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3CA

Control Change Cause Analysis Manual

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3CA
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Author: J. Kingston
John Kingston Associates, UK

for

The Noordwijk Risk Initiative Foundation,
P.O. Box 286, 2600 AG Delft, Netherlands.
www.nri.eu.com

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Preface

Control Change Cause Analysis has its origins in a co-operative project[1] run by Humber Chemical Focus and the UK Health & Safety Executive between May and November 2000. The venture was aimed at line managers of chemical sites in the Humber region and sought to develop their skills in identifying underlying causes of accidents and incidents. The project aimed to equip people with tools to help them investigate and identify lessons to be learned.

The core method taught in the training workshops was Events and Causal Factors Analysis, a sequencing technique used to clarify cause and effect relationships. It was advocated as a means of gaining a secure understanding of what happened in an incident. ECFA was used in concert with a root cause method provided within the HSE publication "Successful Health and Safety Management".

Most incidents contain more than one event that requires explanation, often there are several. Identifying events for root cause analysis can be approached in a number of ways; the first method considered for the workshops was Energy Trace and Barrier Analysis[2], this uses "unwanted energy flows" as the defining characteristic. ETBA was evaluated and found not to interface adequately with the root cause method. What was needed was a different tool for identifying problematic events, one that did not use the energy flow concept. This produced a generalised form of barrier analysis called "Control Change Analysis" (or 2CA), still present as the first part of 3CA (columns 0-4 of Appendix 3).

At the end of the project, a number of the participants identified the need for a simpler root cause tool, one that structures the process of inquiring into underlying cause but without burdening the user with long lists of prompts. Informally, we referred to this would-be tool as the *Humber Method*. John Topliss[3], then the Site development manager at the Acordis site at Stallingborough, was keen to be involved with this in a practical way. In response, John Kingston developed 2CA into a prototype of 3CA

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[1] The Project Report is available from Humber Chemical Focus: email info@humberchemical.co.uk or contact via the website at www.humberchemical.co.uk
[2] Discussed further in section 1.2
[3] John Topliss can be contacted by email: John.topliss@btopenworld.com

and produced a presentation to help trials at the Acordis Tencel plant in early 2001. These trials were informal and involved first line supervisors. The results[4] suggested that 3CA:

- is quick to learn;
- provides a structured way of taking the specific events and outcomes of an incident through to the relevant areas of the safety management system. In doing so it helps to identify which aspects of the system failed to be effective;
- is systematic and reproducible;
- produces visible results that are easy to communicate;
- is recordable and can be audited.

Following these trials, and under the auspices of the Noordwijk Risk Initiative Foundation, John Kingston continued to develop 3CA with the intention of release into the public domain. Eighteen months of applying 3CA in a number of different companies and organisations has produced considerable refinements in the method and experience with its use. This manual, which is published with the sponsorship of Humber Chemical Focus, aims to describe the application of 3CA and provide practical advice about its adoption within organisations that wish to use it.

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[4] Topliss, J. May 2001. Personal correspondence with John Kingston.

Contents

Appendices

1 Introduction

This paper describes the use and origins of Control Change Cause Analysis or 3CA.

1.1 Description

3CA is a method of root cause analysis, designed to assist the investigation of accidents of any type. The first stage of the analysis selects episodes of particular significance from the sequence of events under investigation. For the purposes of 3CA, a significant episode is one that markedly increases the risk of unwanted events that might follow. 3CA can be used to analyse these episodes and to structure inquiries into the reasons underlying them.

1.2 3CA and Energy Trace and Barrier Analysis

3CA is based on a generalised form of energy trace and barrier analysis[5] (ETBA also known as "barrier analysis"). Barrier analysis is designed for use with MORT, the management oversight and risk-tree[6]. MORT analyses accidents in terms of the harm or damage caused to people or objects by unwanted flows of energy. Within an accident, there may be several episodes of unwanted energy flow that are associated with harm or threat to people or objects; the purpose of barrier analysis is to identify these episodes. 3CA is also used to identify adverse episodes, but has a wider scope of application. The differences between ETBA and 3CA are summarised in Table 5 in Appendix 1.

2 The 3CA process

This section discusses the practical use of 3CA and provides a detailed description of the method.

2.1 3CA Pre-requisites and limitations

3CA is designed to be flexible and straightforward to apply. However, these advantages are gained at the cost of reduced reproducibility and the lack of a question set to prompt investigators to explore a

[5] W.A. Trost and R.J. Nertney, 1995. "*Barrier Analysis*". US Department of Energy Ref. DOE 76-45/29, SSDC-29

[6] Frei, R. et al. (2002) *"NRI MORT User's Manual"*. Pub. Noordwijk Risk Initiative Foundation, The Netherlands. www.nri.eu.com

broad set of topics. To counteract these drawbacks, two prerequisites are suggested: firstly, that 3CA is always preceded by a structured and systematic identification of the sequence of events that comprise the accident or incident under investigation; second, that 3CA analyses are always subject to review. In addition, experience shows that 3CA benefits from a team approach.

2.1.1 3CA needs to be supported by identification of the sequence of events

In investigations, there is often a danger that the investigators will base analysis on what they *think* happened rather than on what *did* happen as revealed through a structured process of inquiry. The trials at Acordis and elsewhere have underlined the dependence of 3CA on the prior identification of the sequence of events comprising the accident under investigation. Sequencing methods such as STEP[7] *(Sequentially Timed Events Plotting)* and ECFA+[8] provide a means of analysing accidents to reveal a clear picture of what happened. Using 3CA without the benefit of such methods, runs the risk of failing to identify important events for analysis. Indeed, it is possible that by emphasising events within the 3CA that any omissions become further hidden from review.

2.1.2 The importance of review

Root cause methods vary from one another in a number of different ways including the breadth and depth of their scope. Breadth is normally obtained by incorporating a suitably broad set of questions within the tool to act as prompts to the investigator. For example, MORT provides breadth to an investigation through a set of about 1,600 questions to which the MORT diagram acts as an index. However, this takes time to do as well as familiarity with the question set. Where ease and speed of application is a premium, breadth needs to be assured by other means. The most straightforward is to require 3CA analyses to be reviewed independently.

A similar argument can be made about the depth of analysis. 3CA, in common with any form of root cause analysis, cannot prevent users from treating important topics in a superficial way. In investigation this is typically manifest as judgemental, absolute statements rather than justified and reasoned arguments. Review by someone independent of the team or person producing the 3CA analysis is needed to ensure quality of depth as well as breadth of coverage.

Review, although an additional task, can be seen as very beneficial, especially if it is coupled with the expectation of providing feedback to the people originating the analysis. Anything which helps to elevate investigation from being a purely paper exercise to a living process is worth considering, particularly if the burden associated with it is light and felt to be a worthwhile effort by those involved. From the

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[7] Hendrick, K. and Benner, L., 1987. *"Investigating accidents with STEP".* Pub. Marcel Dekker.

outset, 3CA was designed to both assist the investigator and facilitate the communication between them and other interested parties. A completed 3CA analysis sheet provides a very efficient summary of the significant findings from an investigation and gives transparency to the reasoning processes of the investigators.

2.2 3CA Headings

3CA uses a system of headings to analyse events judged to be significant by the investigators. These headings can be grouped into three sets:

- control change set (columns 0-4)
- significance rating (column 5)
- causal analysis set (columns 6-9)

2.2.1 Control change set: columns (0)-(4)

3CA begins by identifying the significant events upon which the rest of the analysis will be focused. As indicated earlier, this is best done after the application of a method such as ECFA+. Once the full sequence of events has been identified, it can then be reviewed to identify those events that increased risk[9]. These events are then entered into column (0) "significant events".

Columns (1) to (4) are used to identify the preventative measures that could have stopped the episodes from occurring. These might work by either stopping the "agent of change" from acting or by nullifying the action.

Columns (1) to (4) are filled in one row at a time, in order to maintain focus on each event. The purpose of these columns is to ensure that the investigator is clear about the mechanics of the event: what is acting, with what effect and what could have been done to maintain control or intervene between the actor and what they are acting on. These columns should be expected to reach a higher standard of reproducibility than the remaining 3CA analysis.

Column (1) "change to person or thing" and column (2) "agent of change" ensure that the investigator is clear about what is being changed and what is effecting that change. Any uncertainty here needs to be clarified before the event can be analysed further. If the investigator has been disciplined about phrasing events (e.g. by meticulous use of ECFA+ or STEP), columns (1) and (2) will add little to the analysis.

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[8] Kingston, J., Jager, J., Koornneef, F., Frei, R., and Schallier, P. (2004) "Events and Conditional Factors Analysis Manual". Pub. Noordwijk Risk Initiative Foundation, The Netherlands. http://www.nri.eu.com.
[9] *Risk* is used in the popular sense rather than as defined technically.

Figure 1 is an ECFA+ chart of an accident that occurred during a fire brigade operation to extinguish a car fire at the side of a road. Table 1, shows the start of 3CA analysis of one event from the ECFA+ sequence.

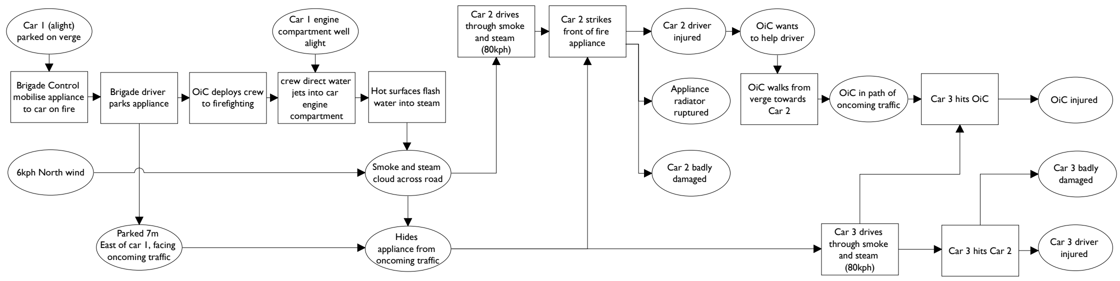


Figure 1: ECFA+- of accident(s) during firefighting operation; this is shown full size in Appendix 2.
Note: OiC is an abbreviation of Officer-in-Charge (of the fire crew)

(0) *Significant Events* ➔	(1) Change to person or thing	(2) Agent of change	(3) Adverse effect of change	(4) Work controls or protective barriers implicated in (1)/(2)
OiC walks from verge towards Car 2	*OiC moves from verge onto carriageway*	*OiC walks*		

Table 1: Example of Columns (0) to (2)

Column (3) allows the investigator to state why the action described in columns (1) and (2) are problematic. The idea of column 3 is to avoid confusing the act with the results of the act.

(0) *Significant Events* ➔	(1) Change to person or thing	(2) Agent of change	(3) Adverse effect of change	(4) Work controls or protective barriers implicated in (1)/(2)
OiC walks from verge towards Car 2	*OiC moves from verge onto carriageway*	*OiC walks*	*OiC in path of oncoming traffic*	

Table 2: Example of Columns (0) to (3)

The need for column (3) becomes clearer when completing column (4), which focuses on the control of the agent and its actions but <u>not</u> on mitigating the consequences of the act. In the example above, column (4) should focus on what controls might prevent the Officer-in-charge from walking into the road. Without column 3, issues such as stopping the oncoming traffic may distract investigators from the

OiC's action. As shown below, stopping and otherwise controlling the traffic is the subject of other rows of the 3CA.

In column (4), the following points need to be observed to keep the analysis on track:

- the focus of column (4) is the agent and the change it causes (columns 1&2) not the effects that might follow (column 3);
- the word *implicated* is used to signal investigators to nominate any control or barrier that they think may have been relied upon or that could have been useful. In this sense, column (4) may require a degree of brainstorming to complete and this is best approached by reserving judgement about the reasonableness of the control or barriers nominated;
- brainstorming can be assisted by applying the "Hierarchy of Measures" (see appendix 4) to columns (1) and (2);
- controls and barriers are those which are tangible at the shop floor level[10]. By this definition, risk assessment is not a control or a barrier. However, the measures specified as the result of a risk assessment may qualify for inclusion in column (4);
- controls refer to the control of work or a process which may or may not offer protection as a by-product;
- barriers are solely protective in nature.

Table 3 shows column (4) completed for three events from the accident sequence; note the use of lettering in the emerging list of barriers and controls.

(0) *Significant Events* ↓	(1) Change to person or thing	(2) Agent of change	(3) Adverse effect of change	(4) Work controls or protective barriers implicated in (1)/(2)
OiC walks from verge towards Car 2	*OiC moves from verge onto carriageway*	*OiC walks*	*OiC in path of oncoming traffic.*	*(a) Segregation of people from traffic.*
Car 3 enters smoke plume	*Driving in dense smoke.*	*Car 3 driver, drives*	*Driver cannot see or react to conditions ahead.*	*(b) Car 3 driver decision.* *(c)Warnings to driver.*
Car 3 hits OiC	*OiC struck (left leg)*	*Car 3 moving at 80kph*	*OiC is injured (badly bruised left leg).*	*(d) Stop/Marshall traffic.* *(e) Velocity of Car 3.* *(f) Physical barrier between OiC and car*

[10] More precisely, the controls and barriers need to operate at the same level of system as the agent and change.

Table 3: Columns (0) to (4) completed for three events. *Note that in this example there are many more rows that could be included in the 3CA table but which have been excluded here for the sake of simplicity.*

2.2.2 Significance rating: column (5)

The purpose of column (5) is to prioritise the significant events for subsequent analysis. Looking at it another way, unless the accident under investigation is very serious, investigators may wish to exclude less important events from further analysis. Exact ratings are not the objective, here; what is important is that there is some degree of thought or debate about significance and how investigative resources should be deployed.

In practice there does not seem to be a single basis for making the ratings. Three bases seem to be used singly or in combination:

(a) the increase in risk engendered by each event (focus on the adverse effects in column 3);

(b) the timing of the event (focus on column (0), early failures to assert control may be seen as more significant than later failures);

(c) the general importance of the controls and barriers to risk management in the organisation (focus on column 4, but framing its contents in a wider context than the accident).

Whatever method is used, the investigator or team should feel that the events chosen justify the further work entailed by root cause analysis and servicing the further inquiries that it may generate. However, this pragmatic approach further underlines the need for review of 3CA analyses; people may differ in their views about which events should be subject to root cause analysis.

2.2.3 Causal analysis set: columns (6)-(8)

The statements in column (6) should aim to provide a clear description of what has failed and these failures provide the focus of what needs to be explained by the subsequent analysis in columns (7) and (8).

The analytical roles of columns (4) and (6) are quite distinct although both are concerned with barriers and controls. Column (4) is concerned with barriers and controls that <u>could</u> have made a difference, whereas column (6) is about which of these <u>should</u> have been in place; column (6) invokes a standard or test of reasonableness. Identifying standards and inquiring into what is reasonable may involve considerable work and this is why column (5) is used to filter out less significant events. Table 4 shows column (6) developed for all three events.

<table>
<tr><th>(0)

Significant Events
↓</th><th></th><th>(4)

Work controls or protective barriers implicated in (1)/(2)</th><th></th><th>(6)

In what way was each measure at (4) ineffective</th><th>(7)

In what way did upstream processes fail to identify or prevent the problems noted in (6)</th><th>(8)

"Why"?

(ask "why" of each entry in column 7)</th></tr>
<tr><td>OiC walks from verge towards Car 2</td><td rowspan="3">Intervening columns omitted to save space on page</td><td>(a) Segregation of people from traffic.</td><td rowspan="3">Intervening column omitted to save space on page</td><td rowspan="3">(a) OiC did not maintain segregation, went to assess casualty before ordering the traffic to be stopped.

(b) Car 3 should have stopped rather than driving through dense smoke

(c)(d) Warnings were not given by Fire Brigade ahead of the smoke plume

(d) Whole crew was deployed to firefighting

(e) Car 3 travelling too fast for conditions

(f) Appliance not used to fend-off (BO "y" applies)</td><td rowspan="3">(a)(d) OiC did not [risk-] assess situation before acting.

(b)(e) Car 3 driver has often seen heath fires near this road: wrongly assumed this fire was also.

(b)(c)(d)(e) BO "x" requires traffic management (cones, marshals, other warnings).

(f) Need for fend-off not recognised by OiC. BO "y" does not require Fend-off for "Car alight" (but does for traffic accidents)</td><td rowspan="3">(a)(f) OiC newly promoted. Perhaps, unused to risk assessment discipline?

(b)(c)(d)(e) OiC not formally trained on BO"x". Also, wanted to get-to-work quickly on fire. Training for Competence and verification process?

(f) Fend-off required for road traffic accident but not car alight. Risk controls for various types of road incidents are not harmonised.</td></tr>
<tr><td>Car 3 drives into smoke.</td><td>(b) Car 3 driver decision.
(c) Warnings to driver.</td></tr>
<tr><td>Car 3 hits OiC</td><td>(d) Stop/marshal traffic.
(e) Velocity of Car 3.
(f) Physical barrier between OiC and cars.</td></tr>
</table>

Table 4: Columns (6) to (8) completed for events with columns 1, 2, 3 and 5 truncated *("BO"=Brigade Order). Note that for the purposes of this example, columns 6, 7 & 8 have been completed for all rows; normally the ratings in column 5 would be used to select only those rows thought to warrant further analysis.*

Column (7) provides the investigator with the opportunity to tease out the reasons for the failures noted in column 6. It does this from the perspective that the organisation(s) concerned is best placed to ensure control through the management of tasks, equipment and the competence and performance of individuals. In completing column (7) the investigator needs to identify the administrative systems and managerial (such as training, procedures, maintenance, risk assessment, etc.) or design processes that were expected to avoid the problems noted in column 6. Furthermore, the investigator needs to 'diagnose' in what way these systems and processes were faulty (or verify that they were functioning adequately). The more precise and well-evidenced this 'diagnosis', the more reliable is the basis for recommendations.

3CA does not impose a set of categories on the investigator and so column (7) should reflect the user's understanding of the organisational context of the event. It is not enough to name management systems and processes; this simply reflects a lack of insight into actual problems. To be useful, analysis in column (7) needs to produce justified statements that clearly demonstrate connection with the problems noted in (6). The breadth of topics presented in column (7) analyses is a matter for particular attention when the analysis is reviewed.

In column (8), the investigator needs to consider the reasons behind the issues raised in column (7). On occasion, the reasons identified in (8) do themselves require explanation. Rather than adding new columns (generally impractical), adding sentences can accommodate these higher levels of explanation as has been done in item (f), column (8), of Table 4.

When completing columns (7) and (8), the investigator may not have all the necessary facts. In these circumstances, the relevant issue(s) should be stated as a question. If further inquiries do not answer the question, <u>it should remain in the final 3CA table as a question</u> (as shown in column (8) of Table 4).

3 3CA Aide Memoire

This section provides a step-by-step description of the 3CA process. It assumes that the reader has read the contents of section 2, which provides a more detailed description of the terms used here.

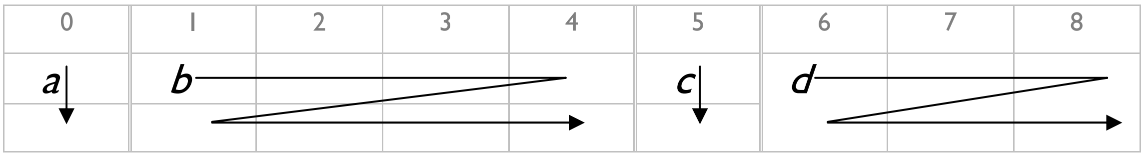


Figure 2: 3CA schematic showing sequence of use (letters correspond to plan below)

a) Identify significant events:

   i) Identify and place events in logical order (e.g. using ECFA+ or STEP);
   ii) Review the ECFA+ chart, one event at a time, starting with the final event in the sequence. Select each event that creates an adverse change in risk and/or control;
   iii) Enter these events into column (0) of the 3CA table.

b) Complete columns 1-4, one row at a time:

   i) Consider the event: What is the change? What attribute is being altered?
   ii) What is the agent of change? What is the actor and action?
   iii) What is the immediate, unwanted effect of the change?
   iv) What work controls or protective barriers are implicated in the change and agent columns? Only consider those that are specific and have a direct effect "at the coal face".
   v) Repeat the process for each remaining event, one row at a time.

c) Complete column 5 by rating the significance of each row

   i) Rate "significance": 1 = Low, 3 = High. Debate significance using one or more of the following bases:

      - the increase in risk engendered by each event (focus on the adverse effects in column 3);
      - the timing of the event (focus on column (0), early failures to assert control may be seen as more significant than later failures);
      - the importance of the controls and barriers to risk management in the organisation (focus on column 4, but framed in a wider context of operations and activities).

   ii) Decide which rows are to be taken forward into columns 6 to 8

d) Complete columns 6-8, one row at a time:

   i) Complete column 6: in what way was the barrier or control stated at column 4, ineffective?
      - Your statement needs to be clear and specific to the event discussed;
      - You statement should be justifiable (e.g. against an applicable standard, expert opinion or supportive argument)

   ii) Complete column 7: Identify what upstream measures would have put the control or barrier (in 6) in place, made it work and notice if it failed. In what ways did these fail?
      - Your statements need to be clear and specific and justifiable;
      - If uncertain about the facts, write a question and use a "?".

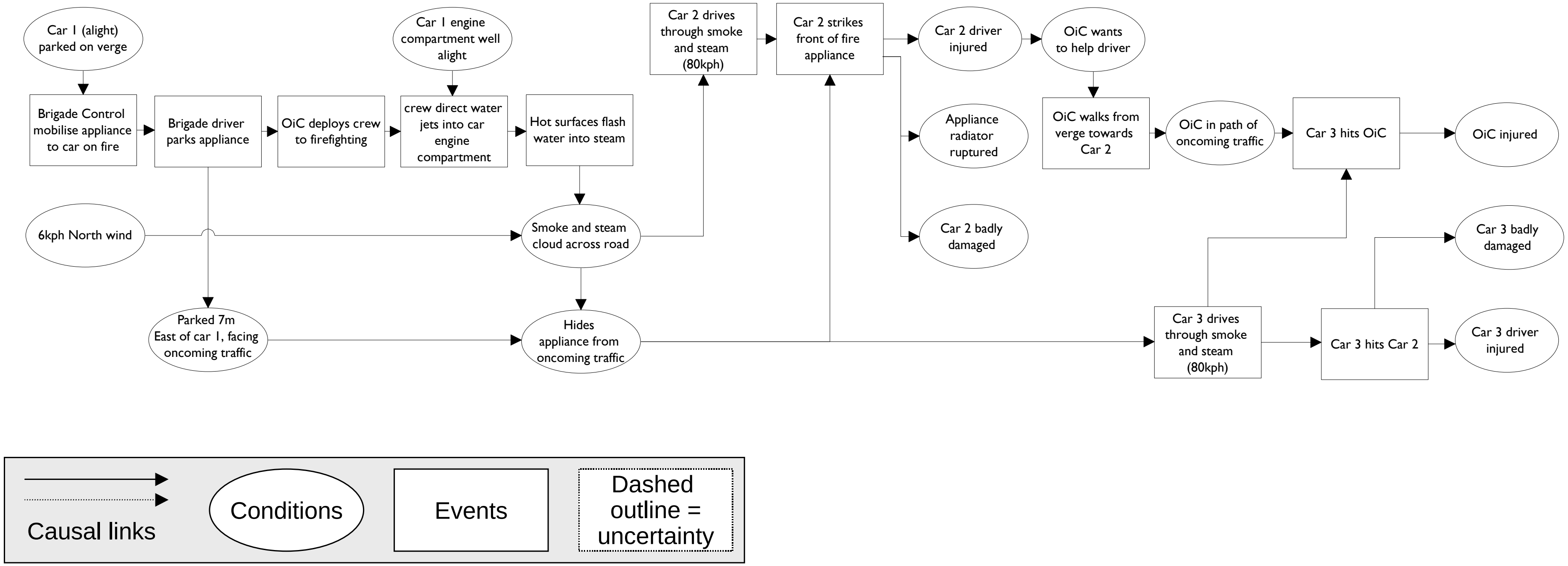
   iii) Complete column 8: explain why were the measures in column 7 ineffective:
      - Keep questioning "why", seeking to uncover deeper causes;
      - Your statements still need to be clear and specific and justifiable;
      - If uncertain about the facts, write a question and use a "?".

Appendix 1

Variables for analysis	Method	
	3CA	ETBA
Disturbing factor	Agent of change *Person, thing, energy or substance that can change the condition of the target*	Energy Flow *Potentially harmful energy flow or adverse environmental condition*
Vulnerable target	Change to person or thing *Harmful changes to people and assets.* *Unwanted changes to objects and arrangements*	Target *Vulnerable people or objects*
Preventative measures	Barriers & Controls *Barriers: Solely protective devices and systems.* *Controls: Devices and systems designed to deliver operational goal, which protect as a by-product*	Barriers & Controls *Barriers: Solely protective devices and systems.* *Controls: Devices and systems designed to deliver operational goal, which protect as a by-product*

Table 5 Comparison of 3CA and ETBA (Barrier Analysis)

Appendix 2



A condensed events and conditional factors analysis of accidents that occurred during a firefighting operation. Because the chart has been condensed, the majority of the events shown would qualify as significant events for inclusion in column (0) of the 3CA.

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Appendix 3: 3CA Table Format

(0) *Significant Events* ↓	(1) Change to person or thing *(include attribute altered)*	(2) Agent of change *(include actor and action)*	(3) Adverse effect of change	(4) Work controls or protective barriers implicated in (1)/(2) *(controls or barriers with direct effect at "the coal face")*	(5) Signif-icance Rating *(1 to 3, where 3 = very)*	(6) In what way was each measure at (4) ineffective *(be specific and precise)*	(7) In what way did upstream* processes fail to identify or prevent the problems noted in (6) *(be specific and precise)*	(8) "Why"? *(ask "why" of each entry in column 7)*

1. Complete column (0); a significant event is one that creates an adverse change in the control of work.
2. Complete columns (1) to (4) ONE ROW AT A TIME
3. Review table and assign significance rating in column (5)
4. Decide which rows are to be considered further
5. If required, complete columns (6) to (8) ONE ROW AT A TIME (be specific, general statements are not helpful and reflect lack of insight into actual problems)

* ***Upstream*** *meaning organisationally, administratively or managerially prior to the matter in question*

Appendix 4

Hierarchy of measures for 3CA

Apply these phrases to the contents of columns 1 and 2 of the 3CA analysis sheet to generate ideas for barriers and controls:

1. Do not use…
2. Use less of…
3. Use safer form of…
4. Prevent build-up of (or divert)…
5. Barrier on…
6. Barrier between…
7. Separate in time or space.
8. Use stronger…
9. Evasion by…
10. Less people or less valuable thing…
11. Repair thing or rehabilitate people.
12. Absorb loss or transfer the risk.

Example: in the accident described in the summary ECFA+ chart (Appendix 2) steam is created when the fire crew direct jets of water into the engine compartment of the burning car and, later, Car 2 ruptures the appliance radiator when it crashes into the front of the appliance. These are considered in the table below.

Example / *Hierarchy*	*Water from hoses flashes into steam...*	*Car 2 ruptures radiator of fire appliance*
1. Do not use…	Do not use water as the fire-fighting medium	Do not use car 2 (i.e. Brigade stop traffic on arrival)
2. Use less of…	Less volume by using ultra-fine droplet size water spray	Car 2 – less speed
3. Use safer form of…	Use a different fire-fighting medium (e.g. foam or powder)	n/a
4. Prevent build-up of (or divert)…	n/a	Divert traffic around appliance (e.g. crew members act as traffic marshals)
5. Barrier on…	n/a	Crumple zone on car 2
6. Barrier between…	n/a	Physical guard between radiator and front of appliance
7. Separate in time or space	n/a	Position radiator away from exposed areas of appliance
8. Use stronger…	n/a	More resilient type of radiator
9. Evasion by…	n/a	n/a
10. Less people or less valuable thing…	n/a	Do not rely on radiator as critical part of system (engine drives pump) for fire-fighting
11. Repair thing or rehabilitate people	n/a	n/a
12. Absorb loss or transfer the risk	Tolerate steam hazard created by fire-fighting	n/a

Hierarchy of measures used to brainstorm a list of barriers and controls
(NB. the practicability of the barriers and controls would need to be verified before further 3CA analysis)

NRI Document Improvement Proposal

1. Document reference	2. Document date	3. Document title
3CA Manual v2.7	31 May 2005	3CA Manual

4. Recommended improvement (identify page, paragraph and include modified text or graphic, attach pages as necessary)

5. Reason for recommendation

6. Originator of recommendation

Name:	Organisation:	
Address:	Phone: Fax: E-mail:	**7. Date of submission**

8. Send to NRI Secretariat

Name:	*Address:*	
F. Koornneef	Noordwijk Risk Initiative Foundation P.O. Box 286 2600 AG Delft The Netherlands	Phone: +44 (0)1952 850595 Fax: +44 (0)1952 850596 email: info@nri.eu.com