# Root Cause Analysis

December, 9th, 2008

# Root Cause Analysis

- **Introduction**
- Root Cause Analysis, according to The Joint Commission is a "process for identifying the basic or causal factors that underlie variation in performance, including the occurrence or possible occurrence of a sentinel event.“
- Sentinel events include medication errors, patients' suicide, procedure complications, wrong site surgery, treatment delay, restraint death, elopement death, assault or rape, transfusion death, and infant abduction.
- Direct causes bring about the sentinel event without any other intervening event.
- Most direct causes are physically proximate to the sentinel event.
- The effect of root causes on sentinel events are always through some direct cause.
- Because of accreditation requirements and due to renewed interest in patient safety, many hospitals and clinics are actively conducting Root Cause Analyses.

# Root Cause Analysis

- When a sentinel event occurs, most employees are focused on the direct causes that have led to the event.
- For example, many will claim that the cause of medication error is a failure to check label against the patient's armband.
- But this is just the direct cause.
- To get to the real reasons, one should ask why did the clinician not check the label against the armband.
- The purpose of Root Cause analysis is to go beyond direct and somewhat apparent causes and figure out the underlying reasons for the event
- The objective is to force one to think harder about the source of the problem.
- It is possible that the label was not checked against the armband because the label was missing.
- Furthermore it is also possible that the label was missing because the computer was not printing.

# Root Cause Analysis

- Then, the root cause is computer malfunction and the direct cause is the failure to check the label against the armband.
- Exhorting employees to check the armband against the label is a waste of time, if there is no label to check in the first place.
- A focus on direct causes may prevent the sentinel event for a while, but sooner or later the root cause will lead to a sentinel event.
- Inattention to root causes promotes palliative solutions that do not work in the long run
- The value of root cause analysis lies in identifying the true, underlying causes.
- An investigation that dos not do this is at best a waste of time and resources, and at worst can exacerbate the problems it was intended to fix.
- But how do we know if our speculation about the causes of an event are correct?

# Root Cause Analysis

- **Root cause analysis techniques**
- Simplest technique out of all the RCA Techniques
- For every **effect** there is a **cause**
- There is a fairly long chain of relationship between the **cause** and its **effect**
- As we move along the chain these cause and effect become finer and finer
- Just like we dig a tree its roots become finer and finer
- The finest **cause** if removed, the problem will not re-appear
- This is the essence or Root Cause Analysis.

# Root Cause Analysis

- **Root cause analysis** (**RCA**) is a class of problem solving methods aimed at identifying the root causes of problems or events
- The practice of RCA is predicated on the belief that problems are best solved by attempting to correct or eliminate root causes, as opposed to merely addressing the immediately obvious symptoms
- By directing corrective measures at root causes, it is hoped that the likelihood of problem recurrence will be minimized
- However, it is recognized that complete prevention of recurrence by a single intervention is not always possible
- Thus, RCA is often considered to be an iterative process, and is frequently viewed as a tool of continuous improvement.

# Root Cause Analysis

- RCA, initially is a reactive method of problem solving
- This means that the analysis is done **after** an event has occurred
- By gaining expertise in RCA it becomes a pro-active method
- This means that RCA is able to **forecast** the possibility of an event even **before** it could occur.

# Root Cause Analysis

- Root cause analysis is not a single, sharply defined methodology
- there are many different tools, processes, and philosophies of RCA in existence
- However, most of these can be classed into five, very-broadly defined "schools" that are named here by their basic fields of origin:
  - safety-based
  - production-based
  - process-based
  - failure-based
  - and systems-based.

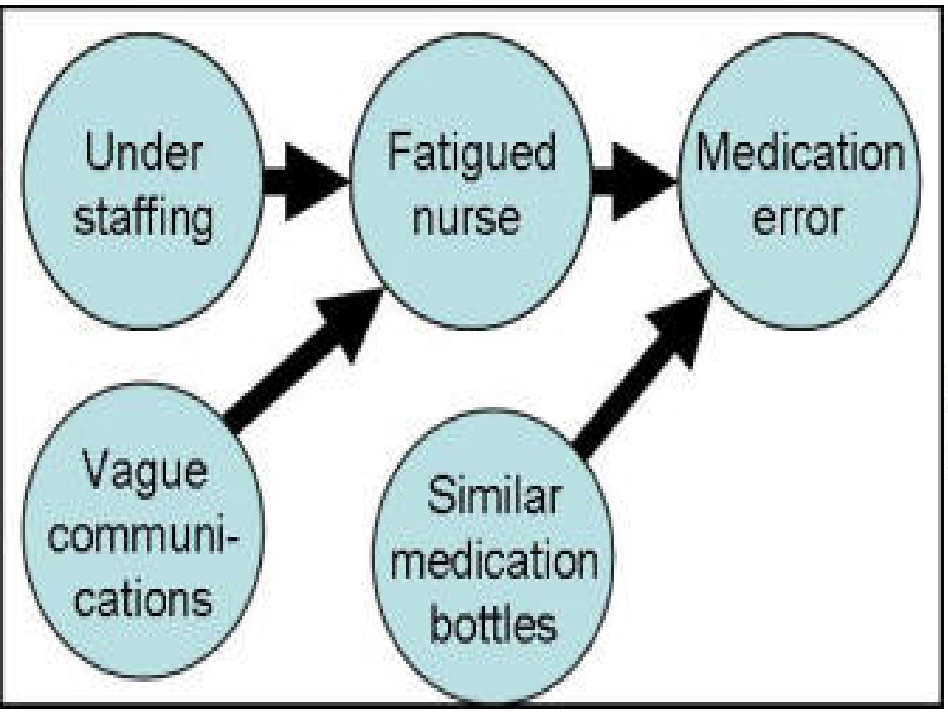
# Root Cause Analysis

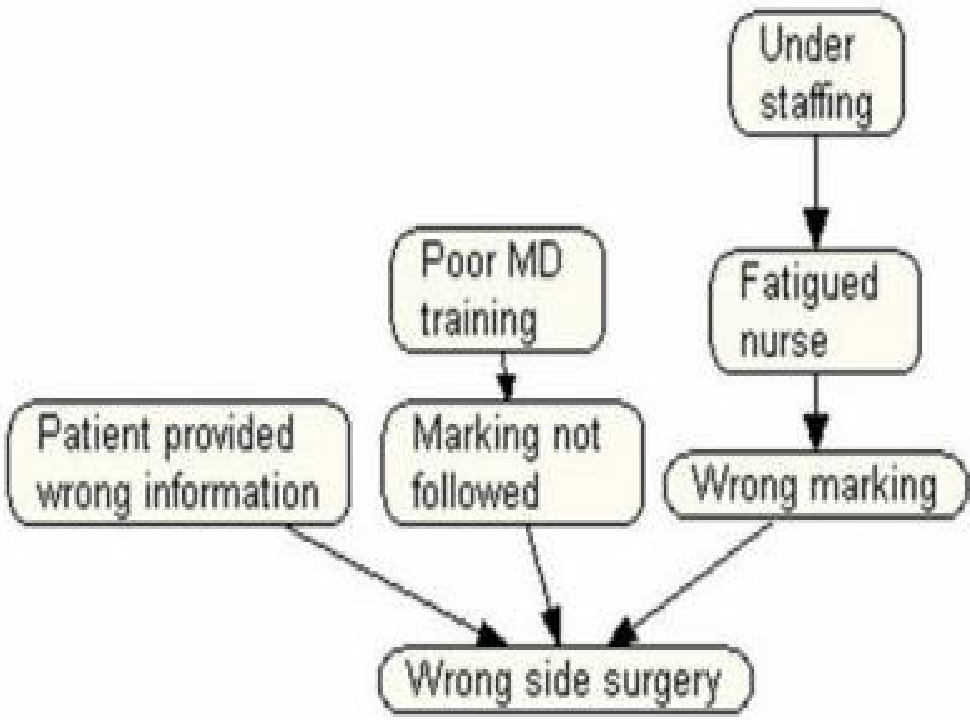
- Safety-based RCA descends from the fields of accident analysis and occupational safety and health.
- Production-based RCA has its origins in the field of quality control for industrial manufacturing.
- Process-based RCA is basically a follow-on to production-based RCA, but with a scope that has been expanded to include business processes.
- Failure-based RCA is rooted in the practice of failure analysis as employed in engineering and maintenance.
- Systems-based RCA has emerged as an amalgamation of the preceding schools, along with ideas taken from fields such as change management, risk management, and systems analysis.

# Root Cause Analysis

- **General principles of root cause analysis**
- Aiming performance improvement measures at root causes is more effective than merely treating the symptoms of a problem.
- To be effective, RCA must be performed systematically, with conclusions and causes backed up by documented evidence.
- There is usually more than one root cause for any given problem.
- To be effective the analysis must establish all known causal relationships between the root cause's) and the defined problem.

# Root Cause Analysis



# Bayesian Network

- A **Bayesian network** (or a **belief network**) is a probabilistic graphical model that represents a set of variables and their probabilistic independencies
- For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms
- Given symptoms, the network can be used to compute the probabilities of the presence of various diseases.

# Bayesian Network

- Formally, Bayesian networks are directed acyclic graphs whose nodes represent variables, and whose missing edges encode conditional independencies between the variables
- Nodes can represent any kind of variable, be it a measured parameter, a latent variable or a hypothesis
- They are not restricted to representing random variables, which represents another "Bayesian" aspect of a Bayesian network
- Efficient algorithms exist that perform inference and learning in Bayesian networks
- Bayesian networks that model sequences of variables (such as, for example, speech signals or protein sequences) are called dynamic Bayesian networks
- Generalizations of Bayesian networks that can represent and solve decision problems under uncertainty are called influence diagrams.

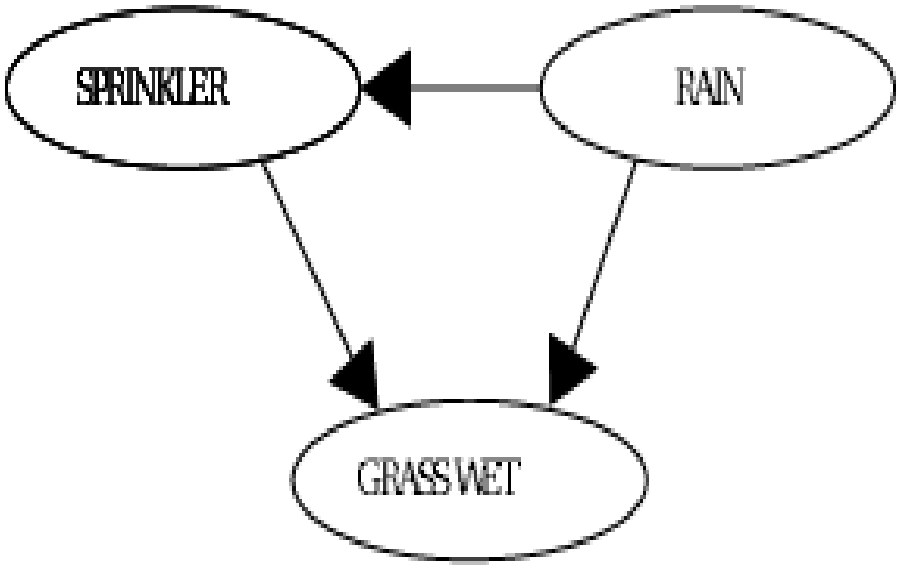
# Bayesian Network

- Suppose that there are two events which could cause grass to be wet:
- either the sprinkler is on or it's raining.
- Also, suppose that the rain has a direct effect on the use of the sprinkler (namely that when it rains, the sprinkler is usually not turned on).
- Then the situation can be modeled with the adjacent Bayesian network.
- All three variables have two possible values T (for true) and F (for false).

# Bayesian Network

- The model can answer questions like "What is the probability that it is raining, given the grass is wet?" by using the conditional probability formula and summing over all nuisance variables
- Because a Bayesian network is a complete model for the variables and their relationships, it can be used to answer probabilistic queries about them.

| | SPRINKLER | |
|---|---|---|
| RAIN | T | F |
| F | 0.4 | 0.6 |
| T | 0.01 | 0.99 |



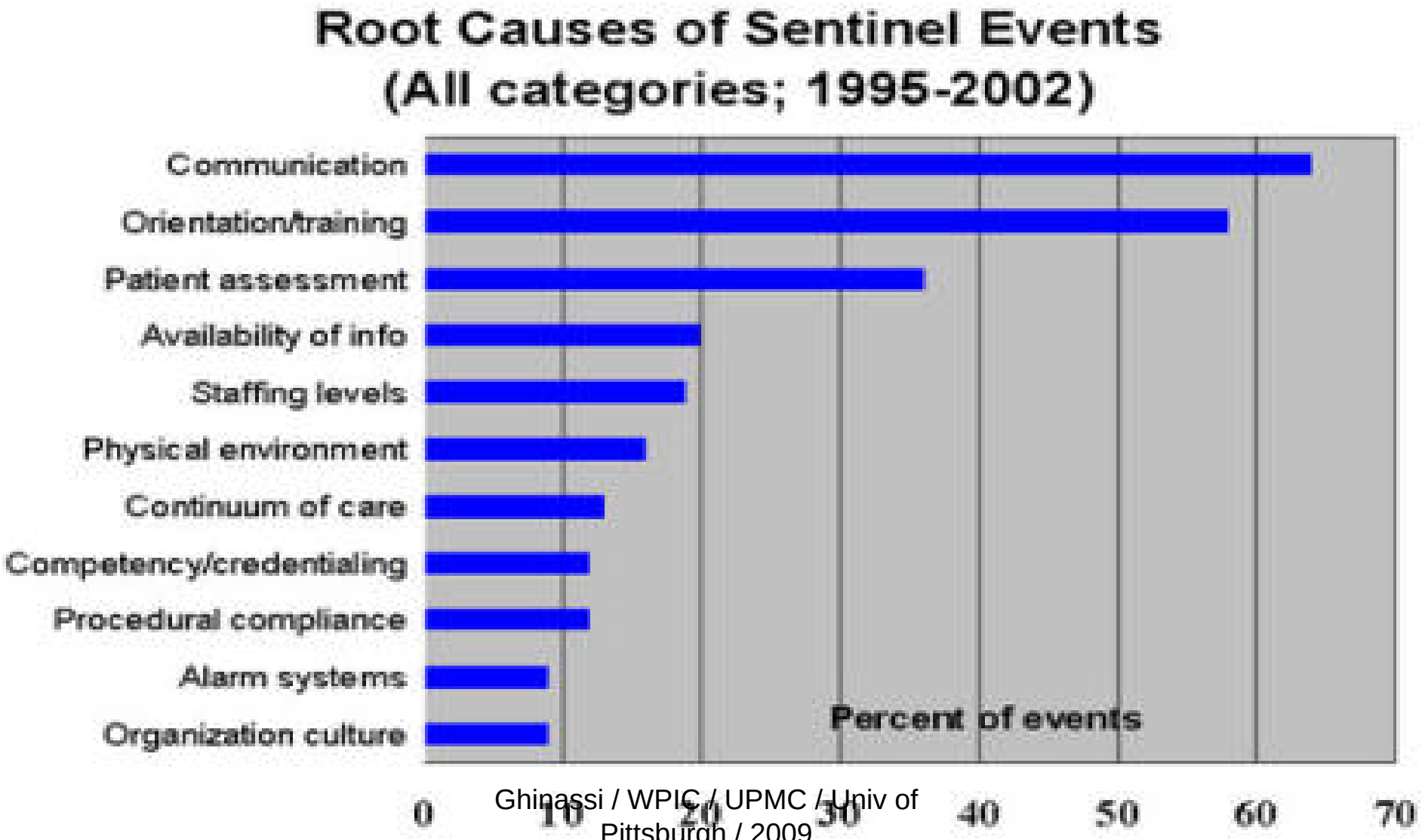

| | RAIN |
|---|---|
| T | F |
| 0.2 | 0.8 |

| | | GRASS WET | |
|---|---|---|---|
| SPRINKLER | RAIN | T | F |
| F | F | 0.0 | 1.0 |
| F | T | 0.8 | 0.2 |
| T | F | 0.9 | 0.1 |
| T | T | 0.99 | 0.01 |

# Bayesian Network

- **Reverse Predictions**
- The Bayesian network can also be used to calculate the probability of observing a cause given an effect has occurred
- This is the reverse of how most people think about causes and effects
- Most people start with a cause and want to predict the probability of the effect
- Bayesian probability models allow us to do the reverse
- One can start with known sentinel events and ask about the prevalence of a particular cause among them
- Since causes are not as rare as sentinel events, this procedure allows us to check on the adequacy of the analysis without having to wait a long time for reoccurrence of the sentinel event
- To make matters easier, the Joint Commission on Accreditation of Healthcare Organizations publishes prevalence of categories of causes among sentential events
- These data can be used to examine the consistency of the Root Cause Analysis
- Large discrepancy between observed prevalence of causes among sentinel events and assumed prevalence of causes in the investigative team's model suggest errors in assignments of probabilities as well as possible missed cause or constraint.

# Root Cause Analysis



# Root Cause Analysis

- **Discussion**
- Investigative teams often rely on their own intuitions for listing the root causes of a sentinel event
- They rarely check the validity of their analysis
- Bayesian networks can be applied to root cause analysis to test the validity and/or consistency of the analysis
- Real analysis should be a careful examination of facts and not a cover for wishful speculation
- By creating a Bayesian Network and estimating the probabilities of various events, one can scrutinize assumptions made in root cause analysis
- In particular, one can check to see
  - if important root causes have been missed
  - if the analysis is focused on root causes or direct causes
  - if frequency of sentinel event corresponds to expectations and experienced rates
  - if prevalence of causes of sentinel events correspond to known rates
  - and if assumptions of dependence or independence are wrong.
- These are not exact ways of checking the accuracy of the analysis. But these methods allow us to check the intuition of investigative teams and help them think through the implication of their analysis.

# PROBLEMS

No Matter how Great and Destructive your Problems May Seem Now, Remember, You've Probably only Seen the Tip of Them.

# Root Cause Analysis

- **General process for performing and documenting an RCA-based Corrective Action**
- Notice that RCA forms the most critical part of successful corrective action
- It directs the corrective action at the root of the problem
- That is to say, it is effective solutions we seek, not root causes
- Root causes are secondary to the goal of prevention, and are only revealed after we decide which solutions to implement.

# Root Cause Analysis

- Define the problem.
- Gather data/evidence.
- Ask why and identify the causal relationships associated with the defined problem.
- Identify which causes if removed or changed will prevent recurrence.
- Identify effective solutions that prevent recurrence, are within your control, meet your goals and objectives and do not cause other problems.
- Implement the recommendations.
- Observe the recommended solutions to ensure effectiveness.

# Root Cause Analysis

- 5 Whys
- - original root cause analysis process developed in 1958, which provides a fact-based approach to systematically rule out possible causes and identify the true cause
- My car will not start. (the problem)
- *Why?* - The battery is dead. (first why)
- *Why?* - The alternator is not functioning. (second why)
- *Why?* - The alternator belt has broken. (third why)
- *Why?* - The alternator belt was well beyond its useful service life and has never been replaced. (fourth why)
- *Why?* - I have not been maintaining my car according to the recommended service schedule. (fifth why, root cause)

# Root Cause Analysis

- **History**
- The technique was originally developed by Sakichi Toyoda
- later used within Toyota Motor Corporation during the evolution of their manufacturing methodologies
- It is a critical component of problem solving training delivered as part of the induction into the Toyota Production System
- The architect of the Toyota Production System, Taiichi Ohno, described the 5 whys method as "... the basis of Toyota's scientific approach ... by repeating why five times, the nature of the problem as well as its solution becomes clear.“
- The tool has seen widespread use beyond Toyota, and is now also used within Six Sigma.

# Root Cause Analysis

- **Criticism**
- While the 5 Whys is a powerful tool for engineers or technically savvy individuals to help get to the true causes of problems, it has been criticized by Teruyuki Minoura, former managing director of global purchasing for Toyota, as being too basic a tool to analyze root causes to the depth that is needed to ensure that the causes are fixed. Reasons for this criticism include:
  - Tendency for investigators to stop at symptoms rather than going on to lower level root causes
  - Inability to go beyond the investigator's current knowledge - can't find causes that they don't already know
  - Lack of support to help the investigator to ask the right "why" questions
  - Results aren't repeatable - different people using 5 Whys come up with different causes for the same problem
  - These can be significant problems when the method is applied through deduction only
  - On-the-spot verification of the answer to the current "why" question, before proceeding to the next, is recommended as a good practice to avoid these issues

# Root Cause Analysis

- Failure mode and effects analysis Also known as FMEA:
  - procedure for analysis of potential failure modes within a system for classification by severity or determination of the effect of failures on the system
  - It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry
  - Failure causes are any errors or defects in process, design, or item, especially those that affect the customer, and can be potential or actual
  - *Effects analysis* refers to studying the consequences of those failures.

# Root Cause Analysis

- Step 1: Severity
- Step 2: Occurrence
- Step 3: Detection
- Risk Priority Numbers
  - RPN = S x O x D

# Root Cause Analysis

- **Limitations**
- Since FMEA is effectively dependent on the members of the committee which examines product failures, it is limited by their experience
- If a failure mode cannot be identified, then external help is needed
- If used as a top-down tool, FMEA may only identify major failure modes in a system
- Fault tree analysis (FTA) is better suited for "top-down" analysis
- When used as a "bottom-up" tool FMEA can augment or complement FTA and identify many more causes and failure modes resulting in top-level symptoms
- It is not able to discover complex failure modes involving multiple failures within a subsystem, or to report expected failure intervals of particular failure modes up to the upper level subsystem or system
- Additionally, the multiplication of the severity, occurrence and detection rankings may result in rank reversals, where a less serious failure mode receives a higher RPN than a more serious failure mode
- The reason for this is that the rankings are ordinal scale numbers, and multiplication is not a valid operation on them
- The ordinal rankings only say that one ranking is better or worse than another, but not by how much

# Root Cause Analysis

- Causal factor tree analysis - a technique based on displaying causal factors in a tree-structure such that cause-effect dependencies are clearly identified
  - Another technique, where each event is enclosed in a rectangle. A series of Events are enclosed in rectangles with lines inter connecting the rectangles. Events progress from Left to Right, just like in a text. Striking of a match Stick is an event. If there is possibility of the interconnection the rectangles are connected with the dotted lines
  - The 'Cause' are identified for each event. In order to differentiate the Cause with Events, Cause are enclosed in Ellipse
  - The 'Presence of inflammable Gases' can be a 'Cause'. Both 'Event' and 'Cause' put together may lead to the accident e.g. 'Explosion‘’
  - A structured root cause analysis system built around a problem solving process with six embedded techniques to guide investigators beyond their current knowledge to the root causes of human performance and equipment failure related incidents

# Root Cause Analysis

- **Basic elements of root cause**
- Materials
  - Defective raw material
  - Wrong type for job
  - Lack of raw material
- Machine/Equipment
  - Incorrect tool selection
  - Poor maintenance or design
  - Poor equipment or tool placement
  - Defective equipment or tool
- Environment
  - Orderly workplace
  - Job design or layout of work
  - Surfaces poorly maintained
  - Physical demands of the task
  - Forces of nature

# Root Cause Analysis

- Management
  - No or poor management involvement
  - Inattention to task
  - Task hazards not guarded properly
  - Other (horseplay, inattention....)
  - Stress demands
  - Lack of Process
- Methods
  - No or poor procedures
  - Practices are not the same as written procedures
  - Poor communication
- Management system
  - Training or education lacking
  - Poor employee involvement
  - Poor recognition of hazard
  - Previously identified hazards were not eliminated

# Root Cause Analysis

- **Summary of Proposed Method for Root Cause analysis**
- Sentinel events can be reduced if health care organization create a blame-free environment, conduct Root Cause Analysis and take concrete actions on the basis of the analysis. To conduct root cause analysis we propose the following steps:
  - Before a sentinel event occurs, an investigative team is organized
  - The team should include a facilitator and a team leader
  - The facilitator's responsibility is to organize tasks, serve as staff to the team, and conduct team meetings in an efficient and effective method
  - The facilitator should be trained in probability models
  - The leader's responsibility is to make sure that the investigation is carried out thoroughly and to provide content expertise.

# Root Cause Analysis

- When a sentinel event is reported, the employees closest to the incident are asked to record facts (not accusations) about the event, including:
  - what happened
  - who was present
  - where did the event occur
  - when did it occur
  - and what was the time sequence of the events that preceded the sentinel event.
- The investigative team meets and brainstorms:
  - (1) potential causes for the incident
  - (2) key constraints that if they were in place would have prevented the incident from occurring
- Two steps are taken to make sure the listing is comprehensive
  - First, the framing bias is reduced by asking for a list of causes with alternative prompts
  - Thus, since constraints can be thought of reverse causes, the team should be asked to list both the constraints and causes
  - Furthermore, because the team is focused on conditions that led to the sentinel event, they should be asked to examine also conditions that prevented sentinel events in other occasions.

# Root Cause Analysis

- The facilitator interviews the investigative team or uses existing data to assign a probability to each cause and a conditional probability for each effect.
- The facilitator checks the accuracy of the causal model and asks the investigative team to revise their model
- The following steps allows one to check the accuracy or consistency of the causal model:
  - The facilitator uses the model to predict the probability of the sentinel event
  - If this probability is several magnitudes higher than historical pattern or investigative team's intuitions, the facilitator seeks additional constraints that would reduce the probability of the sentinel event
  - If the probability is lower than historical experience or the investigative team's intuitions, the team is asked to describe additional mechanisms and causes that may lead to the sentinel event.

# Root Cause Analysis

- **Predictions from Root Causes**
- The causal model behind the root cause analysis can be used to predict the probability of the sentinel event and this probability can then be compared to the intuitions of the investigative team
- The probability of sentinel event can be calculated from each of the direct causes and the probability of direct causes can be calculated from their root causes.
- p (Sentinel event, Various causes) =
  p (Sentinel event | Direct causes) * p (Direct causes | Direct root causes) * p (Root causes)
- To calculate, the probability of sentinel event, S, given a set of different unobserved (CU) and observed causes (Ci), we can use the following formula:

$$P(S \mid C_1, C_2, \ldots, C_n) = \sum_{C_U} P(S \mid C_1, C_2, \ldots, C_n) P(C_{U_1}) P(C_{U_2}) \ldots P(C_{U_N})$$

# Root Cause Analysis

- Obviously, estimates of probabilities from experts is subjective and therefore may be unreliable
- But if experts are provided with tools (calculators, paper, pencils), brief training in concept of conditional probabilities, available objective data (e.g. JCAHO's reports on prevalence of various causes)
- and if experts are allowed to discuss their different estimates, then experts' estimates are sufficiently accurate and reliable to provide a useful model
- These probabilities may not be accurate to the last digit, but can provide for a test of consistency

# Root Cause Analysis

- The facilitator uses the model to calculate the prevalence of the causes among sentinel events
- These data are checked against the investigative team's intuitions as well as against observed rates published by the JCAHO.
  - The facilitator checks that claimed root causes are conditionally independent from the sentinel event
  - If a root cause is directly linked to the sentinel event, the investigative team is asked to redefine the direct cause to be specific to the mechanism used by the root cause to affect the sentinel event
  - If few root causes have been specified, the investigative team is asked to think again through reasons why direct causes occur.
  - The facilitator checks the marginal probabilities against objective data
  - If the probabilities do not match, the facilitator should use the objective probabilities whenever available.

# Root Cause Analysis

- Document the findings
- A chart is organized showing all the nodes and arcs
- The root causes, direct causes and sentinel events are shown in the chart
- Arrows are drawn from root causes to direct causes and from direct causes to sentinel events.

# Root Cause Analysis

- **Question:** How do you really classify a cause as a direct cause as opposed to an indirect cause? Can there be instances where an indirect cause can be an direct cause as well depending how one interprets the analysis?
- **Answer:** Here lies the art of the analysis. A direct cause shows a mechanism that affects the target event in close physical proximity and with few steps, cigarettes are a direct cause of lung cancer because we see how smoke affects the lung. An indirect cause is something that does not have a physical link to the target event. Advertisement for cigarettes directed at children may be considered an indirect cause, as it affects the uptake of smoking but it does not affect the lung itself directly.

# Root Cause Analysis

- **Question:** What would be a simple way to identify the direct cause from the root cause?
- **Answer:** A direct cause often has a physical link to the event of interest. An indirect cause does not. Direct causes can be established by asking questions on what happened, when it happened and where it happened. An indirect cause is more likely to be a more systemic and removed from immediate events surrounding the adverse event.

# Root Cause Analysis

- **Question:** Is there a limit to how many root causes there can be?
- **Answer:** No and yes. There is no theoretical limit but experience with people shows that most people list at most 3-5 causes for a phenomena.

# Questions and Discussion

# Root Cause Analysis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