BPTrends COLUMN

Performance Architecture

Roger Addison, Carol Haig, Mark Johnson

The Case of the Moving Building

The building was moving and it was not supposed to. Water leaks and cracks appeared in a long stucco wall and mold and mildew showed up inside of it. Workers reported that on windy days, plumbing pipes and electrical conduits suspended from inside the roof swayed. Some interior walls and carpet were wet. A number of contractors and sub-contractors, with their teams of workers, were responsible for the building's construction. And they all blamed each other for these problems.

The building's owner brought in a **forensics** team that specialized in architecture, engineering, and construction to help determine the **root cause** of the problems.

Forensics

When you see the word **forensics** what comes to mind? If you think of your favorite crime show on television or a particular movie mystery, that is a good place to begin to understand the science of forensics. Forensics is a four-step process for finding the **root cause** of a problem:

- Identify potential evidence
- Acquire the evidence
- Analyze the evidence
- Produce a report of findings

Besides crime analysis, forensics are used to investigate problems and failures in many arenas including computer technology, medical pathology, ballistics, and construction, among others. Governments and industries of all kinds employ forensic specialists to investigate problems and failures in their products, systems, and organizations.

Forensics and Analysis

To better understand the value of forensics, consider the analysis phase at the beginning of a new project. Performance Architects identify analysis as the most critical part of any project because the work done there specifies what a successful outcome will look like and drives the fulfillment of the desired results. An incomplete or faulty analysis almost always leads to project problems and often failure.

The analysis phase results in a recommended solution. It determines how the project plan is constructed, the deliverables specified, timeline established, and checkpoints identified. Team members receive their assignments, the kick-off meeting is held, and the project is launched.

Well, some projects fail completely, others have mounting difficulties as they progress, and still others launch reasonably well but develop problems later. That is when a **forensic** investigation can help determine what went wrong and identify the **root cause** of the problem so it can be fixed. Even if we are not trained in forensic techniques, we can apply the basic steps and the questions asked in a forensic analysis to projects that run into difficulty. A number of entities, notably the U.S. Coast Guard, solve problems using **root cause** analysis.

Moving Building: The Forensic Investigation

Finding the **root cause** of the problems in the moving building initially proved elusive.

Step 1: At the outset, the contractor responsible for the stucco was blamed for not installing it correctly, but he proved otherwise. He, in turn, claimed the steel studs supporting the stucco were defective and caused the cracks. While the studs were, indeed, poorly installed, they were within the allowed specifications.

Step 2: The sub-contractor who installed the studs said the building's steel frame expanded and contracted in changing temperatures causing the studs to become deformed and damage the stucco. A re-calculation of the steel frame ruled out expansion and contraction as the cause of building movement and damage. The building was a **rigid frame building**, bolted together. Such buildings resist any movement in their structure.

Step 3: The building was completely enclosed, closed for construction, with no active ventilation being supplied to the space. The workers' observations of movement were dismissed because it was a **rigid frame building** that could not move with over 600 bolts holding it in place.

Step 4: A worker who was cleaning fire proofing from the steel frame found a large bolt with a loose nut that he could turn by hand. The bolt was one of 16 that connected two large structural pieces together. The forensic specialists then checked all 600 bolts in the75,000 square foot building. More than half were not properly tightened, allowing the entire building to move.

Step 5: The forensic team determined that the sub-contractor responsible for applying the fire proofing to the steel frame was anxious to earn an early completion bonus and had covered half the bolts before the previous subcontractor could tighten them. Neither contractor reported this dangerous situation to the building's owner.

The Conclusion: At the end of the forensic investigation, the senior engineer said he had never seen such a dangerous oversight. His previous conclusion that a **rigid frame building** could not move was based on the **unverified assumption** that all the bolts in the building had been tightened, making it rigid, which was not the case. The **root cause** of the cracks and leaks that caused the wall to fail was the loose bolts that allowed the building to move and moisture to enter the building through the exterior stucco wall. And the actual evidence of the loose bolts was accidently

discovered by the worker. All bolts in the building were re-tightened and fireproofed at considerable additional expense.

Key Learning: No matter how experienced and knowledgeable we may be, it is never wise to proceed based on an **unverified assumption**, regardless of how confident we are or how many times we have done similar work.

Forensic Process Steps

Let's explore some of the questions the forensics team asked about the moving building as they completed each step in the forensic process and what they learned from the answers.

Identify Potential Evidence – *What did you design or build?*

- What empirical evidence is available? What can you observe, measure?
  - Cracks, leaks, mildew, mold, moving pipes and conduit, wet walls and carpet
- What made you determine that there was a problem or a failure?
  - The empirical evidence cited above
- To what extent was the original project/process well-documented and properly designed?
  - The design was proper and the planning documents complete
  - The application of the fire proofing before the bolts were fully tightened was neither documented, inspected, nor reported by the original construction team members
- What are the key factors/examples cited as evidence of a failure/deficiency?
  - Loose bolts compromised the steel building frame and allowed the **rigid frame building** to move
- What are early opinions on the **root cause** of the problem/failure, as distinct from **symptoms?** Two premature examples of symptoms vs root cause were:
  - Faulty stucco application
  - Poorly installed studs

Collect the Evidence – *What evidence of the problem/failure have you found?*

- What evidence categories have you established to direct the collection of evidence?
  - Examples: key process components, user information, environment, training
  - For the moving building: physical evidence, worker information
- What evidence are you collecting?
  - Photographs of cracks and water damage in the stucco
  - Samples of loose bolts
  - Workers' eye-witness accounts of building movement
  - Mold and mildew found inside the building
- When was the evidence collected?

    - The defective wall and the moving building were discovered during the forensic investigation which took place approximately eight years after initial construction was completed
- Who gathered the evidence and what was their role in the original development of the project?
    - Evidence was reported by construction crew members working on the building and gathered by the forensics team
- Who from outside the project was invited to observe, gather evidence, and interview the project's key developers?
    - Forensic specialists: architects, engineers, and construction experts who looked at the building and its problems with fresh eyes

Analyze the Evidence – *What information about the building's problems does the evidence you've collected provide?*

- Who will analyze the evidence?
    - The forensics team
    - The lead engineer and lead contractor
- What experts in related fields are looking at the same evidence for clues to the **root cause?**
    - Technical experts were brought in to closely examine the proposed root cause and any related symptoms or damage to other building systems
- How is the evidence being organized/categorized?
    - Evidence was organized into categories that mirrored the respective systems and components of the building: structural, walls, roof, plumbing, etc.
- How are connections between the various evidence examples being explored?
    - As each symptom was uncovered—stucco cracks, leaks, moving pipes and conduit, wet interior walls and office carpets—the forensic experts searched for the **root cause** of each symptom and any relevant connections
- To what extent are the original developers of the problem/failed project involved in the investigation?
    - In this case the original contractor was not involved for legal reasons
    - The lead engineer was actively involved in the search for a **root cause**
    - Representative experts for the major building systems and components were hired: structural engineers and construction managers, experts in building envelope/water intrusion, sealants, steel fabricators

Report the Findings

The purpose of the findings report is to identify the **root cause** of the problem/failure and to document how the forensic investigation was performed. It is written when the forensic investigation is complete and documents the investigator's process as driven by the four investigative steps and the questions asked in each step.

The **root cause** is derived from objective, provable facts that can be addressed with specific corrective action and then monitored for continued success.

Key Forensic Concepts

Key components of a forensic investigation that make the process different from other trouble-shooting efforts include:

Symptoms vs. Root Cause

People engaged in the search for a solution to a vexing problem are understandably anxious to figure out what happened and how to fix it. It is easy to confuse a symptom, such as faulty stucco wall construction and water leaks with the **root cause** of all the problems: bolts throughout the building that were not completely tightened because of premature application of fireproofing that then allowed the hazardous, unintended movement of the building.

Fig. 1 Moving Building Bolt

Evidence Categories

It is helpful to establish relevant categories for the collection of evidence. These often include the:

- Original basis of the design: plans, specifications, key performance indicators, programming
- Team members' roles, responsibilities, and qualifications
- Performance criteria
- Desired outcomes
- User/owner input
- System components
- Expert input

Connections

Connections are a valuable aspect of forensics as few investigations are solved based on one simple, obvious fact. Even if the **root cause** is a single factor—loose bolts—it may take many steps and connecting unrelated clues from many people and sources to get to it.

Questioning Technique

Questions address both what is known now about the problem, and what is unknown now and could occur later. This helps avoid jumping to cause before investigating all the evidence and looking carefully at the interrelationships among the symptoms.

Outside Expertise

A unique feature of forensic investigation is the notion of a fresh set of eyes observing the situation/problem, looking at the evidence collected, bringing a different perspective from the team intimately involved in the project. Typically, the outside experts come from related disciplines and benefit from having a fresh perspective and fewer pre-conceived notions/assumptions about the problem.

Forensic Thinking

Researching and learning about forensics has raised the authors' awareness of opportunities to recognize and even apply forensic thinking to some interesting problems.

A colleague, Klaus Wittkuhn, shares an example of forensic thinking. Consider the airplane below. No, the red dots do not represent where passengers who tested positive for COVID-19 were sitting. It is a composite of WWII fighter planes and the red dots show the locations where enemy fire most often made contact. The areas without red dots were not typically hit.

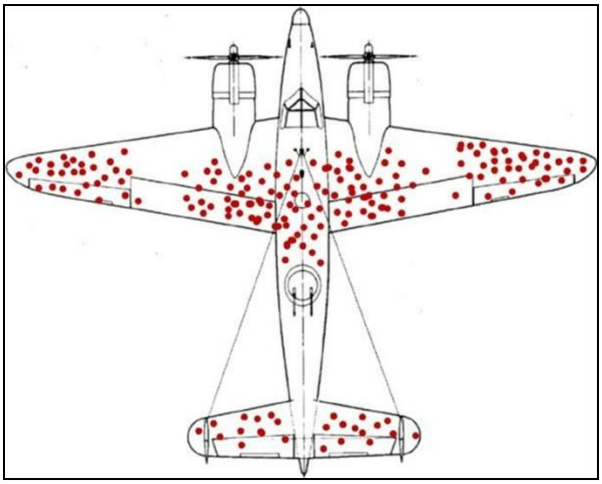

Fig. 2 Airplane

The illustration was shown to a group of experts who then discussed how best to reinforce the planes in the red dot areas so that enemy fire could not damage them. There was detailed conversation about how much additional weight the planes could handle and still be able to fly. The group was ready to make recommendations about how to proceed when one person asked, "What do the planes look like that did not make it back?"

That person was using forensic thinking that saved lives and money.

Forensics and Business Process

We encourage you to borrow from the basics of forensics that we have shared here to help you troubleshoot processes that are not working as they should. We also suggest that you help guard against process problems or outright failures by applying the forensic process to your projects in the design phase.

- Start with the desired results such as these
  - The building's driveway canopy must stand up to significant winds
  - Customers should stand in line no longer than five minutes before being served
- Verify all the initial project documentation one more time, no matter how often you have gone over it
  - Project Plan
  - Specifications
  - Target Users
  - Environment
  - Other key factors
- As the project progresses, check each step in the project plan to determine if it was done correctly and completed as specified in the plans and specifications

Taking these extra steps can help keep your project on track and on schedule and give you and your team opportunities to address small problems before they become big ones.

Your Turn

Have you had an opportunity to be part of a forensic investigation or observe one in progress?

What are some examples of projects or processes you know about that did not provide the desired results and cost a lot of time and money to fix? How might the forensic investigative process have helped find the **root cause?**

What will you do differently in your work now that you know something about forensic investigation?

Summary

The example: an eight-year-old building was moving that should not have been. A number of problems with the structure, such as cracks, leaks, and movement were identified. Neither the original contractor nor the chief engineer could identify the **root cause** for any of these symptoms. A team of **forensic** experts that specialized in construction problems was brought in to examine the evidence and find the **root cause.**

The team followed the four-step process for a f**orensic** investigation, asking critical questions during each phase:

- Identify potential evidence
- Acquire the evidence
- Analyze the evidence
- Produce a report of the findings

The key concepts of a **forensic** investigation include:

- Distinguishing between symptoms and **root cause**
- Establishing categories to organize empirical evidence
- Questioning technique
- Inviting in outside expertise

Forensic techniques are accessible to anyone investigating a product or system problem or failure. Consider how some of these could help you with a current or past project.

Authors

Roger Addison, Carol Haig, and Mark Johnson

Resources

Berger, W. (2014). A more beautiful question: The power of inquiry to spark breakthrough ideas. Bloomsbury.

Firestein, S. (2012). Ignorance – how it drives science. Oxford University Press.

Levy, M. and Salvador, M. (2002). Why Buildings Fall Down. W.W. Norton Company

Science Direct. Retrieved from: https://www.sciencedirect.com/topics/computer-science/forensic-process

Winkler-Dawson, K. (2020). American sherlock – murder, forensics, and the birth of american CSI. Putnam.