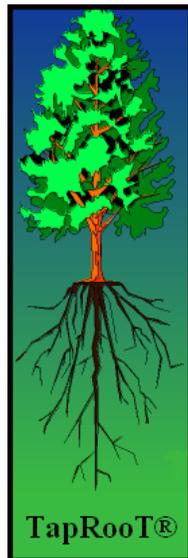


Example Application of TapRooT®



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Example Applications of Analytical Tools for Airline Flight Safety

Preface

This example application has been prepared by Systems Improvement in conjunction with the Global Aviation Information Network (GAIN) Working Group B (Analytical Methods and Tools) (WGB) as one of a number of such examples of the use of analytical methods and tools described in the “*Guide to Methods & Tools for Airline Flight Safety Analysis*”. The intent of these example applications is to illustrate how various tools can be applied within an airline flight safety department, and provide additional information on the use and features of the tool and the value of such analysis. GAIN WG B hopes that these example applications will help increase the awareness of available methods and tools and assist the airlines as they consider which tools to incorporate into their flight safety analysis activities.

Each example application of an analytical method or tool is posted on the GAIN website (www.GAINweb.org). Readers are encouraged to check the website periodically for a current list of example applications, as further examples will be added as they become available.

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TapRoot® Investigation System Software

1 Introduction

1.1 OVERVIEW OF THE TOOL FUNCTIONALITY

The TapRoot® system for root cause analysis is a set of integrated tools put together for the purpose of evaluating, for root causes and corrective actions, any occurrence or audit finding. From these investigations and analyses the data produced can be evaluated using Statistical Process Controls (SPC) to define the user's system and evaluate those systems for trends.

The system contains tools and techniques to help a user facilitate an investigation including: SnapCharT®, Root Cause Tree®, Pre-defined Root Cause Tree® User's Dictionary, Corrective Action Helper®, Equifactor®, Change Analysis, Critical Human Action Profile, Safeguards Analysis, and SMARTER Corrective Actions. In combination these tools allow the user to understand first "What" has happened, then to dig down to define "Why" something has occurred, and finally to "Fix" the underlying system problems that contributed to an occurrence or to a negative audit finding (See figure 1). This allows for systematic, consistent investigative data while evaluating both Human Performance and Equipment Performance and their respective impact. First, to fully understand TapRoot®, you also need to understand the definition of a "root cause."

ROOT CAUSE: *The most basic cause(s) that can reasonably be identified, that management has control to fix and when fixed will prevent (or significantly reduce the likelihood of) the problem's reoccurrence.*

The definition above is the fundamental building block on which this system was designed. The definition highlights a basic investigation trade-off. The investigator must find "basic" causes but has limited resources (reasonable effort). The factor that should decide this trade-off is the ability to "fix" the problem. Therefore the definition focuses on finding causes that management can fix.

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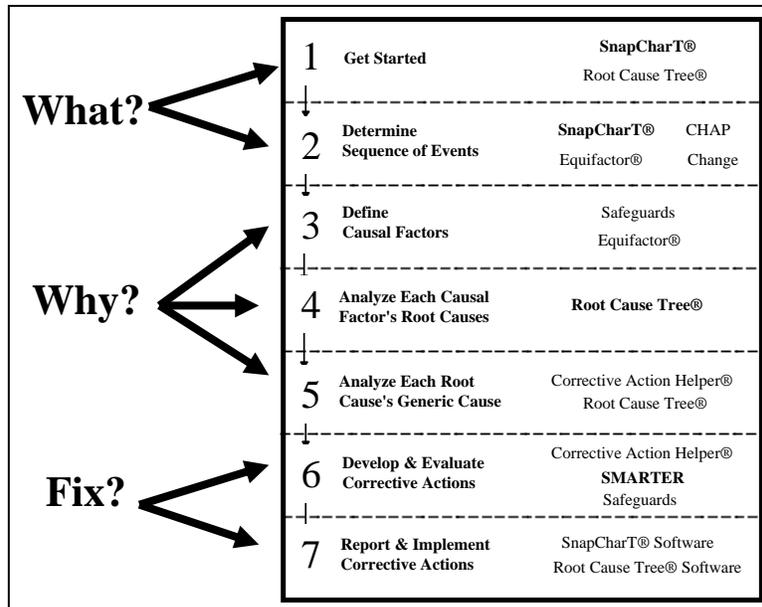


Figure 1 TapRoot® Investigation Reactive Flow

As can be seen in the flow, the different techniques provide the investigator tools to be used throughout the overall investigation process. These tools built into the TapRoot® System Software, provide an electronic means for **consistent, objective** data collection, system evaluation, corrective action development/tracking, and data storage for trending and data analysis in a single software package. The TapRoot® System Software also provides two database views and flows for performing both occurrence investigation as well as audit and observation evaluation. Although the same techniques and basic flow are used (from an analysis perspective) the program separates the two types of analyses which allow the program administrator more flexibility for protection of information. Included with all of the techniques listed in figure 1 as well as the aforementioned functionality is the following:

- 1) Ability to be used as an incident reporting tool allowing anonymous or login based reporting
- 2) Electronic versions of all the techniques listed for maximum documentation and discovery
- 3) Built-in flowcharting tool for flowcharting process being investigated for maximum understanding
- 4) Built on SQL Database to store and secure the investigation data
- 5) Produces reports that can document and communicate investigative findings
 - a. Incident Report
 - b. Corrective Action Summary and Tracking Reports
 - c. Technique level reports for each analysis technique
 - d. Flowcharts
 - e. Database wide Corrective Action Tracking Reports
- 6) Allows for customization of an unlimited number of reports through the use of data-warehousing
- 7) Built in search capabilities allow for easy queries of data
- 8) Security at the program, incident and technique levels

In the sections that follow, we will provide guidance on how TapRoot® works and how the software functionality supports the investigation team with easy to use tools for Root Cause Analysis.

1.2 INTRODUCTION TO THE EXAMPLE APPLICATION

The example that will be used to demonstrate the TapRoot® process and techniques is an older airline incident involving the crash of an L-1011 on approach to Miami international airport. The nose-gear warning indication light did not illuminate (giving either a warning or OK for landing gear configuration). This failure led to a number of human performance issues while the crew focused on the indicator and not the flight requirements. This occurrence was not originally evaluated using the TapRoot® methodology but will provide a good representation of the level of detail and analysis that the TapRoot® system provides.

2 Input Data

Now that we have a basic understanding of TapRoot®, we can look at the depth of information prompted for by the techniques and investigation process. The investigator(s) first enters basic investigation information to begin the process of an investigation. One key piece to an objective investigation is to use only job titles, to describe individuals involved when describing What happened. NEVER use personnel names as this reduces the level of objectivity and increases subjectivity. This data can be used to determine needed resources and the level of analysis necessary. This initial information includes:

- 1) Incident Title, Date, Time
- 2) The Incident location is documented (chosen from a pre-determined, user defined list).
- 3) The Incident classification(s) is determined (chosen from a pre-determined, user defined list)
- 4) Investigative Team information and security rights are set-up at the Investigation level to provide limited access to investigation data
- 5) A description (and any other custom data concerning the event) can also be entered

This information is entered into the program in the Incident Editor (figure 2). Following this initial report of occurrence and the Incident Description listed above, the investigation team begins to build a picture of “What” has happened by developing an initial SnapCharT®. This technique involves the development of a basic flowchart graphically describing the occurrence from its beginning stages through to the final outcome and post occurrence response. This data is entered into the program using the built-in flow charting tool located on the SnapCharT® tab. This flow charting tool contains all the functionality necessary to fully flowchart an occurrence and provides presentation quality output for use in documentation. All without the use of outside charting tools. This chart is used as the basis for the data collection phases of the investigation (Steps 1 and 2 in the TapRoot® Investigation Flow in figure 1) and subsequently grows as data is collected and added to this flow chart.

The information used to produce this SnapCharT® comes from many investigative sources including:

- Interviews of both those involved (if available) or witnessed and experts
- Flight data
- Procedures/Policies/Work documentation/Maintenance Records
- Training Records
- Equipment Analysis
- Maintenance Records
- Any other data source used to understand the occurrence

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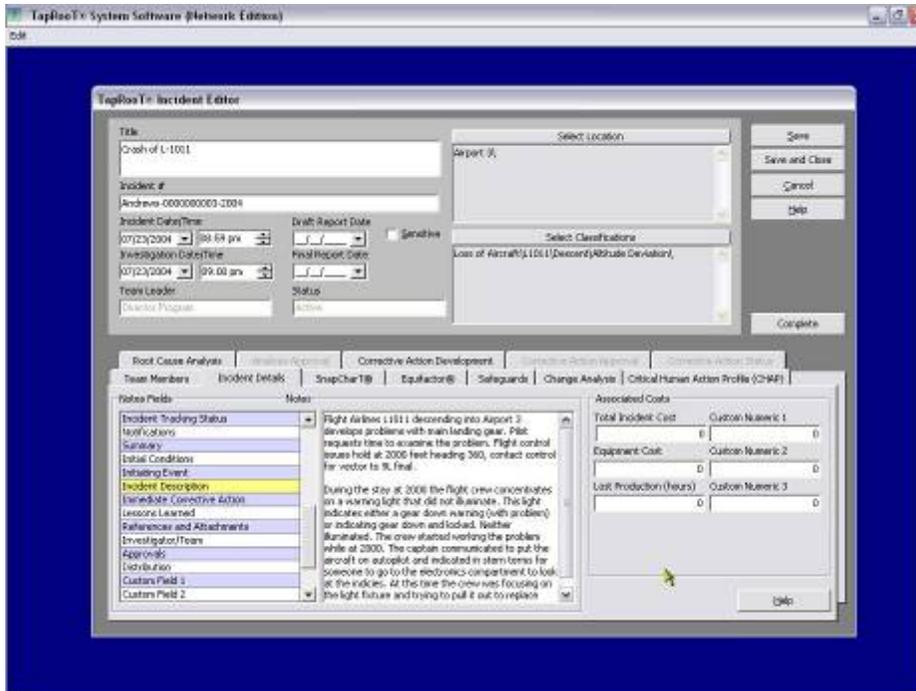


Figure 2 Incident Editor

Data is also collected as part of several evaluation techniques included on the Incident Editor including Equifactor® Analysis (Equipment troubleshooting tables), Change Analysis (evaluation of changes in performance, both human and equipment), Safeguards Analysis (similar to barrier analysis), and Critical Human Action Profile (CHAP, a systematic evaluation of critical human actions for processes involved in the occurrence). Each of these techniques promotes the gathering of and evaluation of data that is subsequently added to the SnapCharT® to aid in the understanding of the sequence of events and its outcome. The basic structure of the chart is: boxes are actions in the sequence of events, ovals are conditions that describe each action, and the circle is the occurrence being evaluated.

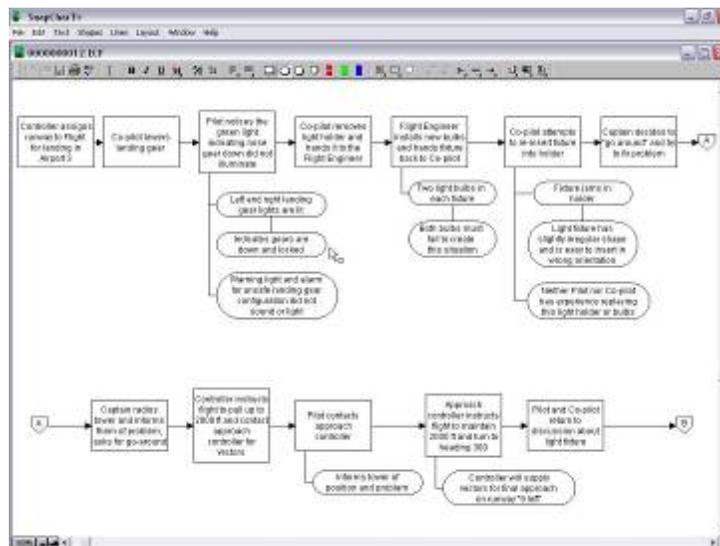


Figure 3 Example SnapCharT® (Single Page from 4 page chart)

3 Analytical Process

Once you thoroughly understand what happened by building our detailed SnapCharT®, you are ready to analyze “Why” a situation happened. This process now is broken into three steps:

- 1) Identification of Causal or Contributing Factors on the SnapCharT®
- 2) Analysis of each Causal Factor through the Root Cause Tree® for Identification of Root Causes
- 3) Development of Corrective Actions and Measurement Strategies for Implementation and Effectiveness

There is not specific guidance on the amount of time required to determine root causes, but if the investigative team has done a thorough job of building the SnapCharT® as shown below and discussed above and has a thorough understanding of the situation as it occurred, this process should not take more than a matter of hours to define the causal factors and then one-half to one hour to analyze each causal factor for root causes. If the team is taking more time in the analysis process, there is probably some disagreement due to a lack of information or knowledge on a particular situation or subject.

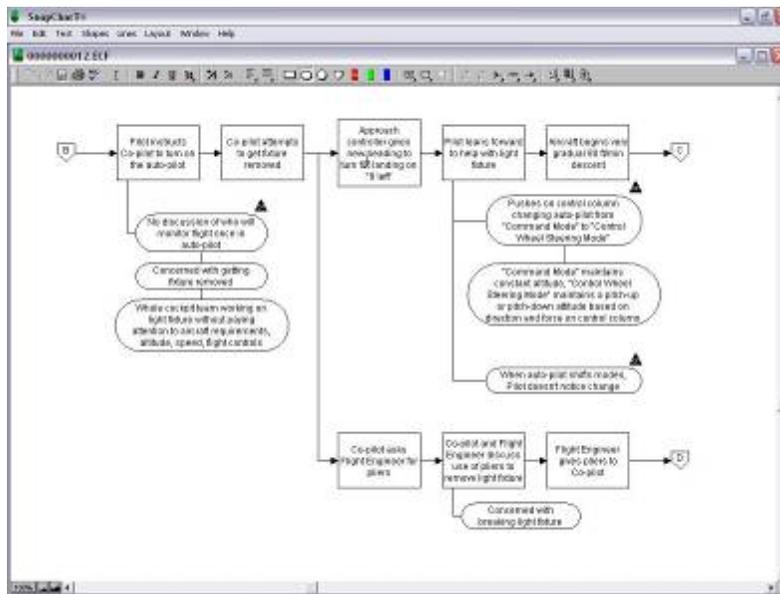


Figure 4 Example of Causal Factors on SnapCharT®

Step 1: Identification of Causal or Contributing Factors

The investigator identifies information on the SnapCharT® that directly contributed to the occurrence being investigated or made the occurrence more severe. Any data matching either of those 2 criteria are marked as a causal factor (see figure 4) on the chart using a solid triangle and will each be analyzed for root causes by using the Root Cause Tree® as will be described in Step 2 below.

Step 2: Root Cause Analysis

To find the real, fixable root causes of a problem we use a technique called the TapRoot® Root Cause Tree®. The TapRoot® Root Cause Tree® was developed to help investigators ask the right questions to find fixable root causes of both equipment & human performance related problems. The tree provides a graphically based system for problem analysis that guides investigators to potential problem areas. This helps the investigator keep from prematurely jumping to conclusions by acting as a checklist that expands the search for the problem's causes to areas that might have been overlooked. For each of the causal factors identified on the SnapCharT®, the investigation team will use the Root Cause Tree to

Example Applications of Analytical Tools for Airline Flight Safety

systematically identify the reasons or root causes for that particular issue. Therefore if the team identifies five causal factors, the team will use the Root Cause Tree five times.

Next we will describe the process of working through the Root Cause Tree. This technique is a top-down flow, that uses a process of selection and elimination to determine the root causes to either human performance or equipment related issues. By starting at the top of the tree and working down to lower and lower (more specific) level of causation the team is ensured of a documented/defendable path that is followed during the analysis. Not simply basing the root cause analysis on opinion.

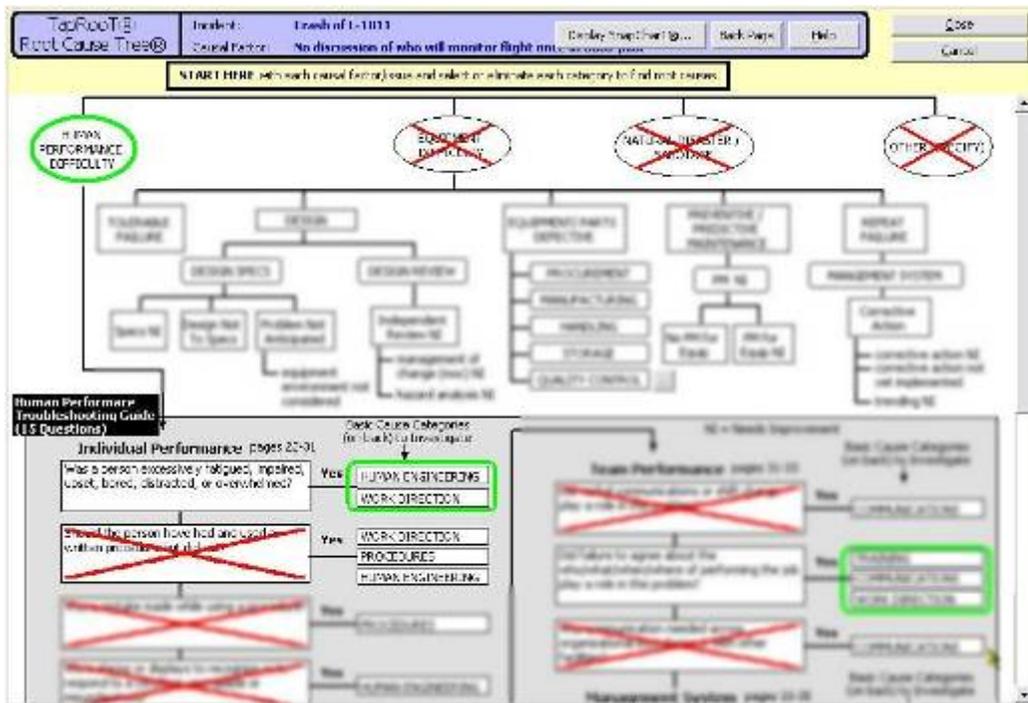
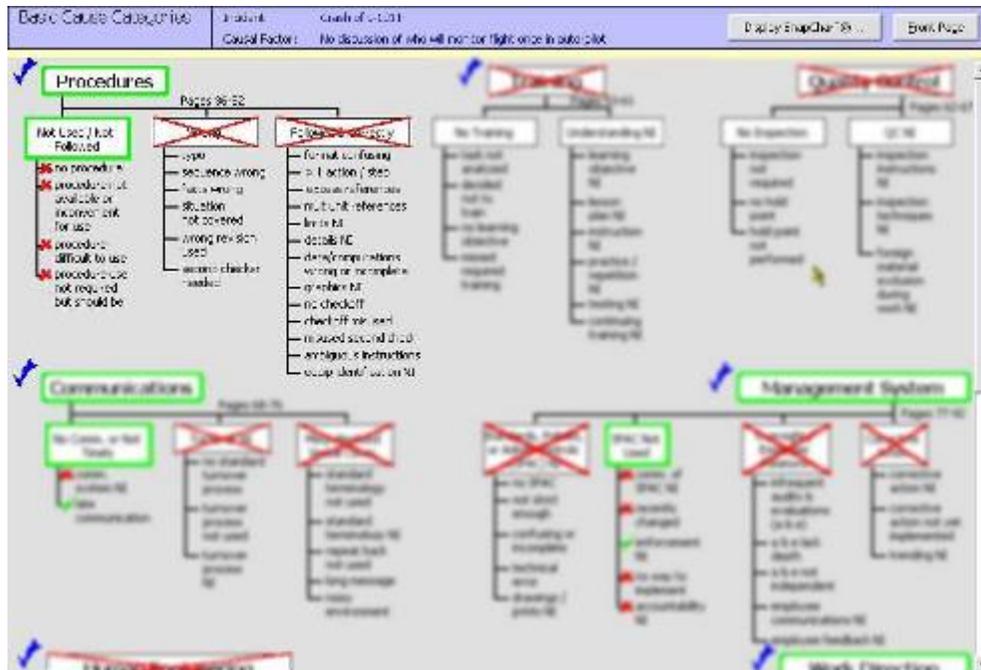


Figure 5 **Root Cause Tree for a Causal Factor**
(Some items intentionally blurred due to copyright)

In addition to make sure that the tree is interpreted consistently, each of the tree's questions and categories is completely defined in the Root Cause Tree® Dictionary. These definitions are in the form of questions that help the investigator search for real, fixable causes of problems. This is included as a right-click selection so that it is easy for the user to read these definitions while performing the analysis. The TapRoot® Root Cause Tree® provides the most guidance for investigators analyzing human performance problems. This assistance starts with the Human Performance Troubleshooting Guide. This troubleshooting flow chart of 15 questions guides the investigator to basic causes to check to see if they could be causing human error (see figure 5). The 15 questions are based on the type of questions asked by human performance evaluation experts. They help an investigator ensure that all likely causes of system induced human error are evaluated.

Example Applications of Analytical Tools for Airline Flight Safety



**Figure 6 Procedures Basic Cause Category on Root Cause Tree®
(Some items intentionally blurred due to copyright)**

Once the investigator has determined which basic cause categories apply (figure 6 above), based on the answers to the 15 question troubleshooting guide, the user evaluates each category that applies to evaluate their impact on the problem and thus identify the root causes that may apply. For example, the root cause "ambiguous instructions" located in the "Procedure" category is an example of the level of detail that an investigator reaches when using the TapRoot® System. When an investigator (or an investigation team) reaches this level of detail, it is much easier to analyze generic root causes and develop effective corrective actions.

Step 3: Development of Corrective Actions

Several corrective action tools are built into this software. These include the ability to develop corrective actions, assign associated root causes, assign responsibility, setup measurement strategies for both verification of implementation and validation of effectiveness, and also tracking reports to follow these corrective actions to completion. These tools along with two development techniques, first there is SMARTER, a review process for evaluation of the thoroughness of corrective actions, and second is Corrective Action Helper®, a module of the software that gives the investigator ideas for fixes for all levels of the Root Cause Tree. These helpful hints support the team in the initial development of corrective actions for the root causes found while enhancing the verification and validation plans.

The process of corrective actions is as follows (see figure 7):

- 1) User decides which root causes will apply to a particular action
- 2) User develops detailed plan for fixing associated root causes and compares to SMARTER
- 3) User assigns responsible person for implementation with due date
- 4) User develops plans, dates, and responsible persons for both verification of implementation and validation of effectiveness
- 5) Responsible persons update status of corrective action and team leader for investigation uses reports to track the status of corrective action until completion.

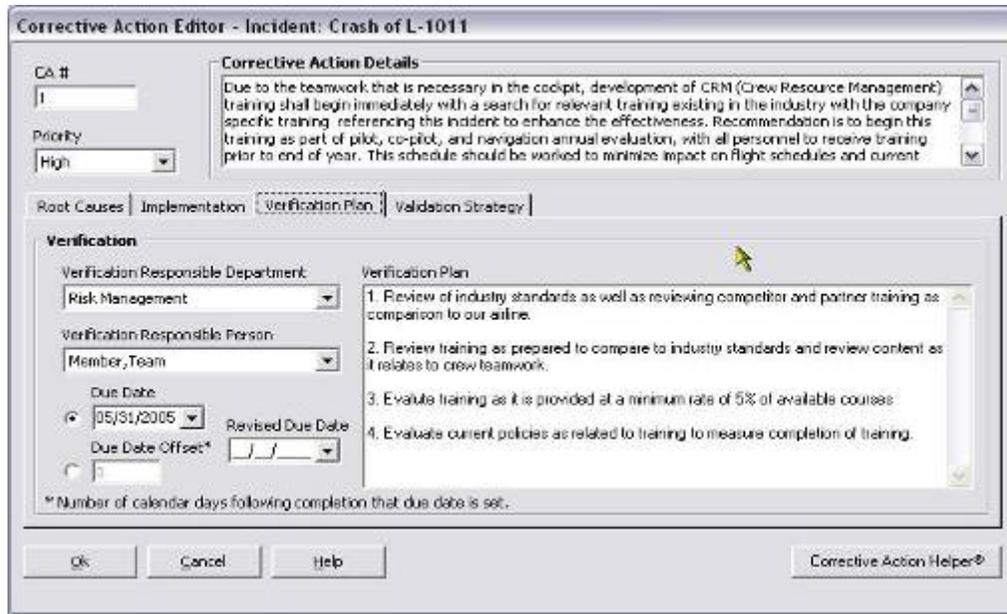


Figure 7 Corrective Action, Verification and Validation Development

4 Output

Output from the TapRoot® software includes reports that cover the entire spectrum from the incident report through to tracking corrective actions to completion. These reports include:

- 1) Incident Report – Includes a summary of all incident information, findings, and corrective actions
- 2) Technique Reports – Reports covering each of the techniques used during the investigation
 - a. SnapCharT®
 - b. Root Cause Tree®
 - c. Equifactor®
 - d. Change Analysis
 - e. Critical Human Action Profile (CHAP)
 - f. Safeguards Analysis
- 3) Corrective Action Reports
 - a. Incident Level
 - i. Summary – for incident
 - ii. Status – separate report for implementation, verification and validation
 - iii. Presentation
 - b. Database Level
 - i. Summary – for database, separate reports for implementation, verification and validation
 - ii. Tracking by Department
 - iii. Tracking by Responsible Person
 - iv. Tracking by Due Date

The software also includes the ability to produce as many custom reports as possible by developing templates in Microsoft® Excel or Microsoft® Access that utilize a data warehouse. This warehouse is dynamically updated to provide the user with the latest data to populate customized reports and documents.

Example Applications of Analytical Tools for Airline Flight Safety

TapRoot® Corrective Actions Overview		
Incident: Airlines-001001003-2004, Crash of L-1011		
Corrective Action	Verification	Validation
<p>Corrective Action: 1</p> <p>Due to the turnover that is necessary in the cockpit, development of CRM (Crew Resource Management) training shall begin immediately with a search for relevant training existing in the industry with the company specific training, following that incident to enhance its effectiveness. The recommendation is to begin the training as part of pilot, co-pilot, and navigator annual evaluation, with all personnel to receive training prior to end of year. This schedule should be worked to minimize impact on flight schedules and aircraft availability.</p> <p>This training should cover the current policies relating to flight monitoring and the dissemination of specific criteria for the process. Training should exceed the minimum standard in our industry and be provided by the training staff at Airport 1.</p> <p>Responsible Person/Department: Director, Program / Operator Due Date: 12/31/2004 Implementation Date: ??</p>	<ol style="list-style-type: none"> 1. Review of industry standards as well as reviewing competitor and partner training as compared to our airline. 2. Review training is prepared to compare to industry standards and review content as it relates to crew resource. 3. Evaluate training as it is provided at a minimum rate of 85% of available courses. 4. Evaluate course policies as related to timing to measure completion of training. <p>Responsible Person/Department: Director, Team / Risk Management Verification Due Date: 02/28/2005 Verification Completion Date: ??</p>	<p>Check flight will begin immediately for the validation of baseline and crew communication during ground and flight operations. These checks should be performed by QC on selected areas and be performed at a rate equal to or above 10% of available daily flights. Checks should be performed a minimum of 20 per crew in each calendar year continuing until compliance is deemed 100% in accordance with the listed policies.</p> <p>Responsible Person/Department: Chief, Crew / Operator Validation Due Date: ?? Validation Completion Date: ??</p>

Figure 8 Example Corrective Action Summary Report

5 Application of Analysis Results

Based on the discussion in sections 1-4 above, it should be obvious that the TapRoot® process and software is very systematic, and provides a well defined path for root cause analysis. This consistency also provides us with data that is perfect for trending and data analysis.

Due to the fact that the user follows a process for evaluation of data collected during an investigation, and along the path of root cause analysis each level and each cause is strictly defined, it does not matter who performs the investigation because if the path is followed similar results will be found. This allows us to use the data collected and the analysis results to be evaluated successfully using Statistical Process Control (SPC) Charts and Pareto Charting. These tools help the investigation team to evaluate and focus improvement efforts as well as define actual process limits for our systems.

Example Applications of Analytical Tools for Airline Flight Safety

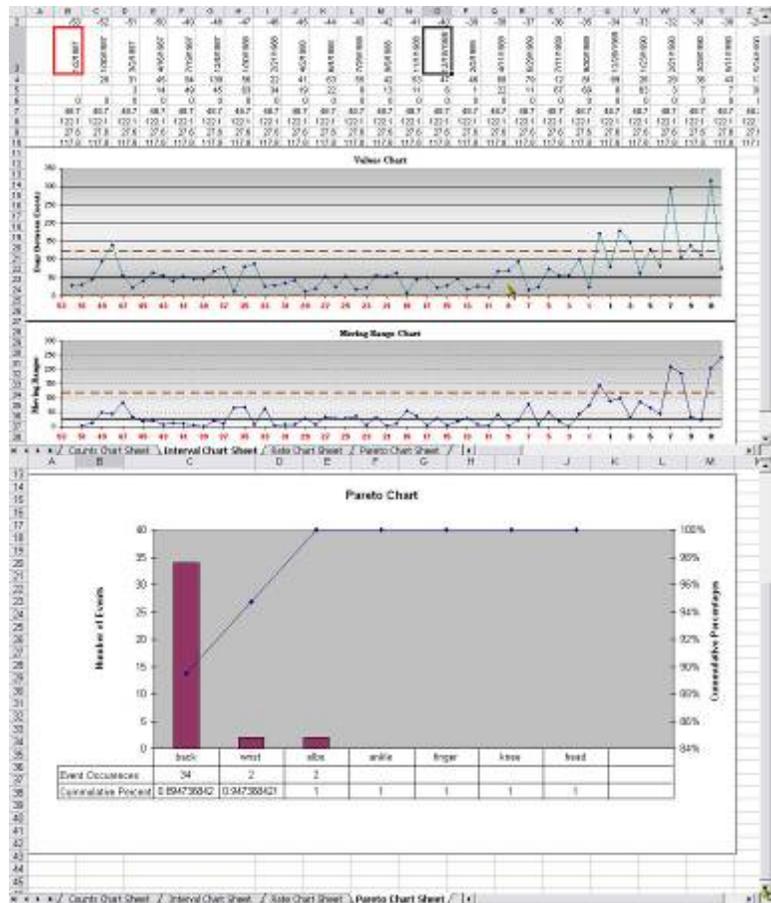


Figure 9 Example SPC Interval Chart and Pareto Chart Output from Provided Tools

By taking the root cause data alone, and trending using SPC count, rate and interval charts, we can understand the system in which we are evaluating and watch for meaningful trends and changes in these systems. This in combination with the excellent documentation of the process of analysis shown in section 4 makes the data almost invaluable to any quality improvement initiative.