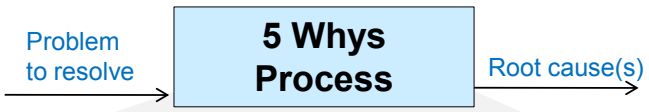
5 Whys
(Root Cause Analysis)

Problem
How to find a problem's root cause?

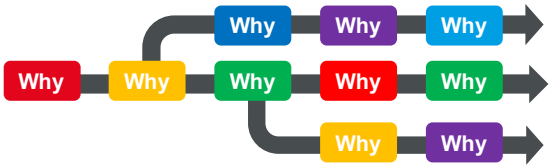
Difficulty
Easy to use

- The "**5 Whys**" technique is a simple & fast way to determine the root cause(s) of a problem.
- The question "Why?" is repeatedly asked, starting at the problem statement. The process stops when the results are not actionable; this often occurs after 5 "Why?" steps.



1. Ensure the problem is clearly articulated.
2. Ask "Why did the problem occur?" There may be several reasons.
3. For each of the reasons, ask "Why?"; each may have several reasons.
4. Continue asking "Why?" until the reasons are no longer actionable.
5. The lowest level reasons that are actionable are the *root causes*. If these are addressed then the problem should be resolved (or mitigated).

Problem	Reason(s)
Why #1: Why did that problem occur?	
Why #2: What did THAT occur?	
Why #3: What did THAT occur?	
Why #4: What did THAT occur?	
Why #5: What did THAT occur?	
Potential Root Cause(s)	



5 Whys – Example – Broken machine

Problem: A specific machine is not working

Why #1

Reason: The drive belt is broken

Why #2

Sub-reason: The drive belt was too dry

Why #3

Sub-reason: The drive belt was not lubricated

Why #4

Sub-reason: There was no oil in the machine

Why #5

Sub-reason: The machine was not maintained according to manufacturer specifications

Why #6

Sub-reason: The maintenance manual is missing

This is a root cause.

Sub-reason: Too much force on the belt

While this sub-reason could be followed with more "Whys", as a machine user (and not the machine manufacturer) we are unlikely to be able to affect the machine design. Hence, this branch is not likely to be actionable.

Sub-reason: There was no oil in the warehouse

Why #6

Sub-reason: No one was tasked to maintain the machine

This is a root cause.

5S Process of Lean

Problem
How to remove distracting clutter?

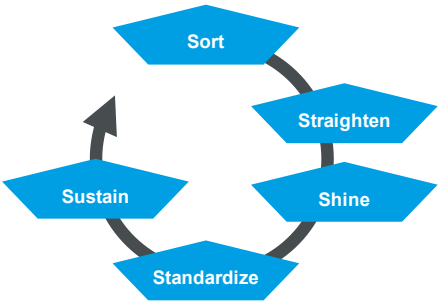
Difficulty
Easy to use

- **5S** is a organization method.
- 5S is based on 5 Japanese words whose transliterations start with the letter "S." These correspond to 5 English words: Sort, Straighten, Shine, Standardize, and Sustain.
- 5S efforts impress customers.
- 5S improves workplace safety, quality, morale, and throughput.

"cluttered" environment → **5S Process** → "uncluttered" environment

Continuously perform the following actions

1. **Sort:** Remove unneeded items from the area.
2. **Straighten:** Make a place for everything and put everything in its place.
3. **Shine:** Clean and inspect everything in the area.
4. **Standardize:** Every process has a standard.
5. **Sustain:** Continue 5S – without being told.

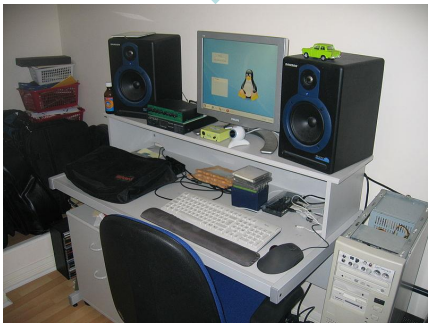


Japanese	English	Meaning
Seiri	**Sort**	**Organize**
Seiton	**Straighten**	**Order**
Seiso	**Shine**	**Clean**
Seiketsu	**Standardize**	**Standards**
Shitsuke	**Sustain**	**Discipline**

5S - Examples

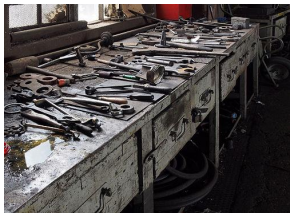
Figure Credits

- https://commons.wikimedia.org/wiki/File:Part_of_my_messy_desk_(430672681).jpg
- https://commons.wikimedia.org/wiki/File:Tawalker's_home_studio_gear_(2007).jpg
- https://commons.wikimedia.org/wiki/File:5S_Tools_drawer.jpg
- https://commons.wikimedia.org/wiki/File:Papan_Bayangan_(Shadow_Board).jpg
- https://www.wikiwand.com/en/Workshop



Popular 5S application areas

1. **Office environments**: especially desks and storage
2. **Manufacturing**: especially kitting of tools and components



Six Thinking Hats

Problem
How to obtain multiple perspectives of an issue?

Difficulty
Work with an SME

- **Six Thinking Hats** has 6 differently colored hats, each representing a specific thought process (see below).
- When the team "puts on a hat," they address an issue from that hat's point of view. Sessions begin with a "blue hat," to discuss the meeting and hat order.
- Sequentially, the team puts on different hats, each for a fixed period.
- The facilitator always wears a blue hat.

	Black	risk assessment
	Blue	organization and planning
	Green	creative thinking
	Red	feelings and instincts
	White	information gathering
	Yellow	benefits and values

Issue to address → **Six Thinking Hats Process** → Multiple perspectives of the issue

1. Select an issue (e.g., project or concept)
2. The facilitator, with the team, selects a hat ordering:
   - **Any meeting**: Blue, White, Green, Yellow, Red, Black
   - **Brainstorming meeting**: Blue, White, Green, Blue
   - **Problem solving meeting**: Blue, White, Green, Red, Yellow, Black, Green, Blue
   - **Strategic planning meeting**: Blue, Yellow, Black, White, Blue, Green, Blue
3. The facilitator sequences through the hats, leads the discussion for each hat, and decides when to move to the next hat.

Six Thinking Hats – Example

Sample initial questions for a facilitator to ask for different hats

• Black Hat:	What risks need to be considered?
• Blue Hat:	What support, systems, or processes will be needed?
• Green Hat:	How can we create new ideas?
• Red Hat:	What are your initial reactions?
• White Hat:	What information do we have?
• Yellow Hat:	Why should we be optimistic?

Sample follow-on questions for the Black Hat:
1. How will this fail?
2. What are the weaknesses or risks?
3. What are potential unintended consequences?
4. How will the competition react?
5. Which stakeholders can prevent success?

Sample follow-on questions for the Green Hat:
1. How can we generate multiple problem solutions?
2. What brainstorming tools can we use to find solutions?
3. What relevant outrageous scenarios can we create?
4. How would <famous person> solve this problem?
5. What thought experiment could we perform?

Sample follow-on questions for the Yellow Hat:
1. What does success look like?
2. What makes this so successful?
3. What are the short term and long term benefits?
4. How does this make things better?
5. If we could not fail, what would we do?

7 Wastes

Problem
How to determine what types of waste are present?

Difficulty
Easy to use

A **value-added task** meets 3 criteria:
1. The customer cares
2. Something changes
3. The task is done right the first time

Everything else is **waste**.
There are **7 classic types of waste**.
(Non-utilized talent is a new 8th waste.)

Existing process → **How to Identify waste (in order to remove it)** → Waste identification

1. **Defects** – Products (or services) that must be corrected
2. **Over Production** – Producing too much of a product.
3. **Transportation** – Moving items unnecessarily
4. **Waiting** – Waiting for the previous step to complete.
5. **Inventory** – Inventory or information not being used
6. **Motion** – Motion not required for process
7. **Processing** – Activities not required for process
8. ***Non-Utilized Talent*** – Employees not effectively used

1. Review process looking for the 7 types of waste (use acronym **DOTWIMP**)
   1. **D**efects (Rejects, Repair, Rework)
   2. **O**ver Production
   3. **T**ransportation
   4. **W**aiting
   5. **I**nventory
   6. **M**otion
   7. **P**rocessing (Excess or Unnecessary)
2. Once waste is identified, try to remove it

Defects | Over Production | Transportation | Waiting | Inventory | Motion | Processing

FIGURES
- https://commons.wikimedia.org/wiki/File:Cooking_chocolate,_broken_bar.jpg
- https://commons.wikimedia.org/wiki/File:Factory_1b.svg
- https://commons.wikimedia.org/wiki/File:Fxemoji_u1F682.svg
- https://commons.wikimedia.org/wiki/File:GSSA_Golden_Clock.svg
- https://commons.wikimedia.org/wiki/File:Vert_queue.JPG
- https://commons.wikimedia.org/wiki/File:Circular_arrow-blue_01.svg
- https://commons.wikimedia.org/wiki/File:Red_Silhouette_-_Gears.svg

 7

7 Wastes – Examples – Two Different Environments

	Manufacturing environment	Office environment
Defects (Rejects, Repair, Rework)	Over producing to allow for expected defects.	Order entry errors. Lost files or records. Adding extra checks or inspection steps into a process.
Over Production	Using more expensive high capacity equipment when low capacity equipment is good enough	Producing reports that no one reads or needs. Duplicating data in multiple places. Creating extra copies. Sending information using multiple medium (e.g., email, post, fax).
Transportation	Reorganizing warehouses. Moving products in and out of storage.	Unnecessary movement of paperwork or information.
Waiting	Waiting for late deliveries to arrive to stock a warehouse.	Waiting for approvals or signatures. Attendees late to meetings. Using slow computers and IT systems.
Inventory	Having stock damaged from it being stored for so long.	Excessive office supplies.
Motion	Switching tasks excessively, resulting in moving between locations.	Searching for files on computer. Re-entering data. Poorly designed work stations resulting in more bending and reaching.
Processing (Excess or Unnecessary)	Including too many layers of packaging.	Obtaining unnecessary approvals on an activity or output.

When including non-utilized talent, use the acronym "**DOWNTIME**"

• D = Defects	• T =Transportation
• O = Overproduction	• I = Excess Inventory
• W = Waiting	• M = Motion
• N = Non-Utilized Talent	• E = Extra Processing

 8

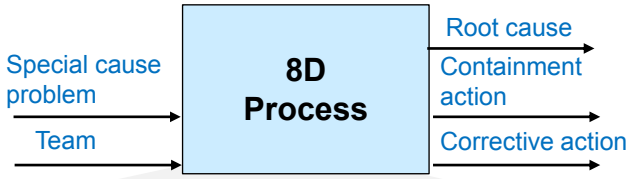
The Eight Disciplines of Problem Solving (8D)

Problem
How to solve a special cause problem?

Difficulty
Work with an SME

- The **8 Disciplines**, also known as the **8D process**, is a team-oriented approach to correct recurring problems.
- 8D has more complexity than the PDCA (plan-do-check-act) approach and less complexity than six sigma's DMAIC.

PDCA	8D
Plan	Step D0
	Step D1
	Step D2
Do	Step D3
	Step D4
	Step D5
Check	Step D6
Act	Step D7
	Step D8



1. Select the problem to be addressed
2. Execute the classic 8D steps (with D0 added):

- D0: Prepare and plan for 8D.
- D1: Select a knowledgeable team.
- D2: Quantify the problem: who, what, where, when, why, how, and how many.
- D3: Develop and implement a containment plan to isolate the customer from the problem.
- D4: Determine the problem root cause(s).
- D5: Identify the corrective actions and test.
- D6: Implement the corrective actions.
- D7: Take preventive measures to prevent recurrence of this and similar problems.
- D8: Congratulate the team.

 9

8D – Example – Illustrative "8D Report"

Example: 8D Customer Complaint Resolution Report

Customer Complaint Resolution Report

Report Title: Healthy Community Coalition (HCC) Meeting Improvement					***Report # 1***	
Dates: 3/15/17-8/15/17	*Customer Complaint:*	*3/15/17*	*Report Initiated:*	*3/22/17*	*Report Completed:*	*8/15/17*
Customer:	*Jane Doe, HCC Member*		***Program/Division:***		*Health Promotion*	

1D – Team Members

Role	Name	Email Contact
Leader	*Jane Eyre*	*jeyre@examplehd.com*
SME	*Atticus Finch*	*afinch@examplehd.com*
Champion/Sponsor	*Kinsey Millhone*	*kmillhone@examplehd.com*

2D – Problem Description

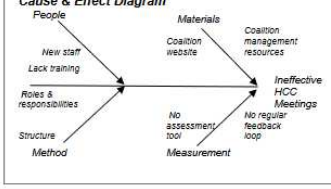
HCC is responsible for convening partners to make progress on the CHIP and for increasing community engagement and mobilization. Kinsey received an email from a key partner (a hospital community benefit director) about the last three HCC meetings. The complaint was a long, detailed list of frustrations about the ineffectiveness of the meetings, which included lack of meeting minutes and timely agendas. Further, the programing for meetings seemed last minute – and mostly committee updates instead of meaningful presentations, shared learning and connecting. The complaint also included frustration that this coalition feels more like a coffee klatch (social chitchat), rather than an effective way to make progress on serious community health concerns.

3D – Interim Containment Actions *(who, takes what action, by when)*

1. *Kinsey immediately replied to the partner stating that she appreciated the feedback and will begin looking into what can be done.*
2. *Kinsey initiated the 8D process to explore the process improvement options.*
3. *Kinsey will provide a more detailed update on the problem-solving process update to the partner prior to the next HCC meeting.*
4. *Jane will cancel the April HCC meeting to assure adequate time to initiate an improvement process.*

4D – Root Cause Analysis

Cause & Effect Diagram



Five Why Analysis

1. *Key partner is reporting ineffective meetings*
2. *Poor planning & execution*
3. *New, poorly trained staff*
4. *Gaps in training & oversight*
5. *No process*

5D – Design Corrective Action *(generate solutions to address root causes)*

What needs to be done?	*Who must be involved?*	*By when?*	*How will success be measured?*
1.Effective meeting training for staff	*Kinsey, Jane*	*April 15*	*Pre-Post Assessment*
2. Develop a coalition program design team	*Jane and 2-4 community partners, including complainant*	*May 1*	*Agenda, participation, minutes, attendance at meetings*
3. Coalition assessment	*Atticus*	*June 15*	*Assessment report shared with coalition, July meeting*
4. Coaching/mentoring for Jane	*Jane, coalition/QI consultant*	*Every 2 weeks for 2 months*	*Kinsey consultation with key partners in late July*

6D – Implement and Validate Corrective Action

Solutions Implemented:	*Results:*		
Contracted for effective meeting training & facilitation skills	*All staff leading and participating in community coalitions now have shared expectations about agendas, design teams, minutes, planning/execution/follow-up.*		
Identified an internal coalition coach for Jane	*Jane has increased support, understands the expectations of external clients, and now exceeds expectations.*		
Coalition Assessment developed, administered & Analyzed	*Discovered new opportunities to improve and learned that most partners are very happy with their level of engagement.*		
Jane, with help from Kinsey, created an HCC Design Team.	*More partners are sharing the work and feeling ownership in the effectiveness of the meetings. Jane is building deeper relationships with community partners. Attendance has increased. Agendas and minutes are available for all meetings on the coalition website.*		
Customer Notification	*Assigned to:*	*Key Messages*	*Completion Date:*
Customer was included in coalition program design team	*Jane*	*Customer participation is key to process improvement*	*8/1/17*

7D – Preventive Action *(policy/procedure change, training protocol, etc.)*

Action Taken	*Responsible Person*	*Completion Date:*
Added a training plan to the agency workforce development plan for both 1) effective meetings and 2) meeting facilitation (with criteria for selecting staff who must complete at least every two years).	*Kinsey*	*8/15/2017*
Adopted a policy, procedure, and schedule for coalition assessment (for customer satisfaction data collection) method for all agency supported coalitions.	*Atticus*	*8/15/2017*

8D – Team and Individual Recognition

Jane, Kinsey, and Atticus completed a QI storyboard documenting the intervention, which will be posted in the agency for the month September. A feature story was shared in the department newsletter focusing on the lessons learned from improved community relationships.

From http://www.phf.org/resourcestools/Documents/8D_Customer_Complaint_Resolution_Report.pdf (with permission)

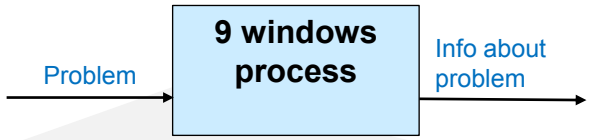
 10

9 windows

Problem
How to improve a product or process?

Difficulty
Work with an SME

1. **9 Windows** considers innovation via 9 "windows" of time and space:
   A. "**Time**" = when the problem could have been solved: **past**, **present**, or **future**.
   B. "**Space**" = where the problem is solved: **super-system, system**, or **subsystem**.
   - Sub-system = component of the system
   - Super-system = external environment the system interacts with
2. A 9 windows grid is below.



1. Select a specific problem (the "system").
2. Create the 9 windows grid
3. Fill in the grid:
   A. Put the problem in the center.
   B. Document the key element(s) of the
      - super- and sub-systems
      - past and future
   C. Then, fill in the remaining 4 corners of the grid (shown yellow in image below left)
4. From the information in the grid assess the innovation opportunities, essentially whether to focus on time attributes or system attributes.

		Time		
		Past	Present	Future
Space	Super-system			
	System		*problem*	
	Sub-system			

9 windows grid

9 windows – Example – COVID restrictions

Problem: *Covid limits face-to-face (F2F) activities for school children.*

		Time		
		Past	Present	Future
Space	Super-system	School districts distribute general guidelines which schools adapt as needed	School districts distribute educational material for Covid's "new normal"	Nationwide, best practices are determined, materials are developed and distributed
	System	School children meet F2F all day at school	*Covid limits face-to-face (F2F) activities for school children*	3D and immersive environments are used in schools
	Sub-system	School children learn social skills while eating lunch.	Students sit 6 feet apart, which limits social interaction	Students engage in fun activites ("games") during lunchtime that support growth of social skills.

Eating lunch at school is a part (a specific sub-system) of the school experience.

These are things that could exist in the future..

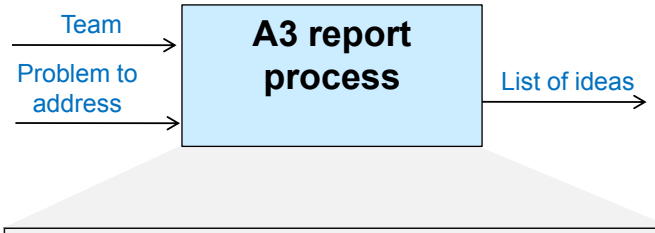
Conclusion: At the local level, it may be that focusing on the "time" aspect is more useful in the short term. The "space" aspect, would be beneficial, but may be take longer.

A3 report

Problem
How to document a project?

Difficulty
Easy to use

- An **A3 report** summarizes important information about an improvement project.
- There is no standard content for an A3 report, although it is typically aligned with PDCA (Plan-Do-Check-Act).
- The A3 report fits on a single page, on paper of size A3.
- A3 reports can be used during project performance, or at project completion.

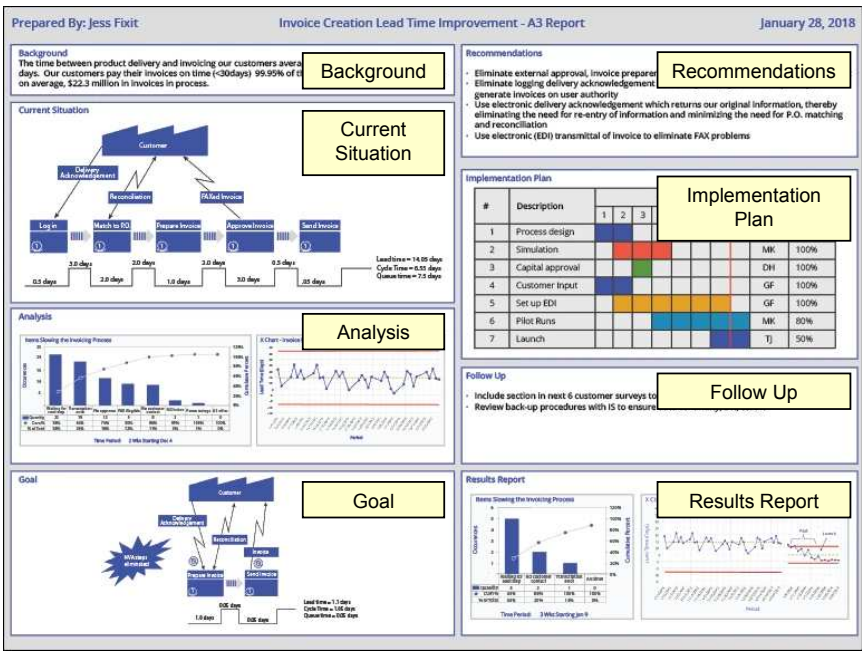


1. Obtain template for your company's A3 report, or use one from the web. (It likely has ~7 categories such as the ones shown below left.)
2. For each category, show the important information using text and/or graphics.
3. Prominently display the A3 report for team and management review, and for educational purposes.

	A3 steps	PDCA steps
1	Background	Plan
2	Problem Statement	
3	Goal Statement	
4	Root Cause Analysis	
5	Countermeasures	Do
6	Effect Confirmation	Check
7	Follow Up Actions	Act

A3 report – Examples from the web

Each company has its own A3 formatting style



Some web examples

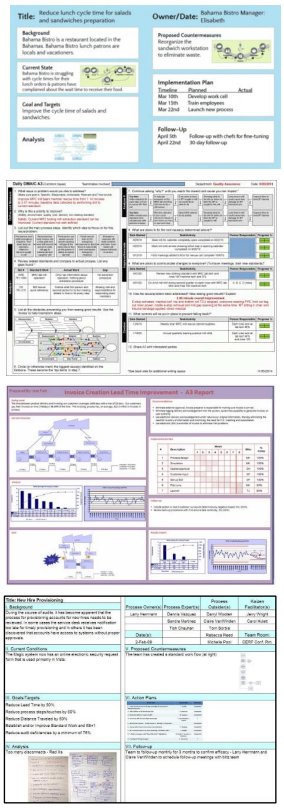


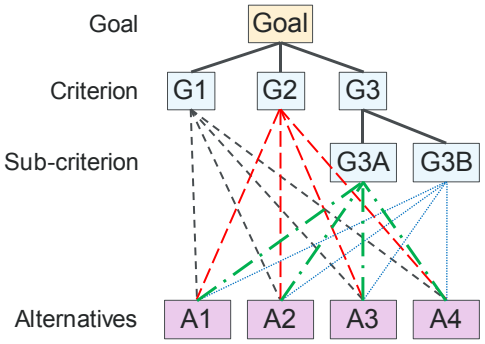
Figure credits
- https://www.moresteam.com/lean/a3-report.cfm
- https://www. https://www.leansixsigmadefinition.com/glossary/a3/
- https://goleansixsigma.com/john-shook-grand-daddy/
- https://goleansixsigma.com/4-new-ways-to-use-a3s-have-you-tried-any-of-these/
- https://www.isixsigma.com/operations/manufacturing-operations/improved-rescue-time-from-a-bolling-mill-machine/attachment/a3-project-summary/

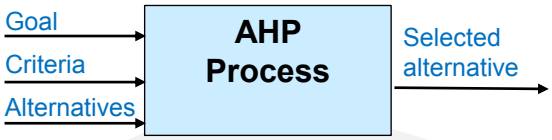
Analytical Hierarchy Process (AHP)

Problem
How to choose among multiple alternatives?

Difficulty
Work with an SME

- The **Analytic Hierarchy Process** (AHP) is a method for making decisions under multiple and complex criteria.
- AHP is easy to use since stakeholders only need to perform pairwise comparisons, assigning values 1-9.
- The pairwise comparisons are performed between all the criteria, between each set of sub-criteria, and between all the alternatives.





1. Define the goal.
2. Define the criteria (simple or hierarchical)
3. Define the alternatives.
4. Determine the weights amongst the criteria, sub-criteria, and alternatives (for each criteria) using pairwise comparison.
5. Use SW to convert pairwise comparisons into weights and confirm consistency.
6. Use SW to combine priorities and obtain overall weights for the alternatives.

Pairwise Comparison Scale	
Intensity	**Definition**
1	Equal Importance
3	Moderate Importance
5	Strong importance
7	Very strong importance
9	Extreme importance

Sample scale with corresponding text

 15

Updated: 2022011

AHP – Example – Choose a 6in6 Manager

- **Want to choose a manager from among 3 candidates.**
- **Compare using 3 criteria:** experience, education, teaching ability

(1) Compare the criteria pairwise to determine their priorities. (If "A" is preferred over "B" by a factor of N, then "B" is preferred over "A" by a factor of 1/N)

Matrix of pairwise results → these are AHP SW inputs

Criteria	Experience	Education	Teaching	Weights
Experience	1	5	9	0.751
Education	1/5	1	7	0.178
Teaching	1/9	1/7	1	0.070
	sums to 1			1.000
	inconsistency			1.5%

AHP SW outputs are the weights

This value says "Teaching is 1/9th as important as Experience" which is the same as "Experience is 9 times more important than Teaching."

(2) For each criteria, compare the candidates pairwise. AHP weights are obtained in each case.

Experience	Alex	Beth	Chris	Weights
Alex	1	3	1/5	0.188
Beth	1/3	1	1/7	0.081
Chris	5	7	1	0.731
	sums to 1			1.000
	inconsistency			3.2%

Education	Alex	Beth	Chris	Weights
Alex	1	1/5	5	0.207
Beth	5	1	9	0.735
Chris	1/5	1/9	1	0.058
	sums to 1			1.000
	inconsistency			5.9%

Teaching	Alex	Beth	Chris	Weights
Alex	1	1/3	5	0.265
Beth	3	1	9	0.672
Chris	1/5	1/9	1	0.063
	sums to 1			1.000
	inconsistency			1.5%

(3) Weight the alternative priorities, for each of the criteria, by that criteria's priority.

Candidate	Experience	Education	Teaching	Row sum
Alex	0.141	0.037	0.019	0.197
Beth	0.061	0.131	0.047	0.239
Chris	0.549	0.010	0.004	0.563

Largest value: Chris is the best choice

0.061 = 0.751*0.081 (see red boxes in
0.549 = 0.751*0.731 steps (1) and (2))

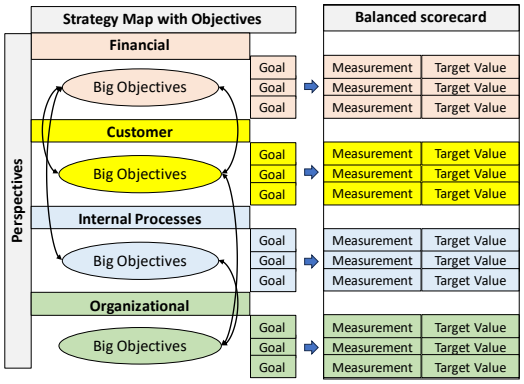
 16

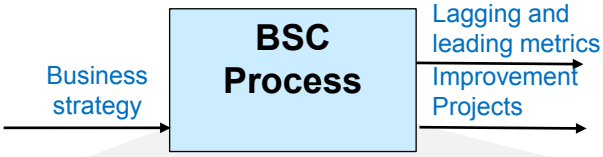
Balanced Scorecard (BSC)

Problem
How to manage an organization's strategy?

Difficulty
Work with an SME

- The **Balanced Scorecard** (BSC) is a framework for tracking and managing an organization's strategy.
- A BSC has four connected perspectives.
  Financial goals: What do shareholders want?
  Customer goals: What do customers want?
  Process goals: What should we be better at?
  People (or learning and growth, or innovations, or organizational capacity) goals: How can we create more value?
- A **strategy map** is a 1 page depiction of a BSC with connections between the perspectives.





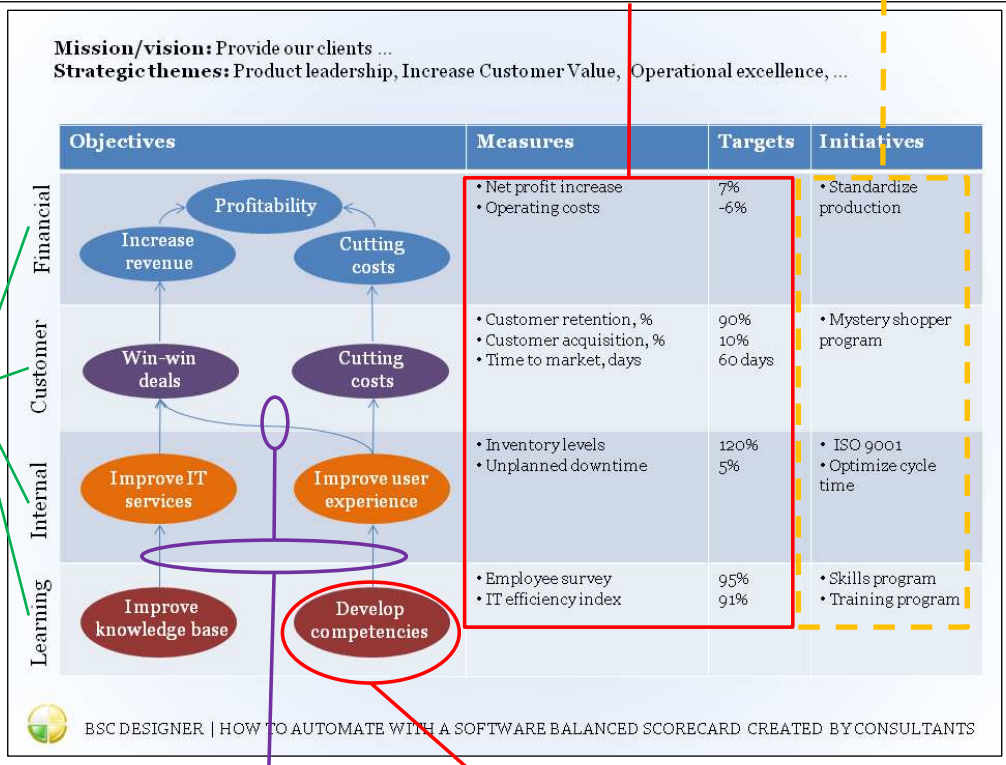
1. Define the **Mission, Vision,** and **Values**.
2. Define **Strategic Priorities**, the top-level goals (e.g., client relations, operations, product)
3. Define the ordered **Four Perspectives**: Finance, Customer, Process, and People.
4. Define the **Business Goals** supporting the perspectives. Create cause and effect relations; the lower perspectives' goals explain how to achieve the higher perspective goals.
5. Describe each goal's **Rationale**, for later review.
6. Define **Leading** (success goals) and **Lagging** (achieved results) **metrics** for each goal.
   - Only leading metrics can be influenced; it can be challenging to identify them.
7. Define **initiatives** to execute the strategy.
8. Flow the information down with local strategy maps aligned with higher level strategy maps.

Updated: 2022010

BSC – Example - Generic

These are trailing metrics

How to achieve objectives



Four perspectives

https://bscdesigner.com/wp-content/uploads/2016/10/bsc-example-by-bsc-designer.png

Perspective objectives are connected and flow up

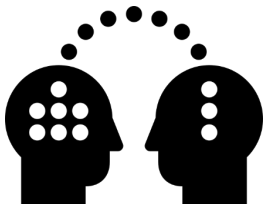
A leading metric would be percentage of employees with new competency training.

Benchmarking

Problem
How to achieve world class performance?

Difficulty
Work with an SME

- **Benchmarking** compares one of your **processes**, **services**, or **products**, to a standard; typically the best in class.
- It may, or may not, focus on your competitors.
- Examples: Amazon has free returns. Disney answers the phone on the first ring. Lands' End has a lifetime guarantee.



Knowledge and capability transfer from the best in class

https://commons.wikimedia.org/wiki/File:Knowledge_transfer.svg

Inadequate performance → **Benchmarking Process** → Improved processes

1. Document current practices, identify problem areas and their key performance indicators (KPIs).
2. Identify industries having similar processes. (Examples: For SW & HW with few defects consider US defense contractors or NASA. For fast SW creation consider the SW startup community.)
3. Identify the leaders in these industries.
4. Determine the processes of these leaders: visit, capture data, score them using your KPIs.
5. Model the leader's processes so they can be applied to your organization.
6. Implement necessary improvement projects.
7. Repeat as needed.

Benchmarking – Example – 6in6 paradigm

Assume 6in6 activities (e.g., selecting topics, creating presentations) need to be improved. Below are some sample needs, the element to improve, an appropriate KPI that can be used across industries, an industry to investigate, and a possible exemplar.

Need	KPI (Key Performance Indictor)	Element to improve	Industry with this skill	Potential exemplar
Selecting content for 6in6 site	Percentage of visitors finding the content "very relevant for me"	Selecting useful content, especially for business concepts	Business schools	Wharton Business School
Creating synopsis for each 6in6 topic	Percentage of site users finding the content to be "very helpful to me"	Creating synopses, especially for business concepts	Publishers	Harvard University Press
Creating useful graphics to accompany 6in6 descriptions	Percentage of site users finding the content to be "very useful to me"	Creating compelling graphics	News media (graphics accompanying news stories)	USA Today
Creating awareness of 6in6 web site and updates	Number of new visitors to website per week	Who makes sticky sites?	Groups managing start-ups	Y Combinator
Formatting for all the 6in6 presentation	Percentage of site users finding the presentation to be "well executed"	Design good story formats	News media	USA Today
Responsiveness to 6in6 inquiries	Percentage of site users finding the responsiveness "very quick"	Timely, complete responses	Vacation travel destinations	Disney Parks

How do this well?

How does this industry do it?

Assess how this company does it?

Body Storming

Problem
How to improve early thinking about a product or process?

Difficulty
Some training required

- **Body storming**, a form of brainstorming, creates user empathy and leads to re-design.
- A **body storming** exercise combines role-play and simulation. It uses prototypes and observations of how users interact with products to understand the user experience.
- There is no standard body storming process, the process is tailored to each specific circumstance.

Early thinking about a product or process → **Body Storming Process** → Improved thinking based on user experiences

1. Define the issue/product/process to be examined.
2. View the issue location and observe:
   A. How people behave at this location.
   B. The artifacts people interact with.
3. Define a scenario to be explored.
4. Assemble an appropriate team.
5. Run the body storming exercise:
   A. Follow the defined scenario
   B. Capture relevant info (e.g., people's behavior)
   C. Optional: Replay scenario using info gained.
6. Gather the participants' subjective experiences
7. Analyze the results and take appropriate actions.

Abstract brainstorming

Hands on Brainstorming

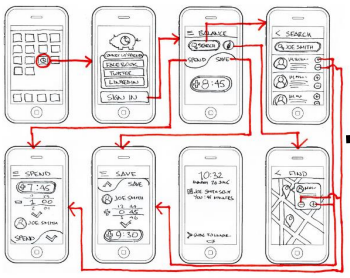
https://commons.wikimedia.org/wiki/File:Business-colleagues-having-meeting-in-conference-KS674JC.jpg
https://commons.wikimedia.org/wiki/File:Working_together_%289598967879%29.jpg

Updated: 202210

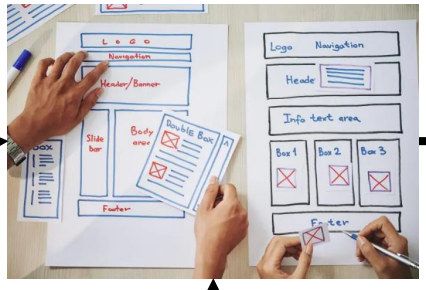
Body Storming – Example – User Interfaces

Paper prototyping is a form of body storming. For user interfaces, paper prototyping is a way to develop ideas and design user flows using hand-created images. Paper prototypes evaluate the user experience more than the design itself.

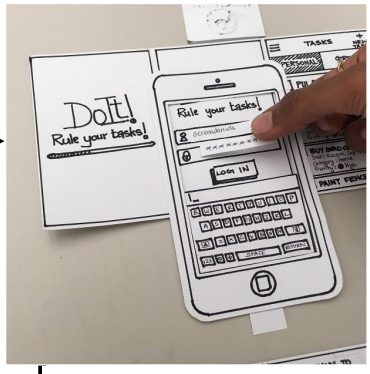
Initial interface thinking



Paper instantiation



Body storming exercise



Revised interface thinking

Users "push" icons and the facilitator appropriately changes the paper model.

User interface evaluation process:
- Observe 3-5 different people attempting to use the interface.
- The facilitator changes the paper model to reflect the user activities.

- https://anniehaydesign.weebly.com/app-design/storyboarding
- https://xd.adobe.com/ideas/process/ui-design/what-is-prototyping/
- https://assets.justinmind.com/wp-content/uploads/2021/01/paper-prototyping-cutouts.png

Brainstorming

Problem
How to identify ideas to solve a problem?

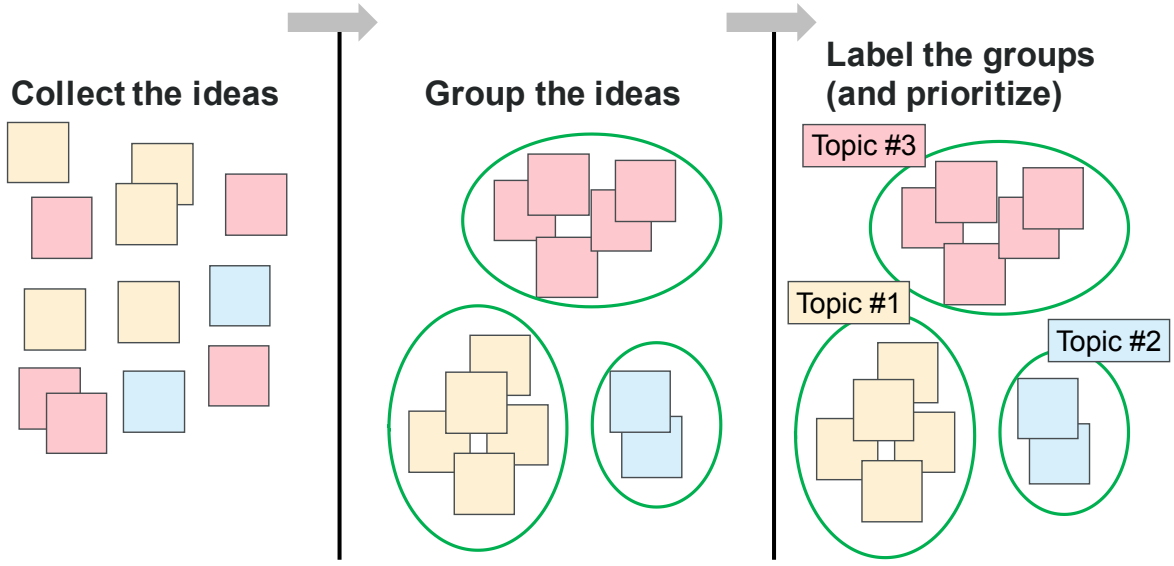
Difficulty
Easy to use

- **Brainstorming** is a way to generate many ideas or solutions to a problem or issue.
- Brainstorming rules:
  - There are no bad ideas.
  - Don't discuss any ideas.
  - Don't criticize any ideas.
  - Encourage people to build on other people's ideas.
  - Encourage quantity over quality.

https://commons.wikimedia.org/wiki/File:Sticky_notes_on_the_wall_of_the_Wikimedia_Foundation_office,_2010-10-26.jpg

1. Define the problem or issue to be addressed. It may be a "why," "how," or "what" issue.
2. Perform the brainstorming – multiple options:
   A. People write their ideas on sticky notes.
   B. For *unstructured brainstorming,* have people call out ideas, and the leader writes them on sticky notes.
   C. For *round-robin brainstorming*, ask each person in turn for an idea (they can pass)
3. Capture all ideas in an area visible to all.
4. Stop when no one has any more ideas.
5. Put the ideas into groups and eliminate duplicates (this can also be done during the session)

Brainstorming – Example – Generic



- The grouping can be done during, or after, the brainstorming session.
- The prioritization is done after the brainstorming session.

Check Sheet

Problem
How to capture data for analysis?

Difficulty
Easy to use

1. A **Check Sheet** is the simplest quality tool.
2. A check sheet is an organized way to capture information.
3. The information captured can be quantitative or qualitative. When quantitative, a check sheet is called a *tally sheet.*
4. Each type of check sheet has a different purpose, such as:
   A. Counting number of defects
   B. Determining defect locations
   C. Determining how defective something is.

Problem	Mon	Tue	Wed	Thu	Fri
Timeliness	I		III		
Quality		II	III		II
Quantity	I			I	
...					

- Existing process
- Team

Check Sheet Process

- Check Sheet
- Data for analysis

1. Define the data needed to address a specific issue.
2. Choose an appropriate check sheet style, such as
   A. Obtaining the distribution of a specific item
   B. Counting the number of defective items
   C. Identifying where defects occur
3. Create the check sheet.
4. Train the team on how to use the check sheet.
   - Test the team and the check sheet to ensure the data captured is correct and useful.
5. Determine how, when, and where to collect data.
6. Collect the data.

Check Sheet – Several Examples

Obtaining the distribution of an item

Date	*6/1/2023*
Product	*widget #1*
Inspector	*Bob*
Batch	*A23*

Specified weight (grams)	Measured difference	Observations
139	< -5	x x x x x x
	(-3, -5]	x x x x x x x x x
	[-0.1, -3]	x x x x x x x x x x x
	0	x x x x x x x x x x x x
	[0.1, 3]	x x x x x x
	(3, 5]	x x x x
	> 5	x x x

Counting defective items

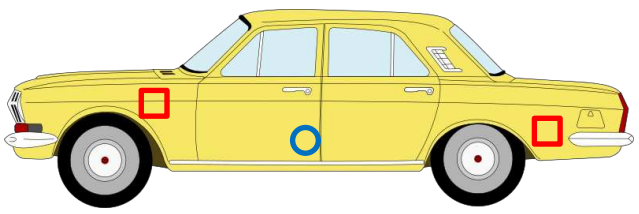
Date	*6/1/2023*
Product	*widget #2*
Batch	*B34*

Shift	Machine	Operator	Defects observed				
			Monday	Tuesday	Wednesday	Thursday	Friday
1	A	Alan			III		II
		Betty		II		II	
	B	Carol	III				
		Dan			I	I	
2	A	Eric	I		II		III
		Frank		II			
	B	George			I		I
		Harry	II			II	

Defect location

Date	*6/1/2023*
Inspector	*Charles*
Vehicle	*stock #8347*

Icon	Defect type	Count
□	dent	II
○	scratched paint	I



https://commons.wikimedia.org/wiki/File:GAZ-24_Volga.svg

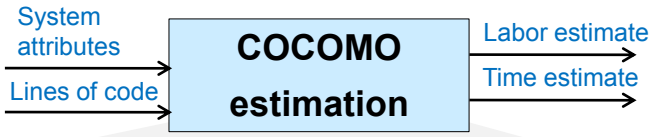
Constructive Cost Model (COCOMO)

Problem
How to determine the effort to create software?

Difficulty
Easy to use

The **Constructive Cost Model** (**COCOMO**) is a SW estimation model which uses SW lines of code to estimate the needed man-power effort and duration.

- Since programming paradigms evolve, COCOMO may be less useful than it was in the past.



1. Identify software product to be estimated.
2. Estimate the Software Lines Of Code (SLOC).
3. Select COCOMO model: **basic** or **intermediate**
4. Determine product attributes. For the basic model:
   - **Organic –** small team / good experience / flexible requirements
   - **Semi-detached –** medium team / mixed experience & requirements
   - **Embedded –** tight constraints
5. Create COCOMO estimates using the equations associated with the model
   - Labor is in person-months
   - Schedule is in calendar months

Basic **COCOMO equations**

- **Labor** = $a\,(\text{KSLOC})^b$
- **Schedule** = $c\,(\text{Labor})^d$

where

Software project type	*a*	*b*	*c*	*d*
Organic	2.4	1.05	2.5	0.38
Semi-detached	3.0	1.12	2.5	0.35
Embedded	3.6	1.20	2.5	0.32

Terminology
- SLOC = software lines of code
- KSLOC = kilo SLOC = 1,000 lines of code

COCOMO – Example – Creating SW program

Problem statement:
You are creating a SW product; the code will be about 10,000 lines (10 KSLOC). How long it will take to create the SW and how much manpower is required?

Answer:

1. If the SW product/team is **organic** (an experienced small team that has worked together on similar products in the past) then the parameters to use in the COCOCO equations are {a=2.4, b=1.05, c=2.5, d=0.38}. Using them
   - **Labor** (in man-months) = a $(\text{KSLOC})^b$ = 2.4 $(10)^{1.05}$ = **27**
   - **Schedule** (in calendar months) = $c\,(\text{Labor})^d$ = $2.5\,(27)^{0.38}$ = **8.7**
2. The conclusion is that a team of size 3 is needed for 9 months.

Notes
1. For a **semi-detached** SW product/team (of the same size)
   - **Labor** = **40** man-months and **Schedule** = **9** calendar months
2. For an **embedded** SW product/team (of the same size)
   - **Labor** = **57** man-months and **Schedule** = **9** calendar months
3. **Conclusion**: The SW development will take 9 months; the team size varies based on the type of SW being developed.

Control Chart

Problem
How to monitor defects?

Difficulty
Some training required

1. A **Control Chart** shows how a process evolves over time. It is used to monitor, control, and/or improve a process.
2. A **Control Chart** includes a
   - center line (average)

   and the data boundaries
   - Lower Control Line (LCL)
   - Upper Control Line (UCL)
3. The LCL and UCL are three standard deviations from the center line (below and above).
4. There are 4 process states, see table below right.

There are 7 control chart types
1. **Discrete data**: c, np, p, u
2. **Continuous data**: Individual Moving Range (I-MR), average-range (Xbar-R), and average-sigma (Xbar-S).

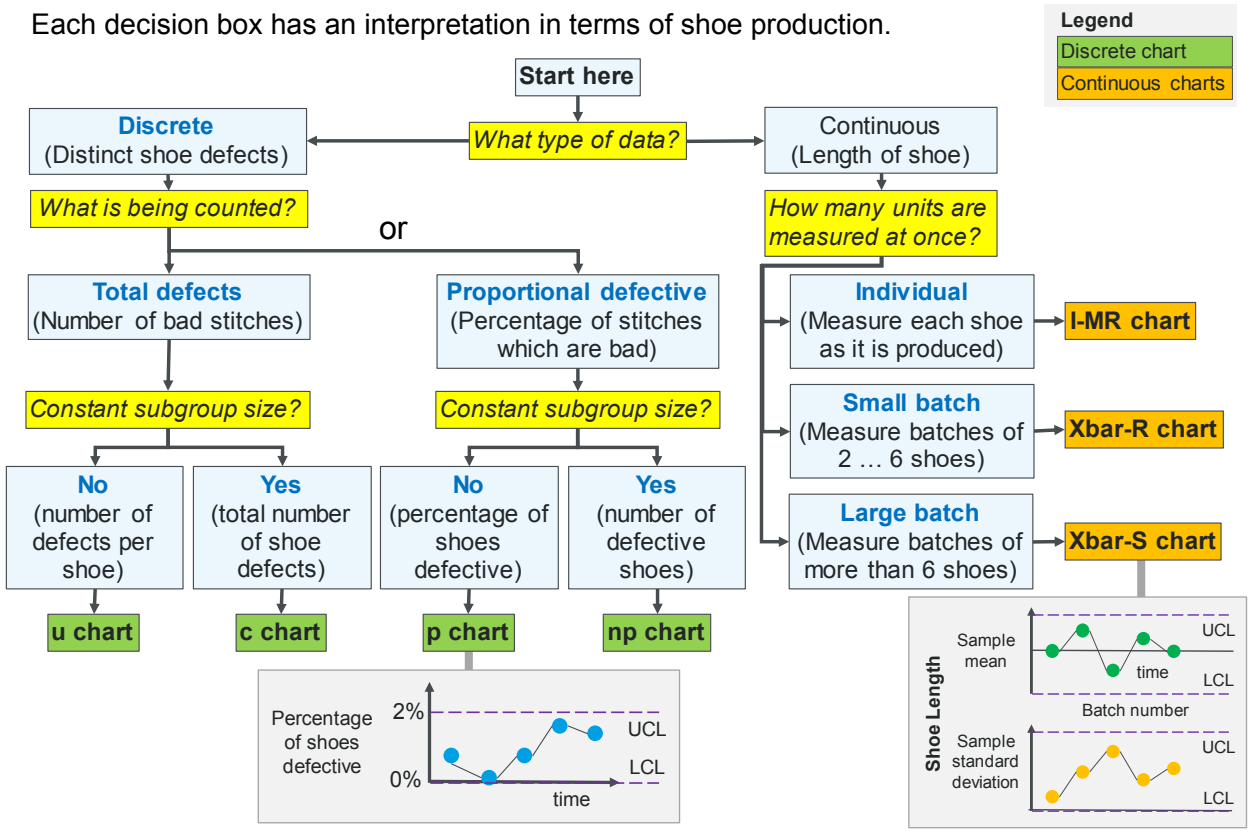
Existing process → **Control Chart Creation** → State of the process

1. Determine which of 7 types of control chart to use (see example). The choice depends on
   A. data type, whether it is continuous or discrete
   B. sample size and whether or not it is constant
   C. type of analysis to be performed
2. Collect the data
3. Perform needed computations
4. Plot the results of the computation
5. Analyze the plots for large variance or patterns.

State	In statistical control?	Data between LCL and UCL?	Process meets customer specifications?
Ideal	Yes	all	NA
Threshold	Yes	most	NA
Brink of Chaos	No	NA	Yes
Out of Control	No	NA	No

Control Chart – Example – Shoe Production

Each decision box has an interpretation in terms of shoe production.



Cost as an Independent Variable (CAIV)

Problem
How to identify best value?

Difficulty
Easy to use

CAIV is a method to determine "best value"
- It is a structured, disciplined process that balances cost, performance, schedule, and risk to arrive at the "best value" soln
- It addresses "Total Ownership Cost" = Development + Acquisition + Ownership (direct & indirect)

- Capability needed
- Options to meet need
- Cost models

→ **CAIV process** →

- "Best" option

CAIV requires
- A detailed specification of a need
- An affordability estimate
- Multiple options that meet the need
- Accurate life cycle cost models

1. Obtain specification for a needed capability
2. Aggregate all system costs (e.g., direct and indirect, acquisition and operational)
3. Identify multiple options meeting the needed capability
4. Price out the multiple options
5. Use CAIV to compare and prioritize the multiple options – that is, find the best value proposition

CAIV can prevent having to make statements such as:
"The last 50% of the cost only bought 1% better performance"

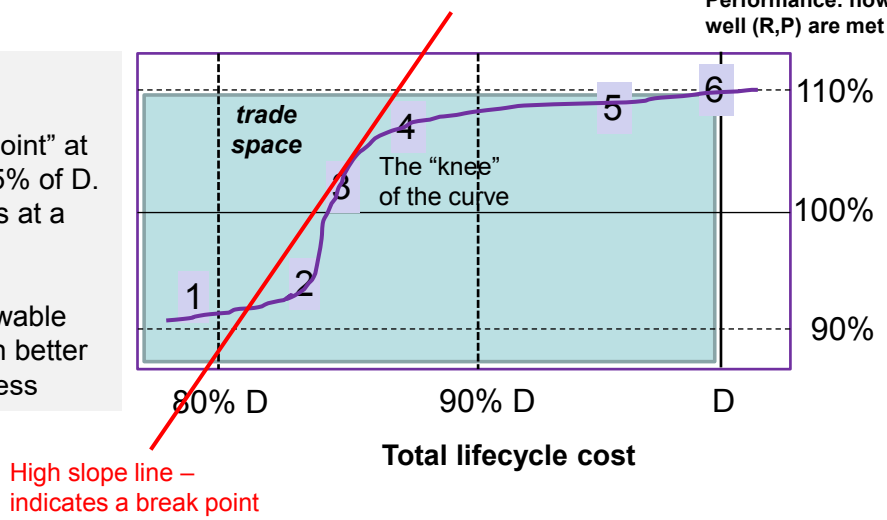
CAIV – Example – Buying a car

How to buy a car
1. Define car requirements (e.g., reliability of R, can carry P passengers)
2. Define car lifecycle budget (can spend up to D dollars over life of car)
3. Find cars meeting (R,P) and are less than D in cost
   - That is, they are in the "trade space" (e.g., used/new, high mileage/low mileage, different brands)
4. From the graph, identify the "natural breakpoints" where more money only buys marginal improvement – this is the "knee" of the curve

Options
1. 15 year old car – high mileage
2. 15 year old car – low mileage
3. 5 year old car
4. 3 year old car
5. new car
6. new car – luxury brand

Analysis
- Graph options 1-6
- Graph has a "break point" at 105% of (R,P) and 85% of D.
- The best value occurs at a cost of less than D

Conclusion
- Can spend up to allowable budget (D), but obtain better "value" by spending less



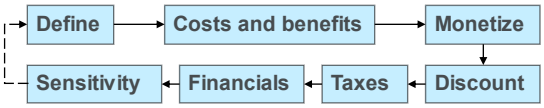
Cost Benefit Analysis (CBA)

Problem
How to financially evaluate a plan?

Difficulty
Some training required

- A **Cost Benefit Analysis** (**CBA**) financially evaluates a plan.
- CBA compares costs and benefits
  - direct & indirect, tangible & intangible, opportunity costs, competitive benefits

  to determine financial metrics
  - net present value (NPV), internal rate of return, payback period, ownership cost
- Costs and benefits are measured in monetary terms, then discounted.
- It can be challenging to identify all relevant CBA factors.
- CBA is often used to compare multiple alternatives.



- Project plan
- Alternatives (optional)

→ **Cost Benefit Analysis Process** → Quantitative analysis of plan(s)

1. Define the analysis framework (project scope)
   - Specify what will be changed.
   - Specify what effects must be considered.
2. Identity and classify costs and benefits.
   - That is, everything which contributes to the financial metrics.
3. Monetize the costs and benefits.
4. Discount the costs and benefits to obtain the net present values.
5. Determine the tax implications (if any).
6. Compute the desired financial metric(s).
7. Perform a sensitivity analysis to ensure credibility of results.
8. Accept results, or refine & repeat the analysis.

Cost Benefit Analysis – Invest in new HW and SW

Investment cost

Assume a 5% discount rate

Investment benefit

Description		Year #1	Year #2	Year #3	
Costs					
fixed	HW	8,500	0	0	
	HW license	1,000	500	500	
	SW	4,000	0	0	
	SW licence	2,000	2,000	2,000	
variable	Advertising	1,000	2,000	3,000	
	Training	1,000	1,000	500	
	Costs - total	17,500	5,500	6,000	
	Discounted costs at 5%	17,500	5,238	5,442	$28,180
Benefits					
tangible	Retire older HW & SW	4,000	4,000	4,000	
	Increased productivity	3,000	3,000	3,000	
	Reduced attrition	2,000	2,000	2,000	
intangible	Employee satisfaction	500	500	500	
	Client satisfaction	1,000	1,000	1,000	
	Benefits - total	10,500	10,500	10,500	
	Discsounted benefits at 5%	10,500	10,000	9,524	$30,024
Overall project benefit					$ 1,844
Benefit cost ratio					1.07
Cash flow: inflow - outflow		$(7,000)	$ 5,000	$4,500	
cumulative cash flow		$(7,000)	$(2,000)	$2,500	
Payback period (years)		2.44			
Internal Rate of return (IRR)		23%			
		Jan-22	Jan-23	Jan-24	

Compute discount as $5{,}422 = 6{,}000/(1+0.05)^2$

$28K is sum of values

$10.5K is sum of values

$1,844 = $30K - $28K

1.07 = $30K/$28K

2.5K = 4.5K + (-2.0K)

2.44 = 2 - (-2000)/4500

Payback period is the duration to break even on the original investments

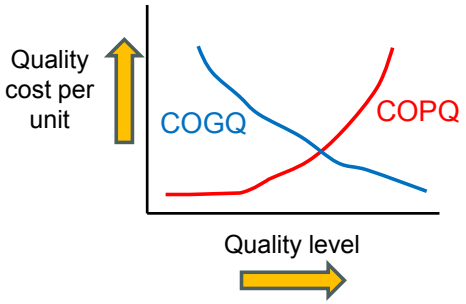
IRR is the discount rate which makes the net present value of the project zero. (Computed using Excel's IRR function)

Cost of Quality (COQ)

Problem
How to minimize the cost of quality?

Difficulty
Work with an SME

- **Cost of Quality=COPQ+COGQ**
- **Cost of Poor Quality (COPQ)**
  - cost associated with poor-quality products/services
  - = Internal Failure costs + External Failure costs
- **Cost of Good Quality (COGQ)**
  - cost to prevent poor-quality products/services
  - = Appraisal costs + Preventative costs



Find 4 costs making up cost of quality → **Minimize Cost of Quality** → Choose which cost to reduce; Implement quality improvements

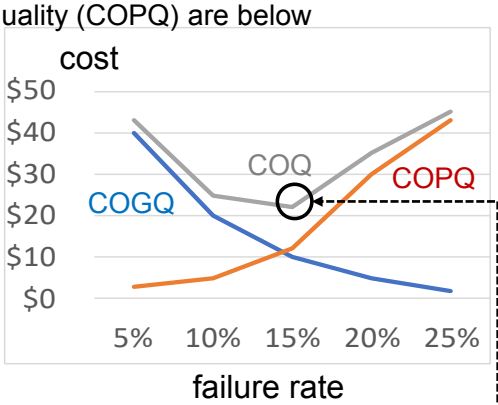
1. Define quality goals; COQ of 10–15% may be OK
2. Collect cost data: internal failure, external failure, appraisal, prevention
3. Identify which quality costs should be reduced (if any), then use appropriate methods for each:
   - For Internal Failure costs: Poka-Yoke (Mistake-Proofing), Root Cause Analysis,…
   - For External Failure costs: Customer Surveys, Warranty Programs, …
   - For Appraisal costs: Statistical Process Control (SPC), Statistical inspections, …
   - For Prevention costs: Audits, Employee Training, …
4. Implement determined quality improvements.
5. Repeat

Cost of Quality (COQ) – Example – Making widgets

Imagine we are making widgets.
The per unit costs of good quality (COGQ) and poor quality (COPQ) are below

failure rate

	5%	10%	15%	20%	25%
COGQ	$40	$20	$10	$5	$2
COPQ	$3	$5	$12	$30	$43
COQ (sum)	$43	$25	$22	$35	$45



For COGQ: it is very expensive to have a low failure rate
- For example: recalibrate machines every hour, update employee training weekly, many inspections of incoming materials, …

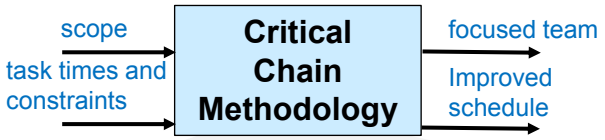
For COPQ: it is very expensive to have a high failure rate
- For example: recalls, replacements, customer ill-will, …

Hence, there is a value where the total cost of quality (COQ) is least.
- In the example, the COQ is minimized at $22/unit at a common failure rate of 15%

Critical Chain Program Management (CCPM)

Problem
How to shorten a project schedule?

Difficulty
Work with an SME



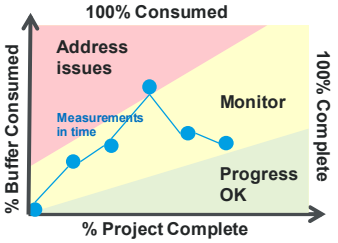
Critical Chain Definition

The longest chain of dependent tasks with resources de-conflicted and individual safeties removed and added back in as a project buffer

If resources are unlimited then ***critical chain*** and ***critical path*** *are similar.*

- **Critical Chain Program Management (CCPM)** is a management methodology which provides information on the right tasks at the right time to ensure on-time delivery.
- **CCPM** is based on the *Theory of Constraints.* In any schedule, at any time, there is **one activity** that is **gating** the progress. The goal is to **identify** that activity and **improve** it.

1. **Develop a robust project plan**
   - Use *Reverse Planning* to create a schedule.
   - Have workers create both *aggressive* and *low risk* duration estimates for tasks.
   - Work to the aggressive duration estimates.
   - Size and create a buffer based on the difference in duration estimates.
2. **Identify constraints & plan Corrective Actions**
3. **Change the culture**
   - Critical Chain tasks get highest priority
   - Minimize multi-tasking
4. **Proactively manage the system**
   - Manage variation via the buffer

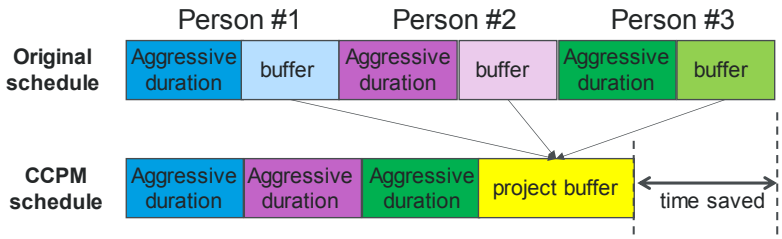


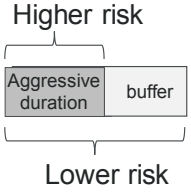
A "fever chart" tracks progress and indicates when corrective action is needed.

CCPM – Example – The CCPM Project Buffer

Consider a job that requires 3 people to perform sequential tasks.

1. Each person
   A. Knows the aggressive (shortest) duration it will take them to perform their task.
   B. Will naturally include a buffer since they don't want to fail (and, perhaps, a task is more challenging than anticipated, or there may be interruptions or sickness). These individual buffers increase the overall time for the job.
2. In CCPM, the aggressive durations are placed end-to-end and the *individual buffers* are statistically aggregated into a overall *project buffer*. This reduces the overall time since some, but not all, of the tasks will take longer than the minimal time.
3. Management challenges include:
   1. Ensuring realistic aggressive durations; failing to meet these time estimates can be both expected and desired.
   2. Rescheduling is required when some tasks take more than the minimal duration.





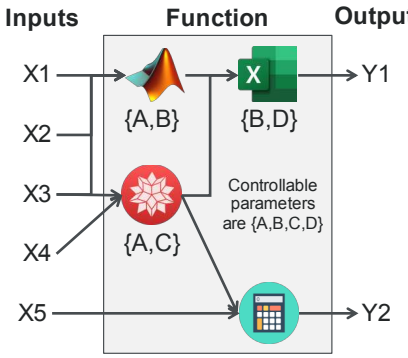
Critical Parameter Management (CPM)

Problem
How to identify and manage critical to quality parameters?

Difficulty
Work with an SME

Critical Parameter Management (CPM)
- A methodology for ensuring product performance
- A mathematical process that links the inputs and outputs, to identify the parameters driving product quality

Existing process → **Critical Parameter Management Process** → Identification of critical parameters



1. Determine the process flow, which must include the inputs, controllable parameters and the outputs of interest. (Typically, the output quality is of interest.)
2. With the help of an SME:
   A. Using experimental data, mathematically model the input/output relationships.
   B. From the model, determine which controllable inputs have the largest effect on the outputs.
      - These are the *critical parameters*
3. Ensure the process flow properly treats the critical parameters (e.g., by having precise tolerances).

https://commons.wikimedia.org/wiki/File:Calculator_icon.svg
https://commons.wikimedia.org/wiki/File:Antu_mathematica.svg
https://commons.wikimedia.org/wiki/File:Microsoft_Office_Excel_(2019%E2%80%93present).svg
https://commons.wikimedia.org/wiki/File:Matlab_Logo.png

CPM – Example – Cake Mixes

https://commons.wikimedia.org/wiki/File:Packet,_food_product_%28AM_2015.4.51-1%29.jpg
https://commons.wikimedia.org/wiki/File:Egg_texture_169clue.jpg
https://commons.wikimedia.org/wiki/File:Atta_flour.jpg
https://commons.wikimedia.org/wiki/File:Whisking_sauce-01.jpg
https://commons.wikimedia.org/wiki/File:Baking_cake_layer_2.JPG
https://commons.wikimedia.org/wiki/File:A_slice_of_coconut_cake.jpg

1. From experiments
   A. Cake mixes have essentially one critical parameter: the ratio of flour to baking powder
      - This ratio is closely monitored during production.
   B. Cake preparation is robust to reasonable variations in:
      - Quantifies of: water, eggs, oil, cake mix
      - Cooking environment: time, temperature, humidity
   C. Cake preparation is *not* robust to altitude. As this is not under the manufacturer's control, there are separate cooking instructions.

Customer Segmentation

How to improve marketing and sales?

Difficulty

Work with an SME

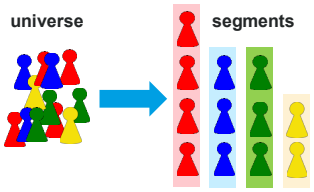
- **Customer segmentation** (CS) divides customers based on common characteristics.
- CS is tailored for each product.
- CS improves marketing efforts.
- Market segmentation relates to the whole market, CS is your part of the market.

- Customer (or leads) data
- Market data & segmentation

→ **Customer Segmentation Process** → Customer segments

1. Review industry data and market analysis.
2. Examine your current customer base.
3. Choose a customer segmentation model.
4. Consider customer segmentation software – essential for very large data collections.
5. Collect customer experience data – both direct (e.g., surveys) and indirect (e.g., social listening).
6. Analyze customer experience data.
7. Refine your customer segments, and repeat.

Segment	Question addressed
Demographic	Who are your buyers?
Psychographic	Why are they buying?
Geographic	Where are your buyers?
Behavioral	How are they buying?
Benefit	What benefits entice your buyers?
Firmographic	What business types are buying?



Customer Segmentation – Example – 6in6 Consulting

Consider starting a Six Sigma consulting business based on 6in6 presentations.
What are the customer segments?

1. Industry data: there are many Six Sigma consulting groups, large and small (e.g., Bain & Company, KPMG, PwC). Presume we have determined the market size (e.g., engagements, dollars) and types of offerings (e.g., classes, seminars, contract work).
2. With no customers, the leads are: supporting non-profits, corporate hourly consulting on demand, teaching academic classes.
3.

Segment	Non-profits	Hourly work	Teaching
Demographic	Older	All ages	Younger
Psychographic	Teach skills they will apply themselves	Needed training and coaching	Baseline student learning, support student projects
Geographic – where to meet decision makers	At their regularly scheduled meetings	At conferences	Go to schools to meet the Dean

4. Skip SW. 5. & 6. Survey target audiences to find what they want/don't want:

• Cost sensitive • Any day/time works	• Want focus in specific areas • Work regular hours	• Want video presentations • Need to be available at all hours to help students

7. Due to lack of specific experience:
   - Drop corporate work (for now)
   - Segment non-profits by funding: low (local arts groups), high (museums)
   - Repeat analysis.

Dashboard

Problem
How to monitor performance?

Difficulty
Easy to use

- A **dashboard** is a business reporting tool consolidating and displaying critical metrics and key performance indicators (KPIs) on one screen/page.
- Dashboards allow real-time performance to be monitored, usually with multiple graphics.
- Dashboards are used at every level of an organization.

Need to communicate current status → **Dashboard Creation Process** → Graphical informational display

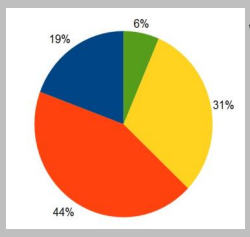
1. **Determine audience**
   A. Who benefits from the dashboard?
2. **Select metrics**
   A. Which metrics, ideally 3-7, should appear? (The audience should influence the metrics.)
   A. Common metrics: customer complaints, product defects, safety, system downtime, or sales.
3. **Design presentation**
   A. How should each metric be represented?
   B. How should the metrics appear in the display?
4. **Implementation**
   1. How will the metric values be updated?
   2. How often will the metric values be updated?
5. **Review and update as needed**

Metrics can use elements to show meta information. Below, see change in color and arrow direction

share price **1.83** ↑

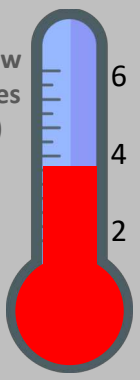
share price **–0.52** ↓

Dashboard – Example – 6in6 web site



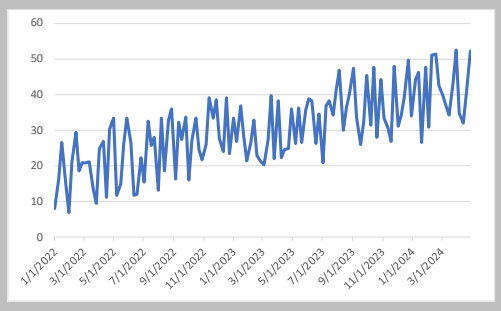
Weekly 6in6 viewers
- Asia
- Europe
- North America
- Other

Number of new 6in6 web pages (this month)



4 July 2023 – 6in6 web site

Weekly number of 6in6 web pages served



DFMA
Today's most popular 6in6 presentation

213
DAYS WITHOUT A REPORTABLE ACCIDENT

Figure credits
https://commons.wikimedia.org/wiki/File:Pie-chart.jpg
https://openclipart.org/detail/323734/thermometer

Design for Manufacturing & Assembly (DFMA)

Problem
How to make products easy to construct?

Difficulty
Work with an SME

Design for Assembly (DFA)
is concerned with **reducing *product assembly* cost**

Design for Manufacturing (DFM)
is concerned with **reducing *overall part production* cost**

Preliminary design → **Design for Manufacturing & Assembly Process** → Improved design
Team →

DFMA has many benefits
- Minimizing the number of parts and extra sizes reduces inventory and confusion during assembly
- DFMA optimizes trade-offs between assembly, part, and life cycle costs.

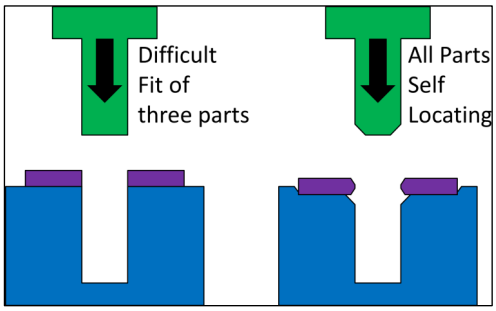
Methodically apply the DFMA principles
1. Minimize the number of parts
2. Minimize the use of fasteners
3. Standardize
4. Avoid difficult components
5. Use modular subassemblies
6. Use multifunctional parts
7. Minimize reorientations
8. Use self-locating features
9. Avoid special tooling
10. Provide accessibility
11. Minimize operations & process steps

Asymmetric part requires alignment

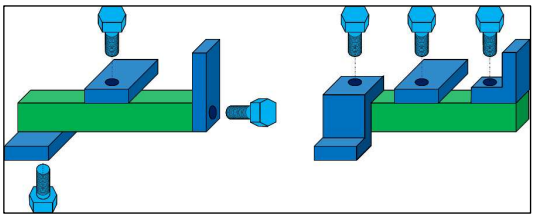
Symmetric part makes assembly easier

DFMA – Examples – Manufacturing

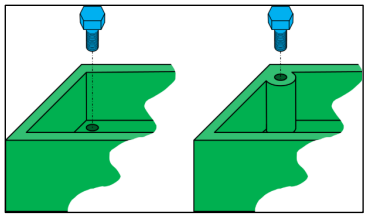
Make parts self-aligning



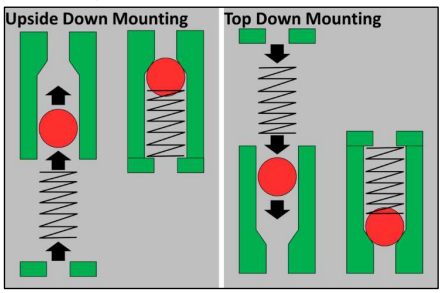
Make assembly from one side



Improve access for assembly



Use gravity when possible



Simplify fasteners

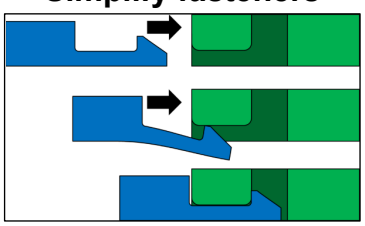


Figure credits
- https://www.allaboutlean.com/dfma-6/dfma-self-locating-2/
- https://www.allaboutlean.com/dfma-6/dfma-upside-down-mounting/
- https://www.allaboutlean.com/dfma-6/dmfa-assemble-from-one-side/
- https://www.allaboutlean.com/dfma-6/dfma-symmetry/
- https://www.allaboutlean.com/dfma-4/dfma-plastic-snap-joint/

Design for Six Sigma (DFSS)

Problem
How to create a new process?

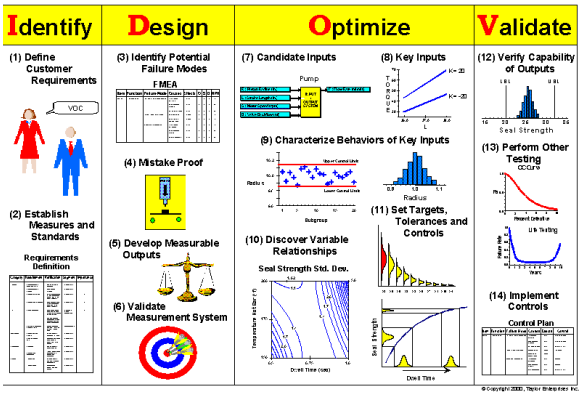
Difficulty
Work with an SME

- **Design for Six Sigma (DFSS)** is used for the complete re-design of a product or process.
  - Traditional Six Sigma improves a current process or product design.
- **DFSS** methodologies include: **DCCDI** (Define, Customer Concept, Design and Implement), **IDOV** (Identify, Design, Optimize, Validate), and **DMADV** (Define, Measure, Analyze, Design, Verify).

Customer need → **DFSS Process** → New process

1. Select a DFSS methodology (e.g., IDOV)
2. Follow the steps of the selected methodology, using multiple six sigma tools for each step.

Design for Six Sigma - IDOV



https://isowatch.wordpress.com/2018/10/23/six-sigma-is-draining-employees-creativity/

Design for Six Sigma – DMADV

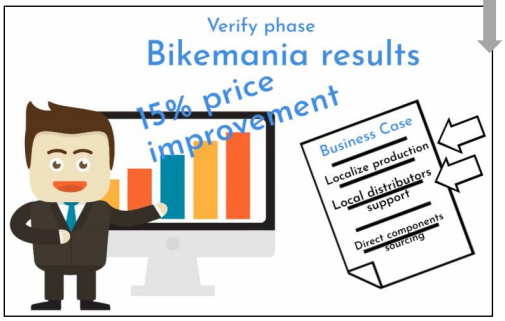
	Typical Tools Used
D – **Define** goals of design activity	▪ AHP ▪ QFD ▪ SIPOC diagrams
M – **Measure** stakeholder metrics	▪ Surveys ▪ Value Stream Analysis
A – **Analyze** the available options	▪ QFD ▪ Statistical tools
D – **Design** the new product	▪ FMEA ▪ DFMA ▪ TRIZ
V – **Verify** the design in the real world	▪ Pilot tests ▪ SPC & control charts

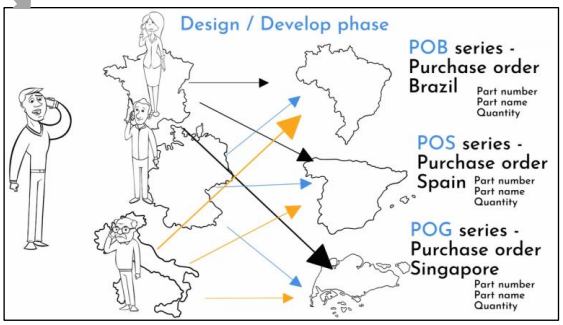
Updated: 202210

DFSS – Example – Bicycle Manufacturer

Three images from "How to do DMADV Process? Supply Chain Easy Example" at https://sixsigmamania.com/?p=338 (with permission)

- **Step 0:** Select DMADV (Define, Measure, Analyze, Design, Verify) process
- **Step 1:** For "Define" step use multiple six sigma tools – see top right graphic
- **Step 2:** Perform "Measure" step
- **Step 3:** Perform "Analyze" step
- **Step 4:** For "Design" step use multiple six sigma tools – see bottom right graphic
- **Step 5:** For "Verify" step use multiple six sigma tools – see bottom left graphic





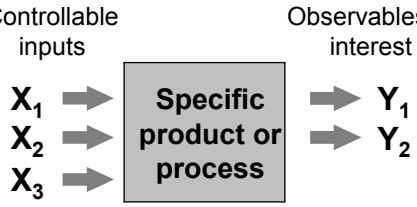
Design of Experiments (DOE)

Problem
How to determine the factors controlling an output?

Difficulty
Work with an SME

- **Design of Experiments** (DOE) is a cost effective statistical approach that quantifies the effect of inputs on outputs.
- DOE makes specific changes to inputs and observes the resulting outputs.

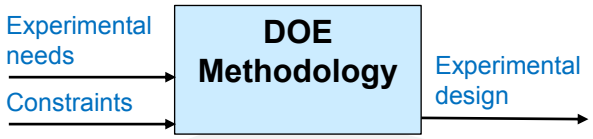
- **This is the system**



- **Problem** – find inputs to minimize (say) the observables, using as few tests as possible.
- **Solution** – use the model below – observables depend on the inputs, with (usually) the earlier terms being more important than later terms:

$$Y_i = \overline{Y} + \sum_i a_i X_i + \sum_{i,j} b_{ij} X_i X_j + \dots$$

overall mean | main effects | Two-way interactions



1. Define the test objective(s)
   - What is the overall problem?
2. Select and quantify the critical response(s)
   - What observables are of concern?
3. Design the experiment (incorporate features such as randomization, replication, and blocking)
   - Define all the inputs for each test
4. Perform all the tests and collect the data
5. Analyze the data (use a SW package)
6. Interpret the results
7. Verify the predicted outcome

Terminology
- Each input has "**levels**" (perhaps 3 different values for X_1 and 4 different values for X_2).
- A "**full factorial design**" has a test for every possible combination of levels.
- A "**partial or fractional factorial design**" uses a subset of the tests in the full factorial design.

DOE – Example – Golf score

Example from: Jack B. ReVelle, *Manufacturing Handbook of Best Practices: An Innovation, Productivity, and Quality Focus*, https://books.google.com/books?id=_EfMBQAAQBAJ&pg=PP5

(1) Want to minimize a golf score based on the following 7 controllable inputs. (Note that each input has 2 levels.)

	Inputs	Level (-1)	Level (+1)
A	Age of clubs	Old	New
B	Time of day	AM	PM
C	Use golf cart	No	Yes
D	Practice at driving range	Yes	No
E	Drink during game	Yes	No
F	Type of ball	Wilson	Titleist
G	Use of caddy	Yes	No

(2) A full factorial seven factor design at 2 levels has 2^7=128 experiments. Instead, use 8 experiments:

Experiment	Inputs (encoded)							Observation			
	A	B	C	D	E	F	G	Y_1	Y_2	Y_3	Y_4
#1	-1	-1	-1	-1	-1	-1	-1				
#2	-1	-1	1	-1	1	1	1				
#3	1	1	-1	1	-1	1	1				
#4	-1	1	1	1	1	-1	-1				
#5	1	-1	-1	1	1	-1	1				
#6	1	-1	1	1	-1	1	-1				
#7	1	1	-1	-1	1	1	-1				
#8	1	1	1	-1	-1	-1	1				

Observed values go here

(3) Convert to input levels and perform the experiments. Potential observable values are shown.

Experiment	Input values							Golf score
	A	B	C	D	E	F	G	Y_1
#1	Old	AM	No	Yes	Yes	Wilson	Yes	84
#2	Old	AM	Yes	Yes	No	Titleist	No	96
#3	Old	PM	No	No	Yes	Titleist	No	89
#4	Old	PM	Yes	No	No	Wilson	Yes	97
#5	New	AM	No	No	No	Wilson	No	94
#6	New	AM	Yes	No	Yes	Titleist	Yes	91
#7	New	PM	No	Yes	No	Titleist	Yes	94
#8	New	PM	Yes	Yes	Yes	Wilson	No	92

(4) A simple analysis finds the most important inputs (to leading order) – these cause the largest change.

	Inputs	Levels	Totals	Means	Effect
A	Age of clubs	Old	366	91.50	1.25
		New	371	92.75	
B	Time of day	AM	365	91.25	1.75
		PM	372	93.00	
C	Use golf cart	No	361	90.25	3.75
		Yes	376	94.00	
D	Practice at driving range	Yes	366	91.50	1.25
		No	371	92.75	
E	Drink during game	Yes	356	89.00	6.25
		No	381	95.25	
F	Type of ball	Wilson	367	91.75	0.75
		Titleist	370	92.50	
G	Use of caddy	Yes	366	91.50	1.25
		No	371	92.75	

Design Thinking

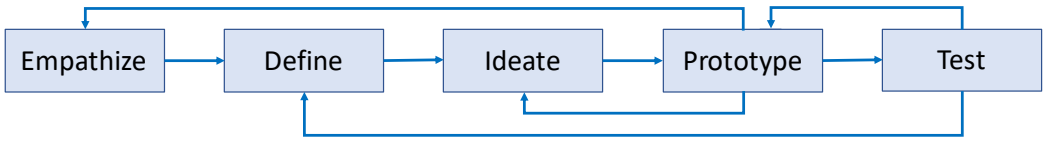
Problem
How to address an ill-defined problem?

Difficulty
Work with an SME

- **Design Thinking** (DT) is an innovation approach which: empathizes with users, creates artifacts that address user needs, tests those artifacts, analyzes feedback, and continuously reworks the solution.
- DT usually has 5 steps: *Empathize, Define, Ideate, Prototype, and Test*.
- While DT steps are shown sequentially, rarely do they occur in a linear fashion. Usually, "backward" steps occur as the team learns more about user needs.
- DT does not address the entire life cycle of a product or solution, it only focuses on specific problems within the life cycle.

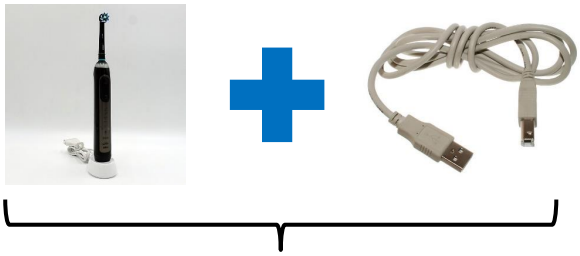
The following steps do not often occur linearly!

1. Empathize with your users
   - Determine how users interact with their environment in the context of the problem space.
2. Define the problem
   - Create a high-level human-centric statement that encapsulates the problem to be solved.
3. Start generating ideas
   - Generate as many ideas as possible to translate the problem statement into practical solutions.
4. Build a prototype
   - Take the most promising product ideas and create minimum viable product (MVP) versions.
5. Test your solution
   - Use test feedback to fine-tune the MVPs.



Design Thinking – Example – electric toothbrush

1. The web has many examples of Design Thinking.
2. An example is the design of the Braun / Oral-B electric toothbrush. Apparently:
   A. An initial Braun goal was to create a high-tech toothbrush that gave feedback to users on how well they brushed.
   B. After user discussions, it was determined that users wanted a less stressful brushing experience.
   C. Some stress related to the charging of an electric toothbrush.
   D. Braun changed their goal and created an electric toothbrush that uses USB charging.



New product: "Technical Portable Compatible for Braun Oral b Replacement Oral Charger Durable Convenient Electric Toothbrush Holder USB"

https://commons.wikimedia.org/wiki/File:A-B_Usb_Cable.jpg
https://commons.wikimedia.org/wiki/File:Oral-B_Genius_X_Electric_Toothbrush_-_48263286922.jpg

The web has examples of Design Thinking applied to problems in:

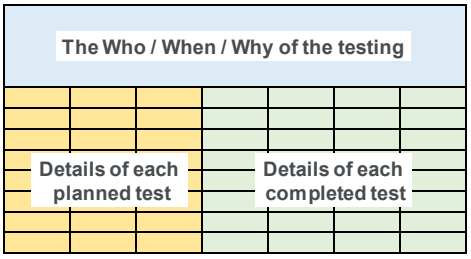
- Education
- Financial Services
- Healthcare
- Journalism
- Non-Profit/NGOs
- Retail
- Technology
- Transportation

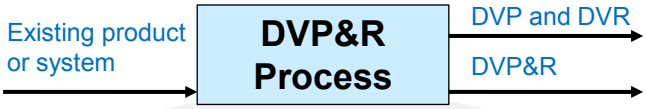
Design Verification Plan and Report (DVP&R)

Problem
How to document that a product is acceptable?

Difficulty
Some training required

- The **Design Verification *Plan*** (**DVP**) documents the strategy used to verify that a product (or system) meets its requirements (e.g., design specifications).
- The **Design Verification *Report*** (**DVR**) documents the test results obtained by using the **DVP**.
- A **Design Verification *Plan and Report*** (**DVP&R**) combines the **DVP** and the **DVR**.
- A **DVP&R** may be used for legal or product "sell off" purposes.
- A **DVP&R** has no standard format.





1. If not available, create the product's planned tests:
   A. Articulate the product's functionality.
   B. Define discrete and actionable functionality tests for the anticipated environments
2. Create a Design FMEA for the product to identify failure modes not detected in the planned tests.
3. Create the **Design Verification Plan** (**DVP**)
   A. Include the planned tests.
   B. Include tests to address the deficiencies identified by an FMEA.
4. Perform the tests in the **DVP** and document the results in the **DVR**.
5. If needed, use the **DVR** results to update the **DVP** and repeat the process.
6. Create the **DVP&R** and file appropriately.

DVP&R – Example – Automobile Radar

Product Name	Automobile Radar	Component	*Sub-system #3*	Requester	*Ron*
Model Number	Rev 2.5.4	Test spec	*Test #3·4·7*	Date	*2/15*

Heading
- **part info**
- **dates**

Verification Plan

Test Number	Test Name	Test or Action	Acceptance Criteria	Responsibility	Tester	Sample Size	Sample Type	Test Start	Test End
1	Signal Processing Design	SW Test #3: clutter rejection	> 27 dBsm rejection	Lisa	*George*	*500*	*SW*	*2/18*	*2/20*
2	Signal Processing Firmware	Track Test #27: clutter rejection	> 27 dBsm rejection	Ben G.	*Alice*	*10*	*mock-up*	*3/14*	*3/14*
3	Signal Processing HW	Vehicle Test #8: clutter rejection	> 23 dBsm rejection	Carla	*David (drive team)*	*5*	*pre-production*	*4/12*	*4/18*
4	Design Review	Design Review of clutter rejection capability	Software, Systems, and Quality teams agreement	Harry	*N/A*	*N/A*	*N/A*	*4/23*	*4/23*
5	Recommended Action	Determine why track and vehicle test results were so different	Results by 5/15	Harry					
6	Recommended Action	Approve for production	Today (4/						
7	Recommended Action	…	…						

Verification Report

Reviewer	Results	Comments	Date
Quality (Nancy)	*28·5 dBsm*	*pass*	*2/22*
Quality (Nancy)	*29·5 dBsm*	*pass*	*3/14*
Quality (Ralph)	*23·5 dBsm*	*pass*	*4/21*
Quality (Ralph)	*N/A*	*Meeting held*	*4/23*

Details of every test *planned*: test name, test method or procedure, test equipment, test performance (e.g., sample size and acceptance criteria)

Details of every test *performed*: test start & end times, results, comments, …

Verification Plan

Verification Report

Enterprise Architecture

Problem
How to fully describe a project?

Difficulty
Work with an SME

1. An **Enterprise Architecture** (EA) shows project details, from business understanding to enterprise deployment.
2. An EA's artifacts includes models, documents, and specifications.
3. Example EAs include DoDAF (52 artifacts in 8 categories) the Zachman Framework (36 artifacts), and TOGAF.
4. Usually, only a subset of an EA's artifacts are created.

DoDAF (Department of Defense Architectural Framework) has 8 categories of elements:
1. All Viewpoint (AV)
2. Capability Viewpoint (CV)
3. Data and Information Viewpoint (DIV)
4. Operational Viewpoint (OV)
5. Project Viewpoint (PV)
6. Services Viewpoint (SvcV)
7. Standards Viewpoint (StdV)
8. Systems Viewpoint (SV)

- Project concept
- Subject matter experts

→ **Enterprise Architecture Process** →

Project details at all levels for all customers

1. Select an Enterprise Architecture
2. Decide on which elements in the EA to create
   - A minimal list of DoDAF artifacts could include
   - AV-1 : Overview and Summary Information
   - AV-2 : Integrated Dictionary
   - OV-1 : High Level Operational Concept Graphic – **most common**
   - OV-2 : Operational Node Connectivity Description
   - OV-3 : Operational Informational Exchange Matrix
   - OV-5 : Operational Activity Model
   - StdV-1 Standards Profile
   - SV-1 : System Interface Description
3. Create the artifacts and review with stakeholders

The **Zachman Framework** has (example instantiations shown below)
- **6 descriptive areas**: data, function, network, people, time, motivation
- **6 perspectives**: planner, owner, designer, builder, subcontractor, enterprise
- The 36 elements are arranged in a 6-by-6 grid

TOGAF (The Open Group Architecture Framework) uses 4 architecture domains: Applications, Business, Data, and Technical

Enterprise Architecture – Example – Phone App

- Consider creating a phone application.
- Choose to use the Zachman framework to show all needed artifacts.
- The 6 perspectives (rows) can be interpreted in several different ways; three are shown.
  - For example: "Objective /Scope" or "Contextual layer" or "Role: Planner"
- The cells in the 6-by-6 grid below contain only some of the items that would be in that cell.

6 perspectives – must be in this top- down order

6 descriptive areas – can be in any order

		What	How	Where	Who	When	Why
		Data	*Function*	*Network*	*People*	*Time*	*Motivation*
(1)	Objective/Scope Contextual layer *Role: Planner*	Business vision & goals	Business processes	Business locations	Departments involved	Future products road map	User needs. app business case
(2)	Enterprise model Conceptual layer *Role: Owner*	Short term goals	App financing, hiring, training	Project locations	Stakeholders buy-in plan	Product release timeline	App alignment with other offerings
(3)	System logic Logical layer *Role: Designer, Architect, or General Manager*	App look and feel	System architecture (e.g., support capabilities)	System connectivity	User interface design	Master schedule	App functionality
(4)	Technology model Physical model *Role: Builder, General Contractor, or Local Manager*	Platform description, wireframe model	App requirements	Technology architecture (e.g., component libraries)	Skill identification	Development milestones	Define function capabilities
(5)	Detailed representation Detailed model *Role: Scientist, Engineer, Subcontractor, or Programmer*	Interface definitions, database schema, code	App design	Communications architecture	Security design	Implementation model (e.g., scrum)	Motivate team to create sucessful product
(6)	Functioning result Enterprise release *Role: End user*	User data needs	Usage instructions	User locations (e.g., sales roll-out plan)	Market segmentation	App responsiveness	Motivation for end-users to obtain and use app

Failure Mode Effects and Analysis (FMEA)

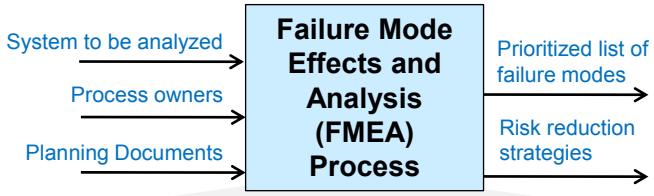
Problem
How to anticipate and mitigate potential problems?

Difficulty
Some training required

FMEA is a **systematic**, **proactive method** for evaluating a process
- to identify **where and how it might fail** and
- to assess the **relative impact of different failures**

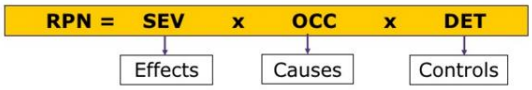
in order to **identify** where the process must be **changed**

FMEAs should be created whenever a failure can result in harm.



FMEA types include:
- **Design (DFMEA)** focuses on components and subsystems
- **Process (PFMEA)** focuses on manufacturing and assembly processes

Process
1. Determine **FMEA type**: **Defect** (FMEA), **Design** (*D*FMEA), or **Process** (*P*FMEA) and obtain appropriate standardized tables
2. Identify potential failure modes.
3. For each failure mode, using standardized tables, assess the following on a 1-10 scale:
   - **Severity** rating (how bad it is, if it occurs)
   - **Occurrence** rating (how often it will occur)
   - **Detectability** rating (how likely it is to be detected, if it occurs)
4. For each failure mode, multiply the above three numbers (each 1 to 10) to obtain a **Risk Priority Number** (RPN)
5. For the failure modes with the **highest RPN** values, determine mitigation strategies



FMEA – Example – Giving a 6in6 presentation

Comprehensive list of failure modes

For simplicity, instead of using values 1 to 10 for {S,O,D}, use {1,3,9} for {low, medium, high}. The values in the grid match the words used.

RPN value is the product of the S, O, D values

Failure mode	Severity	Occurance	Detection	S	O	D	RPN	Mitigation
Forget to show up	High	Medium	Medium	9	3	3	81	Contact on event day
Forget to bring presentation	High	Low	Medium	9	1	3	27	Email presentation
Can't find location	High	Low	High	9	1	1	9	
Hungry during presentation	Low	Medium	High	1	3	1	3	

High severity – which is bad – gets a '9'. High detectability – which is good – gets a '1'

Low RPN values do not need mitigation strategies

Automobile Industry Action Group (AIAG) created the following standards for the North American auto industry

Severity

EFFECT	CRITERIA: SEVERITY OF EFFECT	RANKING
Hazardous - without warning	May endanger machine or assembly operator. Very high severity ranking when a potential failure mode affects safe vehicle operation and/or involves noncompliance with government regulation. Failure will occur without warning.	10
Hazardous - with warning	May endanger machine or assembly operator. Very high severity ranking when a potential failure mode affects safe vehicle op with government regulation. Failure will occu	9
Very High	Major disruption to production line. 100% of p Vehicle/item inoperable, loss of primary funct	
High	Minor disruption to production line. Product m (less than 100%) scrapped. Vehicle operable performance. Customer dissatisfied.	
Moderate	Minor disruption to production line. A portion have to be scrapped (no sorting). Vehicle/ite Comfort/Convenience item(s) inoperable. Cu	

Likelihood / Occurrence

Probability of Failure	Possible Failure Rates	Ppk	Ranking
Very High: Failure almost inevitable	≥ 1 in 2	≤ 0.33	10
	1 in 3	≥ 0.33	9
High: Generally associated with processes similar to previous processes that have often failed			
Moderate: Generally associated with processes similar to previous pro-			

Detectability

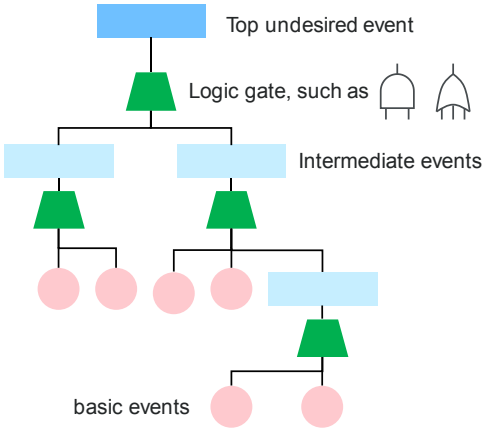
Detection	Criteria: Likelihood the Existence of a Defect will be Detected by Process Controls Before Next or Subsequent Process, or Before Part or Component Leaves the Manufacturing or Assembly Location	Ranking
Almost Impossible	No known control available to detect cause/mechanism of failure or the failure mode	10

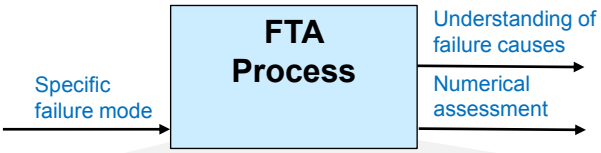
Fault Tree Analysis (FTA)

Problem
How to quantify a specific type of failure?

Difficulty
Work with an SME

- **Fault tree analysis** (**FTA**) is a top-down failure analysis in which an undesired system state (e.g., a failure mode) is analyzed using Boolean logic, combining lower-level events.
- FTA maps the relationship between faults and subsystems via a system level logic diagram.
- FTA can quantify the likelihood of failure.
- FTA can be used in the design process.
- FTA diagrams use a standard set of symbols.



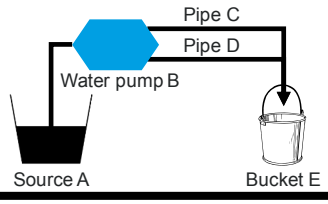


1. Define the top undesired event to investigate.
2. Identify first level contributors, just below the top level, and link these to the top level event using logical gates (e.g., AND and OR gates).
3. Identify the second level contributors and link to the first level contributors using logical gates. Continue with 3rd, 4th, etc level until basic events (root causes) are identified.
4. Construct the fault tree. Use numerical values (e.g. rates) for the basic events, if known.
5. Evaluate the fault tree.
   A. Simplify the fault tree, if possible.
   B. Determine the "cut sets," the event combinations which cause the top event. Determine the "minimal cut sets," the cut sets for which removing any event prevents the top event.
   C. Determine the likelihood of the top event, if numerical values are available.
6. Address (e.g., mitigate) the identified issues.

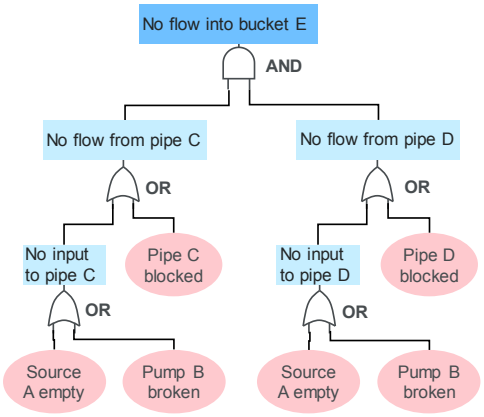
FTA – Example – Pumping Water

https://gerard-avontuur.tripod.com/Chapter2/Chapter2.html
https://commons.wikimedia.org/wiki/File:Bail_(PSF).png
https://commons.wikimedia.org/wiki/File:Half_full_bucket.svg

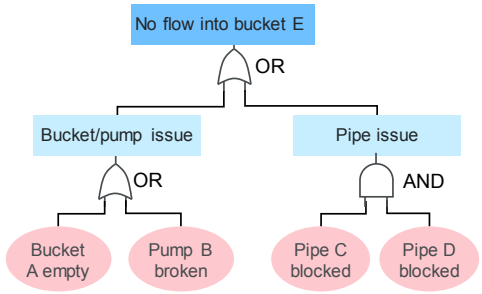
(1) Consider pumping water from Source A to Bucket E, using a pump and two pipes



(2) A fault tree of the pump system is below



(3) Using Boolean logic rules, the fault tree can be simplified to the one below



(4) The minimal cut sets are (any of these cause failure):
- Source A is empty
- Pump B is broken
- Pipe C is blocked and pipe D is blocked.

(5) If $\{P_A, P_B, \ldots\}$ are the failure probabilities for components $\{A, B, \ldots\}$ then the probability of no flow to bucket E (that is, P_E) is given by

$$P_E = 1-(1-P_A)(1-P_B)(1-P_CP_D)$$

Example: If each component has a 10% likelihood of having failed then the probability of no flow to bucket E is 20% since

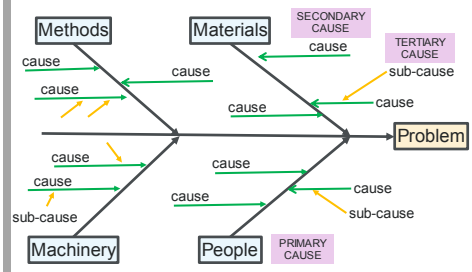
$$P_E = 1-(1-0.1)(1-0.1)(1-0.1*0.1) = 0.20$$

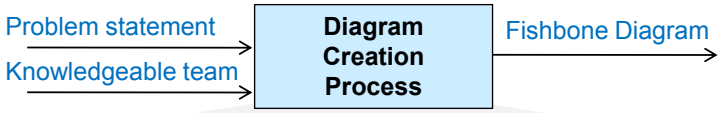
Fishbone Diagram / Ishikawa Diagram / Cause-and-effect Diagram

Problem
How to identify root causes?

Difficulty
Easy to use

- A **fishbone diagram** is a visual tool for identifying and displaying potential causes of a problem.
- A fishbone diagram determines increasingly detailed causes until a root cause is identified.
- Using the given initial structure, ask "Why?" to go from primary causes to sub-causes to sub-sub-causes (similar to the "5 Whys" technique)



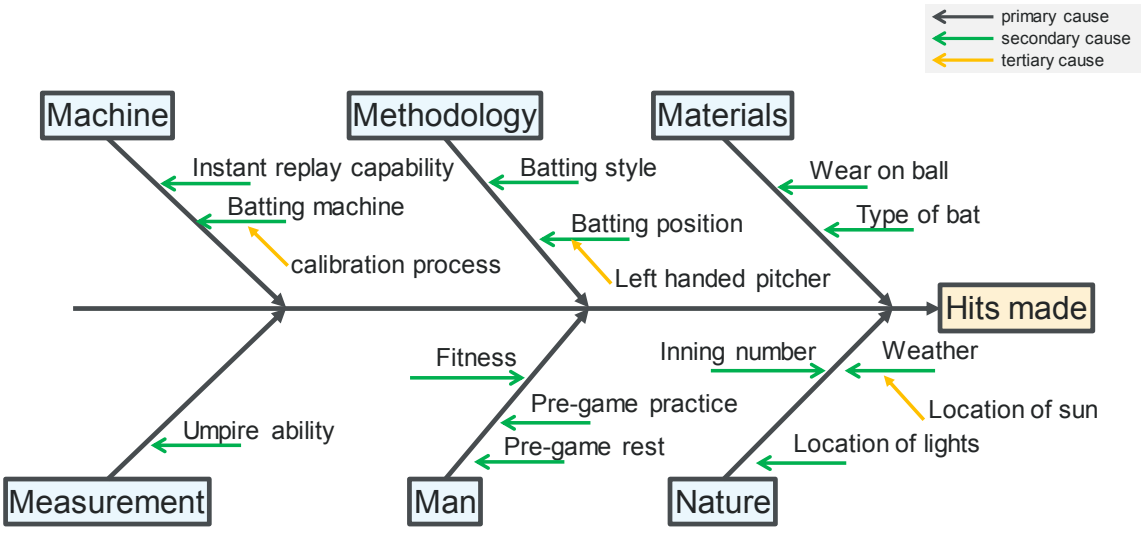


1. Identify the problem to be analyzed. Write this as the mouth of the "fish" (typically on the right).
2. Select 4-8 primary causes – see below – to analyze the problem; these are the major bones of the fish.
3. For each primary cause identify as many secondary causes as possible and add them to the fishbone.
4. For each secondary cause identify as many tertiary causes as possible and add them to the fishbone.
5. Analyze the diagram to identify the causes that require deeper investigation.

Common Primary Causes

- **3M's & P** Methods, Materials, Machinery, and People
- **4P's** Policies, Procedures, People and Plant
- **6M's** Machine, Methodology, Materials, Measurement, Man, and Nature
- **8P's** Price, Promotion, People, Processes, Place / Plant, Policies, Procedures & Product (or Service) (*for administration*)
- **4S's** Surroundings, Suppliers, Systems, Skills (*for services*)

Fishbone Diagram – Example – Baseball team hits



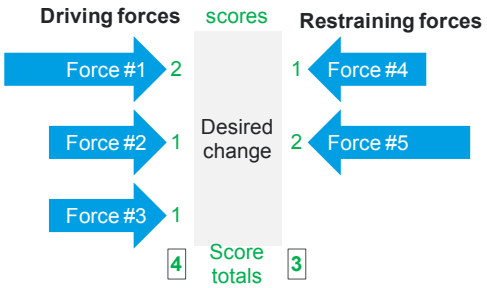
1. For the primary causes, this fishbone started with the 6M's {Machine, Methodology, Materials, Measurement, Man, Mother Nature}. Other possibilities could have been used.
2. By brainstorming on each primary (and then secondary) cause, you can sometimes identify non-obvious potential causes. For example, under "Nature / Weather" the location of the sun may be an issue in non-US baseball parks.

Force Field Analysis

Problem
How to implement a desired change?

Difficulty
Easy to use

Force field analysis helps identify those forces that help accomplish a goal and those forces that hinder the attainment of that goal.

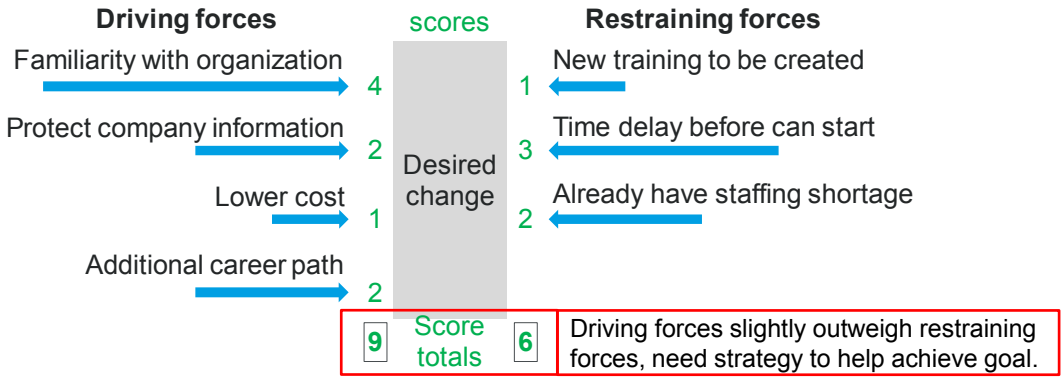


1. Clearly define the desired change.
2. Determine *favorable* driving forces for the change
3. Determine *unfavorable* driving forces for the change
4. Score the driving forces according to the degree of influence (low numbers for less influence and high numbers for more influence).
   - In a graphic, vary the length of the arrow.
5. Total the scores.
6. If the difference between favorable and unfavorable driving forces is too small, create a strategy to
   - strengthen the favorable driving forces; and
   - weaken the unfavorable driving forces.
7. Repeat steps 2-6.

Forces
- *favorable* (same as) *driving*
- *unfavorable* (same as) *restraining*

Force Field Analysis – Example – Hire Consultants

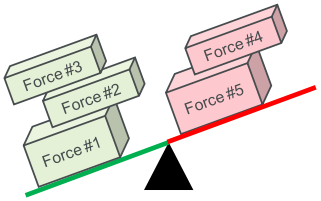
Goal: *Use internal consultants instead of hiring external consultants.*
Force Field Analysis: Might look like the following:



Hence, to encourage the desired change (that is, "use internal consultants"), you could, before promoting this change:
1. Codify the roles and responsibilities of consultants (needed for training) – **partially mitigates "New training …".**
2. Encourage potential internal consultants to take workplace training for new roles – **partially mitigates "Time delay …"**
3. Increase staffing efforts – **partially mitigates "Already have …"**

These activities will increase the value of (driving-restraining) forces.

A graphical representation

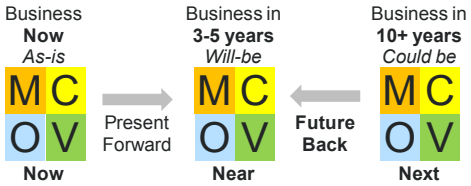


Future Back

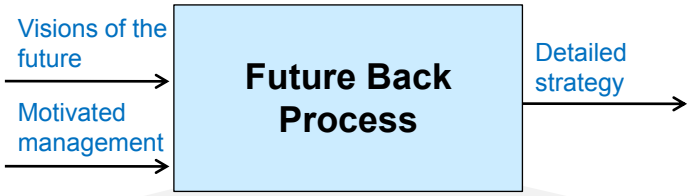
Problem
How to create a strategy?

Difficulty
Some training required

- **Future-back** (or **backcasting**) is a strategy development tool.
- "Present-forward" leaders incrementally improve the current state based on forecasts. "Future-back" leaders visualize a future state and then pursue it.
- Future-back thinking *complements* present-forward thinking; it does not replace it.

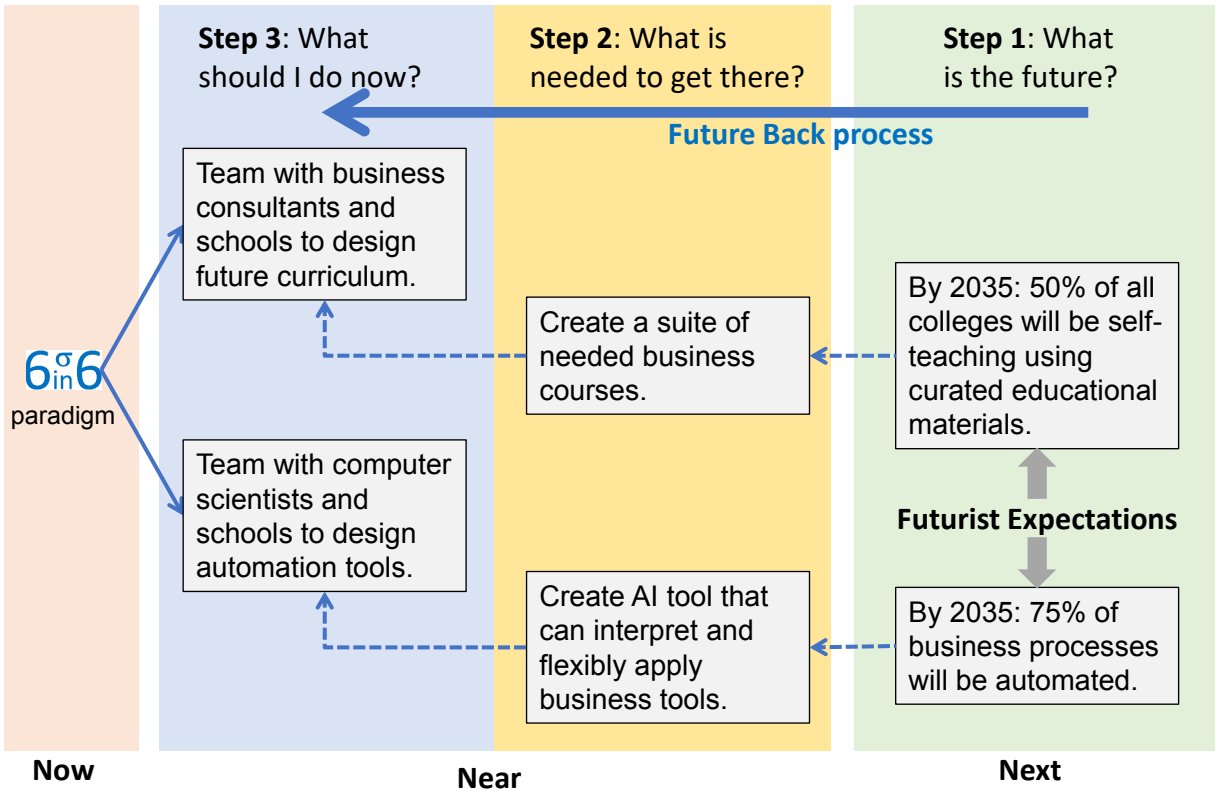


M = Mission
C = Customers
O = Operations
V = Value proposition



1. Imagine the desired/ideal future state ("moonshot")
   - It does not need to be achievable with today's technology and financial resources.
   - Each future state is detailed with a date.
   - Select 2 to 5 future states; not all the desired future states will materialize.
2. Convert the vision to strategy
   - Chart a path to each future state.
   - Set achievable goals.
   - Obtain management buy in.
   - List the milestones along the path.
3. Focus on the first milestone and get started
   - Perform course corrections, as needed
   - Pivot as needed; cancel the effort if needed

Future Back – Example – Future of 6in6 paradigm



Gage R&R
(Reproducibility & Repeatability)

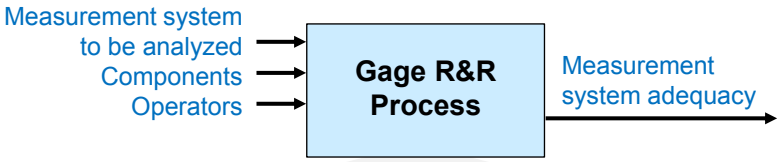
Problem
Hot to assess a measurement system?

Difficulty
Work with an SME

A ***Gage R&R (GRR)*** study finds the **measurement error** in a measurement system.
It addresses measurement system ***precision*** (it does not address ***accuracy***).

Measurement variance includes
The ***product*** variation
The ***equipment*** variation
(repeatability)
The ***operator*** variation
(reproducibility)

Gage R&R test processes
ANOVA approach; or
AIAG approach; or
EMP approach ("evaluating the measurement process")



Process
1. Determine standard that must be met
   Example: AIAG = Automotive Industry Action Group
2. Specify measurement strategy
   Example: 10 parts & 3 operators & 3 measurements each
3. Specify how samples are obtained
   Example: "randomly" or "sequentially"
4. Obtain samples
5. Obtain measurements
6. Perform analysis of data and make conclusions
   Use of a software package is recommended!
7. Document the results

GRR Types
- ***Crossed GRR***: each operator measures each part
- ***Nested GRR***: only one operator measures each part

Updated: 202210

Gage R&R – Example – Sample output from Minitab

Sample output

Key values
%Study Var uses the sample's standard deviation
%Process uses (historical) process standard deviation

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)	%Process (SV/Proc)
Total Gage R&R	0.30237	1.81423	27.86	15.12	43.20
Repeatability	0.19993	1.19960	18.42	10.00	28.56
Reproducibility	0.22684	1.36103	20.90	11.34	32.41
Operator	0.22684	1.36103	20.90	11.34	32.41
Part-To-Part	1.04233	6.25396	96.04	52.12	148.90
Total Variation	1.08530	6.51180	100.00	54.26	155.04

Number of Distinct Categories = 4

Key contributions

NDC = Number of Distinct Categories
NDC is the number of non-overlapping 97% confidence intervals that span the product variation.
Often, use NDC > 5 for study validity.
Examples
NDC = 3 ➔ {Low, Medium, High}
NDC = 5 ➔ {Very Low, Low, Medium, High, Very High}

What percentage of the allowed tolerance has been used

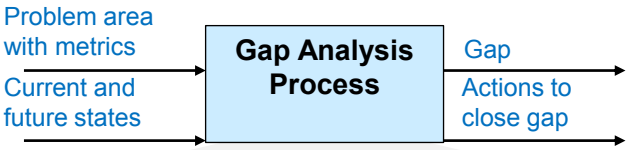
Between 10% and 30% ➔ measurement system is marginally acceptable

Gap Analysis

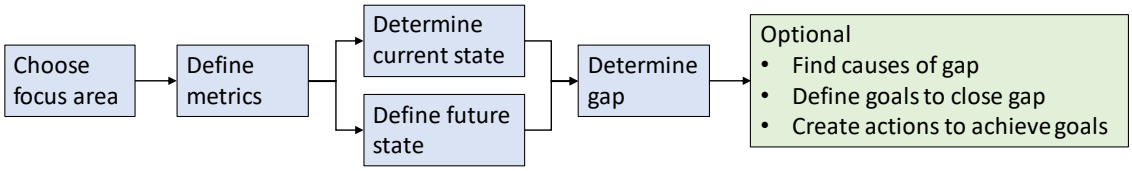
Problem
How to determine the needed improvement?

Difficulty
Some training required

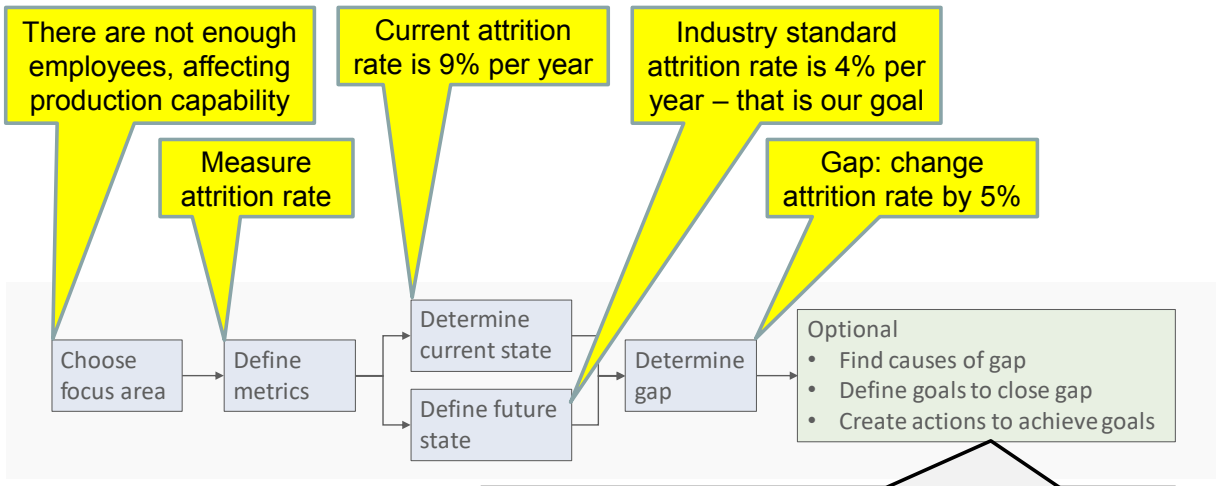
- **Gap Analysis** is used to compare where you are (current state) against where you want to be (future state).
- There is no standard **Gap Analysis** process, the process is tailored as needed.
- A gap is an improvement opportunity. Metrics, such as performance indicators, quantify the gap.
- Gap analyses is often used for: HR, performance (most common), product, and profit.



1. Select a specific problem area on which to focus.
2. Identify relevant metrics for the problem area.
3. Using those metrics, do the following (in either order):
   A. Identify the desired future state
   B. Use data to document the current state.
4. Compare the current and desired future states, this is the gap.
5. Sometimes a gap analysis includes gap closure steps:
   A. Analyze the causes of the gap.
   B. Create SMART goals to remove the gap.
   C. Create action plans to achieve the SMART goals.



Gap Analysis – Example – Employee Attrition



1. **Gap Causes**
   A. Benefit package is worse than industry average.
   B. Less ability to work off-site than industry standard
   C. …
2. **Gap Closure Goals**
   A. Within 2 months define changes to match industry standard benefit package and determine the cost.
   B. …
3. **Gap Closure Actions**
   A. Form HR team to make recommendation, …
   B. …

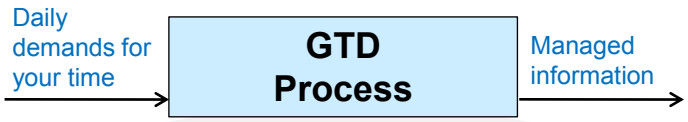
Getting Things Done (GTD)

Problem
How to manage day-to-day activities?

Difficulty
Easy to use

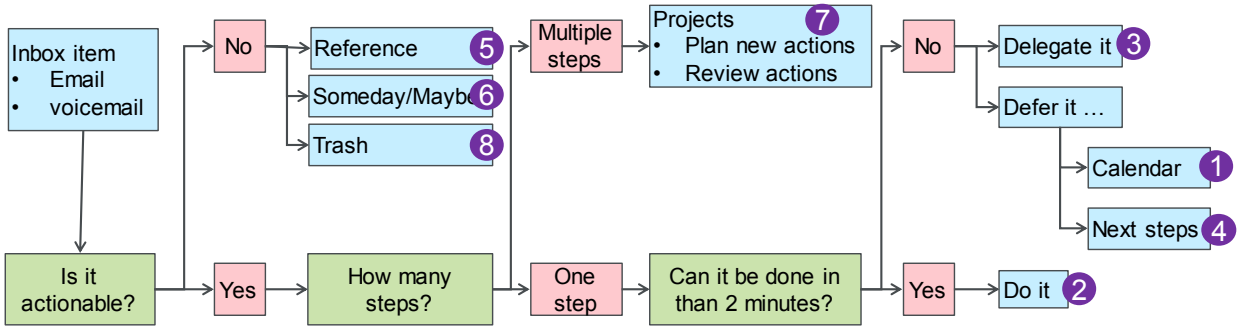
- **Getting Things Done** (GTD) is a time management and productivity system for individuals.
- GTD's process manages daily inputs, and their disposition, to avoid mental clutter and stress.
- GTD has general guidelines, but can be tailored as needed.

GTD created the **2 minute rule**: If an activity will take less than two minutes, do it right away.



1. **Capture everything**: Capture anything that you are involved with, large or small. Put these things in your inboxes. Update daily.
2. **Clarify**: Convert every item in your inboxes into clear and concrete action steps. Determine the next step for each item; remove from inbox and …
3. **Organize**: Disposition each item into one of the lists:
    1. Calendar – holds appointments
    2. Complete action – in less than 2 minutes
    3. Delegate – when appropriate
    4. Next actions – tasks which are not project specific
    5. Reference – file away as needed
    6. Someday/Maybe list – low priority tasks
    7. Project task list – for items with more than 1 step, an item is given a defined action and a next step
    8. Trash – items no longer of importance
4. **Review**: Frequently review, update, and revise your lists.
5. **Engage**: Select activity to do next based on: context (e.g., home, office), energy level, priority, & time available

GTD – Example – Maintaining the 6in6 concept



Managing daily inputs (Note: most emails and texts are acknowledged)

1. Email (from local Quality meeting): Here's the date for your next 6in6 presentation [Put on calendar]
2. Voice mail (from colleague): Have Amazon print up 6in6 PDF file as a book, and send to me. [Do it]
3. Text (from colleague): There is a typo in a 6in6 presentation. [Delegate; send to 6in6 staff to fix]
4. Email (from 6in6 staff): Create template for 6in6 presentations. [Next steps. Put single action on list]
5. Email (from Google): Here is data on the number of 6in6 site visits. [Store for later]
6. Call (from 6 sigma friend): Can you create YouTube videos for each 6in6 topic? [Someday/Maybe]
7. Email (from 6in6 fans): Please create a 6in6 presentation on topic XXX [Project "new presentations": do background research within 2 weeks, follow-up with next production steps]
8. Email (from spammer): Special! Buy 3 tires and get 4th one free. [Trash]

Daily activities

A. Disposition input information (as shown above)
B. Assess current state (e.g., energy level)
C. Select next most important task based on current state and execute.
D. Repeat.

Weekly activities

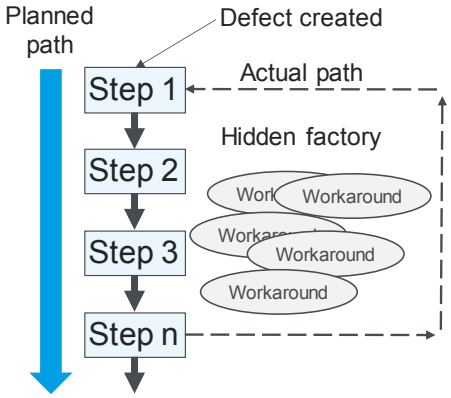
A. Review all lists
B. Move items between lists and change priorities, as needed.

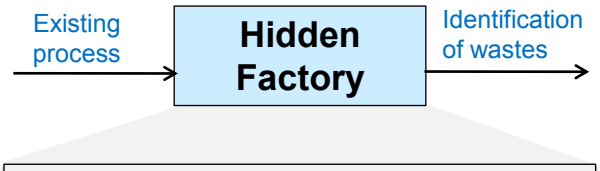
Hidden Factory

Problem
How to identify waste due to unnecessary work?

Difficulty
Some training required

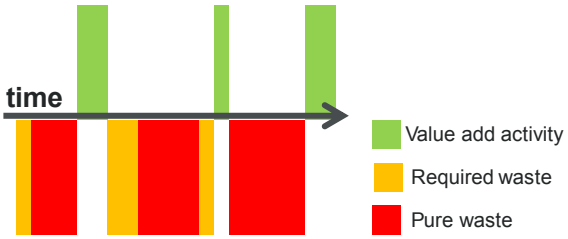
- A **Hidden Factory** is created when a defect flows downstream.
- The hidden factory represents process activities causing loss of: Availability, Efficiency, Schedule, Quality, or Performance.
- Visualization tools can help identify wastes caused by the "hidden factory."



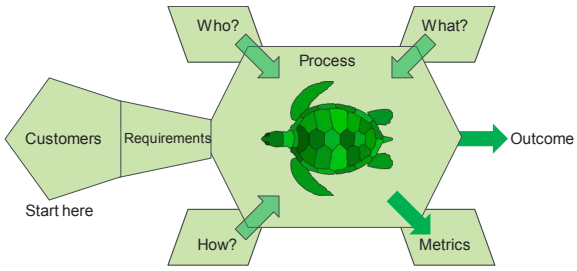


1. Assemble team
2. Scope the mapping effort
3. Choose an appropriate visualization tool, such as
   - Spaghetti diagram
   - Time value map
   - Process map
   - Swim lane diagram
   - Turtle diagram
   - …
4. Map the process
5. Identify waste (and then remove it)

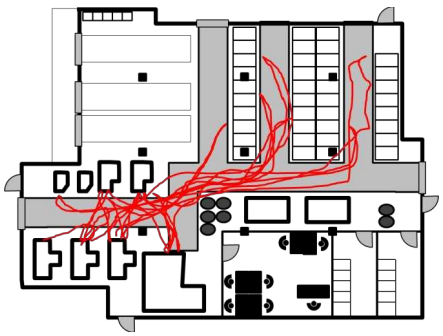
Hidden Factory – Example Mapping Techniques



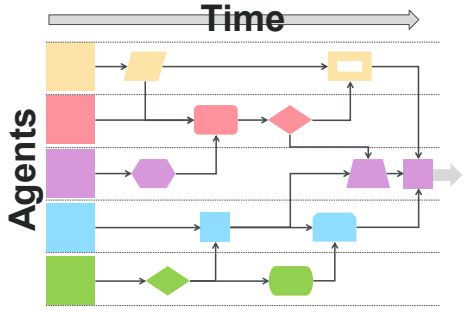
Time value map
Shows non-value added activities with durations



Turtle diagram
Shows key activities
https://creazilla.com/nodes/3164991-turtle-clipart



Spaghetti diagram
Shows unnecessary motion
https://www.allaboutlean.com/wp-content/uploads/2015/06/Spaghetti-Diagram.png



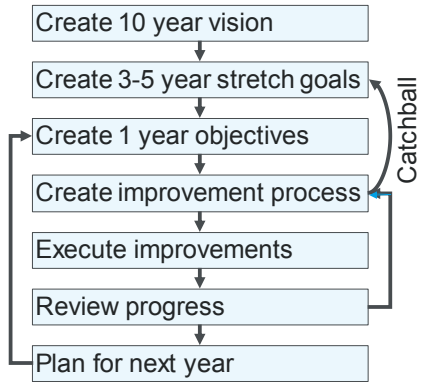
Swimlane diagram
Shows who does what, when, and with what input

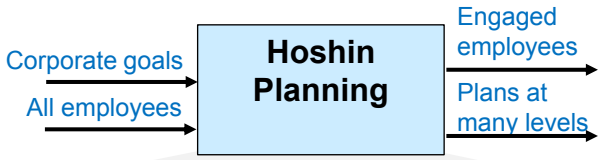
Hoshin Planning (hoshin kanri)

Problem
How to align employees with corporate goals?

Difficulty
Work with an SME

- **Hoshin Planning** creates corporate goals, disseminates them to all, and creates plans to achieve them.
- **Catchball** is a part of Hoshin Planning in which ideas are passed between levels of an organization's hierarchy for feedback and action planning.



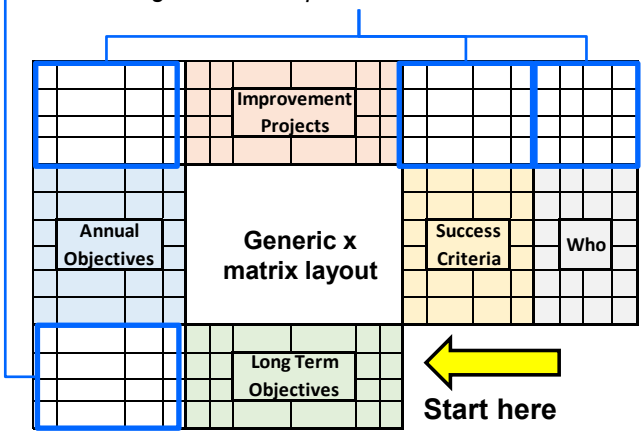


1. Create a 10-year vision.
2. Build 3 to 5-year stretch goals, no more than 5.
3. Create yearly objectives
4. Use catchball process to determine how to achieve the yearly objectives (e.g., determine resource demands) and create metrics. Communicate info to teams for execution.
5. Methodically execute the yearly objectives.
6. At appropriate intervals, review if the yearly objectives are being met and update as needed.
7. Analyze & update objectives for the next year.

Benefits of Hoshin Planning
1. Creates a strategy for continuous improvement.
2. Aligns strategy with actions.
3. Hoshin catchball engages the entire organization.
4. Hoshin Planning provides structure & uniformity.

Hoshin Planning – Example – Improve Company

Corner grids show dependences between activities

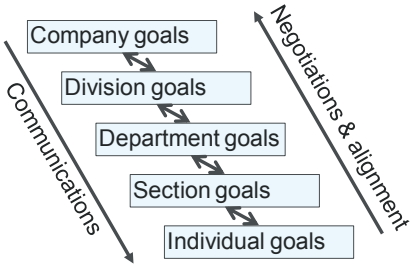


A hoshin kanri **x matrix**, also called a **policy deployment** (pd) document, includes "what," "how," "who," and "how much."

	X	Create new organic product lines		X	X	
X	X	Acquire competitors	X			X
Increase Company Valuation 5%	Increase Customers 10%	(3) Improvement Projects (2) Annual Goal (4) Success Criteria (1) Long term goals	Acquire 2 Competitors	Add 3 Profuct Lines	Alice	Bob
X		Increase Company Valuation 15%				
	X	Increase Customers 20%				

Example: how to improve company

Catchball process



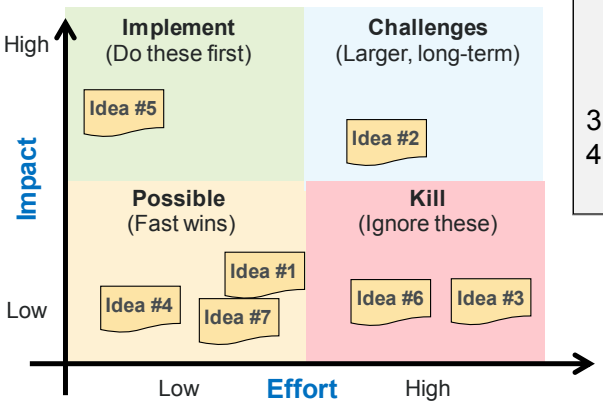
- In "catchball" objectives are passed, like a ball, from top-level management to every organizational level.
- Each level sends feedback and proposals up the management chain.

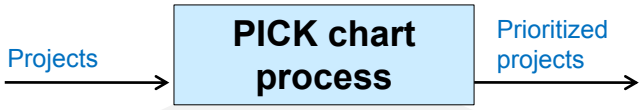
Impact–Effort matrix (PICK chart)

Problem
How to choose among multiple alternatives?

Difficulty
Easy to use

- An **impact-effort matrix**, or a **PICK** (Possible / Implement / Challenge / Kill) **chart**, is a way to categorize projects.
- A PICK chart prioritizes among many projects identifying those with the most value.





1. Create a list of improvement projects.
   - For example, use six sigma techniques.
2. Evaluate each improvement project in terms of "Payoff" and "Difficulty."
   - Multivoting can be used for a quick analysis.
3. Create a PICK chart (see image to left).
4. From the PICK chart determine which projects should be pursued, and in what order.

An Impact/Effort matrix is also called an:
- Action/Priority matrix
- Ease/Benefit chart
- Ease/Impact chart

PICK chart – Example – 6in6 Awareness

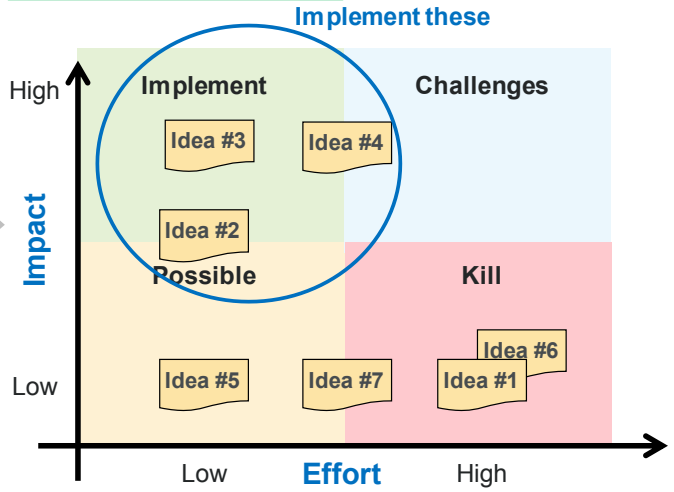
How to improve awareness of 6in6 presentations?

	Idea	Improvement project	Effort	Impact
	#1	Advertise on evening news	High (due to cost)	Low
✓	#2	Send email to Dan's friends	Low	Medium
✓	#3	Announce to 6 sigma groups on LinkedIn	Low	High
✓	#4	Place advertisement in 6 sigma journal	Medium	High
	#5	Put sign on Dan's car	Low	Low
	#6	Obtain celebrity endorsement	High (due to cost)	Low
	#7	Put posters around town	Medium	Low

Potential projects

Evaluations of effort

The above table yields the PICK chart shown

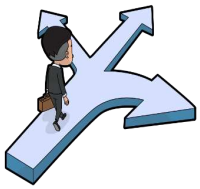


Individual Development Plan (IDP)

Problem
How to encourage employee growth?

Difficulty
Some training required

- An **individual development plan (IDP)** helps employees improve their job performance and achieve their career goals.
- A company's tailored IDP template includes:
  - Professional goals
  - Strengths and talents
  - New skills to be obtained
  - How performance will be enhanced
  - An action plan
  - …



- People-oriented manager
- Sharing employee

→ **IDP Process** →

Employee direction and action plan

1. Create a company-wide IDP template
2. Obtain needed employee information
   A. Manager gives employee the manager's IDP
   B. Employee captures relevant information (perhaps via a questionnaire)
3. Create employee IDP
   A. Manager and employee meet (maybe 1 hour)
   B. They review: questionnaire information and recent performance reviews
   C. They discuss: goals, passions, and skills
   D. They document an individualized employee IDP (leveraging questionnaire info)

- https://www.freepik.com/free-vector/businessman-businesswoman-talking-office_5712994.htm
- https://commons.wikimedia.org/wiki/File:Cartoon_Man_Arriving_At_A_Career_Crossroad.svg

IDP – Example – Web Designer Advancement

Here's a completed IDP for a Web Designer

Employee name: Pat Smith Date: 10/15/20XX
Position, title: Artist level 3, web designer Function: maintain/update web site design
What drives me: (1) Clarity of communication (2) Every piece I create should be a work of art
What I dislike: "Cookie cutter" approaches, use of the color purple
My skills: <long list of items>
My professional goals and aspirations
Internal
Mature my video creation skills, become leader in the field
Manage design of all print materials
External
Obtain peer recognition for my artistic business outreach
Win juried shows of my large stone carvings (> 20 kg)
What I do
- Never give up, always exceed expectations
- Work products are universally admired

What I could do (development opportunities)
- Influence the communication goals to which I now respond
- Have more latitude in how I create solutions

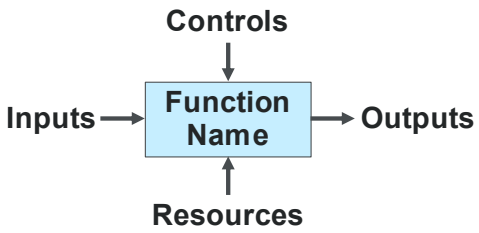
Action plan (specific steps/tasks to achieve goals)
Short term (next 3 months)
Practice creating video product solutions, at least 2 designs per project
Attend and observe bi-weekly business outreach discussions
Long term (within 1 year):
Learn the business' needs and contribute to business outreach discussions

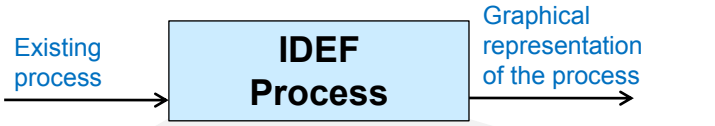
Integration Definition (IDEF)

Problem
How to graphically model a process?

Difficulty
Some training required

- **Integration Definition (IDEF)** refers to a family of 16 modeling languages used in systems and software engineering; only some of them exist.
- IDEF0 (for function modeling) is the most commonly used IDEF, it models the actions, activities, and decisions of a system.
- In IDEF diagrams each function (e.g., activity) is shown as a box. Box locations have specific roles: top (controls), left (inputs), right (outputs), and bottom (resources).

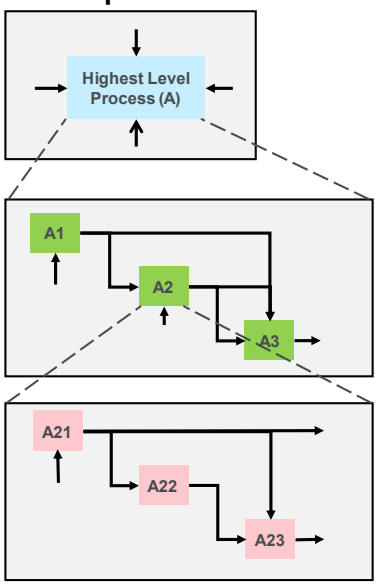




1. Select a process
2. Select a modeling language, one of:
   - IDEF0 Function modelling
   - IDEF1 Information modelling
     - IDEF1X Data modelling
   - IDEF2 Simulation model design
   - IDEF3 Process description capture
   - IDEF4 Object-oriented design
   - IDEF5 Ontology description capture
   - IDEF6 Design rationale capture
   - IDEF8 User interface modelling
   - IDEF9 Business constraint discovery
   - IDEF14 Network design
- Obtain a hierarchical collection of diagrams.
- Use the diagrams for analysis or simulation.

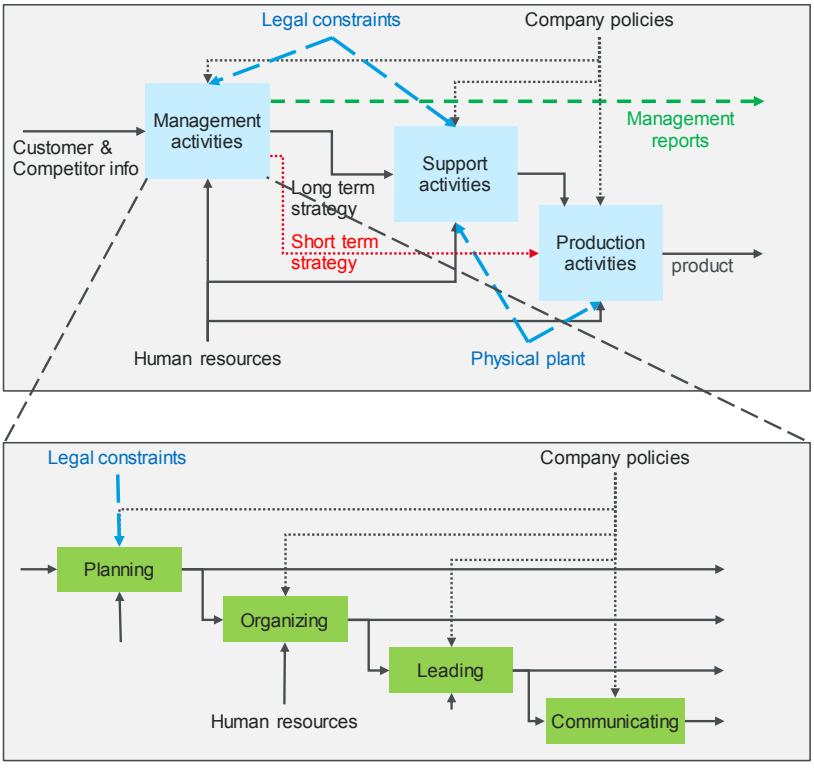
IDEF – Example – Manufacturing Company Process

Hierarchical decomposition



Lower level processes

Notational IDEF0 (many details missing)

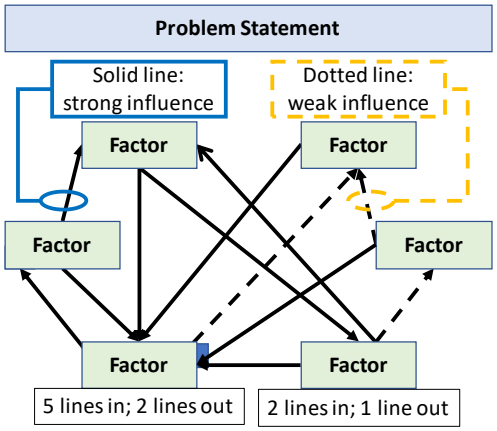


Interrelationship Diagram (Network Diagram)

Problem
How to determine the most important problem factors?

Difficulty
Easy to use

- An **Interrelationship Diagram** (ID) shows the cause and effect relationship among different factors.
- The factors are connected by arrows, tail is a driver and head is an effect.
- An ID finds key factors by counting the number of in and out arrows.



Many root causes → **Interrelationship Diagram Process** → Most important root causes

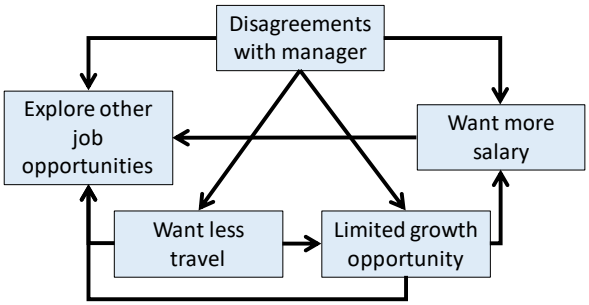
1. Define the problem statement to explore.
2. Use brainstorming to identify the key factors (or root causes).
3. Lay out the diagram, with each key factor placed around a circle.
4. Put arrows on the diagram
   - For each pair of factors A and B, ask "Does A influence B?". If "yes," then draw an arrow from A to B (a solid arrow for strong influence, a dotted arrow for a weaker influence). Repeat for "Does B influence A?".
5. Count the number of arrows going in to, and out of, each factor.
   - Optional: weight dotted arrows as ½.
6. The most important factors are the one with the most lines in or out.

Interrelationship Diagram – Example – Attrition

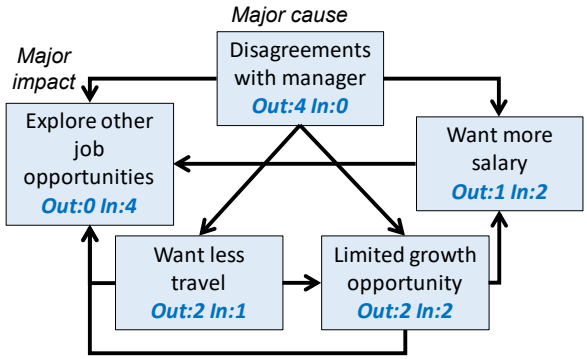
Problem to address: ***Why are employees quitting?***

Step 1: "Employees are quitting"
Step 2:
- "Disagreements with manager"
- "Explore other job opportunities"
- "Limited growth opportunities"
- "Want less travel"
- "Want more salary"
- … (for a realistic analysis, many more factors would be included)

Steps 3 & 4: see figure (top)
Step 5: see figure (bottom)
Step 6: Conclusions
- **Major cause (most out arrows):** "Disagreements with manager"
- **Major impact (most in arrows):** "Explore other job opportunities"



Steps 3&4 (above), Step 5 (below)



Kanban

Problem
How to manage a process workflow?

Difficulty
Some training required

- **Kanban** is a workflow management method to organize, manage, and improve processes.
- A **Kanban board** represents a workflow. Each column represents a task and each **Kanban card** represents a work item.
- A Kanban board is a real-time information repository and it identifies system bottlenecks
- Using WIP (work-in-progress) limits for tasks ensures only a manageable number of items are in progress at one time.
- Limiting WIP creates a "pull system." This is like a grocery store whose shelves are only stocked as needed.

Existing process → **Kanban Process** → A workflow visualization and management scheme

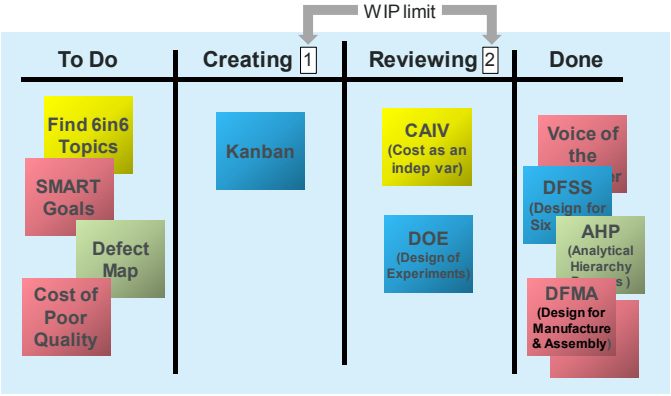
1. Ensure the business process is clearly defined, published, and socialized.
2. Design an appropriate Kanban board.
3. Perform the six Kanban practices while executing the business process:
   A. Visualize the workflow
   B. Limit work in progress (WIP)
   C. Measure and manage flow
   D. Make process policies explicit
   E. Implement feedback loops
   F. Improve collaboratively
4. Repeat from step 2

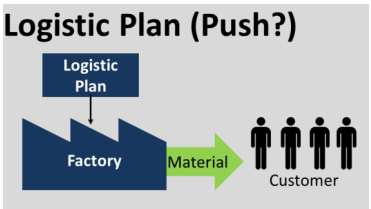
The 4 Kanban principles
1. Start with what you do now
2. Agree to pursue incremental, evolutionary change
3. Respect the current process, roles, responsibilities, and titles
4. Encourage acts of leadership at all levels in your organization

Kanban – Example – Creating 6in6 Presentations

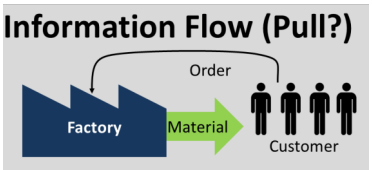
Tailored to 6in6 presentation creation, the Kanban board has 4 categories:
(A) To Do / finding 6in6 topics, (B) creating draft 6in6 presentations (only 1 at a time), (C) reviewing and editing (up to 2) draft presentations, and (D) done.

- The first and last columns can contain any number of items.
- The WIP limits prevent there from being too many 6in6 presentations in-process.





A *push system* uses a logistics plan to determine how much product to deliver – which may not reflect reality. A *pull system* only delivers what is needed.



A Kanban card in a manufacturing environment, which represents a factory order, is at right.

https://www.allaboutlean.com/push-pull/logistic-plan/
https://commons.wikimedia.org/wiki/File:080527-F-0000A-001.JPG

Kaizen

Problem
How to improve a product or process?

Difficulty
Work with an SME

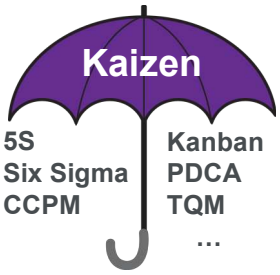
- **Kaizen** is a Japanese term meaning change for the better or continuous improvement.
- **Kaizen** can be implemented by many methods: 5S, Six Sigma, CCPM (Critical Chain Project Management), Kanban, PDCA (Plan / Do / Check / Act), TQM (total quality management), …
- A **Kaizen event** or **blitz** is different, it creates a large change in a fixed time period.

- Teamwork
- Discipline
- Leadership

→ **Kaizen Approach** →

Improved product or process

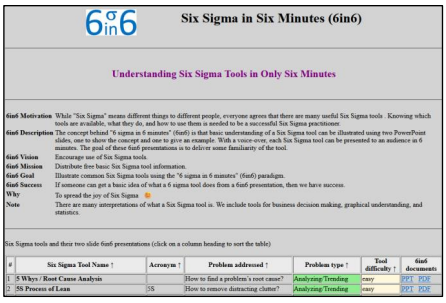
1. Train and motivate employees.
2. Identify an improvement opportunity.
3. Explore new ideas, leveraging employee knowledge and experience.
4. Define an objective and decompose it into components (e.g., sub-objectives).
5. Plan the tasks for each sub-objective.
6. Execute the plan: monitor progress and test results
7. Start again at step 1.



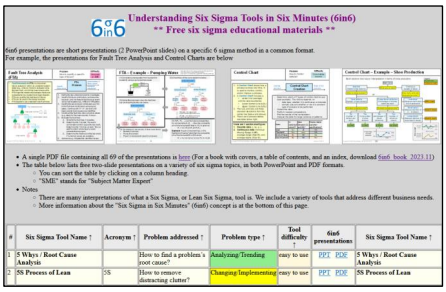
https://pixabay.com/vectors/umbrella-open-opened-handle-rain-891442/

Kaizen – Example – Improve 6in6 web site

2. Every month look at some part of 6in6 to improve.
   - July 2023 → How to improve the "6in6 mission"?
3. Explore new ideas
   - Improve the 6in6 website distributing 6in6 info
4. Define objective
   - Update 6in6 website to current user expectations
5. Plan the tasks
   - Ask friend to critique 6in6 website
   - Hire GUI expert to critique 6in6 website
   - Implement changes
6. Execute the plan
   - Friend: "Why aren't there YouTube videos?"
   - Hired GUI expert using upwork.com
   - Received report which included:
     - At the top: too much text
     - At the top: reinforce the word "free"
     - At the top: give an example deliverable
     - Make it look less like a blog
     - Didn't like logo …
   - Implemented most of the suggested changes
7. Repeat
   - Aug 2023 → How to make 6in6 info more useful?
     - Create "book version" with index …



6in6 web page in June 2022



6in6 web page in January 2024

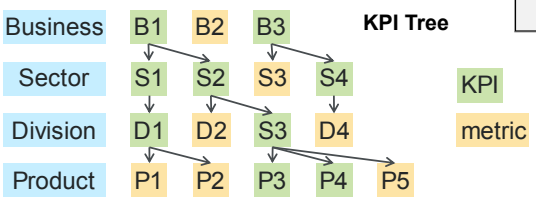
Key Performance Indicator (KPI)

Problem
How to assess performance?

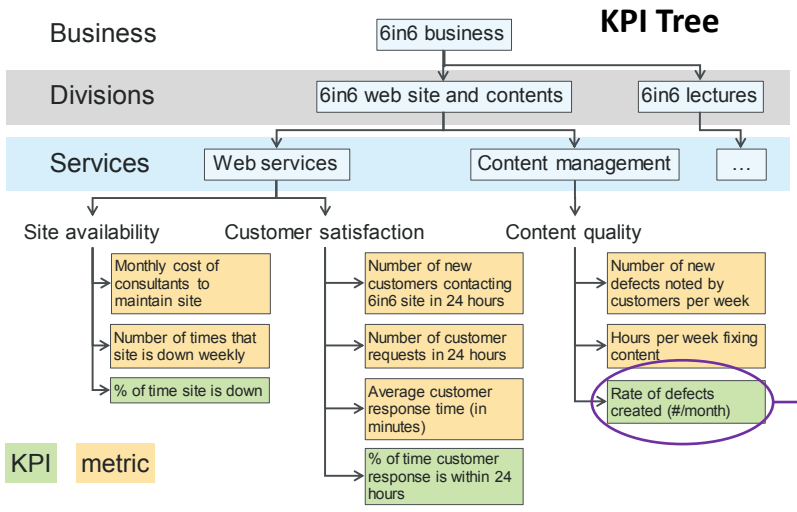
Difficulty
Some training required

- **Key performance indicators** (**KPIs**) are the vital few metrics assessing the success or failure of a project or product.
- KPIs can be quantitative or qualitative and can assess an outcome or a process.
- A KPI Tree is a graphical way to flow down and manage KPIs
- At each level: use 3-6 KPIs, use outcome & process KPIs, use KPIs that are meaningful, measurable, and manageable.

1. Determine the 2 to 5 key business objectives for your organization.
2. Determine metrics that assess these objectives.
3. Select the vital few metrics that are KPIs.
4. Create an operational definition (clear and detailed description) for each KPI.
5. Flow each KPI down to the next level and repeat the above process … this creates a KPI tree.
6. Conduct periodic KPI reviews. For each KPI, decide to: keep, kill, or improve.



KPI – Example – 6in6 "business"



- Per usual, there are many metrics; most are not KPIs.
- Not shown are the metrics & KPIs at the business and division levels.

Performance Indicator	Division	Services
Defect rate	*web site and contents*	*Content management*
Description / Formula		
Combine weekly defects found by Customer rep and Content rep to obtain monthly rate		
Data Source		Process Diagram or Drawings
Bob (Customer) & Charlie (Content)		*NA*
Frequency (When)	Decision Criteria	
Monthly	*Alert on value of 0.7*	
Data Collector (Who)	Owner	
Betty (Quality)	*Dan (President)*	
Baseline	Target	
0.1	*Below 0.5*	

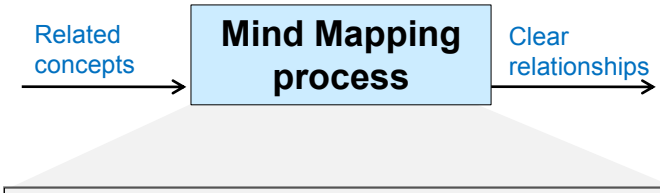
KPI operational definition

Mind Mapping

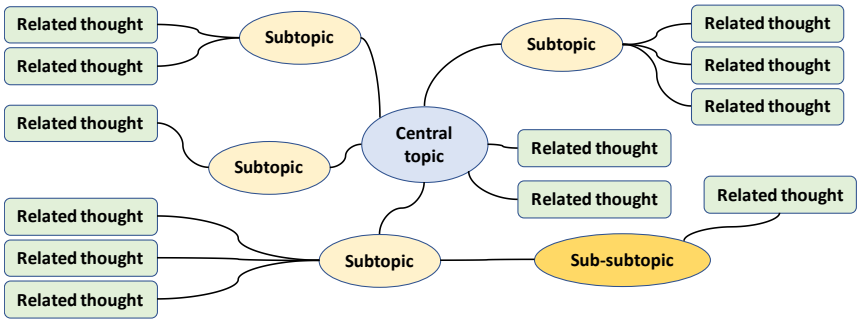
Problem
How to add detail to a concept?

Difficulty
Easy to use

- A **mind map** is a 1-page diagram containing words, ideas, tasks, or other items linked to and arranged around a central key word or idea.
- Mind maps are used to brainstorm, teach information, convey complex information, create an outline for a document, plan an activity, and much more.
- Many different tools can be used to create mind maps.

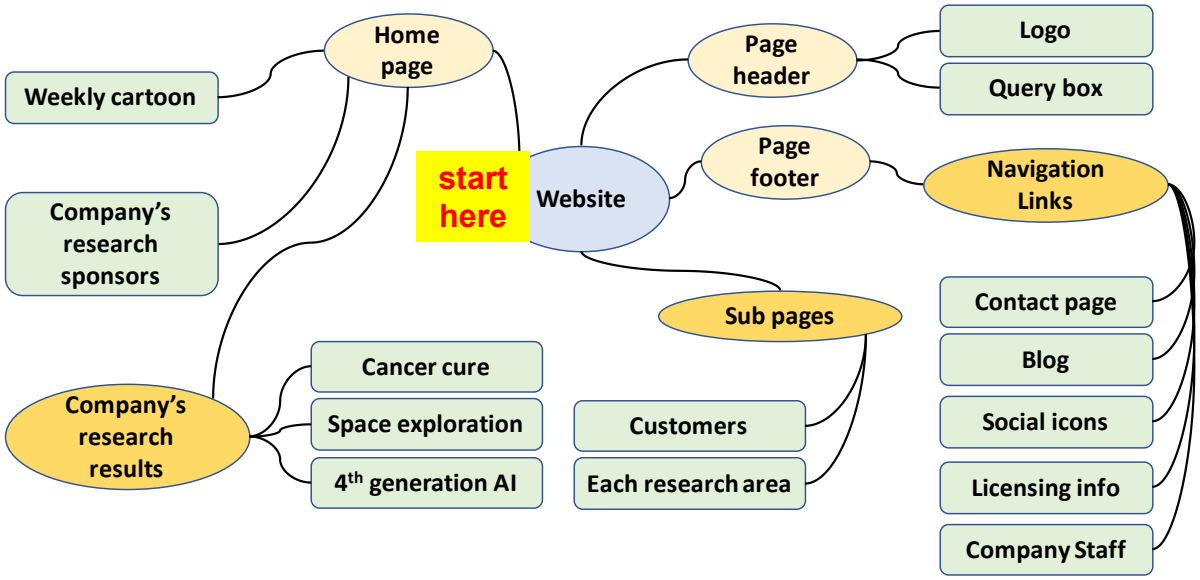


1. Start with a central topic and surround it by a bubble.
2. Recursively expand some of the bubbles by adding new related bubbles, and connecting them to indicate some type of relationship.



Mind Mapping – Example – Website Content

A Mind Map for conceptualizing the contents of a website



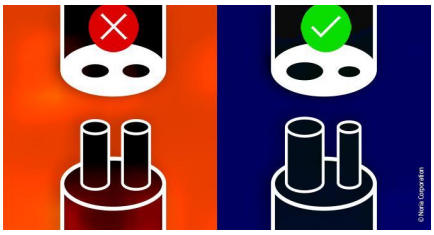
Mistake-Proofing / Error-Proofing (Poka-Yoke)

Problem
How to mitigate potential mistakes?

Difficulty
Some training required

- **Mistake-Proofing** is identifying and correcting problems as close to the source as possible.
- Mistake-Proofing is useful for maintenance, operations, production, and servicing.

Existing design
Design paradigms
→ **Mistake Proofing process** → Improved design



https://www.reliableplant.com/poka-yoke-31862

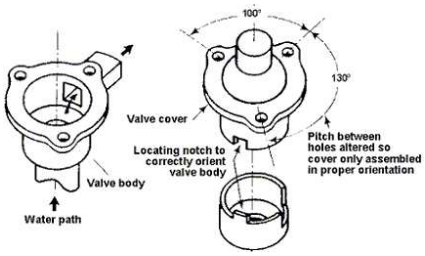
Implement the following principles (as applicable)
1. **Eliminate** – remove task/part that allowed errors
2. **Replace** – use a more reliable process
3. **Prevent** – change task/part to make errors impossible
4. **Facilitate** – make work easier to perform
5. **Detect** – identify & resolve before further processing
6. **Mitigate** – minimize the effects of errors

Automobile examples
- Unleaded gas tank opening
- Gas cap tether preventing loss
- Car doors lock at 18 mph
- Car key cannot be removed unless car is in "park"

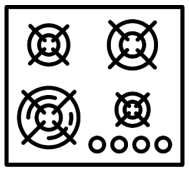
Other Examples
- Sink overflow outlet
- Elevators don't shut doors on people
- Dryer stops when door is opened
- Opening a file drawer locks other drawers

Mistake-Proofing – Examples

Prevent – Make parts as symmetric or as anti-symmetric as possible



https://www.npd-solutions.com/mistake.html

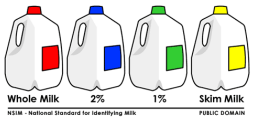


Created by Laymik from Noun Project

Facilitate – Which dial turns on which stove burner?

https://thenounproject.com/icon/stove-top-1474551/

Detect – Milk containers can use color to indicate fat content

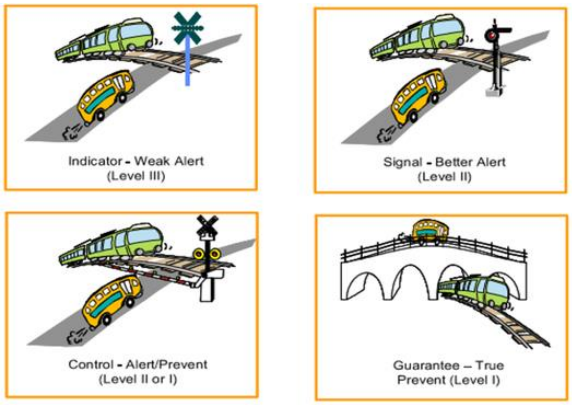


http://www.aleanjourney.com/2011/05/changing-visual-standards-causes.html

Mitigate – To insure cars will fit in a garage with a low clearance, use a go/no-go gauge at the entrance.

https://www.parkinglotsafetysolutions.com/height-guard-clearance-bars.html

Prevent – Different ways to avoid train/car collisions



https://x.com/seanessee/status/633354935908888576

Nominal Group Technique (NGT) / Multivoting

Problem
How to crowd source a response to options?

Difficulty
Easy to use

- **Nominal Group Technique** (also called **Multivoting**) uses a crowd's wisdom to quickly prioritize a list of items (e.g., problems or issues)
- Typically:
  - List has 10 or fewer items.
  - Each person gets 3-5 votes

	Budget Priorities	
1	Attend more conferences	●●●●
2	Hire a consultant	●●
3	Hire more staff	●●●●●
4	New office equipment	
5	Upgrade computer SW	●

Example: 5 topics,
4 people (each with different colored dots),
3 votes/person

- List of items
- Knowledge able team

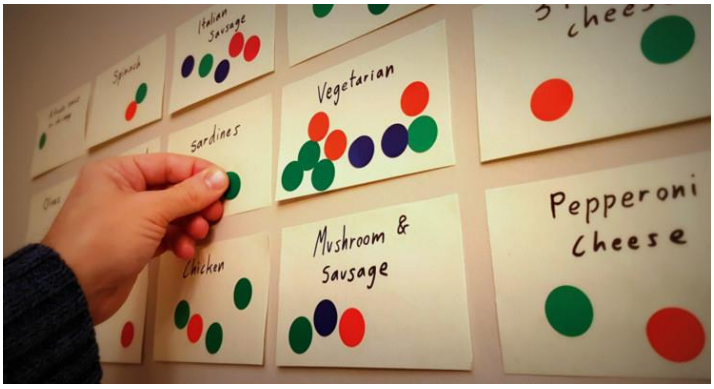
→ **Multivoting Process** → Prioritized items

1. Create a list of items.
2. Every team member is given some number of "votes"
3. Each team member votes for the items they consider most important
   - They can spread their votes out or apply all their votes to a single item.
4. The total number of votes of each item becomes the priority ordering.
   - Have team discussion if there are unusual votes (e.g., one person puts all their votes on one item)

Updated: 202208

NGT – Examples

Figures (with permission)
- https://dotmocracy.org/
- https://www.nngroup.com/articles/dot-voting/



Here, a team is choosing what types of pizza to have for lunch. In this case, the number of dots may determine how many pizzas of each type to order.

A typical situation, a team's votes are on only a few of many alternatives. Here, with 12 items, only 4 items have any votes. The number of votes is {8, 6, 4, 2}. If only two projects are supported, then the projects with 8 and 6 votes are the ones to pursue.

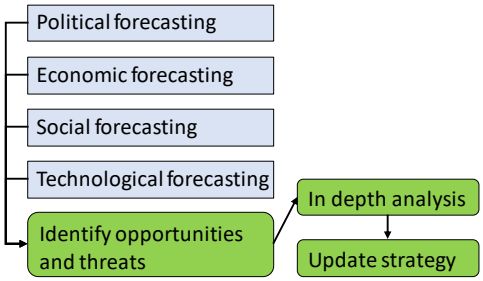
PEST Analysis

Problem
How to use external factors to update business strategy?

Difficulty
Some training required

- **PEST** (**P**olitical, **E**conomic, **S**ocial and **T**echnological) **Analysis** determines the influence of external factors on an organization.
- A PEST analysis is an input to the strategic planning process. (Changes in external factors can create opportunities or threats.)
- PEST is used (with SWOT) to evaluate the pros/cons of a project.

Business strategy → **PEST Analysis Process** → Strategy updates



1. Determine relevant factors within PEST categories:
   A. Political → political stability, taxation and economic policies, trade agreements, …
   B. Economic → economic trends, GDP, interest rate, tax rate, unemployment rate, …
   C. Social → cultural and religious factors, demographic factors, religious factors, …
   D. Technological → effects of technology on: distribution, manufacturing, marketing, …
2. For each factor, do the following:
   A. Identify potential opportunities and/or threats.
   B. Identify sources of information for that factor.
   C. Prepare a questionnaire for that factor.
   D. Collect detailed data for that factor.
3. Analyze the collected data.
4. Take appropriate actions, as necessary.

PEST – Example – Fast Food Chain

Sample Template

	Factors	Potential opportunity and/or threat	Information sources	Questionnaire: questions & data collection plan	Data obtained	Conclusions	Strategy actions
Political	*A, B, …*	*A=threat, B=opportunity, …*	*citations*	*Ask X and Y about Z*	*know K*	*L is likely*	*Prevent P*
Economic	…						
Social							
Technological							

List of factors for each of P, E, S, T — Categorize each factor as "threat" or "opportunity" — Information from others — Information you have obtained — Analysis and actions

Example: Fast food chain (e.g., McDonald's, Burger King) in other countries

1. **Political Factors**
   - Must abide by (changing?) tax rules; product contents depend on import taxes.
   - Must abide by (changing?) labeling requirements; product contents depends on which information appears on label.
2. **Economic Factors**
   - Need to anticipate (changing?) supply chain capabilities, to adjust product contents.
   - Need to anticipate (changing?) buying power of consumers, to adjust prices.
3. **Social Factors**
   - Need to anticipate (changing?) fast food health concerns; to adjust products and offerings.
   - Need to anticipate (changing?) behaviors (workers at home no longer drive past restaurants).
4. **Technological Factors**
   - Need to anticipate (changing?) customer desires to pay via mobile app.
   - Need to anticipate (changing?) customer desire to order on web site, and pick up food in store.

Process Capability metrics (Cp and Cpk)

Problem
How to statistically assess a process?

Difficulty
Work with an SME

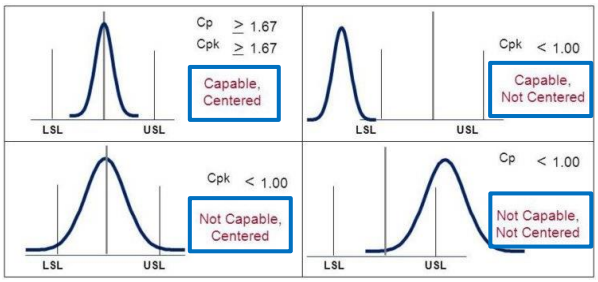
- **Process capability** is a statistical assessment of whether or not a process is *capable* and/or *centered*. You want both.
- Consider a car entering a garage:
  - *capable* (Cp>1) means the car usually arrives at the same location,
  - *centered* (Cpk>1) means the car enters the center of the garage.

Existing process → **Statistical Process Analysis** → Process assessment

1. Obtain customer specs (USL & LSL)
2. Determine the process' sample mean (m) and standard deviation (s)
3. Compute the Cp and Cpk metrics
4. Interpret the metrics

Formulae
Cp = (USL – LSL) / (6*s)
Cpk = minimum((USL–m)/(3*s), (m–LSL)/(3*s))

- **Cp** = **Process Capability** = the number of times the spread of the process fits into the tolerance width. Larger values are better.
- **Cpk** = **Process Capability corrected for position**. Larger values are better.
- **USL** & **LSL** – Customer's Upper & Lower Specification Limits
- **m** = process mean
- **s** = process standard deviation



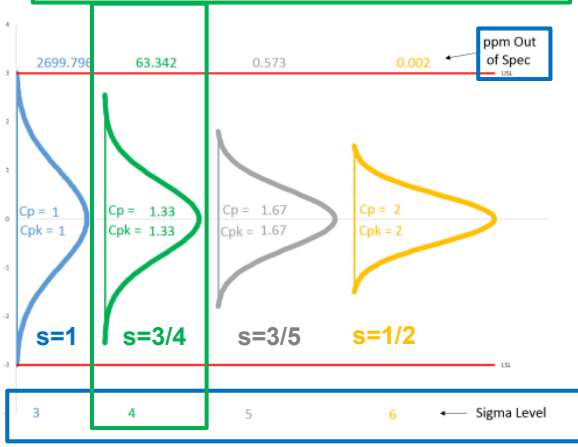
https://www.latestquality.com/how-to-calculate-cp-and-cpk/

Process Capability metrics – Example

Consider the following case
- m = average = 0
- s = standard deviation = as specified below
- LSL = Lower Specification Limit = – 3
- USL = Upper Specification Limit = 3

Deceasing variance ➔ fewer parts out of spec

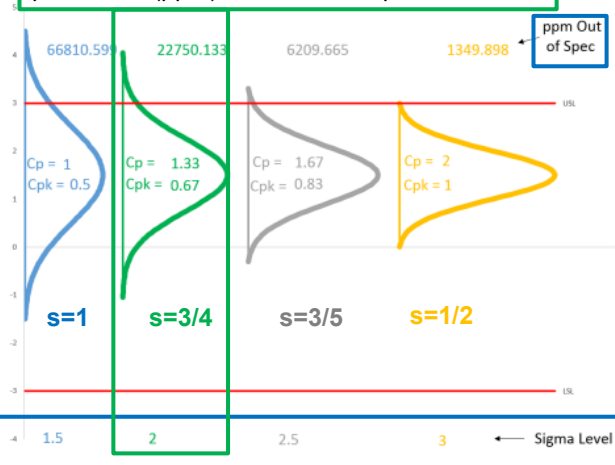
Interpretation: if s=3/4 then, at a 4 sigma level, Cp=CPK=1.33, and 63 parts per million (ppm) will be out of spec



Change the example to have
- m = average = 1.5

Note: a capable process (Cp > 1.0) does not ensure that a product is within specifications.

Interpretation: if s=3/4 then, at a 2 sigma level, Cp=1.33, CPK=0.67, and 22,750 parts per million (ppm) will be out of spec



https://www.spcforexcel.com/knowledge/process-capability/interactive-look-process-capability

Specified six sigma level

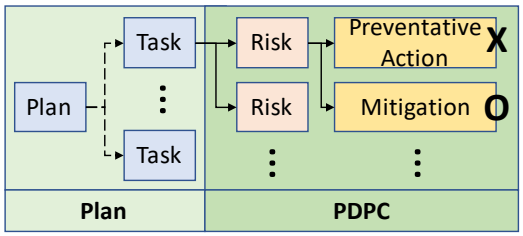
Process Decision Program Chart (PDPC)

Problem
How to anticipate and mitigate potential problems?

Difficulty
Easy to use

- A **Process Decision Program Chart (PDPC)** is a risk identification and mitigation tool.
- PDPC starts with a tree diagram representation of a program plan and systematically identifies risks by asking what-if questions.
- Using PDPC, you can revise the plan or prepared mitigations.

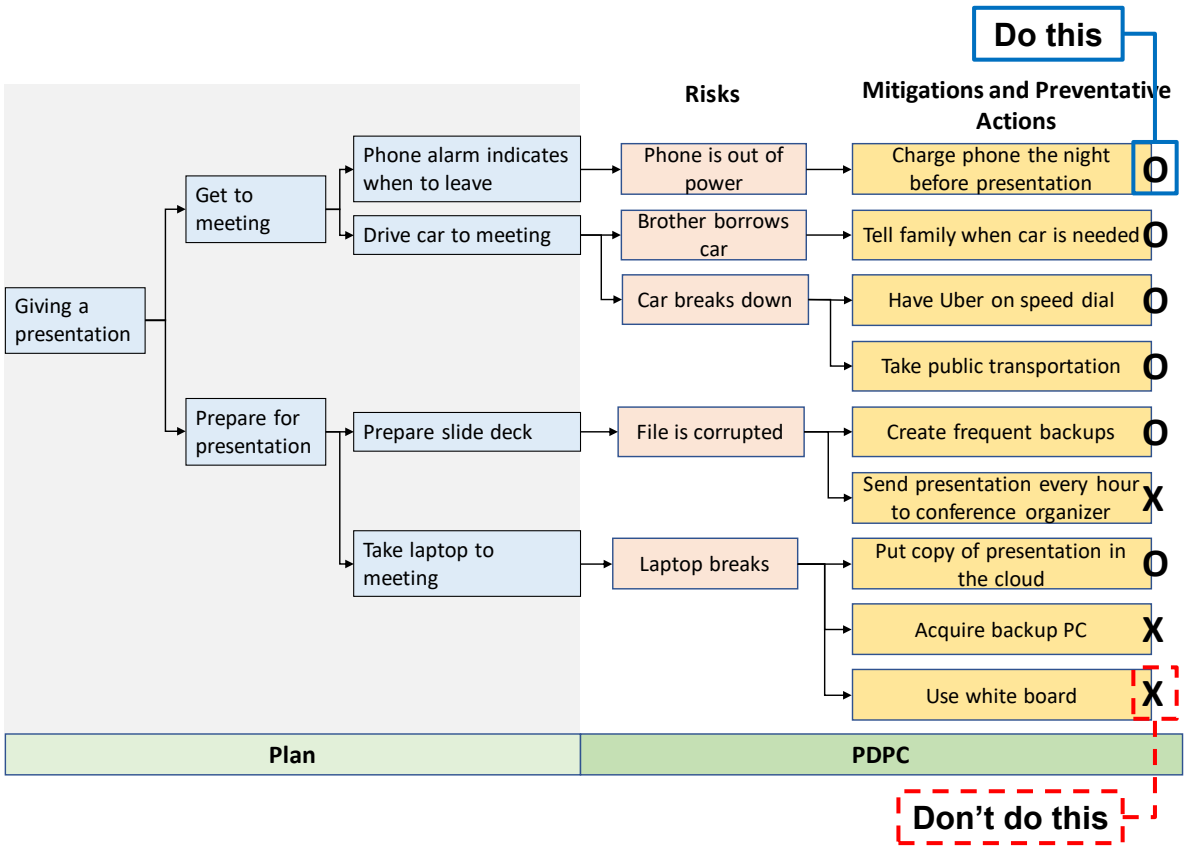
Preliminary plan → **PDPC Analysis** → Plan with mitigations



1. Create a tree diagram for a program plan.
   - Do not make it overly complex.
   - Perhaps, 3 layers to the task level.
2. For each task, identify what can go wrong using brainstorming. Address, perhaps:
   - How could this task fail?
   - Are the assumptions reasonable?
   - Is there margin for error?
3. Add each identified risk to the tree.
4. For each identified risk, brainstorm mitigations and preventative actions.
5. Add each of them to the tree.
6. Evaluate each of them:
   - How easily can it be implemented?
   - How effective is it?

   Label each with an "O" if it is practical, or with an "X" if it is not.

PDPC – Example – Giving a 6in6 presentation



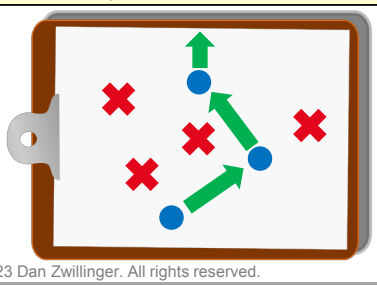
Project Charter

Problem
How to create a project charter?

Difficulty
Easy to use

- Every project begins with a **Project Charter.**
- A **Project Charter** defines a project's objectives, scope, and resources.
- There is no standard **Project Charter** format. Each company, and each application area, creates their own.

Benefits of a Project Charter
- Aligns team members
- Improves team communications
- Manages expectations
- Prevents scope creep
- Provides a framework for decisions
- Secures project resources



Business goals
Pressing need
→ **Project Charter Process** → Approved plan

The following defines the needed elements:
1. Create **Name** and **Description**
2. Define **Purpose** and **Justification**
3. Create **Objectives** and **Scope**
4. Identify **Stakeholders**
5. Define **Deliverables**
6. Identify **Team** and **Roles**
7. Create **Schedule** and **Budget**
8. Identify **Risks** and **Opportunities**
9. Document **Assumptions**
10. Obtain project **Approval**

Then distribute the document to stakeholders and team.

Project Charter – Example – Create 6in6 presentations

Sometimes, to avoid expending effort on unfunded projects, it may be useful to create a project charter in stages, obtaining approval to proceed at each stage.

"Could be good, tell me more" → Review #1

"I like the idea, what will it cost?" → Review #2

"Let's do it! Where do I sign?" → Review #3

PROJECT CHARTER					
Project Name	*Add statistical tools to 6in6 presentations*			Project Sponsor	*Alice*
Project Start	*2Q 2024*	Project End	*3Q 2024*	Project Manager	*Bob*
Business need (Why should we do this now?)					
Have created 6in6 presentations on nearly all major 6 sigma topics, except statistical tools.					
Alignment with business (Why is this part of the overall business model?)					
Comprehensiveness goal necessitates that all major categories of 6 sigma tools be included.					
Project Scope				**Project Deliverables**	
In scope	*1. SW supported tools (e.g., Excel, Matlab)* *2. Tools that are elementary or require minimal training*			*6in6 presentations on 5 different tools*	
Out of scope	*Tools requiring SME help*				
Risks and opportunities				**Assumptions**	
Risks	*May delay updating other 6in6 presentations*			*1. There is demand for these tools* *2. Work will take less than 2 months*	
Opportunities	*May get students to help*				
Resource requirements					
Cost	*$5K*	Team	*Cathy (Research), David (Create), Edward (Review)*		
Milestones		**Target completion date**		**Actual date**	
Presentation #1		*start + 4 weeks*			
Presentations #2 & #3		*start + 6 weeks*			
Presentations #4 & #5		*start + 8 weeks*			
Approval	*Alice Smith (President) 15 April 2024*				

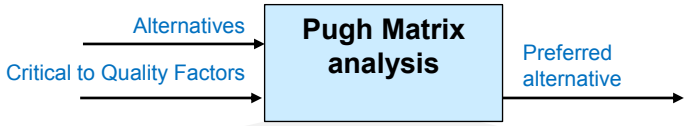
→ Start project

Pugh Matrix

Problem
How to choose among multiple alternatives?

Difficulty
Some training required

- The **Pugh Matrix** is a simple technique for making a decision among multiple alternatives.
- The **Pugh Matrix** uses pairwise comparisons between the alternatives, for each defined criteria or requirement.
- The most time-consuming part of using a **Pugh Matrix** is creating the selection criteria.
  - The assessments are quick and the calculation is easy.



Process

1. Choose the alternatives to be compared
   - List them along the top of the matrix.
2. Define the multiple selection criteria
   - These are the "Critical to Quality" (CTQ) factors.
   - They might come from the Voice of the Customer (VOC).
   - List them along the left side of the matrix.
   - Optionally, define weights for each CTQ (adding up to 1).
3. Define one of the alternatives as the **Reference Design.**
4. Have a team assign values for each alternative for each CTQ:
   - Compare each alternative to the Reference Design.
   - Assign one of the following values:
     - 0: alternative is comparable to the reference design
     - +1: alternative is better than the reference design
     - –1: alternative is worse than the reference design.
6. Calculate the score for each alternative, by adding the values.
   - Optionally. weight each {-1,0,1} by that CTQ's weight.

		Alternatives			
		Alternative A (Reference Design)	Alternative B	Alternative C	Alternative D
Criteria	Criteria 1	0	-1	-1	1
	Criteria 2	0	0	1	1
	Criteria 3	0	-1	-1	1
	Criteria 4	0	1	0	0
	Criteria 5	0	-1	0	-1
	Total Score	0	-2	-1	2

Pugh Matrix – Example – Buying a car

		Alternatives					
		(1) Reference Design: Nissan Ariya	Volkswagen ID4	Chevrolet Bolt	Tesla Roadster	Mercedes-Benz EQC	Criteria weights
Criteria	Price	0	0	-1	1	-1	0.2
	Color choice	0	0	0	-1	0	0.1
	Small size	0	1	0	1	-1	0.1
	Maximum speed	0	1	0	1	1	0.1
	Nearby dealership	0	1	1	-1	1	0.2
	Distance on one charge	0	1	0	-1	1	0.3
	Total Score	0	4	0	0	1	
	Total Score (weighted)	0	0.7	0	-0.2	0.3	

(3) Weighted case: each criteria has a weight

(2) Team created comparison values

(4) Computation when not using weights is a column sum:
1 = (-1) + (0) + (-1) + (1) + (1) + (1)

(6) Best alternatives
- Weighted: 4 is highest value
- Unweighted: 0.7 is highest value

(5) Computation using weights is an inner product:
0.3 = 0.2*(-1)+ 0.1(0) + 0.1*(-1)+0.1*(1)+0.2*(1)+0.3*(1)

Qualify Function Deployment (QFD)

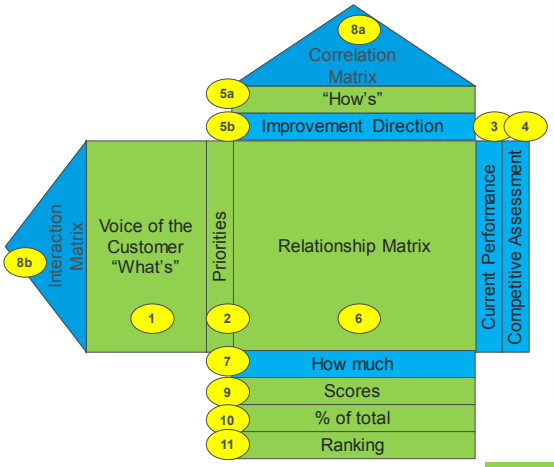
Problem
How to select "how"s to meet a "want"?

Difficulty
Some training required

Quality Function Deployment (QFD) translates a customer's "wants" ("What does the customer want?") into "hows" ("How can we satisfy the customer wants?").

- A weighted decision matrix is used.
- The "hows" are prioritized

Customer "wants" → **QFD Process** → Prioritized "hows"



The green elements are the minimal elements for a QFD. The blue elements are optional.

Minimal

Optional

Process

1. Determine the customer's "What's"
2. Determine the customer's priority ratings
3. *Determine current performance*
4. *Determine competitive assessment*
5. Define the "How's"
6. Determine how well a "How" meets a "What"
7. *Establish Measurable Targets for "How's"*
8. *Complete Correlation and Interaction Matrices*
9. Compute the Score for each "How"
10. Compute percentages and rankings
11. Determine the final result

QFD is also known as the "house of quality"

QFD – Example – Selecting a vacation

Minimal QFD process steps

1. Determine the customer's "What's"
2. Determine the customer's priority ratings
3. Define the "How's"
5. Determine how well a "How" meets a "What"
6. Compute the Score for each "How"
9. Compute percentages and rankings
10. Determine the final result

Example: selecting a vacation

- **What's** (items of concern): cost, child friendly, novelty
- **How's**: go to the beach, go skiing, go to Disneyland, travel internationally, day trips from home

- For steps 2 and 5, use values of {1,3,9} for simplicity
- For step 6, a large score is preferred to a smaller score

2: desire low cost and very child friendly … overall a larger number is a better choice

		Hows				
Customer "what's"	Priority	beach	skiing	Disneyland	travel	day trips
Cost	1	9	3	1	1	9
Child friendly	9	9	3	9	1	3
Novelty	3	1	3	3	9	1
Scores		93	39	91	37	39
% of total		31%	13%	30%	12%	13%
Ranking		1	3	2	5	3

3: These are the different possible "how's"

1: what the customer cares about

5: for cost: travel is expensive (bad) so it is a "1", the beach is inexpensive (good) so it is a "9" … a larger number is a better choice

9: These are the scores divided by 299

6: these are the mathematical "inner product" of each "how" with the priorities. For example: 93 = 1*9 + 9*9 + 3*1. The total of the scores is 299.

10: This row has ranked the "% of total" values. Overall "beach" and "Disneyland" are close and a more detailed analysis of these two "hows" should be made.

RASCI (Responsible / Accountable / Support / Consulted / Informed) Chart

Problem
How to represent task roles?

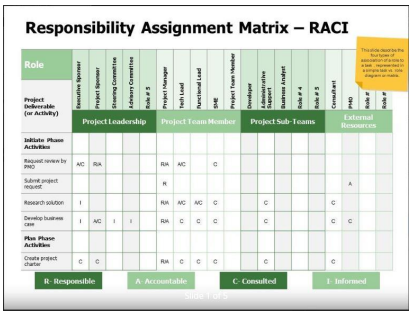
Difficulty
Easy to use

- **RASCI** is a tool to determine *Roles and Responsibilities* for tasks.
- Using RASCI every person in a task has a well-defined role.
- The "Accountable" person is key!
  - Every activity/task has only one "A"
  - From the outside, the "A" person is the single point of contact for a specific task.

Collection of tasks → **RASCI Chart process** → Responsibility assignment matrix; Clear ownership of each task

1. Identify all activities/tasks (these are rows)
2. Identify all the roles/players (these are columns)
3. Identify who has R, A, S, C, I for each activity/task
4. Resolve gaps/overlaps with the team

Role	Meaning
R = Responsible	Those who perform the work to complete a task.
A = Accountable	The person with task ownership.
I = Informed	Those who are kept up-to-date on a task (e.g., progress).
C = Consulted	Those who supply input to a task.
S = Support	Those tasked to support those Responsible for the task.



https://commons.wikimedia.org/wiki/File:RACI_MATRIX_PPT_TEMPLATE.jpg

RASCI – Example – Creating a 6in6 presentation

	Creating a 6in6 presentation	Dan	Alice	Bob	Cathy	David	Elizabeth	Frank
main task	Entire process	A, R						
subtask 6	Update internet	I		A	R			
subtask 5	Final review	I		R		A	R	
subtask 4	Create document	A	R	I		I	I	C
subtask 3	Define key information	I		A, R				C
subtask 2	Research information	I	A, R	I		C		
subtask 1	Choose topic	A, R	I				C	C

Role
R = Responsible
A = Accountable
I = Informed
C = Consulted
S = Support

Notes

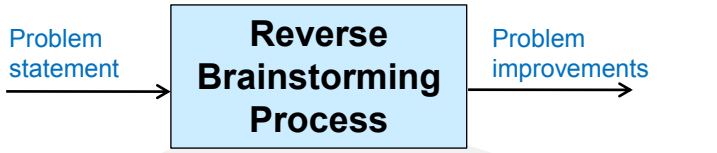
1. To create a new 6in6 presentation, several subtasks need to be performed (read bottom-up).
2. A single person may have multiple roles.
3. There is only one "A" each task/row (the accountable person)
4. There is at least one "R" for each task/row (the responsible person/people)
5. Color coding the {R,A,S,C,I} can make a RASCI chart easier to review.
6. From the RASCI chart, we can infer that
   - Dan is in charge
   - Alice owns the research activities
   - Cathy owns the internet activities
   - David owns the editorial activities
   - Frank is a resource used by many
7. Everyone knows what their role is for each part of the 6in6 presentation creation process.

Reverse Brainstorming

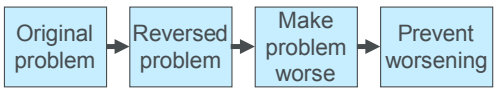
Problem
How to identify ideas to solve a problem?

Difficulty
Easy to use

- Instead of directly solving a problem, **reverse brainstorming** reverses the problem to focus on causes of the original problem or how to achieve the opposite of what is desired.
- The ideas for the reverse problem, which worsen the original problem, are analyzed to determine how to solve the original problem.



1. Clearly identify the problem to be solved.
2. Reverse the problem statement in one of two ways
   A. Instead of "How do I solve this problem?" create the reverse problem "How could I cause the problem?"
   B. Instead of "How do I achieve these results?" create the reverse problem "How could I achieve the opposite results?"
3. Brainstorm answers to solve the reverse problem (do not reject any ideas).
4. For each of the reverse problem ideas, attempt to find solutions to the original problem.
5. Prioritize the solutions to the original problem.



Reverse Brainstorming – Example – Web Site Visits

- **Problem**: How to have more visitors to the 6in6 website (www.sixsigmainsixminutes.com)?
- **Reverse problem**: *How to drive visitors away from the 6in6 web site?*

Potential solutions to the reverse problem

1. Have a lengthy software license that users must agree to.
2. Put in many paid advertisements that take up much screen real estate.
3. Required a complicated log-in procedure with a required long password.
4. Have dead links that do not go anywhere.
5. Host the website on a very slow server.
6. Use many distracting features like flashing text and moving figures.
7. Make the web site hard to read (confusing text, small text, difficult to read fonts)
8. Make it difficult to find desired content.

Potential solutions to the original problem

1. Have no required software license.
2. Have no advertisements.
3. Do not require users to log in.
4. Confirm that all the links work.
5. Use the fastest affordable server.
6. Adopt UX (user experience) best practices; remove distractions.
7. Use simple language and large easy-to-read fonts.
8. Use a simple navigation paradigm.

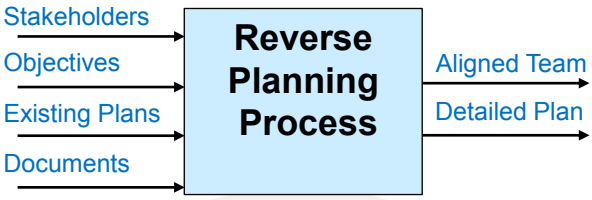
Reverse Planning (AKA backward design)

Problem
How to create a plan to reach a goal?

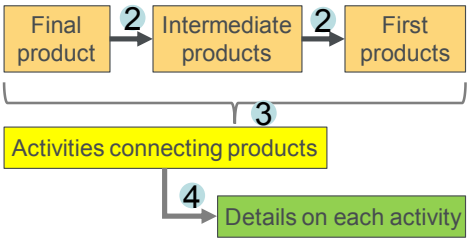
Difficulty
Some training required

Reverse Planning is a high energy team-building approach to develop schedules based on network logic.

When should I use it? When …
- determining needed activities
- building a schedule
- creating a detailed plan to support an existing schedule



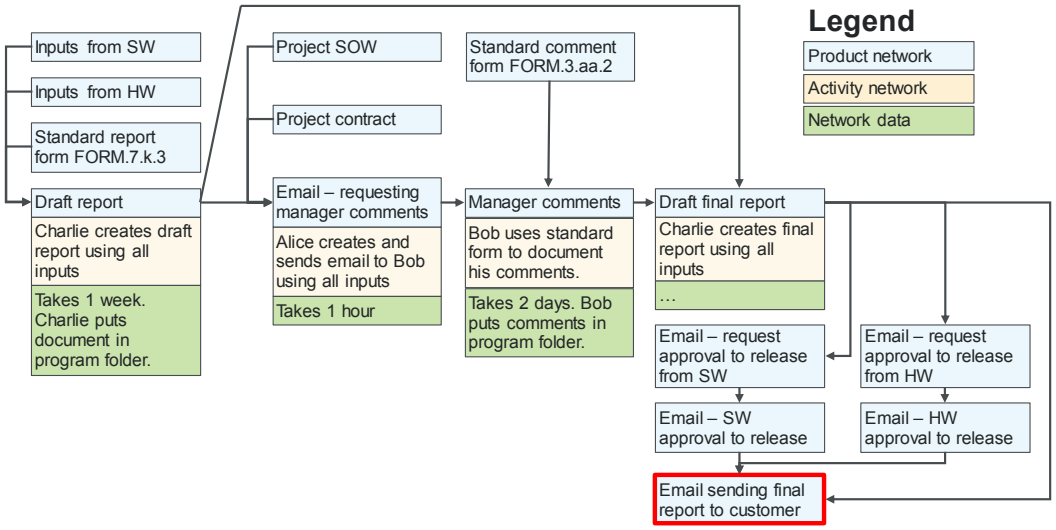
Reverse Planning Process



Tangible products = "something you can hold in your hand" = {emails, designs, reports, approvals, manufactured items, …}

1. Identify the **end objective**
2. Define the **Product Network**
   - Determine the tangible products required, starting with the last; define dependencies between them
3. Define the **Activity Network**
   - Determine the activities necessary to create the products; define their dependencies
4. Populate the **Network Data**
   - For each activity, define its duration, needed resources, and the definition of "Done"
5. Review and **optimize** the network

Reverse Planning – Example – Sending out a report



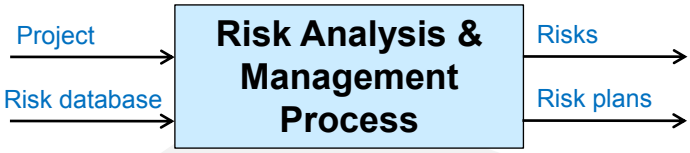
1. This flow chart was created right to left, starting with the desired final result (box with red border).
2. First, the blue boxes were created; each of them is a "thing" (noun), something you can hold in your hand.
3. Second, a few of the needed yellow boxes were defined; they define "who" does "what" to create what is in the blue boxes.
4. Finally, the sender and receiver of each blue box (defined in the yellow box) negotiate the timeline, the inputs and outputs, and where the documents will be placed (this information is in the green boxes).
5. It takes much work to create a complete flowchart. However, when complete, it is clear to everyone what the process is, how long it will take, and who is responsible for what activities.

Risk Analysis & Management

Problem
How to address project risk?

Difficulty
Easy to use

- A **Risk Analysis** determines and prioritizes risks. A risk is something that can delay, halt, or harm your project.
- **Risk Management** is how risks are dealt with.
- There are many risk classes, each with many types of risk.
- Maintaining a generic & project risk database is a best practice



1. **Identify** the risks using assumptions, historical documents, interviews, meetings, and risk database.
2. **Score** risks. Refine high- and medium-scoring risks. Include impacts on quality, time, and cost. Use either
   - **Risk Prioritization Grid**: severity, likelihood
   - **FMEA**: severity, likelihood, observability
3. Plan **responses**:
   - **Accept** the risk: can tolerate, if needed
   - **Avoid** the risk: eliminate it from happening
   - **Reduce** the risk: use mitigation plans
   - **Share** the risk: offload risk to other party
4. **Execute:** Address the high-scoring risks; address the medium-scoring risks, as possible.
5. **Monitor** and control risks.
6. **Document** the learning in the risk database.

Risk Likelihood	Risk severity				
	1 Very Low	2 Low	3 Medium	4 High	5 Very high
1 Very Low	Medium	Medium	High	High	High
2 Low	Medium	Medium	Medium	High	High
3 Medium	Low	Medium	Medium	Medium	High
4 High	Low	Low	Medium	Medium	High
5 Very high	Low	Low	Low	Medium	Medium

Risk Prioritization Grid

Risk Analysis – Example – 6in6 Project Risks

List of risks and their evaluation

#	Risk type	Risk	Likelihood	Severity	Overall risk
1	Audience	Someone copies all the 6in6 presentations to their own site	1 Very Low	2 Low	Low
2	Audience	Few people view 6in6 presentations	3 Medium	3 Medium	Medium
3	Delivery	6in6 website fails since ISP provider goes out of business	1 Very Low	3 Medium	Low
4	Delivery	6in6 website fails since too many people view 6in6 presentations and system crashes	1 Very Low	3 Medium	Low
5	Motivation	No new 6in6 presentations are created since Dan wins lottery	1 Very Low	1 Very Low	Low
6	Motivation	Few new 6in6 presentations are created since Dan moves on to other interests	2 Low	1 Very Low	Low
7	Production	There are factual errors in a 6in6 presentation	2 Low	5 Very high	High
8	Production	There are grammatical/spelling errors in a 6in6 presentation	3 Medium	1 Very Low	Low

Map risk numbers to a risk prioritization grid

Risk Likelihood	Risk severity				
	1 Very Low	2 Low	3 Medium	4 High	5 Very high
5 Very high					
4 High					
3 Medium	8		2		
2 Low	6				7
1 Very Low	5	1	3, 4		

Address all high level risks

Risk #7 strategies:
- **Prevention**: Have experienced 6 sigma practitioner review new presentations.
- **Mitigation:** Respond immediately to audience recognition of an error.

SCAMPER

Problem
How to create an improved product or process?

Difficulty
Easy to use

SCAMPER is an acronym for 7 ways in which an improved or new product or process can be created, based on an existing product or process.

- **S**ubstitute / **C**ombine / **A**dapt / **M**odify / **P**ut to other uses / **E**liminate / **R**earrange (or **R**everse)

1. Identify and review an existing product or process.
2. Investigate the 7 ways in which a new or improved product or process can be created from an existing one.
   - For each, ask probing questions that are likely to elicit useful responses (see example below).
   - While some generated ideas may not work, the goal is to generate as many ideas as possible.
3. Evaluate the responses that were created.

			Example
S	Substitute	Replace a product/process component with another component that works better	A child's book made from cloth, not paper
C	Combine	Put different components together to improve a product/process	Vanilla Coca-Cola
A	Adapt	Change the nature of a product/process by incorporating other ideas	Use a bank card as a credit card
M	Modify	Change how a product/process looks or acts.	Accept soft copies (electronic) copies in addition to hard (paper) copies.
P	Put to other uses	Use the product/process for a purpose for which it was not designed.	Use existing distribution capability for one product to distribute another product.
E	Eliminate	Remove parts that don't add any, or much, value.	Remove wire to obtain a wireless mouse
R	Rearrange / Reverse	Consider the effect of if part of the product/process was done in a different order.	At a fast food restaurant, pre-cook a hamburger before a customer orders it.

Possible Combine questions:

- Can multiple process steps be performed by the same person at the same time?
- Can we combine steps 1&2 or 2&3 or 3&4 and …?
- Can we combine job functions?
- Can we combine customer needs from different business areas?

SCAMPER – Example – Fast Food Chain

McDonald's incorporates many practices which, in retrospect, could have arisen from a SCAMPER analysis of earlier/traditional restaurants:

Substitute
- Use a franchise model instead of having a restaurant run by McDonald's direct employees. (This substitutes people who work for the franchise owner for McDonald's employees.)

Combine
- Create and sell food combinations ("meals") instead of individual products.
- Combine taking food away from a restaurant concept with a seated restaurant concept, to obtain the drive-thru concept.

Adapt
- As other restaurants have done, offer free items with some purchases (e.g., a drink with each burger).
- Accept payment using a contactless payment system on mobile devices (e.g., Apple Pay).

Modify
- Allow the user to customize the contents of their order (a hamburger with no onions)
- Have the customer pay for the food before eating.

Put to another use
- Have franchisees rent land from McDonald's, so they make money on the food and the real estate.

Eliminate
- Allow customers to order food on a phone app, or kiosk, eliminating the need for a cashier.
- Let customers select napkins and straws to eliminate having an employee supply them.

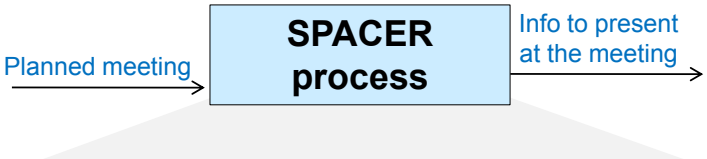
Reverse
- Instead of preparing food after a customer order, pre-cook food to speed up delivery to the customer.
- Instead of having the customer enter a McDonald's, have an employee deliver food to a car.

SPACER

Problem
How to run a meeting?

Difficulty
Easy to use

- **SPACER** is an acronym for information to present at the start of a meeting (see below).
- Using SPACER allows a meeting to stay focused, and prevents the meeting from getting detoured
  - by mistake (e.g., going down a rabbit hole); or
  - by intent (e.g., an attendee wants to hijack the meeting)



1. Prepare the SPACER content before a meeting, see table below.
2. At the start of that meeting, review – and update as needed – the SPACER content with the team.
   - Optionally, but recommended: allow team to negotiate the code of conduct
3. Continue the meeting, staying focused on the meeting agenda.

		Addresses
S	**Safety**	What to do in an emergency?
P	**Purpose**	Why are we having the meeting?
A	**Agenda**	What will we do during the meeting?
C	**Conduct**	How will we act during the meeting?
E	**Expectations**	What will be the result of the meeting?
R	**Roles & Responsibilities**	Who will do what?

SPACER – Example – Starting a Meeting

Opening statement at the beginning of a meeting:

Thank you for coming to today's 6in6 meeting.

S	**Safety**	If the fire alarm goes off, the closest emergency exit is out the door and to the right about 50 feet. There a staircase down to an outside door and the rally point is clearly indicated. Note that the rest rooms are to the left when leaving this room, about 30 feet away.
P	**Purpose**	Today's meeting is to discuss how to get more people aware of the 6in6 presentations that are on the web.
A	**Agenda**	Here is our agenda, which was included in the meeting invite: (*) Discuss the brainstormed ideas from the last meeting. (*) Prioritize the ideas based on cost and impact. (*) Discuss ways to implement the top two ideas.
C	**Conduct**	I'd like to propose the following meeting rules: (*) Listen to each other with respect (*) No cell phones or pagers (*) "Vegas Rules" -- what occurs during the meeting stays in the meeting Are these acceptable? What else should we add?
E	**Expectations**	The expectation is that at the end of the meeting we have draft implementation plans. These plans will be firmed up then reviewed by finance to determine implementation costs, and reviewed by a focus group to determine likelihood of success.
R	**Roles & Responsibilities**	Alice will moderate the overall meeting. Bob will lead the discussion of the brainstormed ideas and their prioritization. Charles will lead the implementation discussion. After the meeting, Diane will take the information produced and firm it up; hence, the meeting -- which might take up to 2 hours -- is not over until Diane is satisfied with the information produced.

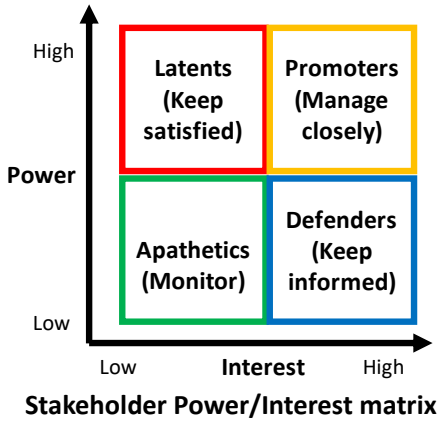
Are there any questions before we begin?

Stakeholder Analysis

Problem
How to obtain stakeholder alignment?

Difficulty
Some training required

- Project success requires that each stakeholder be handled properly.
- A **stakeholder analysis** is a pre-cursor to creating a project communications plan.
- There are many tools for assessing and categorizing stakeholders.



Stakeholder Power/Interest matrix

Project plan → **Stakeholder Analysis Process** → Stakeholder understanding

1. Identify the stakeholders (internal and external, anyone with a stake in the product).
2. Create a ***Power/Interest matrix***: Determine each stakeholder's project interest (will they support?) and their power (can they affect resources?)
3. Create a ***Stakeholder Scoring matrix***: Score the stakeholders (1=unaware, …, 5=leading)
4. Develop a strategy supporting the needs of each stakeholder, leading to a successful project.

Stakeholder Scoring matrix

Stakeholder name	Current Rating	Desired Rating	Rating Rationale	Action Plan

Stakeholder Analysis – Example – Generic

(1) List of stakeholders (first list functions, then identify individuals within each function)

Category	Internal Stakeholders	External Stakeholders
Design	Graphic designer	End users
Development	Developers	--
Documentation	Technical writers	End users
Review	Management	Auditors
Sales	Sales department	Potential customers
Testing	Testing team	Beta users
…		

(2) Stakeholder Power/Interest matrix

	Power	Interest	Type
Alice in marketing	low	high	Defender
Bob in customer support	high	low	Latent
Charles in accounting	low	low	Apathetic
…			

- Actions
- Communication strategies

(3) Stakeholder Scoring Matrix

Ratings used
1. Unaware
2. Resistant
3. Neutral
4. Supportive
5. Leading

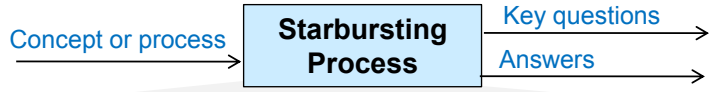
Stakeholder name	Current Rating	Desired Rating	Rating Rationale	Action Plan
Alice in marketing	5	5	She brought idea to company, wants success	None required
Bob in customer support	2	4	Thinks department is already overloaded	(*) Have external company create support materials (*) Encourage and support efficiency improvement projects in customer support
Charles in accounting	3	3	Has no opinion	None required
…				

Starburst brainstorming

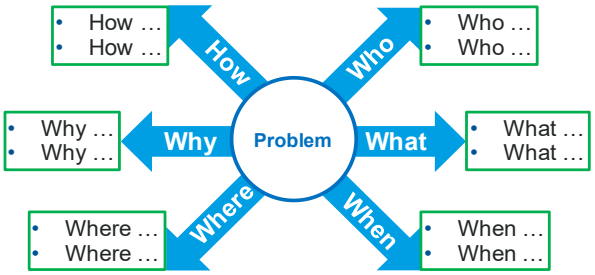
Problem
How to create appropriate brainstorming questions?

Difficulty
Easy to use

- **Starburst Brainstorming** is a type of structured brainstorming that focuses on creating key questions before finding the answers.
- The process uses a six-point starburst diagram, the points of the star are *who, what, when, where, why,* and *how*.
- The facilitator manages the process and addresses off-track (but useful) questions.



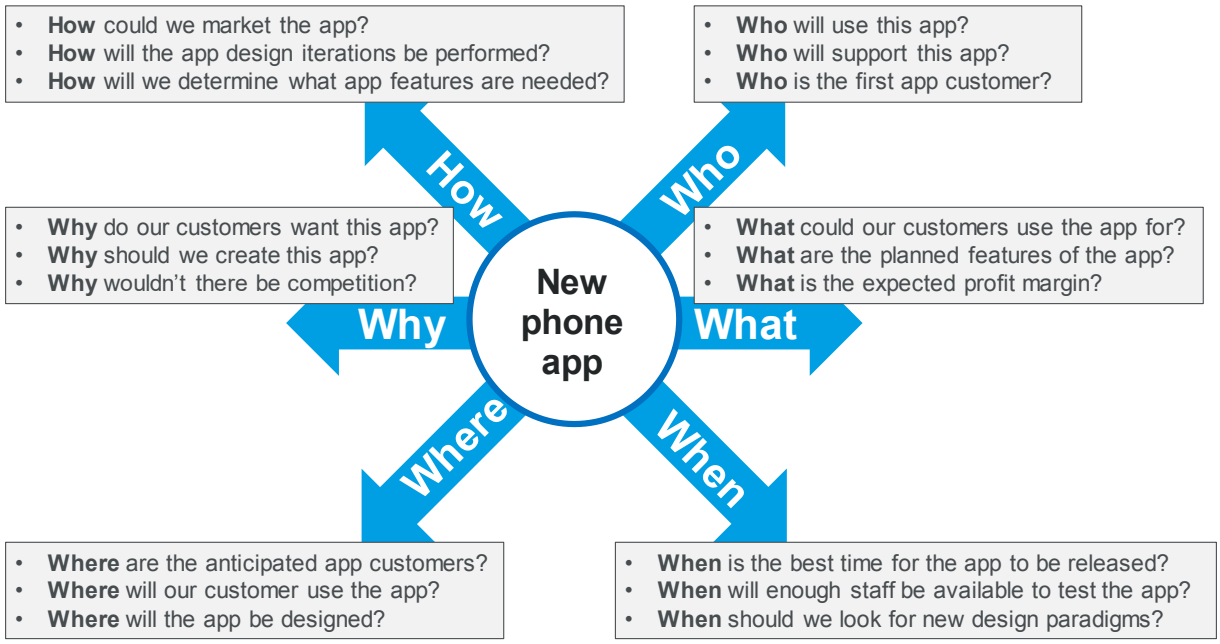
1. Construct a **six-pointed star**
   A. Put the concept, process, problem, product or service in the center of the star.
   B. Add the five 'W's and the 'H' at the star's points.
2. For each of the six star points, **create questions** for the word at that star point and write them down
   A. Do not attempt to answer questions immediately.
   B. Continue brainstorming until there are at least 3 questions for each of the six points of the star,
3. Systematically **address each question**.



Starburst brainstorming – Example – Phone App

Suppose your company is creating a new phone application.
The resulting Starburst might look as follows.

- *There are 6 collections of questions.*
- *Each collection has at least 3 questions.*

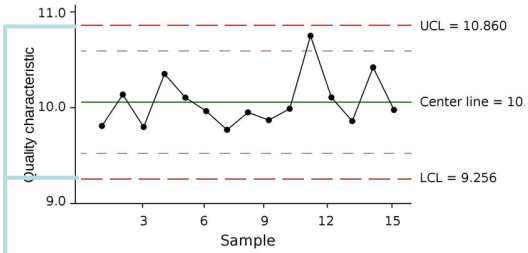


Statistical Process Control (SPC)

Problem
How to ensure process quality?

Difficulty
Work with an SME

- **Statistical Process Control (SPC)** is the application of statistical methods to the monitoring & control of a process to ensure that it produces conforming products
- **SPC** involves collecting data, controlling a process through data charting and analysis, and understanding process capability.



Upper/Lower *Control limits*
(*not* customer specification limits)

Process to be controlled
Process data
SPC tools
→ **Statistical Process Control Process** → Understanding and control of process via data

1. Define the **objectives** for a specific process
2. **Plan** data collection points
3. **Plan** data analysis method
4. **Understand** & improve measurement system (see 6in6 on Gage R&R)
5. **Collect** & **review** data
6. Calculate control limits
7. **Monitor** & correct process based on data collected (see 6in6 on Control Charts)
8. Determine **process capability** (Cp and Cpk, see 6in6 on Process Capability)
9. Iterate process

Statistical Process Control (SPC) – Examples

There are many ways to
- Calculate control limits
- Monitor & correct process via collected data

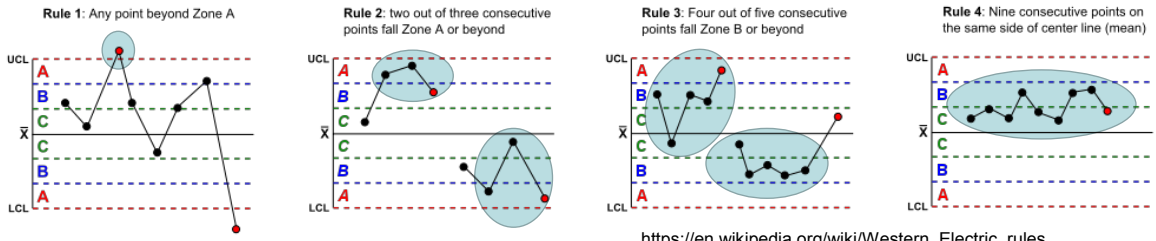
The "Western Electric rules," which are only useful for hand analysis, are below.

Western Electric process
- **Step 0** – find the process' sample mean (m) and standard deviation (s)
- **Step 1** – create symmetric control limits, using ±3s
- **Step 2** – define 3 "zones"
  - Zone C → region within 1s of m
  - Zone B → region between 1s and 2s of m
  - Zone A → region between 2s and 3s of m
- **Step 3** – plot new data points as they arrive and look for certain patterns that may indicate a process is not in control. Some of these patterns are shown below.

For discrete defect data, the different control charts are p, np, u, and c.

		Interest	
		Defects	**Defectives**
Sample size	**constant**	c-chart	np-chart
	variable	u-chart	p-chart

Many other rules have been described:
- There are **8 "Nelson rules"**
  https://en.wikipedia.org/wiki/Nelson_rules
- There are **6 "Westgard rules"**
  https://en.wikipedia.org/wiki/Westgard_rules
- There are **6 "Western Electric rules"** for data analysis using a range (R) chart – different from an (m,s) chart.
  https://en.wikipedia.org/wiki/Western_Electric_rules



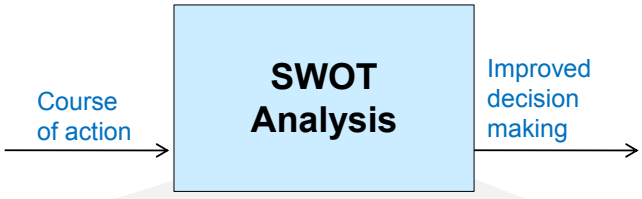
https://en.wikipedia.org/wiki/Western_Electric_rules

SWOT (Strength / Weaknesses / Opportunities / Threats)

Problem
How to assess a project or organization?

Difficulty
Easy to use

- A **SWOT** analysis is a structured strategic method to evaluate an organization or a project.
- SWOT documents the anticipated **S**trengths, **W**eaknesses, **O**pportunities, and **T**hreats.



	Help you	Hurt you
Internal	S Strengths	W Weaknesses
External	O Opportunities	T Threats

1. Clearly specify the desired end state or objective.
2. Identify the internal and external factors that are favorable and unfavorable to achieve that objective. For each SWOT element, address a set of "standard" questions:

- **Strengths**: *What do you do very well, compared to others? What resources do you have? Is your brand strong?*
- **Weaknesses**: *What do your rivals do better than you do? What processes and activities need improvement? What do you do poorly?*
- **Opportunities**: *Are there new ways to create your products? Where are your strengths valued? Are there new markets? Are your competitors' customers unhappy?*
- **Threats** *Will technology change the need for your product? Can customers use alternative products? Are customers needs changing? What are your competitors doing?*

SWOT – Example – Fast Food Chain

A SWOT analysis for a large well-known regional US-only fast food chain might be as follows:

Strengths (help, internal)
- Competitive pricing.
- Excellent economies of scale.
- Large installed base.
- Widely recognized brand.

Weaknesses (hurt, internal)
- High employee turnover.
- Increasing consumer concern about healthiness of food.
- Menu changes slowly.
- Quality control varies due to franchised operations.

Opportunities (help, external)
- Add healthier items to menu.
- Appeal to neglected consumers (e.g., gluten-free offerings).
- Expand business to other regions and/or other countries.
- Increase social activities to reinforce brand.

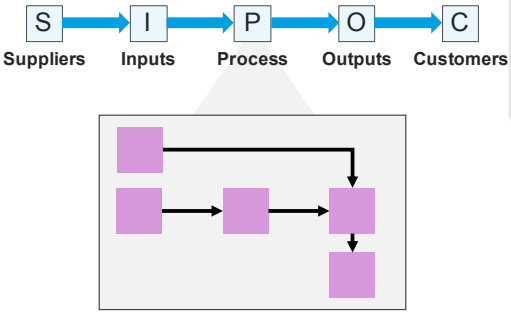
Threats (hurt, external)
- Competitors from other countries may enter US market
- Customers are becoming more health-conscious.
- Other US fast-food chains are also changing their offerings.

SIPOC (Suppliers / Inputs / Process / Outputs / Customers) and IPO

Problem
How to explain a business process?

Difficulty
Some training required

- A **SIPOC** diagram shows an end-to-end business process, from suppliers (S) to customers (C).
- Without the "S" and "C", a SIPOC diagram is an **IPO** diagram.
- A SIPOC diagram explains a business process, keeps team members aligned, and clarifies parts of a process.
- A SIPOC usually fits on one page.
- All 6in6 presentations have an IPO diagram (Inputs/Process/Outputs), see image to right.



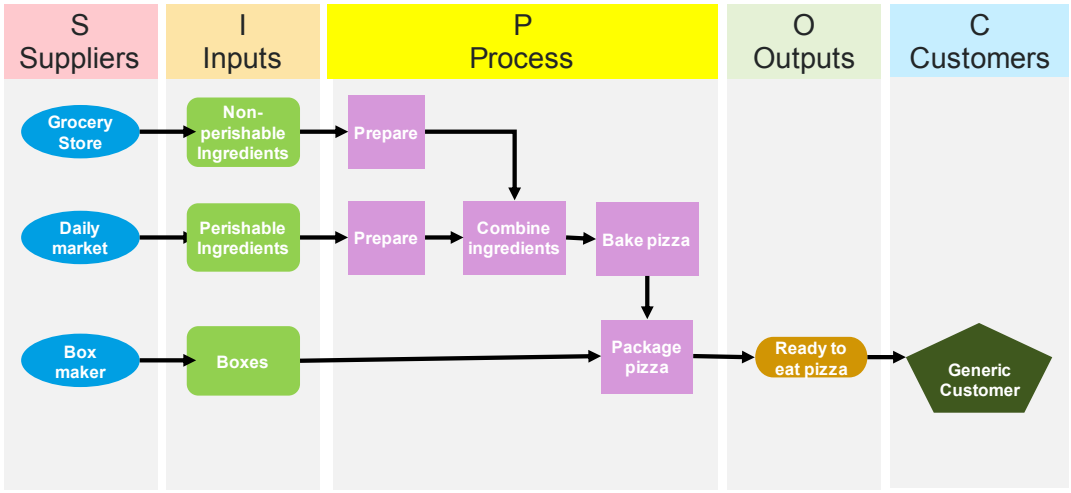
Existing process → **Creating a SIPOC diagram** → Graphical understanding of the process

1. Select a process to document and/or explain.
2. Assemble a small team of process owners.
3. Create the SIPOC diagram in the following order
   A. Define the **process** steps (perhaps 4 to 8): **P**
   B. List the **outputs** (perhaps 3 or 4): **O**
   C. Identify **customers** (internal & external): **C**
   D. List the **inputs** (perhaps 1 to 4): **I**
   E. Identify the **suppliers**: **S**
4. Share the SIPOC diagram.

Terms
- **Suppliers**: The source of the inputs required by the process
- **Inputs**: The resources needed for the process
- **Process**: The high-level steps defining the process
- **Outputs**: The results of the process
- **Customers**: Those who receive outputs or benefit from the process

SIPOC – Example – Making a pizza

A SIPOC using a graphical representation (same data as below)



A SIPOC using a spreadsheet representation (same data as above)

Suppliers	Inputs	Process	Outputs	Customers
Grocery store	Non-perishable Ingredients	Prepare non-perishable ingredients	Ready to eat pizza	Customer
Daily Market	Perishable Ingredients	Prepare perishable ingredients		
Box makers	Boxes	Combine ingredients		
		Bake pizza		
		Package pizza		

Surveys

Problem
How to obtain knowledge from people?

Difficulty
Easy to use

- A **survey** uses questions to collect data from people.
- Survey results are statistically analyzed to draw conclusions. Many responses are required for accurate results.
- Questionnaires, a survey type, are inexpensive and quick to create, and easy to analyze.

Survey question attributes
- Are clear and short
- Are not biased or leading
- Ask about just one thing
- Do not contain abbreviations, jargon, or slang.
- Is a positive statement
- Uses images and videos, as needed, for clarification

Need understanding about a specific topic → **Survey Process** → Statistically obtained knowledge

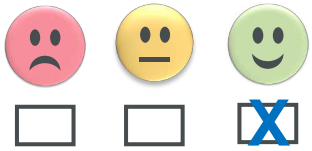
1. **Plan the survey**
   - Define the survey purpose
   - Identify the (unbiased) survey audience
   - Specify survey modality: face to face? online? paper and pencil? telephone? …
2. **Design the survey**
   - Keep it short and include instructions
   - Select question types: multiple choice, ranking, rating, Likert scale, …
   - Create the questions (see attributes at left)
   - Pre-test the survey and revise as needed
3. **Collect data using the survey**
   - Ensure there are enough responses for useful results
4. **Analyze the survey data**
   - Use a SW package to analyze the data

Surveys – Example – Assessing 6in6 usefulness

Do you like the 6in6 presentations?

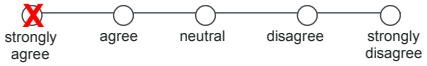
(Rating scale question)

Have the 6in6 presentations improved your understanding of multiple topics?



1. The 6in6 website has a user friendly interfac

2. The 6in6 website is easy to navigate



(Likert scale questions)

Is a video presentation needed for each topic?

◯ Yes ● No

(Dichotomous question)

How likely are you to recommend the 6in6 site to a friend?

1	2	3	4	5	6	7	**8**	9

How many different 6in6 presentations have you used in your work? 7

The 3 things you find most important about 6in6 presentations

- ● Clarity of presentation
- ◯ Useful for teamwork
- ◯ Explanatory examples
- ● Ease in finding appropriate tool
- ◯ Ease of contacting author
- ◯ Large collection of tools
- ◯ Website responsiveness
- ● Cost (free!)

(Multiple choice question)

6in6 site comments

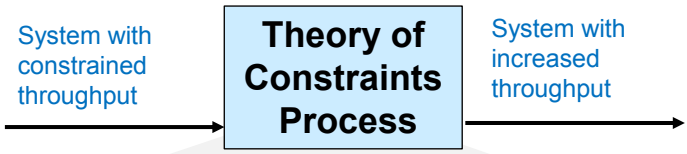
I love the presentation format. Please create more 6in6 presentations.

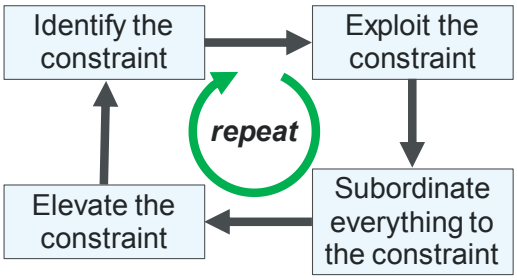
Theory of Constraints (TOC)

Problem
How to identify and remove bottlenecks?

Difficulty
Some training required

The **Theory of Constraints** (**TOC**) states:
- System throughput is limited by a bottleneck, called the *system constraint.*
- An increase in throughput can only be achieved by making an improvement in the system constraint.
- Improvements in other parts of the system are wasted effort.

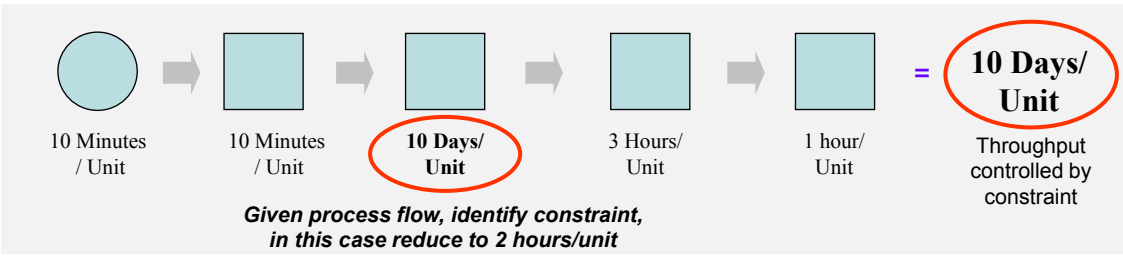




1. **IDENTIFY** the constraint
   - This is the resource preventing the process from obtaining more of the goal.
2. **EXPLOIT** the constraint
   - Ensure the constraint's time is not wasted doing things that it should not do.
3. **SUBORDINATE** all other processes to the above decision
   - Align the whole process to support the decision made above.
4. **ELEVATE** the constraint
   - If possible, permanently increase capacity of the constraint; perhaps "buy more."
5. **REPEAT**

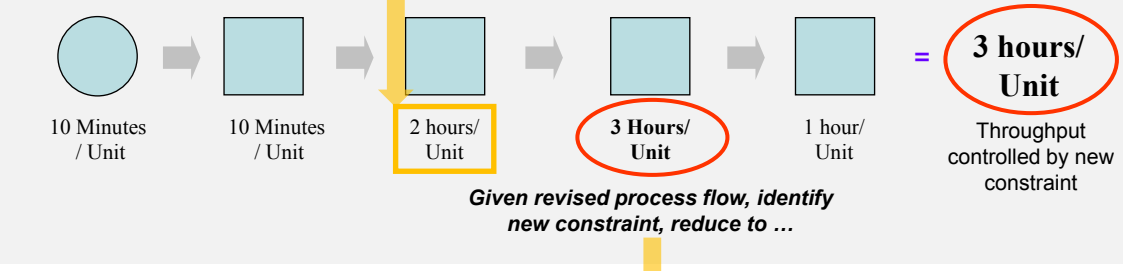
Theory of Constraints – Example

Initial process flow … find bottleneck controlling throughput .. and reduce it



Given process flow, identify constraint, in this case reduce to 2 hours/unit

Revised process flow #1 … find next bottleneck controlling throughput …



Given revised process flow, identify new constraint, reduce to …

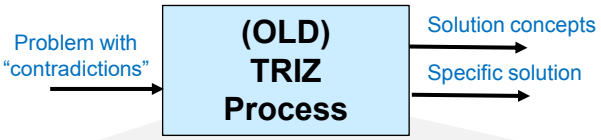
Revised process flow #2 … keep iterating the process …

Theory of Inventive Problem Solving (TRIZ)

Problem
How to be inventive when solving a problem?

Difficulty
Work with an SME

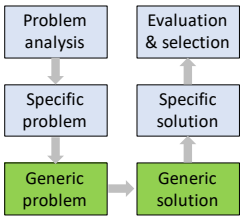
- **TRIZ** is a problem-solving tool obtained from invention patterns in the patent literature.
- TRIZ's approach is that a solution, for something close to your problem, has already been found. The goal is to find that solution and adapt it to your problem.
- Modern TRIZ uses "76 standard solutions."
- (OLD) TRIZ – easier to describe & illustrate – identified technical & physical contradictions involving "39 universal features." All solutions are then one or more of the "40 inventions."



39 Universal Features
1. Weight of moving object
2. Weight of stationary object
3. Length of moving object
4. Length of stationary object
5. Area of moving object
6. Area of non-moving object
7. Volume of moving object
8. Volume of stationary object
9. Speed
10. Force
…
38. Extent of automation
39. Productivity

40 Invention Principles
1. Segmentation
2. Taking out
3. Local Quality
4. Asymmetry
5. Merging
6. Universality
7. Nested doll
8. Anti-weight
9. Preliminary anti-action
10. Preliminary action
…
39. Inert atmosphere
40. Composite materials

1. Create a specific problem statement.
   - Identify a **contradiction** among the **39 universal features**. That is, identify contradiction between features (A) and (B).
2. Create **generic problem** statement:
   - Want to change (A) yet (B) deteriorates
3. Use **contradiction table** to identify which of the generic solutions, among the **40 invention principles,** eliminates the contradiction
4. **Brainstorm** the generic solutions to **create potential solutions** for your problem
5. Evaluate the potential solutions



Solution approach	Standard solutions
Improving the system with no or little change	13
Improving the system by changing the system	23
System transitions	6
Detection and measurement	17
Strategies for simplification and improvement	17
total	76

TRIZ (OLD) – Example – Improving a Beverage Can

(1) Problem: Want to *improve* can wall thickness subject to *undesirable* effect of stress on can wall
➔ A=("#4, length of a stationary object")
➔ B=("#11, stress")

(2) Look up (#4,#11) in universal "contradictions table" (upper left corner shown below) to find applicable invention principles: {1, 14, 35}
- 1 → Segmentation
- 14 → Spheroidality
- 35 → Change physical or chemical properties

Worsening Feature

Improving Feature / Features	1	2	3	4	5	6	7	8	9	10	11	12
1: Weight of moving object	*	-	15 8 29 34	-	29 17 38 34	-	29 2 40 28	-	2 8 15 38	8 10 18 37	10 36 37 40	10 14 35 40
2: Weight of stationary	-	*	-	10 1 29 35	-	35 30 13 2	-	5 35 14 2	-	8 10 19 35	13 29 10 18	13 10 29 14
3: Length of moving object	8 15 29 34	-	*	-	15 17 4	-	7 17 4 35	-	13 4 8	17 10	1 8 35	1 8 40 29
4: Length of stationary object	-	35 28 40 29	-	*	-	17 7 10 40	-	35 8 2 14	-	28 1	1 14 35	3 14 15 7
5: Area of moving object	2 17 29 4	-	14 15 18 4	-	*	-	7 14 17 4	-	29 30 4 34	19 30 35 2	10 15 35 28	5 34 29 4
6: Area of stationary	-	30 2 14 18	-	26 7 9 39	-	*	-	-	-	1 18 35 36	10 15 35 37	-
7: Volume of moving object	2 26 29 40	-	1 7 4 35	-	1 7 4 17	-	*	-	29 4 38 34	15 35 36 37	6 35 36 37	1 15 29 4
8: Volume of stationary	-	35 10	19 14	35 8	-	-	-	*	-	2 18	24 35	7 2

Cell at (row 4, column 11) has 3 entries: invention principles {1, 14, 35}

- https://commons.wikimedia.org/wiki/File:Soft_Drink.svg
- https://commons.wikimedia.org/wiki/File:Titanium.svg

(3) For each invention principle, look up description for inspiration. For example:

Invention principle #1: *Segmentation Principle*
- Divide an object into independent parts.
  - Replace mainframe computer by personal computers.
  - Replace a large truck by a truck and trailer.
  - Use a work breakdown structure for a large project
- Make an object easy to disassemble.
  - Modular furniture
  - Quick disconnect joints in plumbing
- Increase the degree of fragmentation or segmentation.
  - Replace solid shades with Venetian blinds.

(4) Brainstorm on each of the 3 suggested invention principles to determine a solution.

#1 Segmentation Principle
- Make the can wall corrugated – increases material for the same burst strength.

#14 Spheroidality Principle
- Remove corners from the can, make it with rounded walls or make it a sphere – reduces material for the same burst strength.

#35 Change physical or chemical properties
- Make the can out of a stronger or lighter material. Changes amount of material needed, and weight, for the same burst strength.

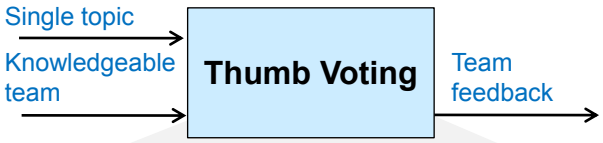
(5) Possible results

Thumb Voting

Problem
How to quickly assess team alignment?

Difficulty
Easy to use

- **Thumb voting** is a fast way to
  - Make a go/no go decision
  - Determine that an issue must be addressed
- Thumb voting can enable a team lead to quickly obtain consensus



1. A topic or path forward is presented.
2. Each team member uses a thumb to vote one of 3 ways:
   - Thumb up – **I agree**
   - Thumb down – **I disagree**
   - Thumb sideways – **I can "live with it"**
3. The team lead asses the thumbs. If the number of sideways thumbs is
   - **Small** – then use the decision from the up and down thumbs
   - **Large** – then more discussion of the topic is likely needed

3 possible votes using a thumb

Yes
I agree

No
I disagree

OK
Good enough

https://commons.wikimedia.org/wiki/File:Thumbs-up-icon.sv

Thumb Voting – Example – Team Meeting

Suppose you have a team meeting with 20 people.
You have proposed a plan and ask for thumb votes on **"Do we proceed?"**

If you obtain	15	2	3	➔ likely safe to proceed
If you obtain	12	3	5	➔ likely need to review plan with team
If you obtain	10	5	5	➔ certainly need to review plan

Here, there are many sideways thumbs, and the "yes" votes do not overwhelm the "no" votes. The team is not aligned.

Here, there are many more "yes" than "no" votes, and the number of "good enough" votes is modest.

https://commons.wikimedia.org/wiki/File:Thumbs-up-icon.sv

Times: cycle, lead, takt

Problem
How to determine if a process is fast enough?

Difficulty
Easy to use

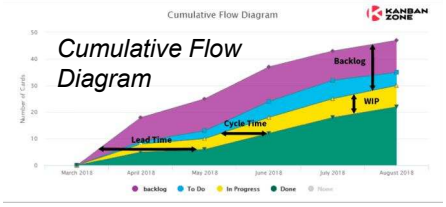
- **Cycle time:** the time taken from start to finish of a task, including loading or unloading of materials, etc.
- **Lead time:** the total time taken from order initiation until its completion, including any waiting times.
- **Takt time:** the rate at which a product needs to be created to meet customer needs.
- The cycle and lead time are determined by the process. Takt time is determined by the customer.

- Process
- Cycle times
- Customer need

→ **Knowing your process times (cycle, lead, takt)** →

- Lead time
- Takt time

1. Ensure process is under control (no large changes)
2. Obtain cycle times for each step, by measurement.
3. Determine times of non-value added activities.
4. Combine value-added times and non-value added times to obtain lead time.
5. Using customer demand, determine the takt time
   - (takt time) = (allowed time) / (number of units)
6. Compare takt time to the cycle times
   - If (takt time) < (all cycle times) then good
   - If (takt time) > (any cycle time) then cannot meet customer rate, need to improve process

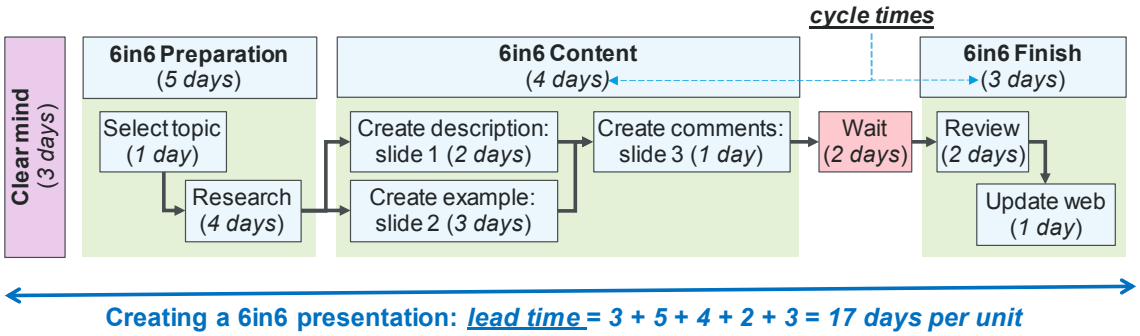


https://kanbanzone.com/2019/power-of-cumulative-flow-diagram/

Times – Example – Creating 6in6 presentations

PROCESS BASED VALUES (cycle times and lead time)

- Creating a 6in6 presentation has three value stream steps: Preparation, Content, Finish.
- Each step and each sub-step have cycle times.
- For the process below, the cycles times are listed in each box.
- The calculated **lead time** is **(17 days)/unit.**



CUSTOMER BASED VALUE (takt time)

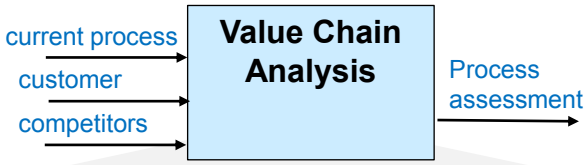
- Suppose a customer requests 26 new 6in6 presentations per year.
- The work year has 260 days = (52 weeks) * (5 work days per week)
- The **takt time** is:
  (takt time) = (1 year)/(26 units) = (260 days)/(26 units) = **(10 days)/unit**
- Since **(each cycle time) < (takt time)**, the process achieves the customer output rate.

Value Chain Analysis (VCA)

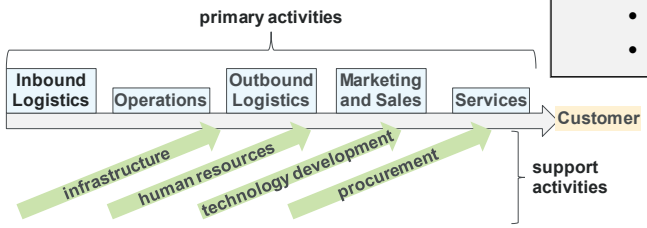
Problem
How to identify customer care abouts?

Difficulty
Work with an SME

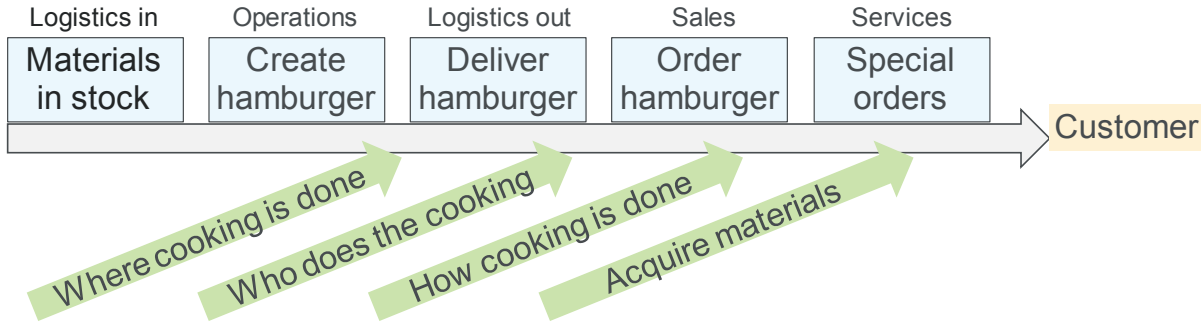
- A **Value Chain Analysis** (**VCA**) shows the business activities and processes involved in creating a product or performing a service.
- A value chain has **primary activities** and **support activities**:
  - **Primary activities** – activities which directly add value to the customer
  - **Support activities** – activities that support primary activities
- A value chain analysis can lead to
  - reduced cost
  - products better aligned with your customer



1. Assess your product's activities, such as:
   - **Primary activities**: Inbound Logistics, Operations, Outbound Logistics, Marketing and Sales, and Services.
   - **Support activities**: Infrastructure, Human Resources, Procurement, and Technology.
2. Analyze the value and cost of these activities.
3. Model your competitors' value chains.
4. Model your customer's assessment of value.
5. For your activities, determine where you
   - can reduce costs or improve efficiency
   - can create a competitive advantage



Value Chain Analysis – Example – Buying a hamburger at a fast food restaurant



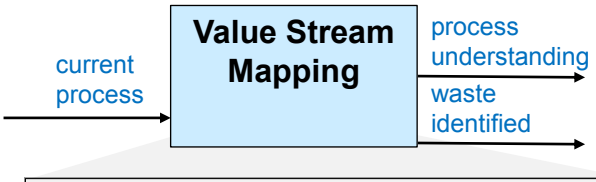
1. The customer understands, and values, the primary activities.
2. The value chain identifies potential opportunities. A customer may pay a premium for
   - better materials (e.g., fresh ingredients)
   - better production (e.g., faster product delivery)
   - better delivery (e.g., on-site or home delivery)
   - an easier ordering process (e.g., phone app)
   - the ability to have special orders.
3. The customer (likely) does not care about where, how, or by whom the cooking is done, nor how the needed materials are acquired.
4. From the Value Chain, we can identify:
   1. improvements (make these)
   2. costly processes (reduce these)

Value Stream Mapping (VSM)

Problem
How to add value for your customers?

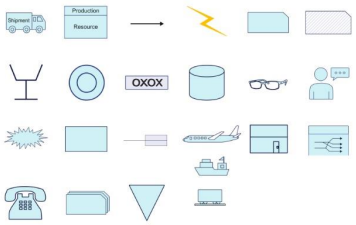
Difficulty
Work with an SME

- A **Value Stream Map** (**VSM**) graphically shows, for a single product or service, the material flows and the information flows that signal and control the material flows.
- A VSM uses standard icons to represent processes, materials, and information.
- The VSM shows how customer value is added at each step.
- Typically both a **Current State Map** (the current process) and a **Future State Map** (what the process could be) are created.



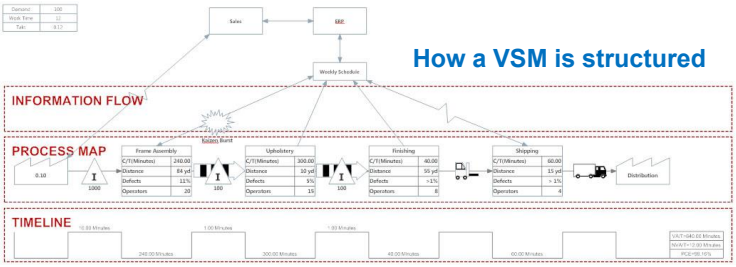
1. Assess your product's or service's steps. For each step, determine:
   - The work and wait **times**
   - The **labor needs** (including overtime)
   - The **error rates**
   - The system **downtime**
   - The **inventory level** (excess or shortfall)
   - The production or process **delays**
2. Create a graphic using standard icons.
3. Assess the current state VSM to identify waste.

Some standard VSM icons



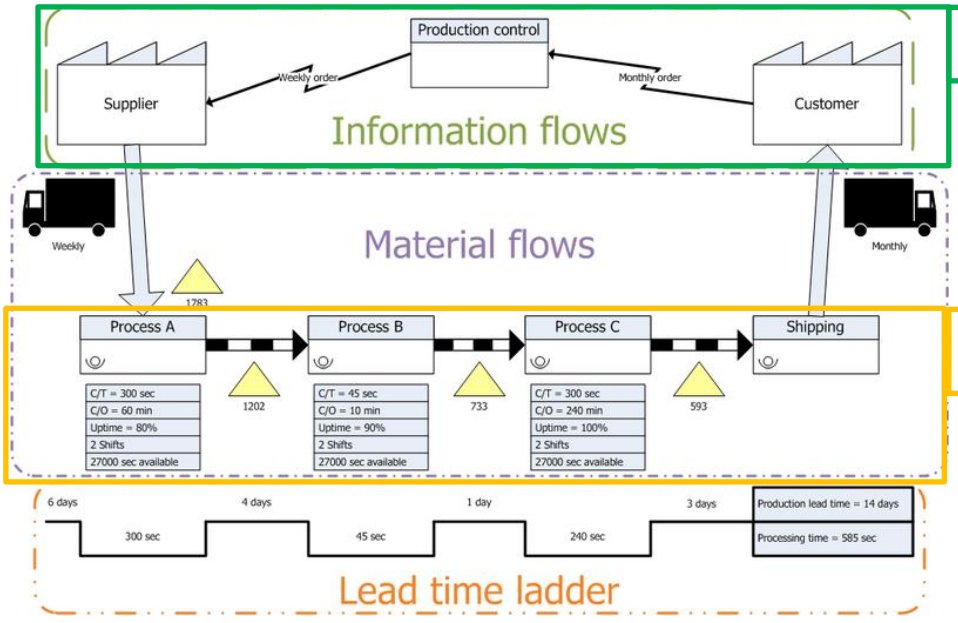
https://www.edrawmax.com/article/value-stream-mapping-symbols.html

How a VSM is structured



https://www.smartdraw.com/value-stream-map/

Value Stream Mapping – Example – Generic Factory



This shows how the **orders flow.**

This shows **deliveries** to and from the factory.

This shows **information about the processes.**

This shows the **timeline** – how long each processing step takes and how long the product waits for the next processing step.

https://en.wikipedia.org/wiki/File:ValueStreamMapParts.png

Voice of the Customer (VOC)

Problem
How to delight a customer?

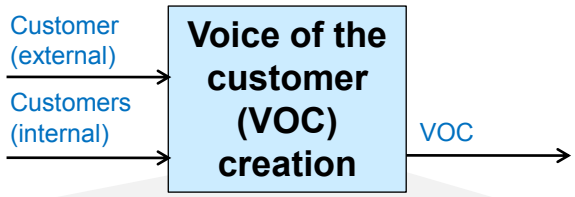
Difficulty
Some training required

The **Voice of the Customer (VOC)** represents the **customer's thinking:**

- Wants
- Don't wants
- Functions
- Features

VOC flows through the value stream:

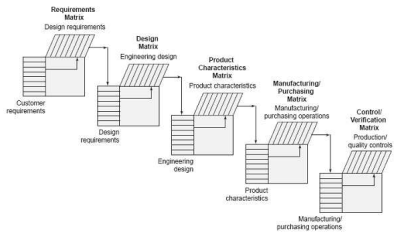
1. Customer to (e.g., NASA)
2. customer to (e.g., Bus Develop)
3. customer to (e.g., Systems Eng)
4. customer to (e.g., Hardware)
5. customer to (e.g., DFMA team)
6. …



1. Identify the **product** and its external customers.
2. Identify the **customers** along the value stream.
3. For each customer – find **product attributes**
   - A great product is one that results in __?
   - A great product is one that is _____?
   - A great product is one that has_____?
   - Problems in similar products_____?
4. Determine improvement **priorities.**

Traceability of VOC – perhaps via QFDs – ensures VOC alignment

Figure 2 — Waterfall relationship of QFD matrices



https://asq.org/quality-resources/qfd-quality-function-deployment

VOC is part of a product's "chorus"

- VOB – Voice Of the *Business*
- VOC – Voice Of the *Customer*
- VOCO – Voice Of the *COmpetitor*
- VOTE – Voice Of the *Environment*

VOC – Example – Assessments and Car Seat Belts

Customer dimensions include satisfaction and functionality. VOC determines a customer's level of each.

Satisfaction scale

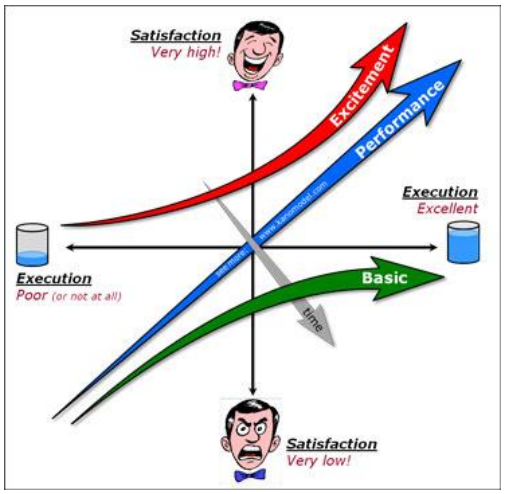
1. Delighted
2. Satisfied
3. Neutral
4. Dissatisfied
5. Frustrated

Functionality scale

None Some Basic Good Best

1. 2. 3. 4. 5.

The **Kano model** – showing functionality versus satisfaction – shows that, over time, "delighters" become "must haves".



https://kanomodel.com/

Three ways a customer responds to an offering:

- **Excitement** – the WOW factor in a product/application
- **Performance** – the more of it, the better
- **Basic** – each of these is must have

Example: car seat belts

- 1950's – car seat belts are **exciting** – wow!
- 1960's – car seat belts indicate **performance** – one of many high end features
- 1970's – car seat belts are a **must have** – can't buy a car without them