INVESTIGATION TOOLS IN CONTEXT

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ABSTRACT

The right tool applied in the right situation can make a significant contribution to the efficiency and effectiveness of an investigation. This paper presents an overview of tools and their uses from contrasting perspectives.

Tools such as sequencing methods, root cause analysis and methods for hypothesis formation, can fulfil a number of roles within investigation. These include facilitating teamwork, assisting with the communication of findings, aiding the transparency of an investigation and assisting the management of complex investigations. Tools add to the confidence of stakeholders in an investigation and to its efficiency. As each tool has a distinctive function and range of application, rather than "one-size-fits-all", a toolkit approach is advocated. For example, sequencing tools can help by allowing investigators to build an externalised model of the events under inquiry that helps direct inquiries to areas of uncertainty. Root cause methods can improve the quality of investigation by ensuring breadth of scope and depth of inquiry. However, the benefits of using tools are far from automatic.

INTRODUCTION

The Noordwijk Risk Initiative Foundation exists to further understanding and sharing of knowledge in the field of risk management. Because we believe that a virtuous circle exists between making tools and developing theoretical understanding, the Foundation develops tools for risk management and maintains them in the public domain.

A first issue for discussion is the application of the word "tool" to analytical methods and procedures. We use *tool* to convey the same meaning as when the word is applied to, say, a mechanical tool; in both cases *an instrument which conveys some advantage to its user in the execution of a task*. A number of issues flow from the analogy between mechanical and 'methodological' tools: the design considerations for tools and the types of benefit derived from using them are two that we shall explore in this paper.

As is true of tools in general, many factors determine performance and inform selection, not just the characteristics of the tool itself. Figure 1 summarises these factors in four groups: the characteristics of people using or choosing the tool or its product; the investigation task in hand, and; the wider social and technical context of the investigation. Each of these factors interacts with the others and so the lines in figure 1 can be regarded as interfaces. Hence, the obvious point that different tasks require different tools and the rather more subtle suggestion that diversity in the population needs to be accommodated by variety in – and flexibility of – the tools available. In all cases, "one size fits all" does not apply to investigative tools.

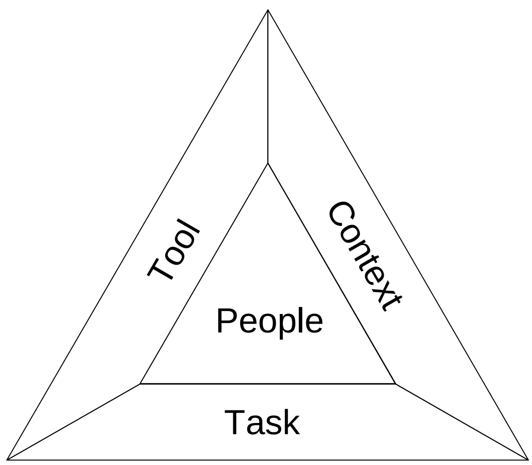

Figure 1. Factors relevant to the selection of an investigation tool

THE RELEVANCE OF THE TASK TO TOOL SELECTION

Within investigation, there are many types of task. Among this variety are four main types to which analytical tools are applied (note that these categories that are not mutually exclusive):

- organising facts sequentially;
- generating hypotheses;
- identifying norms, novelties and deviations;
- delving into root cause.

Sequencing Tools provide a means of reducing accidents to a collection of events and circumstantial facts, ordered using chronology and cause-and-effect relationships. The resulting structures can serve as models of the accident or incident under study.

Rigorous application of sequencing tools can be very helpful for clarifying what actually did happen, a state of knowledge sometimes quite distinct from what the investigators (and sometimes the witnesses also) *think* happened.

Examples of tools in this category include:

- ECFA+ – Events and conditional factors analysis (Kingston et al, 2004);
- STEP – Sequential timed events plotting (Hendrick and Benner, 1987);

Sequencing methods help to clarify what is known at a given point in an investigation and to pinpoint areas of uncertainty about events and their immediate causes. Tools like fault-tree analysis – FTA (Vesely W.E., 1981) and change analysis[1] can facilitate filling these gaps. These work by helping investigators to **develop hypotheses** about alternative scenarios and possible causal factors. In this way, the two classes of tool (sequencing and hypothesis generating) can be used in a complementary way to identify uncertainty and help to organise the search for additional facts about what happened and how. Risk analysis tools such as HAZOP and FMEA, can also help investigators form hypotheses about immediate causes.

The task of identifying **norms, novelties and deviations** (or *INND*, to coin an acronym) is quite distinct from the tasks described so far. When an incident occurs, it sometimes signals failures in the control of an activity or protective systems. To provide the focus for subsequent [root] causal analysis, these failures can be characterised as deviations from norms. In many cases, identifying norms equates to identifying the standards that applied to a specific instance of control or protection. To support the argument that a deviation occurred, the investigator needs to verify that these standards did apply (by supplying a relevant argument or test of reasonableness) and show how their presence would have prevented the occurrence or mitigated its effects.

On occasion, the occurrence or effect may be quite novel relative to the activity in which the accident occurred (e.g. a component failure mode that had never been identified before). In this case, the analytical effort is on characterising the novel problem.

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[1] *Change Analysis*, as described by Bullock (1981), is closely related to *Problem Analysis* (Kepner and Tregoe, 1981)

Tools designed to assist the task of identifying NNDs include Energy Trace and Barrier Analysis (Trost and Nertney, 1995 and also Frei et al., 2002) and Control Change Cause Analysis – 3CA (Kingston, 2002).

Analysis of Root Cause is the fourth type of task and can be assisted by using tools that help to identify *why* events occurred as they did. In this paper, the term "root cause" refers to the organisational/administrative concomitants and antecedents of specific failures of control and/or protection[2].

Root cause tools provide an interpretative structure in which to explain data level phenomena. The logic of root cause analysis is worthy of comment: whereas the other classes of tool operate at the data level (Klir and Rozehnal, 1996) – or zero order – of the system in which the accident occurred, root cause tools are one, or more, levels of abstraction removed from this.

Tools for root cause analysis vary from one another in how they organise the root cause reasoning process. Some tools rely on structuring the *process* of inquiry, others use *prompt-lists* in the form of questions grouped into themes drawn from the risk management theory adopted by the tool designer.

Tools such 3CA provide investigators with a process to help bring problems into focus and analyse them in an orderly way. Within tools such as MORT (Frei et al., 2002) and the root cause tool within HS(G)65 (HSE, 1997), greater reliance is placed on questions to drive the analysis forward.

Throughout this paper we have indicated the need to consider tools in the plural and that "one size does not fit all"**.** However, **not all tools will complement each other.** For example, MORT is designed to be used with Barrier Analysis; both employ Haddon's (1966) energy–barrier–target concept. However, Barrier analysis will not necessarily complement all root cause tools (Kingston, 2002). When building a toolbox, tools need to be selected to ensure that they will complement each other across the range of tasks for which they are intended.

THE RELEVANCE OF PEOPLE TO TOOL SELECTION

In the introduction, we suggested that a tool could be defined as any instrument that conveys some advantage to its user in the execution of a task. In the light of this, it is helpful to consider the usability issues implicit in matching tools to people. When addressing usability, it is necessary to acknowledge the diversity of groups whose needs may vary. In relation to investigative tools, this includes: line personnel serving an investigative function; SHE professionals choosing tools for themselves or others to use; personnel facilitating, managing or reviewing investigations, and; personnel outside the investigation who have a stake in its findings. A tool that satisfies one constituency may not fit the needs and preferences of another; at worst, a corporate motivation to support staff who are undertaking investigations with an ill-fitting tool can amount to placing an obstacle between those staff and the investigative task that they see.

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[2] However, the term "root cause" is sometimes used to refer to the control/protection failure itself.

Complexity can be source of difficulty for people trying to make sense of an incident and investigative tools can be very helpful here. A common-sense approach can take one a fair distance but, ultimately, informal investigations are forced to cut their investigative cloth to fit their cognitive pocket. Consequently, reasonable lines of enquiry may not be followed, evidence conflicts may not be spotted and root causes may be left unidentified. Complexity can be considered as having two forms: *detail* and *dynamic* (Senge, 1992). Sequencing methods are very helpful for people investigating or being briefed about dynamically complex events. Root cause methods, and tools to support hypothesis formation, are of particular help with investigations that are complex in their detail. As well as the advantage to investigators and stakeholders, such methods also support the tasks of reviewing and managing complex investigations by providing a measure of **transparency**.

A Team investigation has many advantages over a solo approach. As noted by Koornneef (2000), the involvement of frontline operational personnel can be especially advantageous in this respect. Two benefits of a team approach stand out:

- people bring different skills and perspectives and the interaction between team members can lead to new and interesting insights;
- investigators learn from taking part in investigations, and a team approach is more likely to be able to maintain learning over time within the organisation.

A sequencing method like ECFA+ can be of great benefit to teamwork because it provides a way of building a **model** of the incident under investigation. As noted by Espejo and Harnden (1989): *“A model is expected to provide a setting, a common frame—in other words, it is expected to make visible a set of constraints, within which certain problems can be enunciated in a particular way, and certain problems solved. Let us be clear about this. A model is a convention—a way of talking about something in a manner that is understandable and useful in a community of observers. It is not a description of reality, but a tool in terms of which a group of observers in a society handle the reality they find themselves interacting with”*.

The advantages that stem from using a model have implications for the medium of the tool used to build it. In this respect, there is a lot to be said for paper and pencil and a reasonable space to allow people to move around, to see the whole analysis at a glance and to quickly add, amend and rearrange data. However, as Schallier (2000) indicates, the visualisation aspect of usable information is an important consideration in the design of ICT systems to preserve, and keep accessible, the knowledge gained from investigation.

Another dimension of teamwork is whether it is synchronous (team members working at the same time) or asynchronous and whether the team members are in the same location or not. The sequenced model provides a useful way for new or “returning” team members to acquaint themselves with the current picture of what is known within the investigation and its key areas of uncertainty. For team members working in separate locations, the analytical product of NND tools (like barrier analysis) has been reported as very helpful for briefing and for soliciting information.

Rasmussen (1988) notes the problem of cutting inquiries short by use of an informal stop rule which he caricatures as *“keep investigating until a familiar cause is found to which the cure is known”*. This has the advantage of neither rocking-the-boat nor appearing wholly superficial. It allows the investigator to send a reassuring message of business-as-normal despite the occurrence of the accident. More generally, investigations by teams can suffer from polarisation of viewpoints and mind-sets about causation. Various measures can help counter these biases, such as careful selection of the team members, allocation of roles and, importantly, detailed terms of reference. In addition, investigative tools can help ensure that the team maintains a suitable breadth of scope, depth of inquiry and a disciplined approach.

The type of User clearly influences the choice of tool. Tools vary in the demands they make on users to learn and when applied. Ideally, all tools should be designed for **usability,** for which Gould and Lewis (1985) suggest the criteria: *"should be easy to learn (and remember), useful, that is contain what people really need in their work, and be easy and pleasant to use"*. When organisations expect line personnel to undertake investigations without specialist support, a high level of usability is a prerequisite in the choice of tools.

Specialist facilitators can supply teams with the higher level of skill required to use certain tools. This approach creates the opportunity for organisations to gain the benefits of using more complex methods, like MORT, that can deliver improvements in the depth and scope of investigations. In contrast to the deployment of a team of specialist investigators, using facilitators has the additional benefit of allowing ownership of an investigation to be retained within a team assembled from line and staff positions.

Communication about the investigation's findings with stakeholders, especially members of the workforce affected by the accident and particularly those who have responsibility for devising and/or implementing remedial change, provides another argument for using analytical methods. Presenting findings using a model of the accident produced by a sequencing tool (such as ECFA+) helps to communicate the facts upon which subsequent discussion and analyses can be based. In effect, the model provides the first rung of a ladder of inference – the set of data on which the people involved will base their diagnosis and remedial actions. As Argyris (1988) explains *"The second rung is the cultural meanings that the actors believe are embedded in the data of the first rung, meanings which are commonly understood by all participants. The third rung of the ladder is the meaning the actors imposed to produce their respective diagnosis"*. A secure start on the first rung allows for efficient and effective discussion about the accident and its implications.

TOOL SELECTION AND THE WIDER SOCIAL & TECHNICAL CONTEXT

The social and technical context of an investigation is a complex milieu composed of the acute issues raised by the accident and the longer term cultural influences upon the stakeholders in the situation. Among the latter, the organisation's approach to learning is of particular relevance to investigation.

Organisational learning can benefit from accident investigation, particularly when the latter takes a structured and team-based approach to understanding events. This can strengthen relationships between the people involved and provide opportunities for management to cultivate investigative skills and recognise their value.

However, not all organisations are well placed to gain these benefits from accident investigation. Those that have gained advantages have had to tackle the difficulties associated with accidents themselves; accidents are negative events with threatening overtones. At the minimum, people involved in an accident or near-miss may feel self-conscious and under scrutiny. Also, accidents carry with them the possibility of personal injury claims and enforcement action by statutory agencies.

Argyris (1988) identifies a characteristic style adopted by people when dealing with threatening problems or situations in organisations. This style seems to be an almost automatic, defensive reflex of which the person concerned seems to be unaware. Citing his work with Schön, Argyris has refined the description of this response, which he refers to as "Model 1". It is characterised by four rules-of-thumb and two strategies:

Rules-of-thumb	**Strategies**
• Strive to be in unilateral control • Minimise losing and maximise winning • Minimise the expression of negative feelings • Be rational	• Advocate views without encouraging inquiry • Unilaterally save face (own and others)

Table 1. *Model 1*– the defensive posture characterised by Argyris & Schön

The difference between advocacy and inquiry is subtle yet powerful. Advocacy relies on the view that the system (such as a work activity) under investigation is completely understood by those who produced the procedures, specified the equipment and assigned the staff. Therefore, anything that goes wrong must be a tactical failure that can be rectified by fine-tuning. The advocacy position is dangerous but seductive: dangerous because it blocks learning and seductive because it allows the reassuring message of “business-as-usual” in the face of signals to the contrary.

The strategy of advocacy and subduing inquiry has serious implications for the usefulness of accident investigation. Ferry (1988) characterises this as follows*: "Some investigators come to the investigation wearing three hats: the fact-finding hat, the determining-cause hat, and the hat of an advocate. The third hat is unprofessional and uncalled for in an investigation. In any event, that often determines the approach used".* It is doubtful whether investigation tools alone could help counter the biases induced by the climate of the sort that Argyris describes. Indeed some root cause tools, like MORT, tend to underline management responsibility for safety and would probably be viewed quite antagonistically.

Argyris (1988) points out that it is very difficult to change the cultural response to threatening situations. However, this does allow the possibility of changing the degree of threat associated with accidents and incidents. Tools have a role here, especially sequencing methods like ECFA+ which are “democratising” when used in a team investigation and accompanied by a clear focus on learning from adversity. This brings to mind a remark made to one of us by a supervisor (during research into investigation practices[3]): “*… what you have to do is change their culture and bring them to a realisation that what is a normal risk for them eventually will hurt someone. The last thing people want are the big boys from 'on high' saying this is how you do it. So if you can go in at their level (and without going in and saying "we are from headquarters, we are here to help you") you can bring people to a situation where, from the bottom-up, they start questioning – honestly questioning – the way they do things. It is very hard to avoid distancing people and patronising them when you come in ‘from above’.”*

[3] for RoSPA, the UK Royal Society for the Prevention of Accidents (Kingston, 1998)

Turning to more **acute factors**, the level of resources allocated by the investigating organisation decides much of the approach to investigation. How organisations go about this is variable but generally linked to the perceived risk (with extra weight assigned to the actual consequences). Risk matrices can be useful tools for organisations seeking to support decision-making about investigation resources.

We have found that the **scale of the investigation**, when combined with an estimate of the **level of abstraction** at which each tool operates, provides a useful way of describing the place of each tool in the investigation toolbox. This is shown below as figure 2. The position on the vertical access is determined in practice by finding the balance between *reproducibility and confidence* on the one hand and on the other, *flexibility and speed.* This involves weighing such factors as the:

- potential severity of consequences;
- complexity of incident;
- need for independence (i.e. impartiality);
- importance of gaining information (i.e. intolerability of uncertainty about causes);
- perceptions of stakeholders (e.g. the workforce, local population and customers);
- opportunity for staff development (i.e. benefits of involvement in investigation).

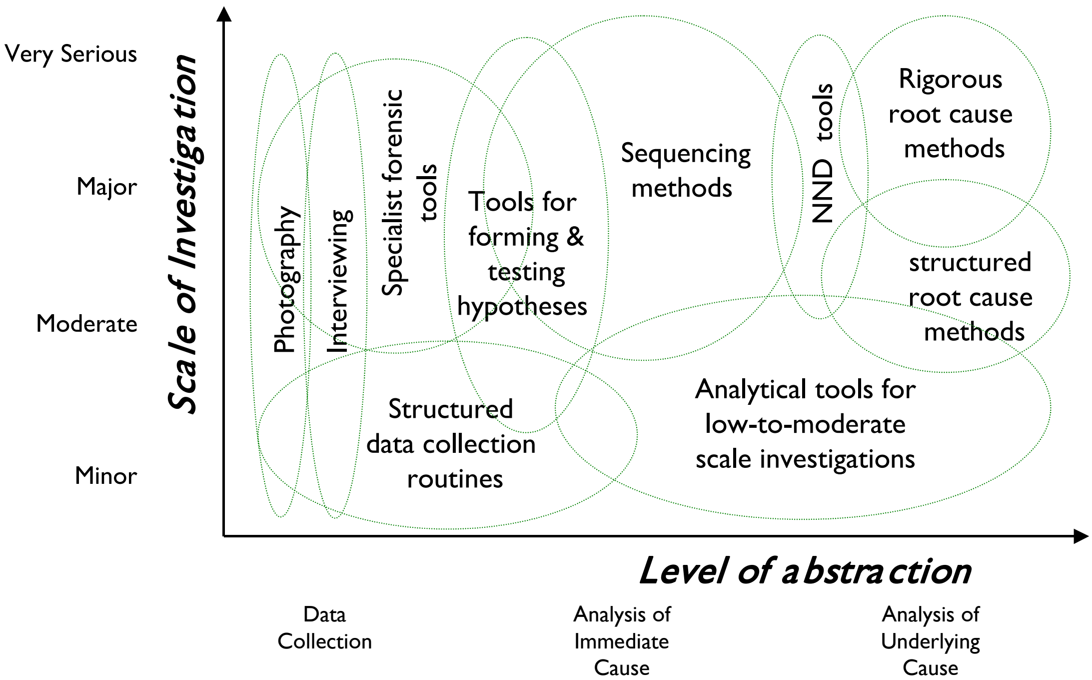

Figure 2. Skills and tools map (schematic)

The technical aspects that are specific to a given incident, clearly influence the approach that is taken, especially to data collection. Certain types of accident require support by specialists (e.g. fire investigation, component failures etc.). As indicated above, even investigations with a large component of specialist data collection can still benefit from operating on the data obtained using "general" tools. Indeed, these types of investigation have particular need to be kept open to consideration of the organisational and behavioural aspects that may seem outside of the comfort-zone of forensic specialists.

CONCLUSION

Investigation tools are not intrinsically valuable to investigation; they are servants not masters. To gain benefits, organisations need to balance the advantages that tools can offer with stakeholders' perceptions of the investigative task in hand.

In the light of this, it is useful to consider the usability issues implicit in matching tools to people. This is in addition to selecting a tool that will best fit the special attributes of the investigative task in hand. Taking these two dimensions together indicates the need for both an appropriate assortment of tools (a flexible toolkit) and that each tool accommodates diversity in the population through design for usability (a flexible tool). For tools that require a high level of practice and skill, the use of a facilitator offers a way of making the benefits of these types of tool available more widely. What matters is that an investigation identifies and communicates the basis for necessary change, in return for this and other benefits, a degree of flexibility of approach needs to be accepted.

REFERENCES

Argyris, C. (1988), "Problems in producing usable knowledge for implementing liberating alternatives". In: *Decision making: descriptive, normative and prescriptive interactions*. Edited by Bell, D.E., Raiffa, H., and Tversky, A., Cambridge, Cambridge University Press.

Benner, L. (1975), "Accident Investigations: Multilinear Events Sequencing Methods", *Journal of Safety Research*, 7, 2.

Bullock, M. (1981), "*Change Control and Analysis*". US Dept. of Energy. Ref. DOE 76-45/21, SSDC-21.

Ferry, T.S. (1988), "*Modern Accident Investigation and Analysis*". John Wiley & Sons.

Frei, R., Kingston, J., Koornneef, F., and Schallier, P. (2002), "*NRI MORT User's Manual*". Ref. NRI-1 (2002), Pub. Noordwijk Risk Initiative Foundation, The Netherlands. http://www.nri.eu.com.

Gould, J.D. and Lewis, C. (1985), "Designing for usability: Key principles and what designer's think". *Communications of the ACM*, 28, pp. 300-311.

Haddon, W. (1966), "The prevention of accidents" In: *Preventive Medicine*. Pub. Little, Brown.

Hendrick, K. and Benner, L. (1987), "*Investigating accidents with STEP*". Pub. Marcel Dekker.

HSE – UK Health and Safety Executive (1997), "*Successful Health and Safety Management*". HS(G)65. 2nd Edition. Pub. HSE Books.

Kepner, B.B. and Tregoe, C.H. (1981), "*The New Rational Manager*". Pub. Princeton Press, New Jersey.

Kingston, J. (1998), Unpublished "*Briefing Document for the RoSPA Roundtable discussion of Accident Investigation Policy and Practice*". Royal Society for the Prevention of Accidents, Edgbaston Park, 353 Bristol Road, Birmingham, B5 7ST, United Kingdom.

Kingston, J. (2001), Unpublished[4] Project Report "*Organisational Learning From Incidents"* Prepared for Humber Chemical Focus, UK.

Kingston, J. (2002) "*3CA – Control Change Cause Analysis Manual*". NRI-3 (2002), Pub. Noordwijk Risk Initiative Foundation, The Netherlands. http://www.nri.eu.com.

Kingston, J., Jager, J., Koornneef, F., Frei, R., and Schallier, P. (2004) "Events and Conditional Factors Analysis Manual". Draft Edition, Pub. Noordwijk Risk Initiative Foundation, The Netherlands. http://www.nri.eu.com.

Klir, G.J. and Rozehnal, I. (1996), Epistemological categories of systems: An overview. *International Journal of General Systems*, 24(1-2), pp. 207-224.

Koornneef, F. (2000), *Learning from small-scale incidents*. Ph.D. thesis, Safety Science Group, Delft University of Technology. Delft University Press, Delft, The Netherlands. pp 109-118. (http://www.tbm.tudelft.nl/webstaf/floork/phd/PhD-fk.pdf)

Rasmussen, J. (1988), "Human Error Mechanisms in Complex Work Environments". *Reliability Engineering and System Safety*. pp 155-167, Vol. 22. 1988.

Schallier, P. (2000), "*Designing a Safety Management Support System Using Open Architecture Databases: The requirements of information representation in the support of managers' risk-related decision-making*". PhD thesis, Aston University, Birmingham, UK. pp 216.

Senge, P.M. (1992), *The Fifth Discipline, the art and practice of the learning organization*. London, Century Business.

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

Vesely, W.E. et al. (1981), "Fault Tree Handbook"". NUREG-0942, U.S. Government Printing Office, Washington DC.

[4] Available from Humber Chemical Focus: email info@humberchemical.co.uk or contact via the website at www.humberchemical.co.uk.