

Transforming Experience Data into Performance Improvement

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Abstract

Undesired incidents generate original source data from which performance improvement actions are derived in organizations. This paper describes how front line incident investigators can leverage their effectiveness by initiating the shortest path between the original source data and actions that improve performance. The key is transforming original source data into building blocks with standardized form, structure and content. These building blocks support a standardized analysis structure, to develop timely validated descriptions of what happened. They also support a readily assimilable standardized lessons-to-be-learned structure to facilitate performance improvements. The paper describes a practical and efficient way to structure source data inputs, analyses and lessons-to-be-learned. The paper also addresses impacts on the creation of valid descriptions of what happened, development of lessons-to-be-learned, and application of those lessons to achieve improved performance, and suggests how introduce the structures.

Introduction

Fundamentally, performance improvement involves changes to processes. Processes consist of successive interactions among people, objects and energies to produce desired outputs. These interactions determine how well the process works and what it produces. Improving process performance requires understanding those interactions and changing them. Often changes are identified from incidents that produced unexpected or unwanted interruptions or outputs. Incidents are investigated and analyzed to understand what happened, resulting in cause findings and recommendations for changes. Could those practices be improved to achieve better performance improvement results?

To identify performance improvement opportunities from incidents, an essential initial task is to observe, transform and document source data generated by an incident. This documented source data forms the basis for reconstructing what happened. When we trace the flow of the data from the incident to the changed behaviors, we see that all tasks that follow the documentation depend on that task.

Despite its crucial role, little effort has been expended to analyze the data flow and tasks for transforming the original source data into a common data output format for all performance improvement uses. Let's examine that now.

We will approach this examination by looking at current practices for producing improvements, following the data inputs on which they are based, and how those inputs affect subsequent tasks until we reach the improved performance. Then we'll look at the challenges and opportunities for doing better. Finding the fastest, most direct data pathway from the experience to the performance improvement will be the objective.

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Current Performance Improvement Practices

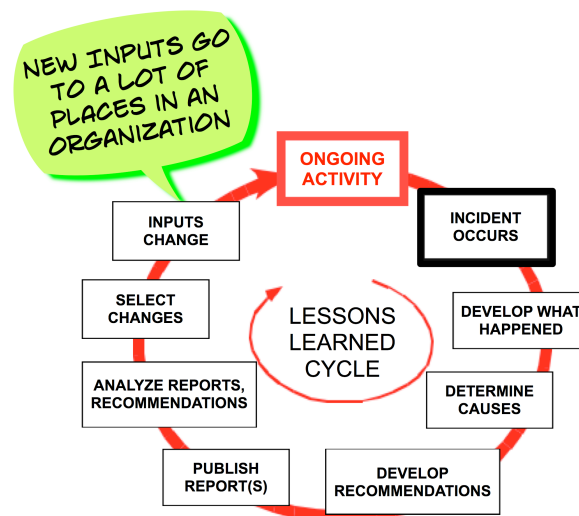
Current perspectives and practices for performance improvement from incidents are based almost exclusively on accident causation models. Investigators “observe” and capture data (or “evidence”) left by incidents, both directly and indirectly, from sources remaining and available after an incident. During the capture, investigators transform each item of evidence they observe into an individual documented input for reconstructing what happened. Organization and analysis of those inputs and their relationships leads to a description of what happened, and the determination of causes or factors and reports of findings. Subsequent analysis develops recommendations for action. Implicitly, the cause findings are the lessons-to-be-learned from the investigation, and the recommendations are the fixes. Thus actions are typically focused on implementing the recommendation.

Ultimately, if a recommendation is adopted, someone changes what they do and initiates new behaviors or develops new habits; thus the cause is removed. Those changes can affect not just individual operators but a large variety of users and objects, both within and outside an organization. Sometimes the new behaviors or behavior patterns are monitored or audited to ensure that expected improvement has been and will continue to be achieved. Until the next incident, when the lesson learned cycle starts all over again.

Those perspectives and practices focus on developing recommended actions in response to cause findings, and implementing recommendations to get performance improvements. If we follow the data from its origins to its ultimate uses, it is evident that present practices put data through many steps, which increase the time between origination and use of source data. Circumventing the recommendation steps by using source data directly in lessons-to-be-learned would reduce some data manipulation tasks in the process.

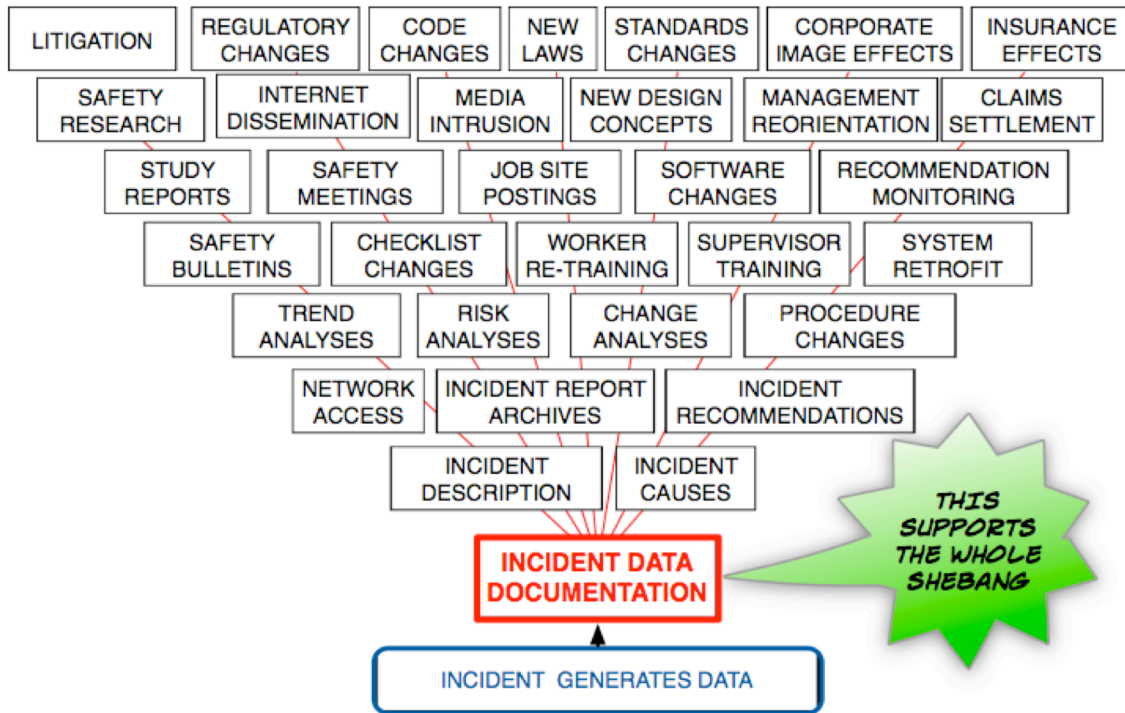
Information in the reports finds its way to many users, into updated databases, training, procedures, safety bulletins or meetings, claims, press releases, software, equipment design and other activities. In addition such reports may be used for trend analyses and other purposes. Each use guides, supports, reinforces or imposes changed behaviors during future operations. Eventually the performance of functions beyond facility operations and further removed from the incident also depend on the data developed from the original sources, such as safety research, changes to codes, standards and regulations, insurance premiums, litigation, public relations problems, or even new statutes. These relationships are depicted in Figure 2 below.

Figure 1. Incident Lessons Learned Cycle



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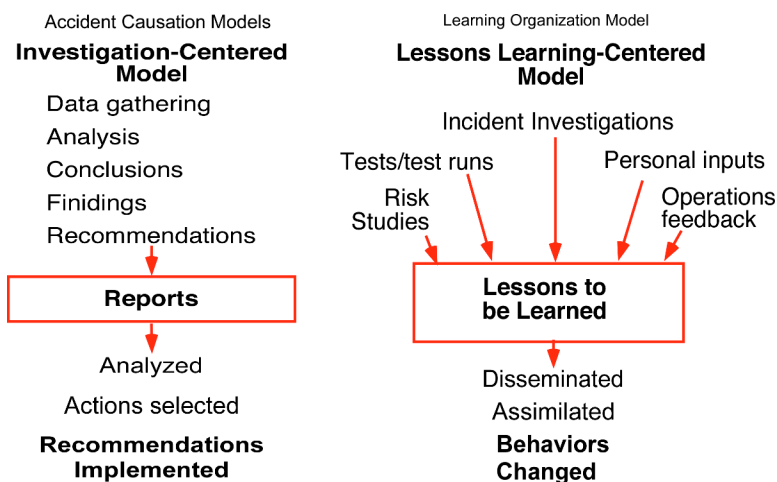
Figure 2. Experience Data Dependency Pyramid.



The pyramid is shown with the peak at the bottom, to emphasize the dependency of everything on the incident source data and its documentation during an investigation of an incident. If that base is flawed, the entire improvement structure is jeopardized.

Switching the improvement focus from recommendations to the overall *learning* process for developing and implementing lessons derived from incidents, which focuses on lessons to be learned, seems promising. Thus all these steps – and more – can be examined critically in the context of data flows in a lessons learning process. The difference in approaches is shown in Figure 3 where the remedial action decision-making is shifted from data analysts to the end users who know their operations most intimately.

Figure 3. Comparison of Learning Process Models



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Incident Data Sources

Incidents generate the original source data from which performance improvement actions are derived. Subsequent results depend on what is done with the data so generated.

Investigators must acquire and document that data to reconstruct a description and gain understanding of what happened, which poses numerous challenges. First, investigators must locate, make observations and describe all the “tracks” left by interactions during the incident. Those tracks may be in many forms, such as changes in physical objects, people’s physiological states or memories, traces on documents or digitized data. Investigators must *transform* their observations of source data into documented input data descriptions that can be used as “building blocks” to integrate all the actions and interactions required to produce the outcome. It is a critical task because every use of the data that follows depends on the quality of these building blocks.

Second, as more is learned about what people, objects or energies did during the incident, investigators need to find the reasons for their actions. This is needed to gain the necessary understanding of what happened and to expose the lessons-to-be-learned from the experience. That requires pursuit of actions by entities whose prior actions “programmed” others’ actions during the incident.

How should this be done expeditiously, to avoid garbage in garbage out problems? The principle that “if you can’t flow chart it, you don’t understand it”ⁱ provides the framework for our thinking about developing a description of what happened. An investigation should produce a flow chart of what happened to ensure it is understood.

An answer is suggested by bringing together several diverse ideas, among them some suggested by studies of work flows,ⁱⁱ some about musical scores, some from work in developing learning organizations,ⁱⁱⁱ some from cybernetics ideas^{iv} and some from economics works.^v Musical scores focus on documenting the actions needed to produce music in a reproducible way with standardized building blocks and arrays. Other works focused on analysis of workflows, or attributes for learning organizations. Cybernetics gave us feedback loops underlying lessons learning systems, and economic models contributed input-output analysis of complex interrelationships.

The musical score is perhaps most illuminating. In a musical score, a standardized universal structure is prescribed for each note or action by each musician involved in the ensemble. These actions are arrayed on a standardized structure of rows and columns, or matrix, positioning the notes for each musician according to their time sequence. That defines their relationship to each other. They are then displayed as part of a standardized output structure in the form of an annotated score describing the individual and collective actions required to produce a melodious outcome. In other words, a musical scenario can be described by showing each player’s actions as building blocks on a time/actor matrix. The musical score offers a realistic and proven model for documenting and analyzing processes like incidents.

Source data transformation structure.

By transforming observed incident source data into actor/action building blocks (BBs), with a common and standardized structure, it is possible to develop consistent practical documented data inputs from all sources for analysis and subsequent uses. To support subsequent uses, the incident-generated data needs to be transformed into BBs that:

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- Are true *logic statements*
 - Grammar, syntax and content enable determination that BB is true or not true, based on observed data and valid logical interpretation.
- Use *unambiguous vocabulary*
 - Words used to describe actions are unambiguous, at lowest level of abstraction and not judgmental or pejorative.
- Facilitate *input data analyses*
 - BBs content enables temporal and spatial ordering on structured display medium or worksheet
- Enable *interaction linkages*
 - Each BB has same structure so actions can be logically linked to show input-output relationships with other BBs, thus describing dynamics of process by forming linked input/output pairs and sets.
- Permit *validation* of descriptions
 - BBs enable application of “necessary and sufficient” testing of input/output relationships of all BBs and behavior pairs to show completeness.
- Support *downstream uses* of data
 - BB behavior sets or pairs can be used directly, without assigning taxonomy or classification, for downstream functions and tasks to achieve “minimal change sets.”

This transformation task is applicable to all kinds of incident source data that can be acquired after an incident, including investigators’ observations, training instructions, residues and debris, injuries, instrument recordings, tests, witness data, previous statements, decisions, and other sources.

A special word about vocabulary: using ambiguous or abstract words in BBs prevents input data organization and logic testing before subsequent uses. Plural actor names (firefighters) or passive voice (was struck) or opinion verbs (inadequate) or compound actor names (crowd) or conditionals (if, may) frustrate input data analysis and validation.

One published BB structure^{vi} that meets these criteria shown in Figure 4. Elements 10 and 11 are needed to satisfy the downstream use and validation requirements in support of machine

Figure 4. Incident Source Data Transformation Structure

ACTOR	1. Person or thing that did sc
ACTION	2. What Actor did
OBJECT/DESCRIPTOR	3. Additional data defining ac
LOCATION	4. Location where action occ
REMARKS	5. For remarks about BB or i
SOURCE	6. Source of data for BB crea
BEGIN DATE/TIME	7. Date and time action bega
DURATION	8. Duration of action
END DATE/TIME	9. Date and time action ende
LINKS FROM/TO	10. Link data with other BBs
N/S STATUS	11. N/S validation test status

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input/output parsing, processing and reporting, described in the analysis discussion below.

Actors named in the incident source data BBs provide a list of the people, objects or energies that must be described in detail in accompanying source references to the extent needed by users to determine BBs' relevance to users' activities. For example, more information about an involved fork lift operator and setting would be needed to determine whether a fork lift operator behavior was relevant to a production line material handling operation or warehouse receiving operation or maintenance practices or other fork lift operations. Such static descriptions are usually recorded quite unambiguously.

Standardized Analysis Structure

Johnson's principle that "if you can't flow chart it, you don't understand it" provides the framework for our thinking about structuring the *analysis* to develop a description of what happened. An investigation should produce a flow chart of what happened to ensure that it is understood.

The source data transformed into BBs can be used to develop flow charts of what people, objects and energies did by defining interactions that produced the outcome(s). An analysis structure to do that efficiently should satisfy certain requirements:

1. The indispensable requirement to produce a validated description of what happened from the incident source data.
 - a. A flow chart, rather than a narrative description is the preferred output for many reasons, including clarity, precision, comprehensibility, verifiability, efficiency and economy of words.
 - b. With a verifiable description, unsupportable lessons to learn are avoided.
2. The accommodation and timely organization of all BBs as acquired.
 - a. The analysis structure must be expandable to accommodate the addition of every new BB developed from the incident source data, as each is documented.
 - b. It must also enable the timely arraying of each new BB to show unambiguously its temporal relationship to every other BB on the matrix.
3. The need to link interacting BBs to show input-output relationships and context.
 - a. Showing successive interactions as input-output relationships is essential to describing what happened, and determining the completeness of the flow chart.
 - b. Identifying BBs that are irrelevant to process description, to dispose of false hypotheses is equally important.
4. The timely identification of gaps in the incident description.
 - a. Arrayed data must expose gaps in flow of interactions indicating unknowns for which more data and BBs are needed.
 - b. Boundaries of gaps in interaction flow to focus additional data acquisition efforts must be readily discernible.
5. Logic testing needs, to assess validity and completeness of description.
 - a. Linked BBs have to allow for necessary and sufficient logic testing of inputs to each action.
 - b. Completeness must be identifiable logically for quality assurance purposes.

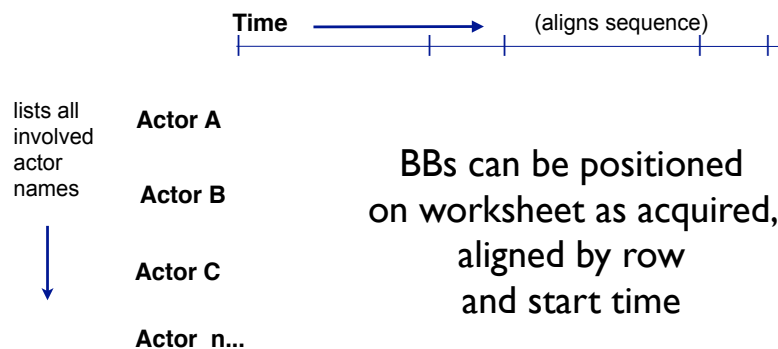
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6. Problem definition facilitation.
 - a. Arrayed BBs should facilitate orderly review of behavior pairs and sets to identify problem interactions or interactions to emulate, found by the investigation
 - b. Behavior sets can show the lessons-to-be-learned from the analysis
7. Desired interoperability capability
 - a. Machine parsing and processing compatibility is essential for element analysis and outputs, and concatenating outputs to aggregate incident experiences.
 - b. Users need to be encouraged to search for and retrieve lessons-to-be-learned by making rapid machine accessibility available.

Data analysis tools have proliferated in recent decades, starting with publication of an accident sequence diagram in an NTSB report in 1971.^{vii} Shortly afterward the AEC developed, adopted and applied the technique as Events and Causal Factors diagrams, an early form of flow charting accidents. Today, there are at least 17 different incident data analysis structures to choose from. The structures vary widely in form, content and complexity from the simple 5 Whys to the complex Functional Resonance Accident Model (FRAM). Many provide data definitions, input taxonomies or characterizations, but only one to my knowledge requires and accommodates structured source data inputs by its *analysis structure*. That structure has two main elements. It works well with standardized BBs from the incident source data just described, and satisfies all the demands for developing flow charts of interactions during incidents.^{viii}

The first element of the structure is the time/actor matrix, shown in Figure 5. This structure enables the correct positioning of every BB in its proper temporal sequence relative to all other BBs as each is documented.

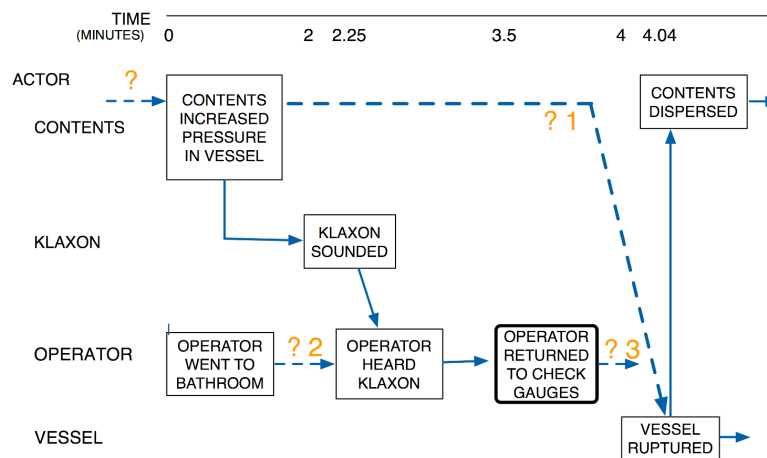
Figure 5. Matrix Elements of Data Analysis Structure



The second main element of this structure is the BB links. With this time/actor matrix and linking structure, BBs can be added as they are developed, linked as interactions are identified, flow logic tests applied as the work progresses, gaps in the flow chart discerned and bridged, and BBs and links parsed to produce outputs for end users. Support software to do this exists to facilitate data handling. Figure 6 shows a sample of this structure.^{ix}

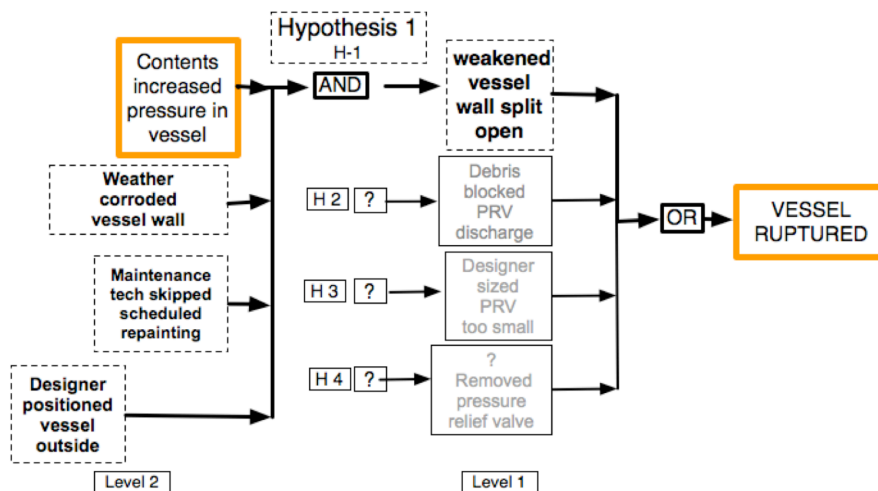
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Figure 6. Section Of Sample Worksheet.



The links show tentative or confirmed input-output relationships. The question marks are placeholders, indicating a need for additional data to complete and validate the description of what happened. These “gaps” can be subjected to hypothesis generation with “bounded” logic trees to further narrow the search for additional source data, as shown in Figure 7.

Figure 7. Example of Bounded Logic Tree Hypothesis Generation to Bridge Worksheet Gaps



The hypotheses are bounded by BBs from the worksheet. The transparency encourages valid inputs from any qualified source. Alternative hypotheses can be tested against available source data to identify the hypothesis with the most supporting data and resultant BBs. The surviving hypothesis BBs are then entered onto the worksheet to fill the gap.

Analysis output structure.

Currently investigative outputs – primarily recommendations – have no commonly prescribed structure, grammar and content, so report and recommendation contents are widely variable among organizations and industries. Their structure and content are dependent on the judgments of analysts, who are assumed to be sufficiently prescient to anticipate successful

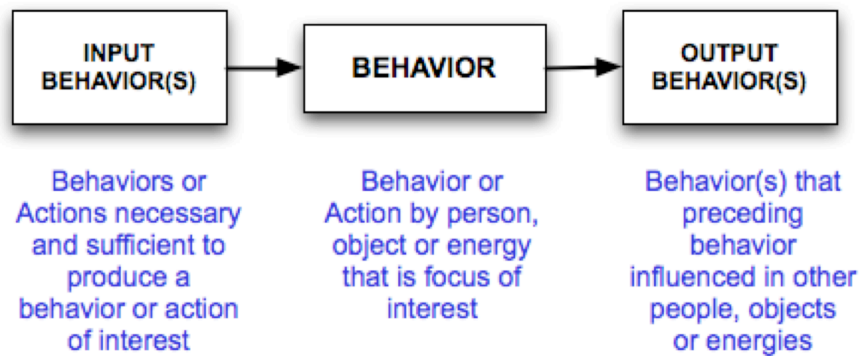
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application by the addressees. Recommendations are based on the problems and lessons-to-be-learned, again as defined by the analyst. Recommendations are typically “closed” when they are accepted. Without no specifications, it is little wonder that recommendations are widely variable structurally, and of largely indeterminate improvement value. We need provide output structure and shift action decision making to the end users, rather than the recommendation analyst?

The end users are all those who actually assimilate the lessons-to-be-learned and bring about the changed behaviors in their activities. Ideally, the analysis outputs would define the context and specific changes in behaviors that all end users could adopt directly to improve performance. Additionally, such outputs would make the behavior patterns to change clearly visible for end users, and minimize disagreements. Finally, those outputs would use economical verbiage and minimal change sets to make end users’ change tasks attractive and efficient.

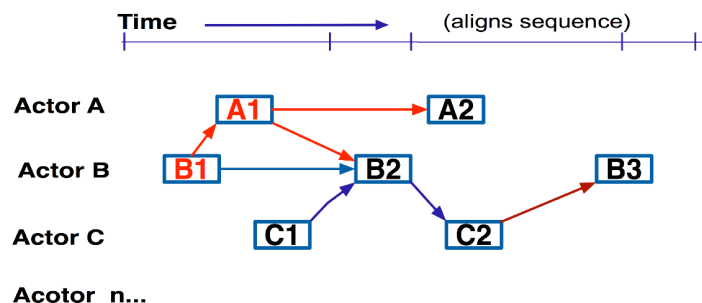
The analysis structure described above supports a common structure for lessons-to-be-learned. On worksheets, linked BBs constitute “behavior pairs” from which “behavior sets” and problem behavior sets—or behavior sets to be emulated—can be defined, as shown in Figure 8.

Figure 8. Input/Output Behavior Set



On these structured analysis worksheets, structured behavior sets can be readily identified by analysts. Figure 9 describes how that is done from the worksheets.

Figure 9. Forming Behavior Sets on Matrix Worksheets



The three BEHAVIOR SETS shown by links on this worksheet are:

1. B1 was a necessary input to A1 which in turn was a necessary input into B2 and A2
or: $B1 > A1 > A2, B2$
2. $B1, A1, C1 > B2 > C2$
3. $B2 > C2 > B3$

B3 is last BB, which is an outcome. $C2 > B3$ is behavior pair,

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Structured this way, “problem” or unwanted behavior sets in those outputs can be differentiated from non-problem behavior sets if the inputs and behavior produce unpredictable, deviant, or harmful output(s). The output’s unwanted magnitude, timing, location, or effects offer a second way. A third way, if processes have been mapped in the flow chart format, is by identifying differences in behavior patterns between incident sets and intended sets or patterns present in similar operations with successful outcomes. In a mishap description, each behavior set is a potential risk raiser.^x

When actors avert significant harm by their actions during an incident, the behavior sets that aborted the progression of the incident process reveal behaviors worth emulating.

In either case, “overlaying” incident behavior sets onto operational behavior sets shows end users the candidates for behavioral changes in their operations.

Actor/action BBs and links can be machine parsed to recast behavior pairs into behavior sets quickly and efficiently. Computer manipulation of behavior sets can produce tabular, graphic or narrative output displays for “overlaying” onto their operations, at the direction of the end users.

Behavior Set Impacts On Related Uses

It is specific input behaviors or behaviors themselves in behavior sets that must be changed, by eliminating the unwanted or adopting desired behavior patterns in ongoing or new processes. This is true whether the change involves supervisory instructions, designs, procedures manuals, training, safety meeting topics, check lists, policies, audits, codes, standards, regulations, claims reduction or other functions.

Changing behavior patterns to achieve enduring performance improvement requires creation of new *habituated* behaviors. This may require new approaches to current recommendation implementation practices, to ensure the new behaviors have been habituated, both short term and long term. By having past problem behavior sets available in minimally worded, actor-defined, readily accessible and retrievable sources, relevant current behaviors and behavior patterns are easily monitored for residual problem behavior sets in an operation. That provides opportunities to assess directly the short and long term effectiveness of the performance improvement efforts, or an assessment metric where now only inferential metrics exist.

By structuring analyses as input-output pairs and then behavior sets, “causes” become irrelevant. That means arguments about causes could be circumvented, possibly encouraging less contentious communications of safety messages among all involved.

However if causes are still demanded, the behavior sets can be translated into subjectively determined “cause” statements as they are now, but their use could be constrained by the more rigorous input-output displays of what happened.

The impact on investigation efficiency and efficacy is also noteworthy. By organizing the transformed incident source data as it is acquired into the matrix analytical structure, the investigation can quickly focus on the essential additional data required to complete the description of what happened, thus avoiding the expenditure of effort on pursuit of irrelevant data. Once the matrix has been started, it can help investigators filter and discard unsupportable theories or hypotheses that don’t fit into the data already acquired which others might want to introduce into the investigation to serve their interests.

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Challenges and conclusions.

End users who have the most to gain for structured data, analysis and lessons-to-be-learned must recognize several general challenges that impede such changes. One is the dominance of accident causation models or framework for thinking about investigation: finding some form of cause or causes dominates investigation objectives. Another is the transformation of raw source data into the building blocks, due in part to natural language barriers. Natural language linearity, grammar and syntax make it difficult to describe dynamic processes. Also, the vocabulary of safety contains many subjective, ambiguous, abstract and pejorative words. Daily safety communication habits utilize loosely structured verbose language to convey imprecise abstractions about common activities.

End users must also recognize challenges confronting investigators, such as finding and making observations of “tracks” left by dynamic actions during an incident; finding “programmer” inputs that influenced those dynamic actions; transforming both into building blocks that facilitate reproducible reconstruction of what happened; and then organizing and analyzing those building blocks to develop readily assimilable lessons-to-be-learned. Each of these impediments affecting source data transformation must be overcome to improve performance.

Other challenges to making changes are economic. The sunken investment in the status quo must be recognized as an impediment to change, but an incremental approach could be feasible. One way to introduce these source data transformation and structural changes to present practices is to add a standardized data input module to the front end of present software to generate standardized BBs. Once standardized BBs become available, adoption of standardized matrix-based analysis tools to develop behavior sets becomes a relatively simple step. When standardized behavior sets become available, publishing and disseminating them for ready accessibility and assimilation also would be a relatively uncomplicated progression.

In conclusion, it seems worthwhile for organizations to critically re-examine present practices to identify shorter data pathways and alternative analyses steps that could produce performance improvements more efficiently, faster and verifiably.

End notes.

- ⁱ Private conversation with W. G. Johnson 1972. His interest in NTSB’s HAR 71-06 Accident Report containing a flow chart of the accident led to his advocacy of Events and Causal Factors Charting in the MORT Safety Assurance System developed for the Atomic Energy Commission.
- ⁱⁱ Taylor, Frederick W., *The Principles of Scientific Management*, Harper & Brothers Publishers, New York 1911 (but without the stop watch and worker bias)
- ⁱⁱⁱ Stenge, Peter, *The Fifth Dimension: The Art & Practice of The Learning Organizations*, ISBN 0-385-26095-4 Doubleday New York 1990
- ^{iv} Weiner, Norbert, *Cybernetics-2nd Edition*, MIT Press 1965
- ^v Leontief, W., *Input-Output Economics-2nd Edition*, Oxford University Press, 1985 ISBN13:9780195035278, Chapter 2.
- ^{vi} Benner, L., *Accident Data for the Semantic Web*, Safety Science 2010 (Article in Press.)

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- ^{vii} National Transportation Safety Board, *Liquefied Oxygen Tank Truck Explosion Followed by Fires in Brooklyn, New York, May 30, 1970* HAR-71-06 adopted 5/12/91
- ^{viii} Hendrick, K. and Benner, L., *Investigating Accidents With Step*, 1986, Marcel Dekker, New York/Basel. ISBN 0-8247-7510-4. Refined in Benner, L., Guide 2, Task Guidance for Organizing and Analyzing Investigation Data, Starline Software Ltd. Oakton, VA 2003, and further refined during the development of Investigation Catalyst software.
- ^{ix} Only a portion of the BB is displayed here to emphasize structure. In practice software slows selection of the BB content to be shown at user's discretion.
- ^x Each behavior pair and set must have occurred to produce the known outcome, or have a probability of 1 during the incident, but some pairs or sets may not constitute a "problem" set.