TRIZ - essential to anyone using Root Cause Analysis (RCA) Toolkits

Root Cause Toolkits are important in many industries for quality, reliability and predictability issues and for locating unexpected / mysterious variations or to explain rogue problems. RCA without TRIZ generally tracks causes or predicts problems or failures but does not solve problems – that is left to team wisdom, experience plus brainstorming which works much of the time.

In many cases uncovering and understanding the roots of straightforward problems needsmore than common sense, relevant experience and knowledge to know what to do next, and RCA always helps. However when solving the difficult, puzzling problems wise RCA experts know they also need TRIZ. These clever RCA experts master and apply TRIZ as well because they recognise it extends, enhances and completes their capability and they can uncover problems with their RCA tools and then solve them with TRIZ rather than random brainstorming. They know how TRIZ takes them far beyond uncovering problemsto improving systems in the most cost effective, systematic, engineering smart ways with the least change, disruption and modification. One ultimate goal of TRIZ is to solve challenging problems without changing anything – when problems emerge in developed systems this TRIZ Zero approach takes us, as far as is practical in that direction, to find elegant, resource efficient good engineering solutions.

Most RCA experts greatly appreciate the power they possess to predict, locate, diagnose and uncover problem causes and are often loyally enthusiastic to the particular RCA toolkit they know and love. In big companies such love is often monogamous and they endue the toolkit they know with every virtue, often wrongly labelling their toolkit as problem solving instead of problem revealing.

RCA toolkit specialists sometimes switch only to new, younger but very similar models of their old toolkit at great expenditure of resources. (Unlike TRIZ, most toolkits are from the excellent Demming Stable of Quality - there are many generations and many famous expanded variations of the simple, powerful, basic themes). These 'new' toolkits are often re-named versions, with extra functionality and can be complicated and resource hungry.

Regular initiatives in big companies to bring in 'new' toolkits (often rebadged but similar to old ones) with disruption, expense for few additional advantage. This has created a resistance to adopting different and much needed toolkits which can offer additional critical, complementary functionality such as TRIZ. Perhaps polygamy (TRIZ Principle One – Segmentation) is needed here so that different toolkits can be taken on to each provide what they do best – TRIZ is an essential addition to all the RCA, Quality, Six Sigma, Systems Thinking, Value, QFD and Lean toolkits as it fills in their problem solving gaps, delivers innovation and provides the next step to rapidly and systematically locating all the best relevant, resource efficient solutions to the problems other toolkits have uncovered.

TRIZ Inventive Principle 1 suggests Segmentation – to get all the functionality we require. Should companies select complementary but different toolkits to get everything they need for innovation & problem solving?

Root Cause Analysis (RCA) Toolkits& TRIZ Capability

RCA has many different forms (some public domain – some licensed- some with software) all used to predict future failures, or diagnose existing ones. RCA capability includes locating unexplained variations and causes of problems, and calculating and predicting likely future hazards/harms to deliver a specified level of reliability.

Well known RCA techniques include:-

1. Barrier Analysis
2. Cause & Effect / Fishbone Diagrams
3. FMEA (Failure Mode & Effects Analysis)& FMECA (+ Criticality Analysis)
4. 5 Whys&Fault Tree Analysis/Causal Chains
5. Mill's method of difference

RCA contributing Causes can be

- independent
- linked / in a chain

RCA helps us both

- Forecast - predict the scale and likelihood of future problems / failures
- Diagnose (conduct an autopsy) on a problem / harm / fault to map its causes when we don't know why it happened and/or what made it happen

Magnitude of Problem =
likelihood x degree of harm /damage

Adopting TRIZ – What does it add to RCA Toolkits?

When adopting TRIZ it is important to understand

- The problem resolution itsignificantly adds to all standard RCA methods– especially the contradiction solving power of taking out harmful components or functions whilst retaining their beneficial functions
- The RCA already existing in TRIZ and the ways this links to /enhances other standalone RCA Methods

There are many maps to locate hidden causes of problems- some are more useful than others

1. Barrier Analysis

A Barrier is something which protects from HARM (e.g. a sheaf for a knife or armour)

How Barrier Analysis works without TRIZ

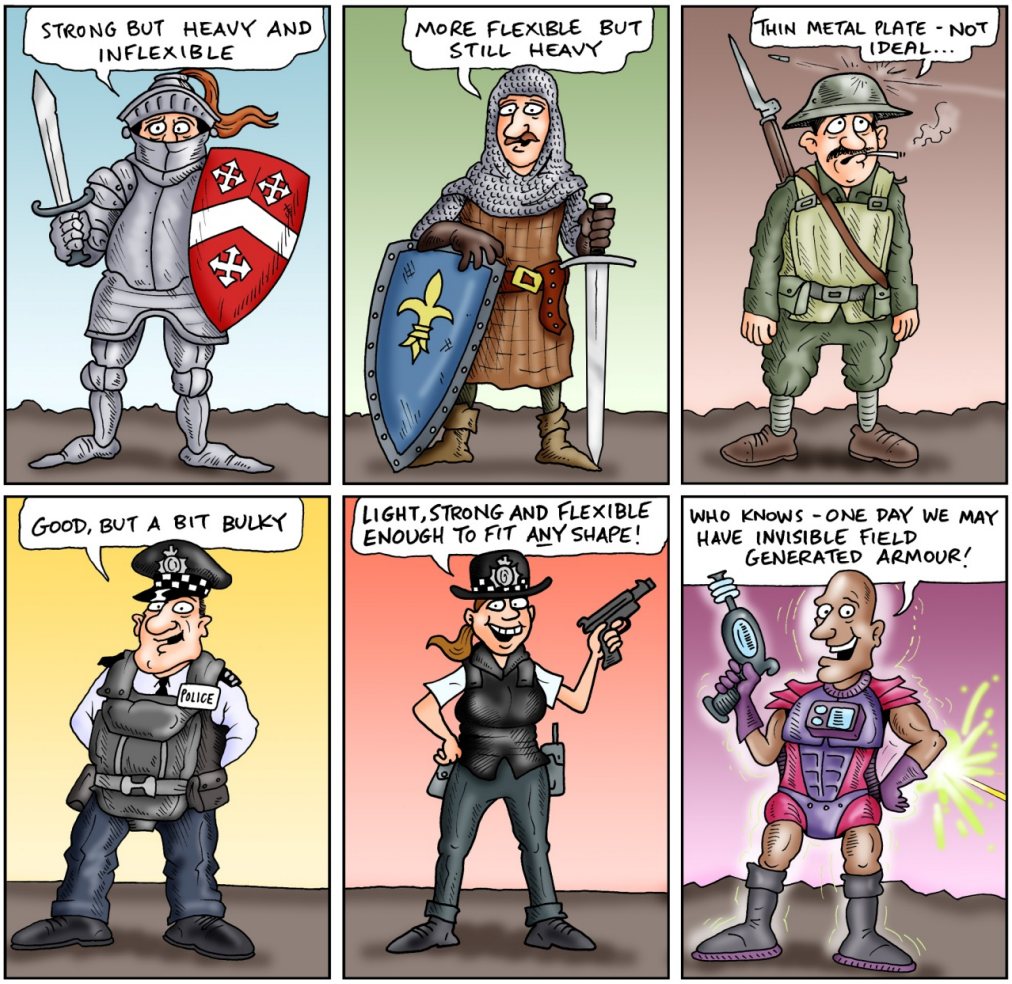
Brainstorm to come up with a list of Barriers which

- Failed
- Were not used
- Do not exist

Then brainstorm ways of dealing with the failures and causes of problems

TRIZ Tools to add to Barrier Analysis to make it more effective

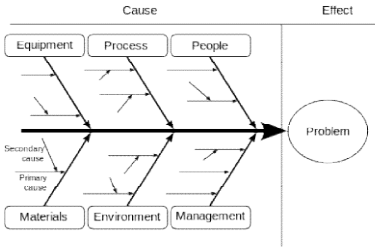
- 9 Boxes to find more existing barriers which were not used or failed
- IDEAL &X Factor to define 'Barriers we want' and what they will achieve
- Resources plus Effects to see 'HOW TO' create desirable barriers
- TRIZ problem solving (including solving contradictions) to deal with problems which arise from creating new barriers
- Standard Solutions (includes TRENDS) to improve existing/ insufficient or missing barriers



The TRIZ Trends of Evolution can be applied to improve (logically evolve) barriers such as armour

2. Cause & Effect / Fishbone Diagrams

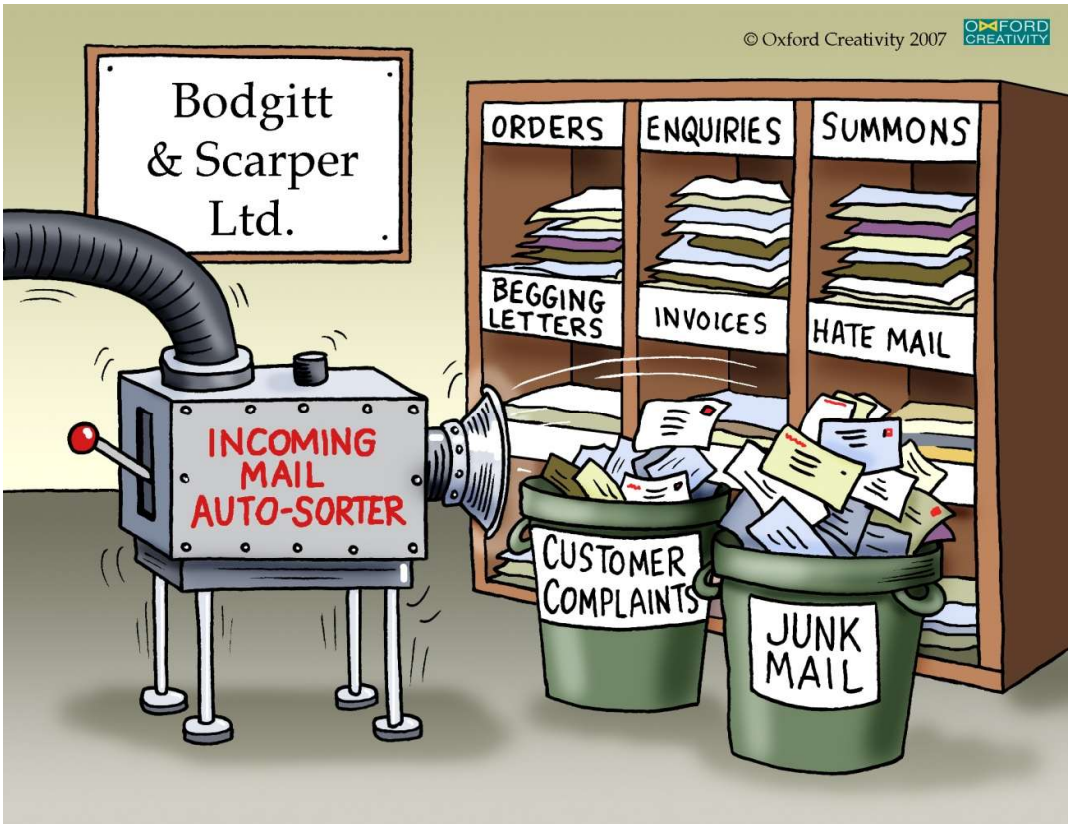
The Fishbone Diagram (also known as the Cause & Effect Diagram) is a technique to graphically identify and organize many possible **causes** of a **problem (effect)**



Put problem in right hand box – then choose relevant/likely factors which may be major causes of the problem/variation such as Equipment, Process, People, Materials, Environment and Management (use smaller arrows to connect the sub-causes to major causes)
Locate **causes of problem**by brainstorming/elimination/seeking relevant knowledge

How to do Fishbone Analysis without TRIZ

- Write down problem
- Get a group of people together with some knowledge of the problem
- Brainstorm possible causes of the problem and map it onto a Fishbone Diagram with some useful /likely categories of problem causes (see diagram above)
- See if this helps anyone have ideas about what caused the problem



Is Fishbone Analysis just a sorting machine?

TRIZ Tools to add to Fishbone Analysis to make it more effective

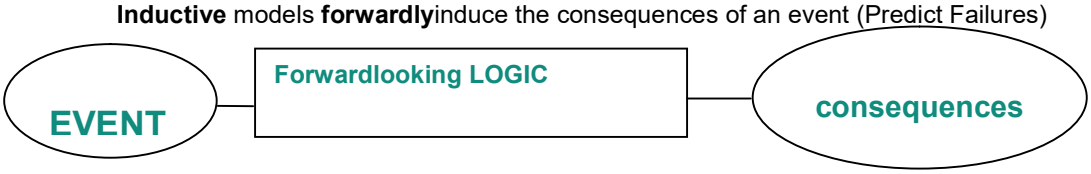
Map in 9- Boxes to identify **causes** and /or **sub-causes**

Use a 9-Bone Skeleton (one bone = one box & use these to identify sub-bones)

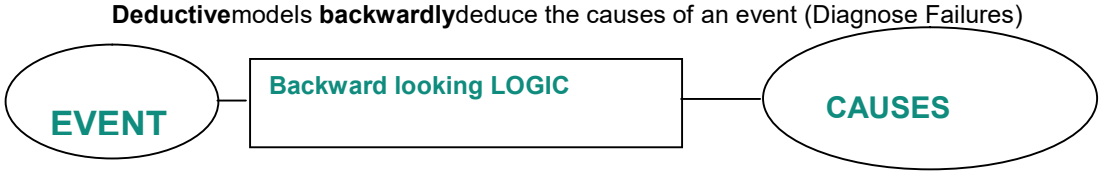
3. FMEA (Failure Mode & Effects Analysis)

FMEA involves reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes, and their likely causes, in order to avoid them AND estimate the effect failure of each would have upon the whole system. Failure Mode = the specific way in which a failure occurs. Sometimes the FMEA is called FMECA to indicate that Criticality Analysiswas undertaken as a second step after the first step of the failure modes and effects analysis (FMEA). This is to give some estimate of how critical would this particular failure be on the whole system.

Inductive models **forwardly**induce the consequences of an event (Predict Failures)



Deductivemodels **backwardly**deduce the causes of an event (Diagnose Failures)



An FMEA predicts likelihood of failure(s) and is an inductive reasoning (forward logic) single point of failure analysis -based on asking questions like:"in what way and what is the likelihood of this particular widget (orfunction) failing? (including 'how have similar ones gone wrong in the past?')And thenalso askif it failed what would be the consequences?"(Criticality Analysis).Therefore FMEA activity identifies potential failure modes based on experience with similar products and processes - or based on common physics of failure logic. *Effects analysis* refers to studying the consequences of those failures on different system levels.

How FMEA works without TRIZ

FMEArequires a detailed understanding of our system - a non-TRIZ limited form of Functional Analysis is used as an input to determine correct/likely failure modes, at all system levels.

It requires us to identifySystemItem(s)andFunctions(s)

For each Item or Function:

–Identify potentialfailuremode(s)

–Identify potentialeffect(s) of failure

–Identify potentialcauses(s)of failure

–Recommendandimplementaction

TRIZ Tools to add to FMEA to make it more effective

Thinking In Time & Scale (9 Boxes)

TRIZ Function Analysis

TRIMMING to remove troublesome or unreliable components

4. FaultTreeAnalysis& 5 Whys

These are two closely related techniques – both are designed to take us to the reasons **why** a component or process is failing in the system - to reach the root cause or anactionablecause.

Fault tree Analysis is more systematic, thorough and powerful than the **5 Whys** although the basic logic is very similar.An example of **5 Whys**

Problem –BIRDSTRIKE - birds fly into the engines of planes at Amsterdam airport

1. **Why?**–The birds are near the planes. (first why)
2. **Why?**–There are places near the airport where they can thrive(second why)
3. **Why?**–There is grass near the runways which attracts birds (third why)
4. **Why?**–The grass contains food sources such as mice (fourth why)
5. **Why?**– Nothing discourages mice

The problem was solved with a very good solution for Amsterdam when many tulips were planted. Mice hate the smell of tulips and were discouraged

I KEEP six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who.
I send them over land and sea,
I send them east and west;
But after they have worked for me,
I give them all a rest.

Rudyard Kipling

The tool the 5 Whys has many fans (like SWOT - it's simple, memorable and it works on straightforward situations). It probably has as many critics who say:-

- Asking so many questions is annoying
- 5 might be too many or not enough
- 5 Whys is like an Armenian Radio Yerevan joke –when both the questions and answers can be contradictory and nonsensical.... for example The Armenian Radio was asked: "Is it true that comrade cosmonaut Yuri Gagarin's car was stolen in Moscow during the celebrations?" The Armenian Radio answers: "In principle yes, but it was not in Moscow, rather in Kiev, and it was not his car, but his bike and it was not comrade cosmonaut Yuri Gagarin, but comrade highschool teacher Gagarin and his first name was not Yuri, but Leonid..."

FAULT TREE ANALYSIS / Chain Diagrams

Fault Trees help us analyse failures in systems to

diagnose what caused the problem(s) after something has failed or gone wrong

or

predict likely or possible failure(s) in a system

Fault Trees map the roads/paths in a system or events that could lead to a foreseeable problem. The paths connect the contributory conditions and events and these are represented by standard symbols. In this way fault tree diagrams reveal the logical and likely occurrence of problems (showing how sub-systems/componentscontribute to the failures) to map how they occur and/or combine to cause undesirable events or whole system failures. After creating the diagram, numerical probability of failure can be assigned to the critical system components to forecast failure (or to calculate reliability).The FaultTree works with 5 Whys but additionally introducesBooleanlogic adding AND & OR. WecanalsohaveInclusiveOR (AND/OR),or exclusiveOR (just OR) to create a tree of causes and causes of causes.

*Reduction of fighting outside pubs was achieved by police handing out chocolate bars at closing time Aggression could be caused by alcohol **and/or** low sugar levels in the blood(**or** gang culture etc.)*

Disadvantages of FAULT TREE ANALYSIS

- It can become very big and very complicated
- Much information/knowledge/wisdom and resources required

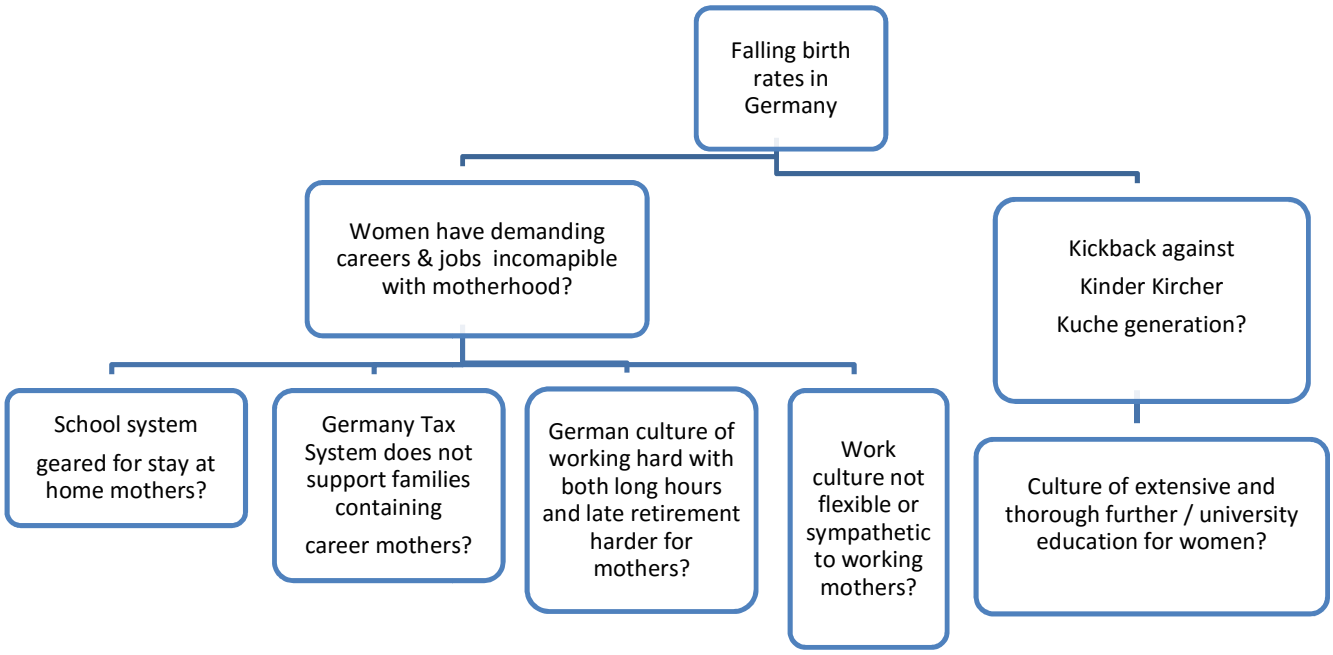
Advantages of FAULT TREE ANALYSIS

- Map showing the paths which led to the hazard/problem/failure
- Critical contributory factors are identified and shown where and when they occur
- Improved system understanding
- Probability of failure estimated
- Resources to prevent failure can be estimated
- Redesign to eliminate failure may be revealed

- Sustainability may be established

Traditional Steps for FaultTreeAnalysis

1. Describe the problem / Define the undesired event
2. Obtain an understandingof the system
3. Construct the fault tree with major possible causes forming their own separate branches
4. Evaluatethe fault tree to traces causes of the problems
5. Deal with / controlthehazardsidentified using available knowledge & brainstorming



In addition to simple examples as above there are various symbols used to build a Fault Tree to add more detail to faults or failures/events (not dealt with here - consult Fault Tree analysis literature)

FAULT TREE ANALYSIS works best when there are...

- Identified problems (with unidentified or many possible causes)
- High risk events or threats/big problems
- Many contributory factors to the problem
- Complicated systems/events and processes

6. Mill's method of difference

*If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance save one in common, that one occurring only in the former; the circumstance in which alone the two instances differ, is the effect, or cause, or an necessary part of the cause, of the phenomenon.**John Stuart Mill -'A System of Logic' 1843. p. 455***

John Stuart Mill was a British philosopher and in '*A System of Logic*' he suggested five ways for uncovering causes of problems – the most famous being the **method of difference**.
When we have a failure in a system, we ask two initial questions

- "Why did this system fail but not other nearly identical systems?"
  And
- "Why did this system fail today but not yesterday?"

Spotting Differences between very similar objects helps locate problems
We look at the *difference* between this system's failure and identical systems (or very similar systems) where failures did not occur. We are looking for the cause of the failure in the **difference** between the two cases. By restricting attention to thedifferences between the two cases, we essentially ignore everything they have incommon and we dramatically reduce the amount of material and the number ofpossible causes we need to consider.

1. Describe problem situation / event / failure
2. List probable / likely causes of failure
3. Summarise what is known / the evidence about each 'likely causes of failure'
4. Look for potential differences between failed system and similar systems
5. Investigate potential identified causes more fully

TRIZ RCA Methods

Adding RCA to classical TRIZ Tools

One great benefit of TRIZ is to take out trial and error and systematically move towards resolution – with clear understanding and efficient location ofall relevant and powerful solutions to problems. When faced with unknown causes of problems TRIZ methods to locate them focus on logical routes to map root causes which exist both within and beyond TRIZ capability. TRIZ philosophy is to never re-invent the wheel so when good tools already exist (which complement and add to the RCA tools already in the TRIZ core toolkit) these are logically linked to TRIZ and applied when needed.The RCA methods added to TRIZ are not those which rely on brainstorming, luck and/or iterative searches such as Fishbone or Barrier but those which either trace or intelligently predict root causes of failures or problems.

Amongst TRIZ Practitioners the best of the assorted RCA tools to have been added to the classical TRIZ Toolkit is Fault Tree Analysis and FMEA. These help extend TRIZ problem solving capability to ensure hidden causes of problems (both past and future) can be quickly located and communicated within teams.For example in the Russian Association of TRIZ (MATRIZ) they require competence in tools which are derived from Fault Tree Analysis methods (known confusingly as Cause Effect Chain Analysis – although it is nothing to do with Cause & Effect Fishbone Analysis). TRIZ Cause Effect Chain Analysis is based on Fault Trees and its embedded BOOLEAN logic.

TRIZ takes us out of our comfort zone &helps us look in the right places to find the real solutions

Applying classical TRIZ Tools to RCA as well as using Fault Trees (Cause Effect Chain Analysis)

We don't always need tools derived from RCA as there are TRIZ powerful tools such as **9 Box - Time & Scale**and **TRIZ Function Analysis** which can help us systematically sort out complicated situations to define the many causes contributing to an horrendous and poorly understood problem. Once the problem causes are located TRIZ methods of TRIMMING then offers us the best ways of eliminating problems whilst keeping all the beneficial aspects of the system or process.Therefore when either locating a hidden root cause of a problem or predicting a future one we use the TRIZ tools already available and add the best RCA tools.

TRIZ RCA Steps to uncover causes of problems & find viable solutions

1. Describe the problem / Define the undesired event
2. Obtain an understandingof the system with

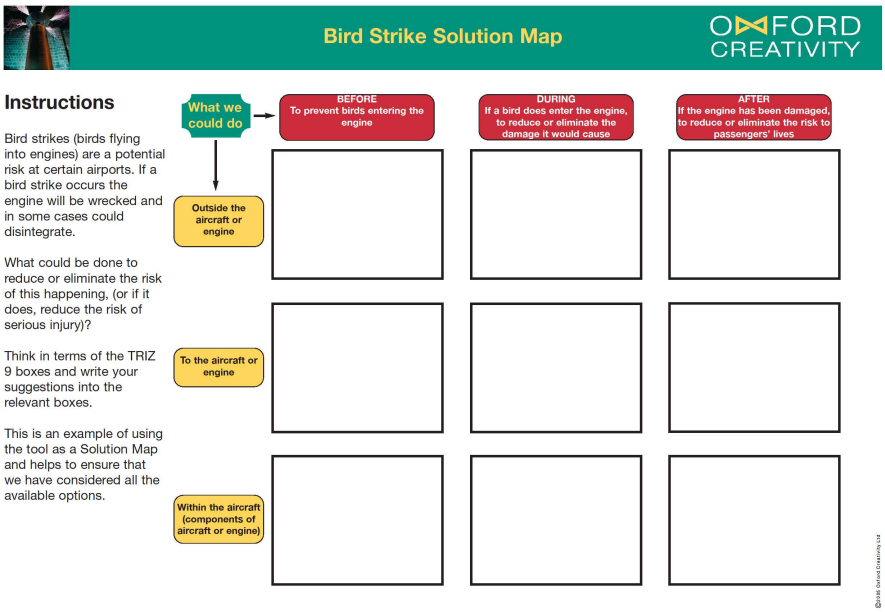
i) ***Time & Scale - 9 Box context map of Probable Causes of Problems***

ii) ***Time & Scale - 9 Box context map of Probable Solutions to Problems***

STOP - If the ***9 Box context maps***have both revealed the causes & found satisfactory solutions

OTHERWISWE CONTINUE with next steps

3. Construct High level **TRIZ Function Analysis** of situation
4. Construct the TRIZ version of a fault tree(Cause Effect Chain Analysis)to map possible root causes (Key Disadvantages) each with their own separate branches / chains
5. Evaluatethe fault tree (Cause Effect Chain Analysis)to TRIM Root Causes (Key Disadvantages)
6. Construct **TRIZ Function Analysis** of critical areas
7. Apply **TRIZ TRIMMING** Rules to remove any critical problem components whilst keeping all the useful functions provided by those components
8. Deal with / controlany remaining hazards/ troublesome componentsidentified which could not be TRIMMED using **Oxford TRIZ Standard Solutions Strategies for HARMS**
9. Build new TRIZ functional model of whole system (or just problem areas if appropriate)
10. Apply TRIMMING Rules to remove any problem components whilst keeping all the useful functions provided by those components
11. Reconfigure system with problem components TRIMMED (removed) but with all functionality still being delivered



9 Boxes Time & Scale is very powerful for Mapping both Problem Causes and Solutions

Examples of using TRIZ RCA Steps to uncover causes of problems & find viable solutions

FoodPoisoning outbreaks in famous Restaurant

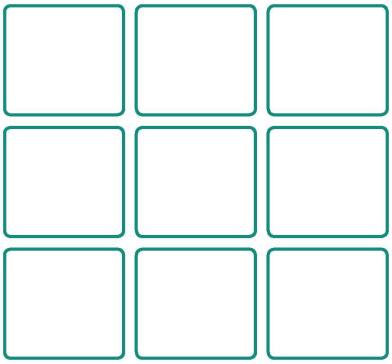
1. **Define the undesired event to study**

Heston Blumenthal's **Dinner** closed temporarily due to norovirus outbreak (see text box)

2. **Obtain an understandingof the system** by undertaking a *Time & Scale 9 Box context maps of*

   i) ***Probable Causes of Problems***

   ii) ***Probable Solutions to Problems***



3.Construct **TRIZ Function Analysis** of situation

Food poisoning has a habit of repeating on you, as many restaurants have experienced. These includethose belonging to **Heston Blumenthal**(top chef and creator of original and expensive menus)found to his cost on 1st February 2014.

Dinner, one of Britain's most exclusive eateries, in Knightsbridge, central London, has fallen foul of the same winter-vomiting bug that hit **Blumenthal's Fat Duck** restaurant in 2009 involving at least 240 people with symptoms such as nausea, vomiting and diarrhoea. Environmental health officers have told staff at the two Michelin star restaurants to wash their hands more often. Five years earlier the food poisoning outbreak at the **Fat Duck** was the biggest linked to Norovirus contamination at a restaurant ever recorded. **Contaminated oysters and handling of food by infected staff were said to be the likely causes.**

It is hoped that lessons learned from this outbreak will help to inform future action by restaurateurs especially in early notification to public health authorities once an outbreak is suspected. It is also notable that diners may often choose to inform restaurants directly rather than their doctors or public health authorities. It is important that both diners and restaurants are provided with better information about whom to inform and when to inform once an outbreak of illness is suspected,"

Blumenthal apologised to diners affected by the outbreak soon after the critical 2009 report. Demand for tables at the Fat Duck has not, however, diminished. Earlier this year the Michelin-starred restaurant was attracting tens of thousands of calls a day from diners, said Blumenthal, who recalled the poisoning incident as an "awful time".

A spokesman for the Fat Duck said: "The reported illness in February 2009 at the Fat Duck was confirmed as oysters contaminated at source by Norovirus. At the time we voluntarily closed the restaurant and called in the authorities. We co-operated with all parties fully and transparently and received a clean bill of health to reopen after a 10-day investigation.

"We also received full support by our insurers who found no fault in our practices following a report from a leading UK independent specialist. There is still no guaranteed safety measure in place today to protect the general public with regards to shellfish and viral contamination. For this reason we still do not serve oysters or razor clams at the Fat Duck."

Examples of using TRIZ RCA Steps to uncover causes of problems & find viable solutions

Map causes of decline of Barn Owls in the UK

Using TRIZ RCA Step 2. Obtain an understandingof the system with

Time & Scale - 9 Box context map of Probable Causes of Problems

Time & Scale - 9 Box context map of Probable Solutions to Problems

1. **Describe the problem / Define the undesired event**

Britain's Barn Owl population suffered a substantial decline throughout most of the 20th century and this has continued in recent years. On minor roads Barn Owls are fifty-seven times more likely to be seen alive than found dead. Conversely, on major roads Barn Owls are three times more likely to be found dead than seen alive.

The growth of so many major roadshas prevented Barn Owl dispersal played a significant part in Barn Owl population decline in parts of Britain.When individual Barn Owls encounter a major road they are very soon struck by traffic. (72% of Barn Owls which are known to have encountered a major road were killed) Major road deaths have more impact on Barn Owls than any other animals (due to their rarity and the frequency with which they are killed)

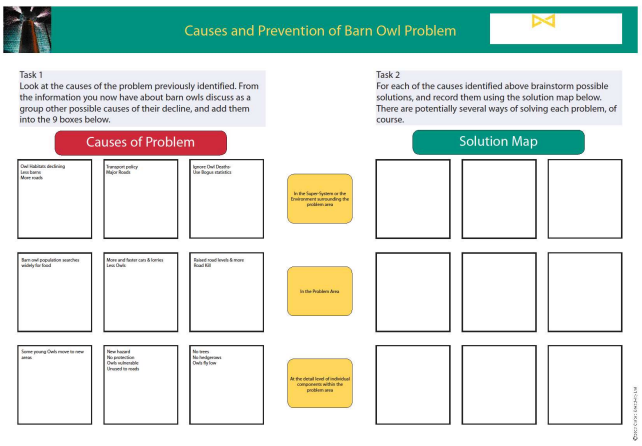
Owls are killed on major roads because:-

- They are moving to new areas
- There are food sources in grass areas near the road (Areas of rough grass are likely to support small mammals)
- Owls fly at a low-level flight across carriagewaysand are hit by vehicles.There are few barriers such as continuous hedges and/or lines of closely spaced trees (>3 metres high) to make them fly at a higher and safer level.

2. Obtain an understandingof the system with

Time & Scale - 9 Box context map of Probable Causes of Problems

Time & Scale - 9 Box context map of Probable Solutions to Problems

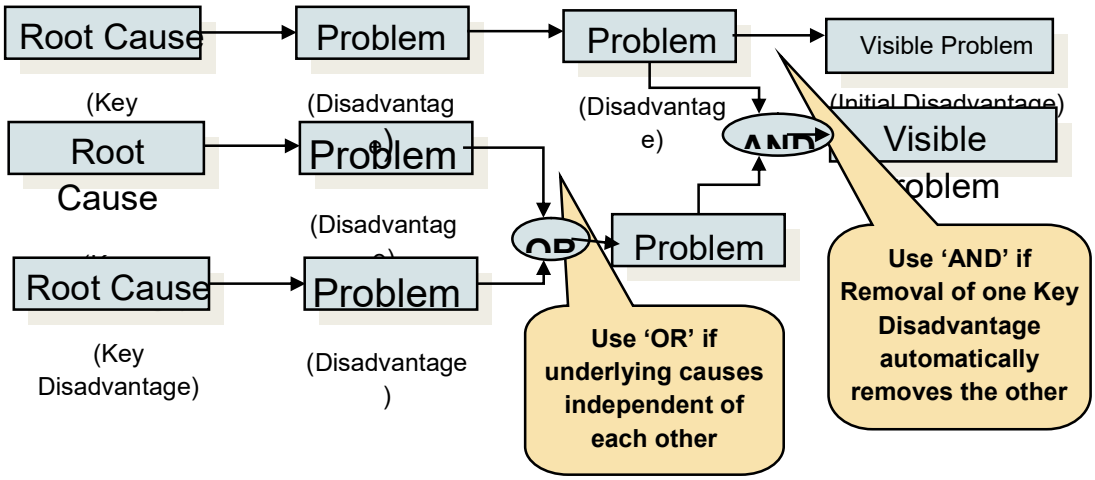


Examples of using TRIZ RCA Steps to uncover causes of problems & find viable solutions

TRIZ RCA Step 4. Constructing Fault Trees (Cause Effect Chain Analysis)

Getting to and dealing with the Root Causes(called Key Disadvantages in MATRIZ) is important and efficient as any number of related and subsequent problems /disadvantages could be created by underlying root causes. Otherwise dealing with initial problems / disadvantages rather than the key ones would be like wasting time and effort carefully pruning away many twigs on a branch and then discovering that the whole branch had to be removed anyway. Mapping and removing (TRIMMING) a Root Cause (Key Disadvantage) first minimises this risk, as it removes allits connecteddownstream problems/ disadvantages with it. Fault Trees (Cause - Effect Chain Analysis) uncovers these Root Causes (Key Disadvantages) and uses BOOLEAN Logic of AND & AND/OR to highlight links in chains.

This Cause-Effect Chain Analysis can be mapped as follows:-



Many of causal chains illustrations for example.....