

NRI-4 (2014)

ECFA+

Events and Conditional Factors Analysis Manual

Second Edition

Produced by



**The Noordwijk
Risk Initiative
Foundation**

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ECFA+

**Events and Conditional
Factors Analysis Manual**

Second Edition

June 2014

This edition prepared by

J. Kingston (UK)
F. Koornneef (NL)

on behalf of the Noordwijk Risk Initiative Foundation,
P.O. Box 286, 2600 AG Delft, The Netherlands.

www.nri.eu.com

In memory of Dr Robert J. Nertney,
our friend and colleague.

6 September 1923 – 13 July 2004

Preface

The NRI Foundation conserves the knowledge created by the MORT programme. Between 1968 and 2002, the programme accumulated a wealth of material to support the U.S. nuclear industry's management of safety, health and environmental protection. Some materials are in the public domain, but paper-based for the most part. The NRI Foundation exists to publish an archive of the written material, and to supplement it where it will help to keep the knowledge relevant.

Purpose of this document

The Noordwijk Risk Initiative Foundation has written this manual and will maintain it in the public domain. The manual is intended to:

- help investigators produce accounts of incidents that are robust with regard to evidence and completeness;
- encourage stakeholders to share information about incidents;
- provide a reference point for practitioners (of investigation), tool developers, researchers and students.

This manual describes a method that is based on "Events and Causal Factors Analysis", ECFA (Buys and Clark, 1995). It includes rules found by experience as well as those derived from published sources (see the bibliography). In order to distinguish this method from its predecessor, it is called ECFA+, Events and Conditional Factors Analysis.

Structure of this document

ECFA+ is explained in three complementary ways. First, the ideas and conventions are introduced (pages 9-18). Second, with the novice user in mind, ECFA+ is described as a set of procedural steps (pages 20-25). Third, to support the more experienced ECFA+ user, summary instructions for ECFA+ are provided in a single-page aide memoire (Appendix 1, page 27).

Status of this document

This is the second edition of the ECFA+ manual. It contains the insights gained by the authors during the last seven years of applying, reviewing and teaching ECFA+. NRI published the first edition of the ECFA+ manual (2007) as a new method based on the procedure described in the 1995 ECFA manual (Buys and Clark).

Acknowledgements

Particular thanks go to the academics and practitioners who reviewed and suggested improvements to this 2014 edition of the ECFA+ manual. We gratefully acknowledge: Dr MJ Cooper, formerly of the European Institute of Health & Medical Studies, University of Surrey, UK; Mark Dixon; Dr Celeste Jacinto of the Universidade Nova de Lisboa; Dr Paul Lindhout; Phil Parry (former Principal Inspector, Health and Safety Executive), and Chris Peace, Risk Management Ltd, Wellington, New Zealand.

The present authors also thank those who helped put together the 2007 version of this manual: Jan Jager; Prof. Germund Hesslow (Emeritus, Lund University), Cedric Gilson; Jane Paul; Mauro Iacobacci; Cara Dawson; Prof. Peter Waterhouse; Ludwig Benner, and; the late Robert J. Nertney.

We remain most grateful to the 3M United Kingdom plc for their permission to use the term "Post-it Note" (a registered trademark of the 3M Company).

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1 Introduction

ECFA+ is a way to produce an account of an incident¹ from the available evidence. This account focuses on the events that comprise the incident. These events are put into the order in which they occurred and then linked using the causal relationships between them. The links are tested to ensure that each event is accounted for. When needed, conditions—passive circumstances that affect the course of events—are included to make sure that the account is complete.

An ECFA+ analysis is built-up iteratively. An early analysis is done to help the investigator identify lines of enquiry. These enquiries might be to fill gaps in detail, or to better prove the facts. Thereafter, new information is added to the evolving ECF chart² and this often raises new topics for further enquiries. Usually, each iteration of the analysis will take between one and two hours, depending on skill and the quality of data.

To allow the whole analysis to be read at a glance, ECFA+ is done using paper and pencil. This needs enough space in which to do the work: a blind wall, four metres wide is adequate for most analyses. If confidentiality is an issue, you will need a secure space. At the end of the analysis, it is normal to record the ECF chart. This can be done by hand, or by taking photographs. If report quality materials are needed, the ECFA+ chart can be drawn-up using a flow-charting package or other vector graphics software application such as Microsoft Visio. You will find Visio templates for this purpose on the NRI Foundation website.

1.1 Team Approach

In most cases, working in a pair is better than working on your own. Working with someone else encourages progress and can help in other ways too. If the people working on the ECFA+ have complementary knowledge, they can help each other to spot relevant facts and opportunities for further enquiries.

In a larger investigation—involving three or more people, say—you might consider using a facilitator. A facilitator can keep the analysis moving in a disciplined way, freeing the other team members to concentrate on the content.

It is ideal to have the analysis reviewed by someone else. Although the ECFA+ rule set will help you to be objective, a fresh pair of eyes provides useful challenge and review.

1.2 Benefits of ECFA+ to investigation

You can use ECFA+ analysis to:

- produce a simple, evidence-based description of an incident;
- identify gaps in evidence and to suggest further lines of enquiry;
- close off some lines of enquiry which are not relevant to the incident (especially where a large number of potential witnesses or events/conditions are being considered).

ECFA+ can be applied to any incident, but you will have to judge on the merits of each case whether it is worthwhile. In larger investigations there is generally more appetite to invest time in fact finding and analysis. On the other hand, even in simple occupational accidents, a detailed look at the timeline can produce insights for prevention that would not be visible from a superficial glance. Like all tools, ECFA+ should be your servant not your master, so only use it when you believe that it is worthwhile. The main benefits of using ECFA+ are:

- to support subsequent root cause analysis. Methods like 3CA (Kingston, 2008) rely on clear, robust descriptions of incidents;
- to make it easier to write a clear, evidence-based description in the investigation report;
- to keep an overview of what is known about the incident and the key areas of uncertainty;
- to assist briefing new investigators joining the investigating team, or for briefing those with responsibility for the progress of the investigation.

¹ Throughout this text the authors will use 'incident' to include all unwanted events.

² The phrase 'ECF chart' (Events and Conditional Factors Chart) refers to any specific instance of applying ECFA+ rules to analyse an incident.

Note that ECFA+ is just one tool in the ‘investigator’s toolkit’. ECFA+ can help to establish a clear sequence of events, but other tools will be needed to analyse the barriers, controls and root causes of those events. This is discussed fully in [Frei et al. \(2003\)](#).

2 The parts used in an ECFA+

ECFA+ is a set of rules about how to make a time sequenced model of an incident. Like any model, it is a simplification of the real thing. An ECF model is made from three types of parts: Events, Conditions and Arrows. You will also see Queries and dashed lines: two ways of showing gaps and uncertainties in an ECF model. All of these features are explained in detail in the subsections that follow.

The analysis includes some attributes, but not others. ECFA+ represents an incident as a set of actions that move a situation from a controlled state to an uncontrolled state, and then back again. In the real situation, many other things may be happening, but ECFA+ includes only those actions that are relevant to control.

The analysis tries to keep things as simple as possible. In the real world, events flow smoothly, but in an ECF analysis they are treated as moments of change. Like a silent movie of the 1920’s, the action in an ECFA+ is jerky. However, there should be enough continuity to allow the viewer to make sense of what is going on.

2.1 Events

The main task in ECFA+ is to identify changes of activity and to transcribe them as simple phrases, referred to as “events”. In ECFA+, events have three attributes:

- the “actor” effecting the change; *(e.g. Mr. Bloggs)*
- the “action” of the actor on the object; and, *(e.g. moves)*
- what is being changed – the object; *(e.g. a valve handle)*

Vague language, especially *passive voice* phrases such as “the pump failed”, can hide the causal ‘mechanisms’ at work in an incident. Making actor, action and object visible helps the investigator to create a concrete description of the incident. Using the active voice³ helps investigators to spot gaps in the evidence—such as unknown actors or ambiguous actions.

The general rule in ECFA+ is that an event should have only one actor and one action. Sometimes the actor is composed of several parts (e.g. a team) but it must work as a unit to produce the action.

When doing ECF analysis using paper and pencil, it is usual to write events onto yellow post-it notes. This allows them to be moved around as the analysis develops, and to see at a glance which items are events. Blank post-it notes are fine, but some investigators use a pre-printed version (an example shown, right). Pre-printed post-it notes remind users about the information needed when stating an event. This, and the desire for a standard approach across several teams, is why the artwork was drawn-up for the investigation of the disaster at Enschede (see page 35). Figure 2 (page 14) describes the artwork and its use.

Evidence	Time	
EVENT		
<i>Use present tense, one actor, action and object</i>		
Comments		
ECFA Ref.	Analyst Initials	NRI Foundation www.nri.eu.com
Format Status	Logic Status	

³ Active and passive voice are explained in Appendix 8 on page 3636

2.2 Conditions

When accounting for the sequence of events—for why events unfolded as they did—events alone are not enough. Investigators need to identify *conditions* which, had they been different, would have altered the course of events. A match struck in an explosive atmosphere gives a very different result to one struck in normal conditions. In ECFA+, the main distinction between events and conditions is that events are active, whereas conditions are passive; conditions persist until acted upon.

ECFA+ analysis begins by identifying events. Conditions are included into the analysis *only* when they are needed to explain those events. This is one way of keeping the analysis as simple⁴ as possible. It also helps to avoid force-fitting conditions that are not strictly relevant.

Although more difficult to prove than objective facts, investigators may want to include decisions, thoughts and feelings in the analysis. ECFA+ uses conditions to describe subjective states like those. This is because it is difficult or impossible to state subjective states in a way that can satisfy the criteria for events. Specifically, subjective states cannot be visualised, nor can they be described mechanistically.

When doing ECF analysis using paper and pencil, it is usual to write conditions onto pink post-it notes. This allows them to be moved around as the analysis develops, and to see at a glance which items are conditions and which are events. As explained earlier, blank post-it notes are fine, but some investigators use a pre-printed version (an example shown, right). Figure 3 (page 15) describes the artwork and its use.

Evidence		Time	
CONDITION			
Comments			
ECFA Ref.	Analyst Initials	NRI Foundation www.nri.eu.com	
Format Status		Logic Status	

Sometimes, investigators want to include *omissions* in an analysis. An example of the general form is “Actor does NOT do action”. In ECFA+, these omissions are called *non-events*, and are discussed in the next section.

2.3 Non-Events

A *non-event* is a special type of condition. You can use it to describe something expected to occur given the circumstances, but which did not happen in the incident. For example, if omitting an action leads to an accident, you might view that non-event as an essential part of the story⁵.

Non-events are passive, and that is why they are treated as conditions. However, unlike other conditions, non-events are negative; they define a condition by what is not happening. ECF analysis includes only the conditions that are needed to account for the sequence of events. This test of relevance applies to non-events, as it does to any other condition. The breaking of a workplace rule might be relevant to your investigation, but it might not be relevant in the ECF analysis.

When describing a condition as a non-event, you need to state your basis for judging it to be relevant to the incident. You do this by stating the standard against which you are comparing the conditions and events in the incident. This means the procedure, good-practice or expert opinion that justifies the behaviour implied by the non-event. If, for example, work was being

⁴ In ECF analysis, the aim is to arrive at the simplest explanation that fits the facts of the incident. This is an application of Occam’s razor: the principle that entities must not be multiplied beyond what is necessary.

⁵ Appendix 5 contains a discussion of this issue; item (e) is of particular relevance.

done without a permit, the non-event must specify the standard that required a permit. This allows other people to verify the analysis.

Although ECFA+ allows non-events, you should consider whether the facts would be better expressed in another way. Bear in mind that you should only include items that are necessary, and without which the sequence of events would have been different. The risk of including non-events is that they tend to exaggerate the responsibility of individuals and may obscure other facts about the context.

In summary, a non-event is a negative condition. Before putting a non-event into your analysis, make sure that it:

- applies in the specific case: you need it to account for an event;
- applies in the general case: the standard used to justify the non-event is valid in the context of the incident;
- can be stated accurately only as a non-event. If you can say the same thing in positive terms, it is simpler to use a regular condition.

2.4 Arrows in ECFA+

In ECFA+, an arrow drawn between two items means that the earlier item—an event or condition—directly causes the later item. To keep their meaning clear, arrows must only be used to mean direct cause.

2.5 Dashed lines

All events, conditions and direct causal relationships (shown by arrows) must be supported by some evidence. However, ECFA+ uses dashed lines to mark where the facts cannot be proved conclusively. Dashes are used as follows:

- a dashed arrow means that there is some evidence for a direct causal relationship, but not conclusive⁶ proof;
- an event (or condition) enclosed by dashes means there is adequate evidence to justify its presence in the analysis, but not enough to treat it as a proven fact.

When enclosed by dashes, events and conditions are called *presumptive*. Usually, investigators accept events and conditions as presumptive only when it is clear that further enquiries would not be able to prove the facts⁷. Before then, while the investigation is still live, it is normal to use the format status box on the post-it notes to show gaps in the evidence. Section 3.3 describes how to use the format status box.

3 How to construct an ECFA+

This section introduces the rules for describing an incident using ECFA+. Before you read the rules in detail, please reflect for a moment on these three points. ECFA+ analysis is:

- iterative, and is usually built-up in two or more sittings;
- best started early in the investigation and added-to as facts come to hand;
- an evidence-based description of the incident, which although useful is a simplification of a more complex reality.

⁶ *Conclusive, that is, at whichever standard of proof the investigator needs to satisfy. This might be 'more likely than not' in civil matters, or beyond reasonable doubt in the context of criminal proceedings. You can find a more detailed discussion of evidence in Appendix 6 on page 34).*

⁷ *Although not part of the ECFA+ rule-set, lines-of-enquiry need to be managed actively. This includes making and recording decisions to curtail further enquiries..*

3.1 ECFA+ start and end points

The decision about where to start and end depends on the purposes of the investigation. It is up to you what you model. Be aware, however, that other stakeholders to an incident will have their own point of view and may see things differently. As a result, their ECF analysis may differ from yours.

It is usual for the ECF chart to include the event that compromises control and the event that makes the situation safe again. For example, the events shown in Figure 1 have created conditions that are not under control. By default, the investigators would continue the time-line forward and include in the analysis the events and conditions that show how control was restored and the situation made safe. In the case of Figure 1, how the car fire was extinguished, and the casualties (including the injured Officer-in-Charge, OiC) were stabilised.

Beginning and ending points are not always clear-cut, because control is generally a matter of degree rather than absolute. The point is to reflect on whether the analysis has made it adequately clear how control was lost and regained.

Conditions are sometimes created by earlier events. When these earlier events (and their associated conditions) fall outside of the time frame of the incident, they are called *secondary event lines*. Where it fits within the scope of your investigation, you may need to include secondary events in your analysis. However, bear in mind the practicalities and consider whether a secondary event line should be made the subject—the *primary event line*—of a separate ECF analysis.

The answer to “how far back in time an investigator may need to reach” depends on whether we are discussing the primary or secondary events. Primary events are generally close in time to the unplanned outcomes which are the focus of the investigation; in the order of minutes, hours, or days. Secondary events are included to explain the coming into existence of conditions; and these may reach back days, weeks, or years.

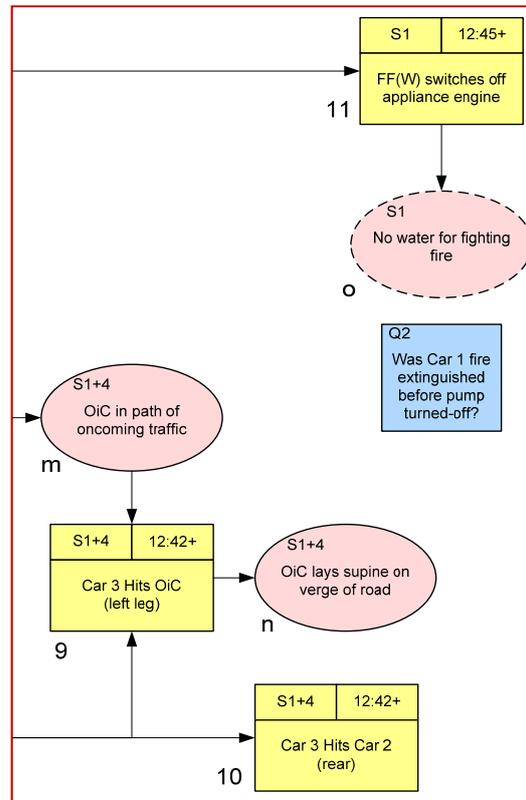


Figure 1. Excerpt from an ECF chart (more at Appendix 2)

3.2 Iterative approach

Usually, investigators begin the ECF analysis early and build it up in two or more sittings. ECFA+, like many forms of analysis, help to structure what is known and unknown. Spotting the unknowns early in the investigation helps to steer further enquiries while the evidence is most easily collected.

There is no limit to how many events and conditions you include in a completed ECFA+. The rule is that all of them should be necessary. However, to make progress at the start of the analysis, you should include no more than 12 events. The first logic check (see section 3.4) of this small set of events will reveal the need to include conditions and more events.

There are exceptions to this rule. Firstly, in large investigations, rather than building the analysis in deliberate iterations, ECFA+ might be a continuous effort done in parallel with other investigative activities. Secondly, when reviewing a completed investigation, or when taking-over a nearly complete investigation, the analysis might be done in one sitting. In all of

these situations, ECFA+ is being used to structure and confirm the facts about how the incident happened.

3.3 Format checking

Analysis involves manipulating data according to a set of rules. Without the rules, the analysis becomes unsystematic and unreliable. This means that the analyst has to keep in mind both the facts of the incident and the ECFA+ process rules. ECFA+ works well when it is done rapidly with the focus on the content. To ensure that rapid progress results in a rigorous analysis, two types of check are done at intervals: format checking and logic checking.

Format checking has two aspects:

1. Check for gaps in evidence;
2. Check for conformity with ECFA+ rules for the format of events and conditions.

In each iteration you will add some events and conditions to the analysis. In the first iteration, you will go from a blank sheet to a set of up to 12 events with, perhaps, one or two conditions. At this point you should check the format of every event and condition in the ECF chart. In later iterations, the format check is performed on each item as it is added into the ECF chart.

Figure 2 summarises what you need to look for when checking the format of an event, and how to record it. Sometimes, you might find that a condition is stated on an event post-it, or vice versa. If so, decide which is appropriate and re-write if necessary.

The format check can have two outcomes. The first—shown by a tick in the “Format Status” box—is satisfactory. The tick means that there is sufficient evidence to treat the event as a fact, and all the needed details are included in the format specified in section 2. The second outcome—shown by a Q_n —is that you decide that more evidence is needed to corroborate or to fill in missing details. The ‘ n ’ is the reference number of the relevant item on the further enquiries list (see Appendix 4).

The diagram shows a yellow event format card with several sections and callouts:

- Evidence**: A callout explains it as a reference to specific items of evidence for investigators to use a ready reference system.
- Time**: A callout explains it as the time when the event happened, with instructions on what to do if the time is unknown or not critical.
- EVENT**: A large central section with a callout asking if the event can be visualised and listing the required components: ACTOR, ACTION, and OBJECT. It also notes that there should be only one actor and that the verb should be precise and concrete.
- Comments**: A callout explains that this section can be blank and that the investigator can use it to point out features of interest.
- ECFA Ref.**: A callout explains that this section can be blank and that events are numbered at the end of the first iteration for ease of reference.
- Analyst Initials**: A callout explains that initials show who added the item, which can be blank if working alone.
- NRI Foundation www.nri.eu.com**: A callout points to the logo of the NRI Foundation.
- Format Status**: A callout explains that a checkmark (✓) means the event conforms to ECFA+ format rules, while a Q_n means more information is needed.
- Logic Status**: A callout points to the logic status box.

Figure 2. What to look for when checking the format of an event

A reference to specific items of evidence. It is usual for investigators to use a ready reference system.

The time when the condition started. If you don't know the time, but it is essential to the facts, put “?” and add an item to the further enquiry list. The result of the format check would be “Q_n”. Otherwise, if not critical, an approximate time is adequate.

This can be blank, unless the condition is a non-event (see 2.3). If so, refer to the relevant procedure, code or standard.

If it is a condition in the normal ECFA+ sense, you can use the comments box to point out some feature of interest.

The condition should be stated precisely. Where appropriate, include numerical information (e.g. grid references, speeds, amounts, weights etc.)

Although less critical than for events, it is usual to state conditions in the present tense.

Use “?” if you want to raise a further enquiry about a con-

This can be blank; Conditions are numbered at the end of the first iteration (for ease of reference).

Initials show who added the item. If you work alone, this can be blank.

You record the result of the check here. A “✓” means that this condition is proven and that it conforms to ECFA+ format rules. A “Q_n” means that more information is needed, and a further enquiry has been added as item ‘n’ to the list of the Further Enquiries (see Appendix 4)

Evidence		Time	
CONDITION			
Comments			
ECFA Ref	Analyst Initials	NRI Foundation www.nri.eu.com	
Format Status	Logic Status	(ij)	

Figure 3. What to look for when checking the format of a condition

Normally, fresh evidence allows you to revise ‘format status’ from ‘Q’ (needs more evidence) to ‘✓’ (satisfactory). However, two situations can make it happen the other way around. Firstly, new evidence can force you to review items that you had thought satisfactory. Secondly, a reviewer may disagree with your interpretation.

Format checking is a critical routine in ECFA+. Events and conditions stated poorly or with inadequate evidence can complicate or undermine the analysis. Furthermore, early checking will give you the best chance of filling any gaps you find. Knowing which rules can be broken, and under what circumstances, is part of being an expert. However, even if you are a supremely confident ECF analyst, always do the format checking!

3.4 Logic checking

The logic check finds the events and conditions that directly cause an item. The aim is to make connections between the item being checked and those that happened earlier in the timeline.

Checking the logic moves forward the analysis in three ways. It:

- finds gaps in the account of the incident;
- adds needed events and conditions;
- adds structure to the ECF chart of the incident.

Starting with the last item—the post-it note to the far right—you will need to check the logic of every event and condition in the analysis. Each item is checked using a six-step routine:

- 1) Select an item to account for.
- 2) Find the earlier events and conditions that directly cause the item.
- 3) If these earlier events and conditions occur, would the item in question always result?
- 4) If the item would not always result, add post-its with the missing facts to the ECF chart:
 - a) add events or conditions, if the evidence allows;
 - b) check the format of any new events or conditions that you add;
 - c) If wanted, reposition all the related items;
 - d) draw arrows (solid or dashed) from the earlier events and conditions to the item;
 - e) add a Query note, if more evidence is needed;
 - f) add to your ‘further enquiries list’ the question asked in the Query note;
 - g) place any Query notes near the item, without drawing arrows (but a dashed line can be used to connect the query with the item it relates to).
- 5) If the item would always result:
 - a) draw solid arrows from the earlier events and conditions to the item;
 - b) If wanted, reposition all the related items.
- 6) Record the outcome of the check (a tick or ‘Qn’) in the logic status box.

3.5 Dashed or Solid Arrows

When drawing an arrow, you need to decide whether to use a dashed line or a solid one. The reasons were given in section 2.5 (page 12). As well as reflecting on the strength of evidence, you will also need to make a note of any further enquiries that might be needed. The decisions, bulleted below, amplify step 4(d) of the six-step logic check routine.

- If the evidence proves the logical relationship, the lines should be solid.
- If the evidence is not strong enough,
 - use a dashed line to show a presumed relationship, and;
 - write a ‘?’ next to the arrow to show that there is a line of further enquiry aimed at strengthening the evidence for a dashed arrow;
 - there should already be a query note asking a question about the subject; if not, add one and make a corresponding entry on the further enquiries list.
- If sufficient evidence is forthcoming, the dashed line can be redrawn as solid.

3.6 Query Notes

Blue ‘Query notes’ are place markers that show the gaps in the ECFA+ account of an incident. Arguably, a ‘Qn’ in the logic status box would be enough to record a gap, but the query note makes it easier to review this aspect of an ECF analysis.

Every time you add a query note, you should make a corresponding entry in the further enquiries list. The further enquiries list belongs to the investigation as a whole, and it needs to be a complete register of all the uncertainties in it.

Usually, query notes are used only to show the more important gaps in the analysis. This is why most query notes are added during logic checking. If every small question of detail was written on a query note, the ECF chart would be overcomplicated by blue post-it notes.

QUERY		
<i>What? Why? When? Where? How? Who?</i>		
Query posted on (date)	NRI Foundation www.nri.eu.com	
Ref. number on list of further enquiries	Analyst Initials	

3.7 Arranging events and conditions

In the early stages of the analysis, you might have grouped actors into horizontal rows. This approach helps to organise the early part of the analysis and makes it easier to spot gaps in the action. However, once each actor's actions are accounted for in the first iteration of the analysis, separate actor rows become less valuable.

Usually, the logic check is the time to move items; but it is optional. If you are content with actor rows, the arrows between logically related events and conditions might have to dodge around intervening items. The arrow between events (2) and (6) in Figure 4 is an example.

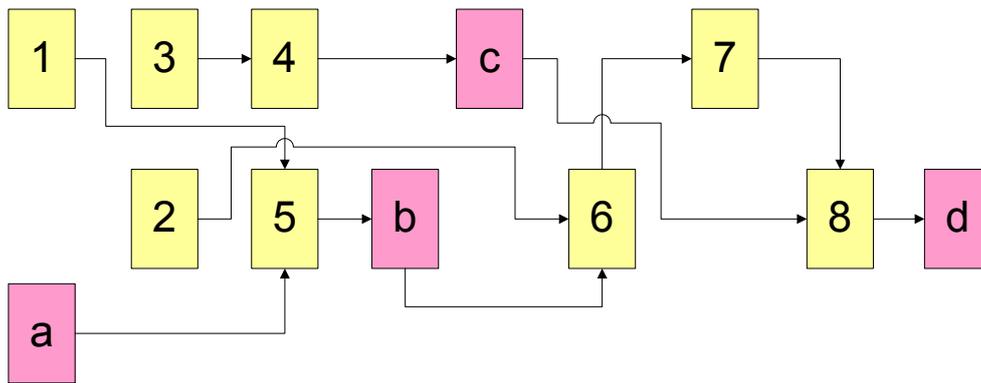


Figure 4. Schematic of an ECFA+ in which items are aligned by actor

So long as the arrows only link items that have direct causal relations, and the time order is preserved, the analyst can suit themselves. However, some analysts find it more intuitive to align causally connected items into horizontal rows, while keeping the time order of the items. This is illustrated in Figure 5.

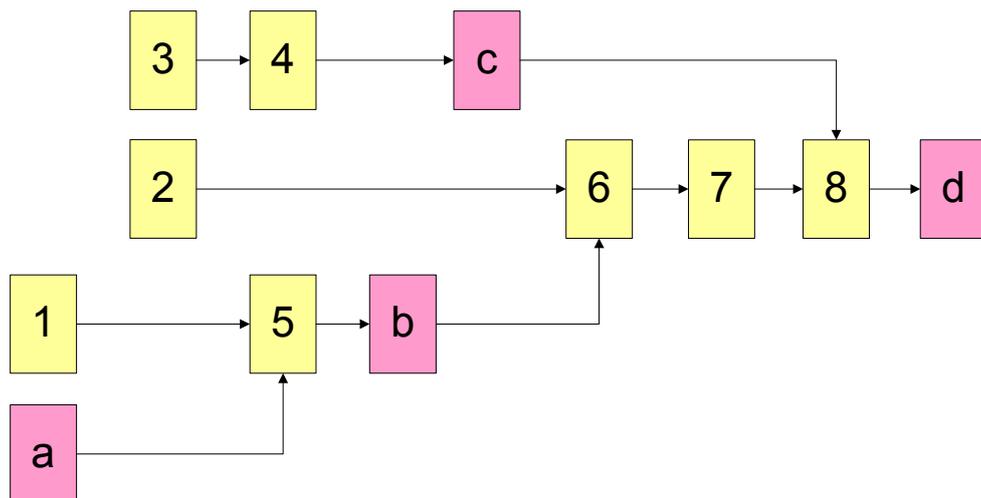


Figure 5. Schematic of an ECFA+ in which items are aligned by causal relationship

4 Finalising the analysis

At the end of the first iteration of the analysis, every format and logic status box should contain either a tick, or a 'Qn' cross-reference to the list of further enquiries. There should be no blank boxes. After the first iteration, keep the analysis updated and available for review until the investigation is closed.

Even in its final form, an ECF chart will still have some dashed lines, query notes and 'Qn' references in the check boxes. An analysis is finished not when all uncertainties have been removed, but when the investigator has no further use for it. Some gaps will remain no matter how much effort is invested in fact finding.

4.1 Independent Review

You should not accept an analysis as final until it has been reviewed. Even when sticking close to the rules set out in this manual, there is still room for differences of interpretation and for error.

You will need to consider how formal a review needs to be. Given the role of ECFA+ in finding new lines of enquiry, rapid reviews done at intervals can add a lot of value.

Another factor is the independence needed by the reviewer. At the minimum, the reviewer needs to bring a fresh pair of eyes, and this means someone who has not been involved in the analysis. You might judge it best to involve someone who has not been involved in the investigation. In either case, to engage critically, the individual will need enough technical knowledge of the content to understand the items and relationships in the analysis. As well as content knowledge, the reviewer will need to be able to verify the format and logic of all items in the analysis. To ensure thoroughness, the reviewer should know how to do these checks before they start the review.

4.2 Recording ECF Charts

You might want to make a record of a paper and pencil ECF chart for a number of reasons:

- to remove the chart and to put it up again later or somewhere else;
- to make a formal record of the ECF chart at the end of the investigation;
- to prepare the ECF chart to be drawn-up for a report or as a prop for briefings.

If you have little time, a series of photographs can capture the ECF chart. To make sense of the analysis, you will need to be able to both read the detail and see enough of the chart at a glance. This might require hard copies of the photographs.

Another option is to make a sketch of the analysis. This is surprisingly quick to do for even a 40-item ECF analyses. The first step is to make sure that every item in the analysis has a unique reference:

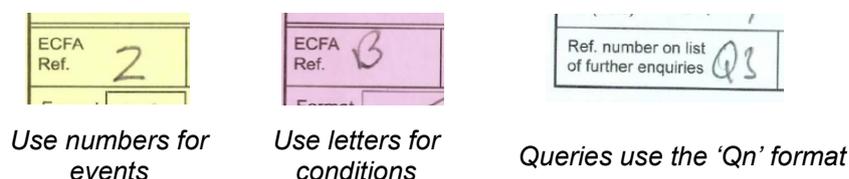


Figure 6. Reference system for ECFA+ items

Next, write the references in the pattern they appear in the ECF chart. Then draw the arrows between the references, being careful to reproduce dashed and solid lines. Similarly, dashes enclosing events or conditions should be added to the sketch. The original post-it notes should be kept with the sketch.

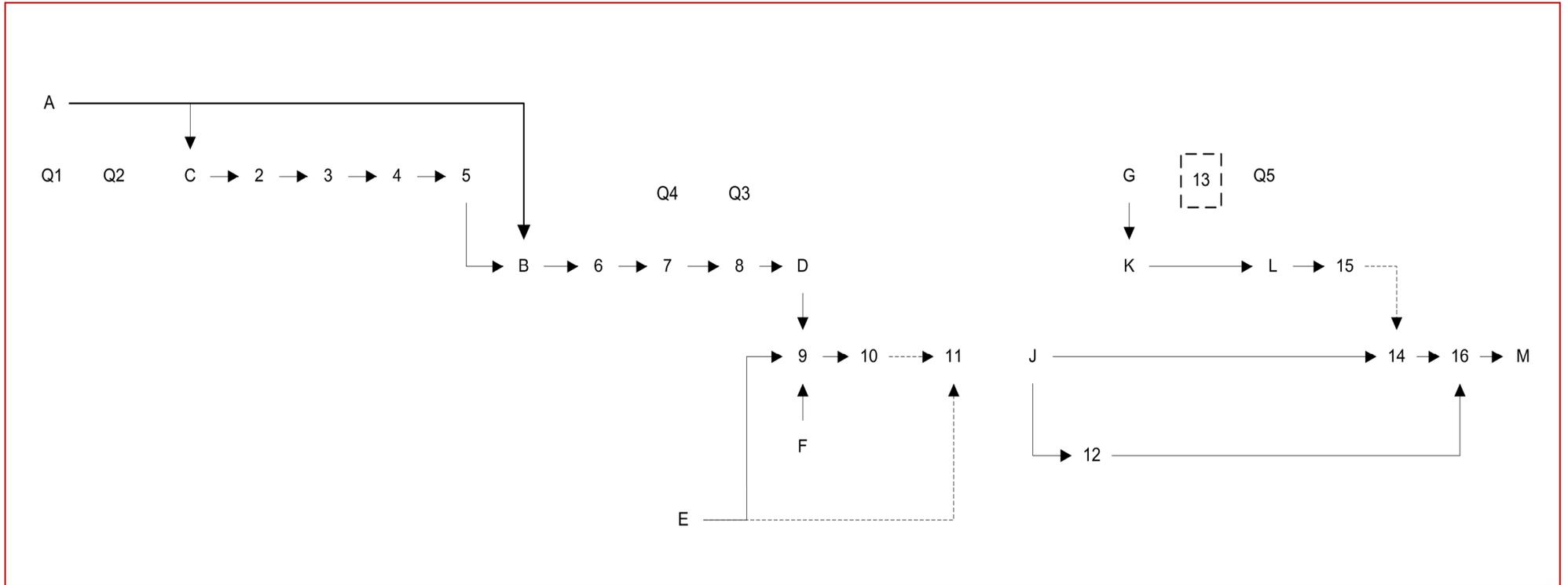


Figure 7. Example sketch of an ECF chart
(allows the final state of the analysis to be recreated using the original post-it notes)

If report quality materials are needed, the ECFA+ chart can be drawn-up using a flow-charting package or other vector graphics software application. You will find Visio templates for this purpose on the NRI Foundation website.

5 Procedure for ECFA+

This procedure is written with the new user in mind: detailed steps are provided together with guidance. Once familiar with this procedure, the one-page aide-memoire (Appendix 1) should be enough to remind users of the key steps.

Task Steps	Description & Criteria	Guidance
1. Study all available information about the incident		<p>Start the analysis early. Applying ECFA+ helps to find gaps in information. It is easy to update the ECF chart in the light of new evidence.</p> <p>Work in pencil (easier to amend).</p>
2. Write out information about actions onto 'Event' Post-it Notes (yellow).	(a) At the start of the analysis, write out no more than 12 events.	<p>To make progress at the very beginning of an ECF analysis, include no more than 12 events. There is no limit to how many events and conditions you can include when you reach step 5, although all must be necessary.</p> <p>You can ignore this rule if using ECFA+ to review a completed investigation, or when taking-over a nearly complete investigation.</p>
	(b) Describe each event as a single moment of change.	<p>If you wish to transcribe an action that continues for some time, consider breaking it down into its constituent actions (separate Post-it Notes for each) or transcribe as a condition.</p>
	(c) Describe the event using just one actor and one action.	<p>An actor can be a person or a thing. If the actor has more than one part or member (e.g. "crew leave site") these parts must be acting as a single unit. If not, consider transcribing events for each distinct actor.</p>

Task Steps	Description & Criteria	Guidance
<p>2. (Continued) <i>Transcribe information about actions onto 'Event' Post-it Notes (yellow).</i></p>	<p>(d) Phrase the event using the present tense and active voice (actor does action)</p>	<p>Use the active voice: make the actor the subject of the sentence stating the event (e.g. <u>Bloggs</u> undoes the clip).</p> <p>Use verbs that describe easily visualised, concrete actions.</p> <p>The thing or person acted on (the object) must be obvious in the event.</p> <p>If you find yourself needing to use the progressive form of a verb (e.g. with an '-ing' ending) either identify the constituent events or consider transcribing the activity as a condition.</p>
	<p>(e) Avoid non-events. An example of a non-event is "Bloggs did not close exit valve";</p>	<p>Non-events are things that did not happen but which, according to some ideal way of carrying-out a task, ought to have.</p> <p>Transcribe non-events as conditions, using (pink) Post-it Notes. State the <u>standard</u> you are relying on to make the judgment (e.g. a specific written procedure, code, or standard). If you do not know the specific standard that applies, make an entry on your list of further enquiries to find out.</p>
	<p>(f) State the evidence for the event occurring (if you lack proof, put a "?" in the evidence box and make a note on your list of further enquiries;</p>	<p>It is <u>essential</u> that all events and conditions either cite evidence or are connected explicitly to a further enquiry.</p> <p>Cross-references to specific items of evidence can be speeded up by using a systematic referencing system.</p>
	<p>(g) State the time, if known;</p>	<p>Knowing the time helps to correlate different sources of evidence for a given event or condition.</p> <p>If you do not know the precise time the event occurred, use a question mark. For example, if after 12:50, but before 13:00; use "12:5?". If wholly unknown; put "?". Consider adding a corresponding entry to the list of further enquiries.</p>

Task Steps	Description & Criteria	Guidance
3. Put event Post-it Notes onto a wall and position them using these rules-of-thumb:	(a) <i>vertically</i> – it can be helpful for each actor to have his/her/its own row, but it is optional.	It is not essential to have a separate row for each actor but it can be helpful if there is a lot going-on in the incident you are analysing. Later in the ECFA+ process, you will probably re-arrange events to emphasise certain sequences.
	(b) <i>horizontally</i> – put events in time order, so that later events are always to the right of earlier events.	ECFA+ does not use a fixed base for time (meaning equal intervals of time marked on the horizontal axis of the ECF chart).
4(a) Check the format of every event.	(a) Is the event stated in the simple present tense? (b) Is the event stated in the active voice? (c) Are the actor, action and object clearly identified? (d) Is the event a moment of change? (e) Can the event be visualised? (f) Is evidence cited? (g) Is the time stated? (h) Has it been initialled by the analyst?	Format checks are essential to ECFA+. Poorly stated events can complicate or undermine the analysis. Also, finding gaps allows further evidence to be collected. Sometimes the object and the actor are the same (“ <u>Bloggs</u> walks to the door”, “the <u>tank</u> explodes”). If the time is not stated, but it is <u>essential</u> to the facts, put “?” and add an item to the further enquiry list. The result of the format check would be ‘Q _n ’. Visualisation: you should be able to form a mental image of every event. If you cannot, there is either a problem with how the event is stated or with your understanding of the action described.
4(b) Check the format of every condition.	(a) Is it stated precisely? (b) Is numerical data given where needed? (c) Is evidence cited? (d) Is the time stated? (e) Has it been initialled by the analyst? (f) If a non-event, is the standard stated?	Anything you include in your analysis implies “after this, therefore because of this”. Because non-events can exaggerate the role played by individuals, check these points: <ul style="list-style-type: none"> • Is it really needed? If not, remove. • Is a non-event the only way to state the facts accurately? If not, use a regular condition. • Does the explicit standard (e.g. a procedure) stated in the “Comment box” apply in the context of the incident?

Task Steps	Description & Criteria	Guidance
4(c) Record the result of the format check in the "Format Status" box.	<p>(a) Tick the box if all details are present and correct.</p> <p>(b) If any data are missing, or the evidence is inadequate, add a numbered entry to the further enquiries list. Record this number in the Format Status box as 'Qn' (where 'n' is the number of the entry on the further enquiries list)</p>	<p>A tick in the "format status" box means that the analyst is satisfied that the event is an accurate factual representation of the action described.</p> <p>An example format for a further enquiries list is provided in Appendix 4.</p>
5. Check the logic of cause and effect for every item (event and condition).	<p>Start with the last item.</p> <p>Focus on the item (event or condition) to be checked for logic:</p> <p>a) identify the earlier events (or conditions) that directly cause the item in question;</p> <p>b) if these earlier events and conditions occur would the item in question always result?</p>	<p>The 'logic checking' process identifies the chain of cause and effect that links together the various events and conditions.</p> <p>The logic check of an item looks for relationships with other items, whereas the format check focuses on an item in isolation.</p>
	<p>c) If the item can be explained by earlier events and conditions</p> <p>i) draw linking arrows from the relevant events and conditions to the event in question;</p> <p>ii) reposition the Post-it Notes to achieve the simplest arrangement (but preserve time order);</p> <p>iii) tick the "logic status" box.</p>	<p>A linking arrow between two Post-it Notes means that the earlier "causes" the later to occur. You need to consider the strength of evidence for this causal relationship.</p> <p>When repositioning, try to avoid crossing lines. This is not always possible, but the idea is to make the ECF chart as clear as possible.</p> <p>A tick in the 'logic status' box means that the event is explained.</p>

Task Steps	Description & Criteria	Guidance
<p>5. (Continued) <i>Check the logic of cause and effect for every item (event and condition).</i></p>	<p>d) If the item <u>cannot</u> be explained by the events and conditions present in the ECF analysis:</p> <ul style="list-style-type: none"> i) add needed events or conditions, if the evidence allows; ii) check the format of any new events or conditions that you add; iii) if wanted, reposition all the related items; iv) draw (solid or dashed) arrows from the earlier events and conditions to the item; v) add a Query note, if more evidence is needed; vi) add to your 'further enquiries list' the question asked in the Query note; vii) place any Query notes near the item, without drawing arrows; viii) write 'Qn' in the logic status box (where 'n' is the number of the entry on the further enquiries list). 	<p>The logic check will often trigger you to recognise the relevance of events or conditions that need to be added to the ECFA+ chart. This is especially true of conditions.</p> <p>Arrows should be drawn from events and conditions to the item in question, even when the item cannot be fully explained. If the item cannot be explained, each arrow still represents a 'necessary cause'. However, all of the arrows taken together are 'insufficient' to explain the item.</p> <p>When drawing an arrow, you need to decide whether to use a dashed line or a solid one. The arrows represent direct causal relationships and must be supported by some evidence. Dashed lines show relationships that cannot be proved conclusively. As well as reflecting on the strength of evidence, you will also need to make a note of any further enquiries that might be needed.</p> <p>Query notes are blue and provide a way of "parking" an uncertainty that needs to be kept visible in your analysis, but without trying to resolve the issue there and then. This allows you to keep making progress with the analysis.</p> <p>Further enquiries should be numbered sequentially. A pro-forma for recording these is provided in Appendix 4.</p>
<p>6. As new events and conditions are added to the analysis, apply the format and logic checking rules.</p>	<ul style="list-style-type: none"> (a) Add new events and conditions in the light of fresh information. (b) Consider obtaining an independent review of the analysis. 	<p>ECFA+ is usually done in two or more sittings. At each sitting, new events and conditions are integrated into the ECF chart using the format and logic checking rules.</p>

Task Steps	Description & Criteria	Guidance
7. Perform final revision	Challenge any events left in the analysis that do not satisfy format or logic criteria:	When all evidence collection is finished, the ECF chart needs to be finalised to show the final state of information, including remaining uncertainties. Most investigations leave some uncertainty. It adds to the value and credibility of your analysis to be explicit about what was not explained by your investigation.
	a) If any event or condition has a blank box (format or logic status): <ol style="list-style-type: none"> i) If you judge that the event or condition is not critical to the analysis, remove it. ii) If the item is essential, decide what the status should be and write it in. 	‘Dashed’ events and conditions should be used sparingly in ECFA+. Ensure that all dashed items are based on some evidence and reasoned hypothesis (and not just unqualified opinions).
	b) Remove, or outline with dashed lines, events or conditions that have ‘ Qn ’ in their format status box: <ol style="list-style-type: none"> i) If you judge that the event or condition is <u>not</u> critical to the analysis, remove it. ii) If the item is essential, but lacking detail or evidence, enclose it in dashes. 	
8. Record the analysis	c) Make a suitable record of the analysis (e.g. by sketch, storage of original materials, or photographs).	

Bibliography

- Benner, L., and Rimson, I. (1991) Quality Management for Accident Investigations – Part 1, *ISASI forum*, Oct 1991 (24:3). Available via internet: http://www.iprr.org/LIB/QMA_P1.html
- Benner, L., and Rimson, I. (1992) Quality Management for Accident Investigations – Part 2, *ISASI forum*, March 1992 (25:2). Available via internet: http://www.iprr.org/LIB/QMA_P2.html
- Buys, J.R. and Clark, J.L. (1995), “*Events & Causal Factors Analysis*”. US Dept. of Energy. Ref. DOE 76-45/14, SSDC-14. <http://tis.eh.doe.gov/analysis/trac/14/trac14.pdf>
- Chambers (1996) “*Guide to Grammar and Usage*”. Compiled by George Davidson. Larousse. Edinburgh.
- Frei, R., Kingston, J., Koornneef, F., and Schallier, P. (2003), “*Investigation Tools in Context*”. JRC/ESReDA Seminar on “*Safety Investigation of Accidents*” in Petten, The Netherlands, 12-13 May 2003. Available via internet: www.nri.eu.com.
- Giannelli, P.C. (2003) “*Understanding Evidence*”. LexisNexis.
- Hayakawa, S.I., and Hayakawa, A.R. (1990) “*Language in Thought and Action*”. 5th edition. Harcourt Brace & Company.
- Hesslow, G. (1988) “*The Problem of Causal Selection*”. In *Contemporary Science and Natural Explanation: Commonsense Conceptions of Causality*. D. Hilton (ed.), Brighton, Harvester Press. Full text at: <http://www.hesslow.com/germund/philosophy/Problemselection.htm>.
- Hendrick, K. and Benner, L. (1987), “*Investigating accidents with STEP*”. Marcel Dekker.
- Kingston, J. (2008) “*3CA – Control Change Cause Analysis Manual, Form B*”. NRI-5 (2008), Noordwijk Risk Initiative Foundation, The Netherlands. Available via internet: www.nri.eu.com.NRI5.pdf
- Tapper, C. (2003). “*Cross & Tapper on Evidence*”. 10th Edition. LexisNexis.
- Trost, W.A. and Nertney, R.J. (1995), “*Barrier Analysis*”. US Department of Energy Ref. DOE 76-45/29, SSDC-29.

Appendix 1: Aide Memoire

1. Familiarise yourself with available information (including the site, if accessible).
2. Write up to 12 actions into Event (yellow) Post-it Notes.
3. An event (e.g. 'Smith opens valve 2') should conform to the following criteria:
 - It describes a moment of change.
 - It identifies the actor, action and object.
 - It describes the action simply, concretely and precisely.
 - It is written in the present tense using the active voice (sentence starts with the actor)
 - The event can be visualised.
 - A source of evidence (e.g. statement, photograph) is stated in the "Evidence box".
 - The time (and date, if needed for clarity) is given in the "Time" box.
 - It is initialled by the analyst who put the event into the ECF chart.
4. Most conditions (e.g. 'Solvent flows from the open flange of valve 2') will be written at step 8, but some will appear as a by-product of identifying events. Unlike events, conditions endure and are passive. Conditions may be started and stopped by Events. A condition (written using pink Post-it Notes), should conform to the following criteria:
 - It is described precisely.
 - A source of evidence (e.g. statement, photograph) is stated in the "Evidence box".
 - If a non-event, is it justified?
 - All relevant quantitative data are given.
 - It is initialled by the analyst who put into the ECF chart.
5. "Park" queries on your list of further enquiries. Keep the analysis moving.
6. Put items (events and conditions) into chronological order.
7. Verify that all items conform to ECFA+ criteria. Note items requiring further enquiries. Use the 'format status box' to record the result of the check.
8. Question causation item-by-item (more conditions are produced by this stage)
 - Can you prove that there is a direct causal connection between the item in question and earlier items? If yes, draw arrows from the precursor items to the item in question. If no, make a note of the further enquiries required on a blue Query Post-it Note and cross refer with the list of further enquiries.
 - Are the precursor events and conditions stated sufficient to explain the event? Would these precursors always produce this event – if not, note further enquiries, add-in and connect the necessary events and conditions.
9. Review the analysis. Ideally, ask a colleague who hasn't been involved to review the analysis and try to visualise the event line. If they have trouble, there may be gaps.
10. Correlate with other techniques. Root cause methods often produce conditions, some of which may be relevant in the ECF analysis. When integrating these into the ECFA chart, ensure that the conditions meet ECFA criteria (for evidence and precision in particular).
11. Record the Chart: number all Post-it Notes
 - Events: Numbers (1, 2, 3...)
 - Conditions: Letters (A,B,C...)
 - Queries: Prefix "Q" plus the relevant entry in the further enquiries sheet (e.g. Q1)

Either photograph the analysis or make a sketch of the pattern of numbers and arrows on a piece of paper. Remove and store the Post-it Notes.

Appendix 3: ECFA+ Artwork for printed Post-it® Notes†.

EVENT: Print onto yellow

CONDITION: Print onto pink

Evidence		Time	
EVENT			
<i>Use present tense, one actor, action and object</i>			
Comments			
ECFA Ref.	Analyst Initials	NRI Foundation www.nri.eu.com	
Format Status	<input type="text"/>	Logic Status	<input type="text"/> 

Evidence		Time	
CONDITION			
Comments			
ECFA Ref.	Analyst Initials	NRI Foundation www.nri.eu.com	
Format Status	<input type="text"/>	Logic Status	<input type="text"/> 

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† Post-it is a registered trademark of 3M Company.

QUERY: Print onto blue

QUERY		
<i>What? Why? When? Where? How? Who?</i>		
Query posted on (date)	NRI Foundation www.nri.eu.com	
Ref. number on list of further enquiries	Analyst Initials	

Appendix 4: Pro-forma for Further Enquiries List

Ref.	Information required	Source of Info	Priority

Appendix 5: Note on Causal Selection

This note is a condensed version of the chapter written by Germund Hesslow and published in "Contemporary Science and Natural Explanation: Commonsense Conceptions of Causality". D. Hilton (ed.), 1988, Brighton, Harvester Press.

The full text, which contains many examples, extensive discussion of the issues and a full attribution of sources, can be obtained from:

<http://www.hesslow.com/germund/philosophy/Problemselection.htm>.

THE PROBLEM OF CAUSAL SELECTION

Introduction: the plurality of causes

Events, facts, states or properties have infinitely many causes. There are three reasons for this:

1. an event will normally depend on the immediately preceding occurrence of several different events;
2. it will usually be possible to trace a causal chain backwards in time;
3. it is generally possible to conceptualise the causes in infinitely many different ways.

Selecting one or more causes from a set of conditions is a special case of the weighting of causes according to their relative importance. For instance, although we might explain someone's alcohol problems by their biochemical susceptibility to alcohol dependence, we might also concede that other factors, such as personal problems, were contributory. When the selection criterion unequivocally picks out one condition we call this the cause, but when other conditions come close to satisfying the criterion these are termed contributory, and the condition which best fits the criterion is considered more important than the others.

Two basic distinctions: "selection versus connection", "individual versus generic"

The selection problem has two interrelated aspects:

- the "connection problem" – the existence of a causal relation between two events. The connection problem is the problem of understanding the process by which we determine that, say, the presence of oxygen, combustible material and a source of ignition are all *necessary* conditions for houses catching fire.
- the "selection problem" – the relative importance of causes. The selection problem is the problem of deciding which of the necessary conditions was the most important, in a concrete individual case. We do not say that a fire was caused by oxygen, in spite of the fact that we know that there is a causal connection between oxygen and fire. Instead, we mention only the combustible material and the source of ignition.

There are two kinds of causal relationship, individual and generic:

- Individual causal relationships are those which obtain between concrete individual occurrences of events, such as the house's catching fire at 9.05 p.m. yesterday because of the explosion in the television set a moment earlier or the fact that Smith's recent death was caused by a heart attack.
- Generic causal relationships are those which obtain between kinds of events (generic events) or between properties, such as the general propensity of explosions to cause fires, or the fact that heart attacks cause death.

One view of the relationship between these two kinds of causal relation is that we arrive at generic causal relations by generalising from individual cases of co-occurrence and then apply this general knowledge to other individual occurrences. Thus, since a large proportion of

those who have heart attacks die, we conclude that the disease is deadly. If Smith has an infarction and dies, we use our knowledge of the general causal relation to justify the belief that his death was caused by the infarction. *Note, however, that a general causal statement can be true while a corresponding individual statement is not.* Smith's heart attack may not have killed him and he may have been killed by something else.

Criteria which govern causal selections and weightings

There are many different criteria that can be applied to the task of selecting a relevant subset of causes from the infinitely large set of causes that can be argued to precede any event or state. It is not self-evident that any of the criteria described below, are "true" or "correct". Most people, when confronted with this list of selection criteria, would probably find some truth in each of them. To those of us who like compromises, it is tempting to conclude that all, or at least most, of the criteria are true but that different criteria are used in different contexts.

(a) Unexpected conditions. According to Mill, *"If we do not... enumerate all the conditions, it is only because some of them will in most cases be understood without being expressed, or because for the purpose in view they may without detriment be overlooked. For example, when we say, the cause of man's death was that his foot slipped in climbing a ladder, we omit as a thing unnecessary to be stated the circumstance of his weight, though quite as indispensable a condition of the effect which took place"*.

On this basis, some conditions are not mentioned because they are presumed to be already known to the listener, and stating them explicitly would be superfluous. Consequently, we select as causes only such conditions that are unknown or unexpected.

We do not generally require explanations when things behave normally; we ask "why" mainly when something unexpected happens. A relevant explanation will state events which were both unexpected and would have enabled us to predict the surprising event if we had known about them.

(b) Precipitating causes. It is often possible to divide the complete cause into more-or-less permanent states and instantaneous changes or events. We usually select the events immediately preceding the effect which we are trying to explain. In such cases, we explicitly use the distinction between permanent conditions and the instantaneous event which came last into existence.

(c) Abnormal conditions. This selects factors on the basis of making the difference between an accident and normal functioning. In a railway accident there are conditions such as the normal speed, weight of the train and routine stopping and acceleration. These conditions are true both in the case where such accidents occur and in the normal cases where they do not, and so we reject them as the cause of the accident, *even though it is true that accident would not have occurred without them.* It is this consideration that leads us to conclude that to cite factors which are present both in the case of disaster and normal functioning, would explain nothing: such factors do not 'make the difference' as would a bent rail.

There is substantial difference between unexpected and abnormal conditions: abnormality refers to objective facts; things are normal or abnormal independently of our knowledge of them, while unexpectedness refers to a subjective state.

(d) Variability refers to the selection of those conditions which are variable in contrast to more permanent conditions. This is a blend of the first three criteria discussed.

(e) Deviation from theoretical ideal. Theoretical concepts often guide causal selections. For instance, in explaining a deviation we select causes which are also deviations from an ideal model of the system in question.

(f) Responsibility. Causal statements may have an evaluative component. Indeed, the Greek word for cause, *aitia*, also means guilt. The ancient Greeks modelled their idea of causation in nature by analogy using ideas about social organisation. A *cause* was thought of as some-

thing that brings about a disturbance in state of harmonious equilibrium in nature, and the *effect* as something that restores this equilibrium, much as a punishment restores the social harmony after a crime. In general, we identify the cause of a tragedy before assigning blame. However, it may be claimed that in selecting among the causal conditions we pick out those events or actions which deviate, not from what is normal, but from what is good, reasonable or appropriate. A cause will often be an omission which coincides with what is reprehensible by established norms of conduct. Thus, when we say that a fire was caused by negligence of the authorities (who failed to notice the special dangers in the building), we are not denying that oxygen, a heat source etc. had something to do with it. Neither are we saying that negligence is abnormal. We are, rather, specifying what went wrong.

(g) Predictive value. This holds that an explanation for a certain event consists of information that, had we had access to it before the event to be explained occurred, would have enabled us to predict it. In view of this, a natural and intuitively compelling selection criterion would be that we select as the most important causes those that most effectively predict the effect.

(h) Replaceability and necessity. Most of us think about certain historical figures like Napoleon, Gandhi or Lenin as being important causal factors in history. Historians sometimes take a different view and argue against the role of the individual in history – that even if the person X had not done this or that, someone else would have done it instead, and therefore history would not have been much different. This argument does not deny that X did bring about certain things, only that X was not necessary. However, if there were other people with similar characters, motives etc., they could have achieved the same effects, hypothetically speaking. X was, we might say, replaceable, and therefore not as important a cause for historical developments as causes which were irreplaceable.

There are similarities between the replaceability criterion and the criterion of predictive value: a condition which could be replaced is also a bad predictor of the effect. However, predictive value focuses on the probability that the effect occurs, whereas replaceability focuses on the probability that the effect does not occur in the absence of the causal candidates.

(i) Instrumental efficacy. It is possible to consider causes as levers by means of which we can produce or prevent certain effects. If causality is viewed in this way, it is very natural to think that we select those conditions which enable us to manipulate effects. If we want to bring about something, we will select conditions which come as close as possible to being sufficient for a desired end, and if we want to prevent something, we select conditions which come as close as possible to being necessary for whatever it is we wish to avoid.

(j) Interest. This holds that causal selections are governed by the particular interests of the person giving an explanation. For example, explaining a road accident, a road engineer might point out that the road had a poor surface and that the cause of the accident was the slippery highway. A policeman might instead pick out some other factor, like the excessive speed of the car, and a psychologist yet another factor such as the driver's disturbed state of mind. Each person looks at the situation from a special point of view and singles out that factor that interests him or her most.

Appendix 6: Standards of Evidence

ECFA+ has three levels of confidence, these are denoted by: solid lines (established as fact); dashed lines (presumptions with some evidence, but not proof); and queries (queries need to be justified by some reasoning). It is essential that the analyst ensures that all items and connections shown in an ECF chart are supported by adequate evidence. What constitutes *adequate* is a complex matter that needs to be decided in context. This paper highlights principles for the reader to keep in mind during ECFA+; it does not advocate a particular standard of proof or any particular methodology for acquiring and handling evidence⁸.

Reliability and validity

Reliability and validity are two qualities often associated with matters of measurement and which provide insight into the more general topic of evidence. *Validity* is the extent to which a quantity measures what it purports to. *Reliability* is the extent to which measurements of a given phenomenon give consistent results and are uninfluenced by other factors. Applied to evidence, *reliability* is about the way that the evidence was created, collected and relayed; whereas validity is about the extent to which evidence is a true indicator of the fact asserted. The two qualities are connected: evidence cannot be valid without being reliable; but reliable evidence can be invalid. In practice, validity often implies interpretation on the part of the person receiving the evidence.

Promoting reliability

Evidence can be seen as the link between a person such as an investigator and the specific condition or event from the past that they are considering. In this perspective, evidence can be seen as a process of communication between a particular historical state or action and the investigator. Error and distortion can affect any stage of this communication, which can be considered as a five stage process:

- Create – the change created in the witness plate⁹ by the action or state in question;
- Collect – the collection of data from the witness plate;
- Conserve – the preservation of the data in or acquired from the witness plate;
- Convey – the transfer of the data to the investigator or other interested party;
- Consider – the examination of the data as evidence for the action or state in question.

Reliability is a necessary but not sufficient condition to consider when evaluating evidence. However, highly reliable tests and assessments can give the impression of scientific credibility which may seduce investigators into assuming that the data so produced are valid evidence about the matter question.

Assuring Validity

Assessing the validity of evidence is a matter of gauging the extent to which the evidence supports the assertion as fact of the event, condition or causal connection in question. The following questions may be useful in stimulating critical assessment if the validity of evidence:

- Could the same evidence support another interpretation?
- What other evidence would we expect to find given the fact in question?
- What is the justification for asserting a relationship between the evidence and the fact in question?

⁸ For readers interested in the consideration of evidence within systems of law, texts such as Tapper (2003) and Giannelli (2003) are helpful guides. However, the detailed conventions developed in legal systems do not constitute a complete solution for the complex issues of evidence.

⁹ Witness plates, which can be people or things, “provide data about the events that changed them” ... “One investigative task is to identify the people and things who or which were the witness plates to an accident. Obtain the accident data, the signals, that the witness plates have captured, and then read the data to reconstruct the events that produced the data. The witness plate idea helps locate and evaluate sources of data recorded during an accident.” (Hendrick and Benner, page 73-74, 1987).

Appendix 7: ECFA+ criteria developed to assist the investigation of the emergency service response to the fire and explosion at Enschede, the Netherlands, 13 May 2000

On 13 May 2000, there was a large explosion in the town of Enschede in the Netherlands. To advance the subsequent investigation, the emergency services needed to process substantial quantities of data collected by several teams of investigators from a variety of sources. To assist with this task, NRI worked with the investigators to develop criteria for identifying relevant events and conditions. The criteria are listed below:

A. Communication

1. inter-agency (e.g. between Fire Brigade and Police)
2. intra-agency
3. external

B. Decision making

1. assessing the situation (to inform decision making)
2. to deploy resources
3. to disseminate information
4. to enact a plan or procedure

C. Operation

1. actual deployment of resources (following decision making)
2. a planned change
3. unplanned change (positive)
4. unplanned change (negative)

The criteria have different bases: category “A” is needed to integrate data provided by the various agencies and to bring into focus command and control; category “B” makes decision-making visible to analysis, and; category “C” is an important catch-all that helps to identify differences between theory and practice of disaster management.

The criteria were used to filter the data obtained by the various investigation teams. When applied to reports, the investigators noted which criterion was relevant to each datum. This ensured that the transformation of source reports and other material into ECF charts was transparent. It also provided traceability between each item in the ECF chart and the evidence that corresponded to it.

Lastly, when applying criteria to select-in relevant data, it is prudent for the analyst to watch for instances where seemingly pertinent data are filtered-out. This “sense” check was applied by investigators in the Enschede analysis to develop and refine the criteria as well as to ensure that relevant data were included.

Appendix 8: Glossary of Terms

Action: The means by which an actor changes the state of an object. In ECFA+ actions are described using transitive verbs.

Active Voice: Chambers (1996) states that “A verb is said to be in the active voice when the subject of the verb is performing the action or is in the state described by the verb. ‘Voice’ is simply the technical word for that aspect of the grammar of verbs that is covered by the terms ‘active’ and ‘passive’. For example, in *The boy stroked the cat*, the *boy* is the subject of the verb *stroked* and it is the boy who is performing the action of stroking; *stroked* is therefore in the active voice.” ... “The opposite of an active verb is a passive verb, as in *The cat was stroked by the boy...*”.

As well as a clearly identified actor, each event need to be described using an accurate, clear-cut verb. The verb should make it easy to visualise the action, like a frame from a video. The active voice makes it clear who or what is acting; choosing an accurate action also needs to be clear. the rule is to be sure that the event is stated in a way that makes it clear what is acting, how it is acting and the object affected.

Actor: A person or thing that acts on an object.

Condition: A passive state that endures for some period of time. E.g. “40kph SE wind”, “Valve shut”, “Road open to traffic”. Written onto pink Post-it Notes, if available.

Dashes and dashed-lines are used to denote uncertainty in ECF charts and can be applied to both connecting arrows and to the outlines of events and conditions.

ECFA+ is the acronym of the title “Events and Conditional Factors Analysis”. The “+” character is used to distinguish this method from its predecessor “Events and Causal Factors Analysis” (Buys and Clark, 1995).

ECF chart: Any diagram produced by applying the ECFA+ procedure.

Event: A moment, generally of short duration, characterised by a change of state. In ECFA+, an event is described by the action of an actor on an object (e.g. “Car enters smoke plume”, “Smith moves PTO lever to ‘on’ position”). Written on yellow Post-it Notes, if available.

List of Further Enquiries: an open-ended table in which questions and uncertainties can be noted as they arise during the investigation. An example is provided in Appendix 4.

Non-event: an event that would be expected to occur given the circumstances, but which in fact did not happen. In ECFA+, non-events are treated as conditions and the analyst is required to identify the standard of judgement that they

are using – such as a procedure, custom or practice, or theory). This approach enables other stakeholders to challenge the judgement of the analyst and reminds the analyst of the need to justify their reasoning in such instances.

Object: The person or thing receiving the action of an actor.

Occam’s razor refers to the principle of minimising the number of items in an explanation to only those needed. It is also sometimes called *the principle of economy*.

Primary Events/Conditions are generally close in time (i.e. minutes, hours, or days) to the unplanned outcomes in question. Primary is defined in relation to Secondary (see *Secondary Events/Conditions*, below).

Query: The third type of item that can be used in ECFA+ (the others are events and conditions). Queries are used to denote areas of uncertainty, especially where this has causal relevance. Written on blue Post-it Notes, if available.

Secondary Events/Conditions: Secondary events are included to explain the coming into existence of primary conditions; these may reach days, weeks, or years back in time from the unplanned outcomes which are the focus of investigation.

Simple Present tense: Chambers (1996) states that “The present tense of a verb is the tense which refers, among other things, to actions going on or states existing at the present time or in general”. This is in contrast to the progressive or continuous form of the present tense which “...consists of the *-ing* form of the verb in combination with the auxiliary Verb *to be*”.

Appendix 9: Changes (2014 ECFA+ manual compared to the 2007 version)

1. No blank check boxes

This version introduces a new way to manage further enquiries. In the previous version, the format and logic checking boxes would be ticked to show completeness, or else left blank. After further enquiries, the analyst would review these blank items. However, blank boxes can have several meanings, leaving the status of an analysis unclear. Blank boxes could mean that the item:

- has not been checked;
- has been checked and a problem found (e.g. missing data or lacking evidence);
- has been checked and found satisfactory, but the decision was not recorded.

2. Artwork has changed

The artwork of events and conditions has been changed to encourage analysts to record the results of checking format and logic. The boxes have been enlarged and the labels changed.

The labels of the boxes now read:

- “Format Status” (previously, “Format Check Passed”)
- “Logic Status” (previously, “Logic Check Passed”)

The enlarged boxes allow the analyst space to write a cross reference to a further enquiry. This takes the form ‘Qn’, where ‘n’ is the reference number of the entry on the further enquiry list.

3. First iteration: Maximum 12 events

Previously, the analyst was free to write out an unlimited number of events and conditions. This remains true, but an arbitrary maximum of 12 has been set on the number of events that can be written at the start of the analysis. As soon as the analyst reaches the stage of checking the logic, they are free to add more events and conditions.

This rule prevents the process being overwhelmed by too many items at the start of the analysis. Limiting the number avoids the following problems:

- slow progress, which discourages the investigator and costs time;
- unreliable format and logic checks, which allow errors and miss gaps;
- overcomplicated ECF charts, which limits their value to the investigation;
- stating events at a level of description that is unnecessarily low, which creates long chains of events where just one would be enough;
- analysis that is disconnected from the terms-of-reference of the investigation, in essence becoming the master rather than the servant of the investigator.

4. Readability

The main body of the text (i.e. pages 9-24 of the 2014 version) was re-written to bring it up-to-date and to improve readability. The authors checked the effect on readability using specialist software (Readability Studio). The software uses several measures, including the ‘Flesch Reading Ease’ which measures readability on a scale of 0-100, where 100 is the easiest. The main body of the 2007 ECFA manual scored 46, whereas the new manual scored 57.

The software estimated how easy the text would be for ‘English as a second/foreign language’ (ESL/EFL) readers. Using the McAlpine EFLAW test (McAlpine, 2006), the software predicts that ESL/EFL readers would find the 2007 manual “very confusing to read”. In contrast, the software predicts that these readers should find the 2014 manual “very easy to read”.

At the time of writing, NRI plans to release a Dutch version of the revised manual by 2015.

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Name: Dr Rudolf Frei	Address: NRI Foundation P.O. Box 286 2600 AG Delft The Netherlands	Phone: +44 (0)121 288 3206 email: info@nri.eu.com