Root Cause Failure Analysis

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DECEMBER 2016

RCFA

- RCFA is a reliability technique used to identify the casual factors for component, equipment, or system failures.
- The key to a successful RCFA program is to identify and implement a set of recommendations that address the cause of each failure that is analyzed.
- RCFA is the best way to understand why a critical component or a piece of equipment failed and what is required to prevent such failures again.

RCFA

- RCFA is a major evolution component in engineering sectors such as metallurgy, welding, process control, electronics and other.
- RCFA is the general approach for discussed and the implementation of a procedure that is applicable to wide range of situations is described in detail.

RCFA

- Root cause failure analysis is trying to understand why something went wrong…
- RCFA identifies the basic source or origin of the problem so that recurrence of the problem may be prevented.
- RCFA provides a methodology for investigating, categorizing, and eliminating the root cause of incidents safety, quality, reliability &manufacturing process consequences…

RCFA

- RCFA is a tool to better explain what happened, to determine how it happened and to better understand why it happen…
- When the facts are backed up by evidence & science and they are separated from the fiction we now have a better understanding as to the real root cause of the problem.

Analyst

- Analyst are manufacturing detective.
- Analyst act like detectives when analyzing failures, since failures leave some sort of clues when they occur.
- Every equipment failure happens for a number of reasons. There is definite progression of action and consequences that leads to a failure.
- RCFA investigation traces the cause and effect trail from the end failure back to the root cause much like a detective trying to solve a crime.

Ways to know cause

- Symptom
- Problem
- Root cause

- Exercise: Specify 3 ways of know cause in your problem of happened in your company.

RCFA Implementation

- Data collection
- Assessment

1. Human roots
2. Physical roots
3. Latent roots

- Corrective action
- Inform
- Follow-up

Causes

- Human causes:

The human errors of omission or commission that resulted in the physical roots. Someone did something wrong or did the wrong things.

- Physical causes:

This is the physical reason why the parts failed. This is the technical explanation on why things broke or failed.

- Latent cause:

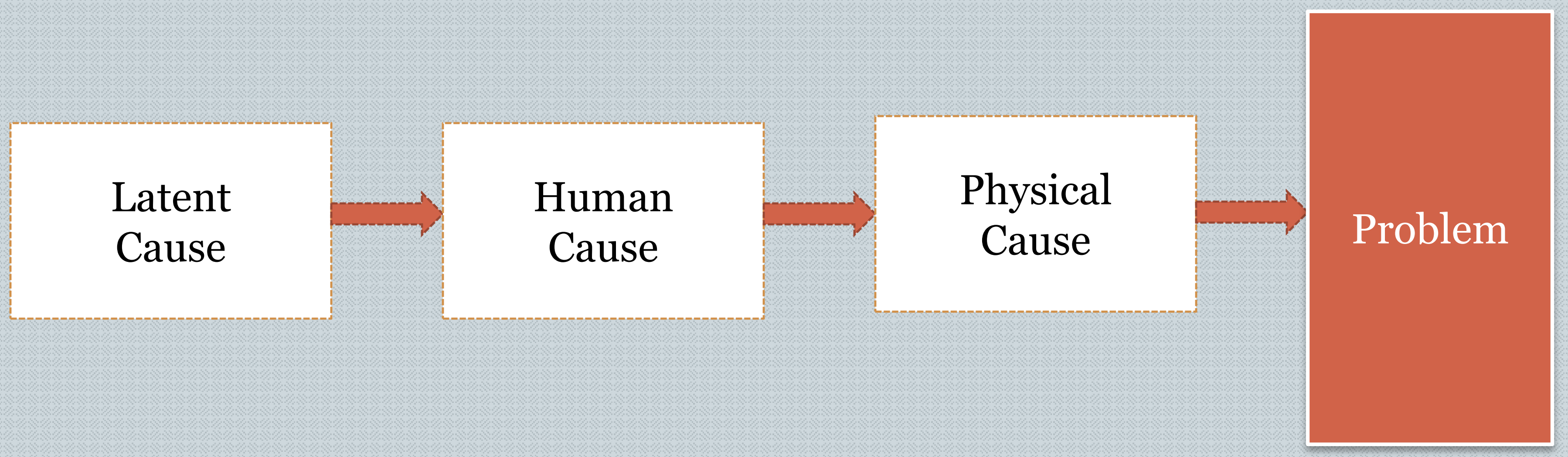
The deficiencies in the management approaches that allows the human errors to continue unchecked.

Flaws in the system & procedures.

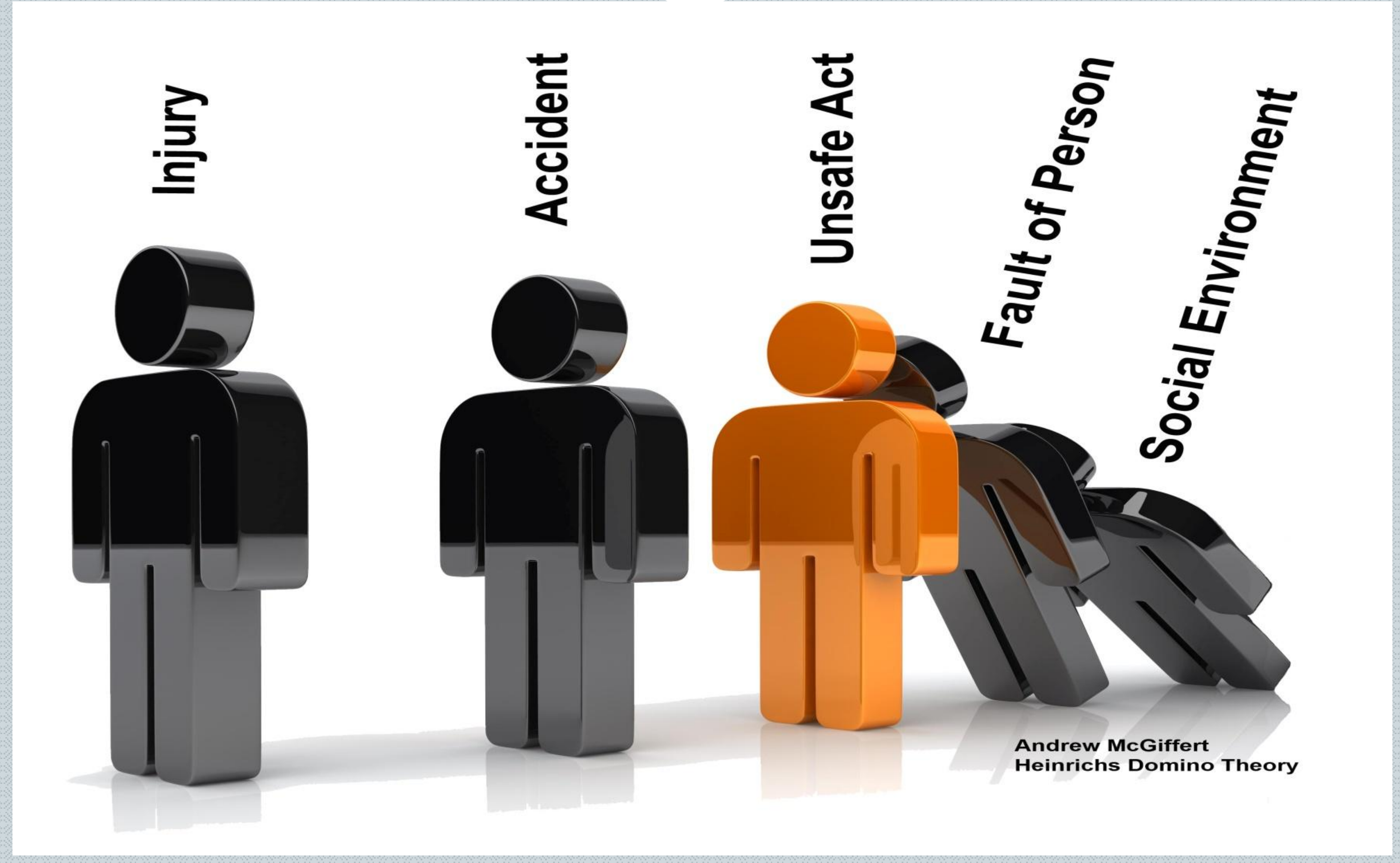
Unintentional human fault

- Lack of awareness
- Lack of skill
- Confused work environment
- The presence of unrelated men at work
- Inappropriate working time
- Multiplicity job description
- Unmotivated
- Stress
- Personal issues and Distractions
- Lack of access to equipment and tools

Causes



Domino Theory



Nelms Model

- In nelms Model (Like as domino theory)You see events such as a movie(but end to first)
- In this model 4 kid of cause has investigated:

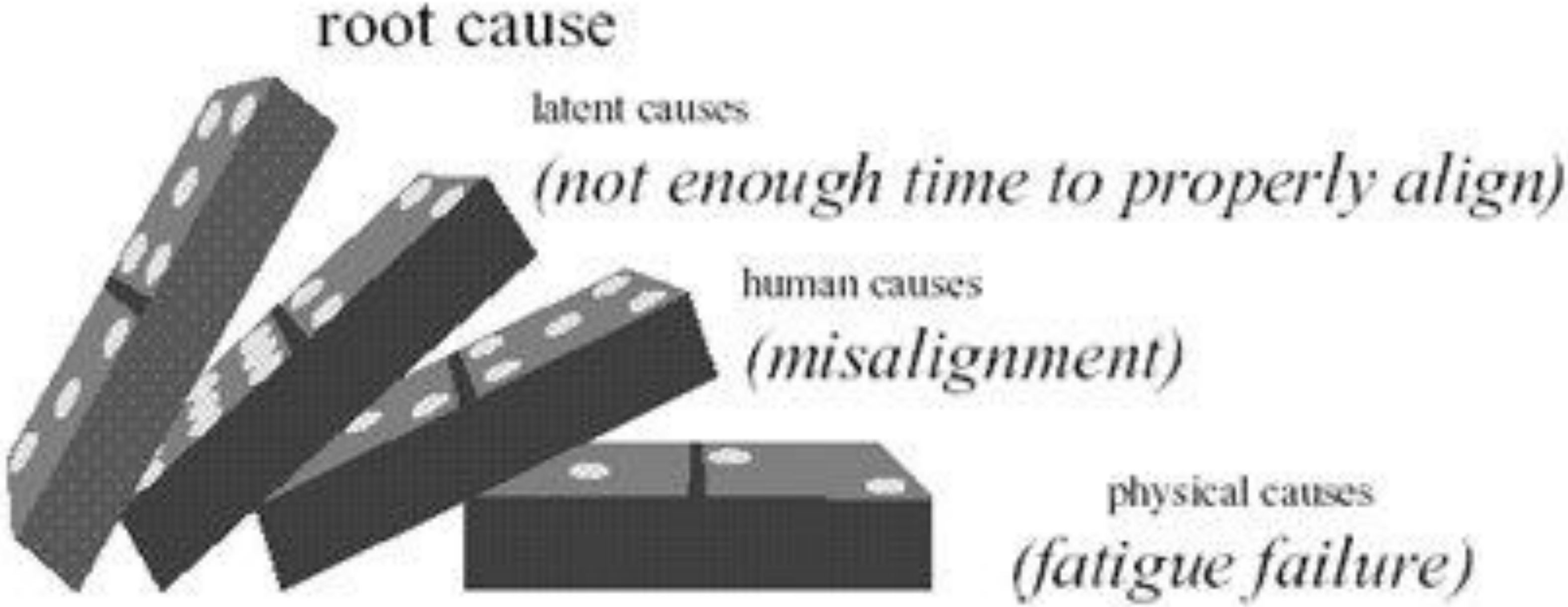
1-Physical cause

2-Human cause

3-Latent Cause

4-Root cause

The Domino Theory



Effective Items to emergency stop and reduction of machine life cycle

- Inattention to basic condition of machine
- Nonconformity from machine use standard
- Lack of skill to use, justification and set up
- Problem in design of equipment
- Lack of implementation of corrective action
- Lack of implementation of preventive action

RCFA Tools

5 WHY

5 why

Why

Is the powerful question… own it!!

5 why

- **Who are the best at asking questions to solve problems?**
  - When working with people to solve a problem,

it is not enough to tell them what the solution is. They need to *find out* and *understand* the solution for themselves. You help them do this by asking *open-ended* , thought provoking questions.

5 why

Close-Ended: Structures the response to be answered by one word, often “yes” or “no”. Usually gives a predetermined answer.

Example: *"Did the lack of standardization cause the incorrect setup?"*

Open-Ended: Leaves the form of the answer up to the person answering which draws out more thought or research.

Example: *"How is setup controlled?"*

Benefits of Open-Ended Questions

- ✓ Requires thought
- ✓ Promotes additional research
- ✓ Enhances problem solving skills
- ✓ Does not assume there is one right answer
- ✓ Avoids predetermined answers
- ✓ Stimulates discussion
- ✓ Empowers the person answering

More Examples

Example 1: **"Did the lack of a PM system cause this tool to break?"**
(Close-Ended question, can be answered by a "yes" or "no", gives the person a predetermined answer that PM is to blame)

"What could have caused the tool to break?"
(Open-Ended, probing question forces the person to think about all possibilities, not just PM)

Example 2: **"Would improving material flow help reduce lead times?"**
(Good question but it's still Close-Ended, focuses the person on material flow as a means to reduce lead time. Is this the best improvement?)

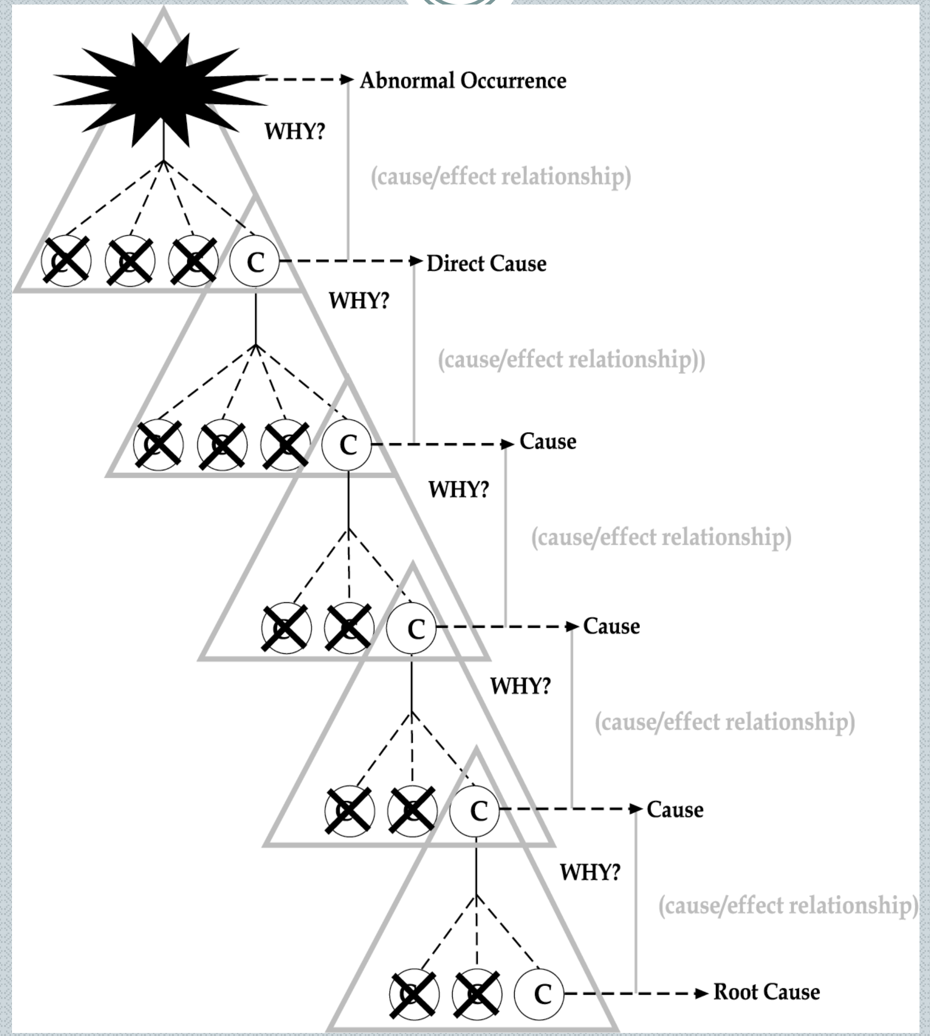
"What are some options on improving lead time?
(Open-Ended, triggering more thought and research on all variables impacting lead time.)

Example 3: **"Is equipment capability causing the variation in your process?**
(Close-Ended, can be answered by a "yes" or "no", focuses the person on equipment being the source of variation)

"What could potentially cause variation in your process?
(Open-Ended, triggering more thought and research, opens up possibilities of variation with man, material & method, not just machine)

- Part I – Grasp the Situation
  - Step 1: Identify the Problem
    - In the first step of the process, you become aware of a problem that may be large, vague, or complicated. You have some information, but do not have detailed facts. Ask:
    - What do I know?
  - Step 2: Clarify the Problem
    - The next step in the process is to clarify the problem. To gain a more clear understanding, ask:
    - What is actually happening?
    - What should be happening?
  - Step 3: Break Down the Problem
    - At this point, break the problem down into smaller, individual elements, if necessary.
    - What else do I know about the problem?
    - Are there other sub-problems?

- Step 4: Locate the Point of Cause (PoC)
  - Now, the focus is on locating the actual point of cause of the problem. You need to track back to see the point of cause first-hand. Ask:
  - Where do I need to go?
  - What do I need to see?
  - Who might have information about the problem?
- Step 5: Grasp the Tendency of the Problem
  - To grasp the tendency of the problem, ask:
  - Who?
  - Which?
  - When?
  - How often?
  - How much?
  - It is important to ask these questions before asking “Why?”


Abnormal Occurrence
WHY?
(cause/effect relationship)
C
Direct Cause
WHY?
(cause/effect relationship))
C
Cause
WHY?
(cause/effect relationship)
C
Cause
WHY?
(cause/effect relationship)
C
Cause
WHY?
(cause/effect relationship)
C
Root Cause

Problem

The problem is stated through the eyes of the customer

The first why is the main cause

The second why is what causes the main cause

Etc.

Why?

Therefore

Etc.

Root Cause

You have root cause if you can demonstrate:

- cause on, problem on
- cause off, problem off

5-Why Example - Business Plan

Problem

Did not meet the annual business plan goal of a 10% increase in sales

Did not thoroughly evaluate market/competition

Did not have adequate resources

Did not anticipate required resources

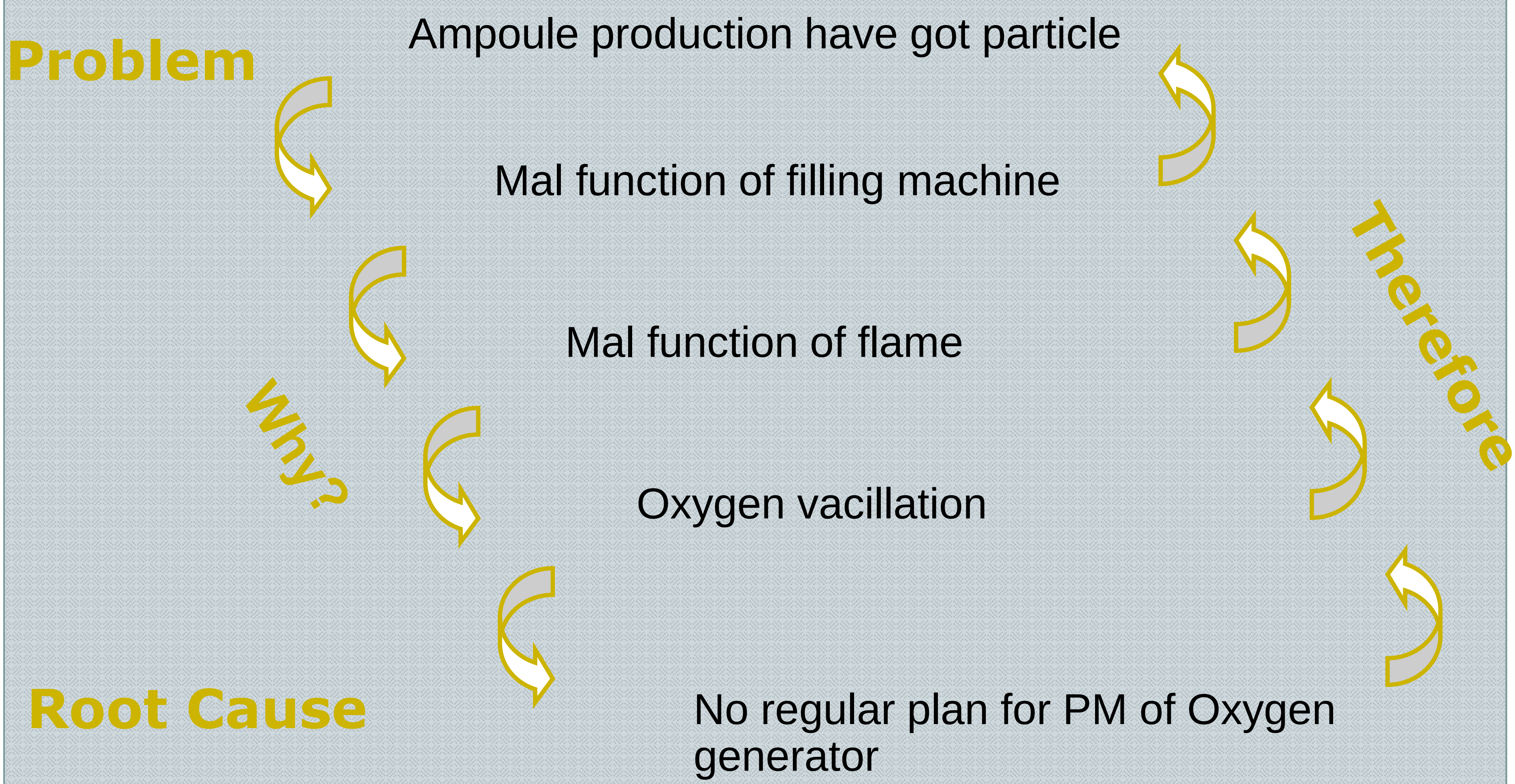
Did not develop a plan as to "how" the goal would be reached

Root Cause

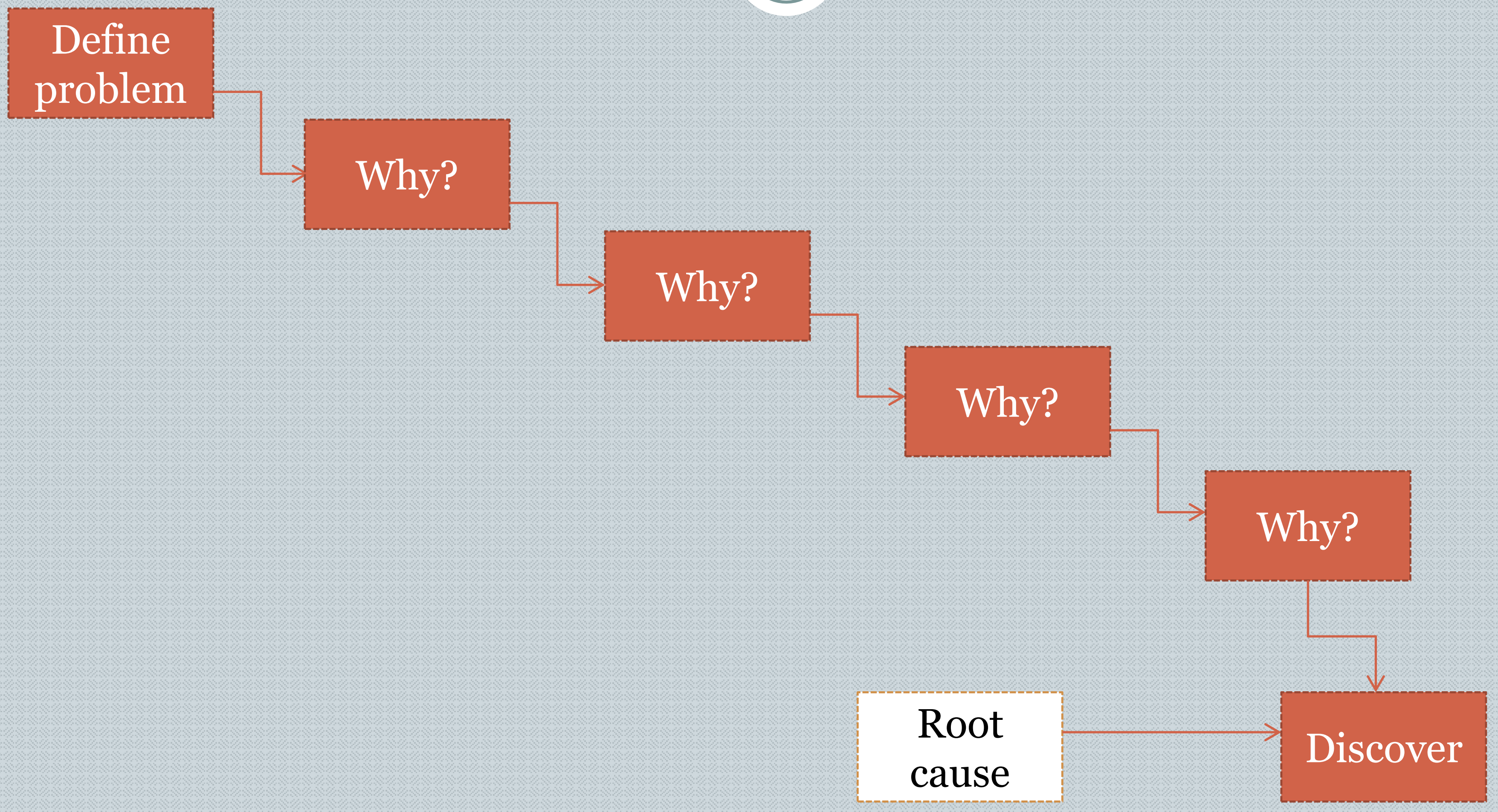
Why?

Therefore

5-Why Example – Nonconformity product



5 Why Diagram



Exercise

- Rooting a cause in your company process with 5 whys method.

ISHIKAWA DIAGRAM

Ishikawa diagram

- The Fishbone Diagram is a neat little visual tool. It helps with the brainstorming process of determining causes and root causes. It also provides a quick visual representation of cause density. It's called the fishbone diagram, because when you're starting out, it has a sideway tree look to it which resembles a fish skeleton. Sometimes it's called a cause and effect diagram or Ishikawa diagram because of what it depicts and who came up with the thing, respectively.

Ishikawa diagram

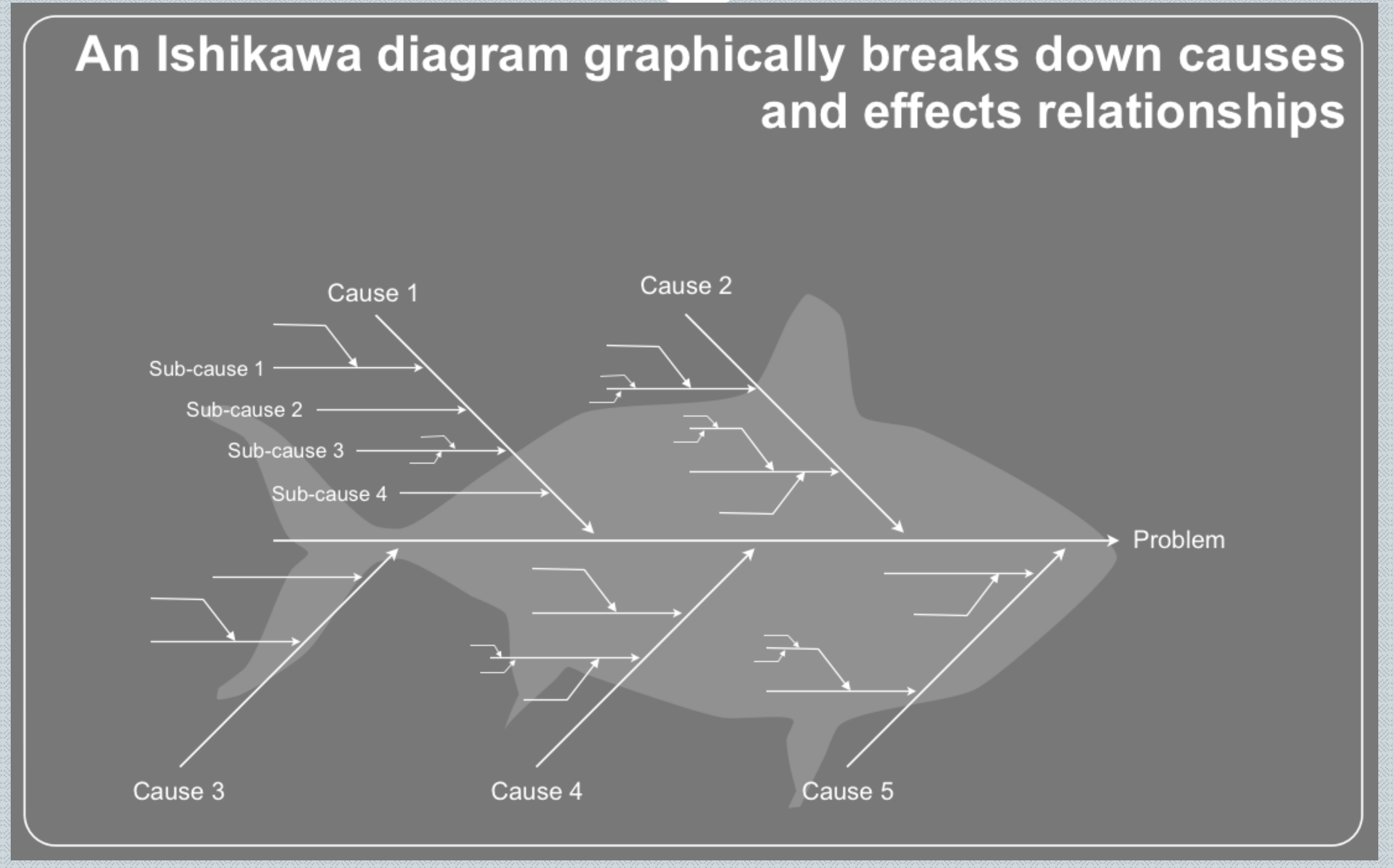
- A graphic tool used when you need to identify and explore and display the possible causes of a specific problem or condition.
- Developed to represent the relationship between some “effect and all the possible “causes” influencing it.
- The effect or problem is stated on the right side of the chart and the major influences or ‘causes’ listed to the left
- Causes might be summarized under the categories of Materials, Methods, Equipment, Environment, Leadership and People

Benefits

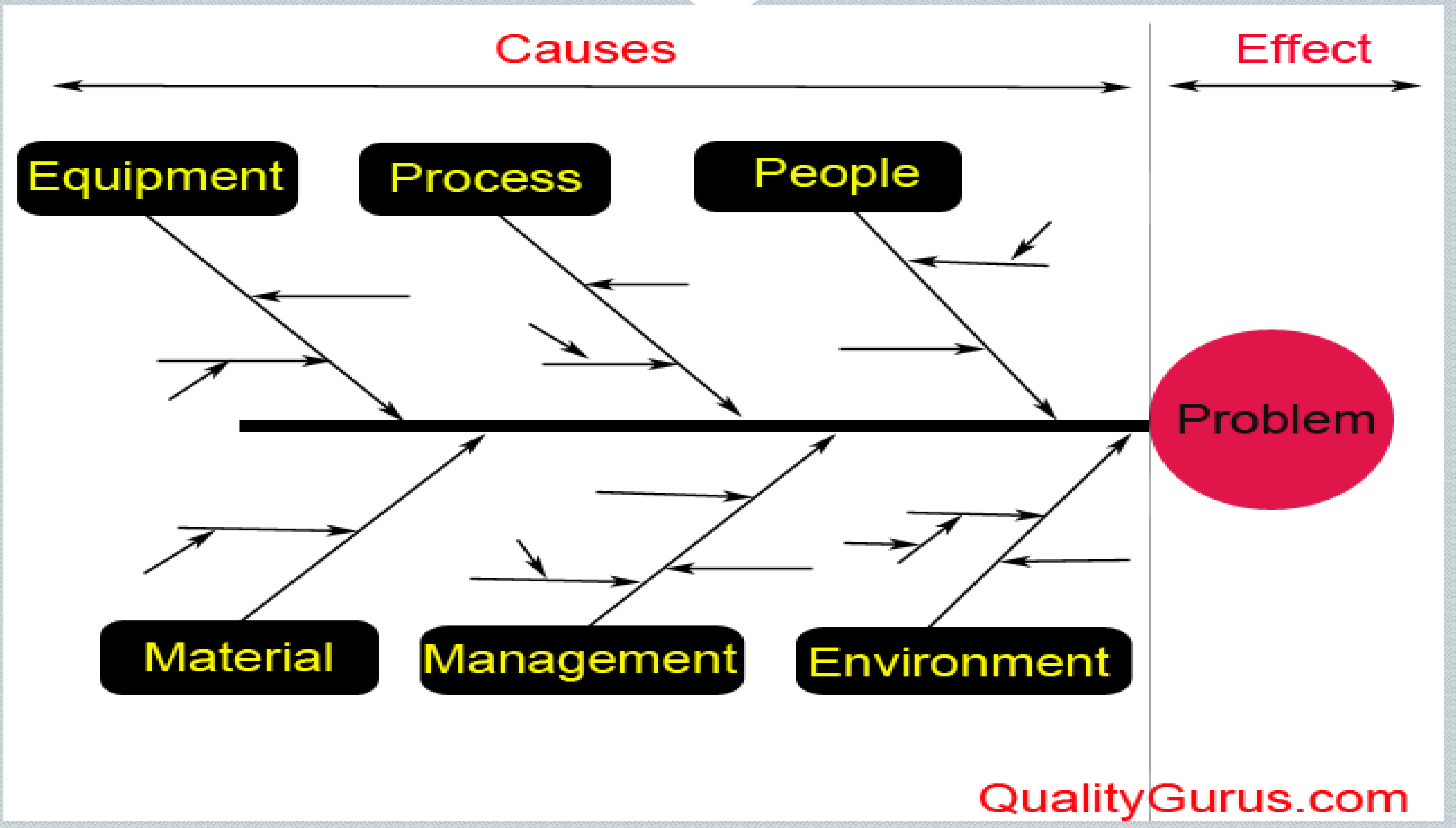
A cause and effect has these benefits:

- It helps teams understand that there are many causes that contribute to an effect
- It graphically displays the relationship of the causes to the effect and to each other
- It helps to identify areas for improvement

Ishikawa Fishbone (Cause and effect) diagram



Ishikawa diagram



Ishikawa diagram

There are a few standard choices for different sectors (fishbone suggested categories):

Service Industries (4S)

· Surroundings · Suppliers

· System · Skills

(+ Safety)

Manufacturing Industries (6M)

· Machines · Methods

· Materials · Measurements

· Mother Nature (Environment)

· Manpower (People)

Administration/ Marketing (8P)

· Product (or service) · Price

· People · Place · Promotion

· Procedures · Processes

· Policies

Ishikawa diagram

In any organization *problem analyzing tool* is crucial to success. In software quality management the Fishbone diagram is used for this purpose.

Possible causes are usually classified into six categories: *method*, *man*, *management*, *measurement*, *material*, *machine*.

Ishikawa diagram

Method – ways of doing things or the procedures followed to accomplish a task. A typical cause under the method category is not following instructions or the instructions are wrong.

Man – people are responsible for the problem. The problem may have been caused by people who are inexperienced.

Management – project management. Poor management decisions may cause technical problems.

Ishikawa diagram

Measurement – Problems may occur if measurements are wrong or the measurement technique used is not relevant.

Material – material basically refers to a physical thing. Software can't always handle errors caused by bad material, for instance a bad backup tape, so while material may be the least likely cause, it is a possible cause.

Machine – a machine in software usually refers to the hardware, and there are a lot of possibilities that a problem can be due to the machine.

Ishikawa diagram

- After identifying a problem, the leader initiates a discussion with the project team to gather information about the possible causes until arriving at the *root cause*.
- If possible root cause has been identified the *action plan* has to be derived to *fix it*.

Exercise

- Rooting a cause in your company process with Ishikawa diagram.

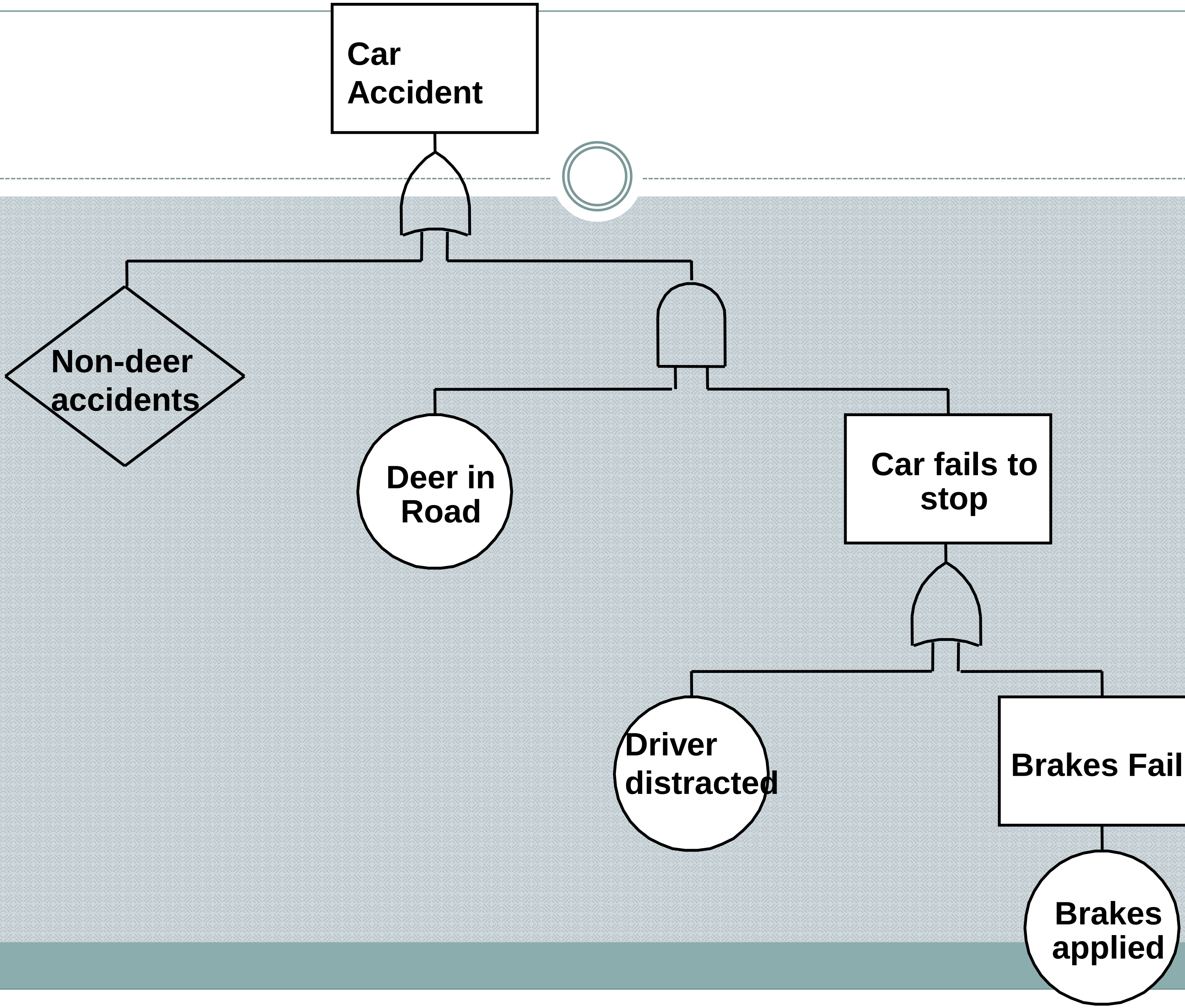
FAULT TREE ANALYSIS

Fault Tree Analysis

- "A method to decompose it and look for situation that might lead to **failure**" (Software Engineering)
- Displayed the logical path from effect to cause

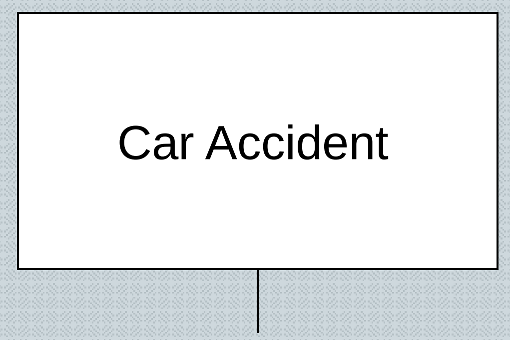
Why Fault Tree Analysis (FTA) is carried out

- To gain an understanding of the system
- To document the failure relationships of the system
- To exhaustively identify the causes of a failure
- To assure compliance with requirements or a goal
- To identify any weaknesses in a system
- To prioritize contributors to failure
- To identify effective upgrades to a system
- To optimize operations and processing
- To quantify the failure probability and contributors


Car Accident
Non-deer accidents
Deer in Road
Car fails to stop
Driver distracted
Brakes Fail
Brakes applied

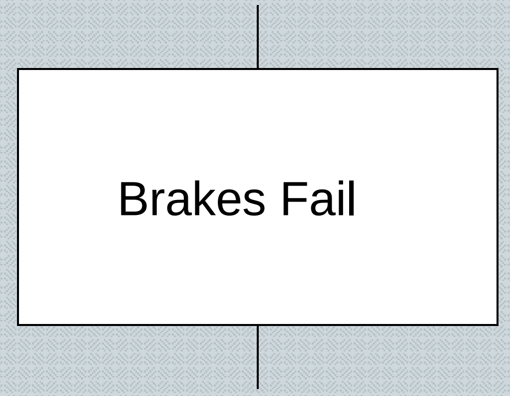
Top Event

- Primary undesired event of interest
- Denoted by a rectangle



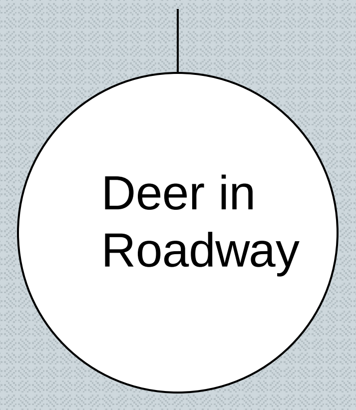
Intermediate Event

- Fault event that is further developed
- Denoted by a rectangle



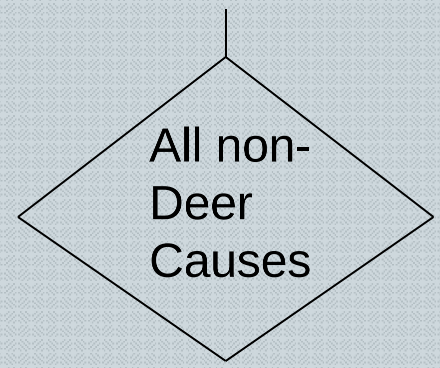
Basic Event

- Event requiring no further development
- Denoted by a circle



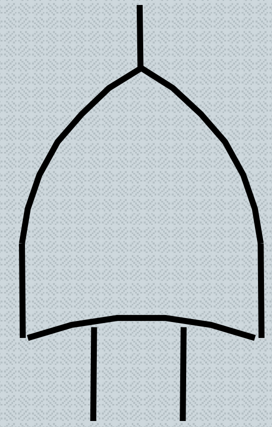
Undeveloped Event

- Low consequence event
- Information not available
- Denoted by a diamond



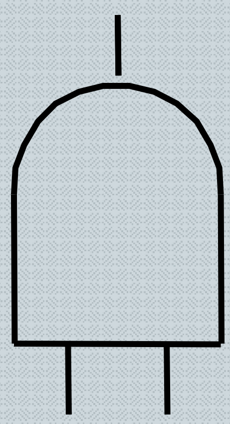
"OR" Gate

- Output event occurs only if one or more input event occurs
- Systems in series
- $+$, $\cup$, union



"AND" Gate

- Output event occurs only if all input events occur
- Systems in parallel
- • , $\cap$, intersection



Boolean Algebra

Operation	Probability	Mathematics	Engineering
Union of A and B	A or B	$A \cup B$	$A + B$
Intersection of A and B	A and B	$A \cap B$	$A \bullet B$
Complement of A	Not A	A'	A'

Probability Possibilities

- If $S = F + G$

$$P(S) = P(F) + P(G) - P(FG)$$
$$= P(F) + P(G) - P(F)P(G|F)$$
$$= P(F) + P(G) - P(F)P(G) \text{ if independent}$$
$$= P(F) + P(G) \text{ if rare events}$$

- If $S = F \bullet G$

$$P(S) = P(F)P(G) \text{ if independent}$$

Deer Accident Equations

- Car Accident (S) if
  - Deer in roadway (C) AND
  - Driver distracted (A) OR brakes fail (B)
- $S = (A \cup B) \cap C$
- $S = (A + B) \bullet C$
- S = (A union B) intersect C
- S = (A intersect C) union (B intersect C)

Probabilities

Event	Probability, f(time)
Deer in roadway	0.0026
Distracted driver	0.001
Brakes applied	0.999
Brake failure	0.0002

Deer Accident Probability

$S = (A + B) \bullet C$

$P(S) = [P(A) + P(B) - P(A)P(B|A)] \cdot P(C)$

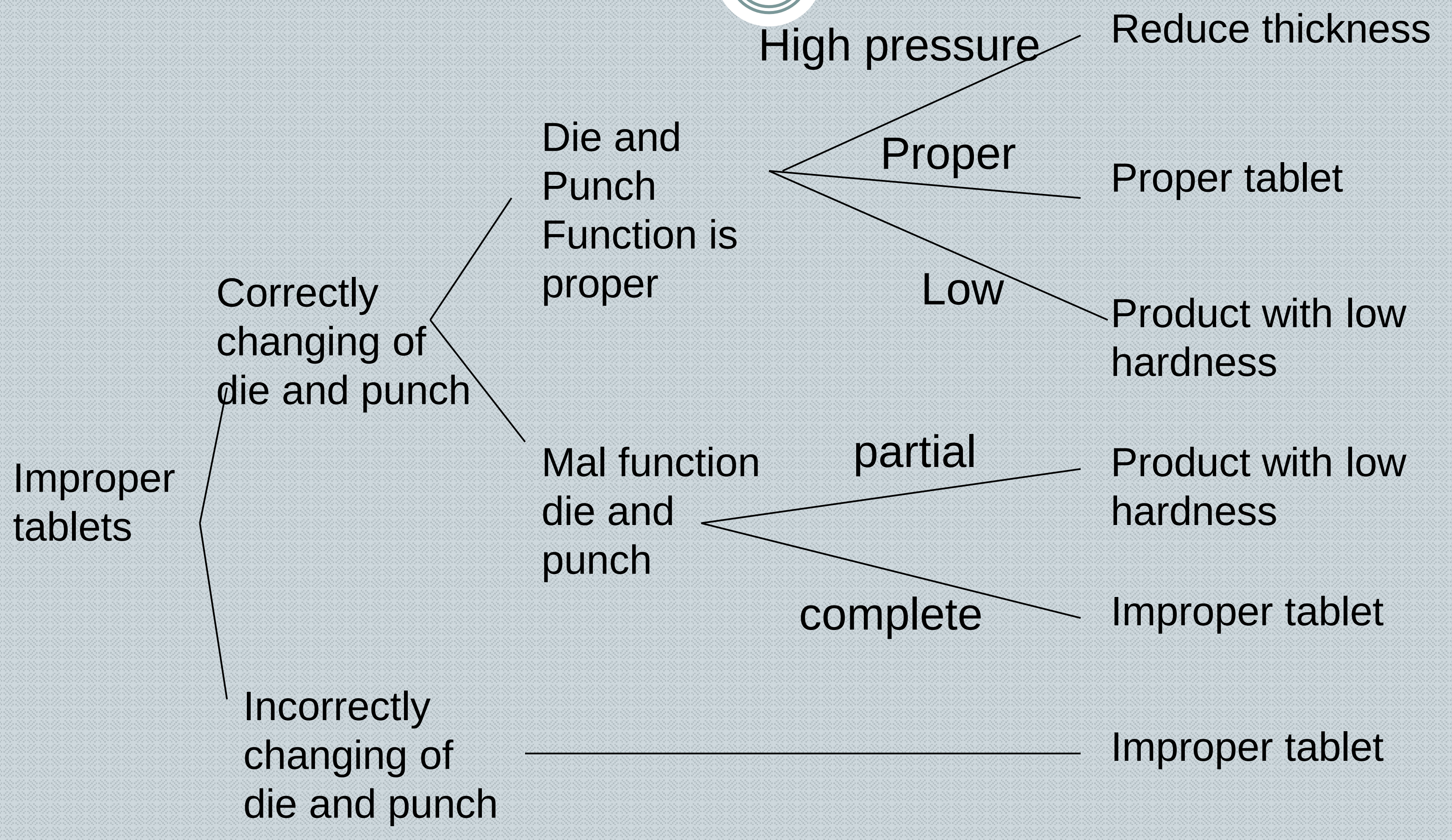
Note: A and B are dependent (why?)

$P(S) = [P(A) + P(B)] \cdot P(C)$

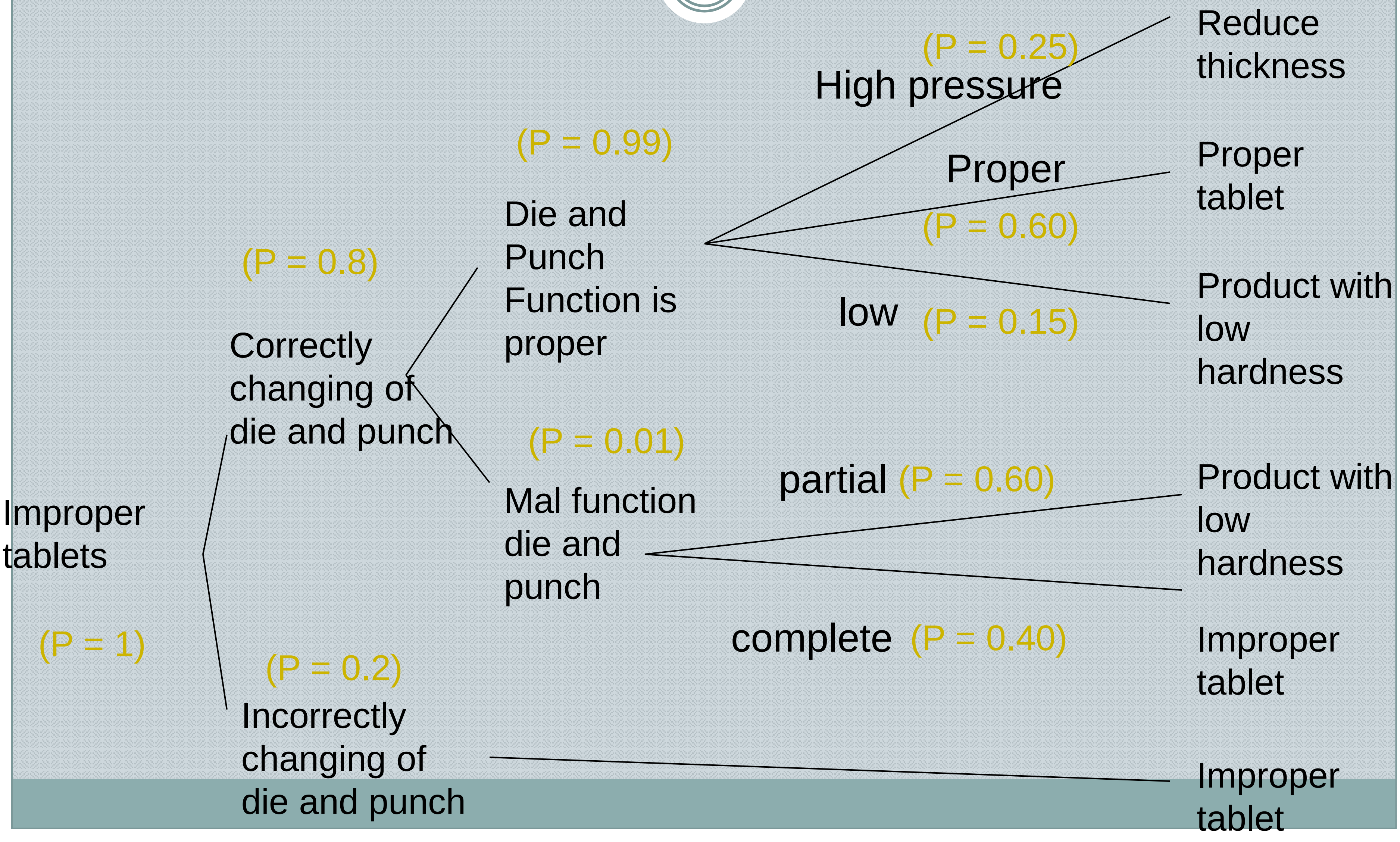
$P(S) = (0.001 + 0.0002 \times 0.999) \times 0.0026$

$P(S) = 3 \times 10^{-6}$

Example


High pressure
Reduce thickness
Die and Punch Function is proper
Proper
Proper tablet
Correctly changing of die and punch
Low
Product with low hardness
Improper tablets
Mal function die and punch
partial
Product with low hardness
complete
Improper tablet
Incorrectly changing of die and punch
Improper tablet

Deer in Road Event Tree Probabilities



Probabilities

Out come	Sub-outcome	calculation	Probability
Product tablet	(none)	0.8*0.99*0.6	0.4752
Improper tablet	Correctly changing of die and punch	0.8*(0.99*0.15+ 0.01*0.6)	0.3216
	Incorrectly changing of die and punch	0.2+0.8*0.1*0.4	0.2032

Exercise

- Rooting a cause in your company process with fault tree analysis method.

PARETO CHART

Pareto analysis

- Pareto analysis is a formal technique useful where many possible courses of action are competing for attention.
- Pareto analysis is a creative way of looking at causes of problems because it helps stimulate thinking and organize thoughts.

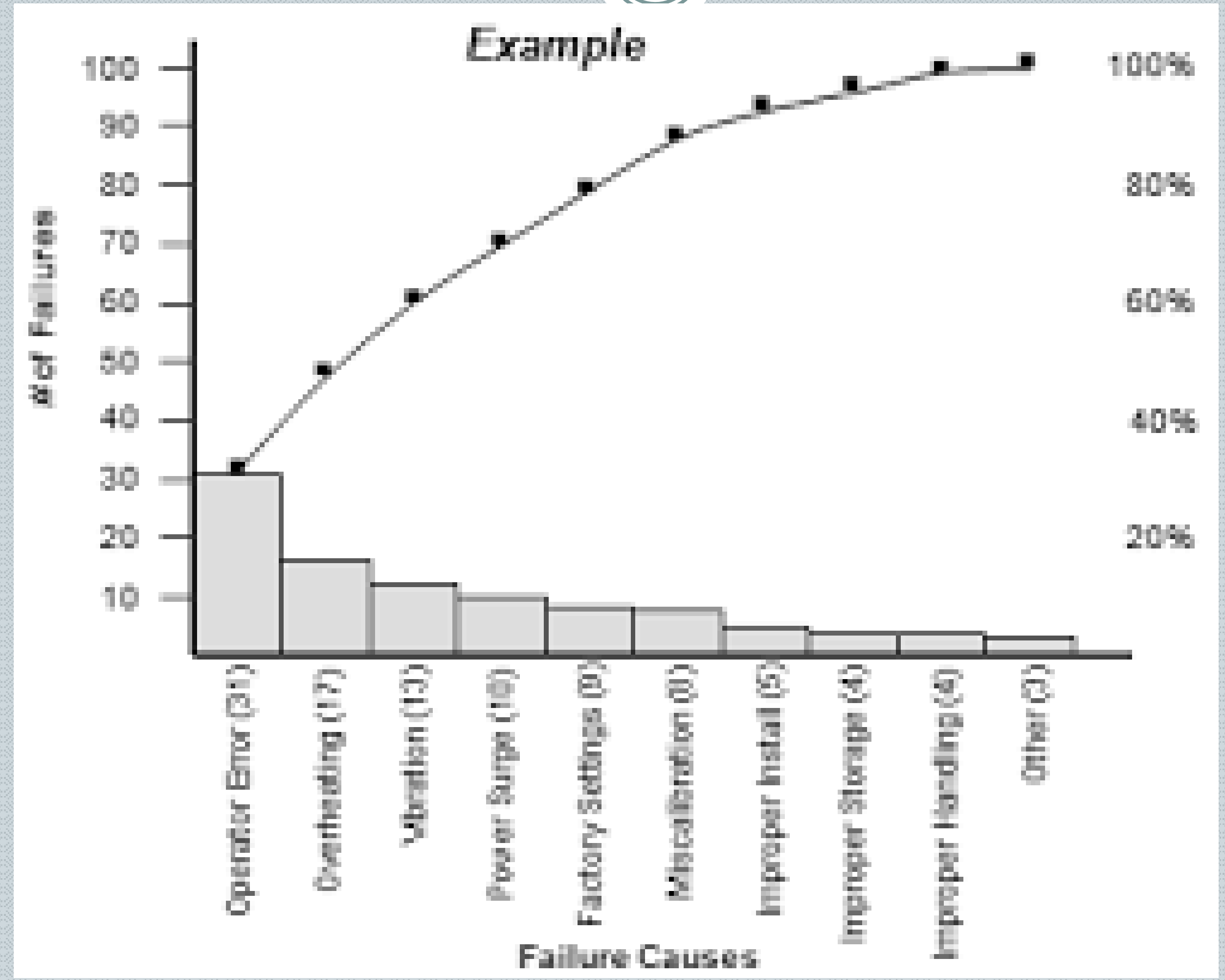
Pareto Chart

- This technique helps to identify the top 20% of causes that needs to be addressed to resolve the 80% of the problems.

Pareto

- 80% of sales are generated by 20% of customers.
- 80% of Quality costs are caused by 20% of the problems.
- 80% of problem in production line are generated by 20% of causes.

HOW TO USE IT ?

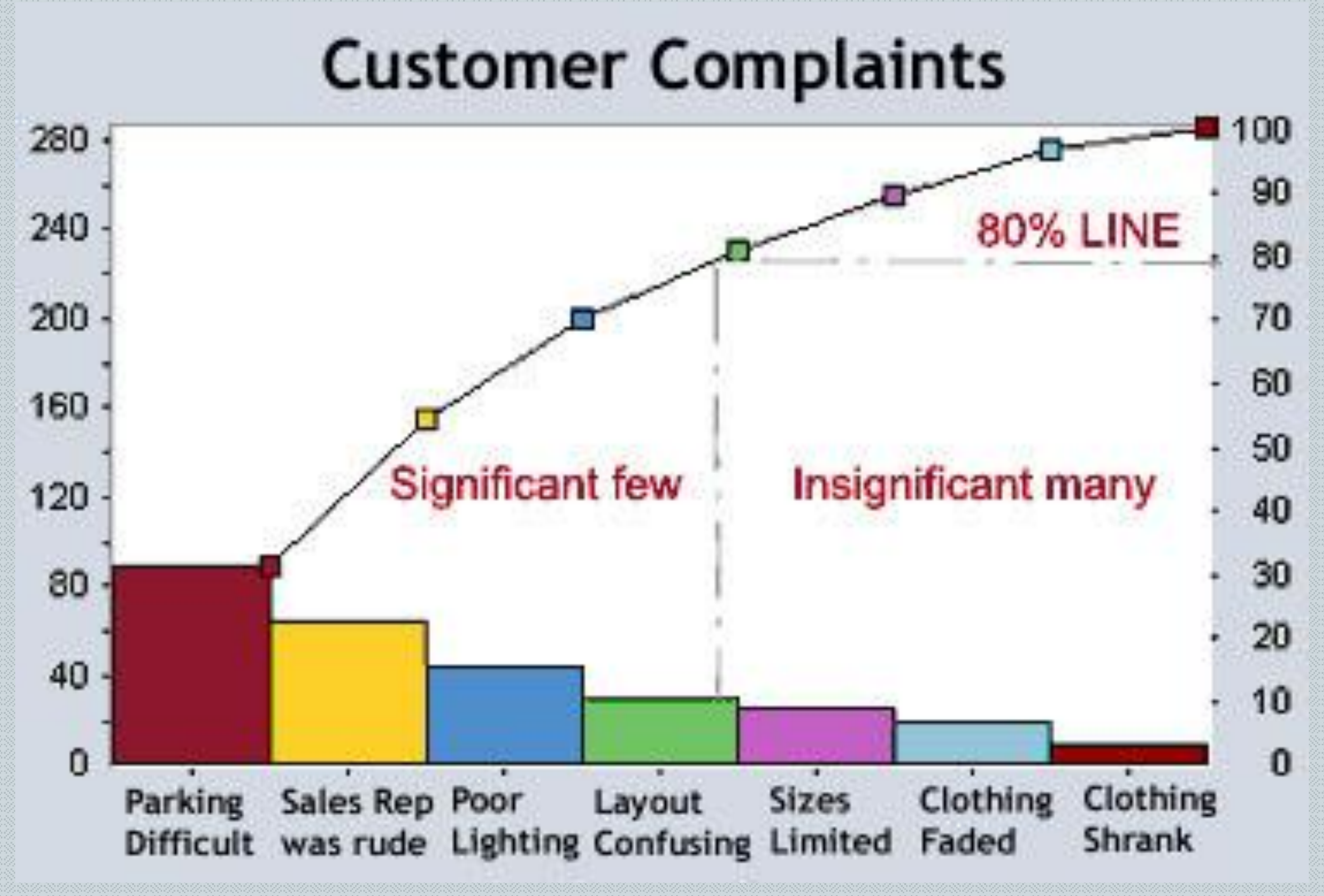


Example
# of Failures
100
90
80
70
60
50
40
30
20
10
100%
80%
60%
40%
20%
Operator Error (31)
Overheating (17)
Vibration (13)
Power Surge (10)
Factory Settings (9)
Miscalibration (8)
Improper Install (5)
Improper Storage (4)
Improper Handling (4)
Other (3)
Failure Causes

How to use it?

- 1. Gather facts about the problem, using Check Sheets or Brainstorming, depending on the availability of information.
- 2. Rank the contributions to the problem in order of frequency.
- 3. Draw the value (errors, facts, etc) as a bar chart.
- 4. It can also be helpful to add a line showing the cumulative percentage of errors as each category is added. This helps to identify the categories contributing to 80% of the problem.
- 5. Review the chart – if an 80/20 combination is not obvious, you may need to redefine your classifications and go back to Stage 1 or 2.

Pareto chart



Exercise

- Rooting a cause in your company process with Pareto Analysis method.

CAUSAL/ BARRIER ANALYSIS

What is a Causal/barrier Analysis?

- A causal/barrier analysis is:
  - A systematic process for identifying the problem.
  - A method for determining what causes the barriers.
  - A way to identify what improvement opportunities are available.
- Causal/barrier analysis has also been called:
  - Root cause analysis

Developing improvement strategies

- Identify barriers to reaching improvement
- Opportunities for improvement?
- Determine intervention(s)

How do I perform a causal/barrier analysis?

Determine why an event or condition occurs.

1. What is the problem?
   - Define the problem and explain why it's a concern.
2. Determine the significance of the problem.
   - Look at the data and see how the problem impacts your consumers and/or health plan.

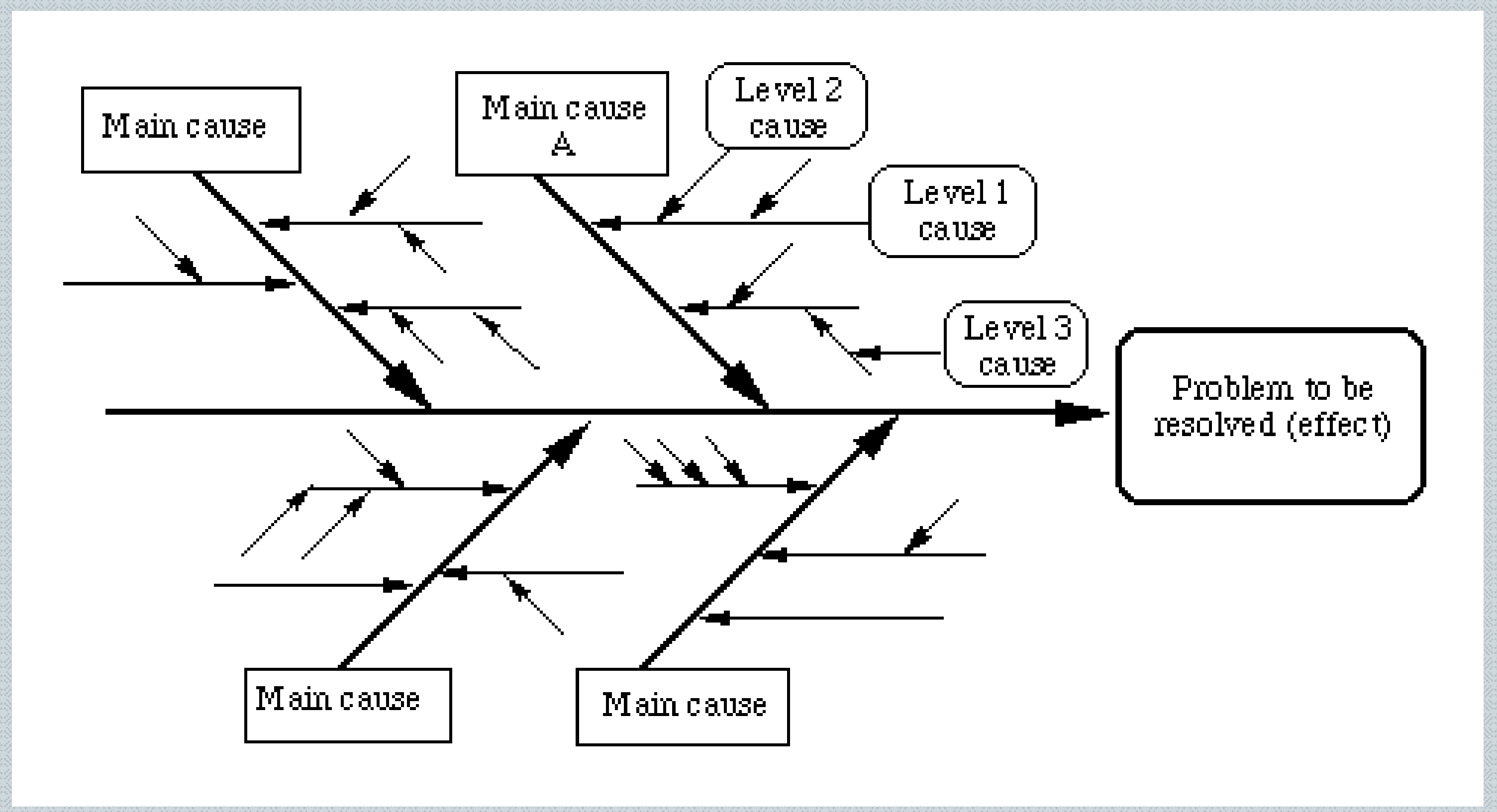
How do I perform a causal/barrier analysis?

3. Identify the causes/barriers.
   - Conduct analysis of chart review data, surveys, focus groups.
   - Brainstorming at quality improvement committee meetings.
   - Literature review.
4. Develop/implement interventions based on identified barriers.

Causal/barrier methods and tools

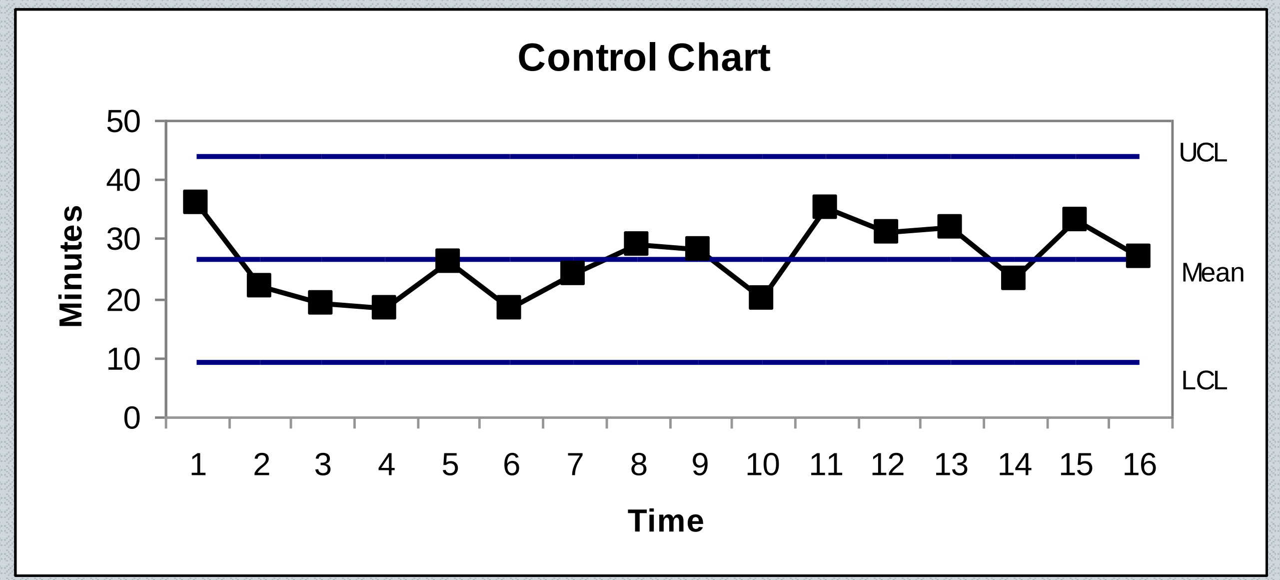
- Methods:
  - Quality improvement committees
  - Develop an internal task force
  - Focus groups
  - Consensus expert panels
- Tools:
  - Fishbone
  - Control chart
  - Flow chart (process mapping)
  - Barrier/intervention table

Quality improvement tools



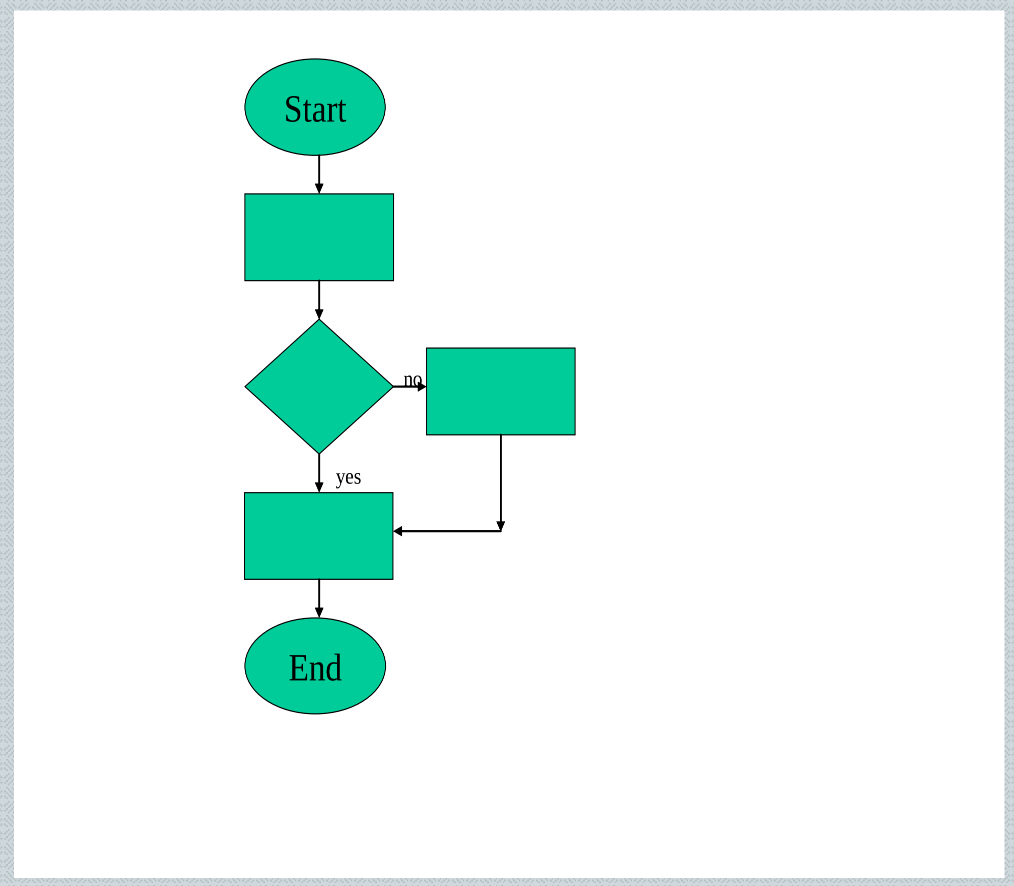
Quality improvement tools

- Control chart



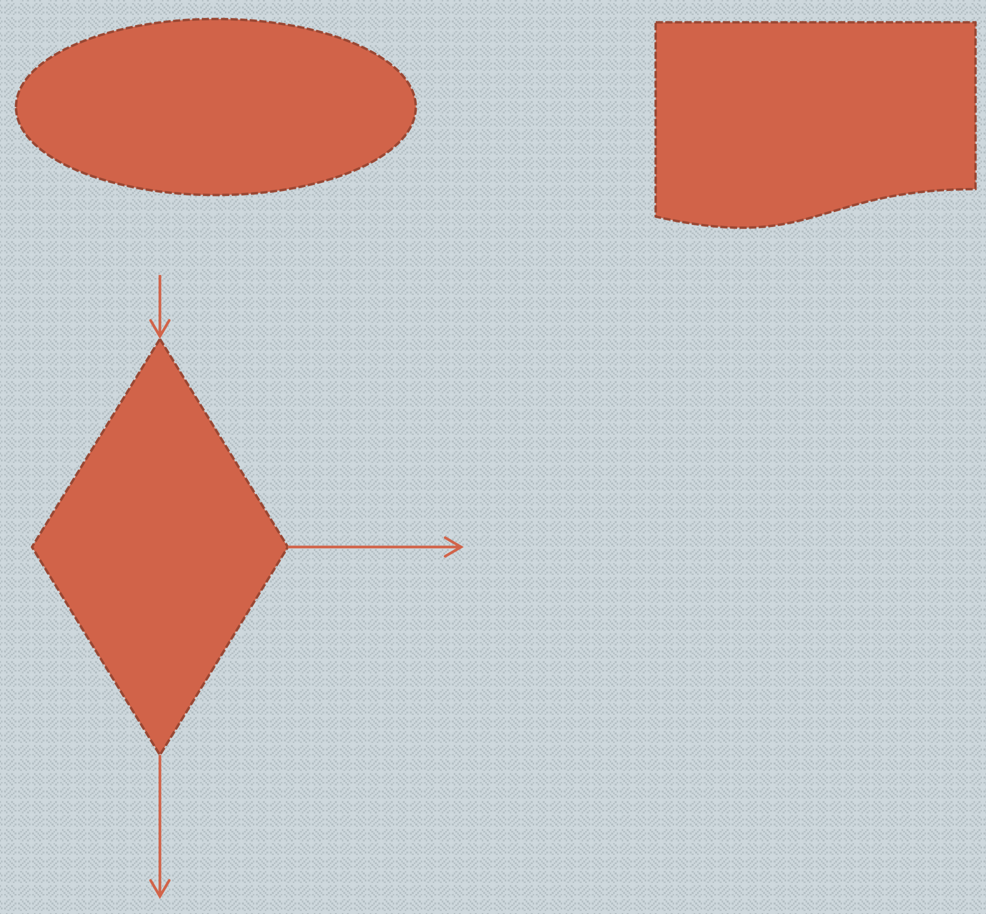
Quality improvement tools

- Flow chart



Flowchart

- Start and end
- If



Flowchart

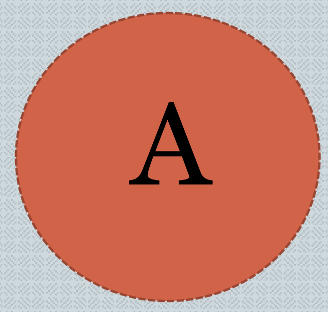
- Entrance and Exit

- Connection line

Flowchart

- Process

- Communication



Quality improvement tools

- **Barrier/intervention table**

Interventions taken for improvement as a result of analysis. List chronologically the interventions that have had the most impact on improving the measure. Describe only the interventions and provide quantitative details whenever possible (e.g., "hired 4 customer service reps" as opposed to "hired customer service reps"). Do not include intervention planning activities.			
Date Implemented	Check if ongoing	Interventions	Barriers that Interventions Address
9/1/04	X	Education to mental health providers on the importance of coordination of care.	No documentation of mental health services in PCP medical record.

How was the intervention chosen?

- By reviewing the literature
  - Evidence-based
  - Pros and Cons
  - Benefits and Costs

- Develop list of potential interventions – what is most effective?

Interventions checklist

- Analyze barriers (root causes)
- Choose and understand target audience
- Select interventions based on cost/benefit
- Implement interventions
- Track intermediate results (optional)
- Re-measure
- Modify interventions as needed

Exercise

- Rooting a cause in your company process with Control chart method.

FMEA

FMEA

- **Why**
  - Methodology that facilitates process improvement
  - Identifies and eliminates concerns early in the development of a process or design
  - Improve internal and external customer satisfaction
  - Focuses on prevention
  - FMEA may be a customer requirement (likely contractual)
  - FMEA may be required by an applicable Quality Management System Standard (possibly ISO)

FMEA

- A structured approach to:
  - Identifying the ways in which a product or process can fail
  - Estimating risk associated with specific causes
  - Prioritizing the actions that should be taken to reduce risk
  - Evaluating design validation plan (design FMEA) or current control plan (process FMEA)

When to Conduct an FMEA

- Early in the process improvement investigation
- When new systems, products, and processes are being designed
- When existing designs or processes are being changed
- When carry-over designs are used in new applications
- After system, product, or process functions are defined, but before specific hardware is selected or released to manufacturing

The FMEA Form

Process/Product
Failure Modes and Effects Analysis Form
(FMEA)

Process or Product Name:		Prepared by:	Page ____ of ____
Responsible:		FMEA Date (Orig) ____________ (Rev) ____________	

Process Step / Input	Potential Failure Mode	Potential Failure Effects	SEVERITY	Potential Causes	OCCURRENCE	Current Controls	DETECTION	RPN	Actions Recommended	Resp.	Actions Taken	SEVERITY	OCCURRENCE	DETECTION	RPN
What is the process step and Input under investiga-tion?	In what ways does the Key Input go wrong?	What is the impact on the Key Output Variables (Customer Requirements)?		What causes the Key Input to go wrong?		What are the existing controls and procedures (inspection and test) that prevent either the cause or the Failure Mode?			What are the actions for reducing the occurrence of the cause, or improving detection?		What are the completed actions taken with the recalculated RPN?				
								0							0
								0							0
								0							0
								0							0
								0							0

Identify failure modes and their effects

Identify causes of the failure modes and controls

Prioritize

Determine and assess actions

Types of FMEAs

- Design
  - Analyzes product design before release to production, with a focus on product function
  - Analyzes systems and subsystems in early concept and design stages
- Process
  - Used to analyze manufacturing and assembly processes after they are implemented

FMEA: A Team Tool

- A team approach is necessary.
- Team should be led by the Process Owner who is the responsible manufacturing engineer or technical person, or other similar individual familiar with FMEA.
- The following should be considered for team members:
  - Design Engineers
  - Process Engineers
  - Materials Suppliers
  - Customers
  - Operators
  - Reliability
  - Suppliers

FMEA Procedure

1. For each process input (start with high value inputs), determine the ways in which the input can go wrong (failure mode)
2. For each failure mode, determine effects
   - Select a severity level for each effect
3. Identify potential causes of each failure mode
   - Select an occurrence level for each cause
4. List current controls for each cause
   - Select a detection level for each cause

FMEA Procedure

5. Calculate the Risk Priority Number (RPN)
6. Develop recommended actions, assign responsible persons, and take actions
   - Give priority to high RPNs
   - MUST look at severities rated a 10
7. Assign the predicted severity, occurrence, and detection levels and compare RPNs

Severity, Occurrence, and Detection

- Severity
  - Importance of the effect on customer requirements
- Occurrence
  - Frequency with which a given cause occurs and creates failure modes (obtain from past data if possible)
- Detection
  - The ability of the current control scheme to detect (then prevent) a given cause (may be difficult to estimate early in process operations).

Rating Scales

- There are a wide variety of scoring “anchors”, both quantitative or qualitative
- Two types of scales are 1-5 or 1-10
- The 1-5 scale makes it easier for the teams to decide on scores
- The 1-10 scale may allow for better precision in estimates and a wide variation in scores (most common)

Rating Scales

- Severity
  - 1 = Not Severe, 10 = Very Severe
- Occurrence
  - 1 = Not Likely, 10 = Very Likely
- Detection
  - 1 = Easy to Detect, 10 = Not easy to Detect

Risk Priority Number (RPN)

- RPN is the product of the severity, occurrence, and detection scores.

Severity x Occurrence x Detection = RPN

Exercise

- Rooting a cause in your company process with FMEA method.

CAUSE MAPPING METHOD

The Cause Mapping method

- Cause Mapping is a root cause analysis method that improves the way people analyze, document, communicate, and solve problems. In many companies, problem solving is a confusing maze of different tools, baffling terms, and puzzling categories. An investigation should make a problem clearer, not more complicated. Cause Mapping demystifies root cause analysis. It's an uncomplicated approach, grounded in the basics, that people find easy to learn and straightforward to apply. The Cause Mapping method leverages fundamental principles to improve both the effectiveness and efficiency of problem solving

Cause mapping

- Three key principles of Cause Mapping are:
- **Systems approach**

  Reveal the system of causes to mitigate risk.
- **Visual communication**

  Take advantage of the power of visual communication.
- **Simple and effective**

  Don't stray from the basics.

A problem well defined is a problem half solved

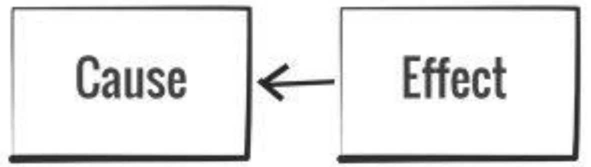
- A clearly defined problem is an important step of the problem-solving process. Without a clear problem statement, people can drift off course, waste valuable time, and miss opportunities to solve the problem. The "problem" with defining problems is that everyone has a different perspective on what the "real" problem is. The Cause Mapping method uses a structured problem outline that reveals 3 key benefits to effective problem solving. A well-defined problem at onset will help you avoid the common pitfalls that can derail your investigations.

Three key benefits of a well-defined problem:

- Problem alignment
- Total impact – gaps & risks
- Guidance on level of detail for analysis

What is a Cause Map?

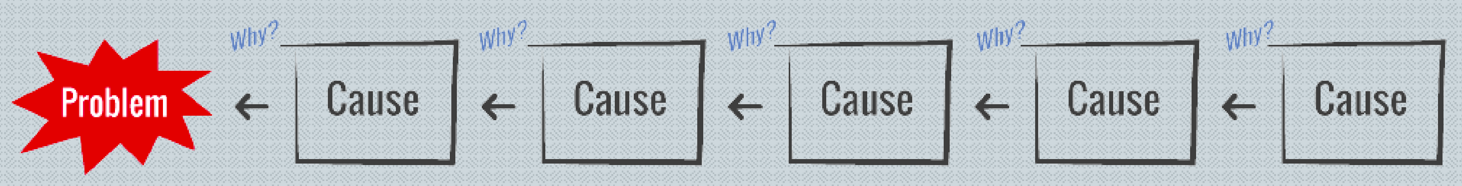
- A Cause Map provides a visual explanation of why an incident occurred. It connects individual cause-and-effect relationships to reveal the system of causes within an issue. A Cause Map can be very basic or it can be extremely detailed depending on the issue.



Cause-and-Effect Relationship
"Building Block"

How to read a Cause Map

- Start on the left. Read to the right saying "was caused by" in place of the arrows. Investigating a problem begins with the problem and then backs into the causes by asking *Why* questions. The questions begin, "Why did this effect happen?" The response to this question provides a cause (or causes), which is written down to the right.

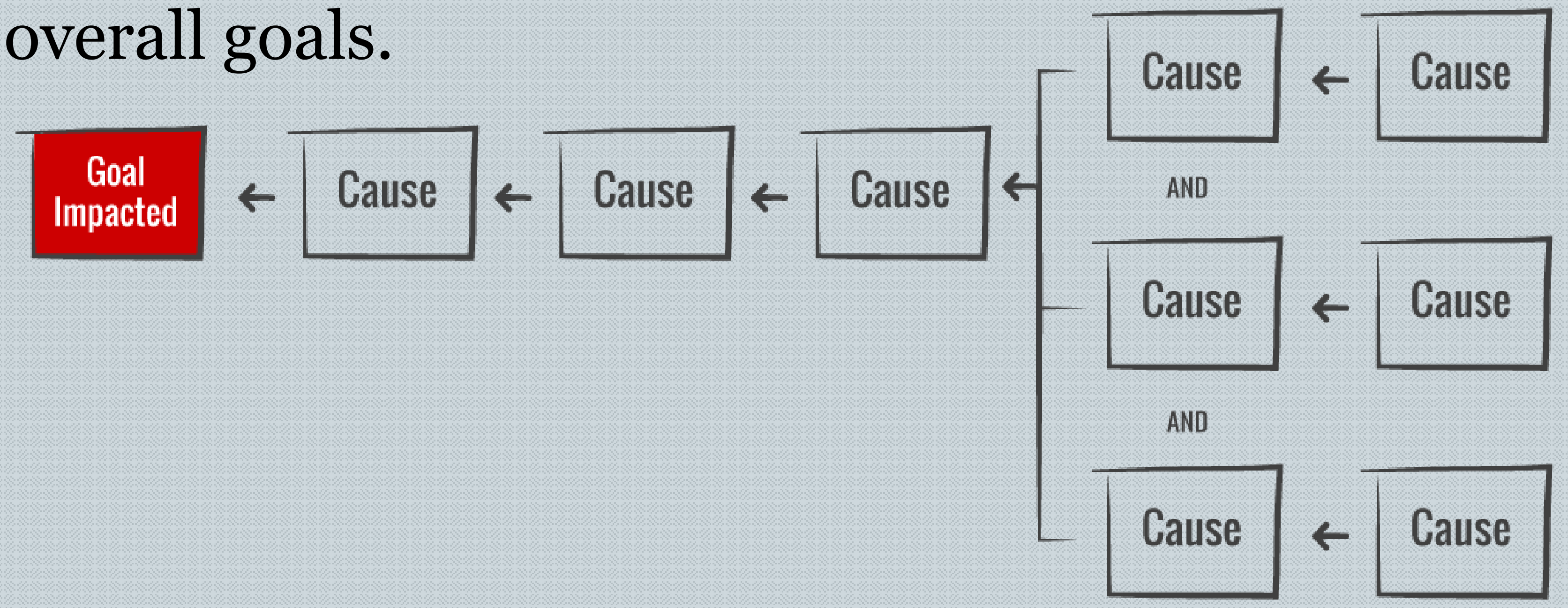


Cause mapping

- The next question is again, “Why did this effect happen?” The cause that was written down last becomes the effect for the next *Why* question. Anyone who’s ever had a three-year-old in their life will immediately recognize how Why questions change a cause into an effect. This is fundamentally how causes and effects link together to create a chain of events. Writing down 5 *Whys*, as shown below, is a great way to start an investigation because it’s so simple.

Cause mapping

- In the Cause Mapping method, a problem within an organization is defined as a deviation from the ideal state. A Cause Map always begins with this deviation, which is captured as the impact to the organization's overall goals.



Cause mapping

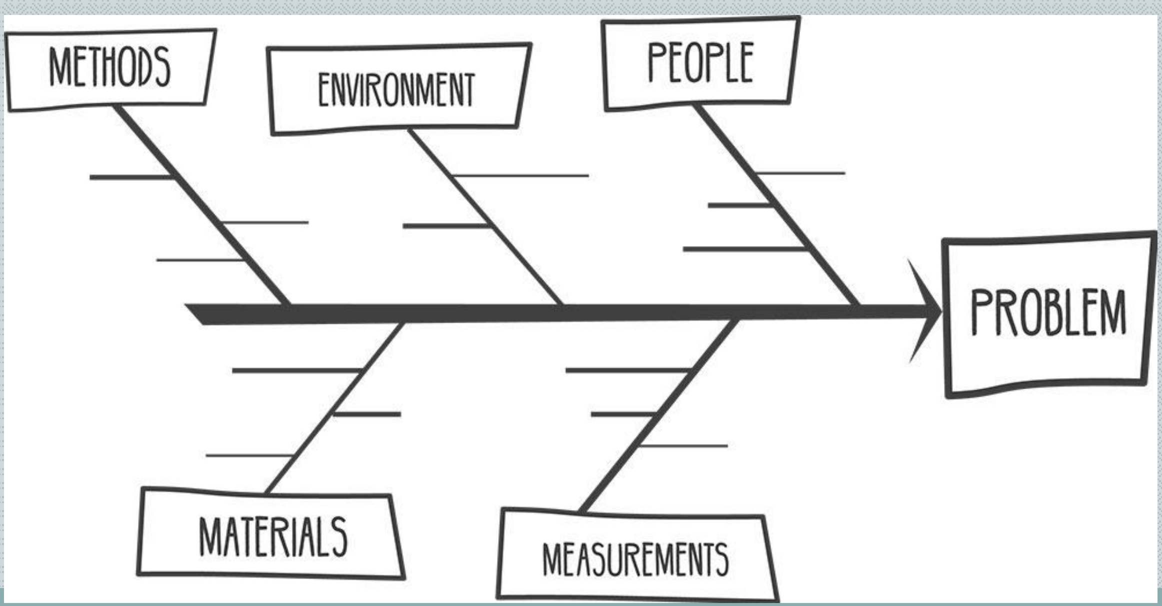
- In addition to the standard *Why* questions, which tend to create linear cause-and-effect relationships, the Cause Mapping method also asks "What was required to produce this effect?" Anything that is required to produce an effect is a cause of that effect. This question, "What was required?," allows you to build a detailed Cause Map that provides a more complete representation of the actual issue.

Why does the Cause Map read left to right?

- It should be noted that the popular fishbone cause-and-effect diagram starts with the problem on the right and builds the causes to the left. It was created by Kaoru Ishikawa (1915-1989) in Japan. The fishbone diagram builds from right to left because the Japanese language reads from right to left. The Cause Mapping method actually uses Ishikawa's convention by asking *Why* questions in the direction we read. The fishbone is widely recognized as one of the standard quality tools. Ishikawa was a pioneer with his approach. The fishbone cause-and-effect diagram is part of every Six Sigma program. A Cause Map builds on the original lessons with the fishbone with some subtle but important distinctions.

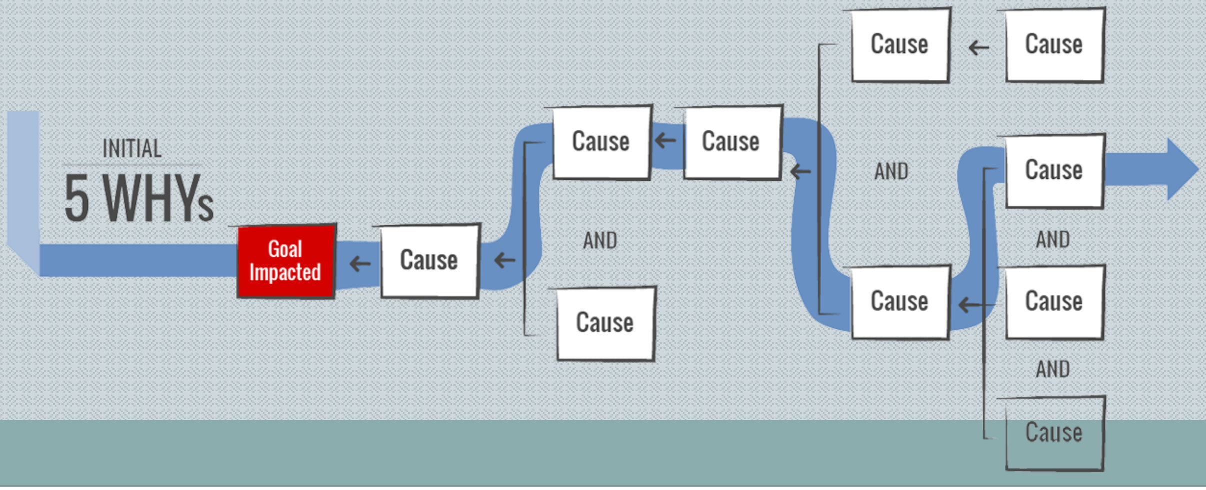
How does the Cause Map differ from the fishbone approach?

- A fishbone starts with just one, single problem, which doesn't reflect the nature of real-world issues. It reads right to left because the Japanese language reads that direction. It mixes causes and possible causes without specifying evidence. And, it breaks apart the fundamental cause-and-effect relationships within an issue by grouping the causes into general categories.



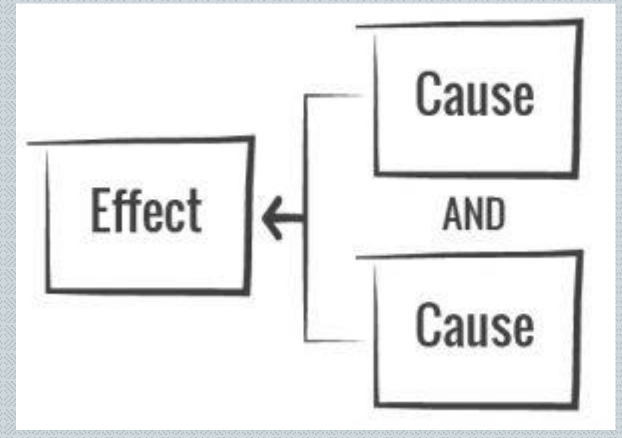
5-Whys on a Cause Mapping

- The 5-Why approach is an excellent example of basic cause-and-effect analysis. Just as a journey of a thousand miles begins with the first step, every investigation, regardless of size, begins with one *Why* question. The *Why* questions then continue, passing through five, until enough *Why* questions have been asked (and answered) to sufficiently explain the incident. The 5-Why approach, created by Sakichi Toyoda (1867 – 1930), the founder of Toyota, is a simple way to begin any investigation. A Cause Map can start with just one *Why* question and then expand to accommodate as many *Why* questions as necessary. Some refer to the Cause Mapping method as "5-Whys on Steroids."



Some causes are linked with "AND" in between

- ANDs show where more than one cause is required. When an effect has more than one cause, both causes are placed on the Cause Map. Each cause is connected to the effect with AND placed in between. These causes are independent of each other, but they are both required to produce that effect. An AND is needed when people provide different, yet valid, explanations of a cause. People think of cause-and-effect as a simple one-to-one relationship: an effect has a cause. In reality, every effect has causes.



Exercise

- Rooting a cause in your company process with Cause mapping method.

RCFA Procedure

1. Failure occurs

- Reference the RCA Worksheets. Continue the RCA process if:

1-1 The failure is a repetitive failure;

1-2 It is a safety or regulatory related failure;

1-3 The failure interrupts production;

1-4 Or, the failure incurs significant cost

2. Containment Action:

- Containment action is the first step in the process. These are actions taken immediately following awareness of the event to stop the event from occurring and preventing or minimizing impact from the failure. This is referred to as the Immediate Corrective Action.

2-1 Stop the event from occurring

2-2 Once the event has been stopped, determine what and how much damage has

been done

2-3 Contain effects of the damage

2-4 Notify affected personnel and departments

3. Define the problem

- Clearly define the actual problem. The steps involved in problem definition are:

3-1 Forming a team

3-2 Identifying the problem

3-3 Gathering and verifying data

4. Forming the team

- Assemble a team of stakeholders in the problem. Include personnel who know the process, have the data and experience, and the ones that will have to implement the corrective actions. This may include Maintenance, Management, Operations, Safety,

Training, Vendors, etc. Without the full buy-in and support of the stakeholders, long-term solutions are unlikely. All members must be able to contribute information, technical expertise, management support, advice or facilitation. In larger issues, the team may be dynamic, with members changing as expertise is required.

4-1 It is acceptable to determine the need for outside RCA assistance or facilitation,where cost effective.

5. Identifying the problem(s)

- In order to provide a valid corrective action, the problem must be clearly and appropriately defined. Frequently, the failure identified is not really the problem, but the symptom of the problem.

5-1 What is the scope of the problem?

5-2 How many problems are involved?

5-3 What is affected by the problem(s)?

5-4 What is the impact on the plant/facility?

5-5 How often does the problem occur?

5-6 Once defined, the problem must be stated in simple terms. The event question must be short, simple, concise, focused on one problem and starts with ‘Why?’ It must not tell what caused the event, instruct what to do next, or explain the event.

Gather and verify data

- Some areas to be considered when determining what information is needed include:

1- Activities related to the occurrence

2- Initial or recurring problems

3- Hardware (equipment) or software (programmatic-type issues) associated with the

4- Occurrence Recent administrative program or equipment changes

5- Physical environment or circumstances.

Gather and verify data

- Types of data to collect include:

1- Location: The site, building, facility, department, field, equipment or machine where the event took place.
2- Names of Personnel: Personnel, visitors, contractors, etc.
3- Date and time of event
4- Specifications: What are the requirements?
5- Operational Conditions: Start-up, shutdown, normal operations or other
6- Environmental Conditions: Noise levels, visual distractions, lighting, temperature, humidity, weather, etc.
7- Communications: Verbal or written, what orders or procedures were being followed?
8- Sequence of Events: In what order did things take place?
9- Equipment: What was being operated?
10- Physical Evidence: Damaged equipment or parts, medical reports.
11- Recent Changes: In personnel, equipment or procedures.
12- Training: Classroom, OJT, none
13- Other Events: Has there been other similar occurrences?
14- Ensure that gathered data is correct and complete.

7. Analysis

- The procedure recommended by this best practice is referred to as

the 5-Why process. It is named this because it normally takes 5 'why' questions to get to the logical end of the cause chain. Not all cause chains will be complete in 5 whys, some will take 7 and others will reach their end in 3. The answers to the why questions form a chain of causes leading to the root cause. The answer to the first Why is the direct cause. The logical end of each chain (problems can branch out) is a root cause and the causes in between the direct cause and the root cause are contributing causes. There may be no contributing causes, but there is always a root cause – the best and logical place to stop as identified by the team. This place is where continuing to ask why adds no value to prevention or recurrence, reduction or cost savings.

7. Analysis

7-1 For example, if the event is:

- 7-1-1 A procedure does not exist or needs revision – why doesn't it exist (and stating that someone didn't know is not acceptable) – What was the systematic reason for the lack of knowledge?
- 7-1-2 Operator (or maintenance) not trained and/or qualified – Why was the operator not trained (stating that training was not conducted only restates the finding) and why is an unqualified operator performing work?
- 7-2 There may be multiple branches and multiple root causes. Each branch will need to be analyzed and worked down to its logical end. Many of these identified causes may not directly relate to the problem at hand, but point to issues that still need to be addressed to prevent future problems.

8. Impact

- Review the original problem statement and ensure that it is correct with the additional information that is known at this stage in the process.

9. **Solution**

- These are the solutions to the root cause, of which some may have been addressed as part of the containment action (step 2).
- 9-1 Preventive Corrective Action: These are the actions taken to prevent recurrence. They focus on breaking the cause chain completely by fixing the contributing cause and the root cause.
- 9-2 Preventive Action: Is a series of actions that positively change or modify system performance. It focuses on the systemic change and places in the process where the potential for failure exists. Preventive Action does not focus on individual mistakes or personnel shortcomings. In determining solutions, consider the following:

9. Solution

9-2-1 Feasibility: The solutions need to be feasible within the plant/facility's resources and schedule;
9-2-2 Effectiveness: The solutions need to have a reasonable probability of effectively solving the problem;
9-2-3 Budget: Solution costs must be within the budget of the plant/facility and
also appropriate for the extent of the problem;
9-2-4 Employee Involvement: The departments and personnel affected by the problem need to be involved in creating the solution(s);
9-2-5 Focus on Systems: The solution(s) should be focused on systemic issues. Operators do make mistakes, but that is not usually the root cause of the problem.
9-2-6 Contingency Planning: All solutions are developed with a certain expectation of success. Critical elements of the solution should have contingency plans available to prevent failure of the entire solution.

9. Solution

- 9-3 Guidelines for solution development:

9-3-1 There may not be an absolute correct solution.

9-3-2 Do not rush to a solution and be willing to think about alternatives over a reasonable period of time.

9-3-3 Always be willing to challenge the root cause as a symptom of a larger problem.

9-3-4 Never accept an assumption as fact without significant data.

9-3-5 Does the corrective action reduce the risk of the event recurring to a reasonable level? Are there any adverse effects for the application of the corrective action?

9. Solution

9-4 If a corrective action is deemed unacceptable, note the reasons for rejecting the action.

9-5 Set responsibility for accomplishment and defined timelines.

10. Assessment

- 1- Equipment/Material Problem:

1-1 Defective or failed part

1-2 Defective or failed material

1-3 Defective weld, braze, or soldered joint

1-4 Error by manufacturer in shipping or marking

1-5 Electrical or instrument noise

1-6 Contamination

10. Assessment

- 2- Procedure Problem:

2-1 Defective or inadequate procedure

2-2 Lack of procedure

10. Assessment

- 3- Personnel Error:

3-1 Inadequate work environment

3-2 Inattention to detail

3-3 Violation of requirement or procedure

3-4 Verbal communication problem

3-5 Other human error

10. Assessment

- 4- Design Problem:

4-1 Inadequate man-machine interface

4-2 Inadequate or defective design

4-3 Error in equipment or material selection

4-4 Drawing, specification, or data errors

10. Assessment

- 5- Training Deficiency:

5-1 No training provided

5-2 Insufficient practice or hands-on experience

5-3 Inadequate content

5-4 Insufficient refresher training

5-5 Inadequate presentation or materials

10. Assessment

- 6- Management Problem:

6-1 Inadequate administrative control

6-2 Work organization/planning deficiency

6-3 Inadequate supervision

6-4 Improper resource allocation

6-5 Policy not adequately defined, disseminated, or enforced

6-6 Other management problem

10. Assessment

- 7- External Phenomena:

7-1 Weather or ambient condition

7-2 Power failure or transient

7-3 External fire or explosion

7-4 Theft, tampering, sabotage

10. Assessment

- 1- Schedule Follow-Up date.
- 2- Follow-Up: Corrective actions must be assigned to someone who is responsible to assure that the actions are implemented as stated. When verifying implementation, it is important to take things literally. Was everything accomplished as you stated in the report? Where the tasks accomplished per the established timeline?
- 3- Assessment: Once the action has been implemented, the actions must be assessed to determine if they are effective. In order to determine effectiveness, the criteria must be defined by which effectiveness is measured and what is acceptable. Assessing the effectiveness of actions taken will be a significant step in reducing non-sustaining corrective action.

11. Complete RCFA and Corrective Actions:

- determined effective , or return to the cause chain to review corrective actions taken and if the root cause requires more definition

1- Will the corrective action prevent recurrence?

2- Is the corrective action feasible?

3- Does the corrective action allow meeting primary objectives or mission?

4- Does the corrective action introduce new risks? Are the assumed risks clearly stated? (The safety of other systems must not be degraded by the proposed corrective action.)

5- Were the immediate actions taken appropriate and effective?

specific questions and considerations in developing and implementing corrective actions

- 1- Do the corrective actions address all the causes?
- 2- Will the corrective actions cause detrimental effects?
- 3- What are the consequences of implementing the corrective actions?
- 4- What are the consequences of not implementing the corrective actions?
- 5- What is the cost of implementing the corrective actions (capital costs, operations, and maintenance costs)?
- 6- Will training be required as part of the implementation?
- 7- In what time frame can the corrective actions reasonably be implemented?
- 8- What resources are required for successful development of the corrective actions?
- 9- What resources are required for successful implementation and continued effectiveness of the corrective actions?
- 10- What impact will the development and implementation of the corrective actions have on other work groups?
- 11- Is the implementation of the corrective actions measurable?

12. Record and Archive findings

- Follow up and continuous improvement
- Failure Decision Tree

RCM

RCM

- RCM is used to determine what failure management strategies should be applied to ensure a system achieves the desired levels of safety, reliability, environmental soundness, and operational readiness in the most cost-effective manner.

RCM

RCM develops logical decisions based on the following precepts:

- The objective of maintenance is to preserve an item's function(s).
- RCM seeks to manage the consequences of failure –not to prevent all failures.
- RCM is driven first by safety. When safety is not an issue, maintenance must be justified on the ability to complete the mission and finally, on economic grounds.
- RCM acknowledges that at best, maintenance can only sustain the system to its inherent level of reliability within the operating context.
- RCM uses design, operations, maintenance, logistics, and cost data, to improve operating capability, design and maintenance.
- RCM is a continuous process that requires sustainment throughout the life cycle

RCM

The RCM process includes identifying the following items in sequence:

1.Functions:

The desired capability of the system, how well it performs, and under what circumstances

2. Functional Failures:

The failed state of the system (e.g., the system falls outside the desired performance .

3. Failure Modes:

The specific condition causing a functional failure

RCM

4. Failure Effects :

Description of what happens when each failure mode occurs, detailed enough to correctly evaluate the consequences of each

5. Failure Consequences:

The description of how the loss of function matters (e.g. safety, environmental, mission, or economics

6. Maintenance Tasks and Intervals :

The description of applicable and effective tasks, if any, performed to predict or prevent failures

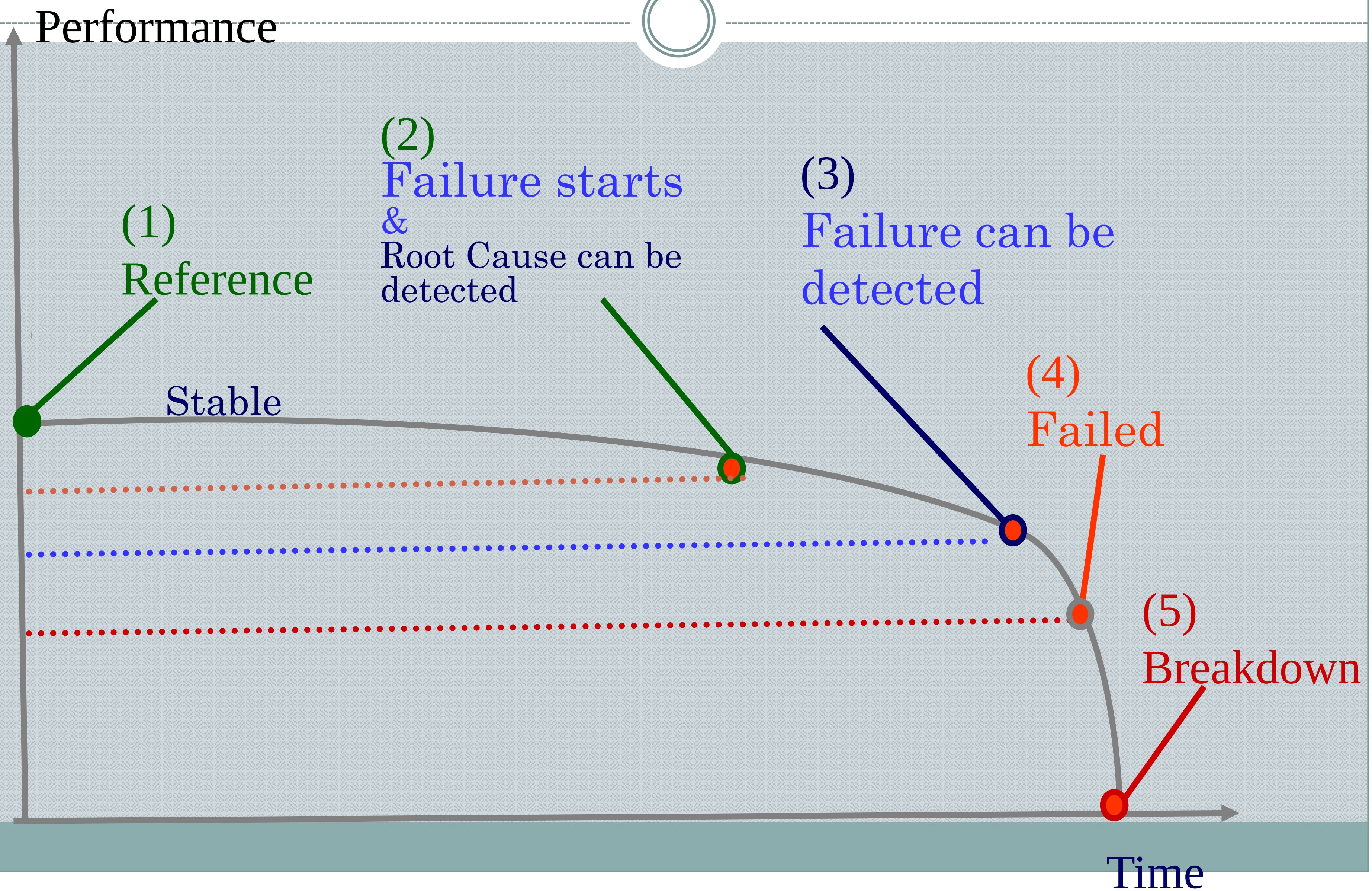
7. Other Logical Actions:

Including, but not limited to, run-to-failure, engineering redesigns, and changes/additions to operating procedures or technical manuals

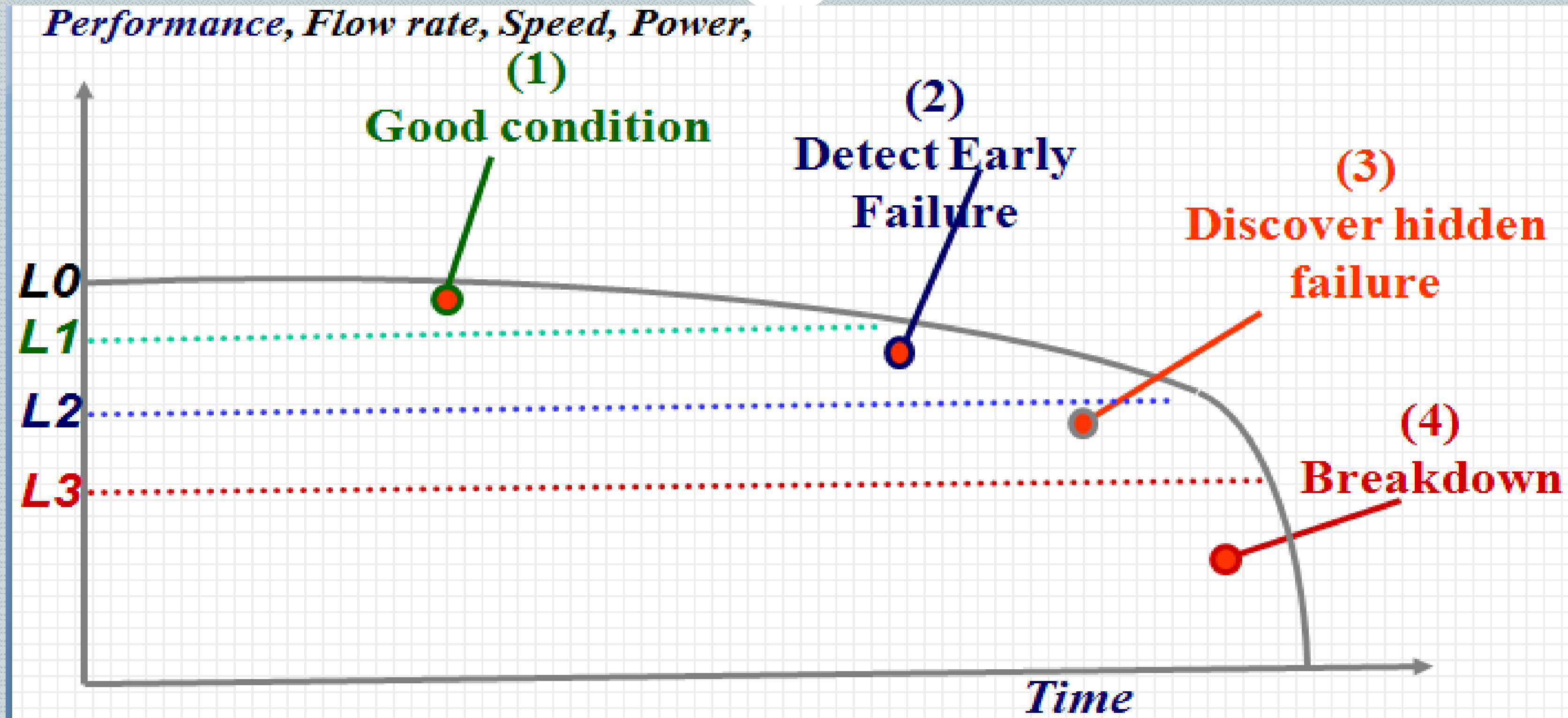
RCFA + RCM

- RCM is science to choose a proper PM program based on reliability expected from system but RCFA science of root cause analysis of machine and determining the right solution to eradicating the main cause of defect.
- Entered data for two method is fault machine information and maintenance record.
- For starting RCM, you want more and more energy and time, but base of RCFA is find a solution in shortage time.
- Success RCFA process has created a lean PM program, but RCFA fixes an issue indicates solution.
- Some companies insist on running RCM but failing to achieve positive result, they giving up to continuing the plan.

When attempting to analyze the root causes of failure



RCFA



Limits:

L0 : Signature (as good as new)

L1 : Call for service (planned PM task)

L2 : Call for repair (planned CM task)

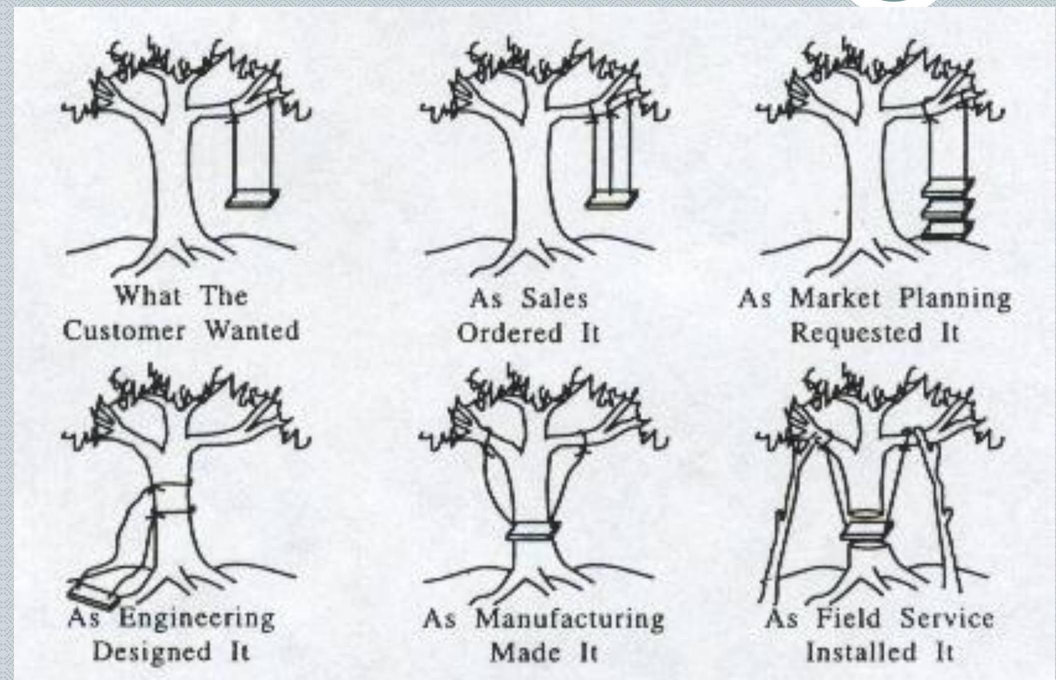
L3 : Breakdown (unplanned CM task)

QFD

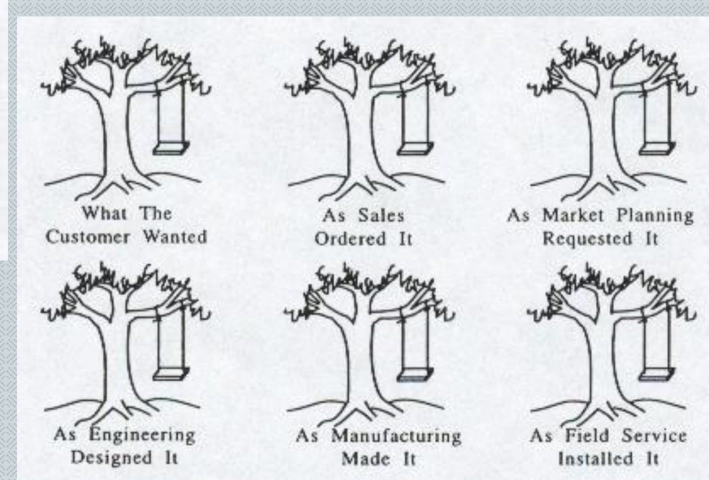
What is QFD?

- There is no single, right definition for QFD; this one captures its essential meaning:
- **A system for translating customer requirements into appropriate company requirements at each stage from research and product development to engineering and manufacturing to marketing/sales and distribution**

QFD

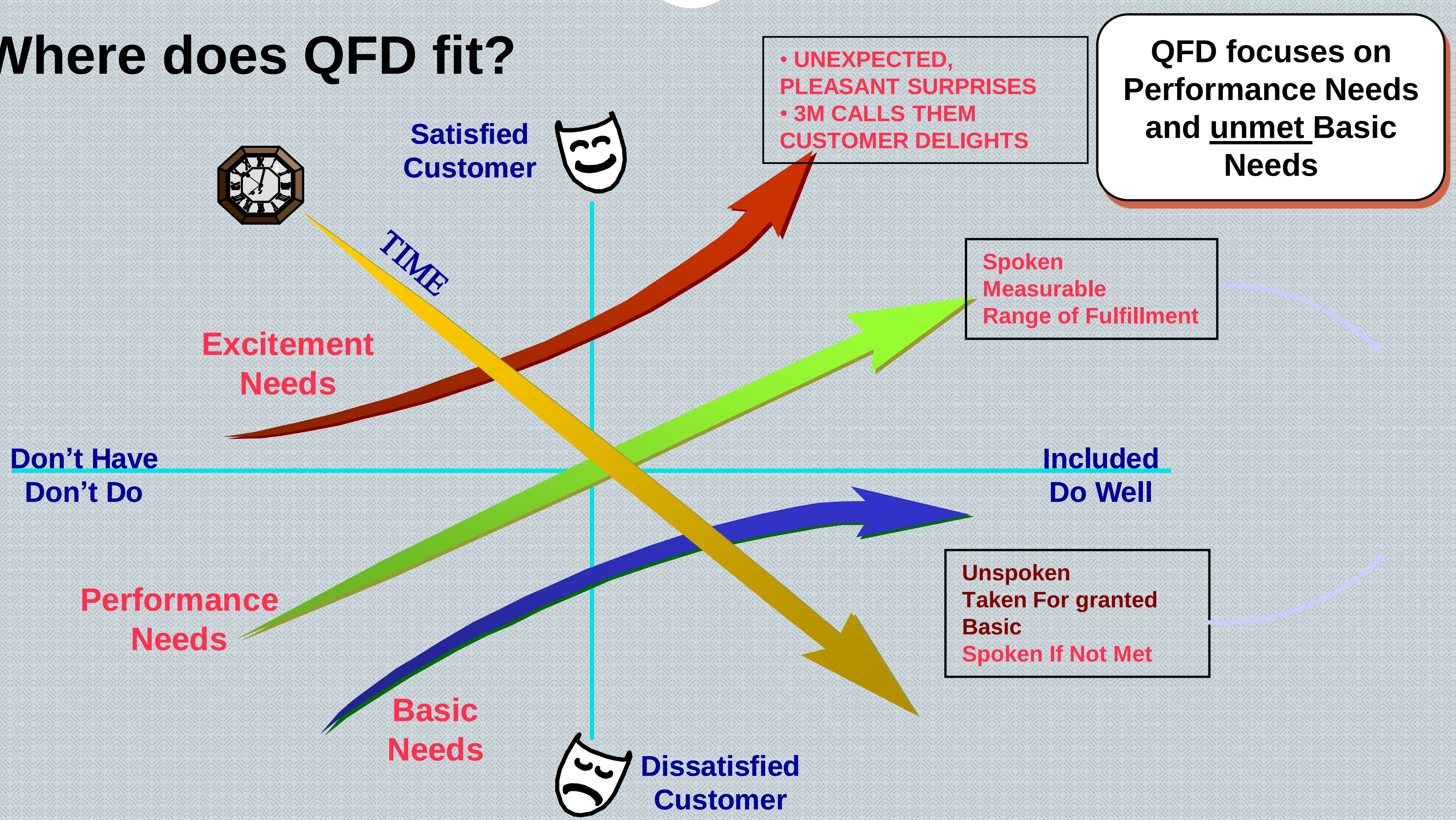


QFD Target

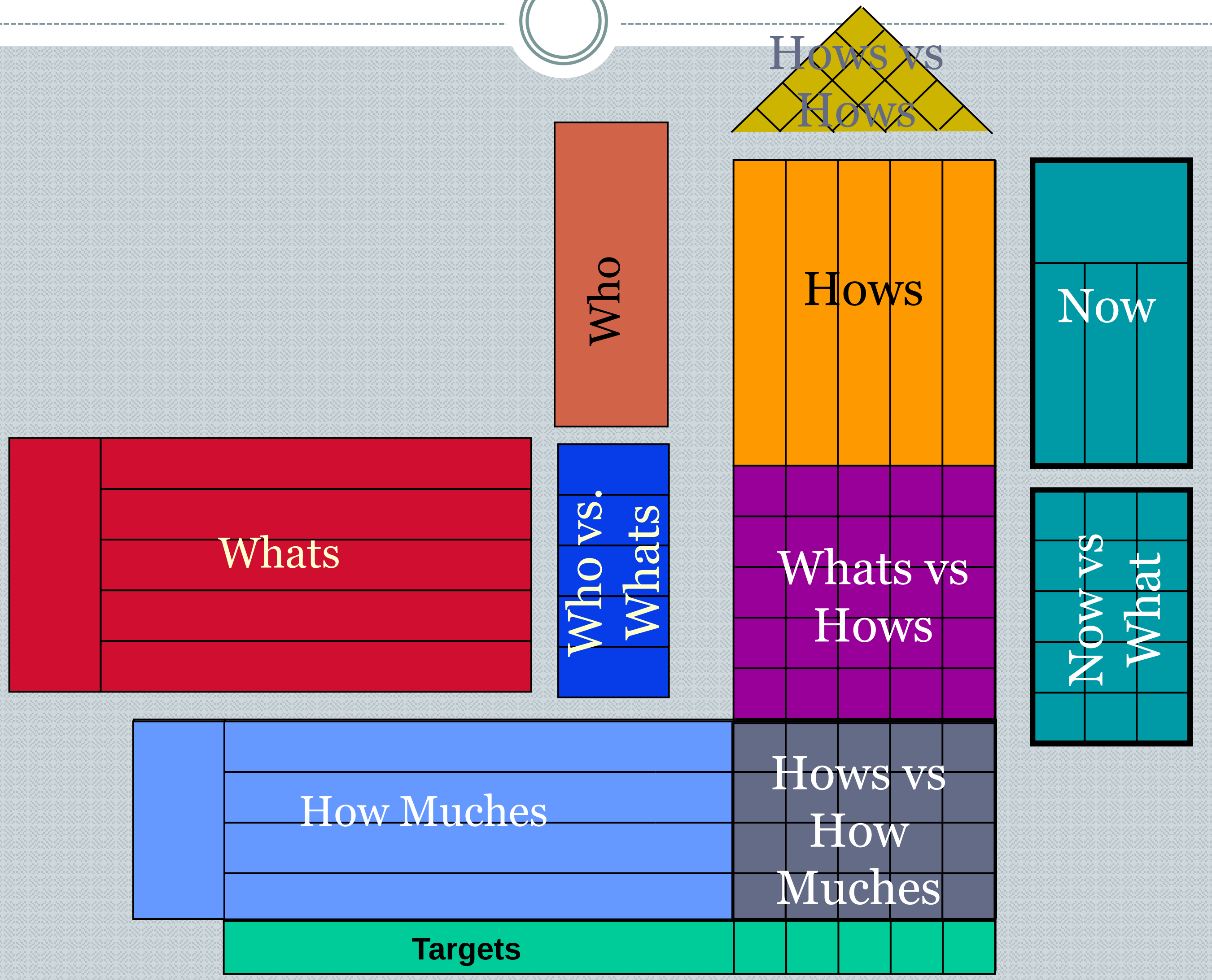


Kano Model

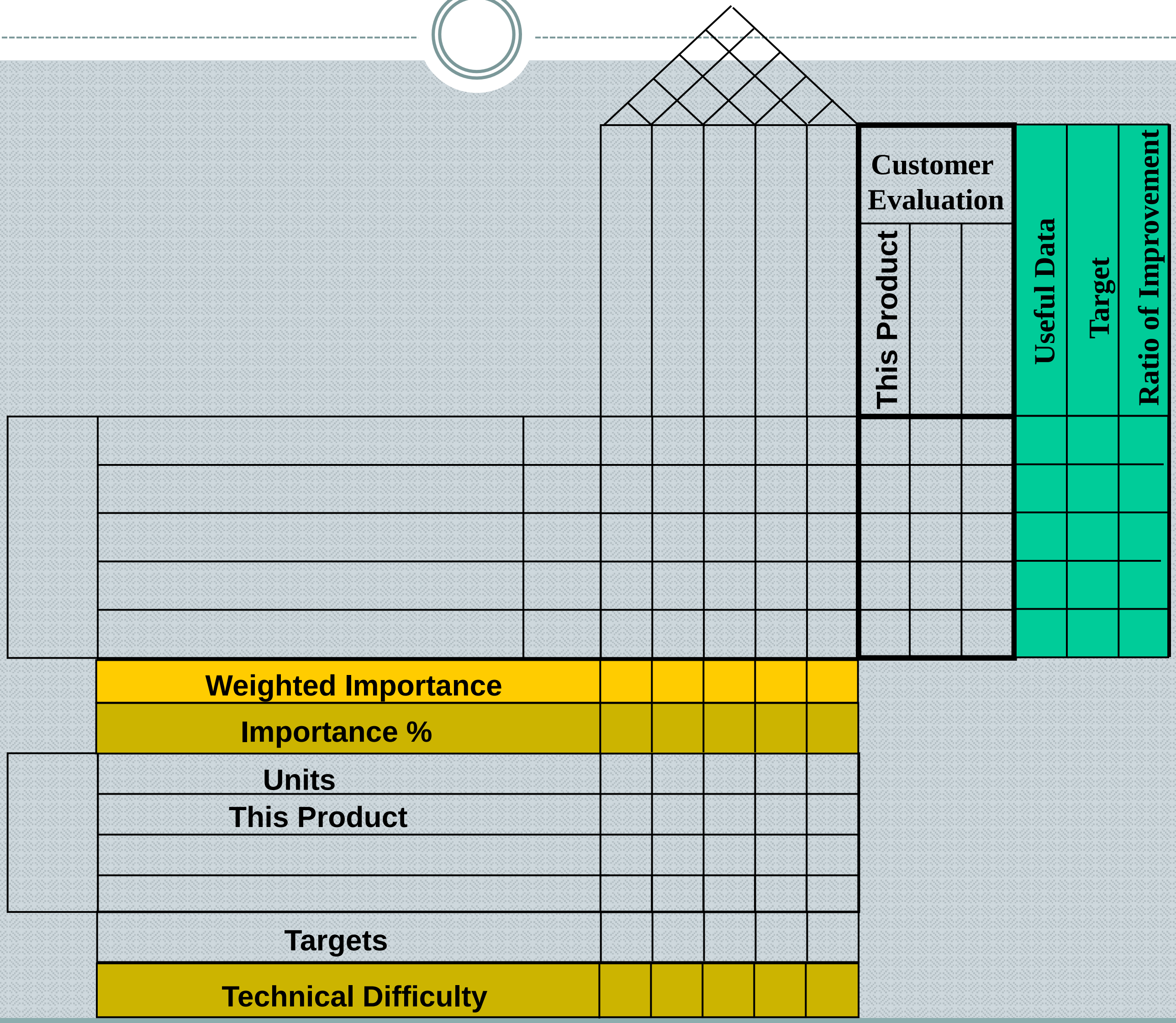
Where does QFD fit?



Components of House of Quality

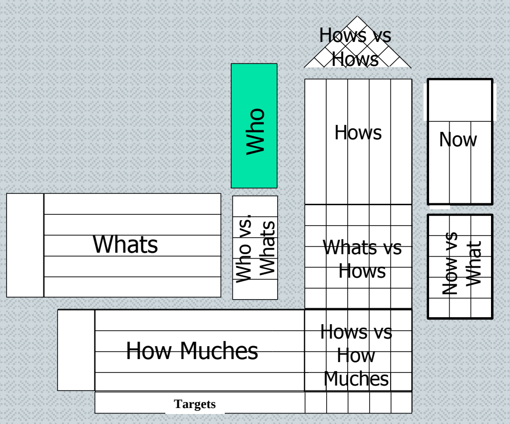


Extensions to House of Quality



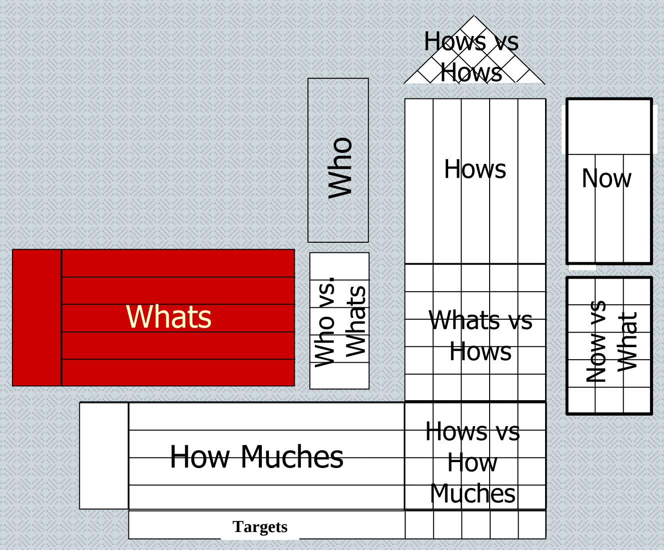
Step 1: Who are the customers?

- To "Listen to the voice of the customer" first need to identify the customer
- In most cases there are more than one customer
  - consumer
  - regulatory agencies
  - manufacturing
  - marketing/Sales



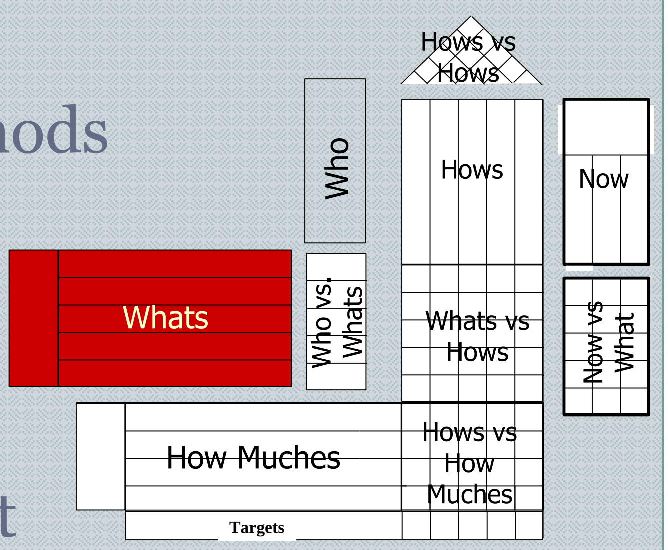
Step 2: Determine the customers' requirements

- Need to determine what is to be designed
- Consumer
  - product works as it should
  - lasts a long time
  - is easy to maintain
  - looks attractive
  - incorporated latest technology
  - has many features



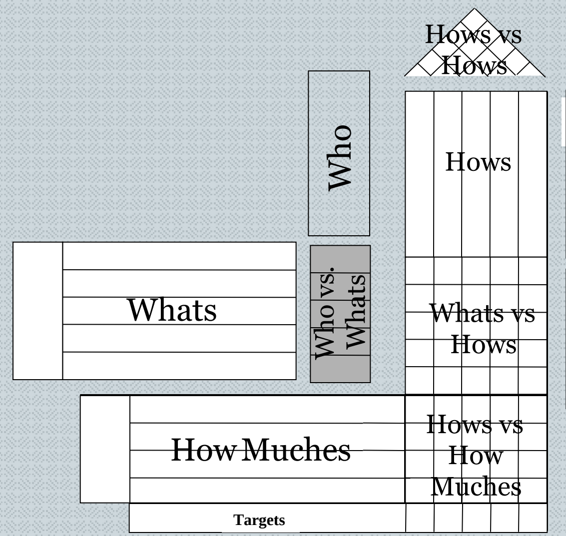
Step 2: Determine the customers' requirements

- Manufacturing
  - easy to produce
  - uses available resources
  - uses standard components and methods
  - minimum waste
- Marketing/Sales
  - Meets customer requirements
  - Easy to package, store, and transport
  - is suitable for display



Step 3: Determine Relative Importance of the Requirements: Who vs. What

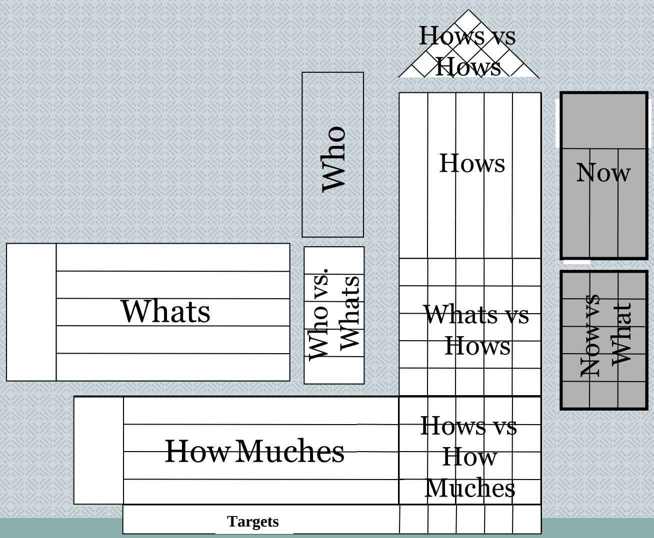
- Need to evaluate the importance of each of the customer's requirements.
  - Generate weighing factor for each requirement by rank ordering or other methods



Step 4: Identify and Evaluate the Competition: How satisfied is the customer now?

- The goal is to determine how the customer perceives the competition's ability to meet each of the requirements
  - it creates an awareness of what already exists
  - it reveals opportunities to improve on what already exists

The design:
1. does not meet the requirement at all
2. meets the requirement slightly
3. meets the requirement somewhat
4. meets the requirement mostly
5. fulfills the requirement completely

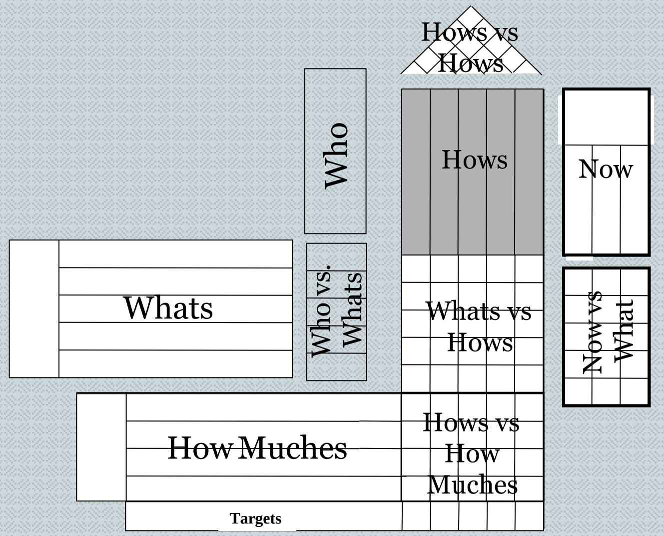


Step 5: Generate Engineering Specifications: How will the customers' requirements be met?

- The goal is to develop a set of engineering specifications from the customers' requirements.

Restatement of the design problem and customer requirements in terms of parameters that can be measured.

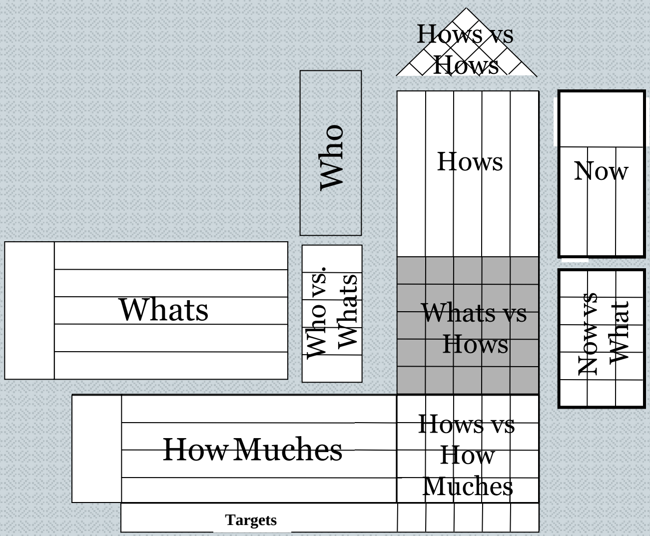
Each customer requirement should have at least one engineering parameter.



Step 6: Relate Customers' requirements to Engineering Specifications: How's measure What's?

- This is the center portion of the house. Each cell represents how an engineering parameter relates to a customers' requirements.

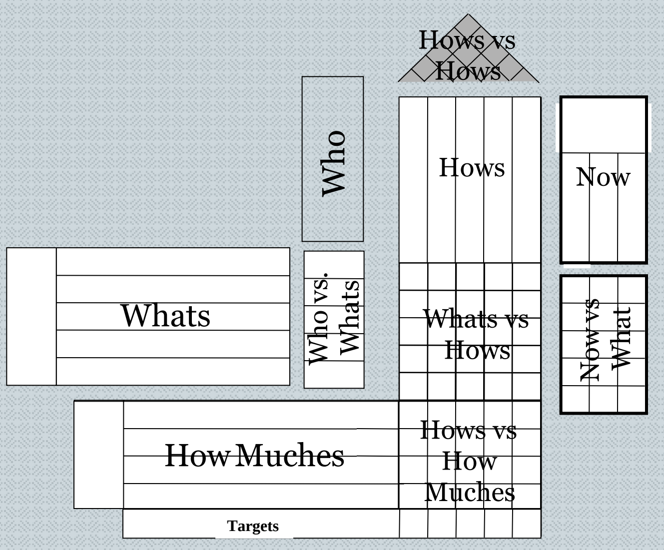
9 = Strong Relationship
3 = Medium Relationship
1 = Weak Relationship
Blank = No Relationship at all



Step 7: Identify Relationships Between Engineering Requirements: How are the How's Dependent on each other?

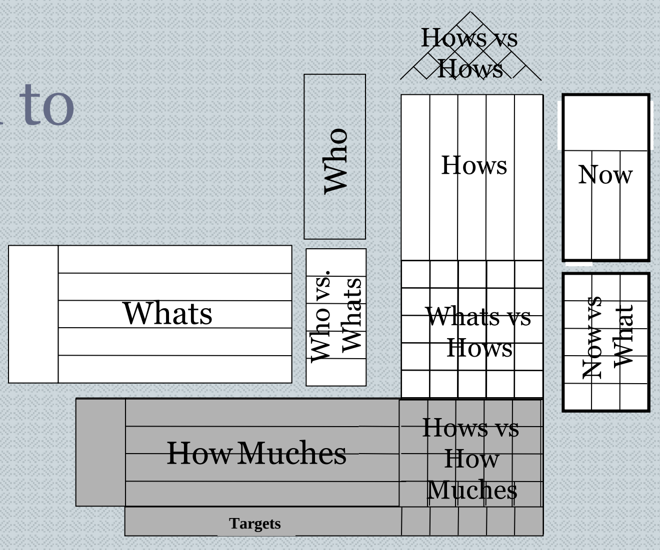
- Engineering specifications maybe dependent on each other.

9 = Strong Relationship
3 = Medium Relationship
1 = Weak Relationship
-1 = Weak Negative Relationship
-3 = Medium Negative Relationship
-9 = Strong Negative Relationship
Blank = No Relationship at all



Step 8: Set Engineering Targets: How much is good enough?

- Determine target value for each engineering requirement.
  - Evaluate competition products to engineering requirements
  - Look at set customer targets
  - Use the above two information to set targets



Thanks for attention