

5 Whys (Root Cause Analysis)

Problem

How to find a problem's root cause?

Difficulty

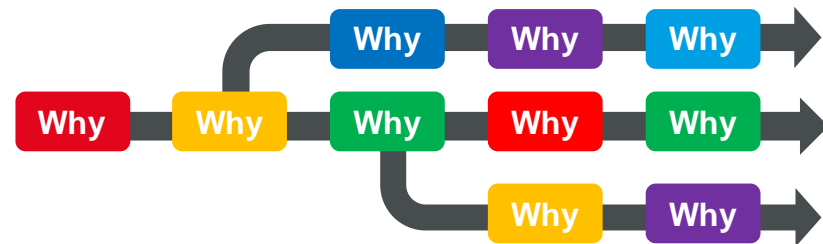
Easy to use

- 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

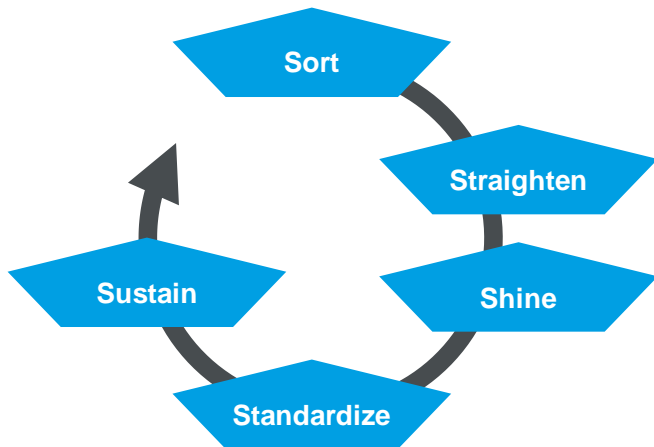
Easy to use

- **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.



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
<i>Seiri</i>	Sort	Organize
<i>Seiton</i>	Straighten	Order
<i>Seiso</i>	Shine	Clean
<i>Seiketsu</i>	Standardize	Standards
<i>Shitsuke</i>	Sustain	Discipline

5S - Examples

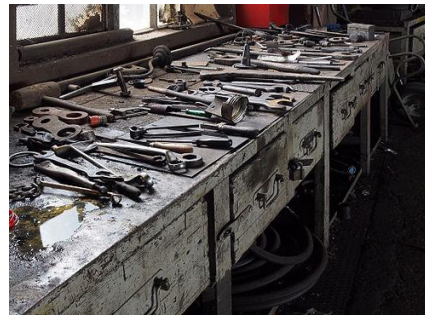
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- [https://commons.wikimedia.org/wiki/File:Part_of_my_messy_desk_\(430672681\).jpg](https://commons.wikimedia.org/wiki/File:Part_of_my_messy_desk_(430672681).jpg)
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- https://commons.wikimedia.org/wiki/File:5S_Tools_drawer.jpg
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- <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

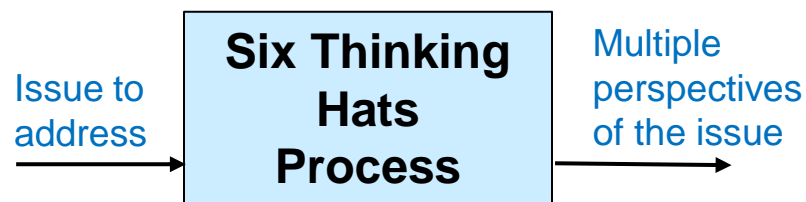
Problem

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.



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.

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

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**.

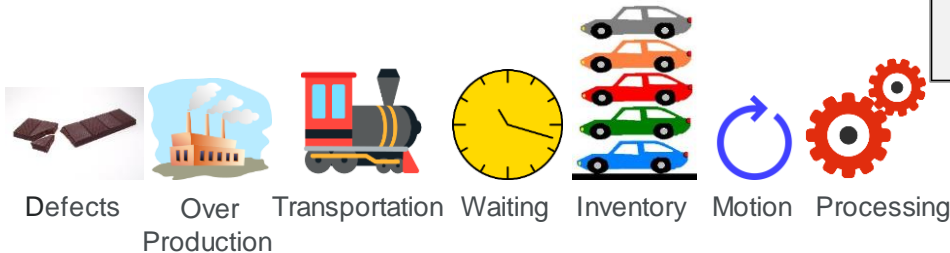
There are **7 classic types of waste**.

(Non-utilized talent is a new 8th waste.)



1. **Defects** – Products (or services) that must be corrected
2. **Over Production** – Producing too much of a product.
3. **Transportation** – Moving items not required for process
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. **Defects** (Rejects, Repair, Rework)
 2. **Over Production**
 3. **Transportation**
 4. **Waiting**
 5. **Inventory**
 6. **Motion**
 7. **Processing** (Excess or Unnecessary)
2. Once waste is identified, try to remove it



FIGURES

- https://commons.wikimedia.org/wiki/File:Cooking_chocolate,_broken_bar.jpg
- https://commons.wikimedia.org/wiki/File:Factory_1b.svg
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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. Poorly designed work stations resulting in more bending and reaching. Re-entering data.
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**”

- | | |
|---|--|
| <ul style="list-style-type: none"> • D = Defects • O = Overproduction • W = Waiting • N = Non-Utilized Talent | <ul style="list-style-type: none"> • T = Transportation • I = Excess Inventory • M = Motion • E = Extra Processing |
|---|--|

The Eight Disciplines of Problem Solving (8D)

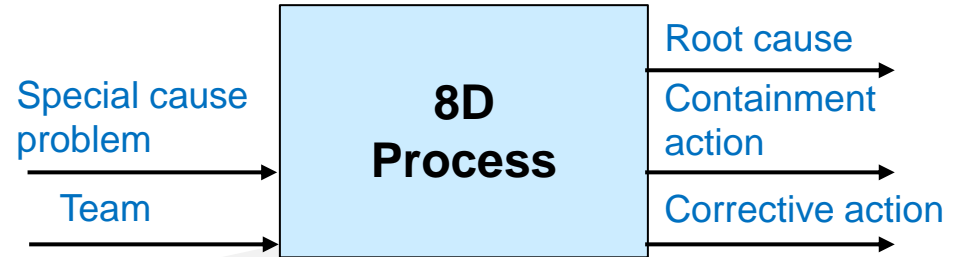
Problem

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.



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.

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

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

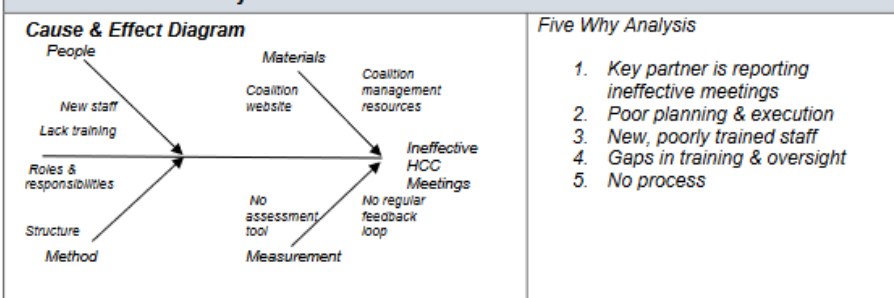
2D – Problem Description

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 programming 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



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

9 windows

Problem

How to improve a product or process?

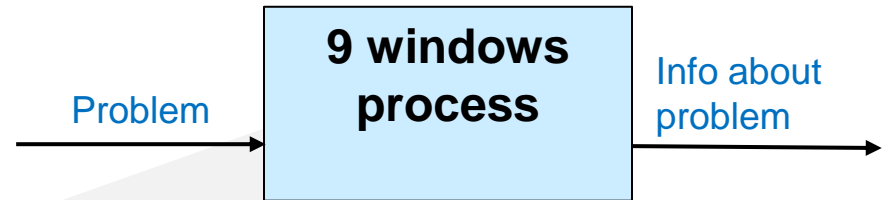
Difficulty

Work with an SME

- 9 Windows** considers innovation via 9 “windows” of time and space:
 - “**Time**” = when the problem could have been solved: **past, present, or future.**
 - “**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
- A 9 windows grid is below.

		Time		
		Past	Present	Future
Space	Super-system			
	System		<i>problem</i>	
	Sub-system			

9 windows grid



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

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	<i>Covid limits face-to-face (F2F) activities for school children</i>	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 activities ("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

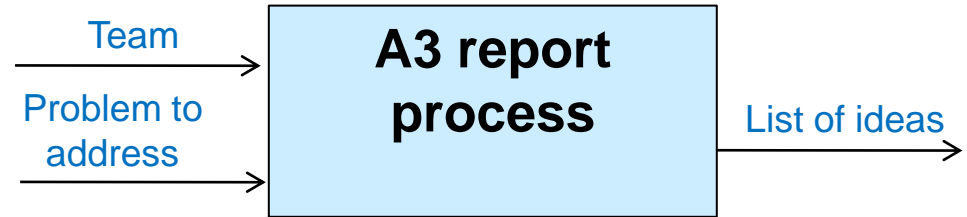
Problem

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

Prepared By: Jess Fixit Invoice Creation Lead Time Improvement - A3 Report January 28, 2018

Background

The time between product delivery and invoicing our customers averages 14.05 days. Our customers pay their invoices on time (<30days) 99.95% of the time. On average, \$22.3 million in invoices in process.

Current Situation

Lead time = 14.05 days
Cycle Time = 6.55 days
Queue time = 7.5 days

Analysis

Goal

Lead time = 1.7 days
Cycle Time = 1.05 days
Queue time = 0.65 days

Recommendations

- Eliminate external approval, invoice preparation
- Eliminate logging delivery acknowledgement
- Generate invoices on user authority
- Use electronic delivery acknowledgement which returns our original information, thereby eliminating the need for re-entry of information and minimizing the need for P.O. matching and reconciliation
- Use electronic (EDI) transmittal of invoice to eliminate FAX problems

Implementation Plan

#	Description	1	2	3	Lead	Target
1	Process design				MK	100%
2	Simulation				DH	100%
3	Capital approval				GF	100%
4	Customer input				GF	100%
5	Set up EDI				MK	80%
6	Pilot Runs				TJ	50%
7	Launch					

Follow Up

- Include section in next 6 customer surveys to ensure
- Review back-up procedures with IS to ensure

Results Report

Title: Reduce lunch cycle time for salads and sandwiches preparation

Owner/Date: Bahama Bistro Manager: Elisabeth

Background: Bahama Bistro is a restaurant located in the Bahamas. Bahama Bistro lunch patrons are locals and vacationers.

Current State: Bahama Bistro is struggling with cycle times for their lunch orders & patrons have complained about the wait time to receive their food.

Goal and Targets: Improve the cycle time of salads and sandwiches.

Analysis: [Diagram]

Proposed Countermeasures: Reorganize the sandwich workstation to eliminate waste.

Implementation Plan:

Timeline	Planned	Actual
Mar 15th	Dewling work call	
Mar 22nd	Train employees	
Mar 22nd	Launch new process	

Follow-Up:

Timeline	Planned	Actual
April 5th	Follow up with chefs for free-tuning	
April 22nd	30-day follow-up	

Daily DMAIC A3 Control Sheet

1. What are the current conditions? (What is the problem?)

2. What are the goals? (What do you want to achieve?)

3. What are the causes? (What is the root cause?)

4. What are the countermeasures? (What actions will you take?)

5. How will you know you are successful? (What are the metrics?)

6. How will you sustain the gains? (What are the follow-up actions?)

7. How will you celebrate? (What are the rewards?)

8. How will you share? (What are the communication actions?)

9. How will you improve? (What are the learning actions?)

10. How will you review? (What are the review actions?)

11. How will you close? (What are the closure actions?)

12. How will you follow up? (What are the follow-up actions?)

Invoice Creation Lead Time Improvement - A3 Report

1. What are the current conditions? (What is the problem?)

2. What are the goals? (What do you want to achieve?)

3. What are the causes? (What is the root cause?)

4. What are the countermeasures? (What actions will you take?)

5. How will you know you are successful? (What are the metrics?)

6. How will you sustain the gains? (What are the follow-up actions?)

7. How will you celebrate? (What are the rewards?)

8. How will you share? (What are the communication actions?)

9. How will you improve? (What are the learning actions?)

10. How will you review? (What are the review actions?)

11. How will you close? (What are the closure actions?)

12. How will you follow up? (What are the follow-up actions?)

The New (or Problematic) Background:

During the course of audit, it has become apparent that the procedure for processing accounts for lease fees needs to be reviewed. In some cases the service does receive notification for late fee (bank processing) and it takes a long time before the accounts have access to systems without proper approvals.

Current Conditions:

The lease system still has an extra electronic security requirement that is used primarily in Visa.

Process Owners:

Process Owner	Process Reporter	Process Controller	Keenest Participant
Larry Hermann	Daria Valdez	Darryl Woodson	Jerry Wright
	Bertha Martinez	Steve Hernandez	Chris Miller
	Tali Chahar	Tom Boris	
	Pablo Perez	Tamara Rose	

Process Owners: [List]

Process Reporters: [List]

Process Controllers: [List]

Keenest Participants: [List]

VI. Action Plans:

- Reduce Lease Time by 50%
- Reduce process steps/touches by 50%
- Reduce Document Touches by 50%
- Eliminate or Improve Banked Touch and EDI
- Reduce audit deficiencies by a minimum of 75%

VI. Analysis:

Too many disconnects - Red fix it

VI. Follow-Up:

Team to follow up monthly for 6 months to confirm audit. Larry Hermann and Chris Miller to receive follow-up meetings with stakeholders.

Figure credits

- https://www.moresteam.com/lean/a3-report.cfm
- 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)

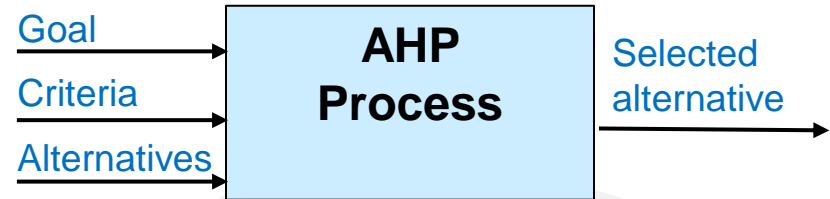
Problem

How to choose among multiple alternatives?

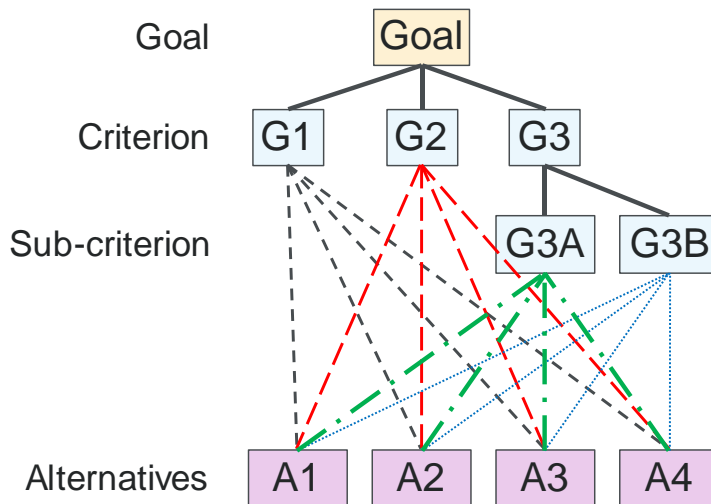
Difficulty

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 priorities amongst the criteria, sub-criteria, and alternatives (for each criteria) using pairwise comparison.
5. Use SW to convert pairwise comparisons into priorities and confirm consistency.
6. Use SW to combine priorities and obtain overall priorities for the alternatives.
7. Use SW to perform a sensitivity analysis.



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

AHP – Example – Choose a Leader (from Wikipedia)

From https://en.wikipedia.org/wiki/Analytic_hierarchy_process_%E2%80%93_leader_example

- Want to choose a leader
- Have 4 criteria: experience, education, charisma, age

(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)

Team pairwise results – inputs to SW

Criteria	Experience	Education	Charisma	Age	Priority
Experience	1	4	3	7	0.547
Education	1/4	1	1/3	3	0.127
Charisma	1/3	3	1	5	0.270
Age	1/7	1/3	1/5	1	0.056
	Sum of Priorities 1.000				
	Inconsistency 0.044				

Priorities found by SW

Always sums to one

Small, good!

(2) The stakeholders compare the alternatives, pairwise, for each criteria.

Experience

	Tom	Dick	Harry	Priority
Tom	1	1/4	4	0.217
Dick	4	1	9	0.717
Harry	1/4	1/9	1	0.066
	Sum of Priorities 1.000			
	Inconsistency 0.035			

Education

	Tom	Dick	Harry	Priority
Tom	1	3	1/5	0.188
Dick	1/3	1	1/7	0.081
Harry	5	7	1	0.731
	Sum of Priorities 1.000			
	Inconsistency 0.062			

Charisma

	Tom	Dick	Harry	Priority
Tom	1	5	9	0.743
Dick	1/5	1	4	0.194
Harry	1/9	1/4	1	0.063
	Sum of Priorities 1.000			
	Inconsistency 0.069			

Age

	Tom	Dick	Harry	Priority
Tom	1	1/3	5	0.265
Dick	3	1	9	0.672
Harry	1/5	1/9	1	0.063
	Sum of Priorities 1.000			
	Inconsistency 0.028			

Team pairwise results – inputs to SW

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

Candidate	Priority with Respect to				Goal
	Experience	Education	Charisma	Age	
Tom	0.119	0.024	0.201	0.015	0.358
Dick	0.392	0.010	0.052	0.038	0.492
Harry	0.036	0.093	0.017	0.004	0.149
Totals:	0.547	0.127	0.270	0.056	1.000

sum of each row's values

largest value

Dick is the best choice

$0.119 = 0.547 * 0.217$ (see outlined red boxes, in steps (1) and (2))
 $0.392 = 0.547 * 0.717$

Balanced Scorecard (BSC)

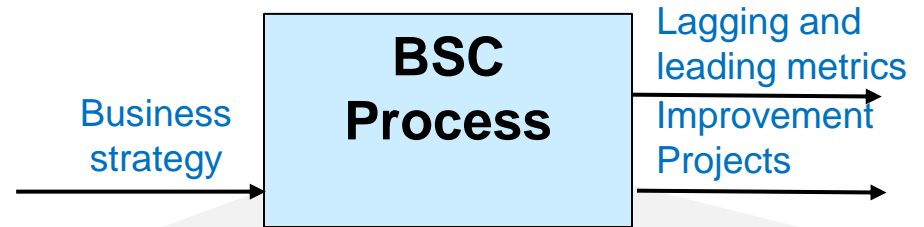
Problem

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 **Four Perspectives** (in priority order): 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.

STRATEGY MAP	OBJECTIVES	BALANCED SCORECARD		ACTIONS	
		MEASUREMENT	TARGET	INITIATIVE	BUDGET
FINANCIAL PERSPECTIVE					
Overall Objectives	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
OBJECTIVE	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
CUSTOMER PERSPECTIVE					
Overall Objectives	Objective	Measurement	Target	Initiative	
Objective	Objective	Measurement	Target	Initiative	
Objective	Objective	Measurement	Target	Initiative	
Objective	Objective	Measurement	Target	Initiative	
Objective	Objective	Measurement	Target	Initiative	
INTERNAL PROCESSES PERSPECTIVE					
Overall Objectives	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
Objective	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
Objective	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
Objective	OBJECTIVE	MEASUREMENT	TARGET	INITIATIVE	
LEARNING & GROWTH PERSPECTIVE					
Overall Objectives	Objective	Measurement	Target	Initiative	
Objective	Objective	Measurement	Target	Initiative	

<https://www.smartsheet.com/balanced-scorecard-examples-and-templates>

BSC – Example - Generic

These are trailing metrics

How to achieve objectives

Mission/vision: Provide our clients ...
Strategic themes: Product leadership, Increase Customer Value, Operational excellence, ...

Four perspectives

	Objectives	Measures	Targets	Initiatives
Financial		<ul style="list-style-type: none"> • Net profit increase • Operating costs 	7% -6%	<ul style="list-style-type: none"> • Standardize production
Customer		<ul style="list-style-type: none"> • Customer retention, % • Customer acquisition, % • Time to market, days 	90% 10% 60 days	<ul style="list-style-type: none"> • Mystery shopper program
Internal		<ul style="list-style-type: none"> • Inventory levels • Unplanned downtime 	120% 5%	<ul style="list-style-type: none"> • ISO 9001 • Optimize cycle time
Learning		<ul style="list-style-type: none"> • Employee survey • IT efficiency index 	95% 91%	<ul style="list-style-type: none"> • Skills program • Training program



BSC DESIGNER | HOW TO AUTOMATE WITH A SOFTWARE BALANCED SCORECARD CREATED BY CONSULTANTS

Perspective objectives are connected and flow up

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

Benchmarking

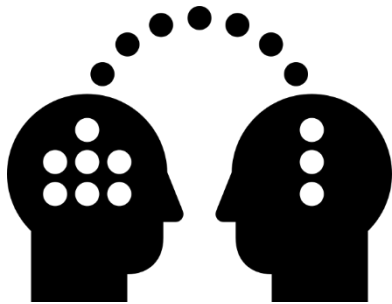
Problem

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 Indicator)	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



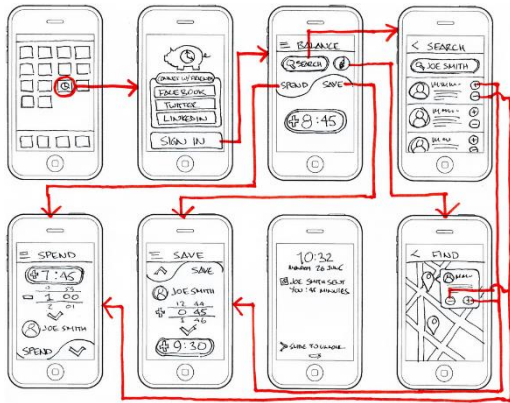
Hands on
Brainstorming

<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

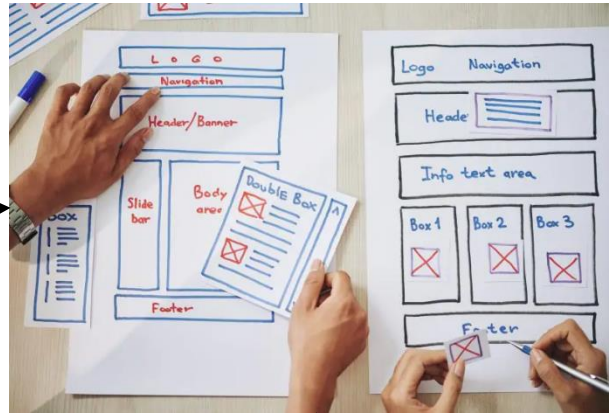
Body Storming – Example – User Interfaces

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://www.behance.net/gallery/43064215/Power-Paper-Prototyping>

Brainstorming

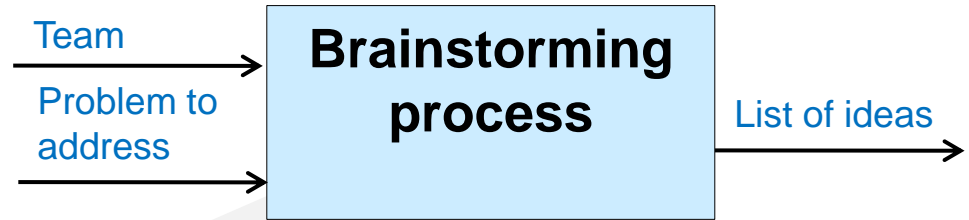
Problem

How to identify ideas to solve a problem?

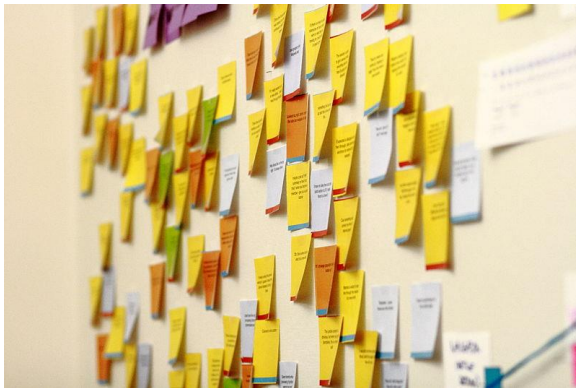
Difficulty

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.



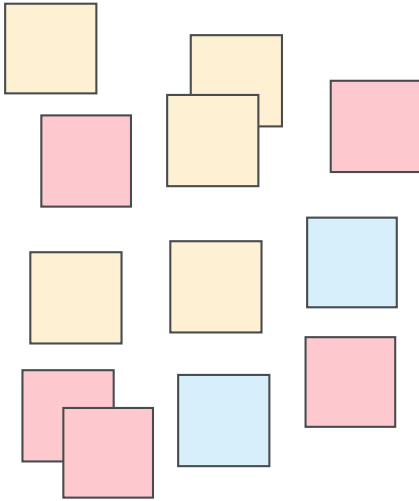
1. Define the problem or issue to be addressed. It may be a “why,” “how,” or “what” issue.
2. Perform the brainstorming – multiple options:
 - A. People write their ideas on sticky notes.
 - B. For *unstructured brainstorming*, have people call out ideas, and the leader writes them on sticky notes.
 - 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)



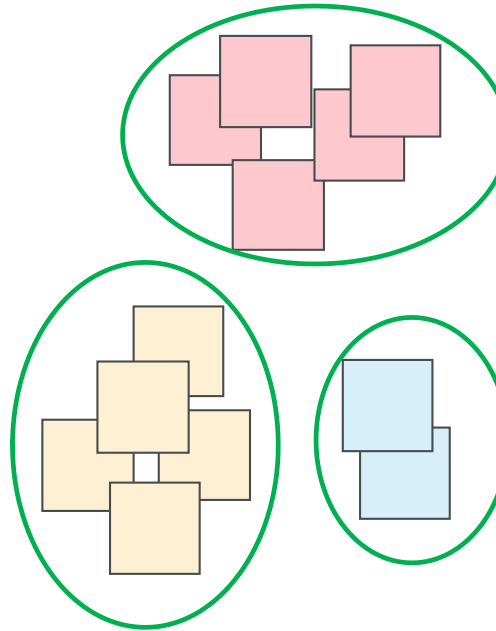
https://commons.wikimedia.org/wiki/File:Sticky_notes_on_the_wall_of_the_Wikimedia_Foundation_office,_2010-10-26.jpg

Brainstorming – Example – Generic

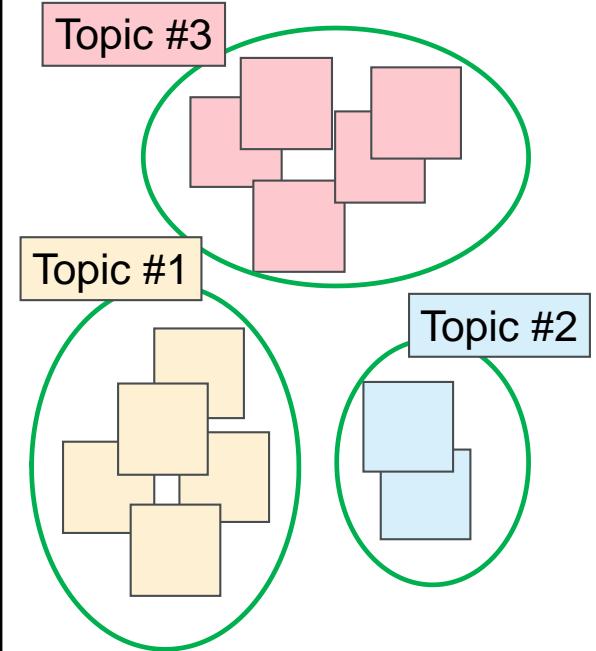
Collect the ideas



Group the ideas



Label the groups (and prioritize)



- 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.

- 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.

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

Check Sheet – Several Examples

Obtaining the distribution of an item

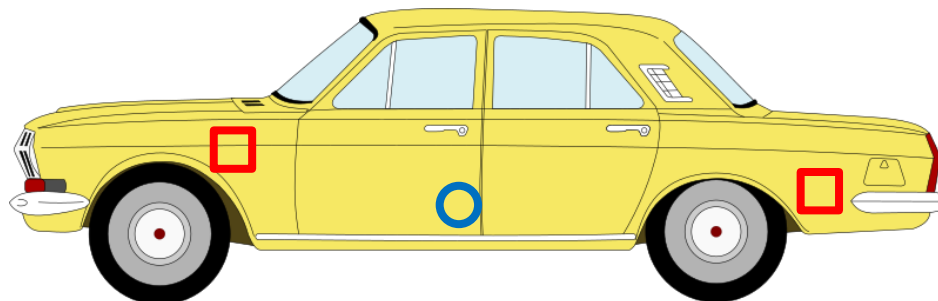
Date	6/1/2023	
Product	widget #1	
Inspector	Bob	
Batch	A23	
Specified weight (grams)	Measured difference	Observations
139	< -5	x x x x x x
	(-3, -5]	x x x x x x x x x
	[-0.1, -3]	x x x x x x x x x x x
	0	x x x x x x x x x x x x
	[0.1, 3]	x x x x x x
	(3, 5]	x x x x
	> 5	x x x

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					
		Betty					
	B	Carol					
		Dan					
2	A	Eric					
		Frank					
	B	George					
		Harry					

Defect location

Date	6/1/2023	
Inspector	Charles	
Vehicle	stock #8347	
Icon	Defect type	Count
□	dent	
○	scratched paint	



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 manpower effort and duration.

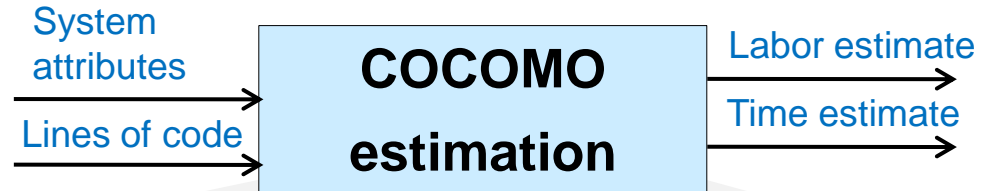
- Since programming paradigms evolve, COCOMO may be less useful than it was in the past.

Basic COCOMO equations

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

where

Software project type	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>
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



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

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)
 - 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

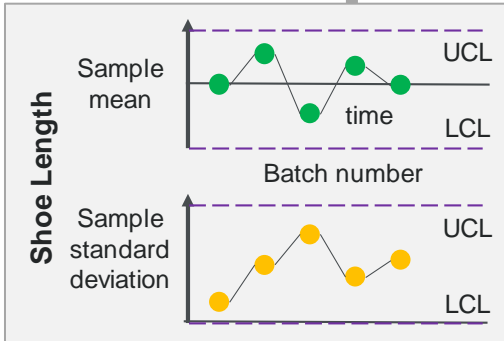
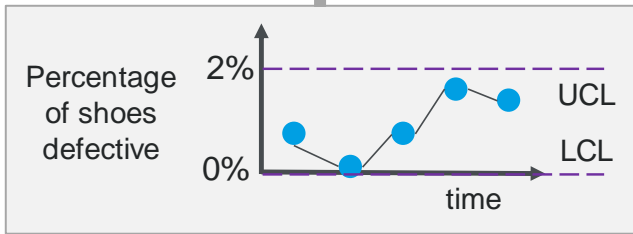
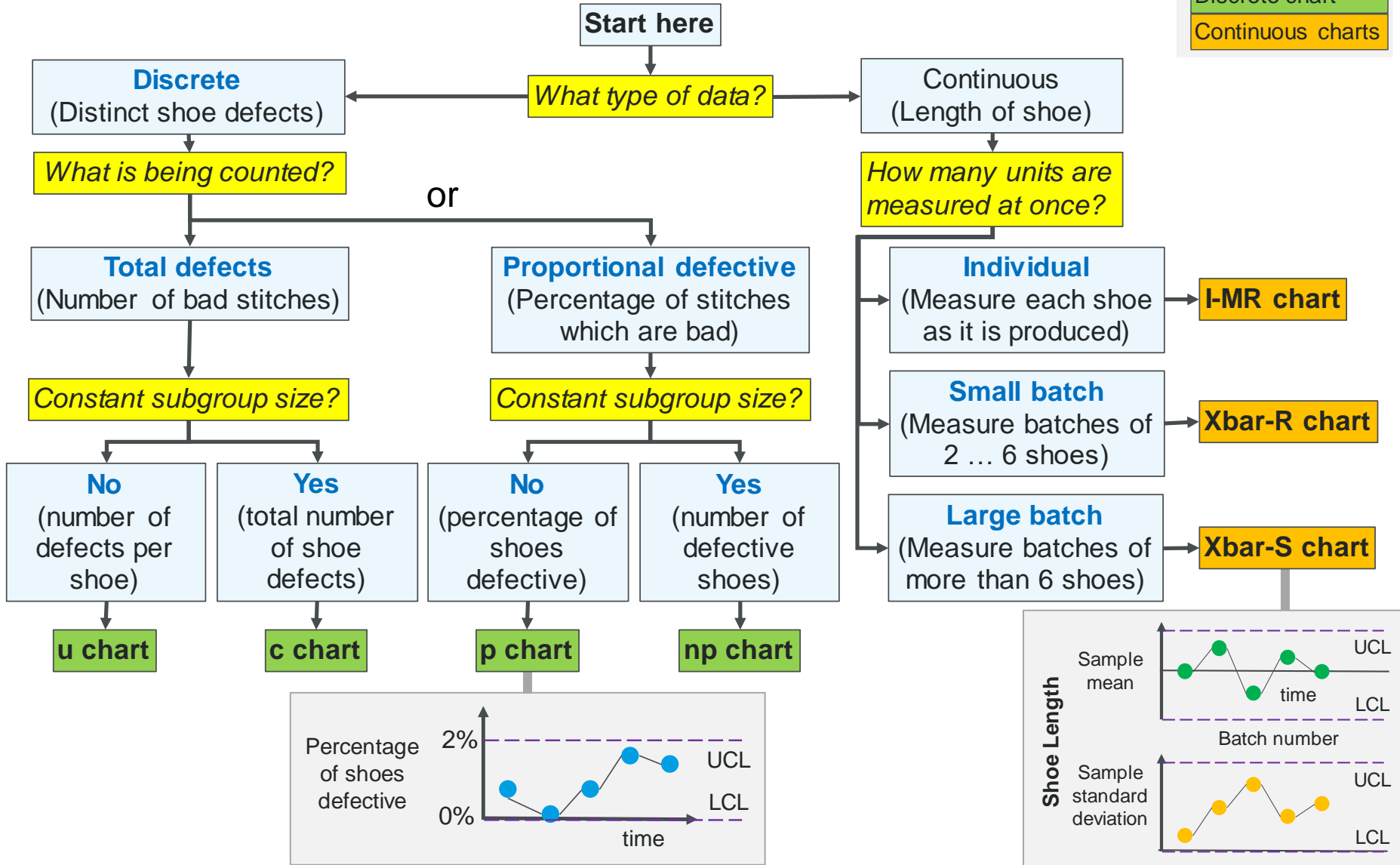
Control Chart – Example – Shoe Production

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

Legend

Discrete chart

Continuous charts



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)

CAIV requires

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

- Capability needed
- Options to meet need
- Cost models

CAIV process

- “Best” option

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

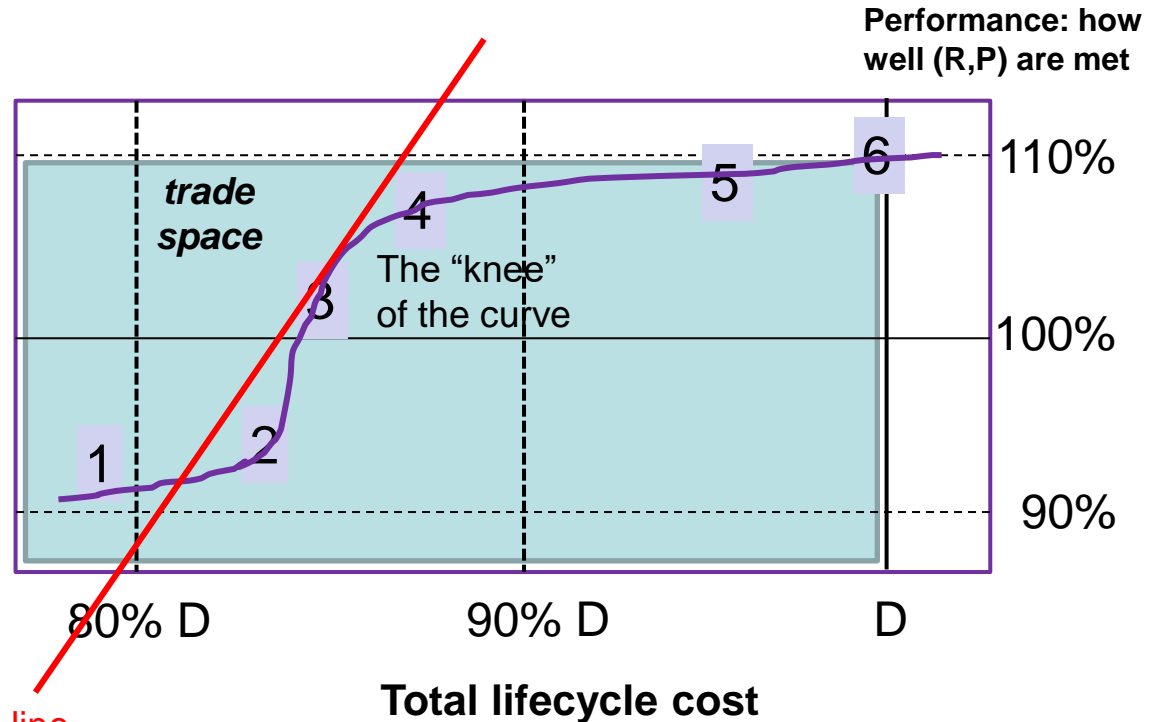
1. 15 year old car – high mileage
2. 15 year old car – low mileage
3. 5 year old car
4. 3 year old car
5. new car
6. new car – luxury brand

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



High slope line –
indicates a break point

Cost Benefit Analysis (CBA)

Problem

How to financially evaluate a plan?

Difficulty

Some training required

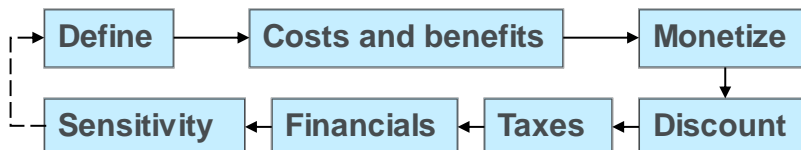
- A **Cost Benefit Analysis (CBA)** financially evaluates a plan.
- CBA compares costs and benefits
 - direct & indirect, tangible & intangible, opportunity costs, competitive benefitsto determine financial metrics
 - net present value (NPV), internal rate of return, payback period, ownership cost
- 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

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
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
Discounted benefits at 5%		10,500	10,000	9,524

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

\$28,180

\$28K is sum of values

Investment benefit

\$10.5K is sum of values

\$30,024

\$1,844

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

Overall project benefit

1.07

Benefit cost ratio

1.07 = \$30K/\$28K

Cash flow: inflow - outflow

Year #1	Year #2	Year #3
\$(7,000)	\$5,000	\$4,500

cumulative cash flow

Year #1	Year #2	Year #3
\$(7,000)	\$(2,000)	\$2,500

2.5K = 4.5K + (-2.0K)

Payback period (years)

2.44

2.44 = 2 - (-2000)/4500

Internal Rate of return (IRR)

23%

Jan-22	Jan-23	Jan-24
--------	--------	--------

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)

Critical Chain Program Management (CCPM)

Problem

How to shorten a project schedule?

Difficulty

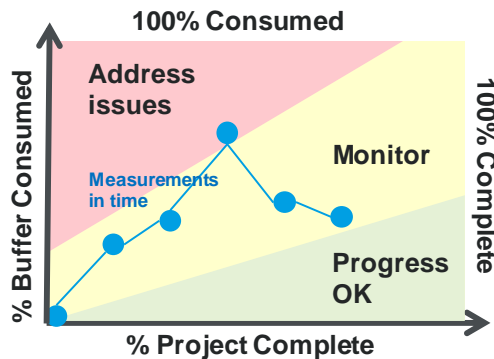
Work with an SME

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.



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



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.

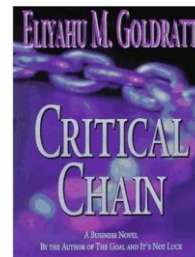
2. Identify constraints & plan Corrective Actions

3. Change the culture

- Critical Chain tasks get highest priority
- Minimize multi-tasking

4. Proactively manage the system

- Manage variation via the buffer



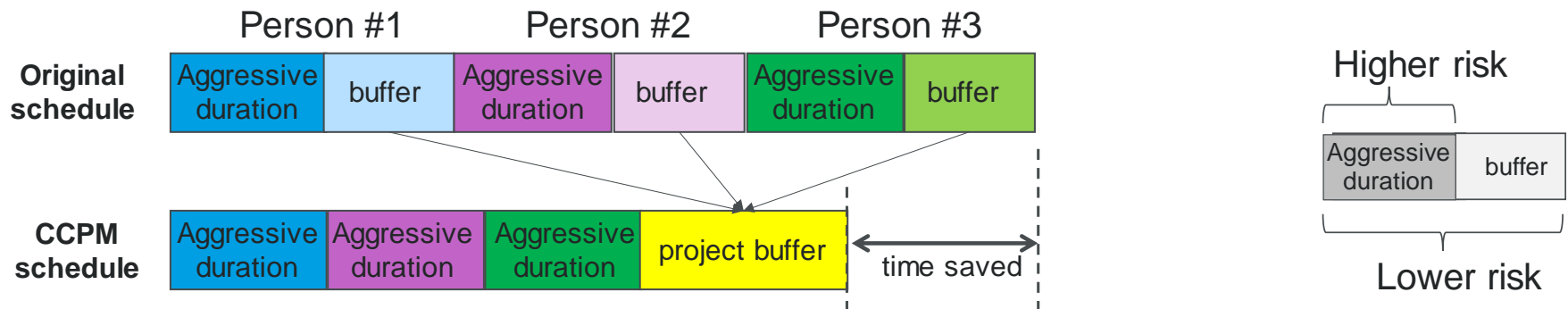
CCPM was defined in the book *Critical Chain* by Eliyahu M. Goldratt

<https://en.wikipedia.org/wiki/File:CriticalChain.jpg>

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

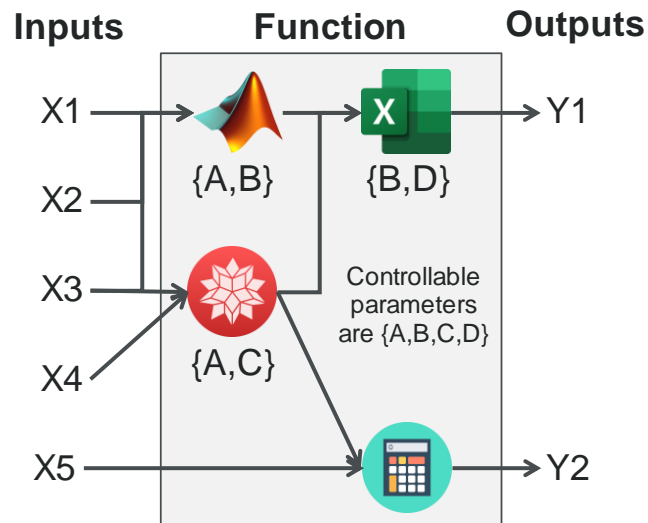
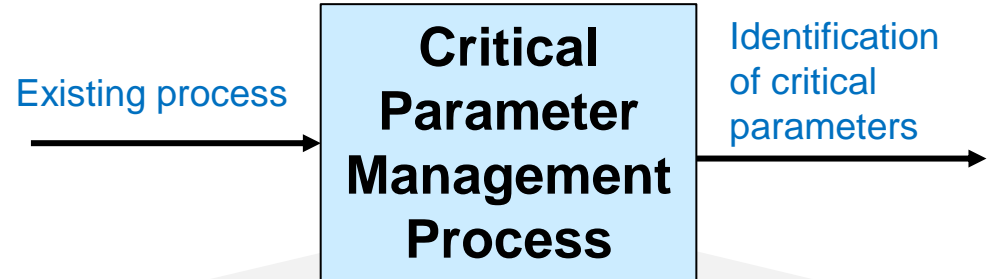
How to identify and manage critical to quality parameters?

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



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).

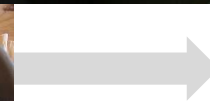
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[https://commons.wikimedia.org/wiki/File:Microsoft_Office_Excel_\(2019%E2%80%93present\).svg](https://commons.wikimedia.org/wiki/File:Microsoft_Office_Excel_(2019%E2%80%93present).svg)
https://commons.wikimedia.org/wiki/File:Matlab_Logo.png

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.

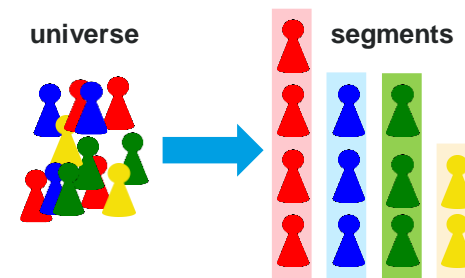
- Customer (or leads) data
- Market data & segmentation

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:

<ul style="list-style-type: none"> • Cost sensitive • Any day/time works 	<ul style="list-style-type: none"> • Want focus in specific areas • Work regular hours 	<ul style="list-style-type: none"> • 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

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

share price

1.83



share price

-0.52



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?

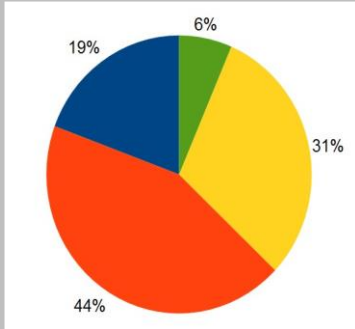
4. Implementation

1. How will the metric values be updated?

2. How often will the metric values be updated?

5. Review and update as needed

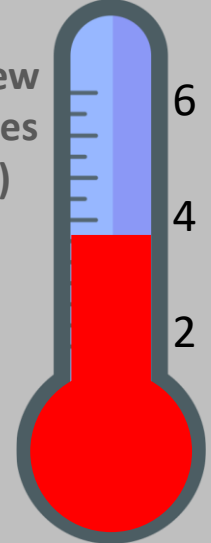
Dashboard – Example – 6in6 web site



Weekly 6in6 viewers

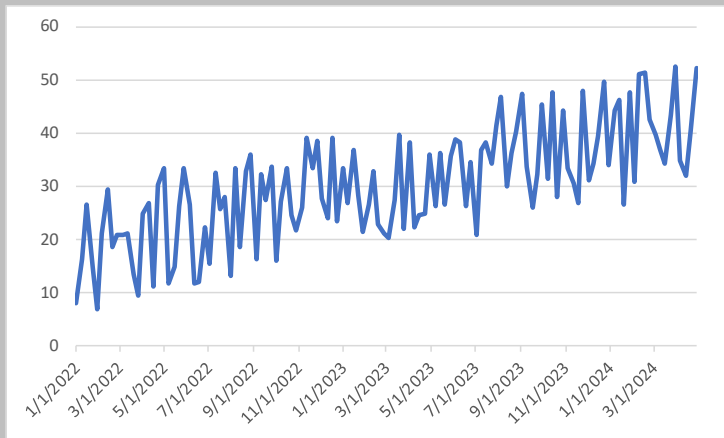
- Asia
- Europe
- North America
- Other

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)

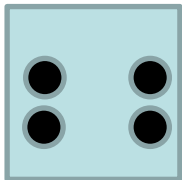
is concerned with **reducing product assembly cost**

Design for Manufacturing (DFM)

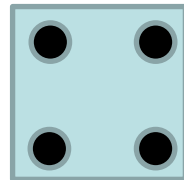
is concerned with **reducing overall part production cost**

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.



Asymmetric part requires alignment



Symmetric part makes assembly easier

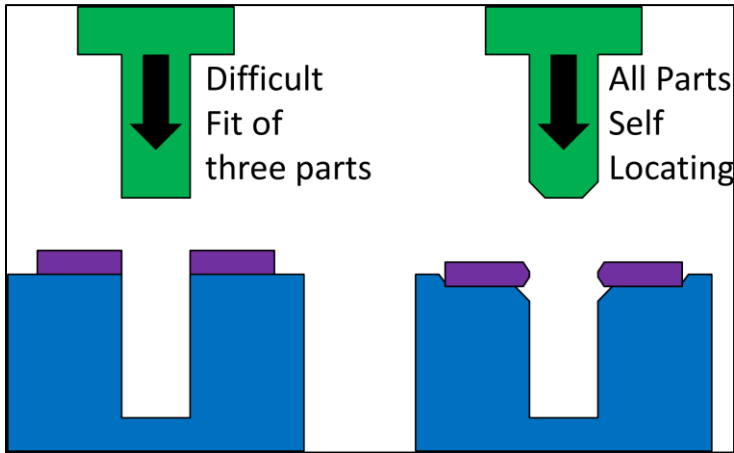


Methodically apply the DFMA principles

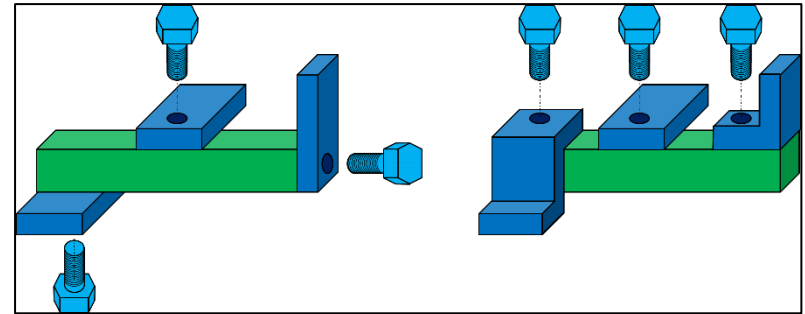
1. Minimize the number of parts
2. Minimize the use of fasteners
3. Standardize
4. Avoid difficult components
5. Use modular subassemblies
6. Use multifunctional parts
7. Minimize reorientations
8. Use self-locating features
9. Avoid special tooling
10. Provide accessibility
11. Minimize operations &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

DFMA – Examples – Manufacturing

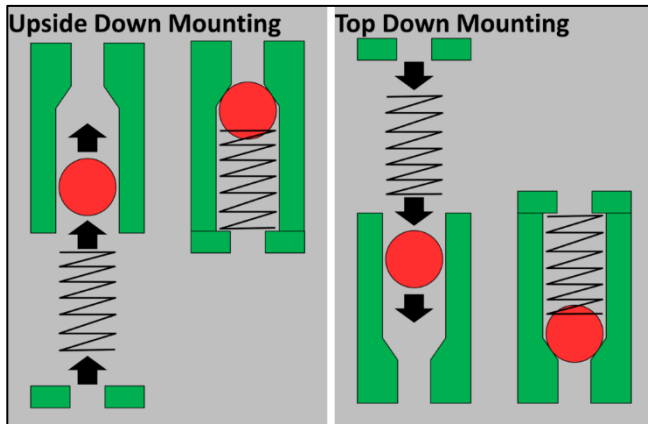
Make parts self-aligning



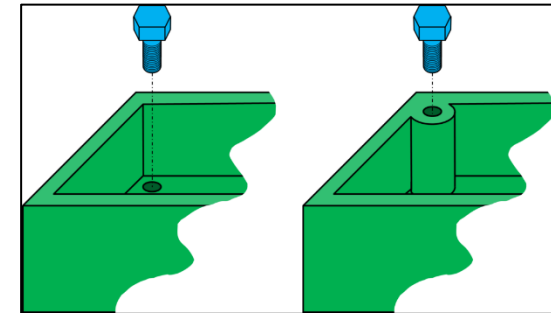
Make assembly from one side



Use gravity when possible



Improve access for assembly



Simplify fasteners

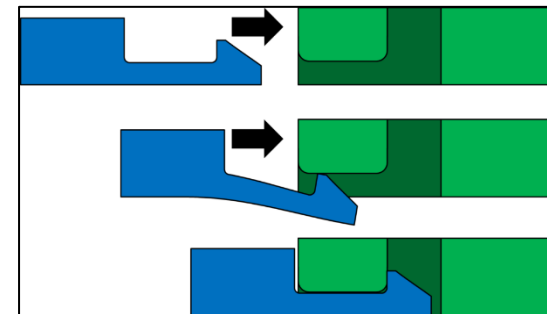


Figure credits

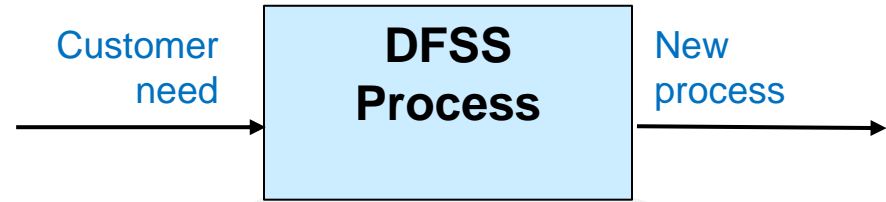
- <https://www.allaboutlean.com/dfma-6/dfma-self-locating-2/>
- <https://www.allaboutlean.com/dfma-6/dfma-upside-down-mounting/>
- <https://www.allaboutlean.com/dfma-6/dfma-assemble-from-one-side/>
- <https://www.allaboutlean.com/dfma-6/dfma-symmetry/>
- <https://www.allaboutlean.com/dfma-4/dfma-plastic-snap-joint/>

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).



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

Identify	Design	Optimize	Validate
<p>(1) Define Customer Requirements</p>	<p>(3) Identify Potential Failure Modes</p> <p>FMEA</p>	<p>(7) Candidate Inputs</p> <p>(8) Key Inputs</p>	<p>(12) Verify Capability of Outputs</p>
<p>(2) Establish Measures and Standards</p> <p>Requirements Definition</p>	<p>(4) Mistake Proof</p> <p>(5) Develop Measurable Outputs</p> <p>(6) Validate Measurement System</p>	<p>(9) Characterize Behaviors of Key Inputs</p> <p>(10) Discover Variable Relationships</p> <p>(11) Set Targets, Tolerances and Controls</p>	<p>(13) Perform Other Testing</p> <p>CCDFs</p> <p>(14) Implement Controls</p>

Design for Six Sigma – DMADV

	Typical Tools Used
D – Define goals of design activity	<ul style="list-style-type: none"> ▪ AHP ▪ QFD ▪ SIPOC diagrams
M – Measure stakeholder metrics	<ul style="list-style-type: none"> ▪ Surveys ▪ Value Stream Analysis
A – Analyze the available options	<ul style="list-style-type: none"> ▪ QFD ▪ Statistical tools
D – Design the new product	<ul style="list-style-type: none"> ▪ FMEA ▪ DFMA ▪ TRIZ
V – Verify the design in the real world	<ul style="list-style-type: none"> ▪ Pilot tests ▪ SPC & control charts

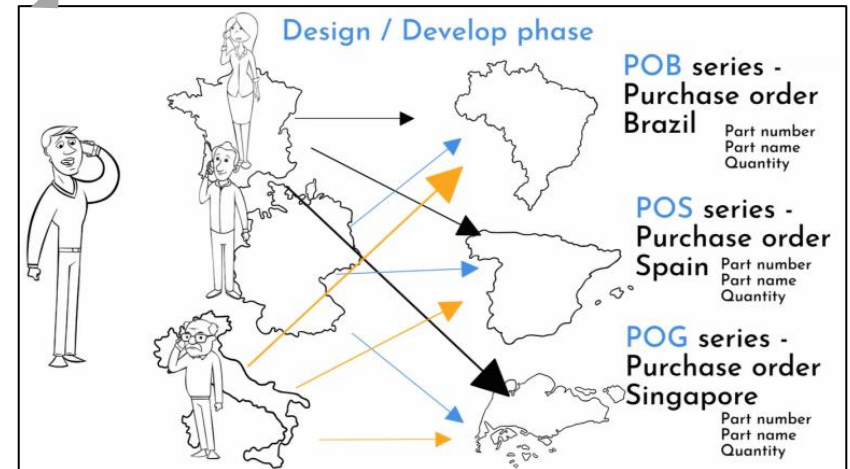
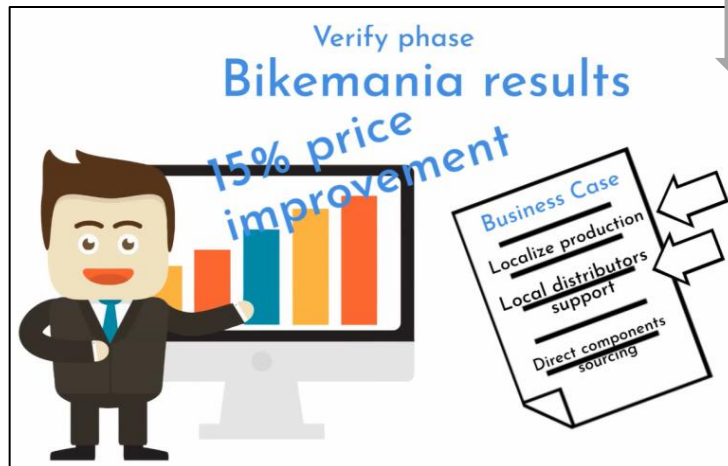
<https://isowatch.wordpress.com/2018/10/23/six-sigma-is-draining-employees-creativity/>

© copyright 2020, Taylor Enterprises, Inc.

DFSS – Example – Bicycle Manufacturer

Images from “How to do DMADV Process? Supply Chain Easy Example”
at <https://sixsigmamania.com/?p=338>

- **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

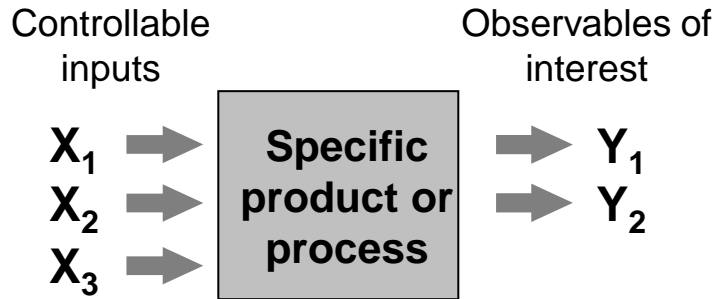
How to determine the factors controlling an output?

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:

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

overall mean

main effects

Two-way interactions

Experimental needs
Constraints

DOE Methodology

Experimental design

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:

		Inputs (encoded)							Observation			
		A	B	C	D	E	F	G	Y ₁	Y ₂	Y ₃	Y ₄
Experiment	#1	-1	-1	-1	-1	-1	-1	-1				
	#2	-1	-1	1	-1	1	1	1				
	#3	1	1	-1	1	-1	1	1	Observed values go here			
	#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				

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

		Input values							Golf score
		A	B	C	D	E	F	G	Y ₁
Experiment	#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

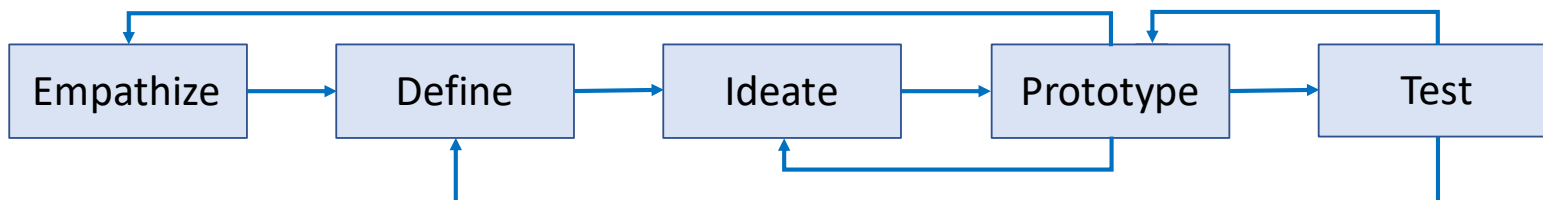
Work with an SME

- **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; some stress related to the charging of an electric toothbrush.
 - C. Braun changed their goal and created an electric toothbrush that uses USB charging.



New product: “Techinal 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)

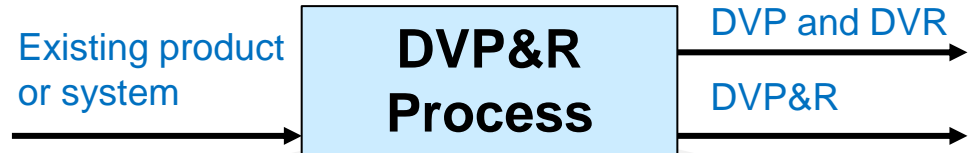
Problem

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.

The Who / When / Why of the testing

The Who / When / Why of the testing						

Details of each planned test

Details of each completed test

DVP&R – Example – Automobile Radar

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

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	<i>George</i>	<i>500</i>	<i>SW</i>	<i>2/18</i>	<i>2/20</i>
2	Signal Processing Firmware	Track Test #27: clutter rejection	> 27 dBsm rejection	Ben G.	<i>Alice</i>	<i>10</i>	<i>mock-up</i>	<i>3/14</i>	<i>3/14</i>
3	Signal Processing HW	Vehicle Test #8: clutter rejection	> 23 dBsm rejection	Carla	<i>David (drive team)</i>	<i>5</i>	<i>pre-production</i>	<i>4/12</i>	<i>4/18</i>
4	Design Review	Design Review of clutter rejection capability	Software, Systems, and Quality teams agreement	Harry	<i>N/A</i>	<i>N/A</i>	<i>N/A</i>	<i>4/23</i>	<i>4/23</i>
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 (4/15)						
7	Recommended Action						

Verification Plan

Verification Report			
Reviewer	Results	Comments	Date
Quality (Nancy)	<i>28.5 dBsm</i>	<i>pass</i>	<i>2/22</i>
Quality (Nancy)	<i>29.5 dBsm</i>	<i>pass</i>	<i>3/14</i>
Quality (Ralph)	<i>23.5 dBsm</i>	<i>pass</i>	<i>4/21</i>
Quality (Ralph)	<i>N/A</i>	<i>Meeting held</i>	<i>4/23</i>

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

Verification Report

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

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	
	<i>Data</i>	<i>Function</i>	<i>Network</i>	<i>People</i>	<i>Time</i>	<i>Motivation</i>	
(1)	Objective/Scope Contextual layer <i>Role: Planner</i>	Business vision & goals	Business processes	Business locations	Departments involved	Future products road map	User needs. app business case
(2)	Enterprise model Conceptual layer <i>Role: Owner</i>	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 <i>Role: Designer, Architect, or General Manager</i>	App look and feel	System architecture (e.g., support capabilities)	System connectivity	User interface design	Master schedule	App functionality
(4)	Technology model Physical model <i>Role: Builder, General Contractor, or Local Manager</i>	Platform description, wireframe model	App requirements	Technology architecture (e.g., component libraries)	Skill identification	Development milestones	Define function capabilities
(5)	Detailed representation Detailed model <i>Role: Scientist, Engineer, Subcontractor, or Programmer</i>	Interface definitions, database schema, code	App design	Communications architecture	Security design	Implementation model (e.g., scrum)	Motivate team to create successful product
(6)	Functioning result Enterprise release <i>Role: End user</i>	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

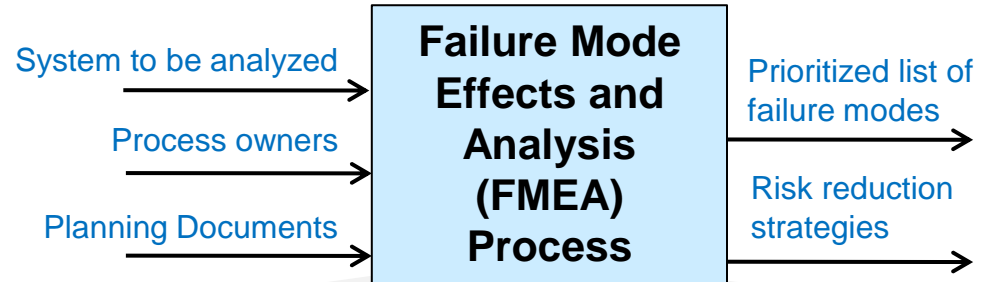
- to identify **where and how it might fail** and
- to assess the **relative impact of different failures**

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** (DFMEA), or **Process** (PFMEA) 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 operation with government regulation. Failure will occur with government regulation.	9
Very High	Major disruption to production line. 100% of product scrapped. Vehicle/item inoperable, loss of primary function.	
High	Minor disruption to production line. Product not (less than 100%) scrapped. Vehicle operable with minor performance. Customer dissatisfied.	
Moderate	Minor disruption to production line. A portion of product have to be scrapped (no sorting). Vehicle/item inoperable. Customer Comfort/Convenience item(s) inoperable. Customer dissatisfaction.	

Likelihood / Occurrence

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

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)

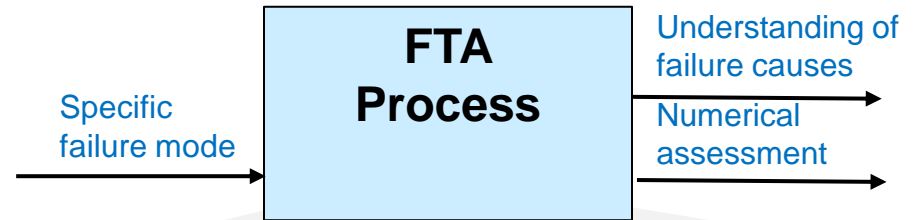
Problem

How to quantify a specific type of failure?

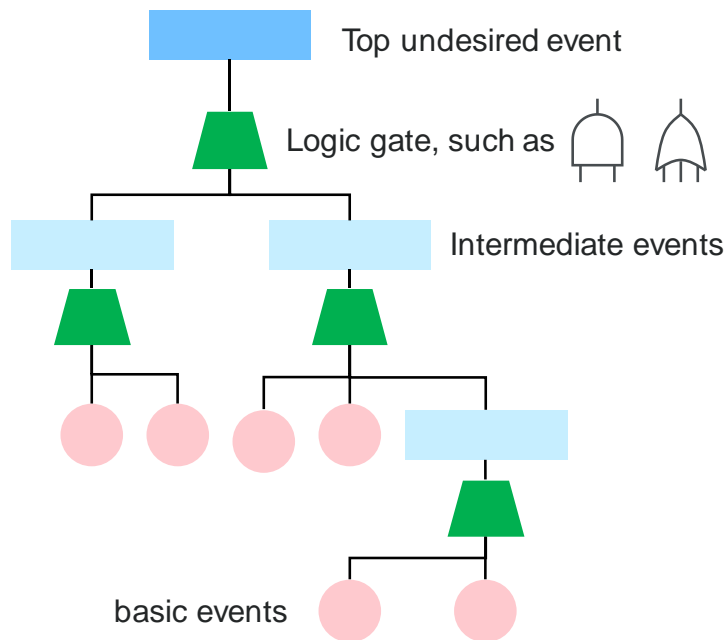
Difficulty

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 identifies the root cause(s) of failure.
- FTA can be used in the design process.
- FTA diagrams use a standard set of symbols.

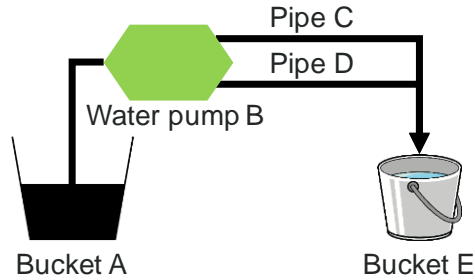


1. Define the top undesired event to investigate.
2. Identify first level contributors, just below the top level, and link these to the top level event using logical gates (e.g., AND and OR gates).
3. Identify the second level contributors and link to the first level contributors using logical gates. 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.

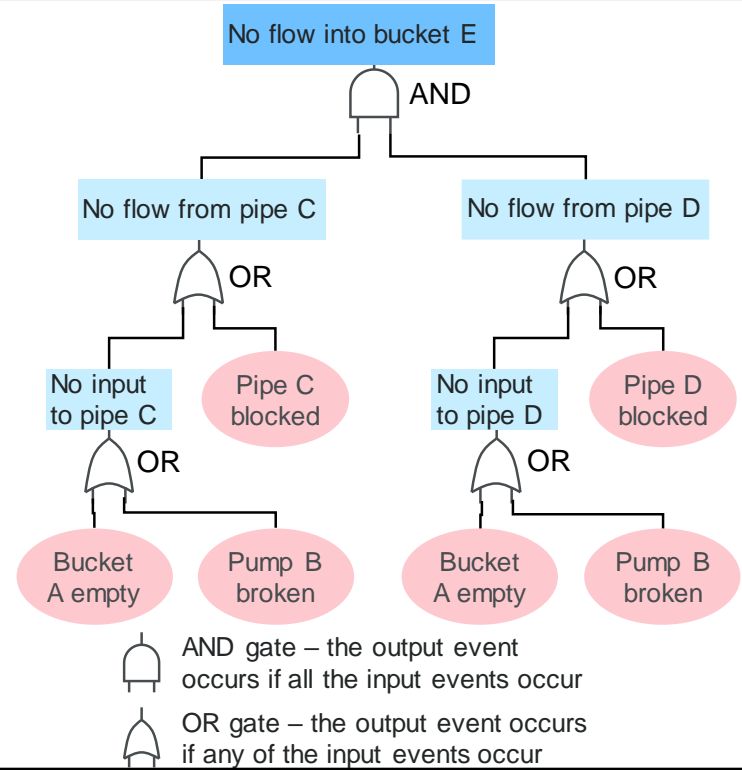


FTA – Example – Pumping Water

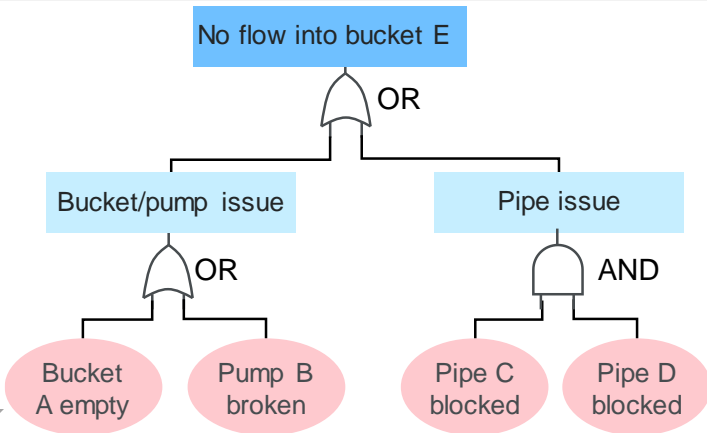
(1) Consider pumping water from bucket A to bucket E, using a pump and two pipes



(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):

- Bucket A is empty
- Pump B is broken
- Pipe C is blocked and pipe D is blocked.

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

$$P_E = 1 - (1 - P_A)(1 - P_B)(1 - P_C P_D)$$

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

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

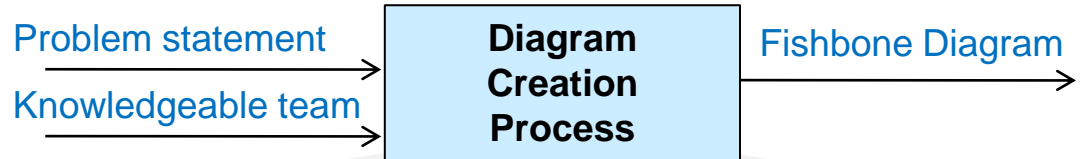
Fishbone Diagram / Ishikawa Diagram / Cause-and-effect Diagram

Problem
How to identify root causes?

Difficulty

Easy to use

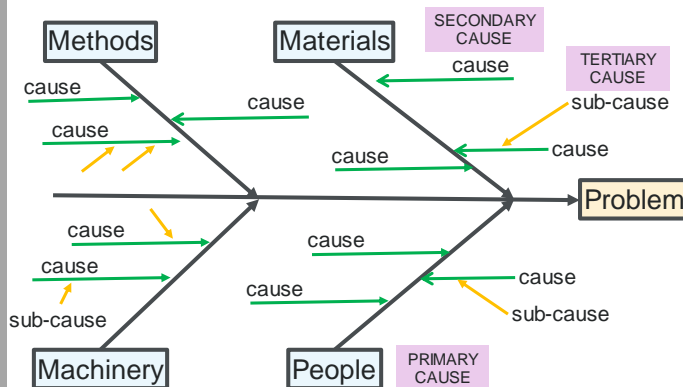
- A **fishbone diagram** is a visual tool for identifying and displaying potential causes of a problem.
- A fishbone diagram determines increasingly detailed causes until a root cause is identified.
- Using the given initial structure, ask “Why?” to go from primary causes to sub-causes to sub-sub-causes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



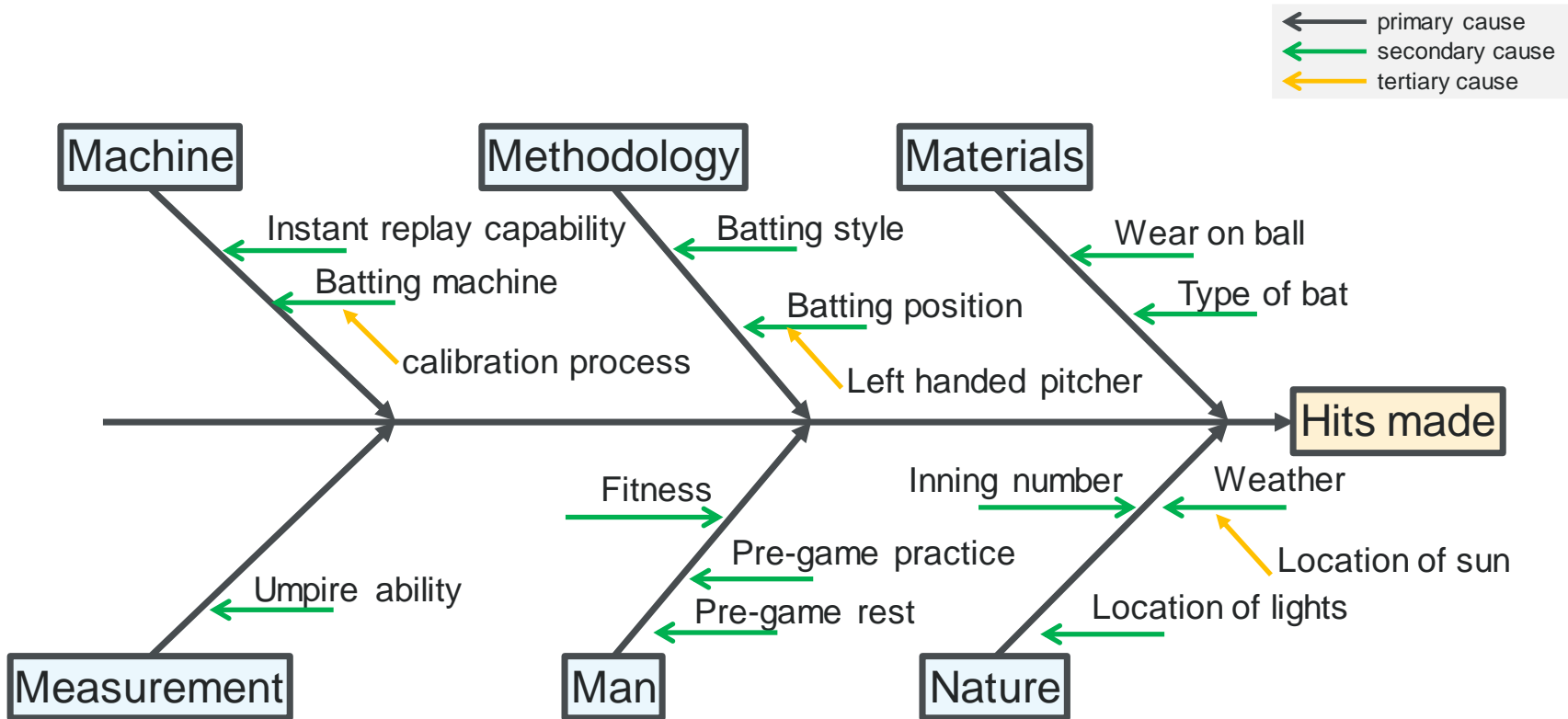
1. Identify the problem to be analyzed. Write this as the mouth of the “fish” (typically on the right).
2. Select 4-8 primary causes – see below – to analyze the problem; these are the major bones of the fish.
3. For each primary cause identify as many secondary causes as possible and add them to the 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

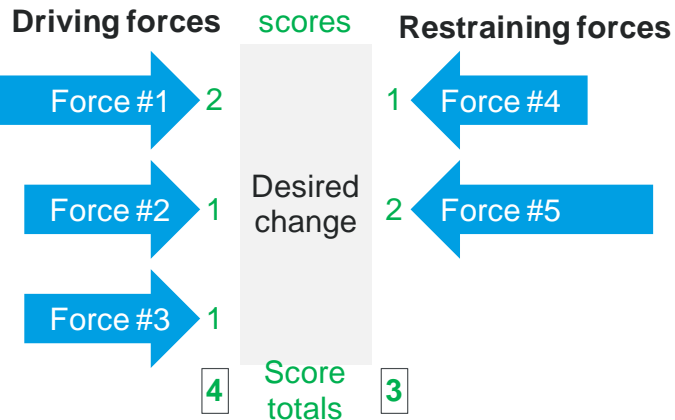
Easy to use

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

Desired change →

Force Field Analysis

→ Strategy to implement change



Forces

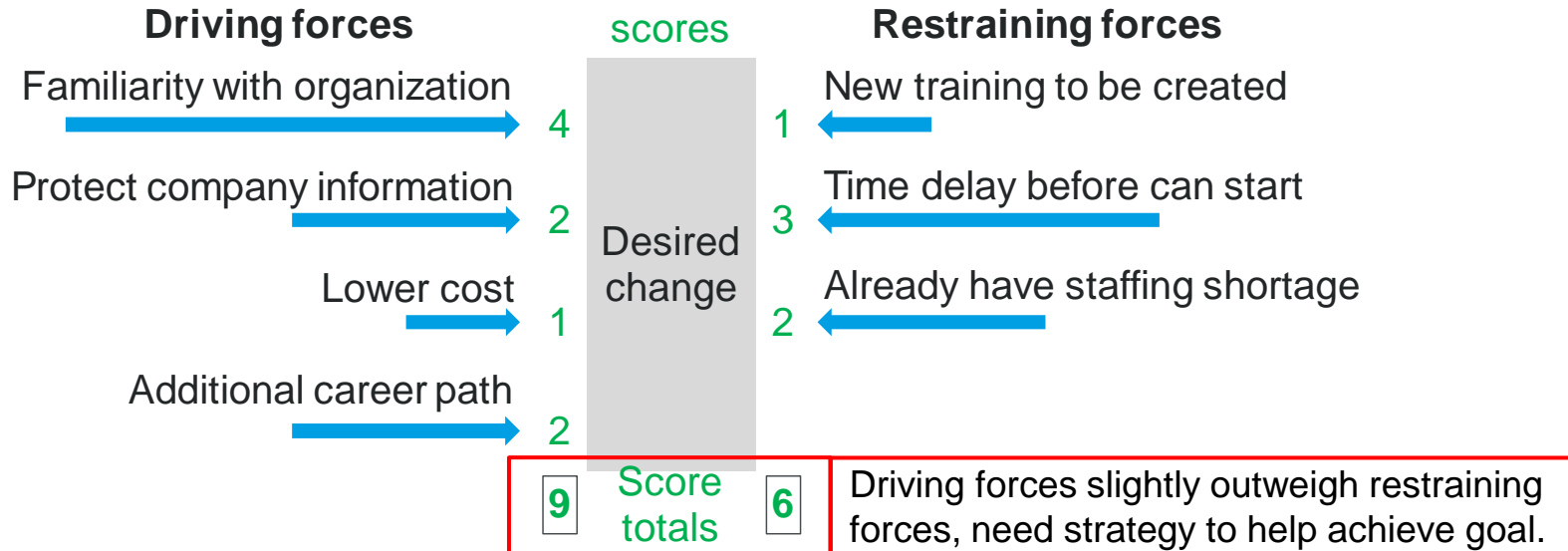
- *favorable* (same as) *driving*
- *unfavorable* (same as) *restraining*

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.

Force Field Analysis – Example – Hire Consultants

Goal: Use internal consultants instead of hiring external consultants.

Force Field Analysis: Might look like the following:

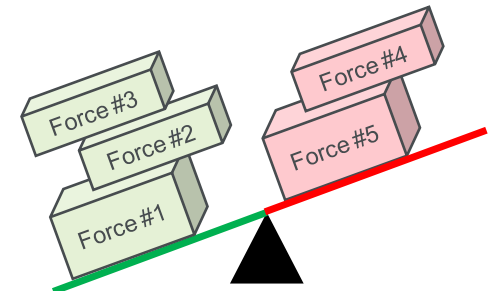


Hence, to encourage the desired change (that is, “use internal consultants”), you could, before promoting this change:

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?

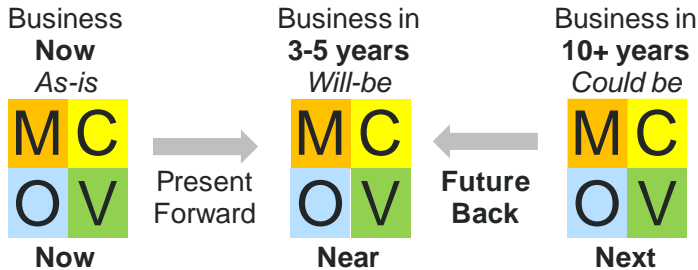
Difficulty

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.

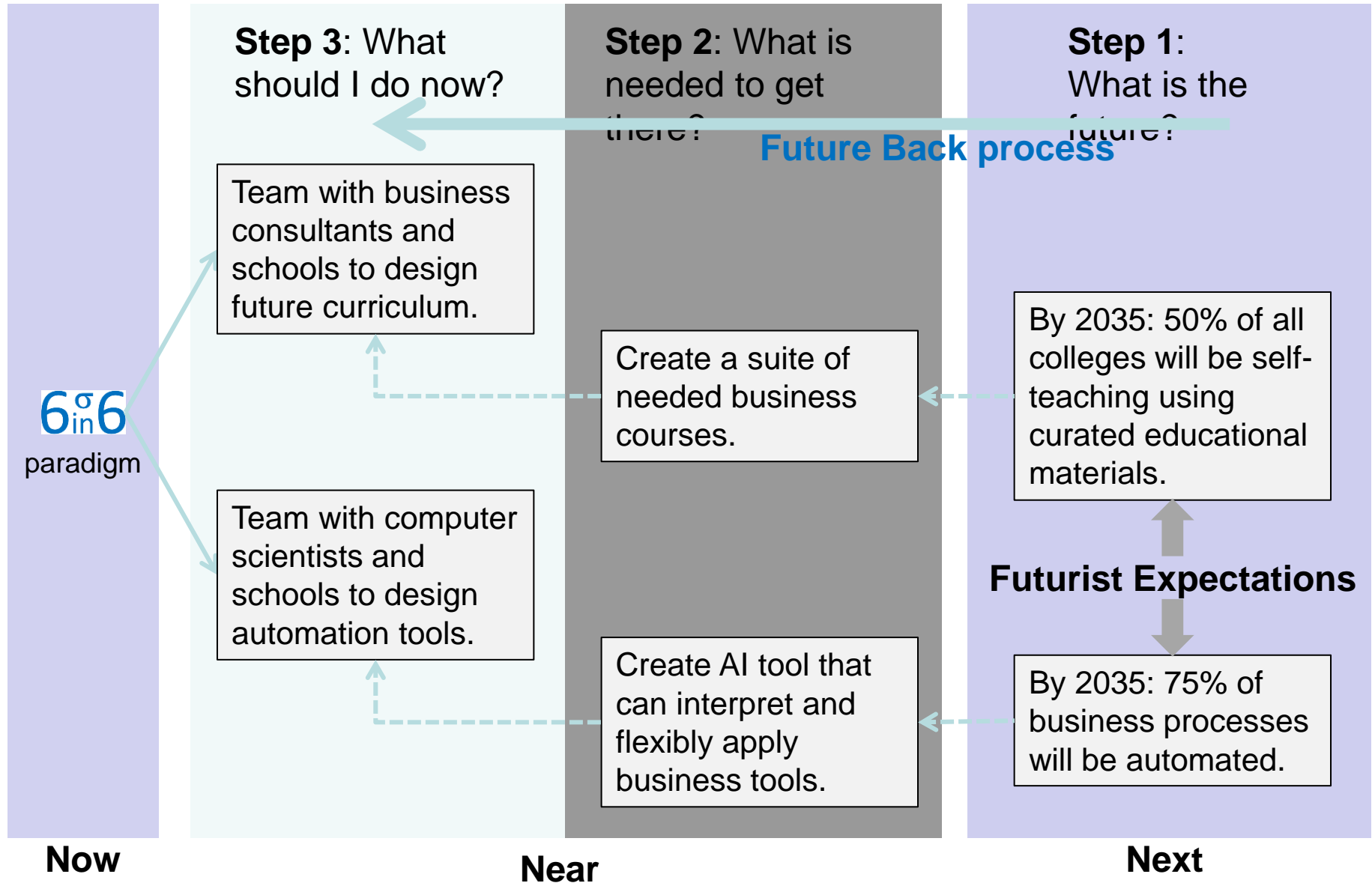


1. Imagine the desired/ideal future state (“moonshot”)
 - It does not need to be achievable with today’s technology and financial resources.
 - Each future state is detailed with a date.
 - Select 2 to 5 future states; not all the desired future states will materialize.
2. Convert the vision to strategy
 - 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



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

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** (not **accuracy**).

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

Gage R&R statistical tests
ANOVA approach
AIAG approach
EMP approach (“evaluating the measurement process”)



Process

1. Determine standard to meet
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 software packages is recommended!
7. Document the results

Gage R&R – Example – Sample Minitab output

From <https://support.minitab.com/en-us/workspace/forms-and-analysis-captures/analysis-capture-tools/gage-r-r-study/>

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

What percentage of the allowed tolerance has been used

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

$NDC = 3 \rightarrow \{\text{Low, Medium, High}\}$

$NDC = 5 \rightarrow \{\text{Very Low, Low, Medium, High, Very High}\}$

Between 10% and 30% \rightarrow measurement system is marginally acceptable

GRR Types

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

Gap Analysis

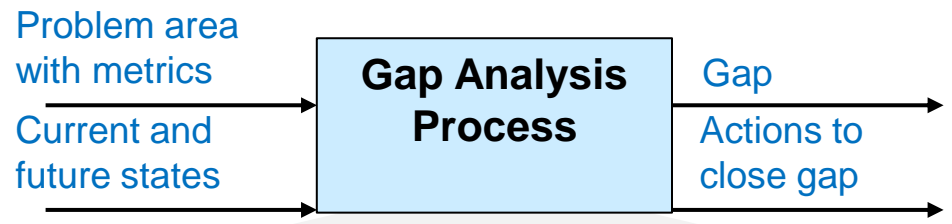
Problem

How to determine the needed improvement?

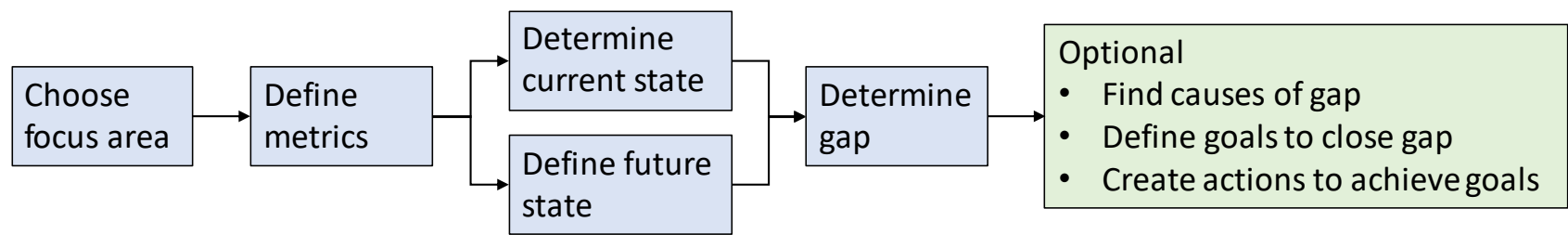
Difficulty

Some training required

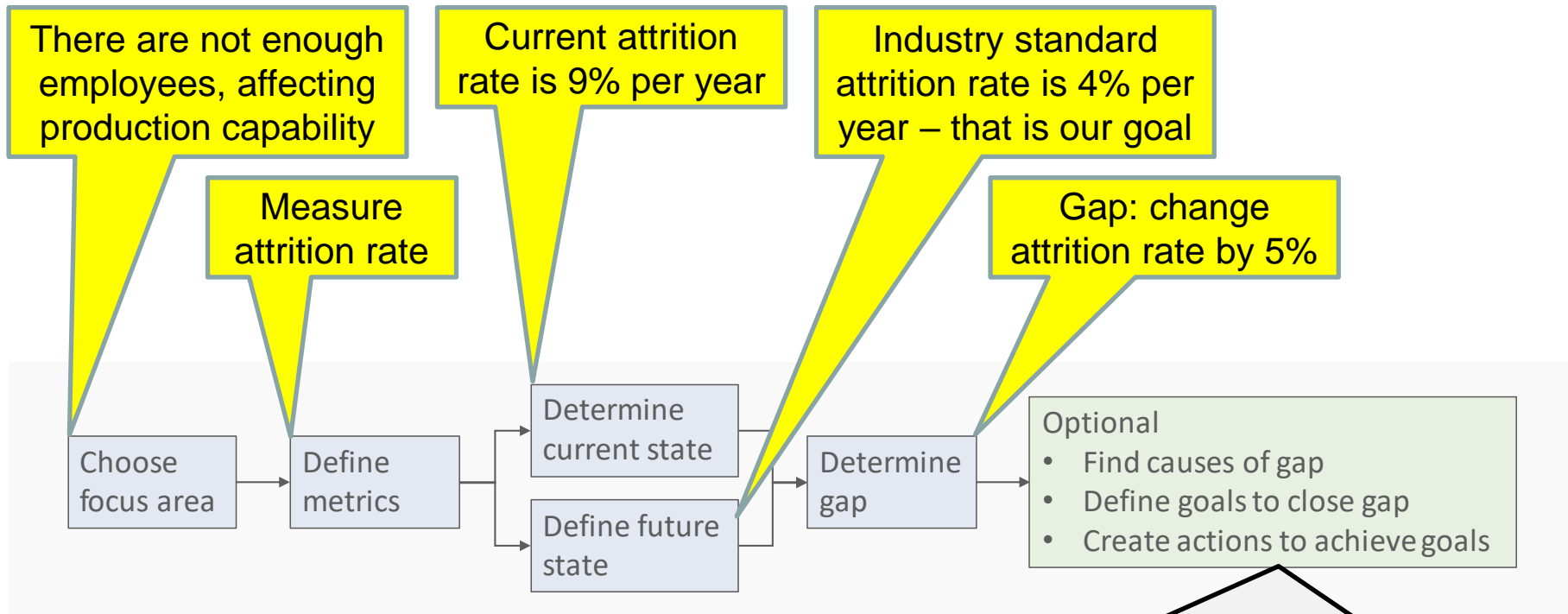
- **Gap Analysis** is used to compare where you are (current state) against where you want to be (future state).
- There is no standard **Gap Analysis** process, the process is tailored as needed.
- A gap is an improvement opportunity. Metrics, such as performance indicators, quantify the gap.
- Gap 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?

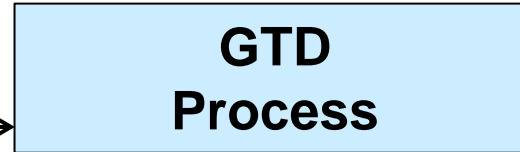
Difficulty

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.

Daily demands for your time

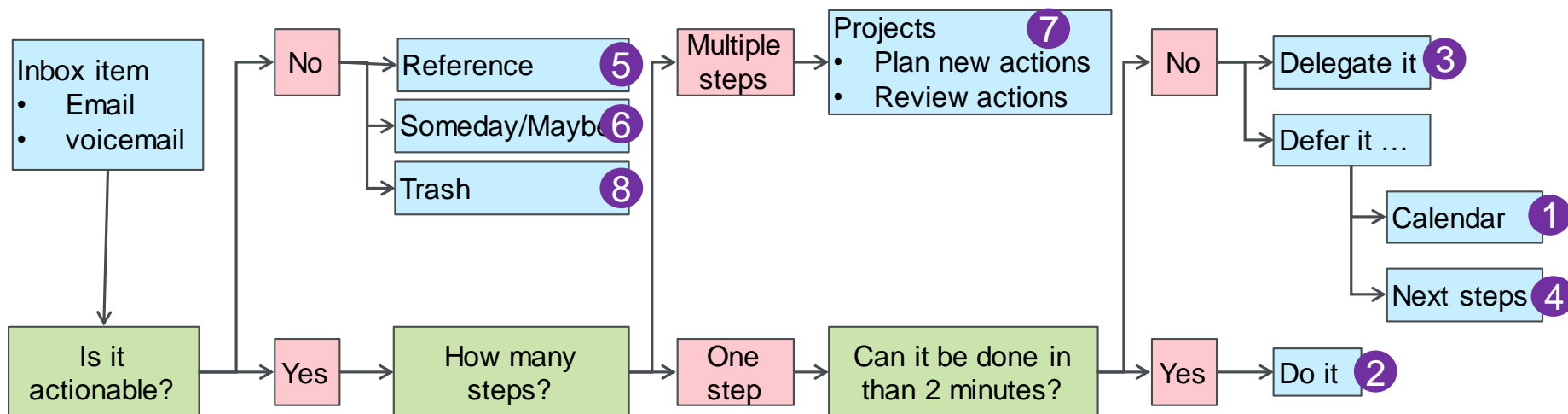


Managed information



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?

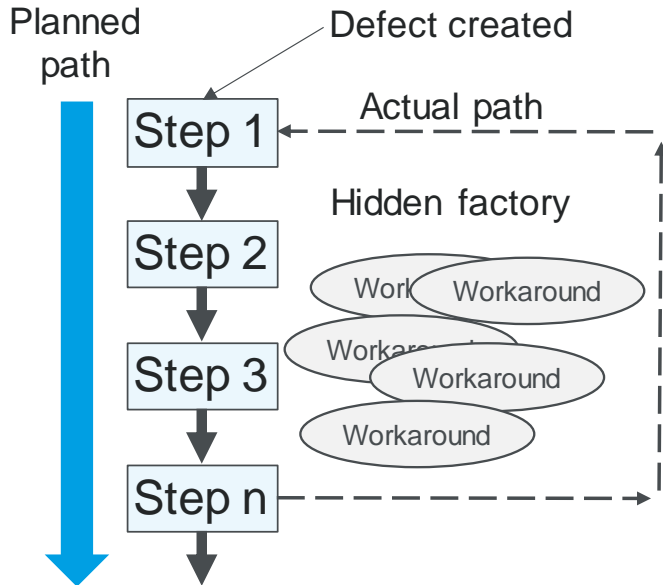
Difficulty

Some training required

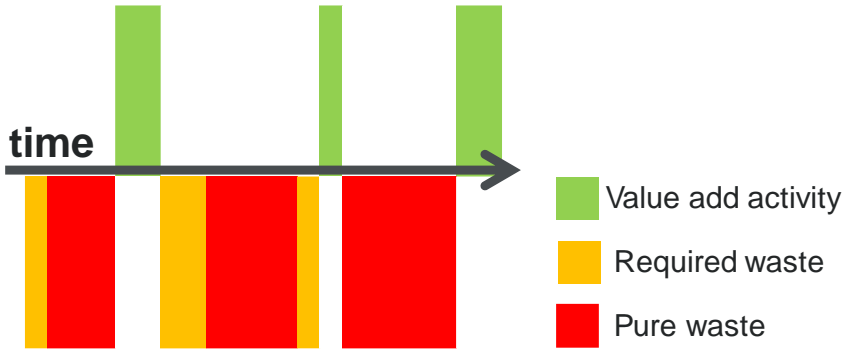
- A **Hidden Factory** is created when a defect flows downstream.
- The hidden factory represents process activities causing loss of: Availability, Efficiency, Schedule, Quality, or Performance.
- Visualization tools can help identify wastes caused by the “hidden factory.”



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)

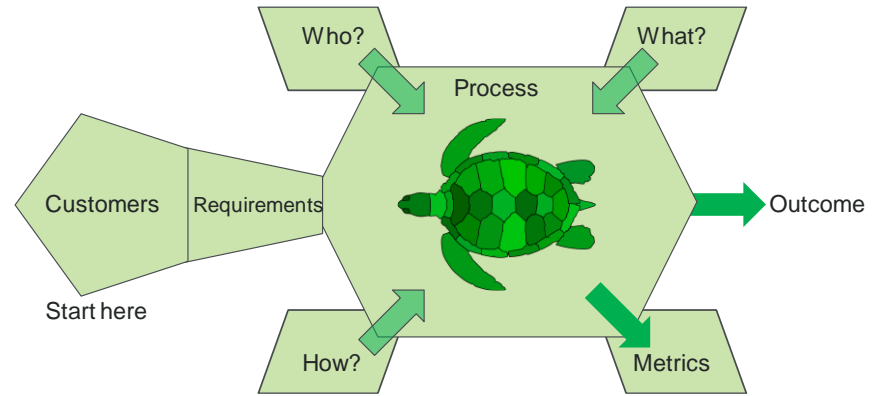


Hidden Factory – Example Mapping Techniques



Time value map

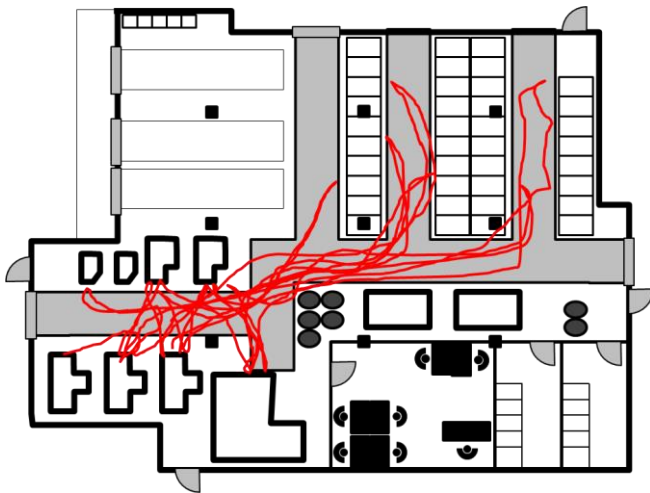
Shows non-value added activities with durations



Turtle diagram

Shows key activities

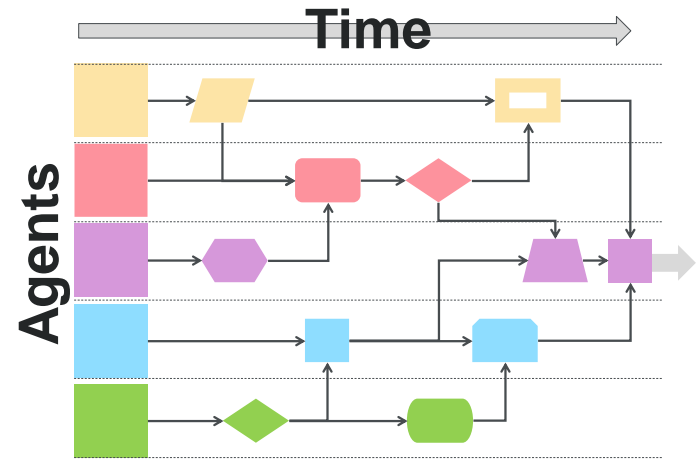
<https://creazilla.com/nodes/3164991-turtle-clipart>



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)

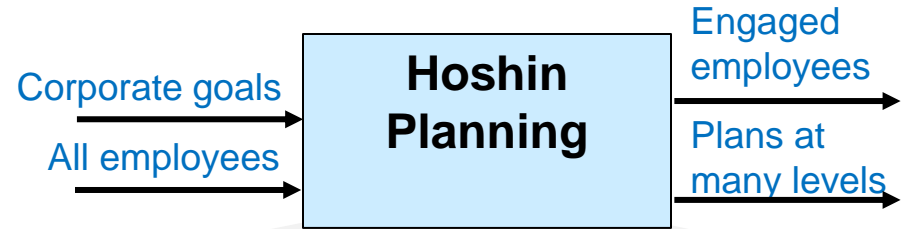
Problem

How to align employees with corporate goals?

Difficulty

Work with an SME

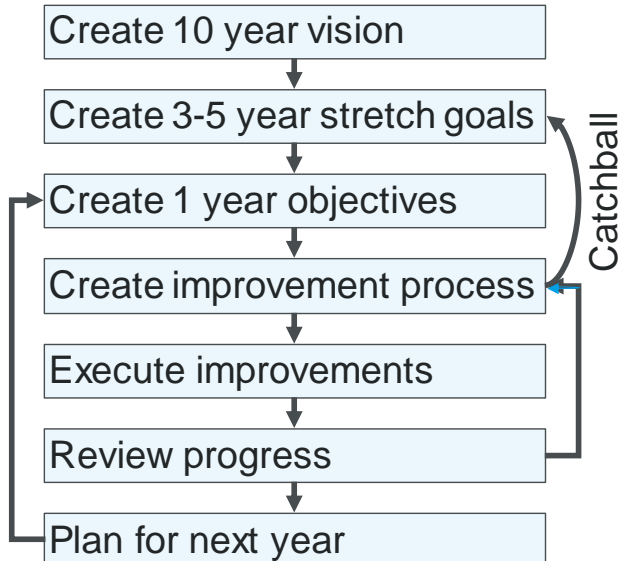
- **Hoshin Planning** creates corporate goals, disseminates them to all, and creates plans to achieve them.
- **Catchball** is a part of Hoshin Planning in which ideas are passed between levels of an organization's hierarchy for feedback and action planning.



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.

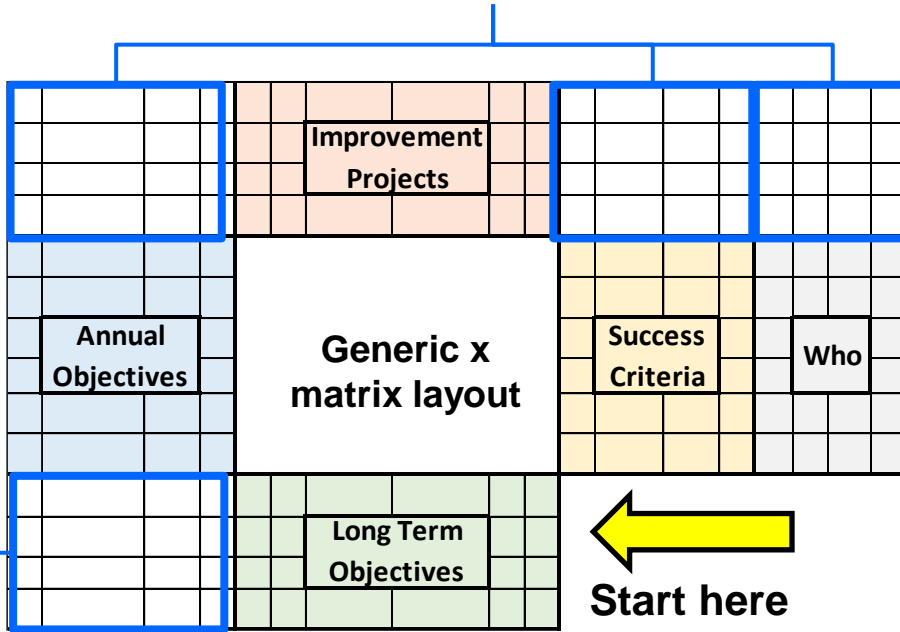
Benefits of Hoshin Planning

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

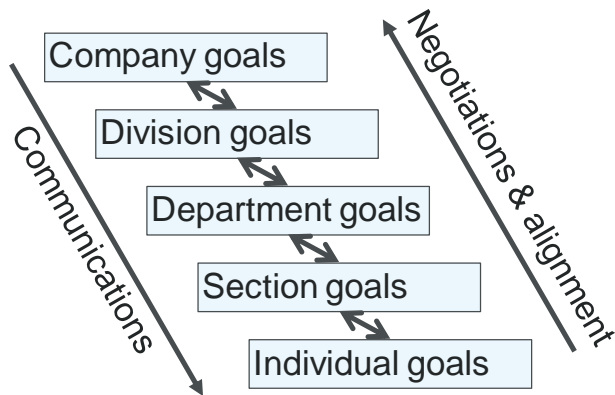


A hoshin kanri **x matrix**, also called a **policy deployment** (pd) document, includes “what,” “how,” “who,” and “how much.”

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

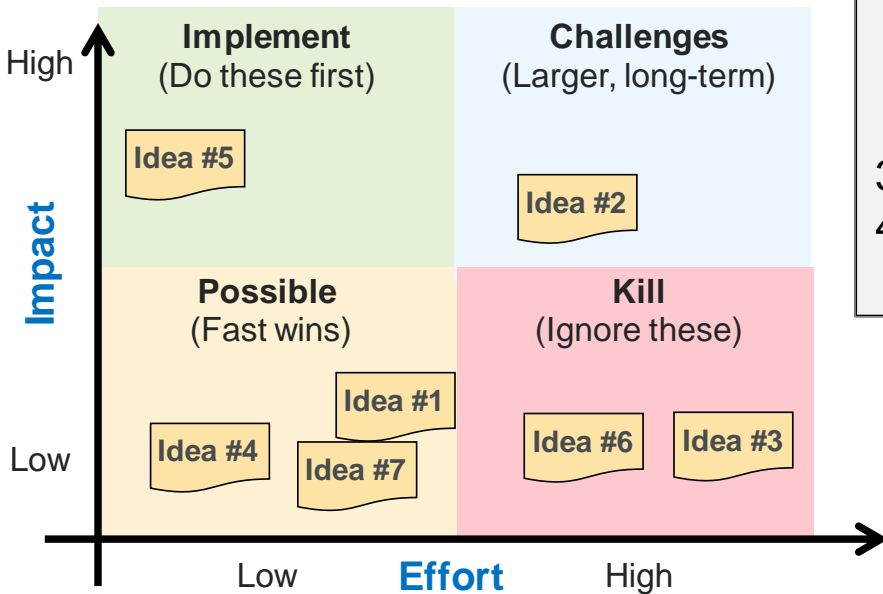
- An **impact-effort matrix**, or a **PICK** (Possible / Implement / Challenge / Kill) **chart**, is a way to categorize projects.
- A PICK chart prioritizes among many projects identifying those with the most value.



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?

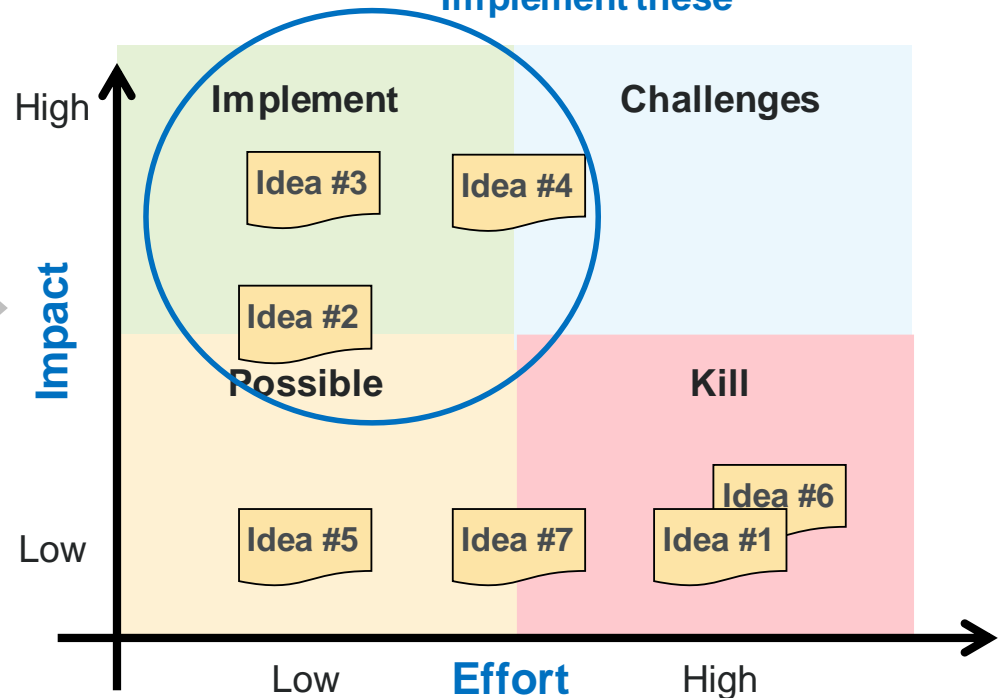
Idea	Improvement project	Effort	Impact
#1	Advertise on evening news	High (due to cost)	Low
#2	Send email to Dan's friends	Low	Medium
#3	Announce to 6 sigma groups on LinkedIn	Low	High
#4	Place advertisement in 6 sigma journal	Medium	High
#5	Put sign on Dan's car	Low	Low
#6	Obtain celebrity endorsement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

Evaluations of effort

Potential projects

Implement these

The above table yields the PICK chart shown



Individual Development Plan (IDP)

Problem

How to encourage employee growth?

Difficulty

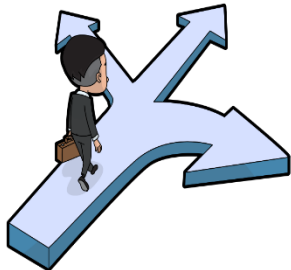
Some training required

- 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



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)

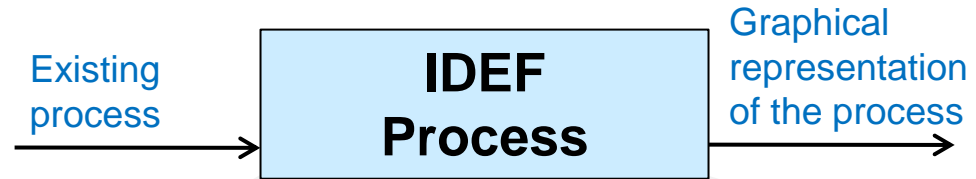
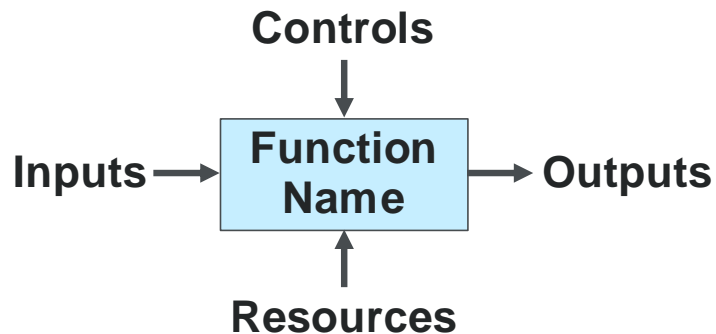
Problem

How to graphically model a process?

Difficulty

Some training required

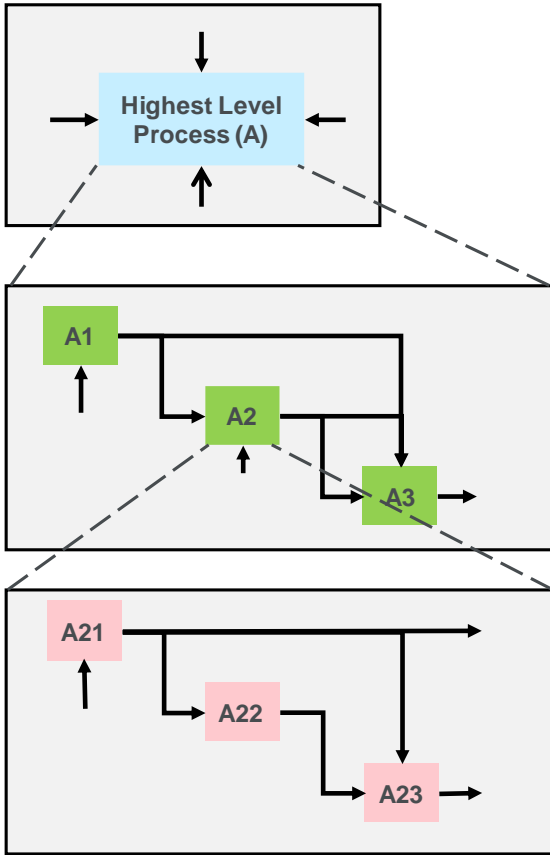
- **Integration Definition (IDEF)** refers to a family of 16 modeling languages used in systems and software engineering; only some of them exist.
- **IDEF0** (for function modeling) is the most commonly used IDEF, it models the actions, activities, and decisions of a system.
- In IDEF diagrams each 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.

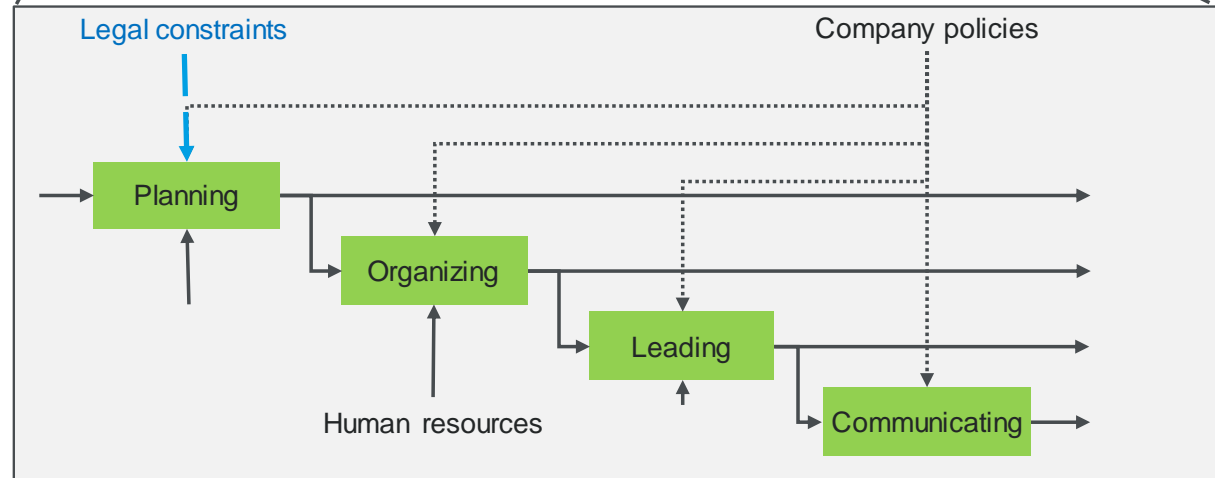
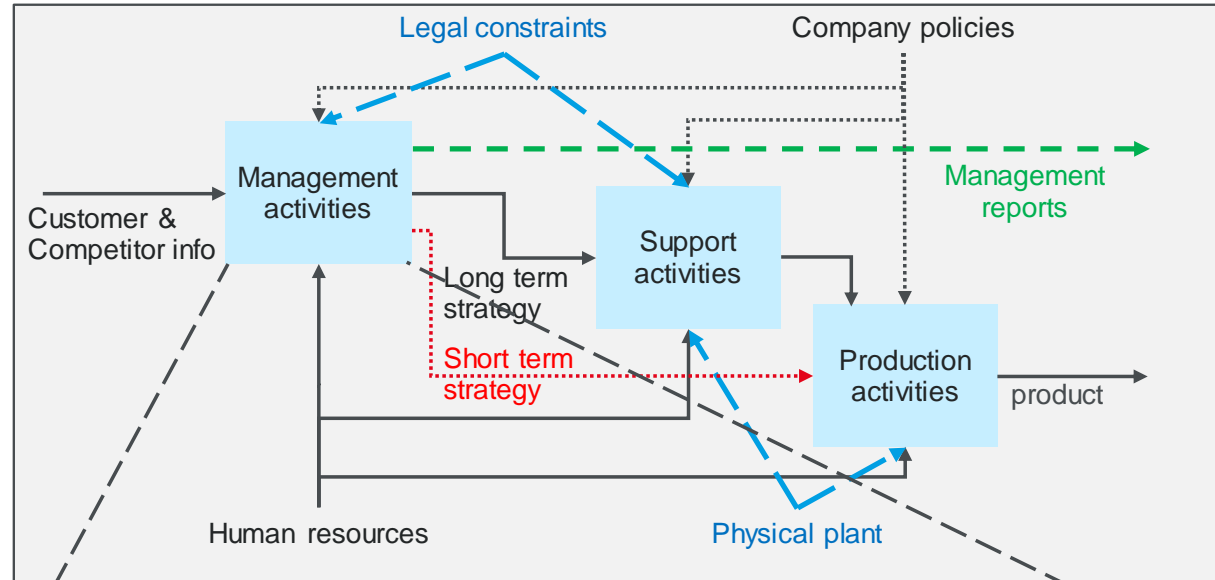
IDEF – Example – Manufacturing Company Process

Hierarchical decomposition



Lower level processes

Notational IDEF0 (many details missing)



Interrelationship Diagram (Network Diagram)

Problem

How to determine the most important problem factors?

Difficulty

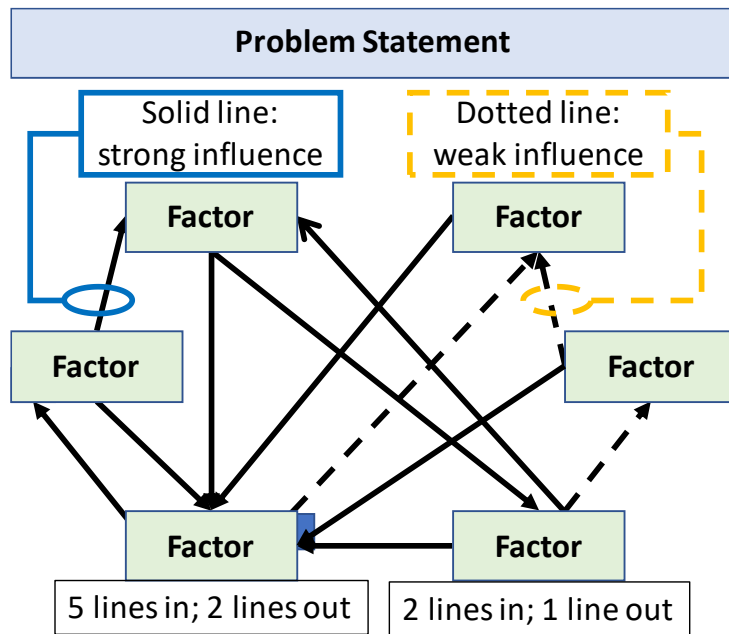
Easy to use

- 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 $\frac{1}{2}$.
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:

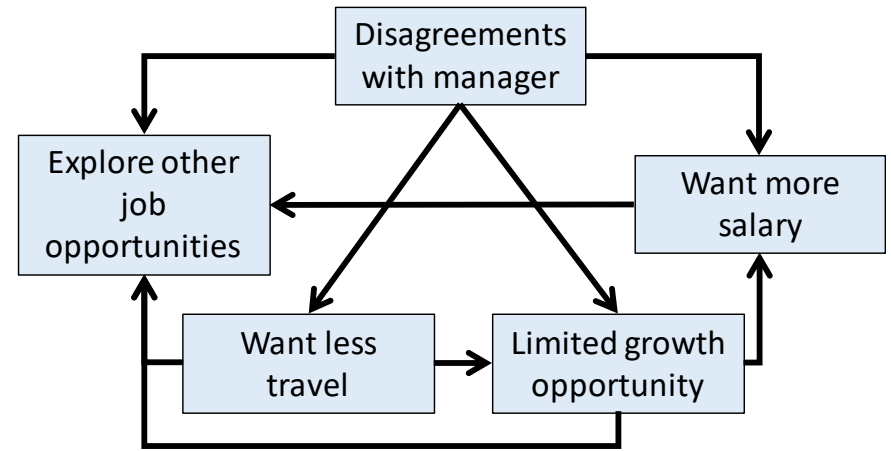
- “Disagreements with manager”
- “Explore other job opportunities”
- “Limited growth opportunities”
- “Want less travel”
- “Want more salary”
- ... (for a realistic analysis, many more factors would be included)

Steps 3 & 4: see figure (top)

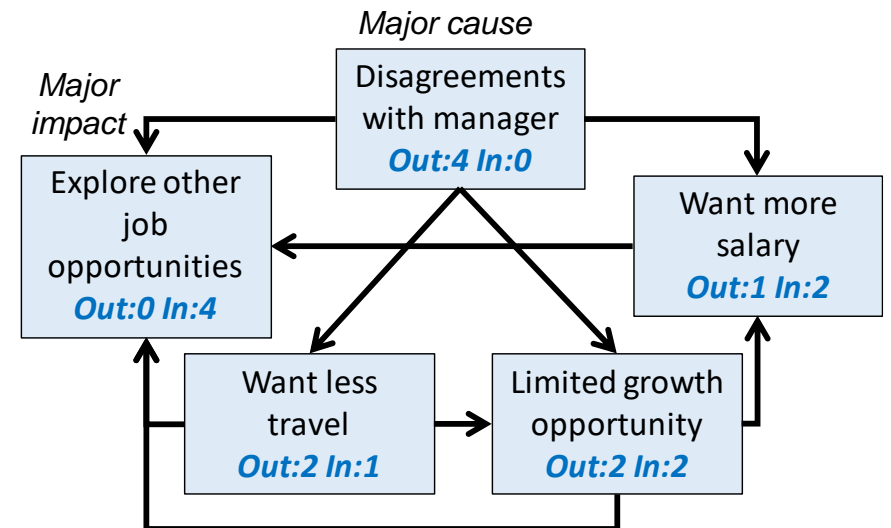
Step 5: see figure (bottom)

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

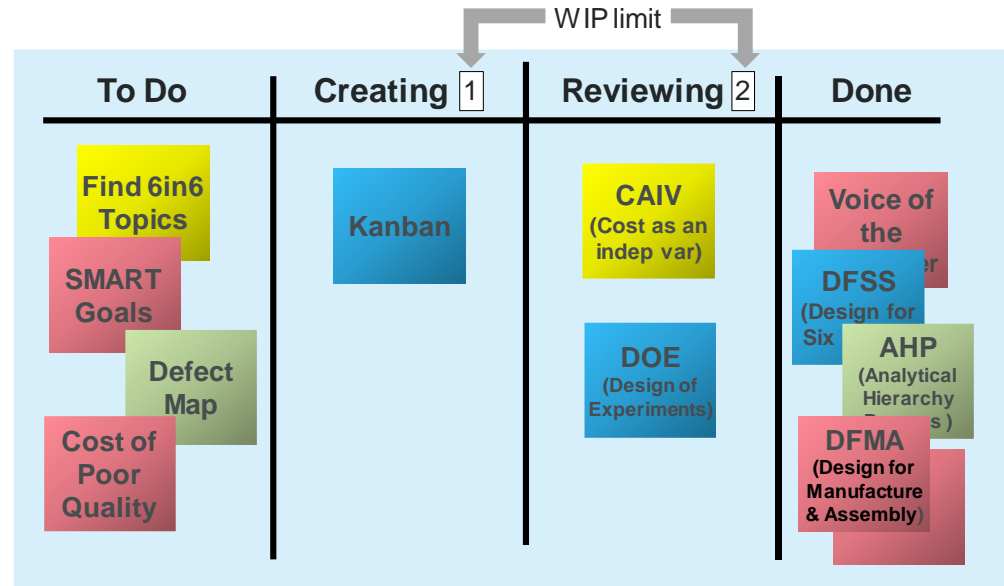
1. Start with what you do now
2. Agree to pursue incremental, evolutionary change
3. Respect the current process, roles, responsibilities, and titles
4. Encourage acts of leadership at all levels in your organization

Kanban – Example – Creating 6in6 Presentations

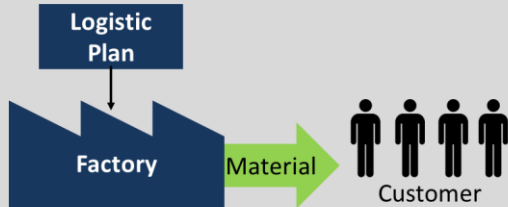
Tailored to 6in6 presentation creation, the Kanban board has 4 categories:

(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.

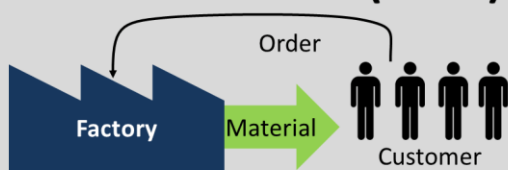


Logistic Plan (Push?)



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.

Information Flow (Pull?)



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

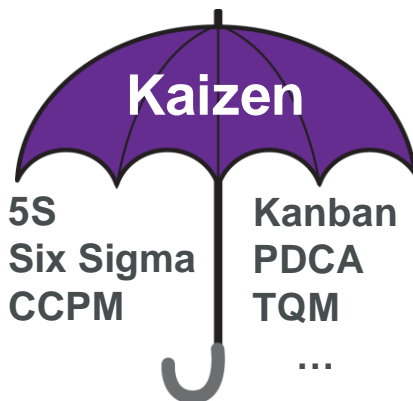
- **Kaizen** is a Japanese term meaning change for the better or continuous improvement.
- **Kaizen** can be implemented by many methods: 5S, Six Sigma, CCPM (Critical Chain Project Management), Kanban, PDCA (Plan / Do / Check / Act), TQM (total quality management), ...
- A **Kaizen event** or **blitz**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


Six Sigma in Six Minutes (6in6)

Understanding Six Sigma Tools in Only Six Minutes

6in6 Motivation While “Six Sigma” means different things to different people, everyone agrees that there are many useful Six Sigma tools. Knowing which tools are available, what they do, and how to use them is needed to be a successful Six Sigma practitioner.

6in6 Description The concept behind “6 sigma in 6 minutes” (6in6) is that basic understanding of a Six Sigma tool can be presented to an audience in 6 minutes. The goal of these 6in6 presentations is to deliver some familiarity of the tool.

6in6 Vision Encourage use of Six Sigma tools.

6in6 Mission Distribute free basic Six Sigma tool information.

6in6 Goal Illustrate common Six Sigma tools using the “6 sigma in 6 minutes” (6in6) paradigm.

6in6 Success If someone can get a basic idea of what a 6 sigma tool does from a 6in6 presentation, then we have success.


Why To spread the joy of Six Sigma 🍌

Note There are many interpretations of what a Six Sigma tool is. We include tools for business decision making, graphical understanding, and statistics.


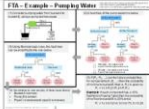


Six Sigma tools and their two slide 6in6 presentations (click on a column heading to sort the table)

#	Six Sigma Tool Name ↑	Acronym ↑	Problem addressed ↑	Problem type ↑	Tool difficulty ↑	6in6 documents
1	5 Whys / Root Cause Analysis		How to find a problem's root cause?	Analyzing/Trending	easy	PPT PDF
2	5S Process of Lean	5S	How to remove distracting clutter?	Analyzing/Trending	easy	PPT PDF

6in6 web page in June 2022


Understanding Six Sigma Tools in Six Minutes (6in6)
** Free six sigma educational materials **

6in6 presentations are short presentations (2 PowerPoint slides) on a specific 6 sigma method in a common format. For example, the presentations for Fault Tree Analysis and Control Charts are below

- A single PDF file containing all 69 of the presentations is [here](#) (For a book with covers, a table of contents, and an index, download [6in6_book_2023.11](#))
- The table below lists free two-slide presentations on a variety of six sigma topics, in both PowerPoint and PDF formats.
 - You can sort the table by clicking on a column heading.
 - “SME” stands for “Subject Matter Expert”
- Notes
 - There are many interpretations of what a Six Sigma, or Lean Six Sigma, tool is. We include a variety of tools that address different business needs.
 - More information about the “Six Sigma in Six Minutes” (6in6) concept is at the bottom of this page.

#	Six Sigma Tool Name ↑	Acronym ↑	Problem addressed ↑	Problem type ↑	Tool difficulty ↑	6in6 presentations	Six Sigma Tool Name ↑
1	5 Whys / Root Cause Analysis		How to find a problem's root cause?	Analyzing/Trending	easy to use	PPT PDF	5 Whys / Root Cause Analysis
2	5S Process of Lean	5S	How to remove distracting clutter?	Changing/Implementing	easy to use	PPT PDF	5S Process of Lean

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.

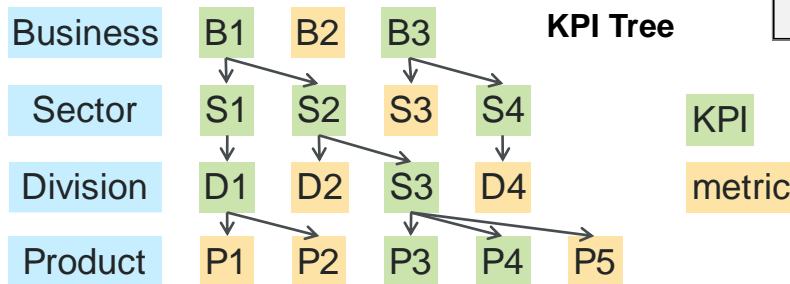
Existing/planned process/product



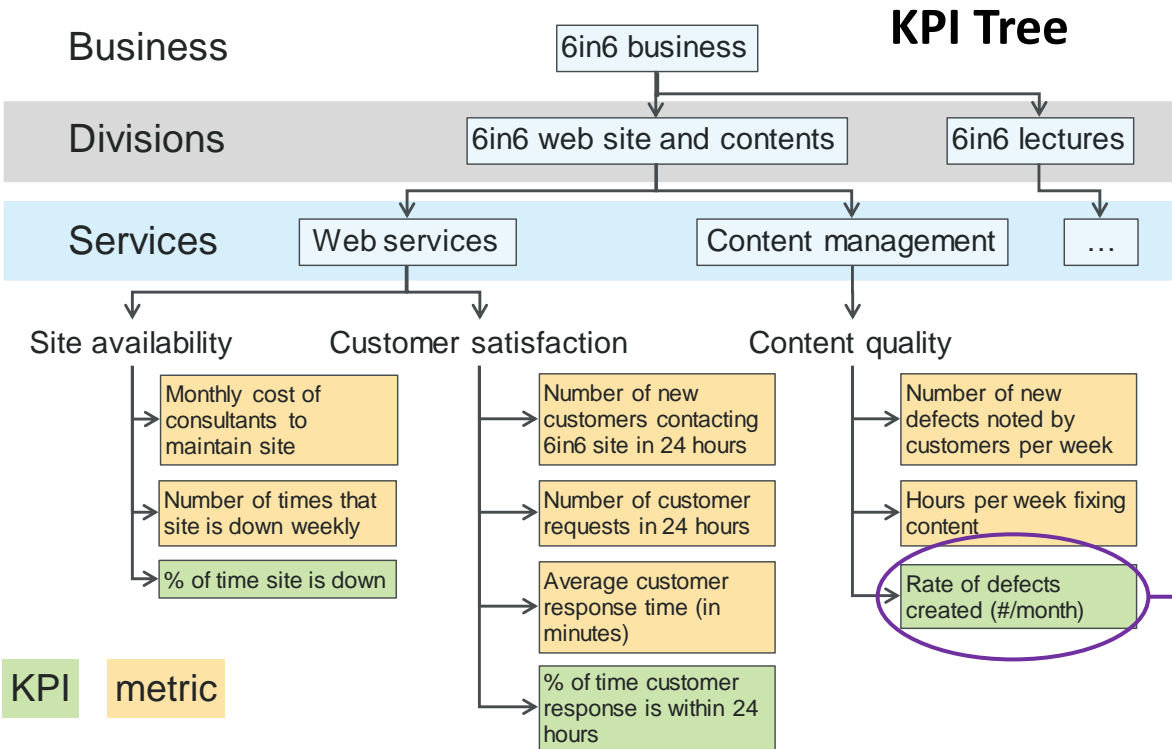
KPIs



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.

KPI metric

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

KPI operational definition

Mind Mapping

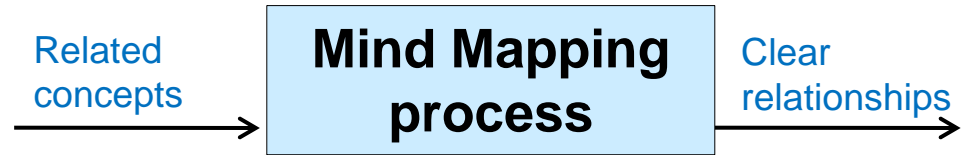
Problem

How to add detail to a concept?

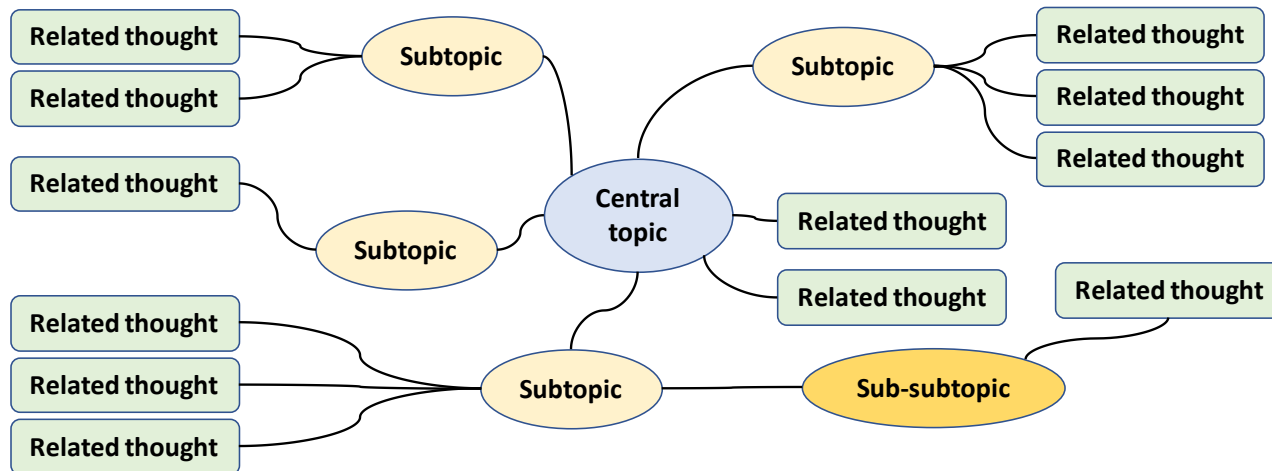
Difficulty

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.

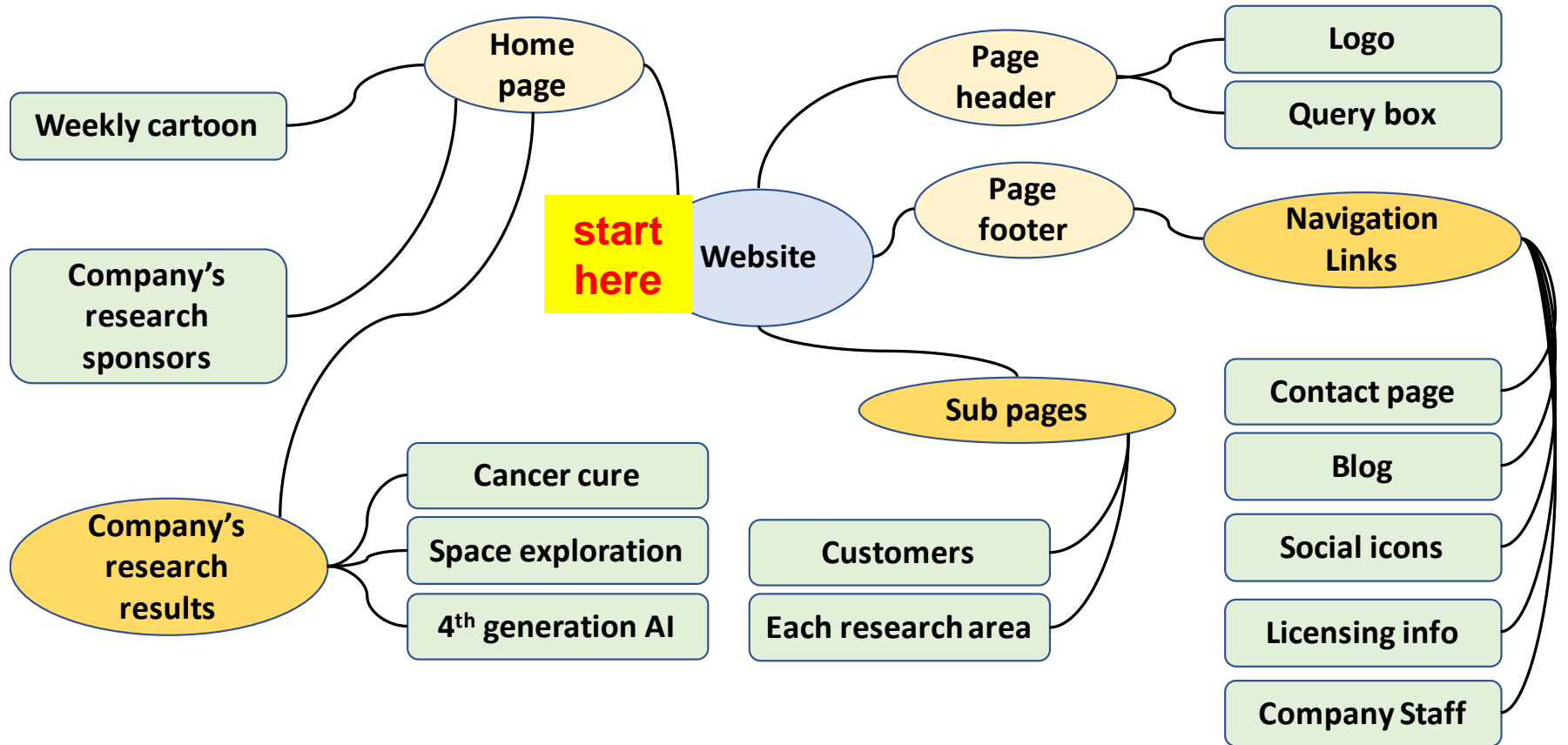


1. Start with a central topic and surround it by a bubble.
2. Recursively expand some of the bubbles by adding new related bubbles, and connecting them to indicate some type of relationship.



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

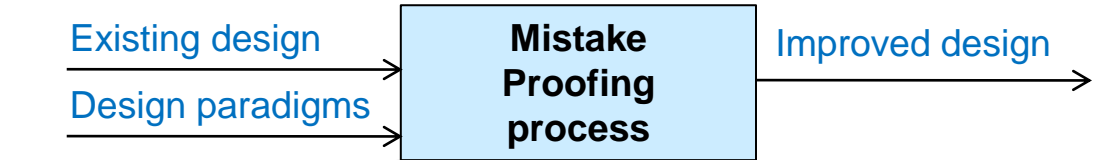
- **Mistake-Proofing** is identifying and correcting problems as close to the source as possible.
- Mistake-Proofing is useful for maintenance, operations, production, and servicing.



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

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”



Implement the following principles (as applicable)

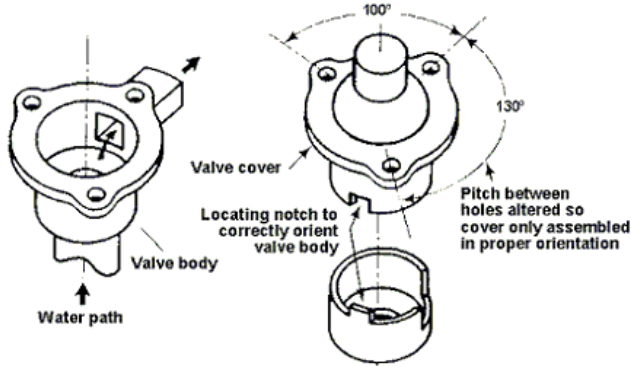
1. **Eliminate** – remove task/part that allowed errors
2. **Replace** – use a more reliable process
3. **Prevent** – change task/part to make errors impossible
4. **Facilitate** – make work easier to perform
5. **Detect** – identify & resolve before further processing
6. **Mitigate** – minimize the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

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>

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



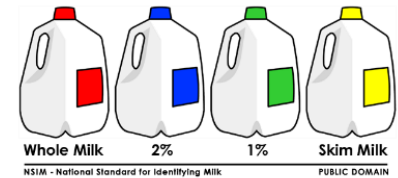
<https://www.parkinglotsafety.com/height-guard-clearance-bars.html>



Facilitate – Which dial turns on which burner?

<https://www.amazon.com/Cooktop-Burners-Stainless-Kitchen-Cooktops/dp/B09957VB52>

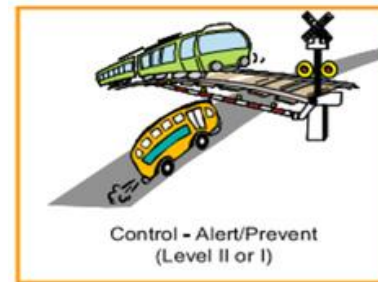
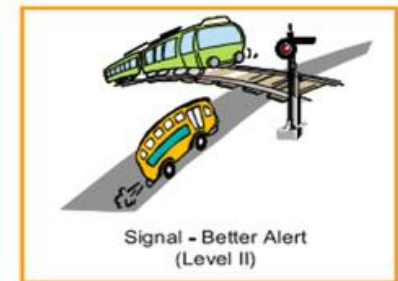
Detect – Milk containers use color to indicate fat content



NSIM - National Standard for Identifying Milk PUBLIC DOMAIN

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

Prevent – Different ways to avoid train/car collisions



<https://pbs.twimg.com/media/CMog9VxWoAAjfdi.png>

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

- List of items
- Knowledgeable 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)

Budget Priorities

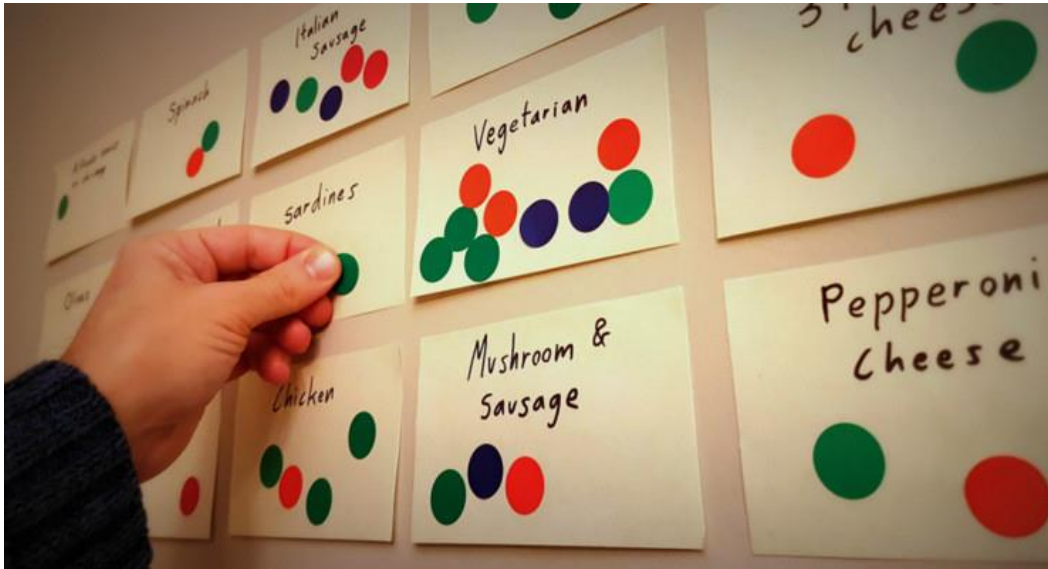
1	Attend more conferences	● ● ● ●
2	Hire a consultant	● ●
3	Hire more staff	● ● ● ● ●
4	New office equipment	
5	Upgrade computer SW	●

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

NGT – Examples

Figures

- <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

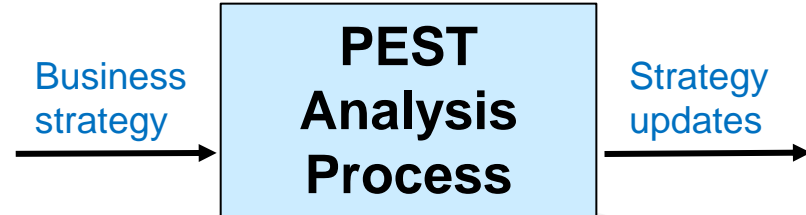
Problem

How to use external factors to update business strategy?

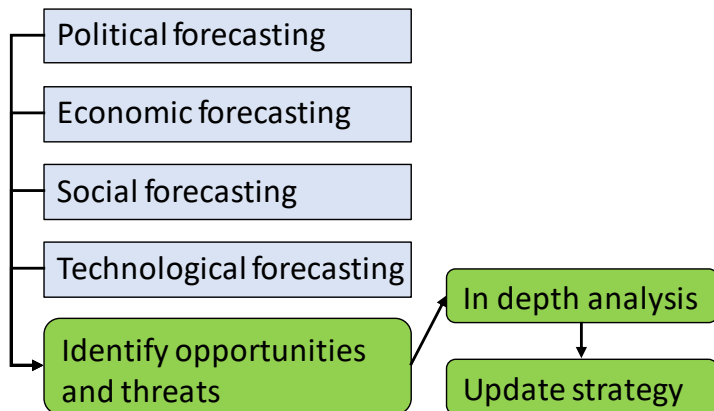
Difficulty

Some training required

- **PEST** (Political, Economic, Social and Technological) **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.



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	<i>A, B, ...</i>	<i>A=threat, B=opportunity, ...</i>	<i>citations</i>	<i>Ask X and Y about Z</i>	<i>know K</i>	<i>L is likely</i>	<i>Prevent P</i>
Economic	<i>...</i>						
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

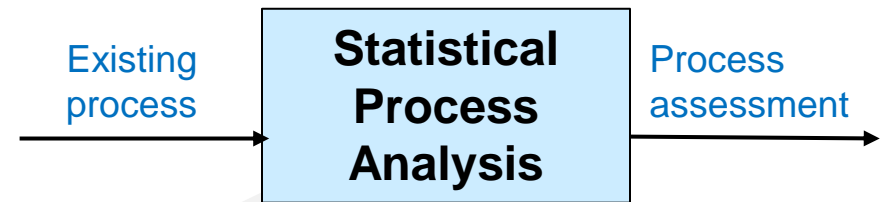
- **Process capability** is a statistical assessment of whether or not a process is *capable* and/or *centered*. You want both.
- Consider a car entering a garage:
 - *capable* ($C_p > 1$) means the car usually arrives at the same location,
 - *centered* ($C_{pk} > 1$) means the car enters the center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

Formulae

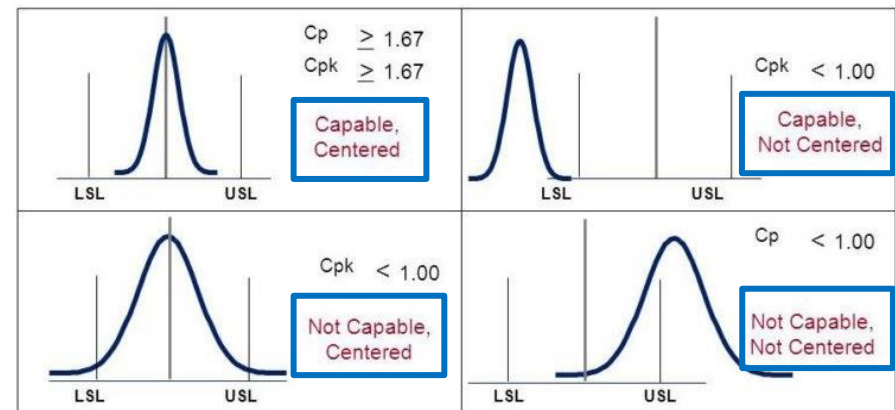
$$C_p = (USL - LSL) / (6*s)$$

$$C_{pk} = \text{minimum}((USL - m) / (3*s), (m - LSL) / (3*s))$$

- **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



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



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

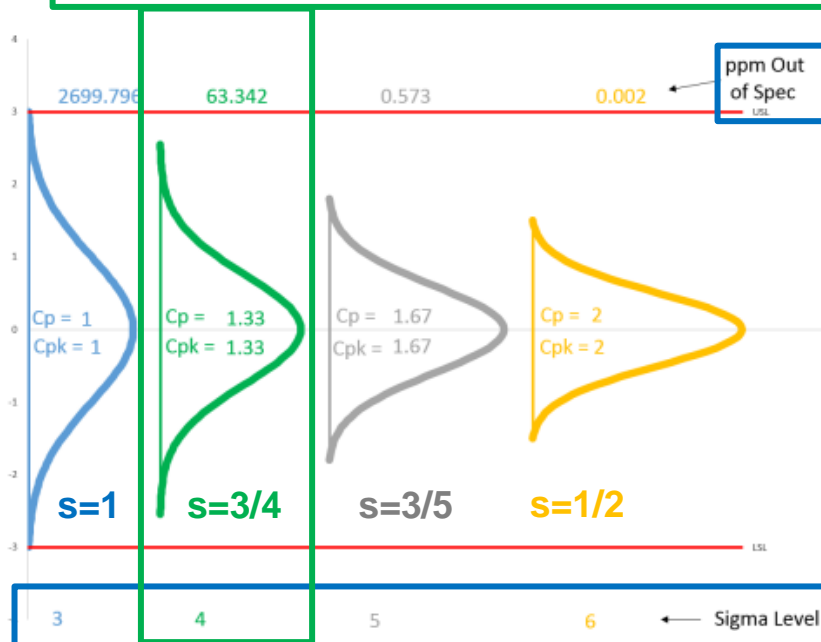
Process Capability metrics – Example

Consider the following case

- $m = \text{average} = 0$
- $s = \text{standard deviation} = \text{as specified below}$
- $LSL = \text{Lower Specification Limit} = -3$
- $USL = \text{Upper Specification Limit} = 3$

Decreasing variance \rightarrow fewer parts out of spec

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

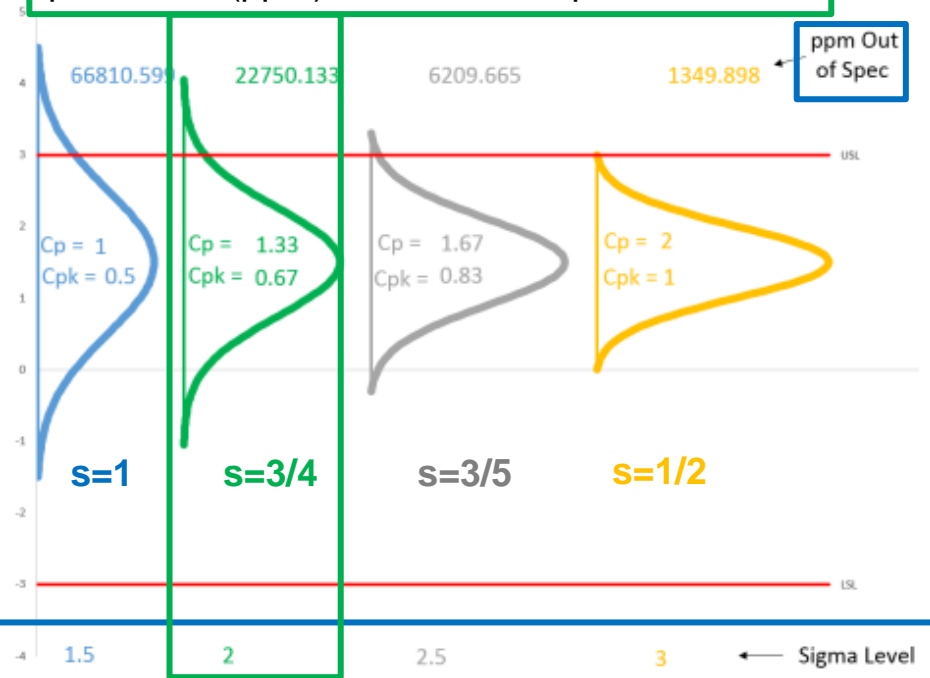


Change the example to have

- $m = \text{average} = 1.5$

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

Interpretation: if $s=3/4$ then, at a 2 sigma level, $C_p=1.33$, $CPK=0.67$, 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

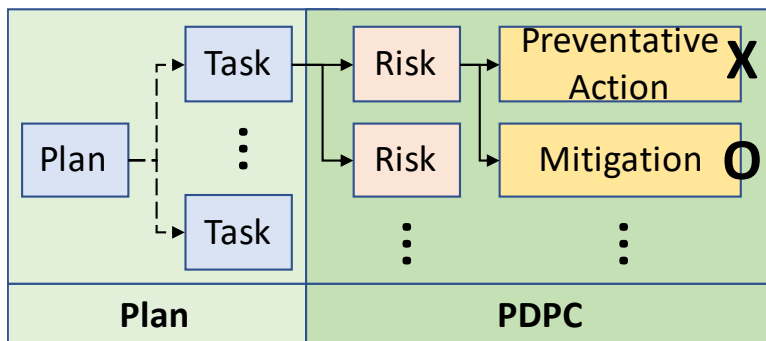
- A **Process Decision Program Chart (PDPC)** is a risk identification and mitigation tool.
- PDPC starts with a tree diagram representation of a program plan and systematically identifies risks by asking what-if questions.
- Using PDPC, you can revise the plan or prepared mitigations.

Preliminary plan →

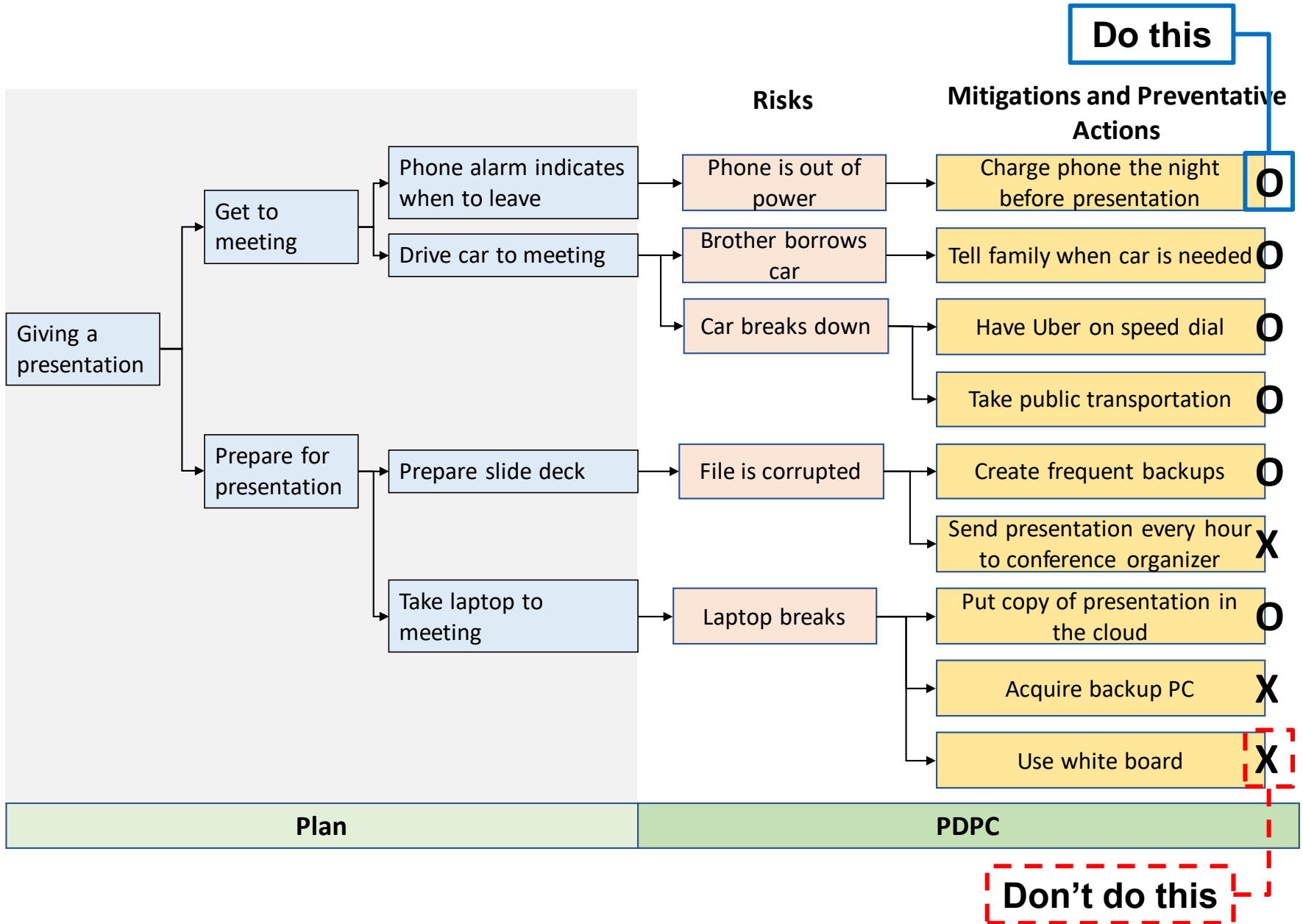
**PDPC
Analysis**

→ 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?

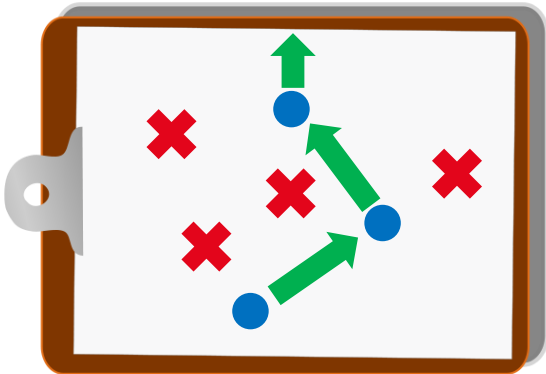
Difficulty

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.

PROJECT CHARTER						
Review #1	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.					
Review #1	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.					
Review #2	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				
Review #3	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				

“Could be good, tell me more”

“I like the idea, what will it cost?”

“Let’s do it! Where do I sign?”

Start project

Pugh Matrix

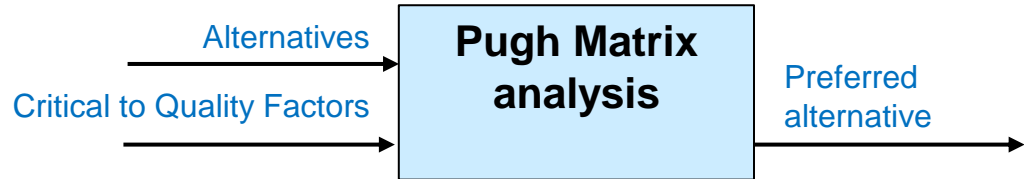
Problem

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

- Choose the alternatives to be compared
 - List them along the top of the matrix.
- 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).
- Define one of the alternatives as the **Reference Design**.
- 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.
- 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					Criteria weights
		Nissan Ariya	Volkswagen ID4	Chevrolet Bolt	Tesla Roadster	Mercedes-Benz EQC	
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	

(1) Reference Design

(3) Weighted case: each criteria has a weight

(2) Team created comparison values

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

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

(6) Best alternatives

- Weighted: 4 is highest value
- Unweighted: 0.7 is highest value

Qualify Function Deployment (QFD)

Problem

How to select “how”'s to meet a “want”'?

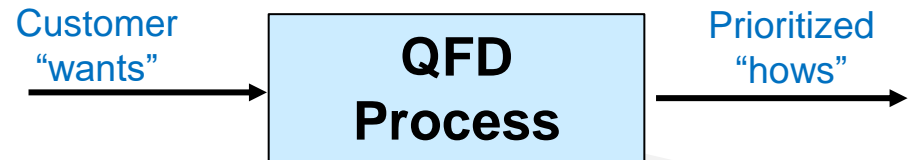
Difficulty

Some training required

Quality Function Deployment (QFD)

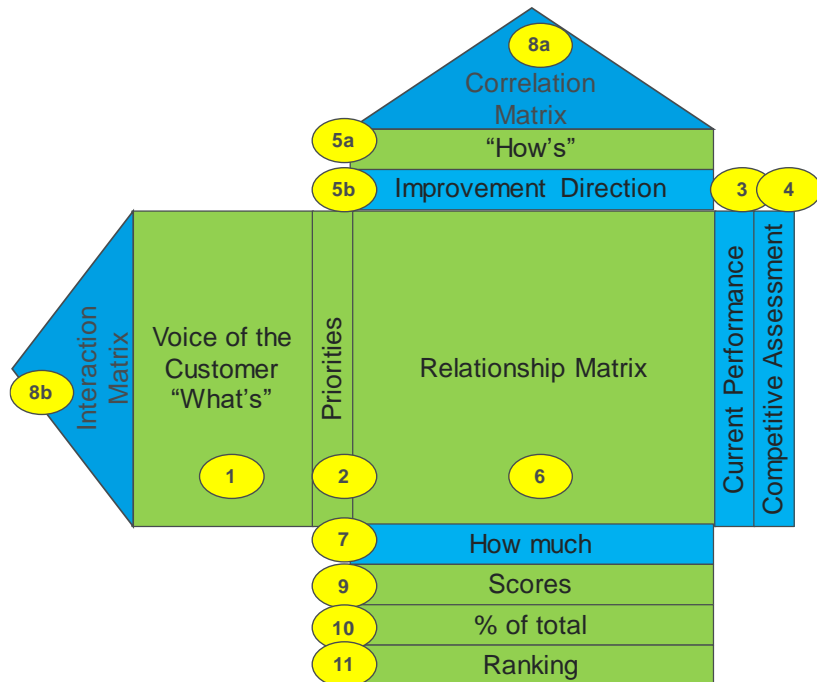
translates a customer’s “wants” (“What does the customer want?”) into “hows” (“How can we satisfy the customer wants?”).

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



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



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

Minimal

Optional

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

Customer "what's"	Priority	Hows				
		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

1: what the customer cares about

9: These are the scores divided by 299

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

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

6: these are the mathematical "inner product" of each "how" with the priorities. For example: $93 = 1 \cdot 9 + 9 \cdot 9 + 3 \cdot 1$. 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.

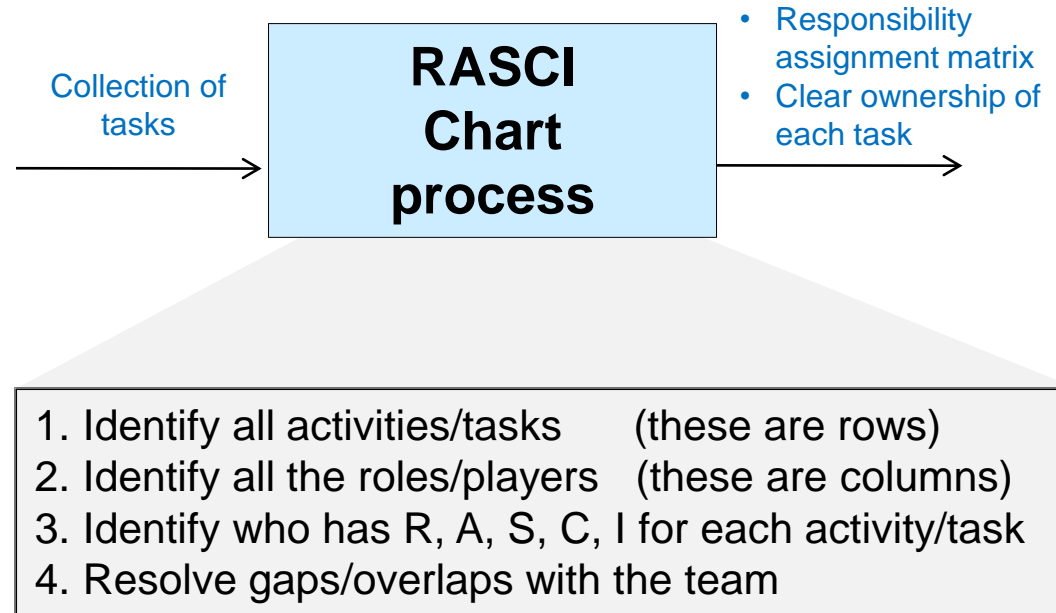
RASCI (Responsible / Accountable / Support / Consulted / Informed) Chart

Problem
How to represent task roles?

Difficulty

Easy to use

- **RASCI** is a tool to determine *Roles and Responsibilities* for tasks.
- With RASCI, every person involved in a task has a well-defined role.
- The “Accountable” (A) 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.



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.

	Jeff	Michael	Retro	YOU	Alex	Anna	Bill	Cindy	Felix	Fred	Hans	John	Livio	Luc	Marco	Paul	Peter	Sue	Ted	Tim	
Planning / Schedule	R	A	I	C						C											Q
Risk Management		I	I	Q						A								R			
Quality Management			R	C						R											A
Procurement				R	Q					R								R			A
1. Specifications Listing								A		R								R			R
2. Site Requirements		C	A	R	Q						R										
3. Call for Tenders				Q	A	R	C				R										R
4. Budget Approval				A	Q					R								R			R
5. Contract Negotiations			A	Q	R	R												R			

* R – Responsible (works on), A – Accountable, C – Consulted, I – Informed, Q – Quality Reviewer

https://commons.wikimedia.org/wiki/File:RACIQ_Chart_-_Responsibility_Assignment_Matrix.jpg

RASCI – Example – Creating a 6in6 presentation

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

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

Notes

- To create a new 6in6 presentation, several subtasks need to be performed (read bottom-up).
- A single person may have multiple roles.
- There is only one “A” each task/row (the accountable person)
- There is at least one “R” for each task/row (the responsible person/people)
- Color coding the {R,A,S,C,I} can make a RASCI chart easier to review.
- 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
- Everyone knows what their role is for each part of the 6in6 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.

Problem statement

Reverse Brainstorming Process

Problem improvements

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.

Original problem

Reversed problem

Make problem worse

Prevent worsening

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?

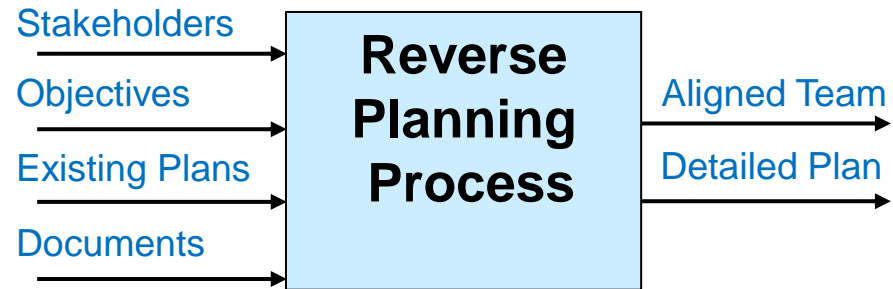
Difficulty

Some training required

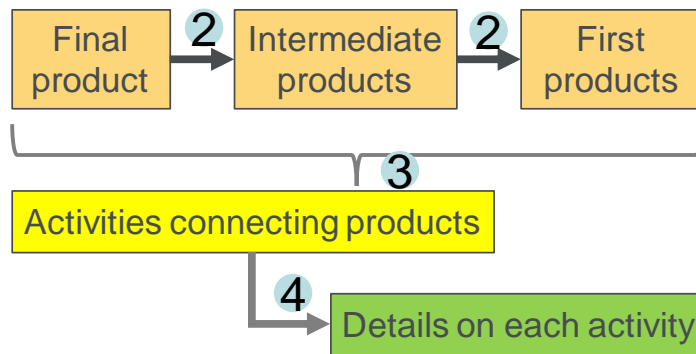
Reverse Planning is a high energy team-building approach to develop schedules based on network logic.

When should I use it? When ...

- determining needed activities
- building a schedule
- creating a detailed plan to support an existing schedule



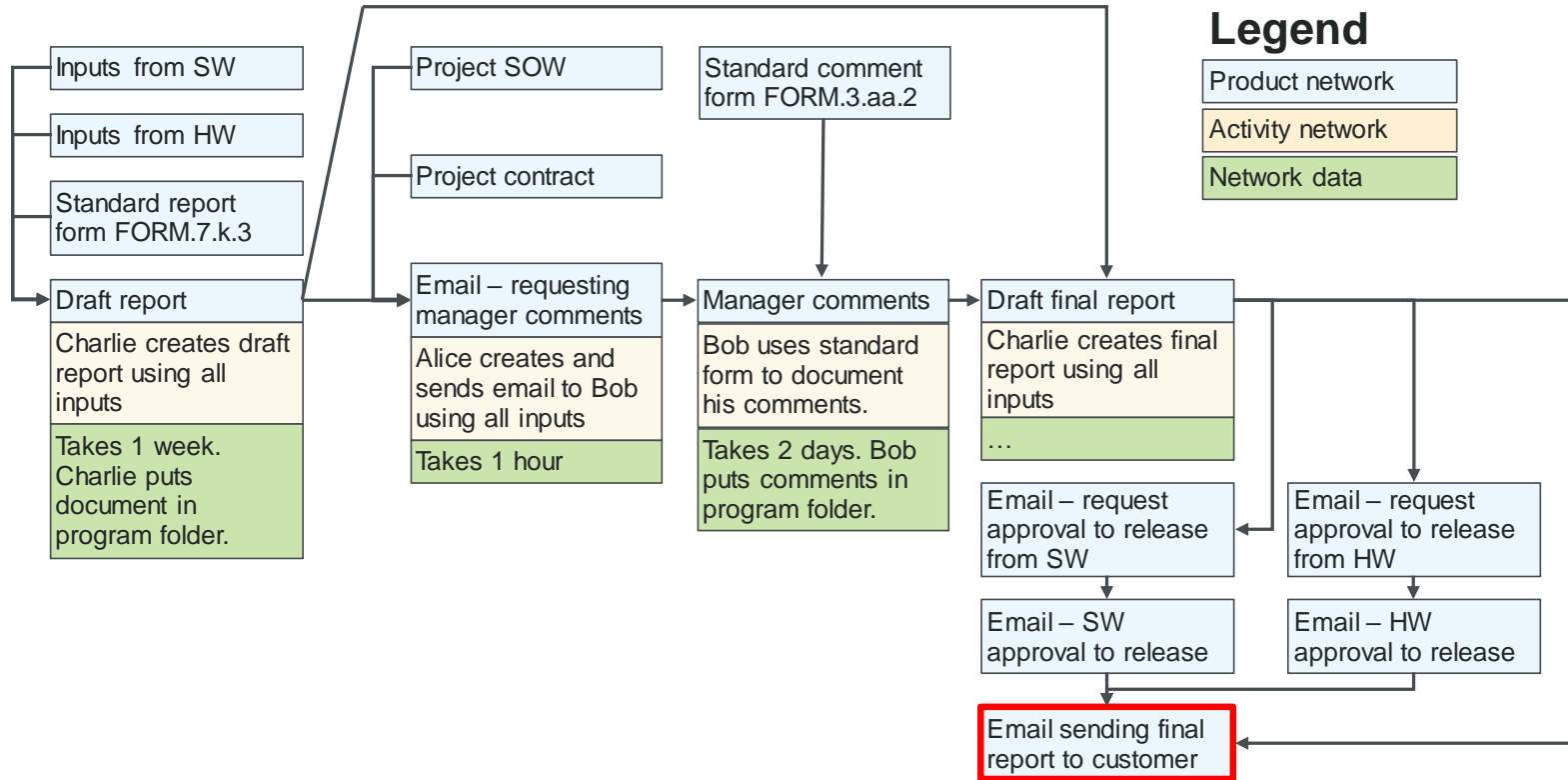
Reverse Planning Process



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

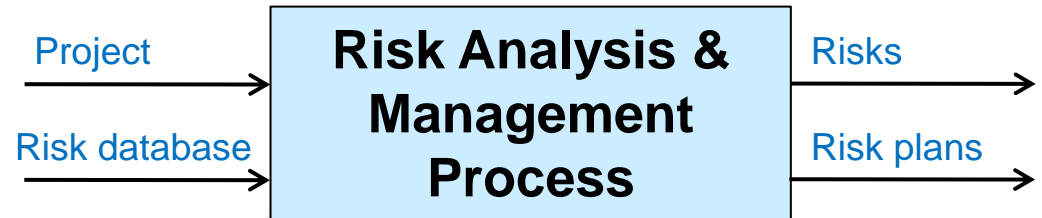
Problem

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)

Existing product or process

SCAMPER Process

Improved or new product or process

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)

Planned meeting →

SPACER process

Info to present at 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

	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?

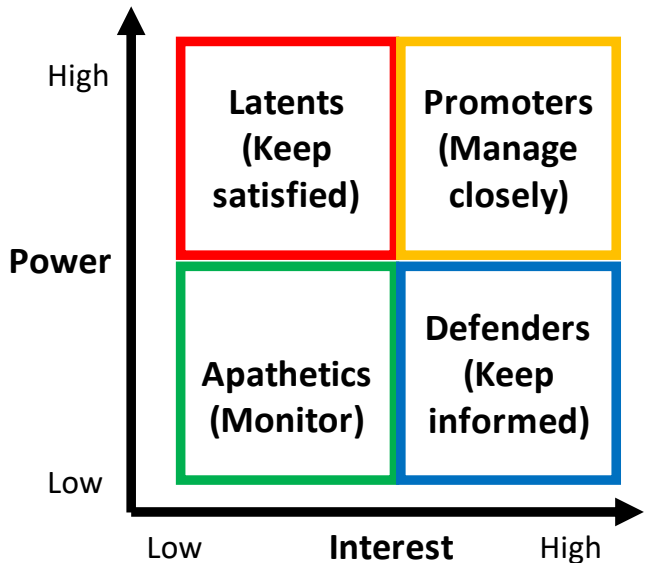
Difficulty

Some training required

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



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 Power/Interest matrix

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

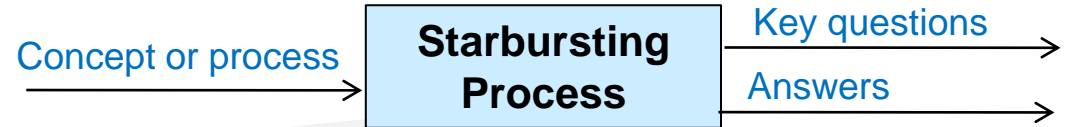
Problem

How to create appropriate brainstorming questions?

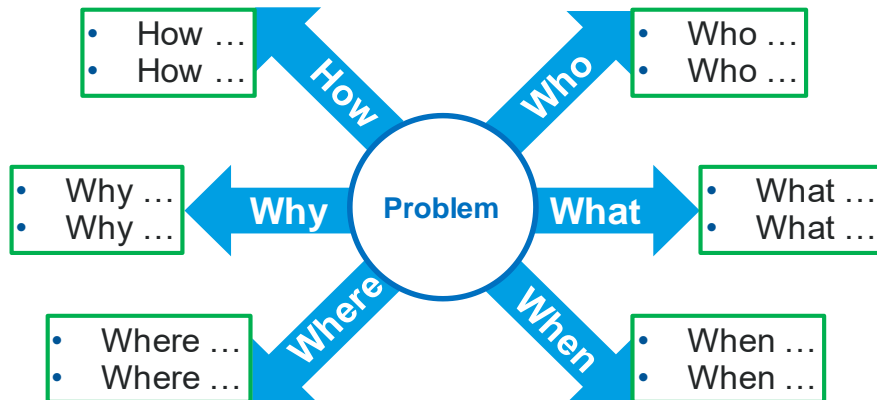
Difficulty

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.



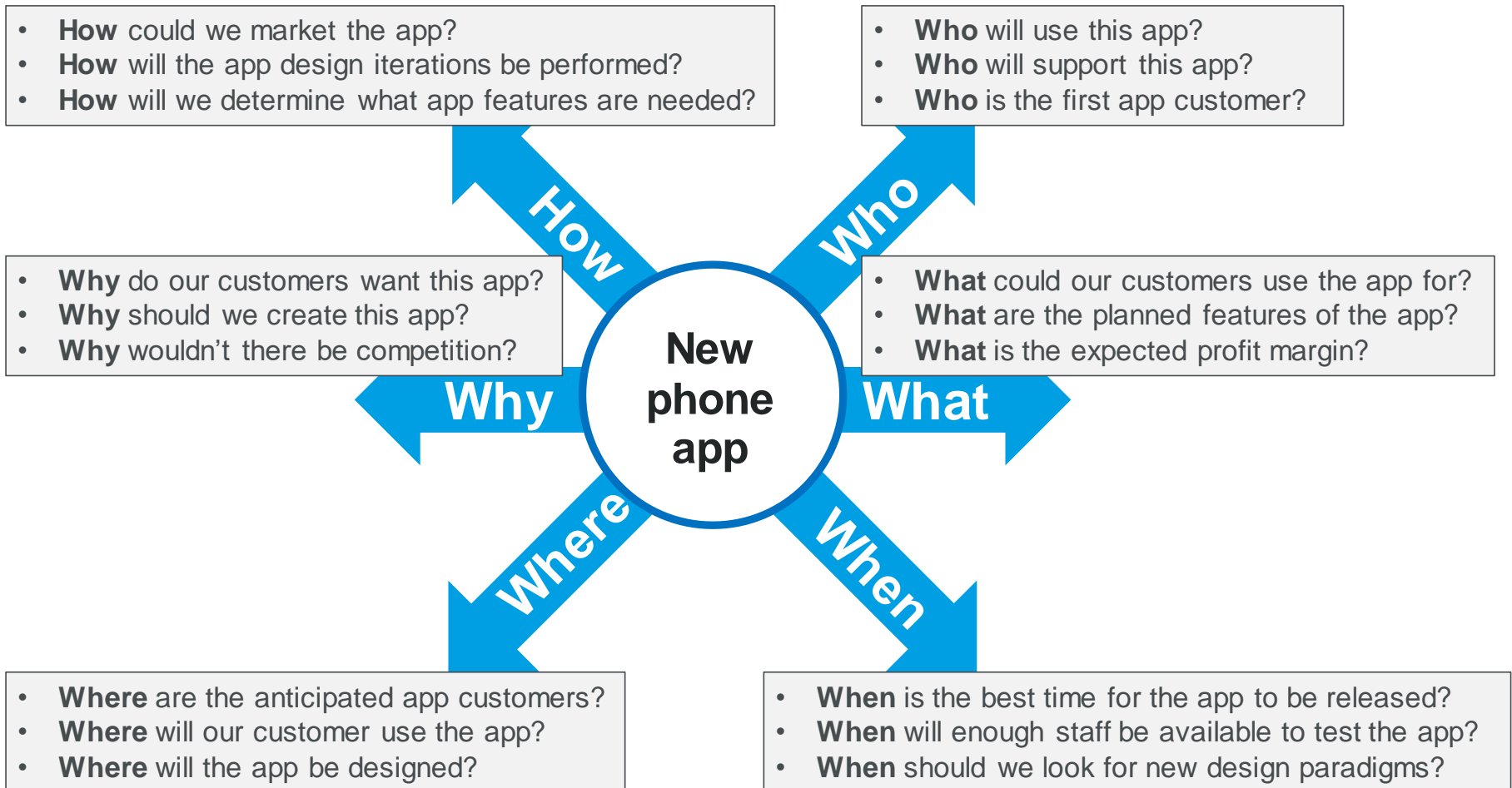
1. Construct a **six-pointed star**
 - A. Put the concept, process, problem, product or service in the center of the star.
 - B. Add the five 'W's and the 'H' at the star's points.
2. For each of the six star points, **create questions** for the word at that star point and write them down
 - A. Do not 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) / Control Charts

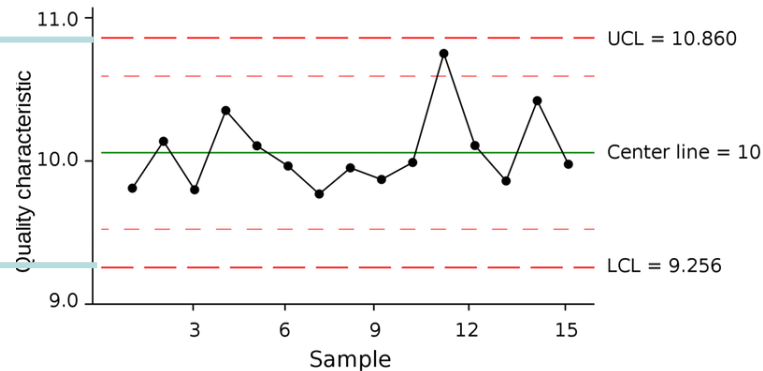
Problem

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)

<https://neatec.org/event/introduction-to-statistical-process-control-spc-for-college-faculty/>

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

One way, for hand analysis, is to use “Western Electric rules” (shown below)

- **Step 0** – find the process’ sample mean (m) and standard deviation (s)
- **Step 1** – For symmetric control limits, use ± 3 sigma
- **Step 2** – define 3 “zones”
 - Zone C \rightarrow region within $1s$ of m
 - Zone B \rightarrow region between $1s$ and $2s$ of m
 - Zone A \rightarrow 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.

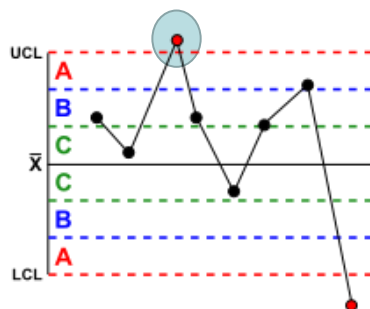
For discrete defect data, the different control charts are p, np, u, and c.

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

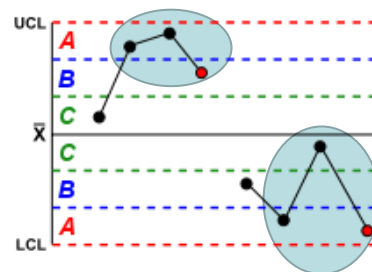
Many other rules have been described:

- 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 – which is not an (m,s) chart.
https://en.wikipedia.org/wiki/Western_Electric_rules

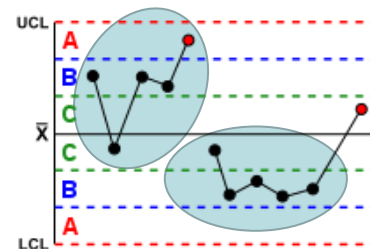
Rule 1: Any point beyond Zone A



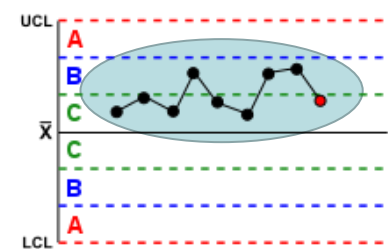
Rule 2: two out of three consecutive points fall Zone A or beyond



Rule 3: Four out of five consecutive points fall Zone B or beyond



Rule 4: Nine consecutive points on the same side of center line (mean)



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

SWOT (Strength / Weaknesses / Opportunities / Threats)

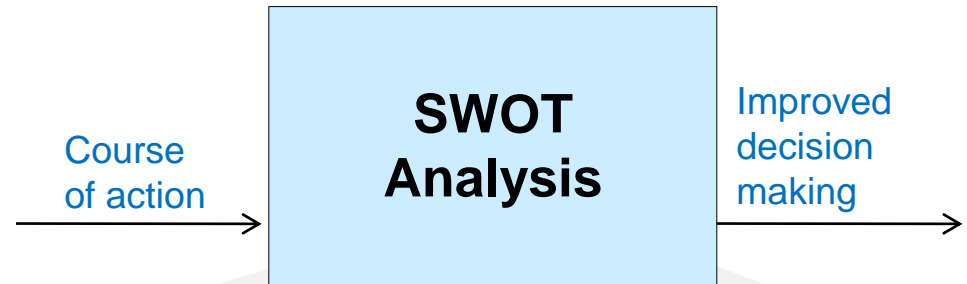
Problem

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

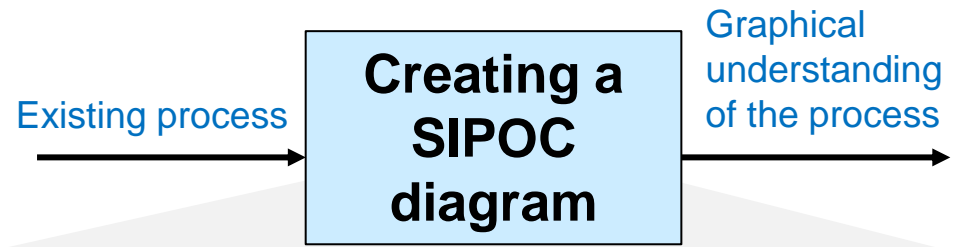
Problem

How to explain a business process?

Difficulty

Some training required

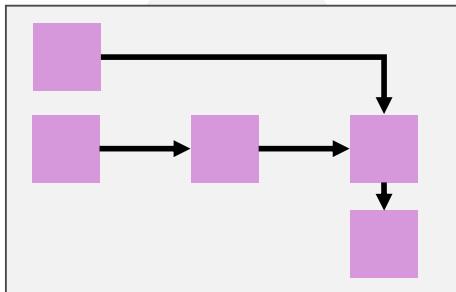
- A **SIPOC** diagram shows an end-to-end business process, from suppliers (S) to customers (C).
- Without the “S” and “C”, a SIPOC diagram is an **IPO** diagram.
- A SIPOC diagram explains a business process, keeps team members aligned, and clarifies parts of a process.
- A SIPOC usually fits on one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



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.

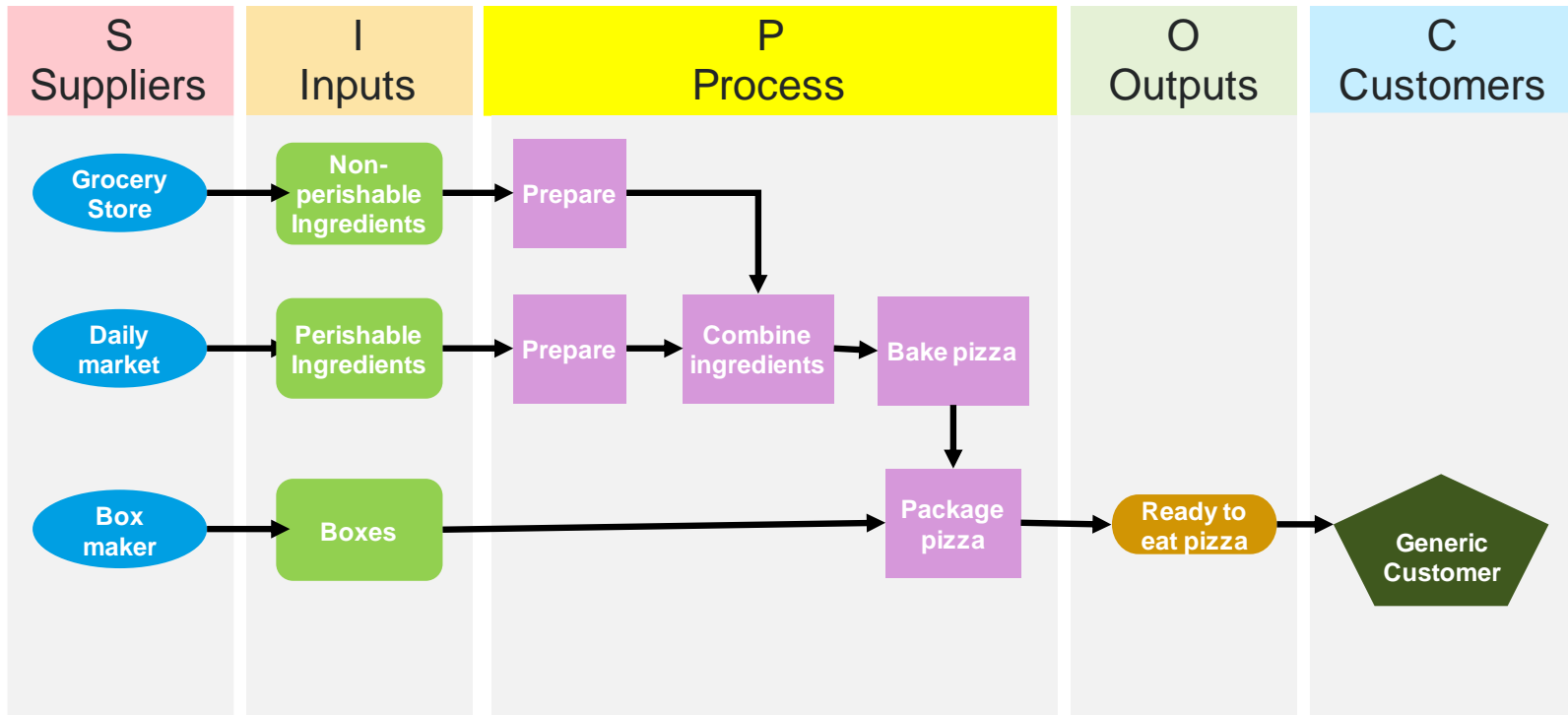
Terms

- **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

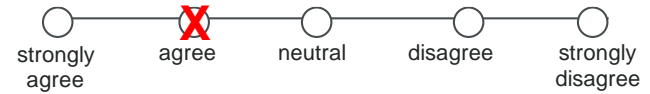
Surveys – Example – Assessing 6in6 usefulness

Do you like the 6in6 presentations?

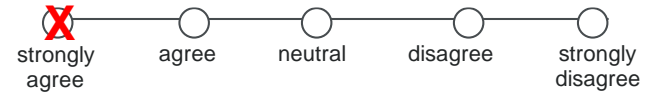


(Rating scale question)

1. The 6in6 website has a user friendly interface

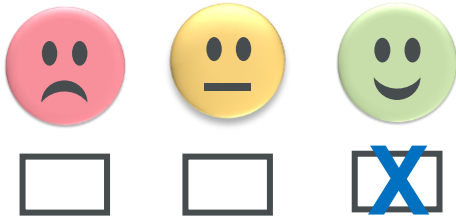


2. The 6in6 website is easy to navigate



(Likert scale questions)

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



Is a video presentation needed for each topic?



(Dichotomous question)

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



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



The 3 things you find most important about 6in6 presentations

- | | |
|---|---|
| <input checked="" type="radio"/> Clarity of presentation | <input type="radio"/> Ease of contacting author |
| <input type="radio"/> Useful for teamwork | <input type="radio"/> Large collection of tools |
| <input type="radio"/> Explanatory examples | <input type="radio"/> Website responsiveness |
| <input checked="" type="radio"/> Ease in finding appropriate tool | <input checked="" type="radio"/> Cost (free!) |

(Multiple choice question)

6in6 site comments

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

Theory of Constraints (TOC)

Problem

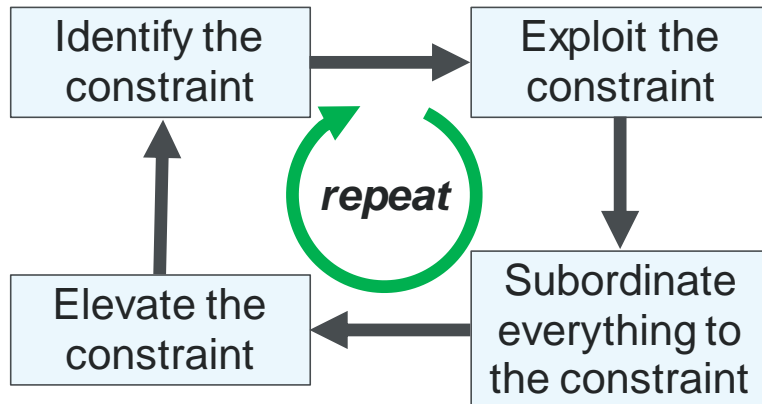
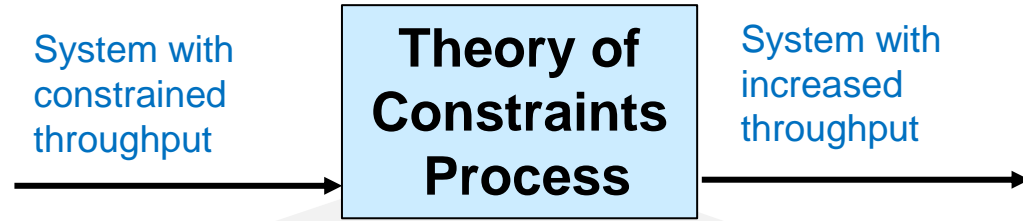
How to identify and remove bottlenecks?

Difficulty

Some training required

The **Theory of Constraints (TOC)** states:

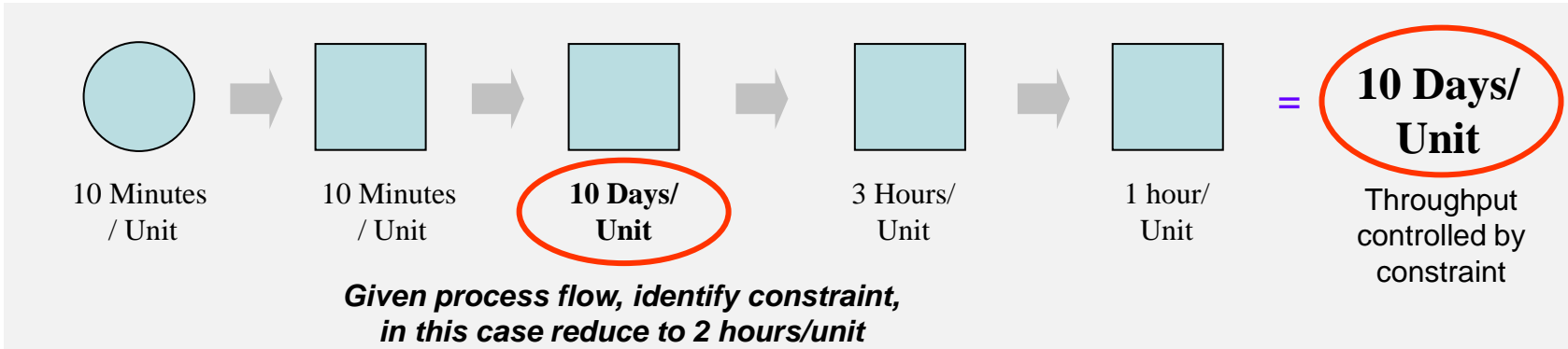
- System throughput is limited by a bottleneck, called the *system constraint*.
- An increase in throughput can only be achieved by making an improvement in the system constraint.
- Improvements in other parts of the system are wasted effort.



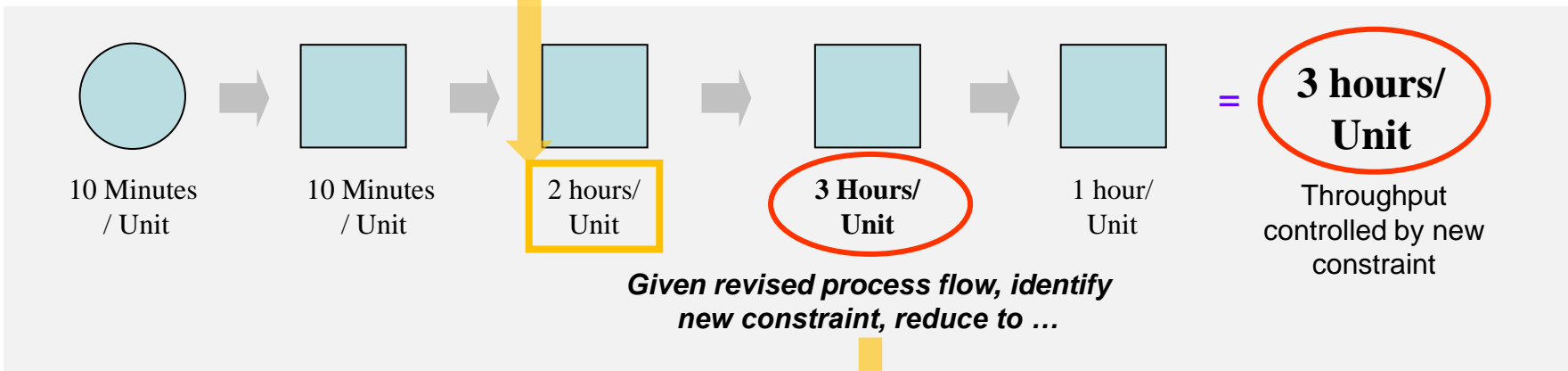
1. **IDENTIFY** the constraint
 - This is the resource preventing the process from obtaining more of the goal.
2. **EXPLOIT** the constraint
 - Ensure the constraint's time is not wasted doing things that it should not do.
3. **SUBORDINATE** all other processes to the above decision
 - Align the whole 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



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



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

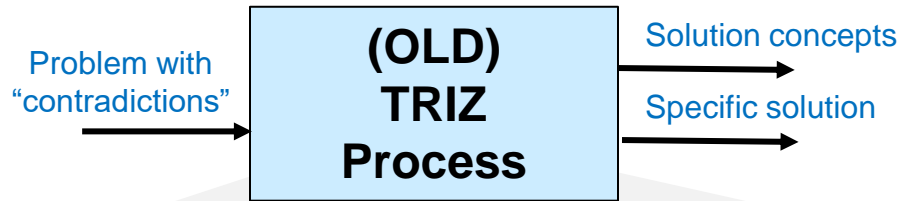
- **TRIZ** is a problem-solving tool obtained from invention patterns in the patent literature.
- TRIZ's approach is that a solution, for something close to your problem, has already been found. The goal is to find that solution and adapt it to your problem.
- Modern TRIZ uses "76 standard solutions."
- (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

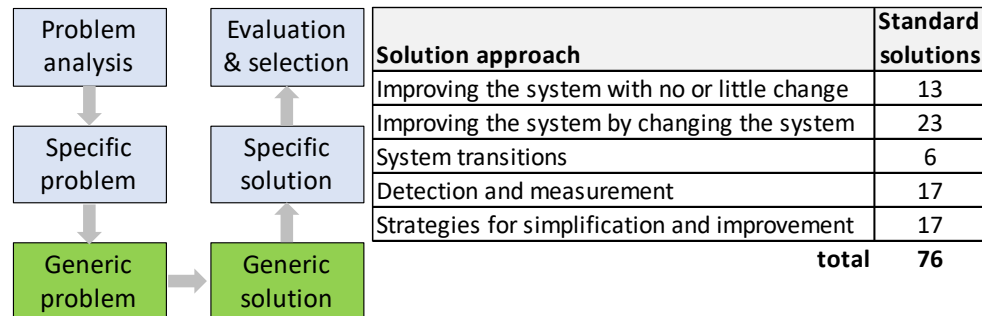
1. Weight of moving object
2. Weight of stationary object
3. Length of moving object
4. Length of stationary object
5. Area of moving object
6. Area of non-moving object
7. Volume of moving object
8. Volume of stationary object
9. Speed
10. Force
- ...
38. Extent of automation
39. Productivity

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



(OLD) TRIZ – 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

(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.

Worsening Feature		1	2	3	4	5	6	7	8	9	10	11	12	
Features		1	2	3	4	5	6	7	8	9	10	11	12	
Improving Feature	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 25	1 8 10 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 36 28	5 34 29 4	
	6: Area of stationary	-	30 2 14 18	-	26 7 9 39	-	*	-	-	-	1 18 35 36	10 15 36 37	-	2
	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 5 36 37	1 15 29 4	2 1
	8: Volume of stationary	-	35 10 19 14	-	35 8	-	-	-	*	-	2 18 24 35	7 2	3	3

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

(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.

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

(5) Possible results



Thumb Voting

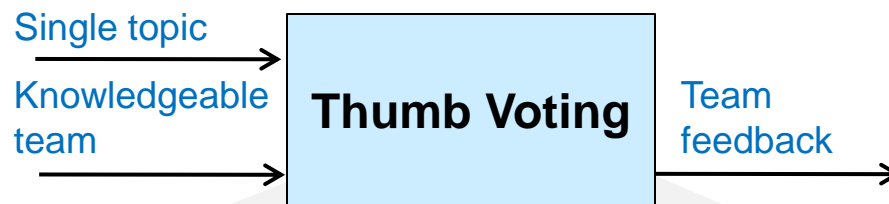
Problem

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 assesses 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://freesvg.org/thumb-up-symbol-with-right-hand>

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://freesvg.org/thumb-up-symbol-with-right-hand>

Value Chain Analysis (VCA)

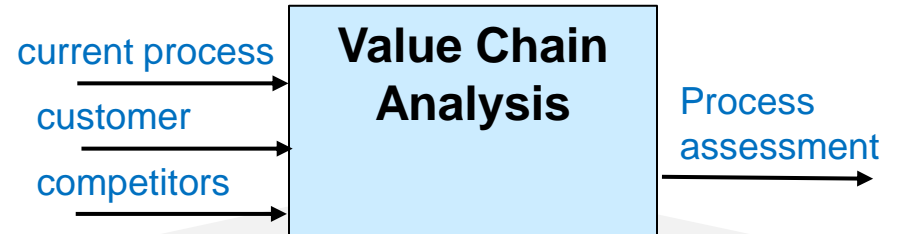
Problem

How to identify customer care abouts?

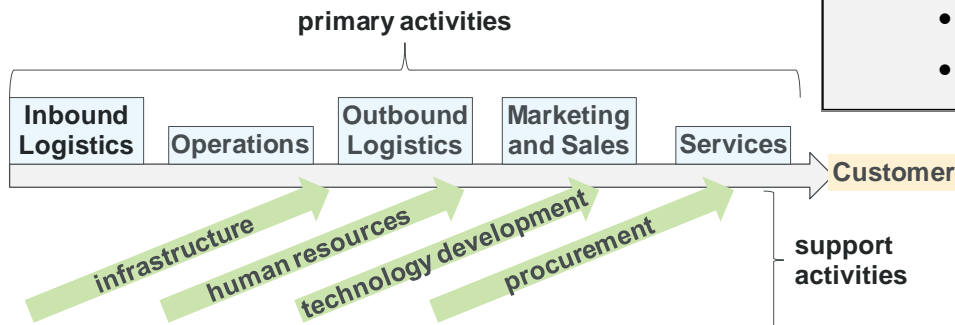
Difficulty

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

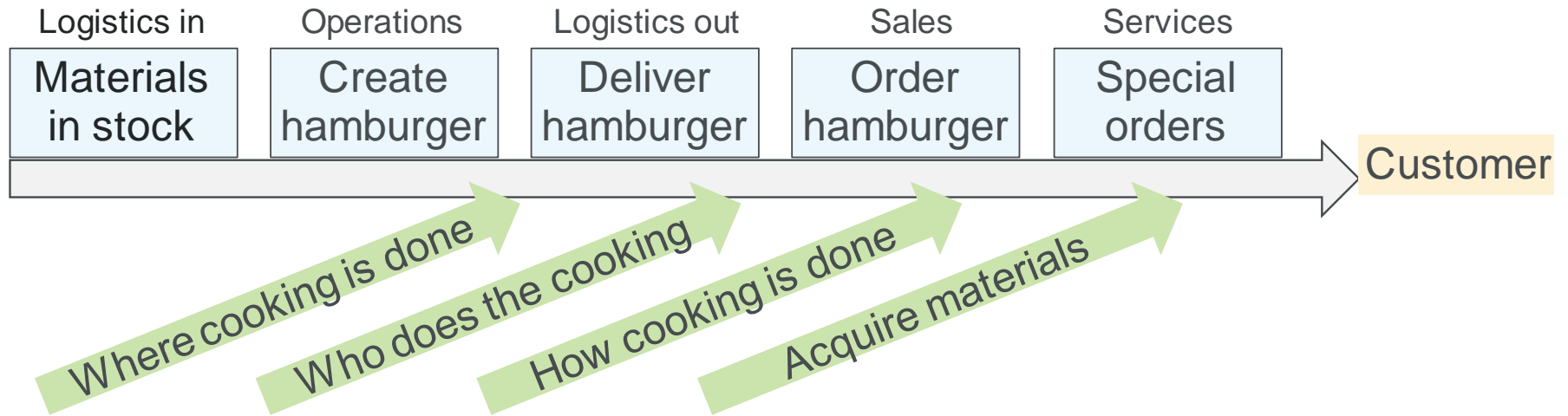


1. Assess your product's activities, such as:
 - **Primary activities**: Inbound Logistics, Operations, Outbound Logistics, Marketing and Sales, and Services.
 - **Support activities**: Infrastructure, Human Resources, Procurement, and Technology.
2. Analyze the value and cost of these activities.
3. 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)

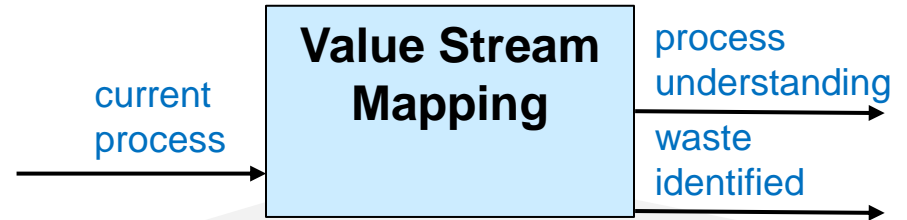
Problem

How to add value for your customers?

Difficulty

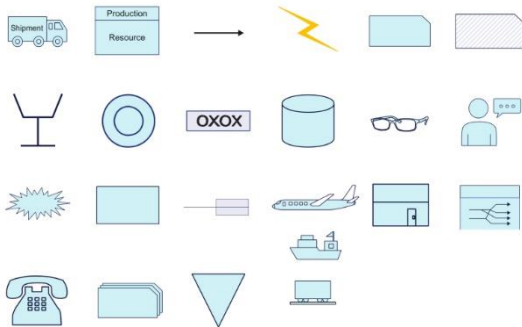
Work with an SME

- 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.



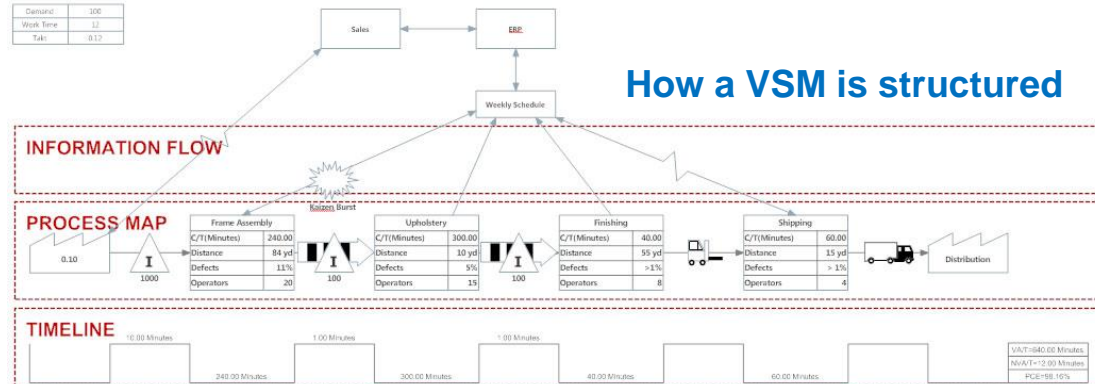
1. Assess your product's or service's steps. For each step, determine:
 - The work and wait **times**
 - The **labor needs** (including overtime)
 - The **error rates**
 - The system **downtime**
 - The **inventory level** (excess or shortfall)
 - The production or process **delays**
2. Create a graphic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

Some standard VSM icons



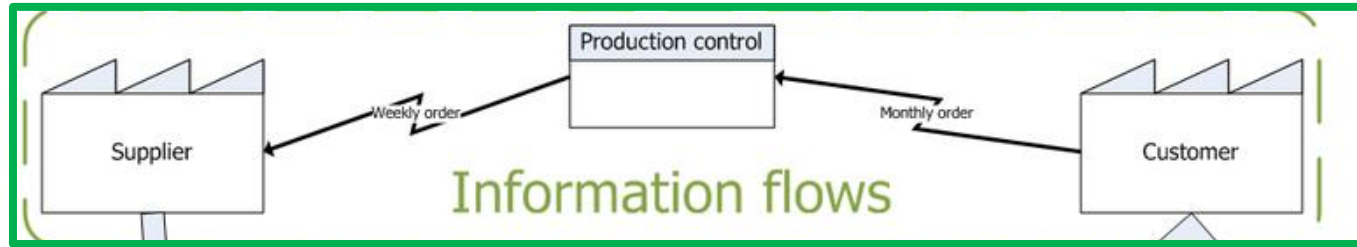
<https://www.edrawmax.com/article/value-stream-mapping-symbols.html>

Demand:	100
Work Time:	11
Takt:	0.12



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

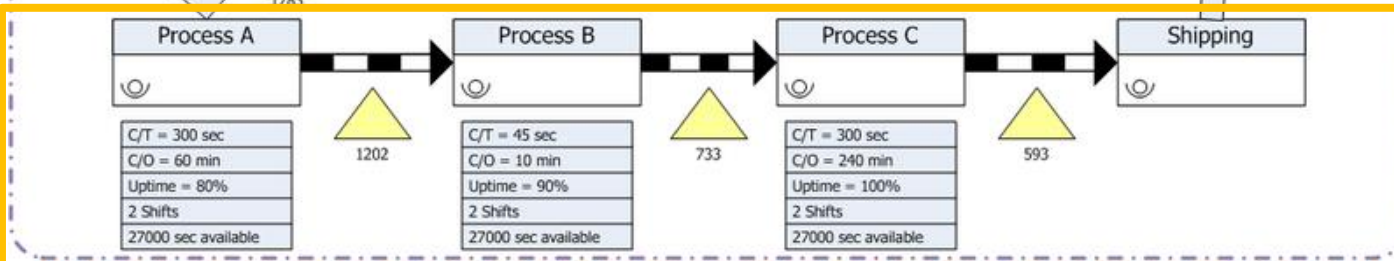
Value Stream Mapping – Example – Generic Factory



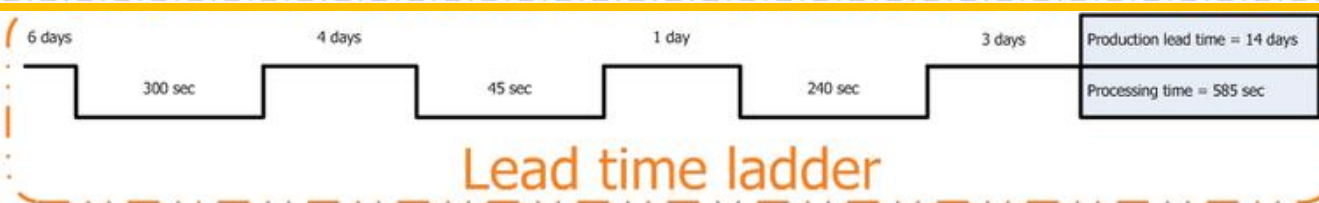
This shows how the **orders flow**.



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**:

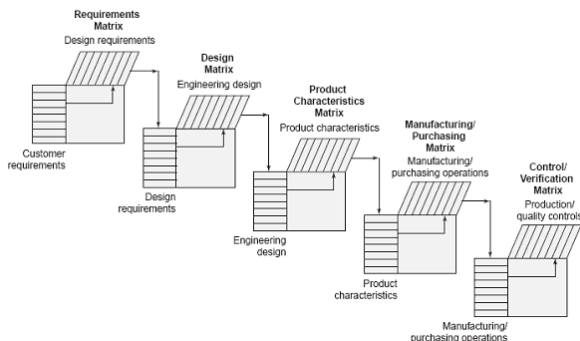
- Wants
- Functions
- Don't wants
- Features

VOC flows through the value stream:

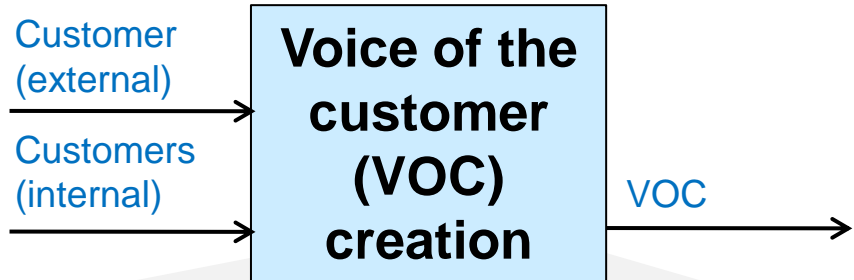
1. **C**ustomer to (e.g., NASA)
2. **c**ustomer to (e.g., Bus Develop)
3. **c**ustomer to (e.g., Systems Eng)
4. **c**ustomer to (e.g., Hardware)
5. **c**ustomer to (e.g., DFMA team)
6. ...

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>



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**.

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.

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

Satisfaction scale

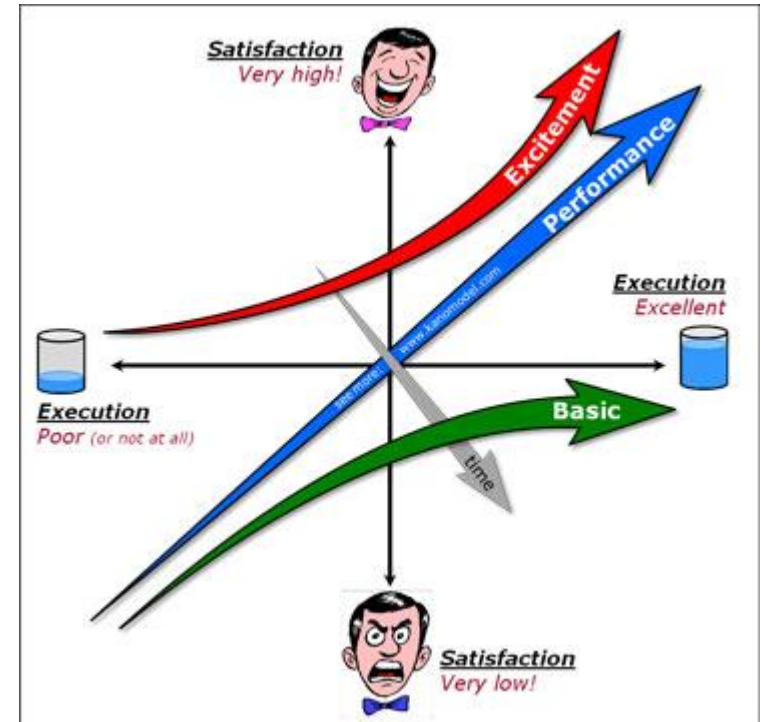


1. Delighted
2. Satisfied
3. Neutral
4. Dissatisfied
5. Frustrated

Functionality scale



- None
Some
Basic
Good
Best
- 1.
 - 2.
 - 3.
 - 4.
 - 5.



<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