	

Timeline	**Define**	**Measure**	**Analyse**	**Improve**	**Control***	**Control**	**End**
Target-Date:	**03.08.20xx**	**31.08.20xx**	**28.09.20xx**	**26.10.20xx**	**23.11.20xx**	**01.06.20xy**	**28.06.20xy**
Completion-Date:							
Evaluation:	**days remaining : 58**	**days remaining : 86**	**days remaining : 114**	**days remaining : 142**	**days remaining : 170**	**days remaining : 360**	**days remaining : 387**

The **smart-criteria** are helpful in formulating the targets:

s: specific -
it must be clear what exactly the target state is

m: measurable -
a measure and a target value or value corridor should indicate the success criterion

a: attractive -
an incentive can additionally make the target attractive for the team and motivate for rapid implementation

r: realistic -
targets that are too high lead to fear or frustration, targets that are too low lead to boredom

t: terminated -
a deadline for the target is important to speed up and control the project implementation

Please select the problems and add scope, team members targets and deadlines

Instructions

Project-Charter

The Project-Charter is the contract for the project that is concluded between all parties involved.
The most important existing information is bundled into one field each:

- Business-Case,
- VoC/ VoB,
- Process & Output,
- Solution ideas.

Please supplement:

Project name

This should succinctly sum up the purpose of the project.

Problems

In the list boxes of the problems field, select a maximum of three problems to be processed in the project, preferably the first three from the Voice-to-Critical (Summary).

Scope

To avoid later misunderstandings and to keep the scope of the project appropriate,
it should be clear and acceptable to all parties involved what is withIN the scope and what is OUTside the scope of the project.

Management & Experts

Here the sponsors, process-owner, belts, experts, controlling, important suppliers and customers can be named as team members.

Targets

In a sense, targets are problems that are upside down.
Therefore, the Yn is already displayed here according to the ranking of the problems Yn and a corresponding target is to be formulated for each problem.

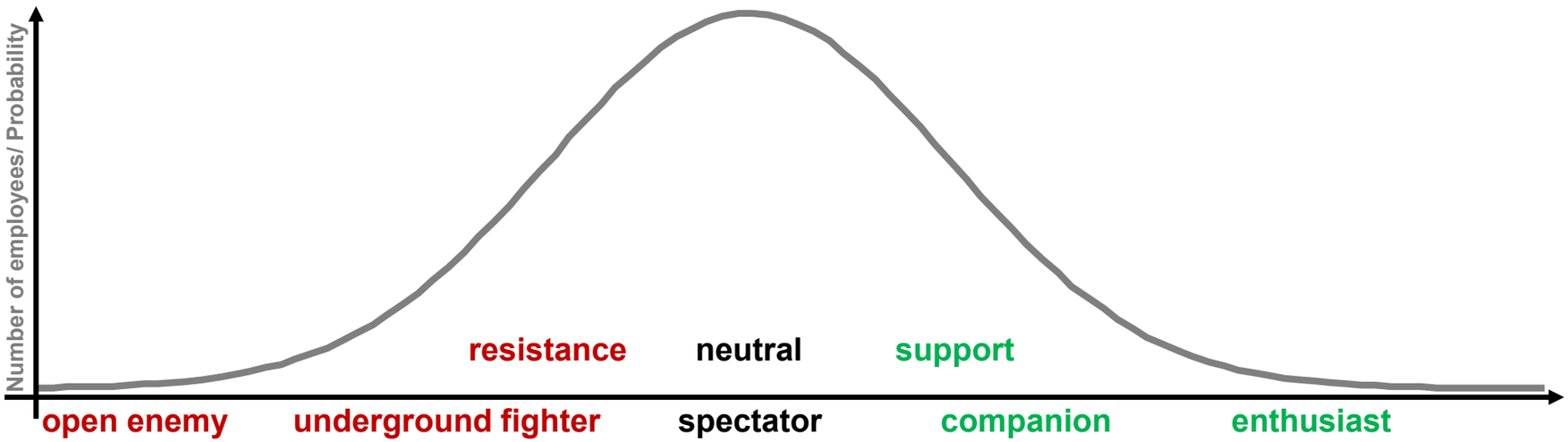
The smart criteria are helpful in formulating the targets:
s: specific - it must be clear what exactly the target state is.
m: measurable - a metric and a target value/corridor of values indicate what the success criterion is.
a: attractive - an incentive can also make the destination attractive for the team.
r: realistic - targets that are too high lead to fear or frustration, targets that are too low lead to boredom.
t: terminated - a deadline for the target is important to accelerate and control project implementation.

Timeline

The deadlines of the DMAIC phases and the dates of the actual completion of each phase are entered here.
An indicator then shows the remaining time and the timeout for each phase.

(Extract from sigmaGuide)

Assume that the resistance to and support for your project is normally distributed



Where does the resistance come from?		What can you do against resistance?
Not knowing don't see the need for improvement, no sense recognizable, distorted perception, bad experience with change	→	**Communicate** communicate basics, facts, opportunities and risks on the topic, give continuous insight into decisions and progress
Not able lack of technical and methodical skills, no say in the matter, fear of making mistakes	→	**Qualify** share easy to understand examples, familiarize with the theoretical basis and tools
Not willing own benefit unclear, preference of routine, arrogance, fear of additional workload and loss of influence	→	**Motivate** identify fears, recognize participation, balance incentives and negative consequences
Not permitted single antagonistic forces, group pressure, secret rules of the game, self-imposed barriers	→	**Integrate** interview, open workshops for participation, clarify roles and tasks, delegate responsibility

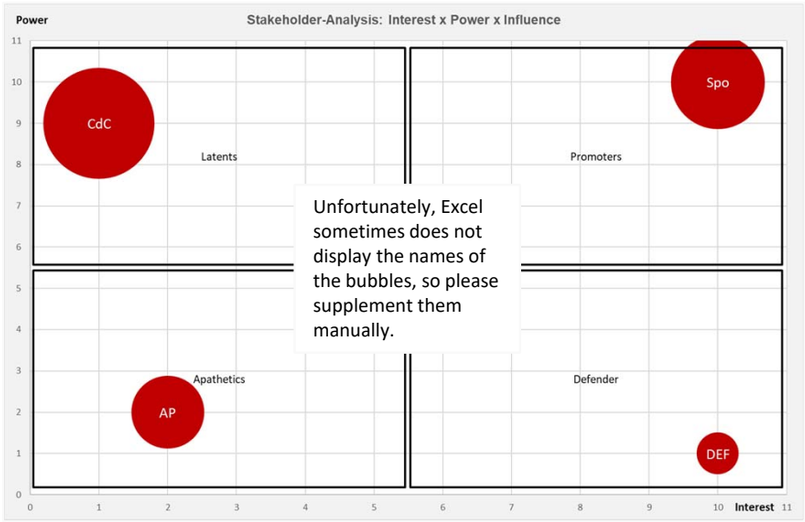
Types of communication to win and increase support for your project:

- Newsletter,
- eMail,
- Personal talk,
- Team discussion,
- DMAIC phase-steering and the
- Final presentation

Take any expression of resistance seriously - it contains the key to gaining support

Continuous communication about and integration into the project supports its implementation

Stakeholder-Analysis and Communication-Plan			Interested in …	Power to support the …	How do you want to win the support of this Person?					Degree of your Influence on this Person	Rank (Power x Interest x Influence)
Select one of your targets	**Who in the company is positively/ negatively affected by the achievement of this target? (Name)**	**Pseudonym**	**… target-achievement**		**Type of communication**	**Frequency**	**Type of communication**	**Frequency**	**Type of communication**		
Y_01 | Improve taste of Cookies (grade of 1,5 in customer rating)	Mrs Sponsor	Spo	10	10	newsletter	monthly	eMail	weekly	personal talk	5	1
Y_05 | Reduce consumption of ingredients and energy (- 20%)	Chef du Cookie	CdC	1	9	newsletter	monthly	eMail	weekly	personal talk	7	2
Y_03 | Adapt cookies to tin diameter (99% yield)	Mr D.E. Fender	DEF	10	1	newsletter	monthly	eMail	weekly	personal talk	1	4
Y_01 | Improve taste of Cookies (grade of 1,5 in customer rating)	Mr A. Pathetic	AP	2	2	newsletter	monthly	eMail	weekly	personal talk	3	3
…?			…?	…?	…?	…?	…?	…?	…?	…?	



The Chart Stakeholder-Analysis shows the Interest in and Power to support the achievement of targets for defined Stakeholders.

The bubble sizes represent the degree to positively influence Stakeholders for the targets of the project.

Stakeholder-Analysis and Communication-Plan

The Stakeholder-Analyses supports to identify important Stakeholder
in the environment of your project.
The Communication-Plan helps to win the support of these persons.

1. Select one of your targets
2. Identify one of the Persons, which is positively or negatively affected by the achievement of this target.
3. For anonymization, give this person a pseudonym.
4. Rate the:
   - degree of interest of this Person in your targets
   - degree of power of this Person to support your targets
5. Determine the media of communication with which you want to win this person to support your goals
6. Set the dates for the respective communication
7. Rate the:
   - degree of your influence to win this Person to support your targets

The rank order shows the arithmetic product: Power x Interest x Influence
Copy the Chart: Stakeholder in your Project-Story-Book and add the pseudonyms to the bubbles

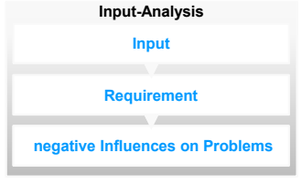
The communication-plan can help to win the support of important stakeholders

MEASURE

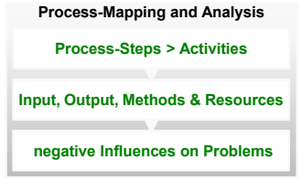
Input-Analysis, Process-Mapping/ -Analysis, C&E-Matrix, Data-Collection-Plan, Hypotheses

Measure: From the identification of influences on the problems to related hypotheses

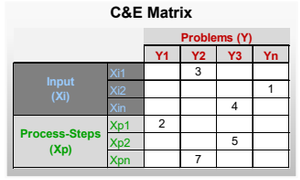
- **Identify the negative influences of the input: Input-Analysis**
  - Focus on the necessary inputs (xi) for the output (Y) from the SIPOC
  - Specify the requirements for the inputs (xi)
  - Classify the inputs (xi) to one of the categories of: Quality, Availability and Consumption
  - Specify the deviations of the inputs (xi) from the requirements and estimate their probability of occurrence



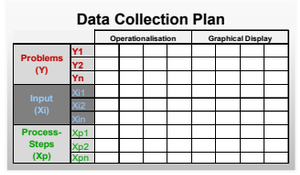
- **Map the process and identify its negative influences: Process-Mapping & -Analysis**
  - Divide the process-steps into activities from the first input (xi) to the last output (Y), specified in the SIPOC
  - Specify the inputs (xi) and outputs (Y) of the activities as well as their associated methods (xm) and resources (xr)
  - Specify the negative influences of methods (xm) and resources (xr) in the activities on the problems of the outputs (Y)
  - Estimate the probability of occurrence of the negative influences (xm; xr)



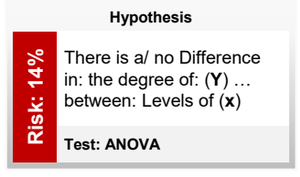
- **Identify the relationships between the influences (xi; xm; xr) on the problems (Y): C&E Matrix**
  - Estimate the impact strength of the negative influences of the inputs (xi) on the problems (Y)
  - Estimate the impact strength of the negative influences of the activities (xm; xr) on the problems (Y)
  - Identify the strongest influences xi, xm and xr on the problems (Y)
  - Check the overall determination of the problems (Y) by the influences xi, xm and xr



- **Plan the measurement/ collection of data (Data Collection Plan)**
  - Operationalize the influences xi, xm and xr and problems (Y) as measurable variables
  - Determine the scale-level of the variables, specification limits and targets
  - Plan a Measurement-System-Analysis (MSA) if necessary and determine sample size (if the statistical test is determined)
  - Plan graphical representation of the variables, determine parameters, the process capability indices and control charts



- **Relate problems (Y) and influences (xi, xm, xr): Statistical Hypothesis $Y_a = Y_b$; Y= f(x)**
  - Statistical hypothesis are automatically formulated on the basis of the given information, with:
    - type of the hypothesis (difference/ relationship) and
    - the relevance of each hypothesis for the problem (risk)
    - a suggestion for an appropriate statistical test to check the hypothesis



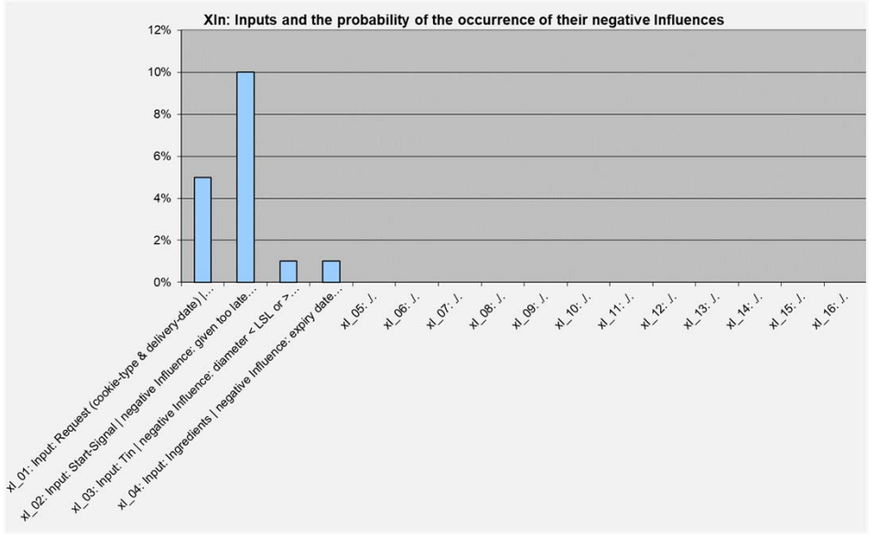
Summary MEASURE: Data collected and their analysis determined

Outlook ANALYSE: Display variables, test the hypotheses and find the root causes of influences (x) on problems (Y)

Please answer the questions and get an overview …

xI_01		
Which Input is necessary for the Process BAKE COOKIES?	**Request (cookie-type & delivery-date)**	**Input**
	Please select an answer.	
What do you require from REQUEST (COOKIE-TYPE & DELIVERY-DATE)?	**unambiguous, complete and understandable**	**Requirement**
	Please enter your answer.	
To which category does the Requirement UNAMBIGUOUS, COMPLETE AND UNDERSTANDABLE belong?	**Quality (Faultlessness/ Fulfilment of Purpose)**	**Requirement-Category**
	Please select an answer.	
Which deviation of REQUEST (COOKIE-TYPE & DELIVERY-DATE) from the Requirement is problematic for the Process?	**ambiguous, incomplete or not understandable**	**negative Influence**
	Please enter your answer.	
How often does the negative Influence REQUEST (COOKIE-TYPE & DELIVERY-DATE) AMBIGUOUS, INCOMPLETE OR NOT UNDERSTANDABLE occur?	**5%**	**Probability of Occurrence**
	Please enter a value between: 0% - 100%.	

The **Chart Influence of xi** displays the Inputs (xi) and the probability of their deviation from Requirements.



The **Input Analysis** examines all Inputs which come from outside into the SIPOC.

Outputs of one Process-Step in the SIPOC going as Input into another Process-Step are represented in [brackets].

You do not need to evaluate them again, because you did it already in the **Voice to Criticals**.

This information will be used in the **C&E Matrix** as negative Influences on the Output.

… of the negative Influences from the Inputs (xi) on the Problems of the Output (Y).

Instructions

Input-Analysis

In this Chapter we will:
- focus on the Inputs from the SIPOC,
- specify the Requirements for the Inputs,
- collect deviations from the Requirements and
- evaluate the frequency, how often the Inputs deviate from the Requirements.

In the SIPOC the Process BAKE COOKIES was already structured in its basic Process-Steps.
The Inputs of these Input-Process-Output-Sequences may come from two different sources:
- Inputs from Suppliers, which enter the Process from outside and
- Inputs which result in the course of the Process, as an Output of a preceding Process-Step.

For this Input-Analysis only the external Inputs are relevant. Internal Inputs are seen as Outputs and analysed in the Voice-to-Criticals.

Please note that:
- internal Inputs which result as an Output from a preceding Process-Step , are [excluded] in the List-Boxes.
- external Inputs are presented without brackets in the List-Boxes. They should be analysed here.

Please answer the questions to the overall 16 possible Inputs.

(Extract from sigmaGuide)

Specify the activities in the process-steps, assign inputs, outputs, methods, resources and …

Process-Mapping-Analysis of: baking cookies

Departments	Activities →					
Customer	transmit request					evaluate cookies
Logistic & Procurement		determine cookie-type & delivery-date		purchase missing ingredients	deliver cookies	
Production Support			determine necessary & missing ingredients			
Chef du Cookie					preheat the oven	…
Inputs		request (cookie)	order(cookie-type; delivery date)	Shopping-List	start-signal	…
Methods		calendar-entry	personal habit	personal habit	cooking-standards	…
Resources					oven	…
Outputs		Order(cookie-type; delivery date)	Shopping-List	Ingredients (complete)		…
negative influences on … Quality		wrong cookie-type determined	wrong ingredients determined			…
negative influences on … Availability				necessary ingredients not available		…
negative influences on … Con-sumption		clarification with the customer is laborious			oven preheated too early/ hot	…
Frequency	0%	10%	5%	5%	5%	…

… identify the triggering influences in the methods (xm) and resources (xr) of the problems (Y)

Standard for the workshop: key questions and procedure

Key questions for the workshop

Involved departments

1. Who is involved in the process?

Activities

2.a What is typically done first?

2.b What happens next? (variant)

Input & Output

3. Which input is necessary for the activity?

4. Which output results from the activity?

Methods & Resources

5. Which resources execute or support the execution the activity?

6. Which methods guide the execution?

Influences & Frequency

7. Which influences from the methods and resources on or by the activities negatively affected the quality, the availability of the output or the consumption and waste of input and resources in the past?

8. How often (%) did the most relevant and most important of these influences affect the output in the past?

Stay to these question, repeat them, do not vary them,
because you might get a different answer than intended

Procedure for the workshop

1. Keep calm – if you get excited: speak slower, breathe evenly, deeply

2. Invite participants and inform the sponsor

3. Ask for a guided tour of the process, get the workshop materials, prepare the room

4. Take care of your participants

5. Take the guided tour of the process

6. Repeat the following microprocess with for each of the key questions (left) for each activity, until you have received a valid answer:
   a) ask one of the standard key questions,
   b) check the answer,
   c) summarize relevant aspects of the answer and
   d) let the participants check your understanding of the answer

7. Note the relevant information of the answers on different stickers each:
   a) **Activities:** describe them as precisely as possible with: verb & noun
   b) **Input, Output, Methods & Resources**: write their names or "personal habits", if e.g. methods are missing
   c) **negative influences:** Identify the last direct influence, i.e. the last trigger in the causal chain that causes or contributes to a defined problem, check: **If influence occurs, then problem arises/increases?**

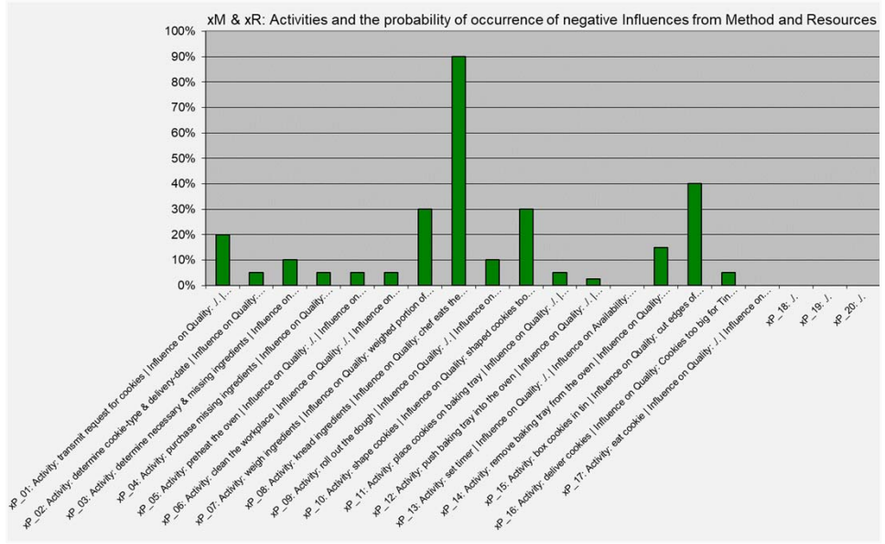
8. In between thank your experts for their participation and their answers

9. Take a picture of yourself and the team in front of your workshop flip charts

Please apply this standard and make your own experiences before changing it

Transfer the information of the Process-Mapping-Analysis after the workshop to sigmaGuide

Process-Mapping-Analysis of the Process: bake cookies						
Who ...	... does what?	Please specify the Process-Steps in detailed Activities the format: Verb + Noun (e.g.: weigh Ingredients)				
		1. Activity	2. Activity	3. Activity	4. Activity	5. Activity
1. Process-Step	Customer (Child)	transmit request for cookies				
2. Process-Step	Logistic & Procurement Service		determine cookie-type & delivery-date		purchase missing ingredients	
3. Process-Step	Production Support			determine necessary & missing ingredients		preheat the oven
4. Process-Step	Chef du Cookie					
5. Process-Step	...?					
6. Process-Step	...?					
7. Process-Step	...?					
8. Process-Step	...?					
9. Process-Step	...?					
10. Process-Step	...?					
11. Process-Step	...?					
12. Process-Step	...?					
Input:	Which Inputs are necessary to start the Activity?	...?	Request (cookie)	Order (cookie-type; delivery-date)	Ingredients	Start-Signal
Methods:	Which Instructions/ Rules direct how to perform the Activity?		calendar-entry	personal habit	personal habit	cooking-standards
Resources:	Which Equipment/ Machines/ Tools operate or support the Activity?					oven
Output:	Which Output results from the Activity?	...?	Order (cookie-type; delivery-date)	Shopping-List	Ingredients (complete)	...?
Which Influences of the: - Methods and - Resources negatively affect:	... the Quality (Faultlessness/ Fulfilment of Purpose) of the Output?		wrong cookie-type determined	wrong ingredients determined		
	... the Availability (right Quantity just in Time) of the Output?				necessary ingredients not available	
	... the Consumption and Waste of Input and/ or Resources?		clarification with the customer is laborious			oven preheated too early/ hot
How often are the Activities affected by these negative Influences?		0%	10%	5%	5%	5%



The **Chart Influence of xP** graphically display the activities and the probability of their deviation from requirements.

The **Process-Mapping-Analysis** lets you detail all the process-steps of the SIPOC into specific activities, their inputs, outputs, the executing resources and the guiding methods

The related negative influences on the output and their probability continue the preparation of hypothesis in the C&E Matrix.

The related chart displays all identified influences and their frequency in the past

Specify the impact strength of each negative influence in the …

C&E Matrix	Output (Y)	Severity	92%	60%	30%	20%	30%	Results for: Impact of Influences (xI & xP) on the Outputs (Y)		
		Kano-Category	Must-Be	More/Less-Is-Better		More/Less-Is-Better	More/Less-Is-Better			
		Problems (= Effects)	Y_01 | Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND	Y_02 | Problem: COOKIES (DELIVERED) DELIVERY > 1 HOUR TOO EARLY/ LATE		Y_04 | Problem: COOKIES (BOXED) INGREDIENT-CONSUMPTION > 10% WASTE	Y_05 | Problem: COOKIES (BAKED) DIAMETER > 10 CM	Product Sum of the Impact of each Influence (xI & xP) on all Outputs (Y)	Percentual Impact of each Influence (xI & xP) on all Outputs (Y)	Ranking of the Impact of each Influence (xI & xP) on all Outputs (Y)
Influences from Input (xI) (= Causes)	**Probability**	**Rank**								
xI_01: Input: Request (cookie-type & delivery-date) | Requirement: unambiguous, complete and understandable | Requirement-Category: Quality (Faultlessness/ Fulfilment of Purpose) | negative Influence: ambiguous, incomplete or not understandable	5%	2	40%					0,02	1%	10
xI_02: Input: Start-Signal | Requirement: given at the right time | Requirement-Category: Availability (right Quantity just in Time) | negative Influence: given too late or too early	10%	1		80%				0,05	3%	8
xI_03: Input: Tin | Requirement: diameter target: 110, LSL: 107 USL: 113 mm | Requirement-Category: Quality (Faultlessness/ Fulfilment of Purpose) | negative Influence: diameter < LSL or > USL	1%	3				5%	100%	0,01	0%	14
xI_04: Input: Ingredients | Requirement: expiry date met | Requirement-Category: Quality (Faultlessness/ Fulfilment of Purpose) | negative Influence: expiry date exceeded	1%	3	80%					0,01	0%	13
Influences from Process-Step (xMR) (= Causes)	**Probability**	**Rank**								
xMR_01: Activity: transmit request for cookies | Input: ./. | Methods: ./. | Resources: ./. | Output: ./. | Influence on Quality: ./. | Influence on Availability: ./. | Influence on Consumption: ./.	0%			90%				0,11	7%	4
xMR_02: Activity: determine cookie-type & delivery-date | Input: Request (cookie) | Methods: calendar-entry | Resour Output: Order (cookie-type; delivery-date) | Influence on Quality: wrong cookie-type determined | Influence on Availab Influence on Consumption: clarification with the customer is laborious			40%					0,02	1%	10
xMR_03: Activity: determine necessary & missing ingredients | Input: Order (cookie-type; delivery-date) | Methods: pe habit | Resources: ./. | Output: Shopping-List | Influence on Quality: wrong ingredients determined | Influence on Availa | Influence on Consumption: ./.			90%					0,08	5%	5
xMR_04: Activity: purchase missing ingredients | Input: Ingredients | Methods: personal habit | Resources: ./. | Output: Ingredients (complete) | Influence on Quality: ./. | Influence on Availability: necessary ingredients not available | Influence on Consumption: ./.	5%	7		90%				0,03	2%	9
xMR_05: Activity: preheat the oven | Input: Start-Signal | Methods: cooking-standards | Resources: oven | Output: ./. | Influence on Quality: ./. | Influence on Availability: ./. | Influence on Consumption: oven preheated too early/ hot	5%	7			100%			0,02	1%	12
Results for: Determination of Outputs (Y) by Influences (x)	**Product Sum of the Determination of each Output (Y) by the Influences (xI & xP)**		4,8823	0,1830	0,0150	0,1401	0,0050			
	Percentual Determination of each Output (Y) by the Influences (xI & xP)		93%	4%	0%	3%	0%			
	Ranking of the Determination of each Output (Y) by the Influences (xI & xP)		1	2	4	3	5			

Problems (Yi)

Influences (xi, xm, xr)

Y= f(x)
Basis for Hypotheses

The **C&E Matrix**:
- Lets you estimate the impact strength of each influence on the problems.
- Every entry in one of the cells at the intersection of input/ activity of process-steps and output thus is an assumption about a causal relationships between an influence (X) and a problem (Y).
- This assumptions about causal relationships are the basis for the formulation of hypothesis.

Guiding **question** to fill the cells is:

How strong (0-100%) is the impact of the negative influence (x_n) on the problem (Y_n)?
with:
- 0% meaning, that the problem (Y_m) is independent from the influence (x_n)
- 100% meaning, that the influence (x_n) always triggers or increases the problem (Y_m)

… inputs (xi) and activities (xm; xr) on the problems of the outputs (Y).

Instructions

C&E Matrix

The C&E Matrix serves to indicate causal relationships between the negative Influences of the Inputs (Xi) and Activities (Xp) (= Causes) on the Problems of the Output (Y) (= Effects).

1. Within the C&E Matrix every Influence (x) in the rows is contrasted with every Problem (Y) in the columns.
   In the xY-intersection cell the strength of each impact can be estimated within a range from 0%-100%.
2. The sum of the impacts of an Influence (x), relativized to its probability of occurrence and the severity of the influenced Problems (Y) indicates the overall impact strength of each Influence (column U).
3. The rank of each Influence shows its importance in relation to the other Influences and thus its importance for the subsequent Hypothesis (see below) (column W).
4. The sum of the impacts of all Influences (x) on a Problem (Y), relativized to their probability of occurrence, indicates the determination of the Problem by its Influences (row 42).
5. The rank of each Problem shows which Problem is relatively strong (high rank) and which Problem is only weakly "explained" by the specified Influences.
   This ranking can thus show, where in the Inputs or the Process-Steps additional Influences should be looked for (row 44).

Please evaluate the strength of the presumed impact of the Influences (xI and xP) on the Outputs (Y).

- To do so enter a value between 1 .. 100% in the intersection of the focused cells.

- It does not matter, whether you assume a positive relationship (the greater x, the greater Y) or a negative relationship (the smaller x, the greater Y).
  In this tool its a question of the absolute strength of the relationship.

- If there is no relationship at all between an x and an Y, the leave the cell empty.

Result per row: Overall strength of every Influence (x), added up over all Outputs (Y)
Result per column: Determination of every Output (Y) by all Influences (x)

(Extract from sigmaGuide)

The Chart C&E Heatmap gives an overview about number and dispersion …

Chart: C&E Heatmap The cells indicate the strength of each relationship between influences (xI and xP) and the related Outputs (Y) as Risks (Probability x Severity). The Risks are the basis for prioritizing of the corresponding Hypothesis between x and Y. (Nothing needs to be entered here)	Severity	92%	60%
	Output (Y) Problems (= Effects)	Y_01 | Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND	Y_02 | Problem: COOKIES (DELIVERED) DELIVERY > 1 HOUR TOO EARLY/ LATE
Influences from Input (xI) (= Causes)	**Probability**	**D**	**E**
xI_01: Input: Request (cookie-type & delivery-date) | Requirement: unambiguous, complete and understandable | Requirement-Category: Quality (Faultlessness/ Fulfilment of Purpose) | negative Influence: ambiguous, incomplete or not understandable	5%	10,63%	
xI_02: Input: Start-Signal | Requirement: given at the right time | Requirement-Category: Availability (right Quantity just in Time) | negative Influence: given too late or too early	10%		8,55%
xI_03: Input: Tin | Requirement: diameter target: 110, LSL: 107 USL: 113 mm | Requirement-Category: Quality (Faultlessness/ Fulfilment of Purpose) | negative Influence: diameter < LSL or > USL	1%		
xI_04: Input: Ingredients | Requirement: expiry date met | Requirement-Category: Quality (Faultlessness/ Fulfilment of Purpose) | negative Influence: expiry date exceeded	1%	11,76%	
Influences from Process-Step (xMR) (= Causes)	**Probability**		
xMR_01: Activity: transmit request for cookies | Input: ./. | Methods: ./. | Resources: ./. | Output: ./. | Influence on Quality: ./. | Influence on Availability: ./. | Influence on Consumption: ./.	0%		
xMR_02: Activity: determine cookie-type & delivery-date | Input: Request (cookie) | Methods: calendar-entry | Resources: ./. | Output: Order (cookie-type; delivery-date) | Influence on Quality: wrong cookie-type determined | Influence on Availability: delay in case of unavailability of the customer | Influence on Consumption: clarification with the customer is laborious	10%	13,72%	
xMR_03: Activity: determine necessary & missing ingredients | Input: Order (cookie-type; delivery-date) | Methods: personal habit | Resources: ./. | Output: Shopping-List | Influence on Quality: wrong ingredients determined | Influence on Availability: ./. | Influence on Consumption: ./.	5%	23,92%	
xMR_04: Activity: purchase missing ingredients | Input: Ingredients | Methods: personal habit | Resources: ./. | Output: Ingredients (complete) | Influence on Quality: ./. | Influence on Availability: necessary ingredients not available | Influence on Consumption: ./.	5%		7,46%
xMR_05: Activity: preheat the oven | Input: Start-Signal | Methods: cooking-standards | Resources: oven | Output: ./. | Influence on Quality: ./. | Influence on Availability: ./. | Influence on Consumption: oven preheated too early/ hot	5%		

The **Chart C&E Heatmap** shows the risk of each influence x problem relationship.

The percentual risk-value combines the:
- probability of occurrence of an influence,
- strength of its impact on the problem and
- severity of the problem.

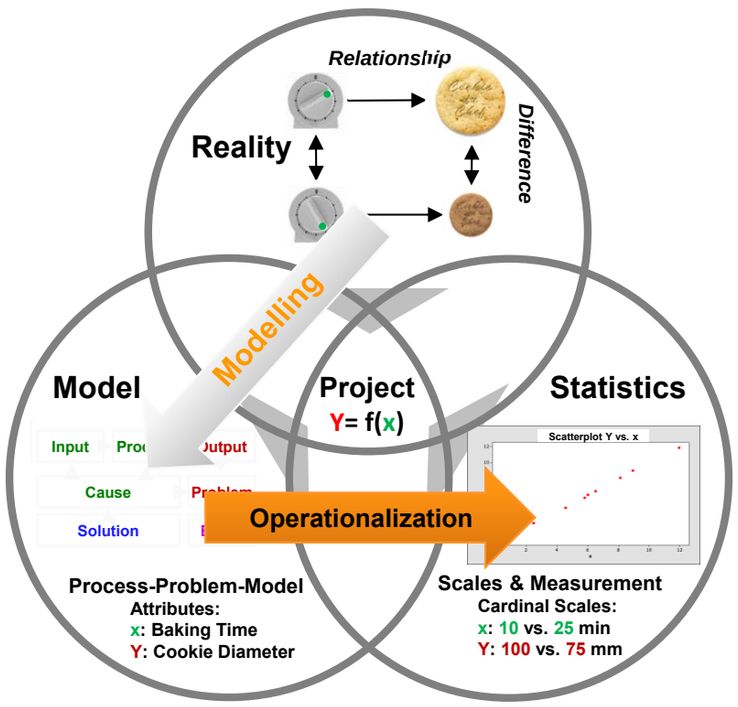
The colours represent the relative risk level for the influence-problem pairs:
- high risk (> 10%)
- medium risk (1% < risk < 10%)
- low risk (< 1%)

for triggering the problem.

Thus the risks of the xY-relations give an overview about the number and dispersion of the hypothesis (see hypothesis).

… of risks resulting from the causal relationships between influences and problems

Measuring means assigning a value of an underlying scale …



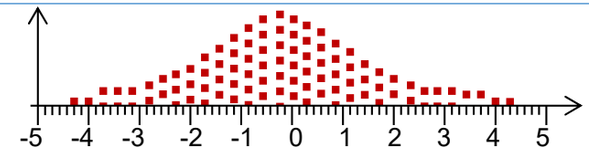
Operationalization is the mapping of an object's attribute to a scale,
so that the measured data represent the attribute validly, reliably and precisely.

amount of information

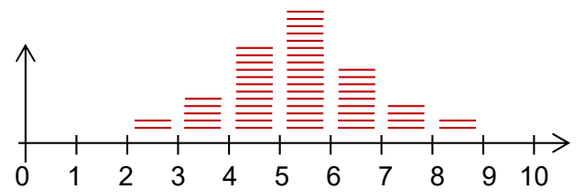
Cardinal-Scale:

- Attribute of object: quantitative
- Values of scale: discrete or continuous
- Value order: value= sum of intervals
- Intervals: unit defined, like values

Punctuality:
Values: - ∞ – + ∞ (continuous)



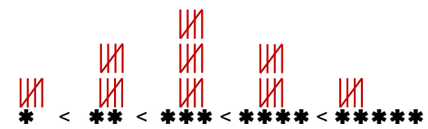
Number of daily eMails:
Values: 0 – ∞ (discrete)



Ordinal-Scale:

- Attribute of object: quantitative
- Values of scale: discrete
- Value order: ranking
- Intervals: undefined

Satisfaction with Product:
Values: ✱ – ✱✱✱✱✱

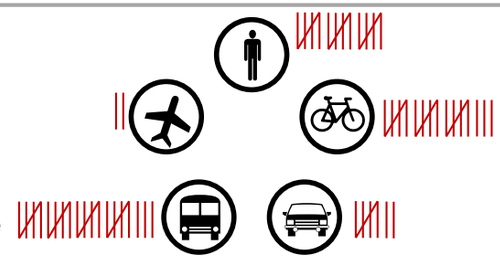


Personal state of mind:
Values: bad/ indifferent/ good

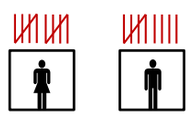
Nominal-Scale:

- Attribute of object: qualitative
- Values of scale: attributive categories
- Value order: undefined
- Intervals: undefined

Means of transport:
Values:
on foot/ bicycle/ car/ bus/ plane



Gender:
Values: male / female



… to the state of an object's attribute

Attributes of objects mapped on scales with different attributes and parameters

Type of attribute of the object of measurement	Attributes of the Scale	Name of Scale	Parameters of central tendency	Parameters of scattering	Example of everyday life	Example from work environment	Example for cookies
quantitative	Values: continuous Value order: value= sum of intervals Intervals: unit defined, continuous	**Cardinal Scale**	Mean (Xbar)	Average Deviation, Standard Deviation, Variance	race duration: hours : minutes : …	length: cm cycle time: hours costs: $/ €/ £/ ¥/ …	weight of cookies: - gram (g) processing time of cookies: - minutes (min)
	Values: discrete Value order: value= sum of intervals Intervals: unit defined, discrete				number of children in a family: 0 … n	Number of phone calls: 0 … n	number of defect cookies: 0 … n
	Values: discrete Value order: ranking Intervals: undefined	**Ordinal Scale**	Median	Range, Percentiles, Interquartile Range	satisfaction assessment: **** smileys grades: A B C D E F / 1 2 3 4 5 6	FMEA Risk-Priority-Number (RPN): 1 - 1000 complexity of projects: project X > project Y	Risk of a Problem: 0% - 100% rating of taste: ****
qualitative	Values: attributive categories Value order: undefined Intervals: undefined	**Nominal Scale**	Mode	number of different values in sample/ number of different possible values in population	election: means of transportation/ parties/ persons/ …	types of different: - products (Y) - errors (Y) - locations (x) - shifts (x)	types of errors: - burnt - salty - …
					physical condition: healthy/ sick gender: male/ female	avaliability of a method (x) for certain activity (yes/ no)	Recipe available and used? (yes/ no)

The **Scale** of a measurand determines the:
- Parameter of central tendency
- Parameter of scattering
- Appropriate statistical test

Values of a higher scale-level can always be transformed to a lower scale level, e.g. if you transform the real age of people (Cardinal Scale) into age categories (Nominal Scale).

This reduction of scale-level reduces the already available information, because the parameters of a Nominal-Scale (e.g. Mode) carry less information then the parameters of a Cardinal-Scale (e.g. Mean).

The same is true for the related statistical tests, where e.g. the Chi^2-Test has less power than the ANOVA.

Thus always plan your measurement on the highest possible level and avoid transformations to a lower scale as far as possible.

Data on a lower scale-level cannot be transformed to a higher scale level

The higher the scale level of a measurement, the more information is carried by the data

Operationalize the measurement of the variables x and Y, …

Data Collection Plan		please answer the questions and plan the graphical display as wenn as initial analyses based on the proposals (right ->)				
Ranking of Influences (xI & xMR) and Outputs (Y)	Influences (xI & xMR) and Outputs (Y)	What should be measured?	Please specify the measurand (e.g. Time)	Please specify the units of the measurand (e.g. days)	Please specify the Target and its Specification Limits - if known - in the format: Target: USL: LSL:	Which different values can the Measurand take? (Scale of Data)
Output (Y)						
1	Y_01 | Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND	taste of Cookies	rating-scale	grades 1 .. 6	Target: 1.5 LSL: 4	Data Rank Ordered (Ordinal-Scale)

How should the Data be collected?	Is a Measurement-System-Analysis (MSA) necessary?	Which Data about the circumstances should additionally be collected? (Blocking-/ Condition-Variables)	How large should the Sample Size be?	Where should the Data be collected? (Location/ Source)	For which Time Interval should the Data be collected? (Start/ End)	Which Variable-Name will you assign to the Measurand?	In which File will the Data be stored?	Who is responsible for the collection of the data?
collect new data	no	cookie-type (Vanilla vs. Chocolate)	50	shop	1 month	Y_01_Taste	Cookie_du_Chef_01.xls	Green Belt

Graphical Representation					Parameter of Central Tendency			Dispersion Parameter		Process-Capability			Control-Charts						Test of one Sample vs. Limit/ Target			
Bar-Chart/ Pareto-Chart	Histogram	Error-Bar-Chart/ Interval-Diagram	Box-Plot	Time-Series-Chart/ Run-Chart/ Line-Chart	Modus	Median	Mean	Quartile	Standard Deviation/ Variance	Error Rate/ DPU/ ppm/ z-Value (Sigma-Level)	DPO/ DPMO/ z-Value (Sigma-Level)	Pp/ Ppk-, Cp/ Cpk / Z-Value (Sigma-Level)	I/ MR-Chart (if N < 60)	X-bar/ R-Chart (if n_total > 80 and if n_subsamples <= 8)	X-bar/ S-Chart (if n_total > 80 and if n_subsamples > 8)	p-Chart (if ok vs. ko is discriminated)	p-Chart (if ok vs. ko is discriminated)	t/P-Test (Percentage vs. Limit/ Target)	Chi-Square goodness-of-fit-Test (Percentage vs. Limit/ Target)	Variance-Test (Variance vs. Limit/ Target)	t-Test (Mean vs. Limit/ Target)	

The **Data Collection Plan** lists all Outputs (Y) and their Influences (xi and Xp) with the ranking of their relevance.

The task is to operationalize the related variables and prepare them for the measurement.

This means to transfer the subject of measurement into measurands and specify the variables, i.e. the:
- subject of measurement
- measurand
- units and its
- scale level
- sample size
- type of Data Collection and the
- conditions of measurement
- responsible persons

As a result some recommendations are given to their graphical display and first analysis of the variables.

The colours represent the suitability of charts, parameters, indices and tests:
- suitable
- interpretation under reserve

… for single case raw data on the highest available scale-level

Instructions

Data Collection Plan

In the Data Collection Plan the Outputs (Y), Influences of the Inputs (Xi) and the Processes (Xp) are operationalised.

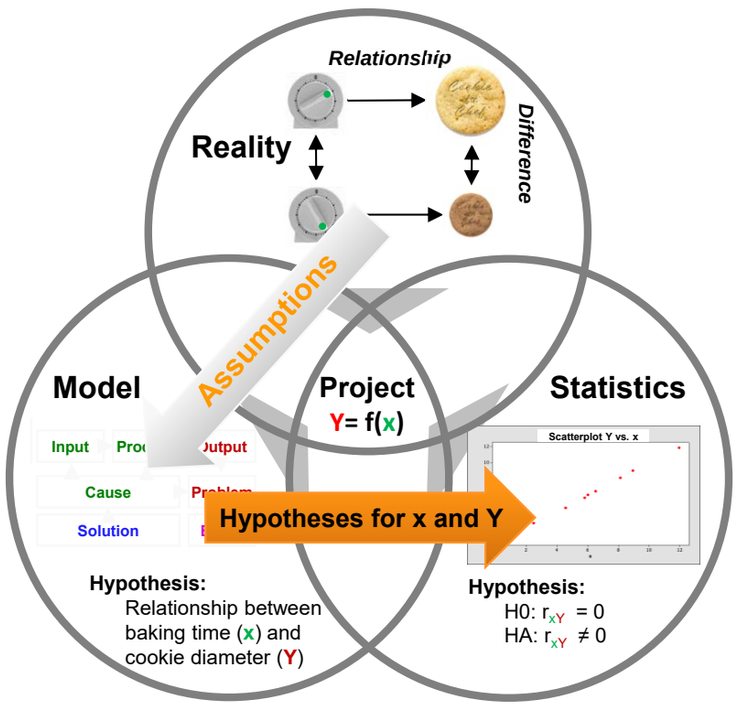
In this Chapter you can determine the:
- subject for the measurement (What should be measured?)
- measurand and the unit of measurement (e.g. Time (hrs.))
- target and specification limits
- scale level of the data (Nominal-, Ordinal- and Cardinal-Scale)
- Type of data collection (collect new or existing data)
- decision whether a Measurement-System-Analysis should be executed or not
- conditions and circumstances, which should be additionally collected? (Blocking-/ Condition-Variables)
- sample size
  (can be calculated with the procedure: Power & Sample Size only after the determination of the statistical test (see Hypothesis))
- location and source of data collection
- time interval in which the data should be collected (eventually with a start- and end-date of measurement)
- name of the variables in the data collection table
- name of the data collection table
- responsible persons for the data collection

On the basis of the scale level recommendations are given for:
- Graphical Representation
- Parameter of Central Tendency
- Dispersion Parameter
- Process-Capability
- Control-Charts
- Test of one Sample vs. Limit/ Target

With these information all requirements are given to form statistical Hypothesis.
In the next chapter you will find a list of automatically formulated Hypothesis with recommended Statistical Tests for their examination.

(Extract from sigmaGuide)

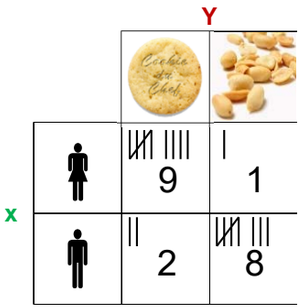
Observations of the reality are transformed into logical assumptions …



A **hypothesis** is the translation of an assumption about objects in reality into an empirically testable format with the measurands **x** and **Y**.

Relationship-Hypothesis:

- **Assumption**: If **x**, then **Y**
- **Attributes of**
  x: 2 … n levels (categories on nominal scale)
  Y: 2 … n levels (categories on nominal scale)
- **Hypothesis**:
  There is a relationship between gender (**x**) and the type of preferred snack (**Y**)
- **Test**: e.g. Chi²-Test



Relationship-Hypothesis:

- **Assumption**: The **x**, the **Y**
- **Attributes of**
  x: discrete or continuous data (ordinal or cardinal scale)
  Y: discrete or continuous data (ordinal or cardinal scale)
- **Hypothesis**:
  There is a relationship between the baking time (**x**) and cookie diameter (**Y**)
- **Test**: e.g. Correlation, Regression

C126	C127
x_bakingTime	Y_cookieDiameter_
12	9,8333
9	10,1111
18	9,5556
25	9,4000
10	10,0000
13	9,7692

Difference-Hypothesis:

- **Assumption**: Difference in **Y**, dependent from type/ level of (**x**)
- **Attributes of**
  x: 2 … n levels (categories on nominal scale)
  Y: discrete or continuous data (ordinal or cardinal scale)
- **Hypothesis**:
  There is a difference in the weight of cookies (**Y**) between cookie types (**x**)
- **Test**: e.g. t-Test, ANOVA

C129-T	C130
x_cookieType	Y_cookieDiameter
Vanilla	10,5
Vanilla	10,2
Chocolate	8,7
Vanilla	9,9
Chocolate	13,8
Chocolate	11,1

… and then translated into hypotheses about relationships or differences

The logical content of each hypothesis on relationships or differences …

… and translated into the format of statistically testable hypotheses

Assumption about reality modeled as …		**Null-Hypothesis (H0)**	**Alternative-Hypothesis (HA)**
	Relationship-Hypothesis	**From the assumption about reality…**	
		There is no relationship between x and Y	There is a relationship between x and Y
		Example	
		There is a/no relationship between baking time (x) and cookie size (Y)	
		… to the statistically testable formulation	
		$H_0: r_{xy} = 0$	$H_A: r_{xy} \neq 0$
	Difference-Hypothesis	**From the assumption about reality…**	
		There is no difference - in the degree of: Y - between the levels of: x (xi, xj, …)	There is a difference - in the degree of: Y - between the levels of: x (xi, xj, …)
		Example	
		There is a/ no difference - in: the taste of cookies (Y) - between: types of cookies (xi) (e.g. Vanilla (x1) vs. Chocolate (x2) vs. …)	
		… to the statistically testable formulation	
		$H_0: Y_{xi} = Y_{xj}$	$H_A: Y_{xi} \neq Y_{xj}$

In reality, we observe relationships and differences that lead us to assumptions of causal connections between **x** and **Y**.

These assumptions about reality are represented in the model as hypothesis about:

- **Relationships** between **x** and **Y** or
- **Differences** in **Y** between levels of **x**.

based on the scale level of **x** and **Y**.

These relationship and difference hypotheses can be statistically tested when translated into the format of statistical hypotheses. In the:

- **Null-Hypothesis** (H_0) **no** relationship or difference is formulated
- **Alternative-Hypothesis** (H_A) **a** relationship or difference is formulated.

Therefore, the Data-Collection-Plan already defines a) the type of hypothesis as relationship or difference and b) determines the appropriate statistical tests.

The statistical tests now checks the Null-Hypothesis and indicates whether the H_0 is confirmed or should be rejected in favour of H_A, based on the calculated p-value of the test and the alpha-level, that we have determined in advance.

… is formally divided into the hypotheses H0 vs. HA for their statistical analysis

Selection of the appropriate statistical test for the examination of hypotheses …

x \ Y	Data in 2 Levels (Nominal-Scale)	Data in > 2 Levels (Nominal-Scale)	Data Rank Ordered (Ordinal-Scale)	Data discrete or continuous (Cardinal-Scale)
Data in 2 Levels (Nominal-Scale)	Relationship Hypothesis Chi-Square-Test	Relationship Hypothesis Chi-Square-Test	Difference Hypothesis Wilcoxon-Mann-Whitney-Test	Difference Hypothesis t-Test
Data in > 2 Levels (Nominal-Scale)	Relationship Hypothesis Chi-Square-Test	Relationship Hypothesis Chi-Square-Test	Difference Hypothesis Kruskal-Wallis-Test	Difference Hypothesis ANOVA
Data Rank Ordered (Ordinal-Scale)	Relationship Hypothesis Binary-Logistic-Regression	Relationship Hypothesis Nominal-Logistic-Regression	Relationship Hypothesis Rank Correlation (Spearman) / Ordinal-Logistic-Regression	Relationship Hypothesis Rank Correlation (Spearman)
Data discrete or continuous (Cardinal-Scale)	Relationship Hypothesis Binary-Logistic-Regression	Relationship Hypothesis Nominal-Logistic-Regression	Relationship Hypothesis Rank Correlation (Spearman) / Ordinal-Logistic-Regression	Relationship Hypothesis Product-Moment-Correlation (Pearson) / General Regression

The scale level of **x** and **Y** determines the content of the hypothesis and the selection of suitable statistical tests.

Based on the determined scale level in the Data-Collection-Plan, sigmaGuide automatically generates hypotheses for **xY** pairs and suggests suitable statistical tests.

… depending on the determined scale level of the involved variables x and Y

Automatically generated (univariate) hypothesis for Y and xi, xm and xr …

1.	Risk	Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)]
	10,63%	There is a/ no Difference in the degree of: Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)] between the Levels of: xl_01: Input: Request (cookie) [Levels of: Cookie-Type (Vanilla, Chocolate)] .
	Difference Hypothesis	Wilcoxon-Mann-Whitney-Test/ t-Test

2.	Risk	Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)]
	46,24%	There is a/ no Relationship between: xMR_07: Activity: weigh ingredients [Degree of: Chocolate weight (grams/ g)] and: Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)] according to the Principle: The larger the value of x, the larger (resp. smaller) is the value of Y.
	Relationship Hypothesis	Rank Correlation (Spearman)/ Ordinal-Logistic-Regression/ General Regression

3.	Risk	Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)]
	69,26%	There is a/ no Difference in the degree of: Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)] between the Levels of: xMR_08: Activity: knead ingredients [Levels of: Chef ate chocolate from weighed portion (yes, no)] .
	Difference Hypothesis	Wilcoxon-Mann-Whitney-Test/ t-Test

Hypothesis

In this Chapter we will:
- summarize the most important information from the DEFINE- and MEASURE-Phase and formulate Hypothesis.

These Hypothesis are based on:
- the xY-pairings of the C&E Matrix,
- the information from the Data Collection Plan and
- the prioritization by the related Risks from the C&E Heatmap.

To sort and actualize the Hypothesis in a consecutive order please press: Ctrl + s

… their risk to cause a problem and recommended statistical tests

Analyse

Data Evaluation, Process Performance, Test of Hypotheses, Root Cause Analysis

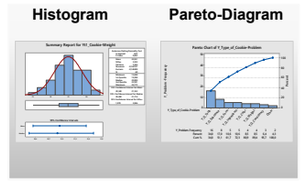
ANALYSE: From the visualization of problems (Y) to the identification of their root causes (x')

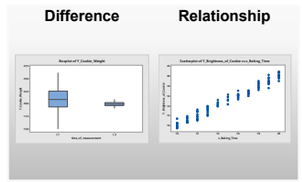
- **Evaluate collected data**
  - Check the plausibility of the collected data and eliminate invalid data
  - Display the data graphically, e.g. with a histogram, pareto-diagram (see the recommendations in the Data-Collection-Plan)

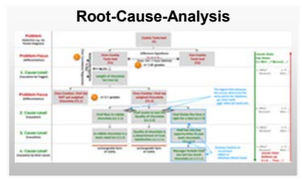
- **Calculate the process capability and monitor process performance over time**
  - Calculate the process capability, e.g. DPMO, Pp/ Ppk, Sigma Level (see the recommendations in the Data-Collection-Plan)
  - Display the process performance over time, e.g. I/ MR Chart (see the recommendations in the Data-Collection-Plan)

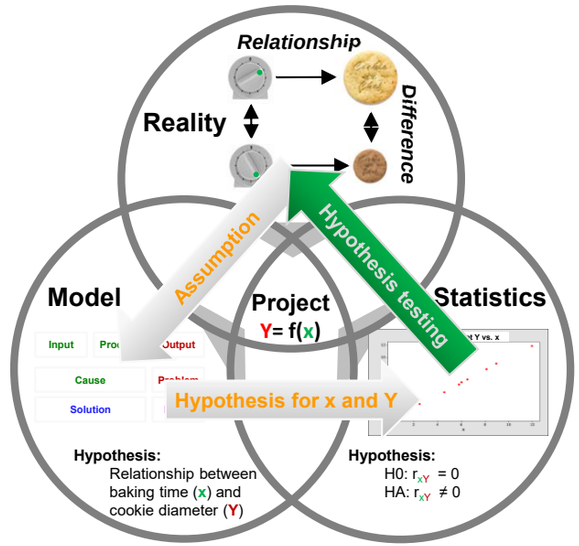
- **Test hypotheses**
  - Select the hypotheses with the highest risks of x-Y pairs (see the risks in the hypotheses)
  - Test the selected hypotheses (see the recommended statistical tests in the hypotheses)
    - Prioritize the problems (Y) by difference hypotheses
    - Identify causes of the triggering influences (x > x' >...) with relationship hypotheses, if data are available

- **Identify root causes**
  - If the root causes could already be identified by statistical tests based on data, then go to IMPROVE
  - Identify causal chains from the influences (x) of problems to their root causes (x') using root cause analysis









By testing the hypotheses we can **confirm** or **reject** our modelled **assumptions** about causal relationships in reality.
However, the **statistics do not provide any proof of causality**, but merely support the usefulness of our assumptions in the model.

Summary ANALYSE: root causes (x') of problems (Y) identified

Outlook IMPROVE: develop solutions to eliminate, adjust or circumvent the root causes (x')

Input of collected data, correction of invalid and useless data and …

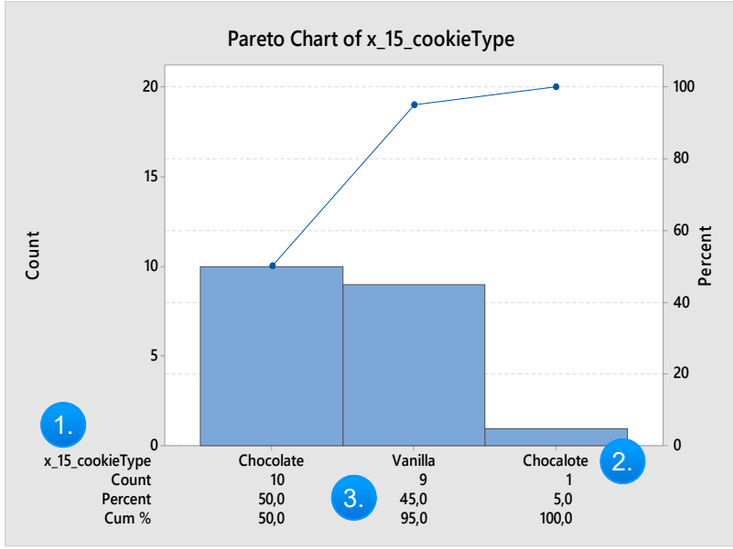
Excel

	A	B	C
	Y_07_cookieDiameter	x_15_cookieType	x_16_Date
	10,5	Vanilla	28.08.2018
	10,2	Vanilla	28.08.2018
	9,9	Vanilla	28.08.2018
	8,7	Chocolate	29.08.2018
	13,8	Chocalote	29.08.2018
	11,1	Chocalote	29.08.2018
	11,0	Chocolate	29.08.2018
	10,1	Vanilla	30.08.2018
	9,8	Vanilla	30.08.2018
	10,O	Vanilla	30.08.2018
	10,3	Vanilla	30.08.2018
	9,9	Vanilla	30.08.2018
	10,1	Vanilla	30.08.2018
	13,9	Chocolate	31.08.2018
	8,8	Chocolate	31.08.2018
	9,1	Chocolate	31.08.2018
	8,7	Chocolate	31.08.2018
	8,6	Chocolate	31.08.2018
	8,9	Chocolate	31.08.2018
	14,1	Chocolate	31.08.2018
		Chocolate	31.08.2018

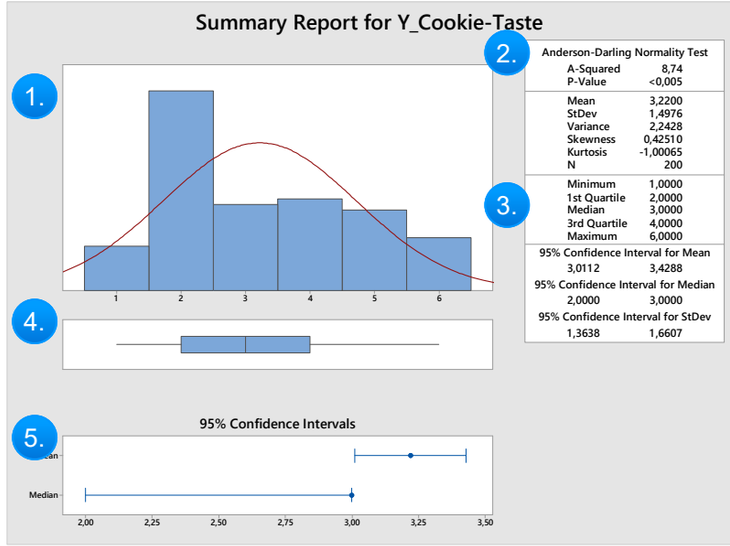
Minitab

C129	C130-T	C131-D
Y_07_cookieDiameter	x_15_cookieType	x_16_Date
10,5	Vanilla	28.08.2018
10,2	Vanilla	28.08.2018
9,9	Vanilla	28.08.2018
8,7	Chocolate	29.08.2018
13,8	Chocalote	29.08.2018
11,1	Chocolate	29.08.2018
11,0	Chocolate	29.08.2018
10,1	Vanilla	30.08.2018
9,8	Vanilla	30.08.2018
*	Vanilla	30.08.2018
10,3	Vanilla	30.08.2018
9,9	Vanilla	30.08.2018
10,1	Vanilla	30.08.2018
13,9	Chocolate	31.08.2018
8,8	Chocolate	31.08.2018
9,1	Chocolate	31.08.2018
8,7	Chocolate	31.08.2018
8,6	Chocolate	31.08.2018
8,9	Chocolate	31.08.2018
14,1	Chocolate	31.08.2018

1. Name problems and influences according to the Data-Collection-Plan, with a meaningful name, with a **Y** in front of the problems and an **x** in front of the influences, supplemented by index numbers.
2. Delete additional rows you may have inserted to structure the table.
3. Make sure that related data columns have the same length. If necessary, delete unneeded entries at the end of a column.
4. Format the data in the Excel table if, e.g., Minitab uses the **T** to display an attributive variable, although they are numeric data.
5. Correct obvious input errors, like the wrong **O** instead of the correct **zero**, which are indexed in Minitab with an asterisk as missing data.



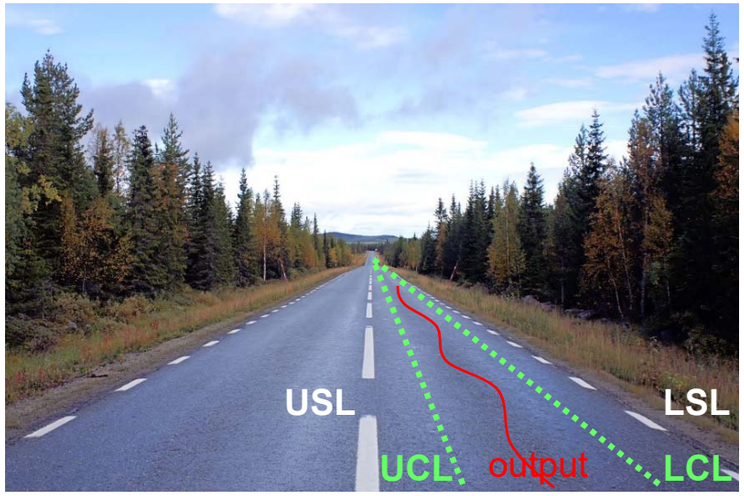
1. Count, percentage proportions and cumulative percentage proportions of cookie types in the sample
2. Wrong spelling - Chocalote - and therefore input errors. Correct wrong entries in the raw data before you proceed.
3. The frequency of chocolate and vanilla cookies in the sample is approximately the same



1. Distribution of the: Taste ratings in a Histogram with a corresponding expected normal distribution curve (1= very good; 6= very bad)
2. Anderson-Darling Normality Test shows a significant result; (p< 0,005), meaning: data are not normally distributed. Additionally important statistics are shown: Mean, Standard Deviation, Median, …
3. Data are in the expected range, from 1 to 6; data outside this range would be invalid
4. Box-Plot of the Distribution (Histogram seen “from above”)
5. Confidence Intervals for the Mean and Median. It means, that with a probability of 95% the Mean/ Median in the population will be within this range.

… plausibility check of the data in the pareto-chart and histogram

Process control refers to the actual performance in relation to "historically" derived control limits



Prozess Control:

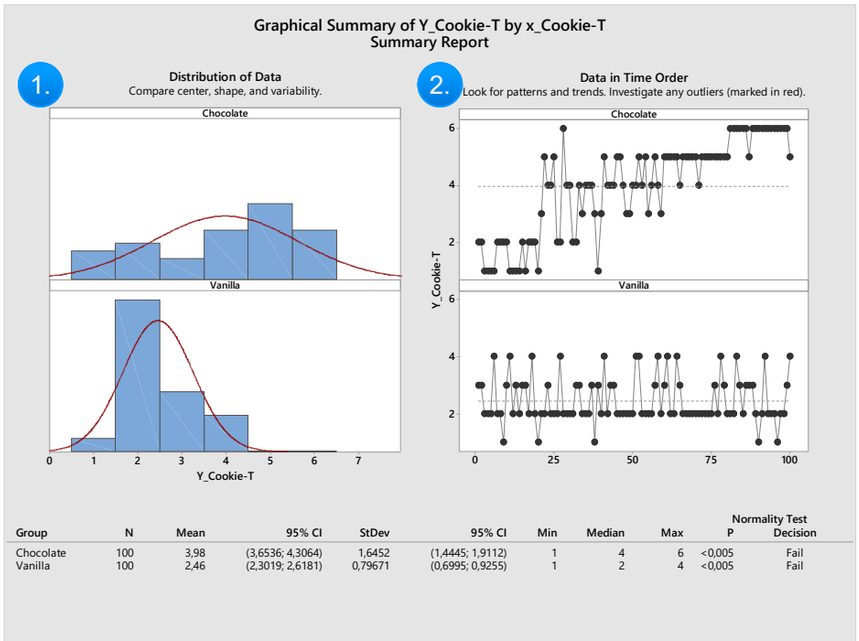
- Focuses on systematic anomalies of individual outputs over time
- Relates the sequence of outputs to control limits (e.g. xbar +/- 3s) and signals in the data
- Control limits are calculated from the variation of the outputs and thus reflect the outputs of the past
- Depending on the extent of variation and the range of values, the following are relevant:
  - Upper Control Limit (UCL)
  - Lower Control Limit (LCL).
- Systematic influences are identified via the control limits and further tests on signals
  (patterns and trends)

Process Capability:

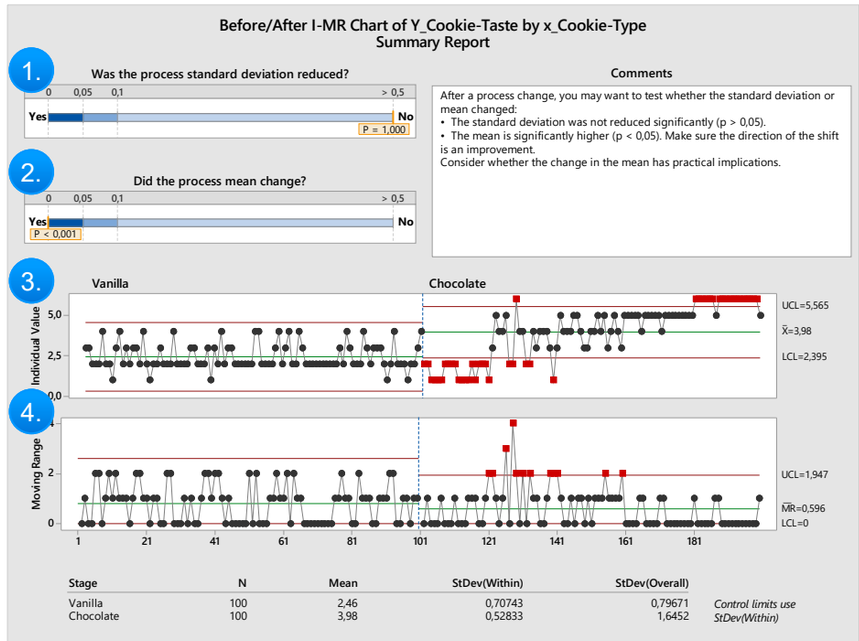
- Focus on the location (e.g. mean) and dispersion (e.g. standard deviation) of outputs over time
- Relates the location and dispersion of the outputs to specification limits and/or a target value (:= target)
- Specification limits are based on requirements from "outside", e.g. from customer
- Depending on the requirement and the value range, the following are relevant:
  - Upper Specification Limit (USL)
  - Lower Specification Limit (LSL)
  - Target value
- The level of process capability indicates:
  - how large the distance of the outputs to the specification limit(s) is and
  - how well the target is met.

Process capability refers to the actual performance in relation to externally specified limits

Distribution and time series of the taste ratings for Chocolate and Vanilla Cookies

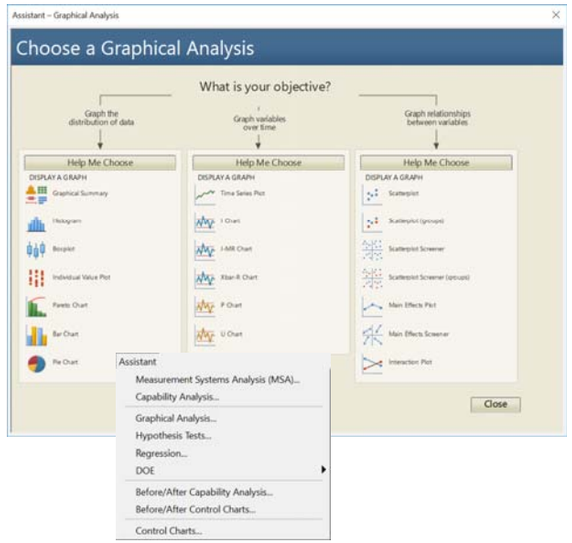


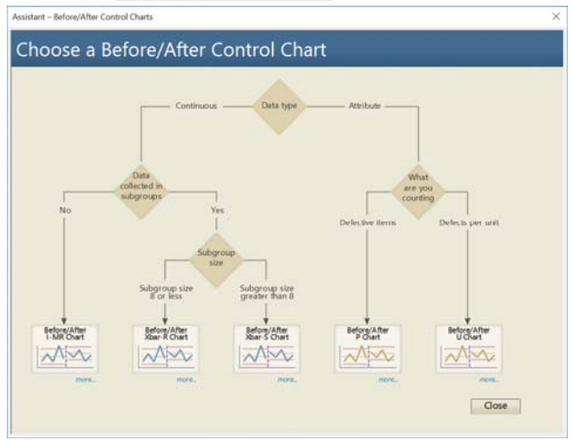
1. Histograms for Chocolate and Vanilla Cookies with the expected overlaid normal distribution curve (N=100), indicating
   a) deviation from the normal distribution (p< 0,005)
   b) different means (3,98 vs. 2,46),
   c) different standard deviations (1,645 vs. 0,796),
   d) within the expected data range from: 1= very good to 6= very bad
2. Time series plots for Chocolate and Vanilla Cookies: the course of data shows, that the rating of Vanilla Cookies is stationary over time, varying around the value of 2, while the rating of the Chocolate-Cookies decreases in the range from 2 (good) to 6 (very bad)



I-MR (**Individual/ Moving Range**) Control Chart for before-after comparisons, applied to compare the Taste of Van.- and Choc.-Cookies

1. The standard deviations of both cookie types do not differ significantly (p= 1)
2. The means of both cookie types differ significantly (p< 0,001)
3. The **Individual Values** chart shows many outliers (red), i.e. ratings that are outside the control limits, overall indicating a shift in the ratings from good to bad and thus a decrease of the performance
4. The **Moving Range** chart shows some noticeable changes from cookie to cookie (red)





The time series plot and the I-MR chart show, that the Taste of Chocolate Cookies (Y) decreases over time

Calculate the capability of your process for …

Indices of Process Capability			
Calculation of Process Capability based on Units, Defects and Opportunities for Defects			
Definitions	**Symbol**		**Enter Your Data**
Units	**U**		1.000.000
Defects	**D**		3,40
Opportunities for a defect	**O**		1
Number of operation steps	**m**		
defective Units	**Symbol**	**Calculation**	**Result**
Defects per Unit	DPU	D/ U	0,0000034
Defect Parts per Million	PPM	D/ U x 10^6	3,40
Defects per Unit			
Total Opportunity	TOP	U x O	1.000.000
Defects per Unit Opportunity	DPO	DPU/ O	0,0000034
Defects per million Opportunity	DPMO	DPO x 10^6	3,4000000
without consideration of the Opportunities			
Yield (%)		(1- DPU)* 100	99,9996600
Defect (%)		100 - Yield	0,0003400
for prediction of long-term Sigma-Level from short-term measurement	Sigma-Level (long-term)	z-Value	4,50
for prediction of short-term Sigma-Level from long-term measurement	Sigma-Level (short-term)	z-Value + 1,5	6,00
with consideration of the Opportunities			
Yield (%)		(1- DPO)* 100	99,9996600
Defect (%)		100 - Yield	0,0003400
for prediction of long-term Sigma-Level from short-term measurement	Sigma-Level (long-term)	z-Value	4,50
for prediction of short-term Sigma-Level from long-term measurement	Sigma-Level (short-term)	z-Value + 1,5	6,00

Conversion of Yield% into corresponding z-Values (Sigma-Level) and vice versa			
Enter Your Data		**Sigma-Level (long-term)**	**Yield (%)**
	Conversion: Sigma - Yield	4,50	99,99966023269%
	(Data from long-term study)	0,00	50,00000000000%
		Sigma-Level (short-term)	**Yield (%)**
	Conversion: Process-Sigma - Yield	6,00	99,99966023269%
	(Data from short-term study)	1,50	50,00000000000%

Calculation: Pp/ Ppk and Sigma-Level			
Parameter	**Enter Your Data**	**Sigma-Level (solely based on dispersion - unusual)**	**Pp**
Lower Specification Limit (LSL)	1,00	2,47	0,82
Upper Specification Limit (USL)	4,00	**Sigma-Level (based on position & dispersion - usual)**	**Ppk**
Mean (xbar)	3,98		
Standard Deviation	1,65	0,03	0,01

Data is nominal scaled:

If you know the number of units and defects then you can calculate: Yield, DPU, ppm and the Sigma Level

If you know the number of units, defects and the opportunities for defect, then you can calculate: DPO, DPMO and the Sigma Level

Data is given as percentual Yield or as Sigma Level:

Data is cardinal scaled and normal distributed:

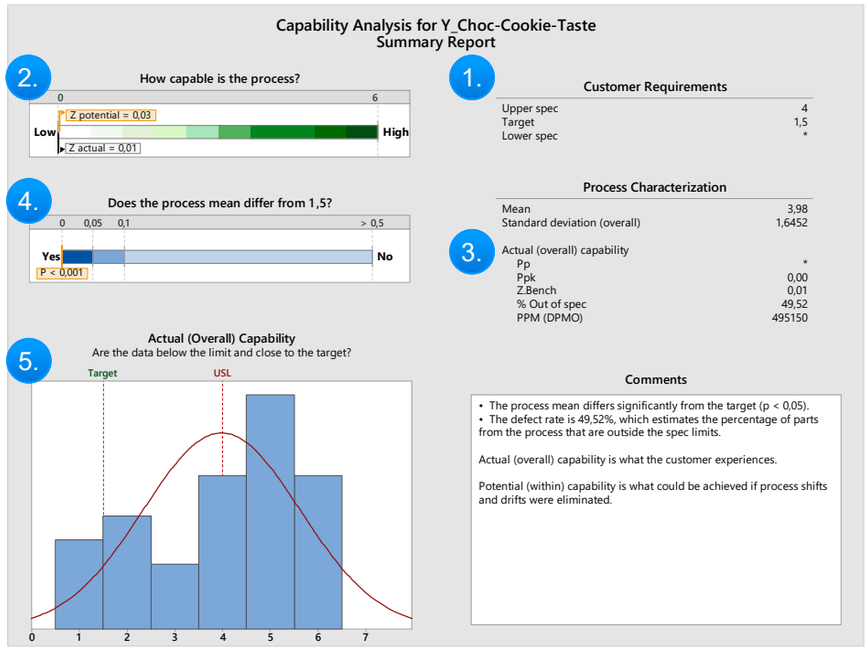
Pp/ Ppk and Sigma Level as an approximation of Z.bench (Interpretation of ordinal scaled, normal distributed data under reservation)

Mikel Harry (1988) of Motorola found in long-term studies that processes vary more over time and change their position because there is a greater chance of extreme values occurring. Typically, long-term studies have a shift of 1.5s compared to short-term studies. To predict long-term performance from a short-term study, the short-term performance is subtracted 1.5s. Conversely, this results in a z value of 4.5 Sigma (a long-term measurement) Motorola's 6 Sigma (for a short-term measurement).

**** Harry, M.J. (1988): The Nature of Six Sigma Quality; Motorola University Press**

… nominal scaled values, percent values and cardinal scaled values

How good is the taste of the critical Chocolate-Cookies (Y)



Because the rating data are not normal distributed, the statements about the process capability should be interpreted with caution.

But we are sure, that we have to improve the taste at least of the Chocolate Cookies.

The bimodal distribution with the two peaks indicates, that there were already conditions for a better process capability (see the shift between the first and last cookies in the time series plot).

The process capability analysis shows:

1. The customer requirements are defined as specification limits on the rating scale of taste (see Data Collection Plan)
   - Upper specification limit (USL):= 4
     (Taste should not be rated worse than 4:= adequate)
   - Target:= 1,5 (:= very good/ good)

2. The Z-Values indicate the actual and the potential Process Capability:
   - Z actual= actual Sigma Level= 0,01
   - Z potential= potential Sigma Level= 0,03
   (The rating of taste of Chocolate Cookies is far away from 6 Sigma)

3. Different Parameter of Process Capability:
   - Pp (process performance): not calculated due to the missing LSL
   - Ppk (k= katayori= centre) = 0,00
   - Z.Bench = 0,01
   - % Out of specification = 49,52%
   - PPM / DPMO = 495150
   These parameter focus on different aspects of process capability

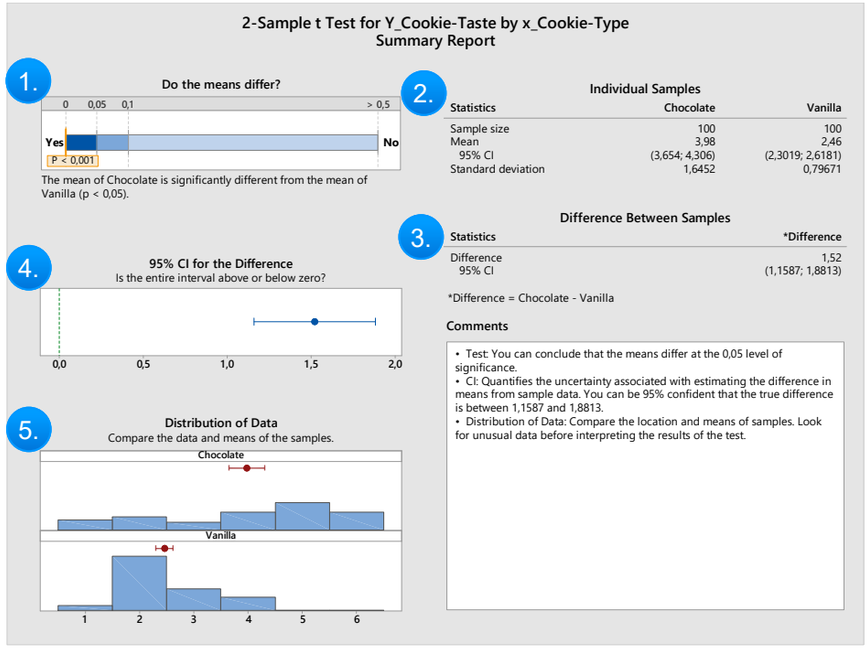
4. The (one-sample-t-) Test indicates a significant difference between the mean of the rating of taste (= 3,98) and the target (= 1,5). We can conclude, that our next cookies would also **not** achieve the target, if we do **not** change the process.

5. The histogram shows a bimodal distribution and the Anderson-Darling Normality Test (not shown here) indicates a significant result, meaning that the data for the Chocolate Cookies are also not normally distributed. This means: interpretation of the results under reserve

Focus is now on the difference of Taste between Chocolate- vs. Vanilla-Cookies (Y)

1. Hypothesis: There is a difference in Taste (Y) between Cookie-Types (x)

1. Risk	Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)]
10,63%	There is a/ no Difference in the degree of: Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)] between the Levels of: xl_01: Input: Request (cookie) [Levels of: Cookie-Type (Vanilla, Chocolate)] .
Difference Hypothesis	Wilcoxon-Mann-Whitney-Test/ t-Test



The tests of the hypothesis with the t-Tests shows:

1. A significant difference in the rated Taste between Chocolate vs. Vanilla Cookies ($p < 0{,}001$)

2. Statistics for the Taste of the two types of cookies:
   - Vanilla: n= 100, mean/ xbar= 2,46, s= 0,796
   - Chocolate: n= 100, mean/ xbar= 3,98, s= 1,645

3. Difference between the means in the sample (1,52) and the corresponding confidence interval (CI= 1,1587; 1,8813) for the population **

4. The Interval Diagram plots the difference between the means and the related confidence interval for the difference

5. The two histograms show the distribution of the rating data, with their means and the related confidence intervals for the means

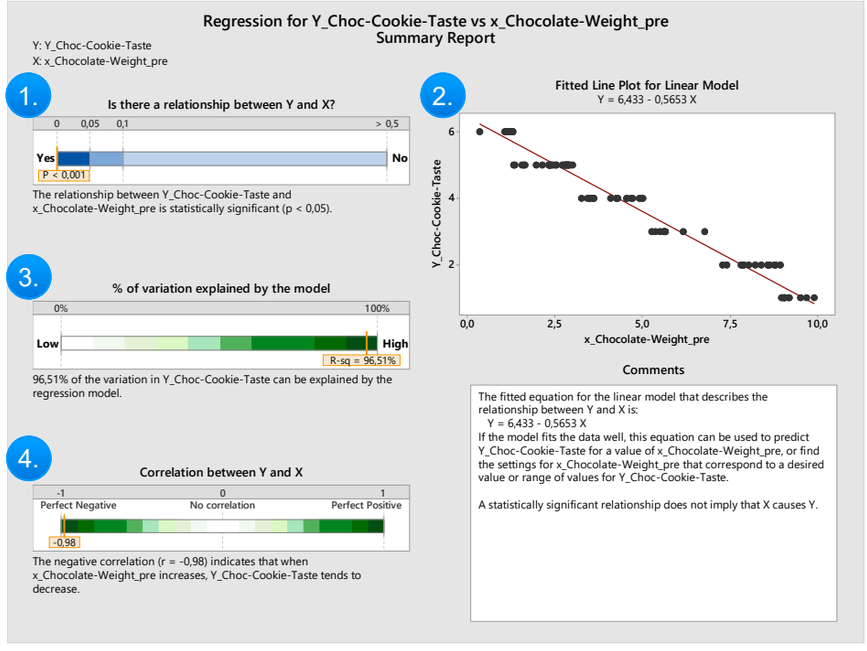
** Data are not normally distributed; interpretation of results under reserve

The t-Test shows, that there is a significant difference of 1,52 grades on the rating scale of Taste.
Our customer likes the Vanilla Cookies more than the Chocolate Cookies. The Chocolate Cookies have a problem!

Focus is now on the negative influences (x) on the Taste of Chocolate Cookies (Y)

2. Hypothesis: There is a relationship between the amount of chocolate (x) and the rating of Taste (Y)

2.	Risk	Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)]
	46,24%	There is a/ no Relationship between: xMR_07: Activity: weigh ingredients [Degree of: Chocolate weight (grams/ g)] and: Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)] according to the Principle: The larger the value of x, the larger (resp. smaller) is the value of Y.
	Relationship Hypothesis	Rank Correlation (Spearman)/ Ordinal-Logistic-Regression/ General Regression



The tests of the hypothesis with the Regression Analysis shows:

1. A significant relationship between the weight of chocolate in the Cookies and the rating of their Taste ($p < 0,001$)

2. The Fitted Line Plot (scatter plot with a regression line) shows a linear relationship between the weight of chocolate in the cookies (x) and the rating of their Taste according to the regression equation:
Choc-Cookie-Taste= 6,433 - 0,5653 x Weight of chocolate in cookie
(The more chocolate the better the rating of taste)

3. The strength of the relationship between weight of chocolate and Taste is expressed by R-square/ R^2 (Determination-Coefficient).
In this example 96,51% of the variation of the rating of the Taste can be explained by the variation in chocolate weight, i.e.: the weight of chocolate is a strong determinant of the rating of Taste.

4. The negative correlation of r= -0,98 (r^2= 96%, see 3.) confirms the negative relationship in the regression equation and the Fitted Line Plot: the higher the value of x, the lower (better) the value of Y

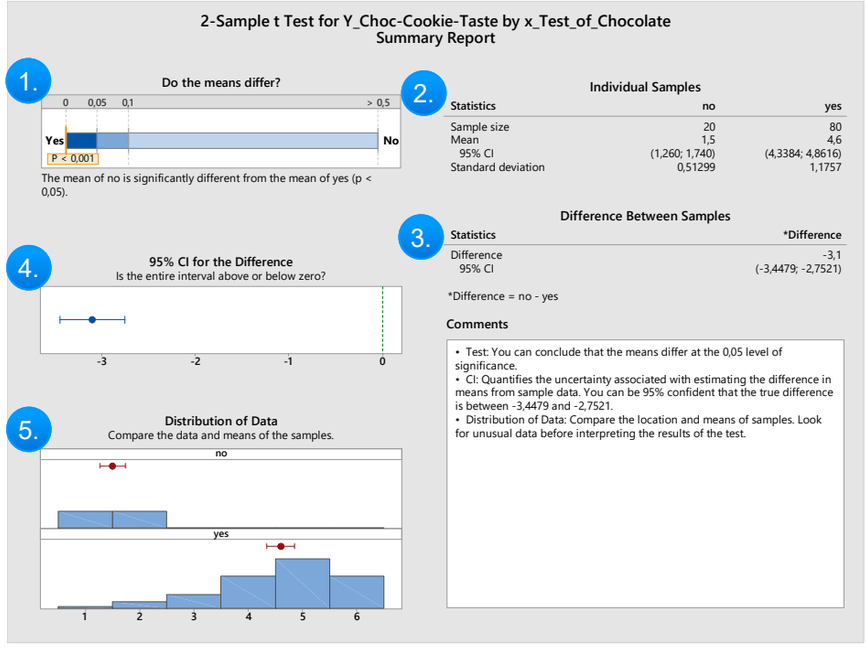
** Data are not normally distributed; interpretation of results under reserve

The regression analysis shows, that there is a significant and very strong relationship between the amount of chocolate in a Chocolate Cookie and the rating of its Taste: the more the better – within the investigated range of the scales.
Our customer likes the chocolate in the chocolate cookies. Why does the amount chocolate in the cookies vary?

Focus is now on the influences (x) on the variation of the amount of chocolate in Chocolate Cookies (Y)

3. Hypothesis: There is a difference in the Taste of a Chocolate Cookie (Y) between the conditions the Chef eats the chocolate from ingredient vs. not (x)

3. Risk	Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)]
69,26%	There is a/ no Difference in the degree of: Y_01: Output: Cookies (baked) [Ranking Position of: rating-scale (grades 1 .. 6)] between the Levels of: xMR_08: Activity: knead ingredients [Levels of: Chef ate chocolate from weighed portion (yes, no)] .
Difference Hypothesis	Wilcoxon-Mann-Whitney-Test/ t-Test



The tests of the hypothesis with the t-Tests shows:

1. A significant difference in the Taste of the Chocolate-Cookies between the conditions: Chef ate chocolate from ingredients: yes vs. no (p < 0,001)
2. Statistics for the two conditions:
   - ate Choc: no: n= 20, mean/ xbar= 1,5, s= 0,51299
   - ate Choc: yes n= 80, mean/ xbar= 4,6, s= 1,1757
3. Difference between the means in the sample (- 3,1) and the corresponding confidence interval (CI= -3,45; -2,75) for the population
4. The Interval Diagram plots the difference between the means as well as the confidence interval for the difference**
5. The two histograms show the distribution of the rating data, with their means and the related confidence intervals of the means.

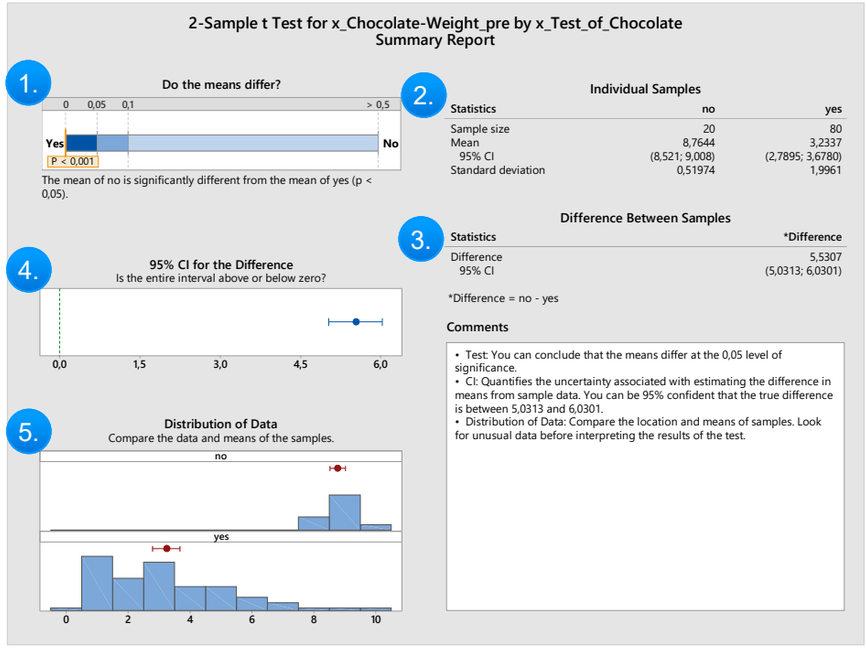
**Data are not normally distributed; interpretation of results under reserve

The t-Test shows, that there is a significant difference of 3,1 grades on the rating scale of Taste.
If the Chef eats the already weighed chocolate, then the rating of taste of the resulting Chocolate-Cookies decreases!

Focus is now on the root causes (x´) of eating chocolate from the ingredients (x)

4. Hypothesis: There is a difference in: the amount of chocolate in (x) in the Chocolate Cookies between the conditions: Chef eats the chocolate from the ingredients vs. not (x)

4. There is a difference in: (Y)	between: Levels of (x)	Scale Level of Y	Scale Level of x	Graphical Representation:	Statistical Test:
The amount of chocolate in (x) in the Chocolate Cookies	*Chef eats chocolate from the ingredients vs. not (x)*	*cardinal*	*nominal*	*Box-Plot*	*t-Test*



The tests of the hypothesis with the t-Tests shows:

1. A significant difference in: the amount of chocolate in the Chocolate Cookies (x) between the conditions: Chef eats chocolate from the ingredients: yes vs. no (x) ($p < 0{,}001$)
2. Statistics for the two test conditions:
   - ate Choc: no: n= 20, mean/ xbar= 8,76; s= 0,51
   - ate Choc: yes n= 80, mean/ xbar= 3,23; s= 1,99
3. Difference between the means in the sample (5,53) and the corresponding confidence interval (CI= 5,03; 6,03) for the population
4. The Interval Diagram plots the difference between the means as well as the confidence interval for the difference**
5. The two histograms show the distributions of the rating data, with their means and the related confidence intervals of the means.

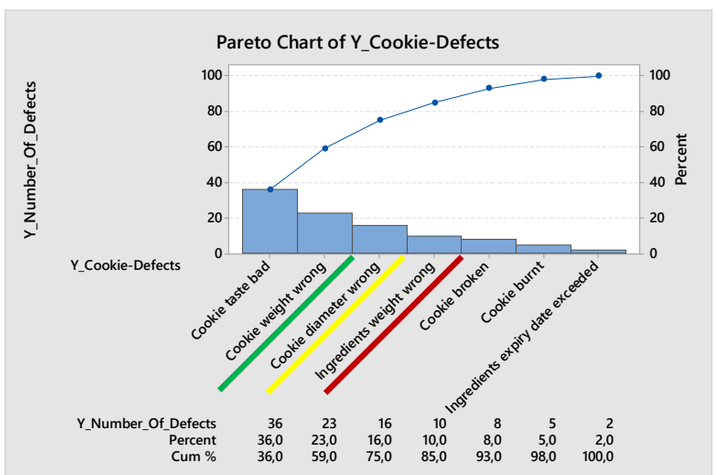
**Data are not normally distributed; interpretation of results under reserve

The t-Test shows, that there is a significant difference of 5,5 grams chocolate in Chocolates Cookies.
If the Chef eats chocolate from the ingredients, then the weight of chocolate in Chocolate Cookies decreases!

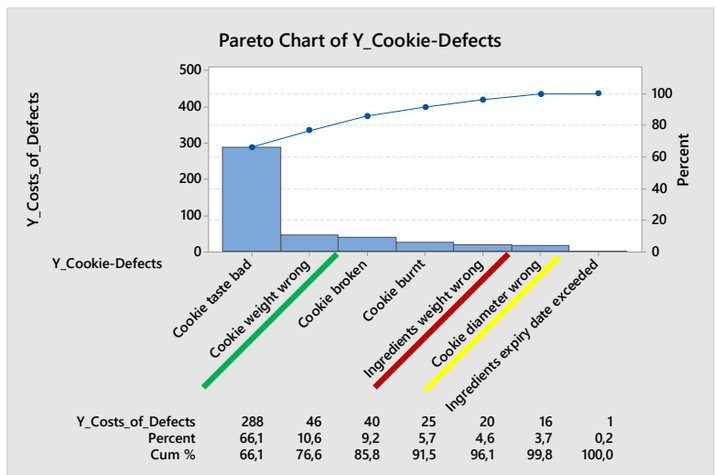
The result confirms: Eating chocolate from the ingredients (x) reduces the taste of Cookies (Y)

Analysis strategy: Prioritize the problems and focus on important problems …

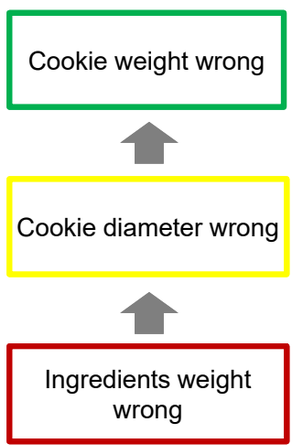
Process-Mapping-Analysis of the Process: bake cookies								
Who …	… does what?	Please specify the Process-Steps in detailed Activities the format: Verb + Noun (e.g.: weigh Ingredients)						
		1. Activity	2. Activity	3. Activity	4. Activity	5. Activity	6. Activity	7. Activity
Process-Steps	Chef	determine order	weigh ingredients	knead ingredients	roll out the dough	shape cookies	bake cookies	box cookies
			Ingredients weight wrong			Cookie diameter wrong		Cookie weight wrong
Which Influences of the: - Methods and - Resources negatively affect:	… the Quality	order misinterpreted	scale wrong calibrated			variable manual sizing		
	… the Availability	customer not available for clarification of order	waiting for missing ingredients	laborious manual kneading		laborious manual shaping	oven occupied and not available	tins not available
	… the Consumption	clarification with the customer	clarifications about missing ingredients	laborious manual kneading		laborious manual shaping		



Prioritization according to problem frequency



Prioritization according to problem costs



Prioritization according to problem dependencies

Basic prioritization criterion:
- Severity of Problems (Voice-to-Critical)

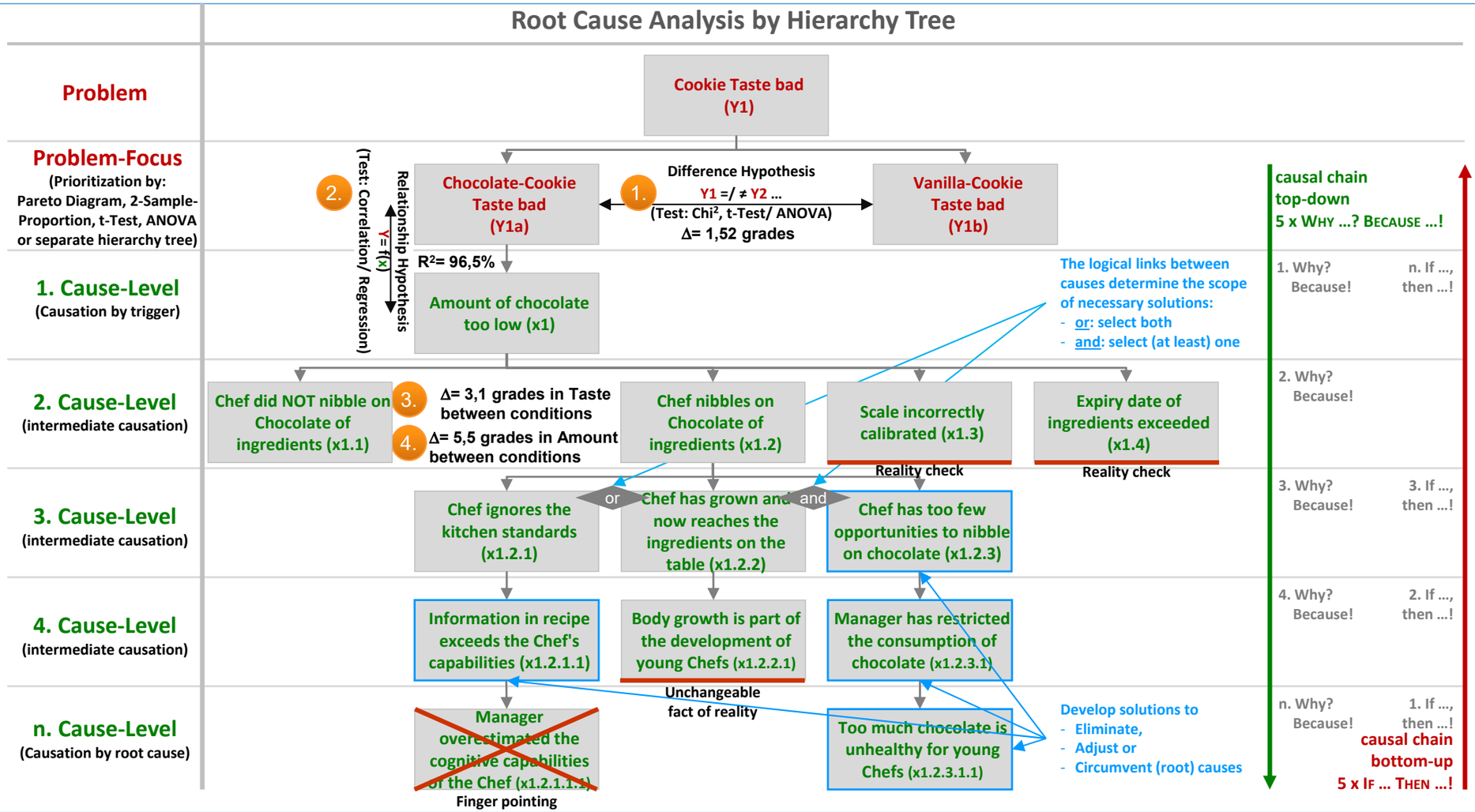
Prioritize between categories:
- Quality problems have priority
- Quality problems can lead to availability problems for necessary corrections and feedback loops
- Corrections and feedback loops consume at least human resources
- Availability problems often result from the sum of many small delays in several activities. Quality problems are often triggered by exactly one activity

Prioritize within categories:
- The Pareto diagram gives an initial indication of the priority of the problems based on their frequencies or costs
- If there are dependencies between the problems, the most frequent or expensive does not need to have the highest priority

Methods for prioritization:
- Depended problems: Relationships and priorities can be uncovered by plausibility considerations, a corresponding hierarchy tree, confirmed by correlation/ regression. Start with the root problem.
- Independent problems: Pareto chart, Chi^2-test, t-Test or ANOVA help to identify the largest deviation as the starting point.

… between and within problem categories (Quality, Availability, Consumption)

Analysis strategy: Combine quantitative statistical results and logical arguments …



Analysis strategy

- Create a tree for each problem
- Identify the trigger for this problem and break it down to its root causes
- Combine statistical results from the hypotheses tests with experts' assumptions, if no data are available
- Ask "Why?" questions to a given cause and note the "Because!" answers as assumptions of underlying causes
- Typically, 5 "Why -Because" levels are recommended to identify the root causes
- Test the assumptions statistically if corresponding data are available
- For quality problems sometimes more than 5 cause-levels are needed
- Availability and consumption problems sometimes need less than 3 levels
- Stop the analysis (of a branch) if:
  - Reality checks are necessary
  - Root causes are identified
  - The next cause will be related to a person which allows finger pointing
  - unchangeable facts of reality are identified
  - Identified causes explain 80% of the problem frequency
- Question assumed causes that contain: no, not, none or the prefix un- (**Solutions?**)

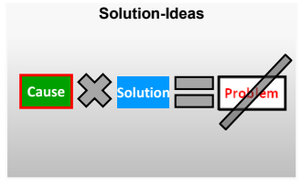
… to identify root causes by (statistically confirmed) assumptions about causal relationships

IMPROVE

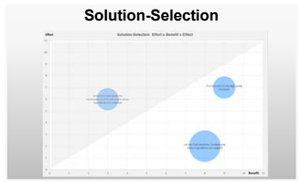
Development and selection of Solutions, Measures and risk prevention, Implementation

IMPROVE: From the development of solution ideas for the (root) causes (x) to the implementation of suitable measures

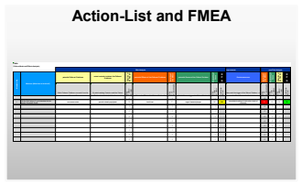
- **Develop solution ideas**
  - Focus on the selected root causes of the root cause analysis
  - Find solution ideas to eliminate, adjust or circumvent these root causes



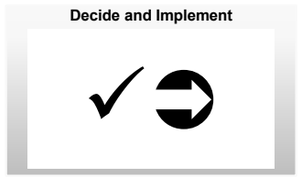
- **Evaluate the solution ideas and select suitable and beneficial solutions**
  - Discuss pros and cons of the solution ideas and derive practicable solutions (Creativity-Techniques)
  - Evaluate solution ideas according to their effort/ benefit ratio (Solution-Selection-Matrix)



- **Specify solutions as measures and minimize their risks**
  - Specify measures for the selected solutions and decide: Who? Does what? Until when? (Action-List)
  - Identify and minimize risks that may arise from the measures (FMEA)



- **Decide on measures and implement them**
  - Present the measures to your Sponsor and let him/ her decide on their implementation
  - Implement measures



Summary IMPROVE: Suitable measures specified and then implemented

Outlook Control: Verification of the improvement, development of a process management plan, completion of the project

Develop solution ideas to eliminate, adjust or circumvent the root causes,

Creativity techniques	
6-3-5 Method (Brainwriting)	6 participants note 3 ideas each on their worksheet. Then they pass it to the respective neighbours. They add their own 3 connotations. After moving 5 times the worksheets arrive at the source again. Result: 108 ideas in 30 min.
Six Thinking Hats	Separation of motives guiding cognitive processes into six consecutive phases, marked by different colours (hats for the particpants)
Morphological Analysis	New design variants for given objects, such as products and services, based on new combinations of the characteristics of their attributes
TRIZ	Problem solving method to overcome trade-offs or dilemma between contradictory objectives or elements

Overview of selected creativity techniques

Morphological Analysis				
Attributes	**Characteristics**			
dough type	yeast dough	shortcrust pastry	puff pastry	
basic flavour	sweet	salty	spicy	sour
diameter	5 cm	10 cm	15 cm	20 cm
shape	round	oval	rectangular	quadradratic
topping	chocolate	dragées	nuts	tomatoes

Example of a morphological analysis

Design of Experiments (DoE)				
		Amount of chocolate (x2)		
		80g (x2.1)	100g (x2.2)	120g (x2.3)
Type of chocolate (x1)	full milk (x1.1)	Y1 ratings Y2 costs		
	dark (x1.2)			

Example of a Design of Experiments

Search for Solutions				
	Root-Causes (Branches of Hierarchy Tree)	**Solution Ideas**	**Objection**	**Solution**
Y_01 | Problem: Cookies Taste bad	Chef has too few opportunities to nibble on chocolate (x1.2.3)	Keep the Chef away from the bakery	Chef will protest	./.
	Manager has restricted the consumption of chocolate (x1.2.3.1)	Checking the quantity of chocolate just before mixing it into the dough and, if necessary, compensating for the missing chocolate	Considerably higher effort, further waiting times expected at the scale	./.
	Too much chocolate is unhealthy for young Chefs (x1.2.3.1.1)	Weigh more chocolate in advance to compensate for the Chef's nibbling	Unclear how much more chocolate has to be weighed; the amount will vary if the Chef has different amounts of nibbles in each case	Chef may weigh herself an extra portion of chocolate; she is also informed about the importance of the ingredients for the taste of the cookies
	Information in recipe exceeds the Chef's capabilities (x1.2.1.1)	Translate standard recipes for children; detailed description of activities illustrated with images	Acceptance of standards are low if they specified externally and then prescribed	Chef documents the baking process for standard recipes with her own photos and drawings; Manager coaches the creation of this standard baking book for the Chef

Search for Solutions by combining brainwriting and Six Thinking Hats

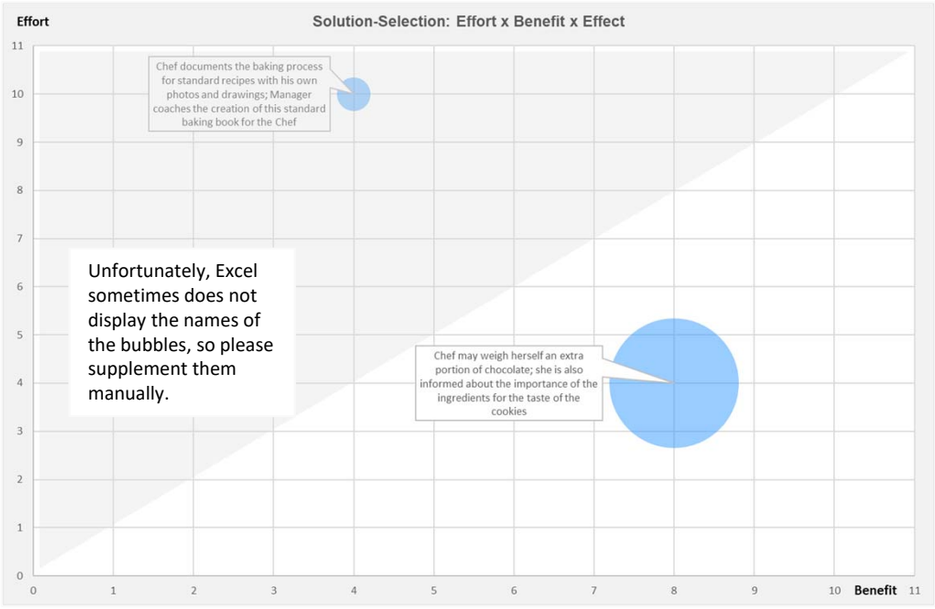
… identify objections and reformulate ideas to practicable solutions

Select the problem, transfer the root causes, the related solutions and evaluate the solutions

Rank	Kano-Category	Costs of the Problem/ Year:	Problem	Root-Causes	Cause determines the Problem to:	Sum of Determination	Solutions	Benefit	Effort	Rank (Effort/ Benefit)	Reduction of Problem-Costs
1	Must-Be	100,00 €	Y_01 | Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND	x1.2.3 Chef has too few opportunities to nibble on chocolate x1.2.3.1 Manager has restricted the consumption of chocolate x1.2.3.1.1 Too much chocolate is unhealthy for young Chefs	75%	80%	Chef may weigh herself an extra portion of chocolate; she is also informed about the importance of the ingredients for the taste of the cookies	8	4	1	75 €
				x1.2.1.1 Information in recipe exceeds the Chef's capabilities	5%		Chef documents the baking process for standard recipes with his own photos and drawings; Manager coaches the creation of this standard baking book for the Chef	4	10	2	5 €
								...?	...?		./. €
								...?	...?		./. €
								...?	...?		./. €
								...?	...?		./. €
								...?	...?		./. €
								...?	...?		./. €
								...?	...?		./. €
								...?	...?		./. €

- Select the problem
- Estimate the quality costs of the problem
- Transfer the root causes of the branches of the hierarchy tree
- Estimate the percentual determination of the problem by root causes.
- Transfer the identified solutions
- Evaluate the relative benefits and efforts of the solutions

The ranking and the reduced costs give you hints for the selection of appropriate solutions.



The Chart Solution-Selection shows all Solutions in an:
Effort x Benefit diagram.

The **size of bubbles** correspond to the effect of the solutions,
i.e. the reduced costs.

Recommended are all solutions of the lower half triangle, where the benefit is greater than the effort.

Nevertheless, there may be reasons to choose solutions of the upper half triangle as well.

Solutions

After the identification of the Root-Causes the Solutions can now be developed.
Depending on the Type of Cause the Solution can serve to:
- eliminate,
- adjust or
- circumvent a Root-Cause.

At first focus on the Problems with the highest Priority.
1. Calculate the Quality-Costs, which are caused by the Problem or at least estimate them.
2. Enter the identified Root-Causes.
3. Evaluate how strong the Problem is determined by each Root-Cause.
4. The Sum of Determination indicates the portion, how strong all Root-Causes together determine the Problem.
5. Develop a Solution-Ideas which could manage the Root-Cause.
6. Evaluate the Benefit of the Solution, i.e. the contribution of the Solution to eliminate, adjust or circumvent the Root-Cause.
7. Evaluate the Effort for the Solution, i.e. the necessary consumption (time/ costs) to implement the Solution.
8. The Effect shows the product: Quality-Cost x Determination of the Problem, i.e.:
   If the Solution is suitable, then the Quality-Costs of the Problem will be reduced by this amount.
9. The Rank of a Solution results from the relation: Effort/ Benefit, i.e.:
   The higher the Effort of a Solution is in relation to the Benefit of the Solution, the lower is its rank.

The Chart: Solution Selection shows all Solutions in a Effort x Benefit Diagram.
The size of bubbles correspond to the Effect of the Solutions, i.e.: reduced Quality-Costs.

The ranking and the chart: Solution-Selection prioritize the solutions for their selection

Specify measures to implement the solutions

Action-Plan														
Rank (Effort/ Benefit)	Reduction of Problem-Costs		Solutions	Measure-No.	Measure (What has to be done?)	Result (What will be achieved?)	Risk-Reduction-Measure (from FMEA)	Costs of Implementation	Cost center	Deadline	Responsibility	Decision on implementation	Implementation-Status in %
1	75	€	Chef may weigh herself an extra portion of chocolate; she is also informed about the importance of the ingredients for the taste of the cookies	1.	1. Purchase of additional necessary chocolate 2. Let the chef weigh an additional 10g of chocolate for a nibble 3. Provide this extra portion on a separate plate 4. The chef is informed about the importance of the ingredients for the taste at every baking	Integrity of ingredients ensured	**Immediate brushing of teeth after each test of chocolate**	10,00 €	SiSi123456789	15.11.20xx	Chef	yes	60%
2	5	€	Chef documents the baking process for standard recipes with his own photos and drawings; Manager coaches the creation of this standard baking book for the Chef	2.	1. Purchase of necessary resources for documentation (camera, notebook, pens, etc.) 2. Introduction to operating the camera 3. Determining the activities in the process that are to be documented 4. Printout of photos in the office 5. Creation of the standard (photos, drawings, texts) 6. Training of the new standard	Notebook with step-by-step documented standard recipes	**Pilot the new standard based on one concrete recipe**	60,00 €	SiSi123456789	31.12.20xx	Manager of Chef	yes	20%
	./.	€										...?	...?

Influences that can make implementation more difficult:

- Individual measures are too complex → Break them down into specific tasks and put them in their chronological order
- Expected result of implementation is unclear → Determine the expected result
- Diffuse responsibility for implementation → Determine responsibilities and deadlines
- Resources for implementation are necessary → Inform your Sponsor and let him/her decide
- Resistance to implementation → see Stakeholder-Communication
- Implemented measures are not accepted → Have the Sponsor present the measures to all affected employees before implementation
- Return to previous habits → Let the Sponsor check compliance with new standards after their implementation

Risks of the measures are reduced by:

- Carrying out an FMEA
- Exemplary implementation for a product/service on a line, at a location (piloting)

Decision for the implementation:

The decision for the implementation of the measures is made by the Sponsor (process owners) within the IMPROVE Steering presentation.
Prepare this presentation so well that decisions can be made at the end of the presentation if possible. It is useful to inform participants in advance about the measures to be taken.

Action-Plan

In the action-plan the solutions are specified.

1. Specify in the measures exactly what needs to be done to implement the solutions.
2. Specify the result, which will be achieved by the implementation.
3. Perform an FMEA (see FMEA).
4. Estimate the costs of the task implementation and define the cost center for the payment.
5. Define a deadline for the implementation.
6. Define a responsible person for every measure.
7. Monitor the progress of implementation.

Make sure that a risk analysis (FMEA) for the measures is performed before implementation

Specify the potential failures/ problems of the specified measures, their causes and effects

FMEA (Failure Mode and Effects Analysis)		Risk-Analysis								Improvement	new Risk-Analysis			
Measure-No.	Measure (What has to be done?)	potential Failures/ Problems	actual controls to detect the Failures/ Problems	Detection of the Problem	potential Effects of the Failures/ Problems	Severity of the Effect	potential Causes of the Failure/ Problem	Probability of Cause	RPN	Countermeasures (integrated in Action-Plan)	Severity of the Effect	Probability of Cause	Detection of the Problem	RPN
		Which Failures/ Problems can result from the Measures?	By which existing Controls can the Failure/ Problem be detected, before it occurs?	Rating: 1= each time - 10= never	Which Effect results from the Failure/ Problem?	Rating: 1= minimal - 10= disastrous	Which Influence triggers the Failure/ Problem?	Rating: 1= never - 10= always	Risk-Priority-Number	How could the trigger of the Failure/ Problem, i.e. their Root-Causes be eliminated?	Rating: 1= minimal - 10= disastrous	Rating: 1= never - 10= always	Rating: 1= each time - 10= never	Risk-Priority-Number
1.	1. Purchase of additional necessary chocolate 2. Let the chef weigh an additional 10g of chocolate for a nibble 3. Provide this extra portion on a separate plate 4. The chef is informed about the importance of the ingredients for the taste at every baking	can cause caries	periodic dental prophylaxis	5	tooth loss	8	sugar/ bacterial plaque	10	400	Immediate brushing of teeth after each test of chocolate	8	2	5	80
2.	1. Purchase of necessary resources for documentation (camera, notebook, pens, etc.) 2. Introduction to operating the camera 3. Determining the activities in the process that are to be documented 4. Printout of photos in the office 5. Creation of the standard (photos, drawings, texts) 6. Training of the new standard	Chef still prefers to work after spontaneous ideas	Close monitoring of the Chef during baking	3	cookies do not meet customer requirements	7	New standard has gaps or is still ambiguous and/ or not motivating enough for our Chef	7	147	Pilot the new standard based on one concrete recipe	7	6	1	42

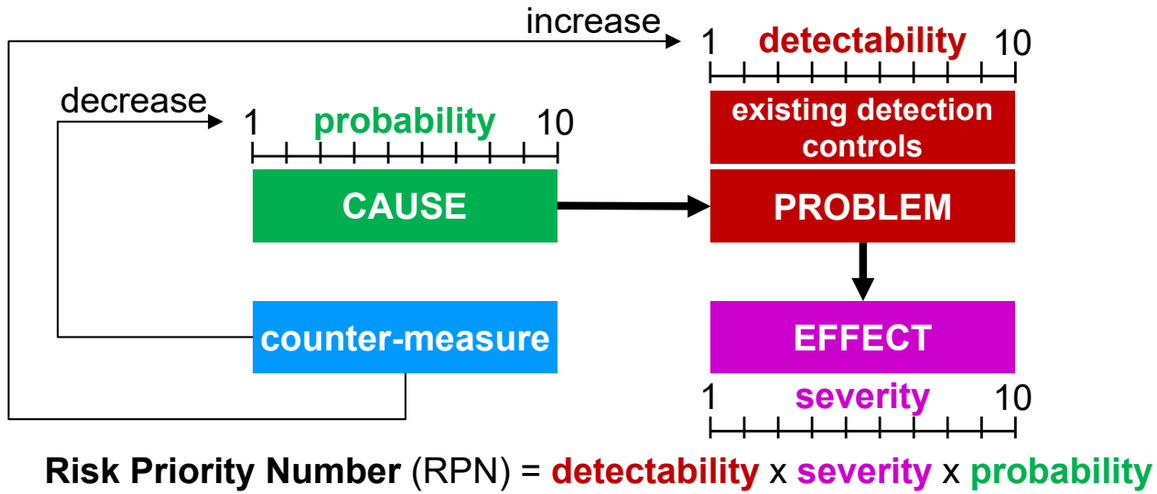
FMEA (Failure Mode and Effects Analysis) is a problem-solving procedure to evaluate and reduce risks of products/ services, their components and processes.

The risk is indicated by the Risk-Priority-Number (RPN) which varies between 1 ...1000.

Risks with an RPN > 100 should be reduced by:

- Increasing the detectability of the problem before its occurrence and
- Decreasing the probability of occurrence of the cause of the problem

The FMEA here has been adapted her to evaluate the risks of the developed measures.



Risk Priority Number (RPN) = **detectability** x **severity** x **probability**

Calculate the related risk and reduce high risks (RPN> 100) by countermeasures

Instructions

FMEA (Failure Mode and Effects Analysis)	
The FMEA, like the DMAIC itself, includes a complete problem-solving cycle. FMEA is typically used to reduce the risk of components (e.g. the brake on the car) (product FMEA) or process steps (process FMEA). In Six Sigma, it serves to identify and reduce the possible risks of the formulated measures. The FMEA here also consists of: - a problem that may result from a Measure, - an effect of the problem, e.g. on the customer or the business, - a cause that triggers the problem and - countermeasures. In addition to the identification of problems, causes, effects is evaluated: - the Detectability of the Problem before it occurs - the Probability of the Cause - the Severity of the Effect Each component is rated on a 10-level rating scale (ordinal-scale), subjectively but typically by experts. This means: - Detectability= 1: high detectability; Detectability= 10: low detectability - Probability= 1: low probability; Probability= 10: high probability - Severity= 1: low severity; Severity= 10: high severity	By multiplying the subjective assessments, the Risk-Priority-Number (=RPZ) results: RPN= Detectabilty x Probability x Severity The RPN can vary between 1 (lowest risk) and 1000 (highest risk). As a rule of thumb, the risk of a formulated Measure with an EPC > 100 should be reduced by countermeasures. Possible countermeasures include: - increase the Detectability of the Problem - reduce of the probability of occurrence of the Cause As a rule, it is assumed that the Severity of the Effect cannot be reduced if the Problem occurs, even if, for example, an airbag could mitigate the Effect of the brake failure. After formulating countermeasures to increase the Detectability of the Problem and/or reduce the Probability of occurrence of the Cause, exactly the Detectability and Probability are re-evaluated. If this assessment leads to the RPN becoming < 100, then the risk is generally considered controlled and the countermeasures can be implemented. In sigmaGuide, the countermeasures are linked to the action list and are thus part of the Measures already formulated.

(Extract from sigmaGuide)

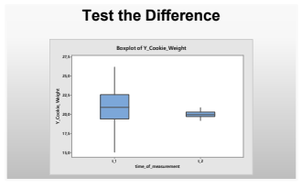
CONTROL

Data-Evaluation, Process-Performance, Improvements & Benefits, Process-Management, Project Completion

Control: From the evaluation of the improvement to sustainable success

- **Graphical Evaluation and Process-Performance** (see the recommendations in the Data Collection Plan)
  - Inspect the data with descriptive graphs and charts, e.g. Pareto chart, Boxplot, Time series plot
  - Monitor process performance over time, e.g. I/ MR Chart
  - Calculate process capability, e.g. Pp/ Ppk, Sigma Level

- **Verify the improvement statistically**
  - Test the effect of the measures using difference hypotheses for the important output variables
  - Calculate the financial and estimate the non-financial benefits on the basis of significant differences
  - Compare your results with your targets from the Project-Charter



- **Ensure sustainability of the improved process performance**
  - Create a Process Management Plan
  - Establish a Continuous Improvement Process (CIP)

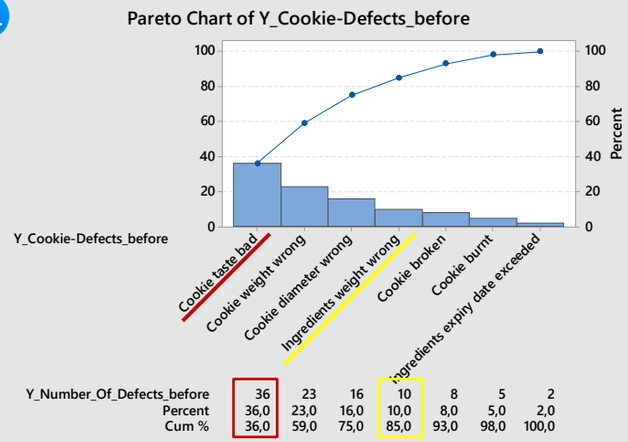
- **Finish the project**
  - Summarize your lessons learned, indicate detected potentials for improvement
  - Finish and present your Six Sigma Project-Story-Book and handover the project

Summary Control: Verify the improvement and ensure its sustainability

Outlook: next Project?

The overall number of defect Cookies was reduced by 38%

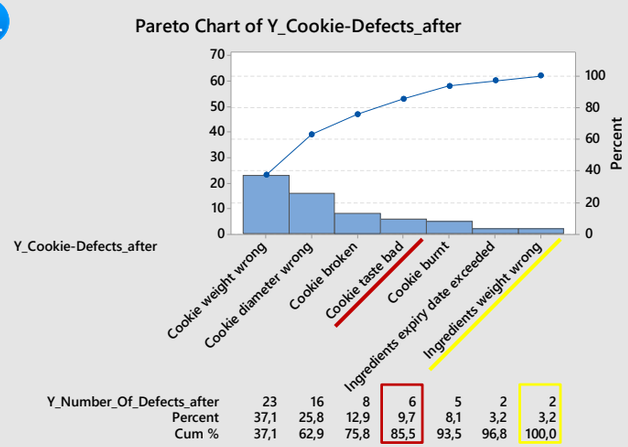
1a.



Y_Number_Of_Defects_before	36	23	16	10	8	5	2
Percent	36,0	23,0	16,0	10,0	8,0	5,0	2,0
Cum %	36,0	59,0	75,0	85,0	93,0	98,0	100,0

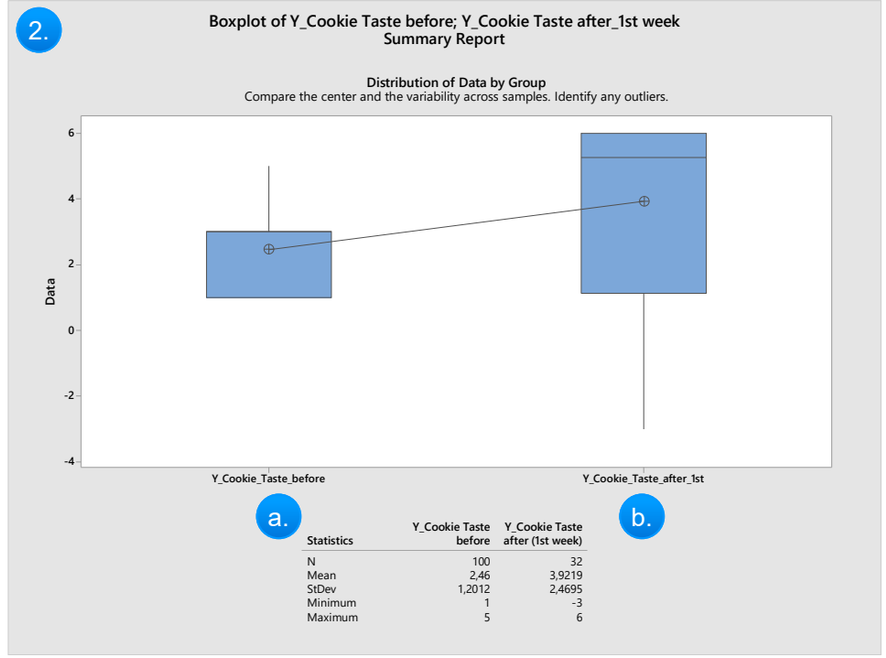
Before / After comparison Cookie defect frequencies

1b.



Y_Number_Of_Defects_after	23	16	8	6	5	2	2
Percent	37,1	25,8	12,9	9,7	8,1	3,2	3,2
Cum %	37,1	62,9	75,8	85,5	93,5	96,8	100,0

2.



Statistics	Y_Cookie Taste before	Y_Cookie Taste after (1st week)
N	100	32
Mean	2,46	3,9219
StDev	1,2012	2,4695
Minimum	1	-3
Maximum	5	6

Before/ After (1st week) comparison of Cookie Taste rating

- The overall number of defects in Cookies was reduced by 38% (100 → 62).
- The focused defects in taste were reduced by 83%
- Additionally the defects in the weight of the ingredients were reduced by 80%.
- In the 1st week the average taste rating even decreased. One reason is that the process was not stable in the 1st week after implementation (→ control chart).
- Potential for improvement is now mainly in: Deviations in cookie weight.

Graphical analysis descriptive statistics:

1. Pareto charts

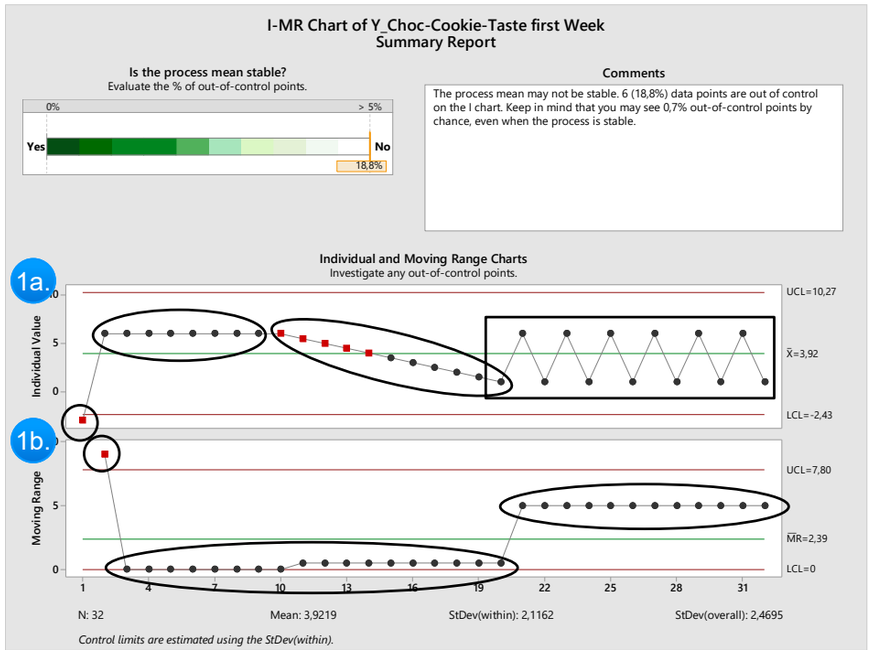
- Frequencies of Cookie defects in comparison a) before vs. b) after improvement (N= 100)
- Overall number of errors decreased by 38%:
  - 83% reduction in: Taste of Cookies
  - 80% reduction in: Weight of ingredients
- Thus it came to a shift of the ranking of the error frequencies.
- Primary problems now:
  - Cookie weight wrong
  - Cookie diameter wrong.

2. Boxplot

- Rating of Cookie taste a) before (N= 100) vs. b) 1st week after improvement (N= 32)
- The mean taste decreased from:
  a) xbar= 2,46 (before) to
  b) xbar= 3,92 (after) (1= very good; 6= very bad)
- The dispersion of taste also increased in the 1st week, from:
  a) s= 1,20 (before) to
  b) s= 2,47 (after)
- The range of data changed from :
  a) 1= very good to 5= bad to
  b) 1= very good to 6= very bad.
- There is at least one invalid value (-3)

In the 1st week however, the taste ratings even decreased from xbar= 2,46 to xbar= 3,92

Patterns in the data of the 1st week after implementation indicate, that the process …



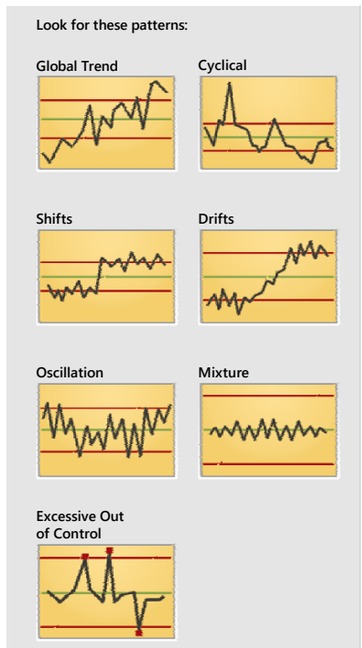


	Chart	Test	Out-of-Control Points
1a.	I	Test 1: Outside control limits	1
		Test 2: Shift in mean	10-14
1b.	MR	Test 1: Outside control limits	2

Test for signals from the *Minitab Assistant* I-MR Control Chart

Data of controlled processes are typically normally distributed.
The variation of the data is based exclusively on random common causes.

Specific influences can systematically affect the process. Tests of the control charts can identify some signals in the data and assign them to certain patterns.

Each systematic event will be analysed for its root causes to develop appropriate solutions!

Test for signals from the *Minitab Statistics* I-MR Control Chart

1a. Individual Value (I) Chart of Y_Choc-Cookie-Taste_post (Tests from I-MR-Chart from statistics menu)

TEST 1. One point more than 3,00 standard deviations from center line.
Test Failed at points: 1

TEST 2. 7 points in a row on same side of center line.
Test Failed at points: 8; 9; 10; 11; 12; 13; 14

TEST 3. 5 points in a row all increasing or all decreasing.
Test Failed at points: 15; 16; 17; 18; 19; 20

TEST 4. 12 points in a row alternating up and down.
Test Failed at points: 31; 32

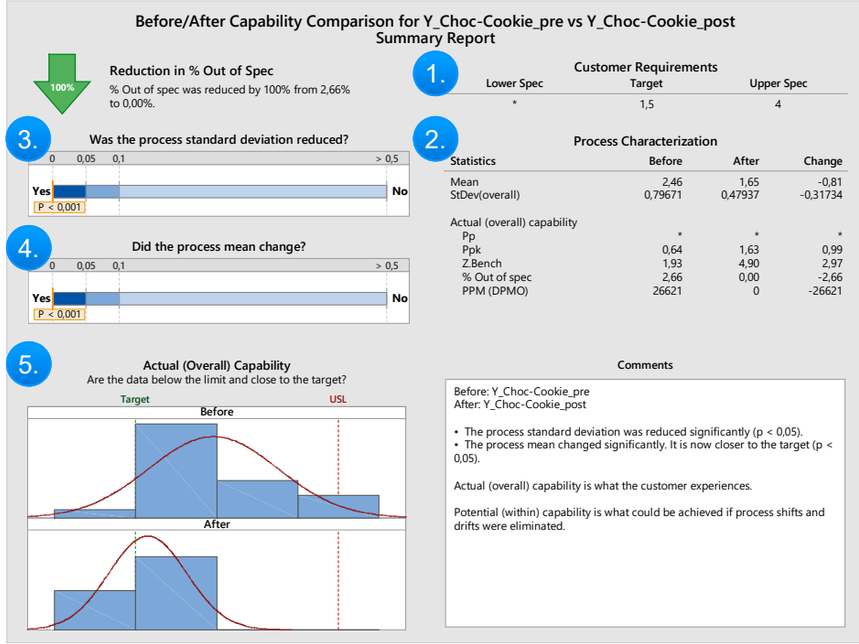
1b. Moving Range (MR) Chart of Y_Choc-Cookie-Taste_post

TEST 1. One point more points more than 3,00 standard deviations from center line.
Test Failed at points: 2

TEST 2. 18 and 12 points in a row on same side of center line.
Test Failed at points: 9; 10; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 27; 28; 29; 30; 31; 32

… was not yet under control and needs to be analysed for specific causes.

The before vs. after comparison of the process capability shows a significant improvement



- **Significant and practically relevant increase of the taste judgement**, from 2.46 to 1.65.
- The **variability of taste** was also significantly **reduced**.

→ We offer customers a better and more consistent taste experience.

- This improvement is reflected in the process capability, increasing approximately 3 Sigma Levels, from 1.93 → 4.9 Sigma.
- The performance of the process is now closer to the goal (1.5).
  (see below: 1-Sample t-test for difference to target)

The Process Capability Analysis shows:

1. The customer requirements are defined as specification limits on the rating scale of taste:
   - Upper specification limit (USL): 4 **(see Data-Collection-Plan)**
     Taste should be rated better than 4:= adequate
   - Target: 1,5 **(see Data-Collection-Plan)**
     The mean of taste rating should be ≤1,5:= very good/ good)

2. Improvement of statistical parameters:
   xbar: 2,46 → 1,65 - Difference: 0,81
   s: 0,80 → 0,48 - Difference: 0,32

   Improvement of capability indices:
   Ppk: 0,64 → 1,63 - Difference: 0,99
   Z.Bench: 1,93 → 4,90 - Difference: 2,97
   % Out of spec: 2,66 → 0,00 - Difference: 2,66 (100%)

3. The standard deviation is significantly reduced (p< 0,001)
   (2 Sample Standard Deviation Test/ F-Test)

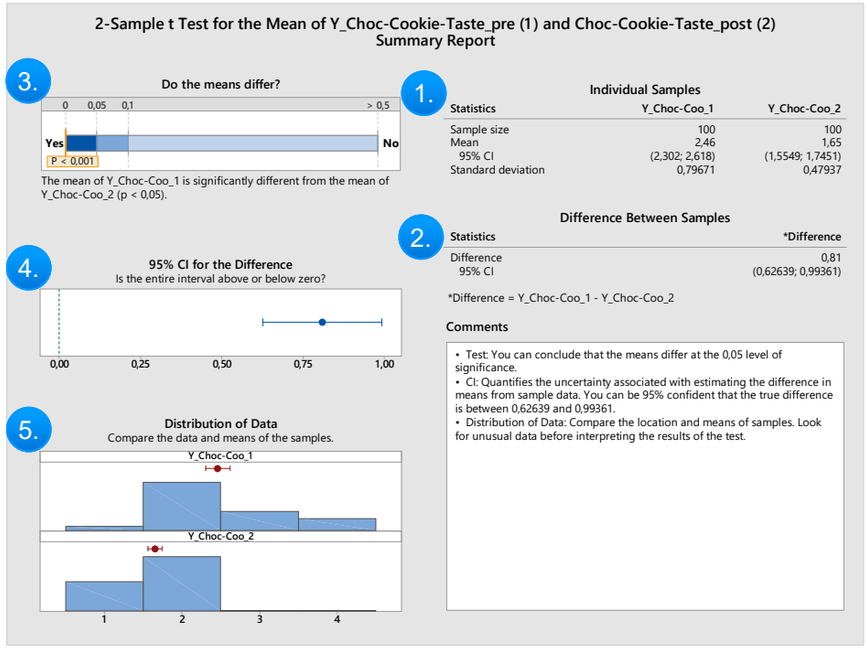
4. The difference in the means: is significant (p< 0,001)
   (2 Samples t-Test)

5. Histograms for the Before vs. After comparison:
   The Anderson-Darling normality test shows a significant result.**

** **interpretation of results under reserve**

Focus is now on the statistical significance and practical relevance of the improvement

Hypothesis: There is a/no difference in: Taste (Y) between: the states before vs. after improvement (x)



The tests of the hypothesis with the t-Test shows:

1. Statistical parameters for the conditions of taste:
   - pre (before): N= 100, Mean/ xbar= 2,46, s= 0,796
   - post (after): N= 100, Mean/ xbar= 1,65, s= 0,479

2. Difference between the means in the sample (0,81) and the corresponding confidence-interval (CI= 0,626; 0,993) for the population **

3. Difference in the taste between chocolate cookies pre (before) vs. post (after) improvement is significant (p < 0,001)

4. The Interval Diagram plots the difference between the means and its confidence interval as well as the difference= 0 for the H0

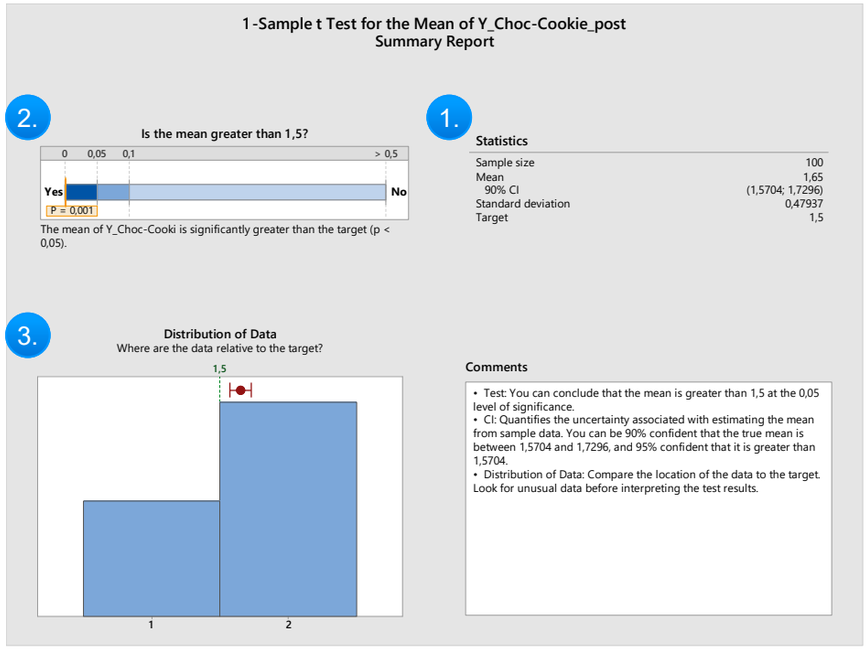
5. The two Histograms show the distribution of the rating data, with their means and the related confidence intervals of the means**

**** Data are not normally distributed; interpretation under reserve**

The t-Test shows, that there is a significant improvement of 0,81 grades in the rating of Taste.
Our customer will like the chocolate Cookies better now. But there are still potentials for improvement!

Focus is now on the degree how good the target for the chocolate Cookies was achieved

Hypothesis: There is a/no difference: in Taste (Y) between: the ratings and the target (Y')



The tests of the hypothesis with the 1-Sample t-Test shows:

1. Statistics for the comparison of taste:
   - N= 100,
   - Mean/ xbar= 1,65, confidence interval (1,57; 1,73)
   - s= 0,479
   - target= 1,5

2. Difference between the rated taste of chocolate Cookies vs. the target is significant (p < 0,001) → Deviation from the target

3. Histogram with target (1,5) and the mean with its confidence interval

There is a significant difference between rating of taste and the target for taste, i.e. the target is still not yet reached, indicated by the target value falling outside the confidence interval of the mean.**

**** Data are not normally distributed; interpretation under reserve**

The 1-Sample t-Test shows, that we nearly reached the target of Taste with our process improvements.

This means, that there is still potential for improvement.

This target should continue to be achieved in order to remain competitive.

After all before-after comparisons tested, we will now deduce the benefits of the improvements

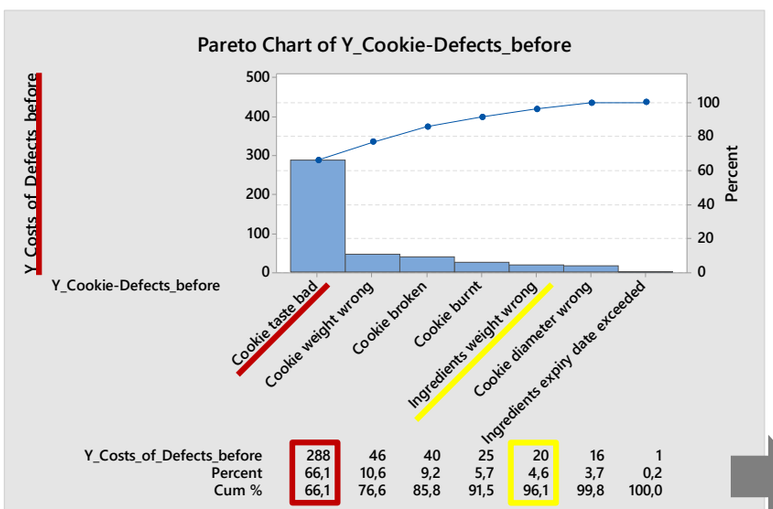
Summarise the main results - from the problems to the measures implemented

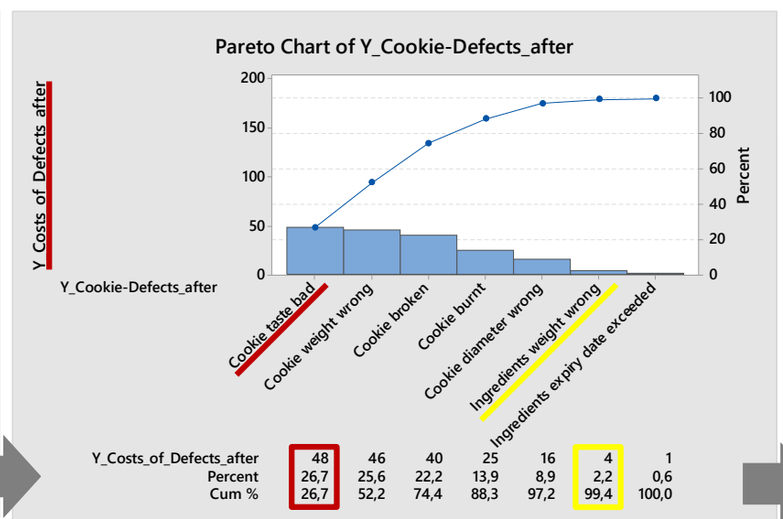
Summary and benefits

Problems	Root Causes	Implemented Measures	Financial Benefits	Other Benefits
Y_01 | Cookies (baked) Cookies taste of nothing	x1.2.3 Chef has too few opportunities to nibble on chocolate x1.2.3.1 Manager has restricted the consumption of chocolate x1.2.3.1.1 Too much chocolate is unhealthy for young Chefs x1.2.1.1 Information in recipe exceeds the Chef's capabilities	x1.2.3.n Chef may weigh an additional portion of 10 g of chocolate so that she can nibble while baking x1.2.3.n Immediate brushing of teeth after nibbling x1.2.1.1 Standard recipe with detailed and illustrated process description		
Y_02 | Cookies (delivered) delivered too early	**negative Influences** of the: Input (x_i), Methods (x_m) and the Resources (x_r) on the Output are the starting point to identify their underlying Root-Causes		**Problem (Y)** in category Quality, Availability or Consumption	
Y_03 | Cookies (boxed) waste of energy	**Solutions (S)** to eliminate, adjust or circumvent the Root-Causes		**Effect (Z)** on Costs (**VoB**) & Satisfaction (**VoC**)	

Derivation of financial benefits based on:

- Significant differences confirmed by e.g.:
  - 2-Sample t-Test
  - ANOVA
  - 2-Sample % Defective (% out of spec.)
  - Chi Square % Defective (% out of spec.)
- Estimate reduced costs and/ or increased profit based on the lower limit (worst case), the expected costs (typical case) and upper limit (best case) of the confidence interval
- Prepare Pareto charts to compare the costs (before) with the expected costs (after)





	Costs (before)	Costs (after)	Savings
Cookie taste bad	288,00 €	48,00 €	**240,00 €**
Ingredients weight wrong	20,00 €	4,00 €	**16,00 €**
		expected	**256,00 €**
		worst case	**212,48 €**
		best case	**299,52 €**

Assign the financial/ other benefits to the measures and have them independently confirmed

Install appropriate control charts to identify deviations in the "new" process, …

Process-Management-Plan		Define measures to sustainably maintain the process-improvements															
Ranking of Outputs (Y)	Outputs (Y)	Measurand	Unit	Target and specification limits (USL; LSL)	Scale-Level	In which time intervals will the control chart be actualized?	How large will the sample size be in each time interval?	How many data points should the control chart represent?	I-MR Chart (if N <= 100)	xbar-R Chart (if N > 100 and if subgroup size <= 8)	xbar-S Chart (if N > 100 and if subgroup size > 8)	p-Chart (if ok vs. ko is discriminated)	u-Chart (if ok vs. different defect opportunities are discriminated)	Which control limits should be used? (LCL; Center-Line; UCL)	Who is responsible for creating the control charts?	In which document is the reaction plan specified?	Who is responsible for maintaining the reaction plan?
Output (Y)		Data from Data-Collection-Plan															
1	Y_01 | Problem: COOKIES (BAKED) TASTE CRUMBLY-BLAND	rating-scale	grades 1 .. 6	Target: 1.5 LSL: 4	Data Rank Ordered (Ordinal-Scale)	**weekly**	**25**	**25**	**25 data points; no subgrouping**					**I-Chart:** UCL: 2.324 Center-Line: 1.438 LCL: 0.551 **MR-Chart:** UCL: 1.089 Center-Line: 0.333 LCL: 0	Mrs X	Reaction-Plan.xlsx	Mr Y
2	Y_02 | Problem: COOKIES (DELIVERED) DELIVERY > 1 HOUR TOO EARLY/ LATE	time	hrs	Target: 0 hrs LSL: - 1 hrs USL: + 1 hrs	Data discrete or continuous (Cardinal-Scale)	**monthly**	**500**	**50**			**50 data points; subgroup size: 10**		**Sample size > data points! Select a smaller time interval?**				
3	Y_03 | Problem: COOKIES (BOXED) ENERGY-CONSUMPTION > 10% WASTE	amount of electricity	kw/h	Target: 0 kw/h USL: + 1 kw/h	Data discrete or continuous (Cardinal-Scale)	**quarterly**	**120**	**60**		**60 data points; subgroup size: 2**			**Sample size > data points! Select a smaller time interval?**				

The **Process-Management-Plan** ensures the sustainability of the implemented measures by:

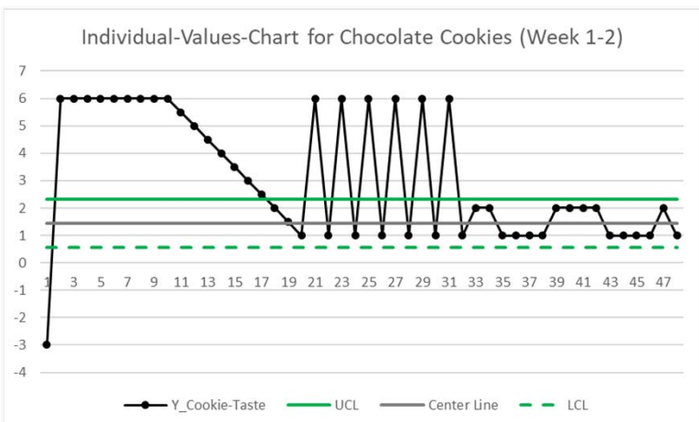
a. Monitoring of the future process performance with **control charts** for the critical outputs, with determined values for their control limits (UCL, LCL) and center line and a schedule for their actualisation

b. Responses to performance drops with a **reaction plan**, which determines, how signals in the control charts are to be treated by whom **(additional document, not part of sigmaGuide)**

- The results of the control charts should be discussed regularly, daily or weekly in the first weeks after implementation, in order to identify weak points immediately and react to them
- Important part of the reaction plan are regular meetings of a Continuous Improvement Team, which analyses the causes of the signals and develops solutions
- The process owner should know and accept the reaction plan and place the control charts visibly in his office. A copy should be visible to all employees on a blackboard (Visual Management)

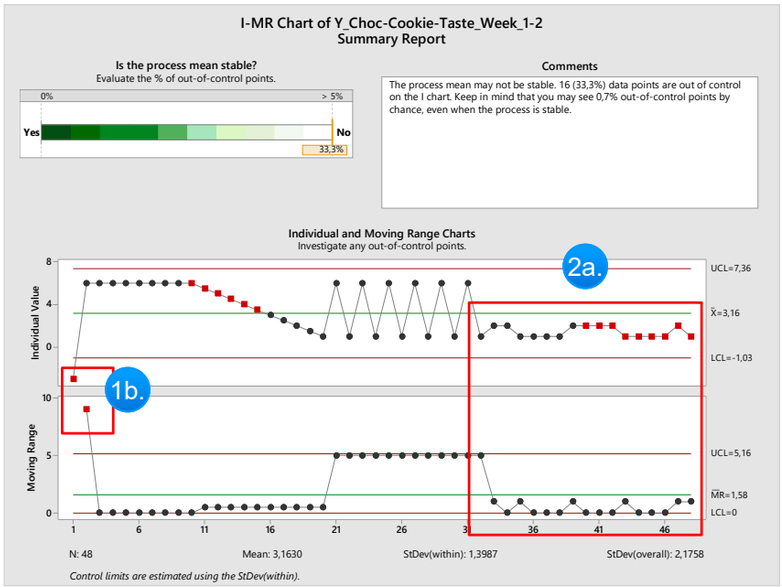
Reproduction of a simple control chart with Excel

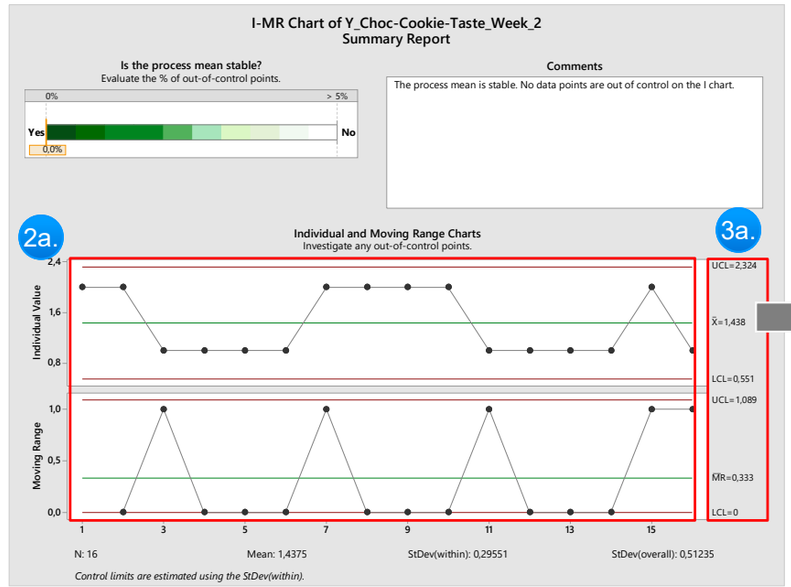
Y_Cookie-Taste	UCL	Center Line	LCL
-3	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
6	2,324	1,438	0,551
5,5	2,324	1,438	0,551
5	2,324	1,438	0,551
4,5	2,324	1,438	0,551
4	2,324	1,438	0,551
3,5	2,324	1,438	0,551
3	2,324	1,438	0,551

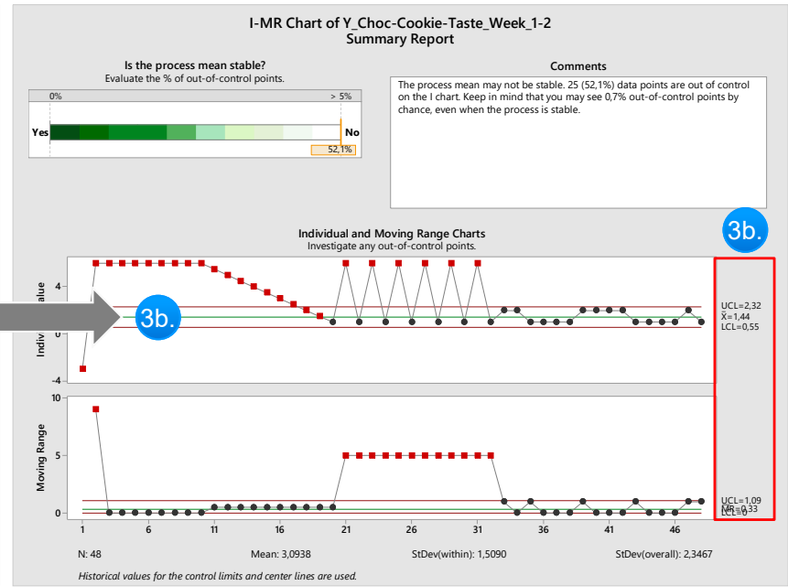


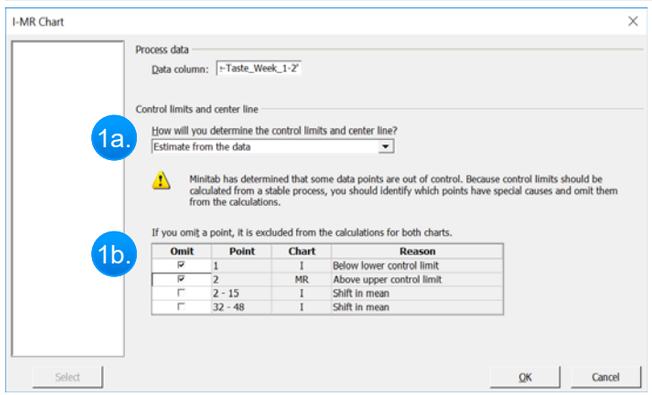
… and develop a reaction plan, to solve these "new" problems and ensure sustainability

Determination of appropriate control limits for control charts

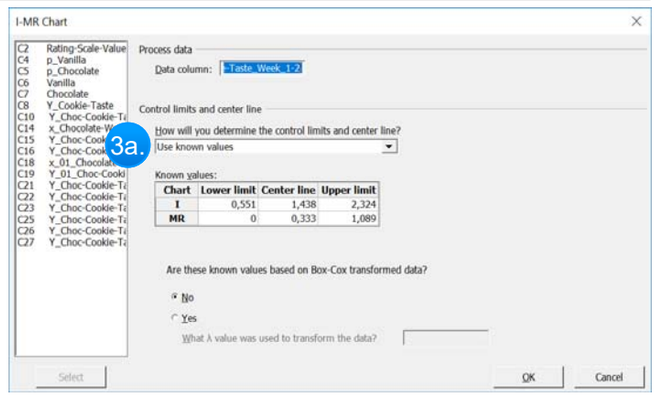








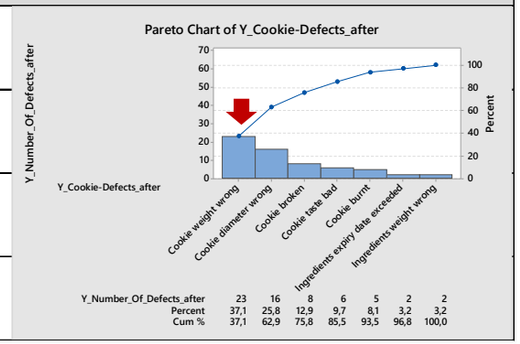
1. **Determination of the preliminary control limits and center line for an improved process:**
   a) Select: Estimate from the data
   b) Omit points outside the control limits, if detected
2. **Determination the control limits and center line for an improved process with already controlled periods:**
   a) Copy the data of the controlled period in a new variable
   b) Select: **Estimate from the data** (see 1b)
3. **Use of calculated control limits and center line for future periods**
   a) Copy the calculated data in the fields for: **Known values**
   b) The calculated limits and the center line of the controlled period now serve as the reference for future data



For the first try: Estimate from the data - For sustainable monitoring: Use known values from controlled periods

Lessons learned and …

What I learned in the course of the project, concerning:
1. Subject matter/ Product:
2. Process:
3. Methods/ Tools:
4. People/ Teams:
5. Management:
6. Finance:
7. Company:

Potentials/ topics for further improvements:	
1.	
2.	
3.	
4.	

Lessons learned
- Structure your lessons learned according to the seven topics and summarize them by short statements

Further potentials
- List the remaining potentials from your project, problems you have not worked on, promising topics that were outside your scope or topics you have noticed additionally

… potentials for further improvements

Progress of the project …

Phase	Tool	Business-Project	Standard-Project	Your check	MBB grade
General	Project-Story-Book	All headers and footers of the slides are specified, results described, interpretations provided, conclusions drawn		yes	5
Define	**Part 1**	**Identify a topic for a Six Sigma project**			
	Project-Topic	Identify Problems of the daily work as a potential for Improvement		yes	7
	Part 2	**Define a Six Sigma project**			
	Project-Definition	Summary: Process, Output, Problem and Effect		yes	8
Define	**Part 3**	**Implement a Six Sigma project**			
	SIPOC	Structure the Process in its important steps, with related Supplier, Inputs and Outputs and Customer		yes	10
	Voice to Critical	Interviews conducted with customers, the sponsor and managers	Interviews conducted with representatives of the municipality/ garbage collector	yes	10
	Project-Charter	Complete and sign the Project-Charter		yes	10
	Stakeholder-Communication	Identify the Stakeholder and develop a Communication-Plan		yes	10
Measure	Input-Analysis	Describe Inputs (xI) of the Process, Requirements on the Inputs and Deficiencies		yes	10
	Process-Mapping and -Analysis	Workshop conducted & documented (photos: Process-Mapping & team))	If possible: Workshop conducted & documented (photos: Process-Mapping & team (municipality/ garbage removal))	yes	10
	C&E Matrix xY	Evaluate relationships between negative Influences of the Inputs (xI) and the Activities of the Process (xP) on the Outputs (Y)		yes	10
	Data-Collection-Plan	Operationalise Measurands of Inputs (xI), Activities (xP) and Outputs (Y); Recommendation for appropriate: Charts, Parameter, Process-Capability-Indices, Control-Charts, One-Sample-Tests		yes	10
	Hypothesis	Overview of all automatically generated Hypothesis, prioritized by their Risk; Recommendation for appropriate statistical Tests		yes	10
Analyse	Data Evaluation	Plausibility of data checked and data graphically displayed		yes	10
	Process Performance	Process performance determined, with capability indices and control charts		yes	10
	Hypotheses Tests	Hypotheses statistically tested		yes	10
	Root-Cause-Analysis	Workshop conducted & documented (photos: Root-Cause-Analysis & team))	If possible: Workshop conducted & documented (photos: Root-Cause-Analysis & team (municipality/ garbage removal))	yes	10
Improve	Solutions	Develop Solutions to eliminate, adjust or circumvent the Root-Causes		yes	10
	Action-Plan	Specify Measures to implement the Solution-Ideas		yes	10
	FMEA	Analyse the Risks of Measures (FMEA:= Failure Mode and Effects Analysis)		yes	10
	Implementation	Measures implemented (at least one for each problem)		yes	10
Control	Data Evaluation	Plausibility of data checked and data graphically displayed		yes	10
	Process Performance	Process performance determined, with capability indices and control charts		yes	10
	Hypotheses Tests	Hypotheses statistically tested		yes	10
	Process-Management-Plan	Define measures to sustainably maintain the process-improvements		yes	10
	Summary and Benefits	Summarize the results of the phases and demonstrate the financial and other benefits of the project		yes	10
General	Lessons Learned	Lessons learned summarized and topics identified for future projects		yes	10
Evaluation:		**96%**	**excellently passed (46% Black Belt Bonus)**		

Progress of your project

- Please document your project progress in sigmaGuide. If you were only able to edit a task partially, then use the entry: partially.

Evaluation of your project

- After project completion, a Master Black Belt will evaluate the quality of your results.
- Here you can achieve 0-10 points per task.
- If you receive at least 5 points in all tasks, your project will be certified (50%).
- If you earn more than this 50%, you will be credited for your Black Belt certification if you want to go for this next level.
- With the best result - 10 points in each task - you will e.g. receive a credit of 50%.
- In this case your Black Belt project doesn't have to be as demanding and complex as it would be without credits.

… and its evaluation for certification by your Master Black Belt

End of this Course

Six Sigma - **Methods and Tools for Process Improvement**