

A systematic approach to root cause analysis using 3 × 5 why's technique

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Systematic
approach to
root cause
analysis

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Abstract

Purpose – The purpose of this paper is to go a step further from the traditional 5 Whys technique by adding three more legs during the root cause analysis stage – occurrence, human and systemic issues that contribute toward the problem, hence the term 3 × 5 Whys. Performing individual 5 Whys for these three components enables to identify deeper root cause(s) that may spawn across multiple groups within an organization.

Design/methodology/approach – Cause-and-effect analysis used during traditional root cause investigations within an 8D or Lean six sigma project is used as a theoretical foundation. Examples from different industries are presented showing the 3 × 5 Why's framework and advantages it brings to the organization along with identifying shortcomings and suggestions to make it more effective.

Findings – If properly used this integrated methodology will reveal higher order systemic causes (e.g. policies or management decisions) stemming from lower lever symptoms (e.g. defective parts, procedural errors). Effective execution of this methodology can provide tremendous results in defect reduction, yield improvement, operational efficiency improvement and logistics management type of projects. Resolving higher level sources of problems allows an organization to evolve itself and maintain a competitive edge in the market.

Research limitations/implications – Adopting this quality management technique in start-up companies entails some challenges and other implications have been discussed with SWOT analysis.

Practical implications – Examples from various sectors using 3 × 5 Why approach have been presented that show that this methodology provides deeper insight into root causes which could be affecting multiple groups in an organization. Using this technique effectively is found to be beneficial to resolve issues in operations management, logistics, supply chain, purchasing, warehouse operations, manufacturing, etc.

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Corrigendum: It has come to the attention of the publisher that Prashant Gangidi, (2018) “A systematic approach to root cause analysis using 3 × 5 why's technique”, published in the *International Journal of Lean Six Sigma*, Vol. 10 No. 1, did not fully attribute a number of sources drawn upon in the paper. These were:

- 3 Legged 5 Why's Analysis', (2009) steering solutions services corp, www.scribd.com/presentation/135077938/5-Why-s
- Five Why's – How to do it better', (2007), <https://web.archive.org/web/20071102221507/http://www.critical-thinking.com/five-whys-how-to-do-it-better>
- Sandesh. A. and Pawan. C., 'First Pass Yield Improvement by Eliminating Base Plug Leakage in Feed Pump Manufacturing' (2014), *International Journal of Science and Research*, Volume 2, Issue 3, www.ijsr.net/archive/v3i7/MDIwMTQxMjQx.pdf
- Eric Ries, 'The Five Why's for Start-Ups', (2010), *Harvard Business Review*, <https://hbr.org/2010/04/the-five-whys-for-startups>
- A D Livingston, G Jackson & K Priestley, 'Root causes analysis: Literature review: Contract Research Report 325/2001', (2001), WS Atkins Consultants Ltd, Health and Safety Executive, www.hse.gov.uk/research/crr_pdf/2001/crr01325.pdf

The author guidelines for the *International Journal of Lean Six Sigma* clearly state that sources drawn upon in the paper must be fully attributed. The author sincerely apologises for this.



Social implications – This methodology has a human component which often results in some sort of resistance as not all working professionals think alike when it comes to accountability and ownership of issues. This may hinder root cause analysis and subsequent corrective actions implementation.

Originality/value – This study is unique in its in-depth real-world case studies demonstrating the need for taking a deep dive approach to root cause analysis by understanding specific, system and human components responsible for causing the failure mode.

Keywords System, Human error, Problem-solving, 3×5 why's, Occurrence, Root cause analysis

Paper type Viewpoint

1. Introduction

5 Why's is an iterative interrogative technique used to explore the cause-and-effect relationships underlying a particular problem (Serrat, 2009). It was refined by Sakichi Toyoda and was used within the Toyota Motor Corporation during the evolution of its manufacturing methodologies. It is a critical component of problem-solving training, delivered as part of the induction into the Toyota Production System (Dunn, 2004). 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 it is now used within Kaizen, Lean manufacturing and Six Sigma. In the past, the success of this technique has depended upon the knowledge, competence and expertise of the analysts to ask the right sequence of questions to get to the true root causes. But at times, the 5 Whys technique has failed to produce the desired results because of the following reasons:

- (1) Lack of tendency/interest of the experts to follow through the investigation with deeper questioning, thereby missing sub system root causes that could be contributing toward the problem.
- (2) Confusing the symptom to be the actual root cause of the problem.
- (3) Inability/unwillingness of the experts to think beyond their area of expertise when required.
- (4) Lack of repeatability of the results – different people could come up with different root causes for the same problem by asking different questions.
- (5) Difficulty in applying known principles – sometimes known principles may not apply well to solve a new problem.

This paper is structured as follows: Section 2 describes the literature review on root cause analysis and 5 Why's. Section 3 describes the importance of structuring a good problem statement followed by standard 5 Why's guidelines with examples. Section 4 talks about the three-legged 5 Why's describing the occurrence-specific, systemic and human issues. Section 5 gives examples of real world case studies with 3×5 Why's application in separating low level symptoms to higher level sources of problems. Section 6 describes how start-up companies can use 3×5 Whys' technique in incremental stages to reap benefits while maintaining their agility, and Section 7 describes SWOT analysis of this methodology. Finally, conclusions of the research study are in Section 8.

2. Literature review on root cause analysis and 5 why's

Root causes analysis is simply a tool designed to help incident investigators describe what happened during a particular incident, to determine how it happened and to understand why it happened (CSSBB, 2010). The definition of a root cause varies between investigators and

root causes methodologies, with different “levels” of causation being adopted by different systems. Figure 1 illustrates the different causation levels that can be ascribed to an incident based on the SIPOC model (Livingston *et al.*, 2001). The root causes lie at Level 1 which inevitably influence the effectiveness of all the risk control systems and workplace precautions that exist at Levels 2 and 3. The most useful definition of root cause identified to date is has been quoted by Paradies and Busch (1988), that is:

[. . .] the most basic cause that can be reasonably identified and that management has control to fix

There are three main terms to extract from the above statement, i.e.:

- (1) *Basic cause* – which specifies exact reasons as to why an incident occurred that enable corrective actions to be implemented which will prevent recurrence of the events leading up to the incident.
- (2) *Reasonably identified* – which tells us that failure mode investigation must be completed in a reasonable time frame.
- (3) *Control to fix* – which involves experts and management that have the authority to establish controls, protocols and procedures to avoid the problem from happening again.

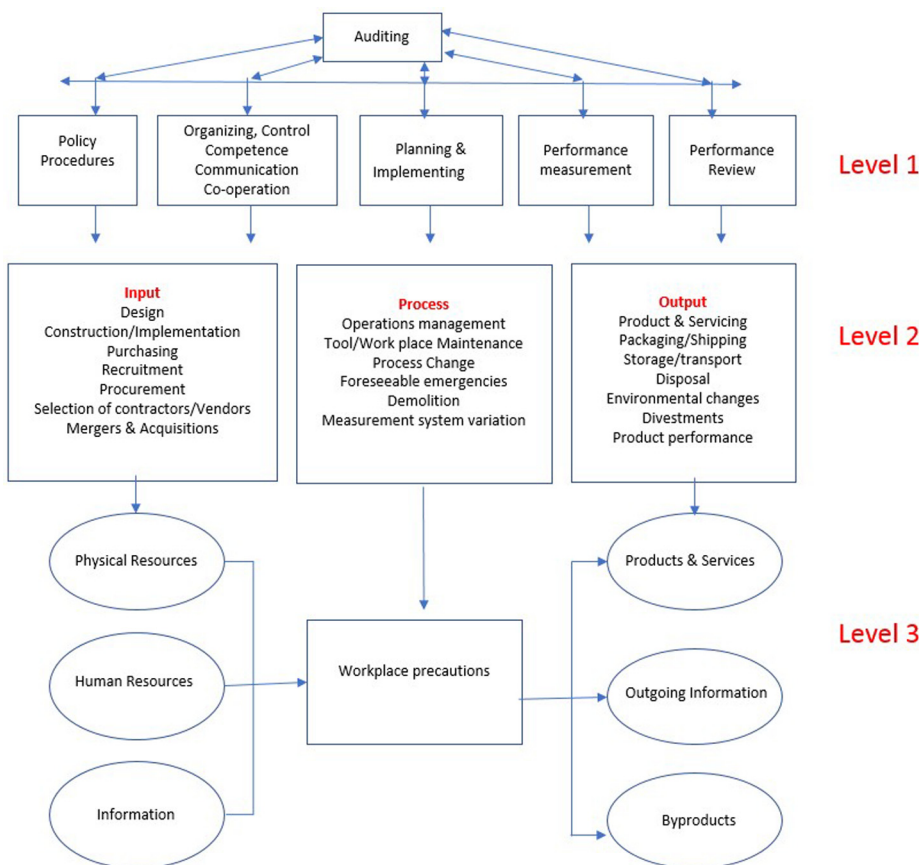


Figure 1.
Levels of causation

General cause classifications such as “human error” are not specific enough to allow those in charge to rectify the situation. Management has the responsibility of understanding why a failure occurred before action can be taken to prevent recurrence. Arriving vague recommendations such as “Remind operator to be alert at all times”, does not solve the problem and poses a risk of re-occurrence which implies a basic enough cause has not been found and investigators need to expend more effort in the investigation process. Also, if causes at Levels 2 and 3 are identified without investigating why the Level 1 systems allowed such failures to occur, then similar or repeat incidents may occur ([Livingston et al., 2001](#)).

Root causes analysis principles have long been recognized in fields such as engineering, quality control, environmental management and in safety management. Techniques have been successfully borrowed from other disciplines and adapted to meet the requirements of the safety field, most notably the development of the “tree” structure from fault-tree analysis, which was originally an engineering technique ([Livingston et al., 2001](#); [Kadu and Unde, 2016](#)). The use of techniques such as events and causal factors charting, multiple events sequencing and the sequentially timed events plotting procedure, will provide a systematic and structured framework to aid the collection of information by identifying where gaps in the understanding of event chains lie ([ISO/TS 16949, 2009](#)). These sequencing techniques can also be used in conjunction with methods such as barrier analysis, change analysis and fault-tree analysis to ascertain the critical events and actions, and thus the direct causes of the incident.

The 5-Why method helps to determine the cause-effect relationships in a problem or a failure event. It can be used whenever the real cause of a problem or situation is not clear. It is one of the simplest root cause analysis techniques at the same time very effective if used correctly. Using the 5-Whys is a simple way to try solving a stated problem without a large detailed investigation requiring many resources. When problems involve human factors, this method is the least stressful on participants. It is one of the simplest investigation tools easily completed without statistical analysis. Also known as a Why Tree, it is supposedly a simple form of root cause analysis.

By repeatedly asking the question, “Why?” layers of issues and symptoms are peeled away that can lead to the root cause. Most obvious explanations have yet more underlying problems. But it is never certain that one has found the root cause unless there is real evidence to confirm it [[Aviation maintenance technicians \(AMT\), 2018](#)].

3. 5 why’s general principles

Defining a good problem statement is the first step in structuring the 5 Whys. A good 5 Whys cannot be effective if the problem statement is unclear to begin with. An initial problem statement is a clear and concise statement that describes the specific observations of an undesired result as you see it with the current information available. Also, the problem statement must contain an object and a deviation. Adding cause into the problem statement including overly complex problem statements must be avoided. Examples of good and bad initial problem statement are listed below:

- *Bad*: Car broke down because it had an engine failure (engine failure is referring to a cause).
- *Good*: Car broke down (object and deviation are concisely listed).

As more data are collected during a standard problem-solving process such as 8D or define, measure, analyze, improve, control, the problem statement may need more refinement to better reflect the issue.

Further refined problem statement: Car with license plate #XYZ broke down on highway 47.

Figure 2.
Cause-and-effect
action loop

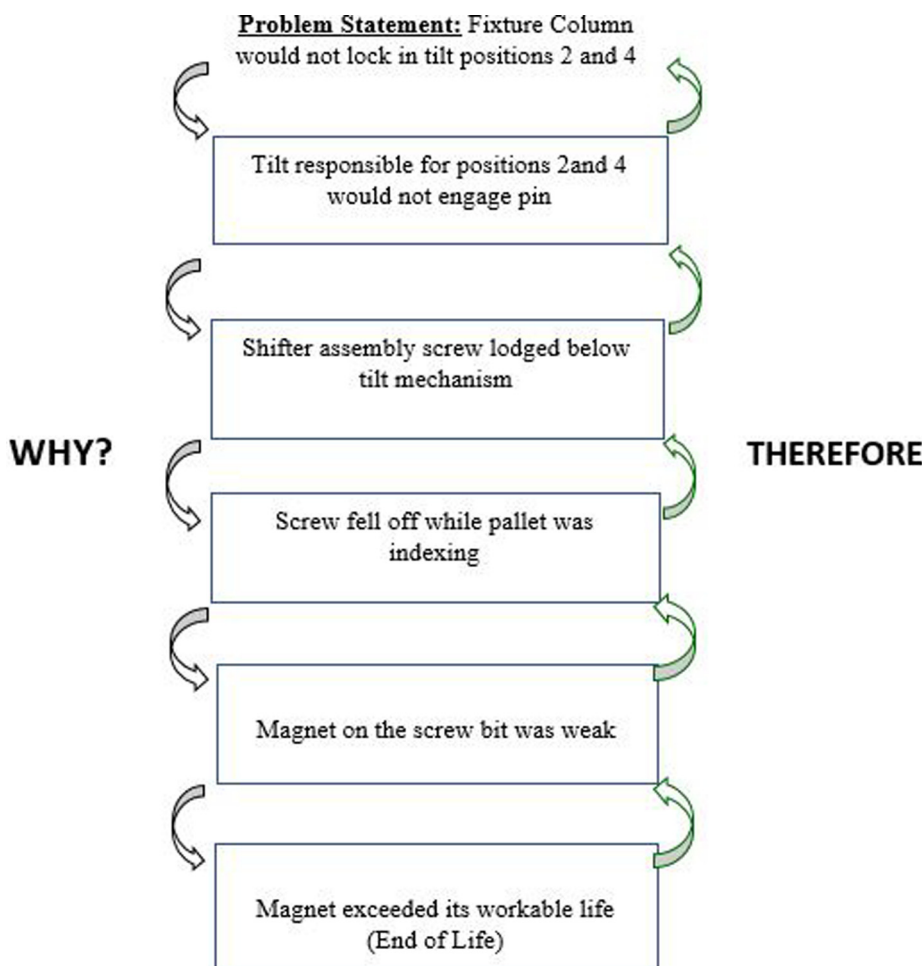
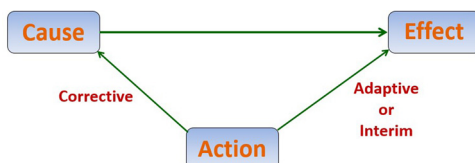


Figure 3.
Reverse path logic
using “therefore” in 5
why analysis

A major problem observed with using the 5 Why procedure is that investigator(s) get stuck at one level. When they should proceed deeper down the causal chain (from problem, to a part, to a procedure, to the system, to a management decision), instead they get stuck providing more and more detail about one link.

After considering several examples from different industries, author has determined that investigator(s) get stuck because at some point they created one (or more) compound cause statement(s) in the 5 Why series.

Compound cause statements example: (How the mind interprets Why? in parentheses.)

Problem Statement: SUV Model Z exhaust system rattle:

- (A) Why? (*Why does the exhaust system rattle?*) Because of a change of *position of bracket* results in *vibration*.
- (B) Why? (*Why does the bracket position cause vibration?*) Because the bracket is *too close* to the pipe resulting in vibration.
- (C) Why? (*Why does being very close cause vibration?*) Because the vibration from the pipe and vibration from the road are additive because of harmonics.
- (D) Why? (*Why are road plus pipe vibrations harmonic?*) [. . .] Pitfall! (Notice how this is off thinking about “HOW” position created more vibrations and not progressing deeper.)

Asking “Why?” of a compound cause reverses the analysis to a cause-effect sequence and out of the effect-cause “5 Whys” pattern. The reverse sequence of causes is interrupted because the mind becomes confused about what “Why?” refers to.

Statement (A) contains a compound cause. Asking “Why?” tricks the mind into interpreting the question as “how did bracket position result in vibration?” The chronology is wrong as the objective is not trying to explain “how” the bracket position caused vibration but focus on the bracket positions and find out “What caused the bracket to be in that position?”.

Always working going back in time from cause to its cause not forward explaining cause to effect is suggested. The purpose of the “THEREFORE” test is thereby recommended for the troubleshooter to check the logical flow of the causal chain from the earliest point in the sequence up to the present.

Statement (B) also contains a compound cause. Asking “Why?” tricks the mind into interpreting this question as “Why (HOW) does being very close create vibration?”.

The following shows the 5 Why procedure without the trap of compound cause statements leading to (or toward) a systemic cause:

Problem Statement: SUV Model Z exhaust system rattles:

- (A) Why? (*Why does the exhaust system rattle?*) Because of the exhaust pipe *vibration*.
- (B) Why? (*Why does the pipe vibrate?*) Because the exhaust *bracket is very close* to the support.
- (C) Why? (*Why is bracket now very close to the support?*) Because the line *workers installed* bracket in this location.
- (D) Why? (*Why did workers install bracket very close to support?*) *Because specifications* stipulate this new location.

Why? Unknown.

4. Expanded 5 whys (3 × 5 why’s)

Implied in the 5 Whys root cause analysis tool, though not often stated openly, is the use of a cause-and-effect tree known as a Why Tree. The method is also called fault-tree analysis. It

is best to build the Why Tree first so that the interactions of causes can be seen. Sometimes only one cause sets off an event, other times multiple causes are necessary to produce an effect. The Why Tree for even a simple problem can grow huge, with numerous cause-effect branches. There can be multiple root causes when looking at a problem. A problem can start off as a human problem, but there could be other factors contributing to the problem. There could be a system problem that affects the overall human interaction with the problem. A problem could be a specific issue with a tool or process, but there could be a system or human interaction (Team Member (TM)/operator error) that needs to be explored.

To assess how far one has pushed in their respective root cause analysis path, questions such as have we asked enough why's? Have we looked for other contributing factors? Or have we settled for what is easiest to address? need to be pondered over. Not asking enough whys or not looking for other factors may address a symptom which could lead to a repeat problem. In the standard 5 Whys methodology, one or more of the why's could branch out into their separate 5 Whys which gives more insight into other issues contributing to the problem which are often ignored. These other issues are classified under occurrence, system and detection. Each of these would need a separate line of question via 5 Whys, hence the term 3×5 Whys. Description of type of problems under each of these categories is listed below:

- *Occurrence* – Specific, Process (machine, material) – Why do we have the specific deviation?
- *Human* – Why or how did the team member contribute to the problem?
- *System* (method, material, environment) – Why did our system allow the problem to occur?

4.1 Occurrence

A popular root cause analysis is the Fishbone diagram wherein all the suspect root causes are bucketed into six M's, namely, man, machine, material, method, measurement and mother nature (Livingston *et al.*, 2001). Four out of these contribute toward occurrence/specific or process-related issues, i.e. machine, material, measurement and man. Key points to address while addressing occurrence-specific type of issues are:

- (1) Why did we have the specific non-conformance/deviation?
 - A lot of quality issues start off here, but as we go down through the 5 Whys, there may be points where we could go down another path as well (human contributions or a system contribution).
- (2) Root cause is typically related to design, operations, dimensional issues, etc.
 - tooling wear/breaking;
 - set-up incorrect;
 - processing parameters incorrect; and
 - part design issue.
- (3) Occurrence/specific issue could be process related and can be coming from one or more of the 4M's – machine, material, measurement and man.

An example for occurrence – specific type of problem is shown in [Figure 4](#) which is a real-world problem in the semiconductor industry.

4.2 Human errors

This section addresses human errors that contribute to the occurrence of the problem. In many cases, if the root cause is human error, engineers tend to stop the problem-solving

Problem Statement: 15 % Yield loss on
memory device transistor chips

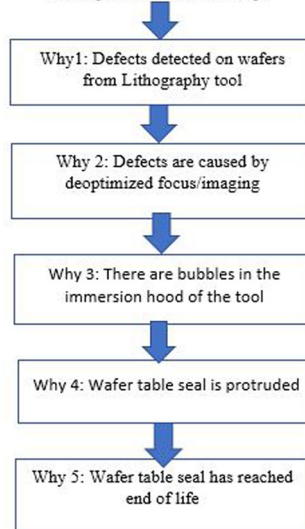


Figure 4.
Occurrence-specific
type 5 whys

exercise at that point which is not correct. A further deep dive is essential in trying to understand the circumstances that led to the human in making a mistake in the first place. In 1990, Gordon Dupont identified 12 factors that contribute to a human error which he termed as “Dangerous Dozen” [Aviation maintenance technicians (AMT), 2018]. The dangerous dozen was first introduced in the aerospace industry, but it has now been widely implemented in other industries as well.

The 12 factors that contribute to a human error are:

- (1) lack of assertiveness;
- (2) distraction;
- (3) fatigue;
- (4) stress;
- (5) lack of teamwork;
- (6) complacency;
- (7) lack of awareness;
- (8) lack of resources;
- (9) lack of knowledge;
- (10) lack of communication;
- (11) pressure; and
- (12) norms.

To address human errors effectively, organizations must develop a system (software, power point slides, spreadsheets) to bucket the human factor causes per the dangerous dozen by asking a list of questions. Manager/supervisors must work with operators responsible (this should not appear like a “job-threatening” exercise to the operators involved) to go over the 5

Why analysis for human factors and follow the template. Through the system used, the dirty dozen must be ranked which can lead to data analysis across shifts, operators, groups over a period of time to identify improvement opportunities. In the era of computer software, organizations must incorporate human factor analysis into their existing quality management system (QMS) software for scalability and sustainability. Some preliminary information that can be entered into a human factors system template are:

- (1) *Basic product/personnel detail*
 - Factory location, date of entry, part ID, # parts affected, TM name, work shift, etc.
- (2) *Sample list of questions*
 - What type of documentation is associated with event – manual/electronic?
 - How often does TM complete the task?
 - Was buddy check in place?
 - Which shift did TM belong to?
 - Was training adequate for this job?
 - Did a communication breakdown occur prior to the task?
 - Was this a repeat occurrence for the TM?
 - Did TM have misgivings about performing the task?
 - What is the experience level of the TM?
 - Was the task a part of TM's responsibilities?
 - Was the TM interrupted during the task?
 - What time during the shift did the incident happen?
- (3) *Dashboard/analytics feature*
 - Based on answers to the prior questions, the system must have an algorithm to rank the dangerous dozen and create a histogram/dashboard. Further analytical tools can be used to identify trends and identify areas of high concern.

Note that the list of questions to be asked could get more comprehensive or more basic based on the organization's scalability and work culture.

Figure 5 shows an example of occurrence – human type 5 Why analysis in a semiconductor manufacturing facility.

Post human factor analysis, a pareto was developed (Figure 6) to analyze the human factor percentage in descending order. The focus should be on the top two-three items to develop corrective actions for future prevention. In this specific example, the operator informed knowledge gaps, lack of proper training and awareness while performing the tool chamber gas purging process resulted in this problem. Appropriate corrective actions were taken post root cause analysis.

4.3 System

Deming's 85-15 rule says that 85 per cent of problems can be traced back to management or a system-related issue and that only 15 per cent of problems can truly be traced to individual contributor making a mistake because they did not care or weren't conscientious (CSSBB, 2010). This tells us that an organization must put a lot of emphasis on continuous improvement of its systems. From the Fishbone diagram, the two M's that contribute to system level failures are method and mother nature/environment. Primary questions in attacking system level issues are Why did our system allow it to occur? What was the breakdown or weakness? Why did the possibility exist for this to occur?

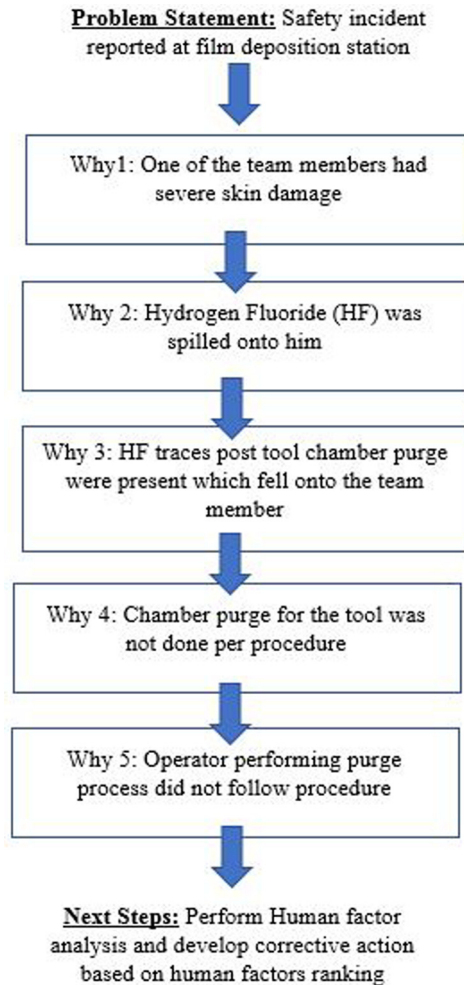


Figure 5.
5 Whys example for
human error

- (1) Root cause typically related to management system issues or quality system failures
 - rework/repair not considered in process design;
 - lack of effective preventive maintenance system;
 - ineffective advanced product quality planning (FMEA, control plans);
 - engineering controls;
 - standards; and
 - available resources.
- (2) Typically traceable to/controllable by support people
 - method;
 - management;

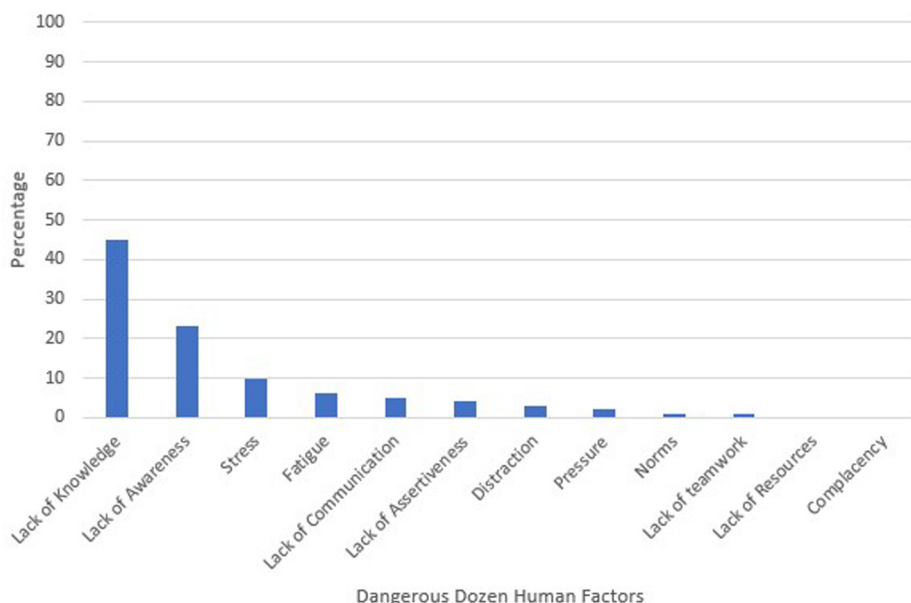


Figure 6.
Human factors
percentage pareto

- purchasing;
- engineering; and
- policies/procedures.

Figure 7 shows an example of a system issue occurring in a heavy machinery industry branching out from an occurrence-specific issue.

Every organization will have certain detection mechanisms in place to prevent quality problems from escaping final line of defense and reach their customers causing significant negative impact. If such a situation arises, a separate 5 Whys must be constructed for the escape point. An escape point is defined as a point in the control system that should have caught the issue *but did not*. Some examples are:

- tool alarm did not notify correctly or as expected;
- Statistical process control (SPC) flag did not alert correctly;
- post maintenance inspection requirement was not performed; and
- buddy check misses.

If there is an escape point then we should be using 5 Whys to make sure we address the escape point correctly and make sure that control point improvements are implemented to eliminate any escape points. An example is listed below for a problem encountered in an automobile manufacturing company.

Problem statement: Customer complaint about limited tire durability:

- (1) *Why 1:* Reliability failure on tire.
- (2) *Why 2:* Worn out rubber.
- (3) *Why 3:* Thickness was way less compared to spec.
- (4) *Why 4:* SPC system did not flag the deviation during manufacturing.

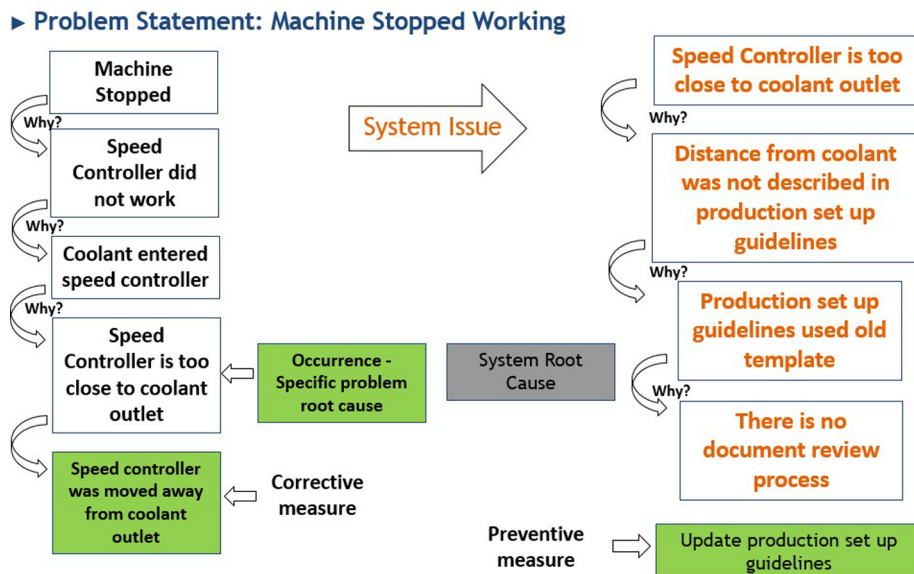


Figure 7.
5 Whys example for
system issue

Problem statement (escape point): SPC system did not flag the deviation:

- (1) *Why 1:* Thickness control limits were not correctly calculated by SPC engineer.
- (2) *Why 2:* Process changes were not notified properly to SPC engineer.
- (3) *Why 3:* Communication break down between manufacturing and design groups.

Corrective actions were implemented in the form of introducing a formal change control board where all new design changes, spec changes and manufacturing procedures were discussed.

5. Case studies from different industries

Case Study 1 (semiconductor manufacturing): Silicon wafers of a particular device technology node were reported to have major yield loss on critical die locations in a semiconductor firm resulting in delayed shipments to the customer. Preliminary data analysis showed strong correlation to a copper electroplating tool in one of the process engineering areas. 3 × 5 Whys was used in understanding the root cause(s) of this problem as shown in [Figure 8](#).

Case Study 2 (postal service): A major postal service company received customer complaints of receiving a wrong packet. 3 × 5 Whys technique was implemented in identifying occurrence – specific, human and system components of the root cause(s) ([Figure 8](#)) ([Figure 9](#)).

6. 3 × 5 why's management implications in start-up companies

Start-ups supposedly do not have time for detailed processes and procedures and yet the key to start-up speed is to maintain a disciplined approach to testing and evaluating new products, features and ideas. As start-ups scale, this agility will be lost unless the founders maintain a consistent investment in that discipline ([Evers, 2003](#)). Techniques from lean manufacturing can be part of a start-up's innovation culture. Unlike larger organizations that have well established

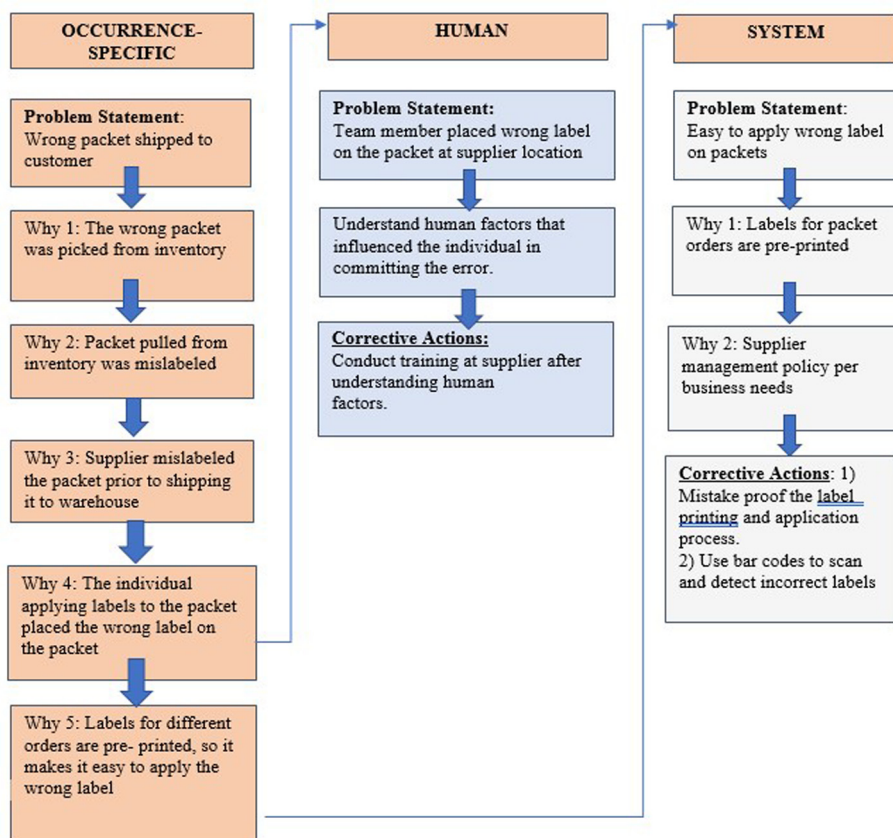


Figure 8.
3 × 5 Whys structure
for case study 1

and trained Lean six sigma experts, start-up companies often run into technical issues that may have resulted because of human or system errors.

What began as a purely technical fault is quickly revealed to be a very human managerial issue in most cases. Traditional Toyota Production System would emphasize fixing the root cause but making a proportional investment at each of the five levels of the 3 × 5 Whys hierarchy would yield better results. Having conversations with people that were involved in the failure mode could be a challenging task in smaller companies. Investing in a training process is something most start-ups tend to avoid to save finances. That is where the proportional investment tactic is so important. If the issue is a minor problem, it is essential that management make only a minor investment. Perhaps a skeptical manager could do the first hour of the eight-week plan to train manufacturing technicians. Even though that does not sound like much, but it is definitely a start. If the problem recurs, 3 × 5 Why's will keep insisting we make progress on it. And, if not, the hour isn't a big loss. At no point, should start-ups stop everything and invest in training. Instead, constantly making incremental improvements to existing process, would reap incremental benefits each time. Over time, these changes compound, freeing up substantial time and energy that was previously being lost to fire-fighting and crisis management.

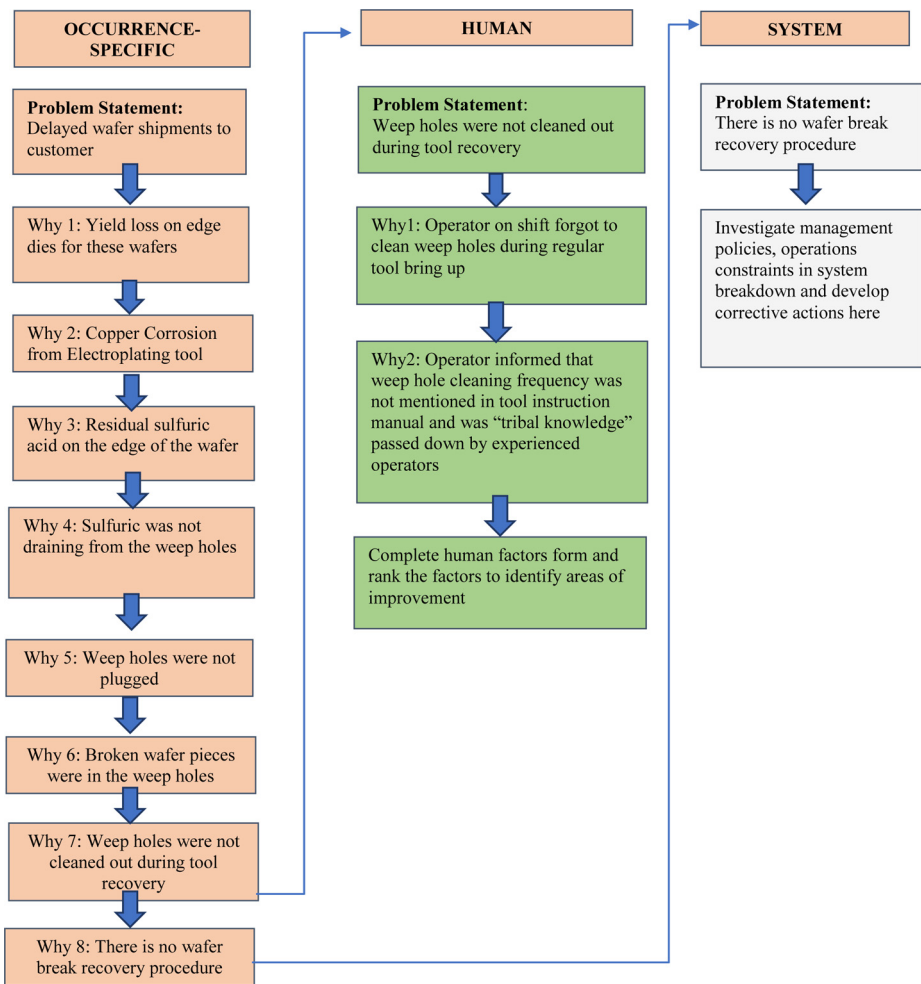


Figure 9.
3 × 5 Whys structure
for case study 2

This is especially important in a start-up, because the constant chaos and confrontation of unknowns leads to plenty of fire-fighting. If the overhead of dealing with those unknowns grows proportionally, it can drain an innovative team of the time and energy necessary to make those courageous changes in direction known as pivots. Lean start-up techniques like the 3 × 5 Whys prevent entrepreneurial teams from going too fast. Start-ups need to maximize their speed measured in validated learning and not just tasks accomplished or energy expended. Lean start-up techniques like the 3 × 5 Whys act as a natural speed regulator. If teams are going too fast to maintain their discipline, regular root cause analysis meetings force the team to automatically invest in some prevention. The more problems, the more prevention. As these prevention investments pay off, the rate of crisis goes down, and the team can speed up again. To tie the rate of progress to learning, not just execution, start-up teams can perform 3 × 5 Whys whenever they encounter any kind of failure – including failures to achieve business results, change customer behavior or even the failure of a proposed business model.

7. SWOT analysis of 3 × 5 why's

Like any quality management tool, 3 × 5 Whys methodology has its pros and cons. A SWOT (strengths, weakness, opportunities and threats) analysis was undertaken to understand different pros and cons of this methodology as shown below in [Table I](#). Having better software capabilities and management support could definitely minimize internal weaknesses and external threats.

Lack of accountability on the part of humans because of various fears at all levels deeply hinders an organization's progress, but it is a challenge for top level management to eliminate fears for their employees by providing appropriate training and constantly coming up with team morale building activities and promoting a quality culture wherein problem-solving is an attitude, which everyone must develop and not a mundane job task residing in the scope of one specific department such as quality control.

8. Conclusions

In summary, expanded 3 × 5 Why's could be a powerful tool in arriving at actionable root causes in an organization while trying to solve problems. Separating a problem statement into 3 categories – occurrence-specific, human and system components and performing individual 5 Why's on each of these components will enable the identification of deeper issues that are causing the problem. Unearthing these deeper 5 Why's provides the maximum financial benefit to organizations. In case of human errors, a human deviation form must be implemented based on the dangerous dozen concept and be used diligently to monitor and prevent human errors in organizations. [Figure 10](#) shows the 3 × 5 Why problem-solving framework in summary.

Internal factors	<i>Strengths</i>	<i>Weakness</i>
	Move from lower level symptoms to higher level symptoms. Clear understanding of human errors and analysis of human factors for improvement. Eliminate sources of waste and process variation by understanding system level issues. Can infuse positive quality culture with respect to root cause analysis. Can be expanded to safety-related issues as well. Improve bottom-line results.	Integration of this methodology in a quality management software could be a challenge. Chances of failure without management support. Operators could feel threatened in case of human error to do a 5 Whys analysis with them. High chance of pencil whipping human factors questionnaire without tight supervision. Difficult to scale for organizations with operations in different geographical regions. Smaller companies and start-ups may find it difficult to invest in human factors such as training.
External factors	<i>Opportunities</i>	<i>Threats</i>
	Move from lower level symptoms to higher level symptoms. Integration of 3 × 5 Whys into a company's QMS enables efficient problem-solving over competition. Fixing system level problems results in huge financial savings for the company. Many third-party software developers available in the market to integrate with existing QMS at affordable costs.	Difficult to avoid human error all together. Software issues can make it difficult for users undermining the process. Losing market share because of advanced manufacturing and system quality from competitors.

Table I.
SWOT Analysis

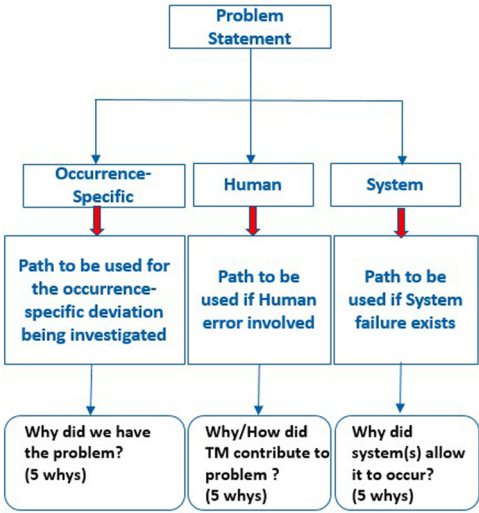


Figure 10.
3 × 5 Why
framework

References

Aviation maintenance technicians (AMT) (2018), *Handbook Addendum Human Factors*, Chapter 14, pp. 12-25, available at: www.faa.gov/regulations_policies/handbooks_manuals/aircraft/media/AMT_Handbook_Addendum_Human_Factors.pdf

CSSBB (2010), "Quality council of Indiana", *CSSBB Primer*, Vol. 4, pp. 125-134.

Dunn, A. (2004), "Getting root cause analysis to work for you", ICOMS, available at: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.172.914&rep=rep1&type=pdf>

Evers, N. (2003), "The process and problems of business start-ups", *The ITB Journal*, Vol. 4 No. 1, Article 3.

ISO/TS 16949 (2009), *Quality Management Systems*, ISO, Geneva.

Kadu, M. and Unde, M. (2016), "Improving the efficacy of root cause analysis", Cognizant solutions, 20-20 insights, available at: www.cognizant.com/whitepapers/Improving-Efficacy-of-Root-Cause-Analysis-codex1806.pdf

Livingston, A.D., Jackson, G. and Priestley, K. (2001), *Root Causes Analysis: Literature Review*, WS Atkins Consultants Ltd, Warrington.

Paradies, M. and Busch, D. (1988), "Root cause analysis at Savannah River plant", *Conference on Human Factors and Power Plants*, pp. 479-483.

Serrat, O.D. (2009), "Five whys technique", Asian Development Bank, February 2009, available at: www.adb.org (accessed 26 March 2012).

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