Events and Causal Factors Analysis

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Executive Summary

Events and Causal Factors Analysis (ECFA) is an important component in the accident investigation repertoire of methods. It is designed as a stand alone technique but is most powerful when applied with other techniques found in the Management Oversight and Risk Tree (MORT) programme. ECFA serves three main purposes in investigations: (1) assists the verification of causal chains and event sequences; (2) provides a structure for integrating investigation findings; (3) assists communication both during and on completion of the investigation. This document discusses the benefits of EFCA and provides a primer in the application of the technique.

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1 Introduction

Accidents are investigated to identify the causes of their occurrence and to determine the actions that must be taken to prevent recurrence. It is essential that the accident investigators probe deeply into both the events and the conditions that create accident situations, and also the managerial control systems that let them develop so that the root accident causes can be identified. Identification of these root causes necessitates understanding the interaction of events and causal factors through a chronological chain of activity starting with an initiating event through to the final loss producing occurrence. Vital factors in accident causation emerge as sequentially or simultaneously occurring events that interact with existing conditions. This pattern of events and conditions are traced out to reconstruct the multifactorial path to unacceptable loss or loss-potential. A meticulous trace of unwanted energy transfers and their relationships to each other and to the people, plant, procedures, and controls implicated in accident occurrence, further defines the sequence of accident development.

The Events and Causal Factors (ECF) chart depicts the necessary and sufficient events and causal factors for accident occurrence in a logical sequence. It can be used not only to analyse the accident and evaluate the evidence during investigation, but also can help validate the accuracy of pre-accident systems analyses.

Events & Causal Factors Analysis (ECFA) is an integral and important part of the MORT-based accident investigation process. It is often used in conjunction with other key MORT tools, such as MORT tree analysis, change analysis, and energy trace and barrier analysis, to achieve optimum results in accident investigation. The fundamentals of this valuable MORT tool are discussed in this paper.

2 Nature of Accident Investigation

Experience has shown that accidents are rarely simple and almost never result from a single cause. Rather, they are usually multifactorial and develop from clearly defined sequences of events which involve performance errors, changes, oversights, and omissions. Accident investigators need to identify and document not only the events themselves, but also the relevant conditions affecting each event in the accident sequence. To accomplish this, a simple straight forward approach can be utilised that breaks down the entire sequence into a logical flow of events from the beginning of accident development . It is important to realise that the end point may be defined either as the loss event itself or as the end of the amelioration and rehabilitation phase. This flow of events need not lie in a single event chain but may involve confluent and branching chains. In fact, the analyst/investigator often has the choice of expressing the accident sequence as a group of confluent event chains which merge at a common key event, or as a primary chain of sequential events into which causative factors feed as conditions that contribute to event occurrence, or as a combination of the two.

Construction of the ECF chart should begin as soon as the accident investigator begins to gather factual evidence pertinent to the accident sequence and subsequent amelioration. The events and causal factors will usually not be discovered in the sequential order in which they occurred, so the initial ECF chart will be only a skeleton of the final product and will need to be supplemented and upgraded as additional facts are gathered. Although the initial ECF chart will be very incomplete and contain many information deficiencies, it should be started very early in the accident investigation because of its innate value in helping to:

- organise the accident data;
- guide the investigation;
- validate and confirm the true accident sequence;
- identify and validate factual findings, probable causes, and contributing factors;
- simplify organisation of the investigation report;
- illustrate the accident sequence in the investigation report.

With all its virtues as an independent analytical technique, ECFA is most effective when used with the other MORT tools (such as Fault Tree Analysis, MORT Chart Analysis, Change Analysis) that provide supportive correlation. Furthermore, ECFA can perform as the framework into which the results from other forms of analysis are integrated. An appropriate combination of the major MORT analytic tools, including ECFA, provides the core for a good investigation.

3 Description of Technique

A simple example of an ECF Chart is provided in Appendix 1.

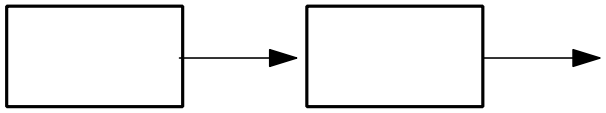
Sections 3.1 and 3.2 provide a set of conventions and criteria to be used in ECFA. These conventions are intended to improve comparability and consistency in accident reporting and to assist the communication of investigation findings. In section 3.3, more general guidelines are given for the administration of the ECFA method.

These conventions are intended to be as simple as possible whilst preserving the effectiveness of ECFA. It is further intended that investigators be provided with helpful guidelines without inhibiting their use of this tool by imposing an overly complex set of rules.

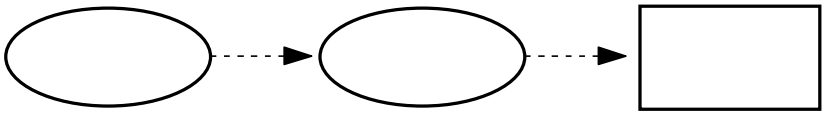
3.1 Conventions for Events and Causal Factors Charts

3.1.1 Events should be enclosed in rectangles, and conditions in ovals.

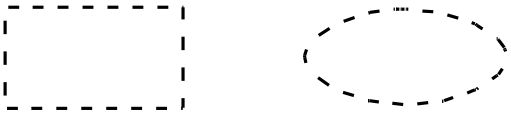
3.1.2 Events should be connected by solid arrows.



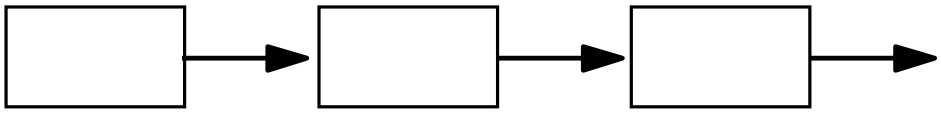
3.1.3 Conditions should be connected to each other and to events by dashed arrows.



3.1.4 Each event and condition should either be based upon valid factual evidence[1] or be clearly indicated as presumptive by dashed line rectangles and ovals.



3.1.5 The primary sequence of events should be depicted in a straight horizontal line (or lines in confluent or branching primary chains) with events joined by bold printed connecting arrows.



3.1.6 Secondary event sequences, contributing factors, and systemic factors should be depicted on horizontal lines at different levels above or below the primary sequence (see **Figure 1** and Appendix 1).

[1] It may be found helpful to draw up an evidence matrix to correlate the analysis with the evidence collected.

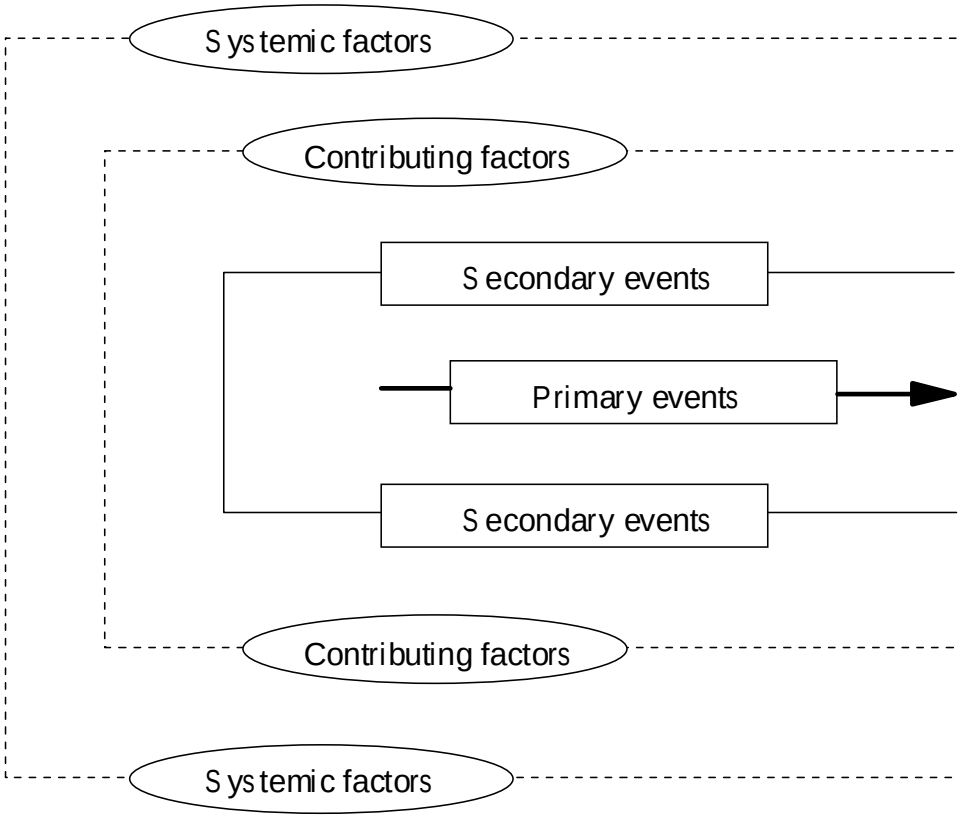
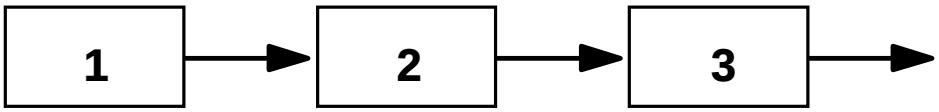


Figure 1. General Format for ECF Charts

3.1.7 Events should be arranged chronologically from left to right.



3.1.8 Events should track in logical progression from the beginning to the end of the initiation-pre-accident-accident-amelioration sequence and should include all pertinent occurrences. This necessitates that the beginning and the end be defined for each accident sequence. Analysts frequently use the accident as the key event and proceed from it in both directions to reconstruct the pre-accident and post-accident ECF sequences.

3.2 Suggested Criteria for Event Descriptions and Conditions

3.2.1 Each event should describe an occurrence or happening and not a condition, state, circumstance, issue, conclusion, or result; i.e., “pipe wall ruptured”, not “the pipe wall had a crack in it”.

3.2.2 Each event should be described by a short sentence with one subject and one active verb; i.e., “mechanic checked front end alignment”, not “mechanic checked front end alignment and adjusted camber on both front wheels”.

3.2.3 Each event should be precisely described; i.e., “operator pulled headlight switch to ‘on’ position”, not “operator turned lights on”.

3.2.4 Each event should describe a single, discrete occurrence; i.e., “pipe wall ruptured”, not “internal pressure rose and pipe wall ruptured”.

3.2.5 Each event should be quantified when possible; i.e., “plane descended 350 feet”, not “plane lost altitude”.

3.2.6 Each event should be derived directly from the event (or events in the case of a branched chain) and conditions preceding it; i.e., “mechanic adjusted camber on both front wheels” is preceded by “mechanic found incorrect camber” which is preceded by “mechanic checked front end alignment” - each event deriving logically from the one preceding it. When this is not the case, it usually indicates that one or more steps in the sequence have been left out.

3.2.7 Conditions differ from events insofar as they (a) describe states or circumstances rather than happenings or occurrences and (b) are passive rather than active. As far as practical, conditions should be precisely described, quantified when possible, posted with time and date when possible, and be derived directly from the conditions immediately preceding them.

3.3 Guidelines for Practical Application

The experience of many people participating in numerous accident investigations has led to the identification of seven key elements in the practical application of ECFA to achieve high quality accident investigations.

(1) Begin early. As soon as you start to accumulate factual information on events and conditions related to the accident, begin construction of a “working chart” of events and causal factors. It is often helpful also to rough out a fault tree of the occurrence to establish how the accident could have happened. This can prevent false starts and ‘wild goose chases” but must be done with caution so that you don’t lock yourself into a preconceived model of the accident occurrence.

(2) Use the guidelines suggested in sections 3.1 & 3.2 as these will assist you in getting started and staying on track as you reconstruct the sequences of events and conditions that influenced accident causation and amelioration. Remember to keep the proper perspective in applying these guidelines; they are intended to guide you in simple application of a valuable investigative tool. They are not hard and fast rules that must

be applied without question or reason. They have grown out of experience and fit well into most applications, but if you have a truly unique situation and feel that you must deviate from the guidelines for clarity and simplicity, do it. Analytical techniques should be servants not masters.

(3) Proceed logically with available data. Events and causal factors usually do not emerge during the investigation in the sequential order in which they occurred. Initially, there will be many holes and deficiencies in the chart. Efforts to fill these holes and get accurate tracking of the event sequences and their derivation from contributing conditions will lead to deeper probing by investigators that will uncover the true facts involved. In proceeding logically, using available information to direct the search for more, it is usually easiest to use the accident or loss event as the starting point and reconstruct the pre-accident and post-accident sequences from that vantage point.

(4) Use an easily updated format. As additional facts are discovered and analysis of those facts further identify causal factors, the working chart will need to be updated. Unless a format is selected which displays the emerging information in an easily modified form, construction of the chart can be very repetitious and time-consuming. Successive redrafts of the ECF chart on large sheets of paper have been done; magnetic display boards or chalkboards have been used; but the technique that has consistently proven most effective and most easily updated is use of "post-it" notes on which brief event or condition statements are written. A single event or condition is written on each note. The notes are then stuck to a wall or a large roll of heavy paper in the sequence of events as then understood. As more information is revealed, notes can be rearranged, added, or deleted to produce a more complete and accurate version of the working chart. Once the note-based working chart has been finalised, the ECF chart can be drawn for inclusion in the investigation report. Several investigators have testified of the value of this approach, commenting that it made their investigations more expeditious and thorough. They further stated that use of the post-it notes for the working chart not only was useful in establishing the accident sequence and identifying key events and conditions, but it also illuminated deficiencies in knowledge, pointed out areas for further inquiry, and finally made the report writing straightforward.

(5) Correlate use of ECFA with that of other MORT investigative tools. The optimum benefit from MORT-based investigations can be derived when such powerful tools as ECFA, MORT chart based analysis, change analysis, and energy trace and barrier analysis are used to provide supportive correlation.

(6) Select the appropriate level of detail and sequence length for the ECF chart. The accident, itself, and the depth of investigation specified by the investigation commissioning authority will often suggest the amount of detail desired. These, too, may dictate whether ending the ECF chart at the accident or loss-producing event is adequate, or whether the amelioration phase should be included. The way the amelioration was conducted will also influence whether this should be included and in

how much depth it should be discussed. Certainly, if second accidents occurred during rescue attempts or emergency action, or if there were other specific or systemic problems revealed, the ECFA should cover this phase. However, the investigators and the commissioning authority involved will have to decide, on a case-by-case basis, what is appropriate depth and sequence length for each accident investigated.

(7) Make a short executive summary chart when necessary. The ECF working chart will contain much detail so it can be of greatest value in shaping and directing the investigation. In general, significantly less detail is required in the ECF chart presented in the investigation report, because the primary purpose is to provide a concise and easy-to-follow orientation to the accident sequence for the report reader. When a detailed ECF chart is felt to be necessary to show appropriate relationships in the analysis section of an appendix of the report, an executive summary chart of only one or two pages should be prepared and included in the report to meet the above stated purpose.

4 Benefits of the Technique

Use of the ECF charting technique by the accident investigator provides benefits in: (1) meeting the general purposes of accident investigation and conducting the investigation, (2) writing the investigation report.

4.1 Contribution of ECFA to Investigation Purposes and Conduct

The primary purpose of accident investigation is to determine what happened and why it happened in order to prevent similar occurrences and to improve the safety and efficiency of future operations. When serious accidents occur, they are often symptomatic of systemic deficiencies which also impair performance and production. When the accident is used as a window through which to view the existing management system, these deficiencies are revealed and benefits are derived which go far beyond correction of the immediate causes of the accident. The emphasis, then, should be placed on discovering all cause-effect relationships from which practical corrective actions can be derived to improve total performance. The intent of the investigation, then, is not to place blame, but rather to determine how responsibilities can be clarified and how loss-producing errors can be reduced and controlled. Accurate ECF analysis can help satisfy these general purposes in the following ways:

- provides a cause-oriented explanation of the accident;
- provides a basis for beneficial changes to prevent future accidents and operational errors;
- helps delineate areas of responsibility;
- helps assure objectivity in the conduct of the investigation;
- organises quantitative data (e.,g., time, velocity, temperature, etc.) Related to loss-producing events and conditions;

- acts as an operational training tool;
- provides an effective aid to future systems design.

More specifically, ECFA:

- aids in developing evidence, in detecting all causal factors through sequence development, and in determining the need for in-depth analysis;
- clarifies reasoning;
- illustrates multiple causes. As previously stated, accidents rarely have a single "cause". Charting helps illustrate the multiple causal factors involved in the accident sequence, as well as the relationship of proximate, remote, direct, and contributory causes;
- visually portrays the interactions and relationships of all involved organisations and individuals;
- illustrates the chronology of events showing relative sequence in time;
- provides flexibility in interpretation and summarisation of collected data;
- conveniently communicates empirical and derived facts in a logical and orderly manner;
- links specific accident factors to organisational and management control factors.

4.2 Use of the ECF Chart in Preparing the Report

The purpose of the investigation report is to convey the results of the investigation in clear and concise language. The investigation report constitutes a record of the occurrence by which the investigation is measured for thoroughness, accuracy, and objectivity. The report should also fully explain the technical elements of the causal sequences of the occurrence and describe the management systems which should have prevented the occurrence. Use of ECFA has been effective in satisfying these report objectives. Specific advantages provided are as follows:

- provides a check for completion of investigative logic. Even the most elementary types of sequence charting can reveal gaps in logic and help prevent inaccurate conclusions;
- provides a method for identification of matters requiring further investigation or analysis. Significant event blocks with vague or non-existent causal factors can alert the investigator to the need for additional fact-finding and analysis;
- provides a logical display of facts from which valid conclusions can be drawn;
- provides appropriate and consistent subject titles for "discussion of facts" and "analysis" paragraphs;
- provides a method for determining if the general investigative purposes and

specific objectives have been adequately met in terms of the conclusions reached;

- provides a method for differentiation between the analysis of the facts and the resultant conclusions.

- presents a simple method for clearly describing accident sequences and causes to a reading audience with divergent backgrounds. Without the use of sophisticated or exotic methodology, the accident causes can be easily communicated to readers with a wide variety of experience and technical expertise;

- provides a source for the identification of organisational needs and the formulation of recommendations to meet those needs. The charting technique provides the basis for a systematic trace of the logic from a statement of the facts through the analysis, conclusions, judgements of needs, and recommendations;

- provides a method for evaluating the factual basis of possible recommendations;

- finally, the technique has shown to be useful in solving various unanticipatad problems associated with preparing the final report for specific accident investigations. The clear and logical development of the accident events and causal factors facilitates agreement among report reviewers on accident causation and minimises negative reaction from those person and organisations whose performance deficiencies contributed to accident occurrence. They may not like what the report says, but they will agree that it is fair and accurate.

Finally, the use of ECFA has proven to be a valuable tool for accident investigators and a clear and concise aid to understanding of accident causation for the report readers. Use it for greater effectiveness in accident investigating and reporting.

5 Bibliography

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Appendix: Events & Causal Factors Chart Example

Application of the suggested format and event description criteria for constructing a typical ECF chart of a simple accident are illustrated in the following example.

Accident Description

The Ajax Construction Company was awarded a contract to build a block of flats on a hill over-looking the city centre. Prior to initiation of the project, a comprehensive safety programme was developed covering all aspects of the project. Construction activities began on Monday, 7 October 1991, and proceeded without incident through to Friday, 11 October, at which time the site was shut down for the weekend. At that time several company vehicles, including a 2.5 tonne dump truck, were parked on the construction site. On Saturday, 12 October, a nine year-old boy, who lives some 400 yards from the site, climbed the hill and began exploring the site. Upon finding the dump truck unlocked, he climbed into the cab and began playing with the vehicle controls. He apparently released the handbrake and the truck began to roll down the hill. The truck rapidly picked up speed. The boy was afraid to jump out and didn't know how to apply the brakes. The truck crashed into a parked car at the bottom of the hill: it remained upright, but the boy suffered serious cuts and a broken leg. The resultant accident investigation revealed that, although the safety programme specified that unattended vehicles would be locked and the wheels chocked, there was no verification that these rules had been communicated to the drivers.

Discussion

Figure 2 is the ECF chart of this accident. Note that the events are in chronological order, that each follows logically from the one preceding and that the dates are indicated where known. Events are enclosed in rectangles and the conditions in ovals. Event statements are characterised by single subjects and active verbs. Primary events are connected by bold solid lines, other events by solid lines, and conditions by dashed lines. Presumptive information (i.e., the inference is clear but the evidence is lacking) is shown in ovals and rectangles drawn in dashed lines. Please note that, in general, the primary event line should be extended forward in time to include amelioration (in this instance, the first aid rendered to the injured boy and subsequent attendance by the emergency services) because inadequate amelioration can make matters considerably worse (and is therefore a contributor to the overall losses incurred through an accident).

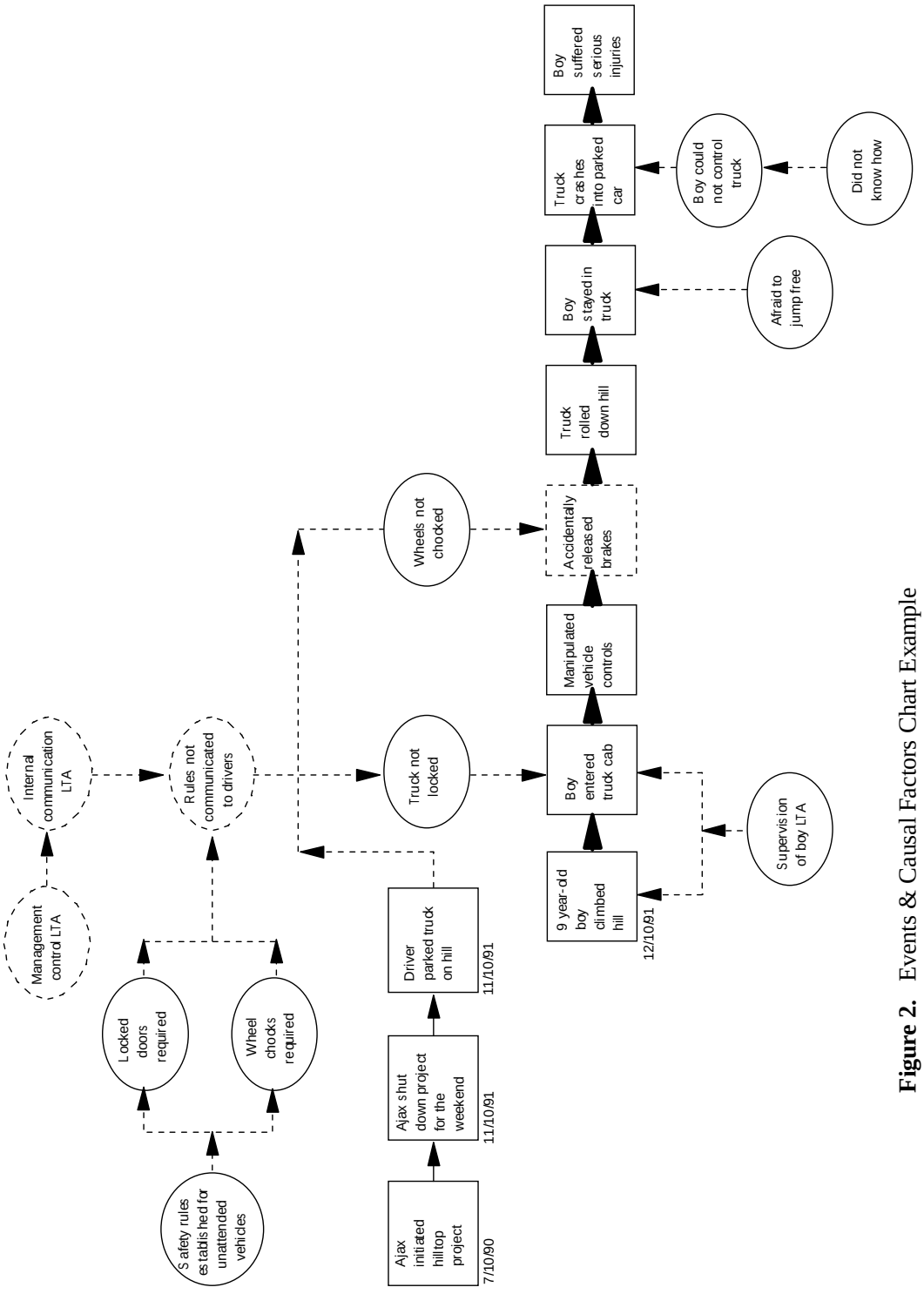

Figure 2. Events & Causal Factors Chart Example