SAFETY MANAGEMENT

Peer-Reviewed

SYSTEMS/MACRO THINKING

A Primer

By Fred A. Manuele

MORE OFTEN THAN IN THE PAST, *systems thinking* is a term used by some safety practitioners and occasionally it is found in safety-related literature. Promoting systems/macro thinking is progressive and commendable, and should be encouraged.

Many safety practitioners would increase their effectiveness by adopting the premises on which systems thinking is based in a form that is practicable and effective in the organizations to which they give advice. To adopt systems/macro thinking, safety practitioners must understand its bases.

What Is Systems Thinking?

Those engaged in the field of systems thinking have not yet arrived at a uniformly accepted definition for their subject, as the writings of several authors show.

To his own question, "What does systems thinking involve?" Goodman (2018) responds:

> The term *systems thinking* can mean different things to different people. Systems thinking is a diagnostic tool. In this sense, systems thinking is a disciplined approach for examining problems more completely and accurately before acting. It allows us to ask better questions before jumping to conclusions.

Richmond (2018) acknowledges that the application of his view of systems thinking can be difficult. He says that applying systems thinking "remains a tough nut to crack" and doing so "requires a whole package of thinking skills."

Several books relating to systems thinking have been published, such as Peter Senge's *The Fifth Discipline: The Art and Practice of the Learning Organization*, first printed in 1990 and revised in 2006, and Donella Meadows's *Thinking in Systems: A Primer*. Several excerpts from Meadows (2008) follow.

> Systems analysts use overarching concepts . . . and have many fractious schools of systems thought.

> As our world continues to change rapidly, and become more complex, systems thinking will help us manage, adapt and see the wide range of choices we have before us. It is a way of thinking that gives us the freedom to identify root causes of problems and see new opportunities. (p. 1)

> I don't think the systems way of seeing is better than the reductionist way of thinking. I think it's complementary and, therefore, revealing. (p. 6)

> The most marvelous characteristic of some complex systems is their ability to learn, diversify, complexify, evolve. The capacity of a system to make its own structure more complex is called self-organization. (p. 79)

Summation to This Point

As Meadows (2008) says, there are "many fractious schools of systems thought" among those who offer themselves as skilled in the field. If safety practitioners are to adopt systems thinking concepts, a definition suitable to the practice of safety must be written.

Meadows also speaks of complex systems and self-organization. Both subjects require comment and cautious consideration. Definitions of complexity, as on the Internet and in some books, are thought provoking and challenging. They may apply to the work of a small percentage of safety practitioners. But this author has difficulty relating them to an enormous share of organizations that make a product or provide a service.

TU Delft OpenCourseWare (2018) provides the following definition:

> A complex system is defined as one in which many independent agents interact with each other in multiple (sometimes infinite) ways. This variety of actors also allows for the "spontaneous self-organization" that sometimes takes place in a system. This self-organiza-

KEY TAKEAWAYS

- **This article discusses systems thinking and the premises on which it is based, and demonstrates that experts in this field of study do not agree on a singular definition.**
- **The author describes the status quo in the practice of safety and discusses the enormity of the culture change needed in some organizations to adopt systems thinking concepts.**
- **The article connects systems/macro thinking to having a sociotechnical balance in operations. It also encourages the use of the five-why problem-solving technique in the early stages of applying systems/macro concepts.**

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> tion occurs without anyone being in charge or planning the organization. Rather, it is more a result of organisms/agents constantly adapting to each other. The complex systems are also adaptive (i.e., they always adapt in a way that benefits them).

Leveson (2011) describes complexity as intellectually unmanageable:

> Complexity comes in many forms, most of which are increasing in the systems we are building. The operation of some systems is so complex that it defies the understanding of all but a few experts, and sometimes even they have incomplete information about the system's potential behavior. The problem is that we are attempting to build systems that are beyond our ability to intellectually manage; increased complexity of all types makes it difficult for the designers to consider all the potential system states or for operators to handle all normal and abnormal situations and disturbances safely and effectively. In fact, complexity can be defined as intellectual unmanageability. (p. 4)

Dekker's (2011) *Drift Into Failure* is devoted principally to complex systems. But it also provides valuable help in understanding the difference between a complex system and a complicated system. About interactive complexity and linear interactions, Dekker (2011) says:

> Linear interactions among component are those (that occur) in expected and familiar production or maintenance sequences, and those that are visible and understandable even if they were unplanned.
>
> But, complex interactions produce unfamiliar sequences, or unplanned and unexpected sequences, that are either not visible or not immediately comprehensible. An electric power grid is an example of an interactively complex system. (p. 128)

Dekker's example of an electric power grid being an interactively complex system is easily understood. When major power failures have occurred, unanticipated, unforeseen and varied consequences have resulted. However, not many organizations have similar exposures.

Dekker (2011) distinguishes between complex systems and complicated systems in the following excerpt:

> Complex is not the same as complicated. A complicated system can have a huge number of parts and interactions between parts, but it is, in principle, exhaustively describable. We can, again in principle, develop all the mathematics to capture all the possible states of the system.
>
> Complicated systems often (if not always) do rely on an external designer, or group or company of designers. The designers may not beforehand know how all their parts are going to work together (this is why there are lengthy processes of flight testing and certification), but in due time, with ample resources, in the limit, it is possible to draw up all the equations for how the entire system works, always.
>
> Reductionism, then, is a useful strategy to understand at least large parts of complicated systems. We can break them down and see how parts function or malfunction and in turn contribute to the functioning or malfunctioning of superordinate parts or systems. (p. 149)

A composite definition of reductionism is a theory that all complex systems can be completely understood in terms of their components; the analysis of complex things into simpler constituents.

Terminology in the literature, such as the following, are difficult to comprehend and are somewhat scary. They may apply in a few organizations, but a rare few:

- The most marvelous characteristic of some complex systems is their ability to learn, diversify, complexify, evolve;
- Self-organization occurs without anyone being in charge or planning the organization;
- Intellectual unmanageability.

This excerpt is repeated for its importance: "I don't think the systems way of seeing is better than the reductionist way of thinking. I think it's complementary, and therefor revealing" (Meadows, 2008, p. 6).

For an enormous share of the risk situations with which safety practitioners are involved, the use of reduction concepts is sufficient in applying systems/macro thinking. Safety practitioners are rarely involved in operations that are self-organizing and unmanageable.

Recommendation

Regardless of the negatives and indications of complexity in the preceding discussion, the author promotes adoption of the premises on which systems/macro thinking is based for the practice of safety. However, the macro thinking model adopted must be practicably applicable in the organizations that safety practitioners advise. In its application, systems/macro thinking applied to the general practice of safety requires:

- taking a macro view of the situation being considered and promoting collaborative discussion;
- looking at the whole of the interrelationships, interdependencies and interconnectedness of units within the processes and the human interactions within those systems;
- looking at the proverbial forest and the trees at the same time;
- being truly diagnostic;
- recognizing that several causal factors may exist for a given situation;
- determining where data can be obtained and used to evaluate the processes and the human interactions within those processes to become predictive;
- recognizing the need for communication feedback loops;
- being willing to champion interventions that may not be popular.

Comments on the Status Quo

By implication, the promoters of systems thinking (macro thinking) would have a large majority of safety practitioners convert the fundamentals of their practice from being person centered (in which unsafe acts of employees are dominant causal factors) to being systems centered (in which multiple and largely systemic hazards and risks should be addressed).

This concept that worker unsafe acts are the principle causes of occupational injuries and illnesses is deeply embedded in many organizations. That is a hindrance to macro thinking. Unfortunately, it defines the status quo (Manuele, 2014).

The author's reviews of more than 1,950 incident investigation reports indicate that a large proportion of safety practitioners take a narrow, micro view as they assist in determining the causal factors for incidents that occur. Examples follow.

1) The author was a speaker at a session arranged by ORC HSE, a consulting organization whose members represent Fortune 500

companies. When the more than 85 attendees were asked for a show of hands indicating whether identifying worker unsafe acts dominated the incident investigation systems in their organizations, more than 60% responded.

2) At a meeting of about 42 safety practitioners who had gathered for technical discussions on a standard, about 50% raised their hands when asked whether worker unsafe acts were the focus of incident investigation reports.

3) At a meeting of 121 safety personnel employed by a large manufacturing company with many locations, the participants were asked this question: "About what percentage of the incident reports at your location identify unsafe acts as the primary causal factor?" Attendees could select from the percentages shown in Table 1.

Participants indicated that for 50% or more of incidents, identification of worker unsafe acts as the primary cause total 73%. As the colleague who conducted this survey said, "we've got work to do."

To achieve a broad adoption of systems/macro thinking in operational risk management, a shift must occur from a focus on unsafe acts of employees as being the principal causal factors for incidents and illnesses to a focus on the work systems and work methods as the principal sources for causal factors. What occurs now for incident investigation in many organizations is micro thinking. Replacing that with macro thinking would constitute a major and beneficial step forward. This will require a major culture change in a huge percentage of organizations.

While providing encouragement, promoters of systems thinking (macro thinking) should be aware of the enormity of the task they undertake.

Systems or Macro Thinking

Kim (1999) says "we hear and use [the term] *system* all the time." Hollnagel (2004) implies that the term *system* is overly used and may not be sufficiently descriptive to convey the thoughts and purposes intended. Hollnagel writes, "The term [*system*] is ubiquitous in technical (and popular) writing today and is generally used on the assumption that it is so well understood by everyone that there is no need to define its meaning."

While supporting the premises on which systems thinking is based, this author now believes that the term may not convey the breadth of thinking necessary for its application. As a term, *systems thinking* may not communicate the breadth of what is intended. If the intent is to propose thinking broadly about the consequences that could derive from hazards and risks, other terms are needed such as *macro thinking, micro thinking* and *collaborative thinking*. Composite definitions of those terms are:

•Macro thinking: Very large in scale, scope or capability, taking a broad and holistic approach to the interdependent and integrated relationships between all aspects of processes and humans.

•Collaborative thinking: In real time, interfacing and discussion with colleagues who may have substantially differing views to achieve plausible and actionable conclusions.

•Micro thinking: Small and narrow in scope, centering on the unsafe acts of employees and immediately apparent physical conditions as causal factors.

Significance of an Organization's Culture

Safety practitioners must understand that how an organization encourages or does not encourage avoiding, eliminating and controlling hazards and risks is established within its culture. In addition, they must be aware that management creates and controls the culture. In too many organizations, taking a narrow, micro view of causal factors is the acceptable practice, and that identifies an element of the culture that has been created.

TABLE 1

INCIDENT REPORTS THAT IDENTIFY UNSAFE ACTS AS THE PRIMARY CAUSAL FACTOR

When safety personnel employed by a large manufacturing company with many locations were asked, "About what percentage of the incident reports at your location identify unsafe acts as the primary causal factor?" participants could select from the percentages shown in the left column.

% of incident reports	% of responses
100%	3%
75%	33%
50%	37%
25%	12%
< 25%	15%

So, for management to adopt macro thinking for operational risk management, a major change may be required that results in broadening the view it has taken of the impact its decisions and actions have with respect to hazards, risks and possible deficiencies in management. Doing so will often require a major culture change.

It cannot be overemphasized that an organization's culture will be the major determinant if a safety practitioner tries to have an entity adopt macro thinking concepts. A relative and all-too-true excerpt from Center for Chemical Process Safety (CCPS, 1994) supports this premise:

> A company's culture can make or break even a well-designed data collection system. Essential requirements are minimal use of blame, freedom from fear of reprisals, and feedback, which indicates that the information being generated is being used to make changes that will be beneficial to everybody. All three factors are vital for the success of a data collection system and are all, to a certain extent, under the control of management.

CCPS says that such guarantees may not be obtained in organizations that maintain a traditional view of incident causation (p. 259).

Relating Macro Thinking to a Model for a Balanced Sociotechnical Operation

Promoting macro thinking should also promote the benefits of having a balanced sociotechnical operation. This should be the foundation for applied macro thinking. Definitions of a sociotechnical system vary. This author's composite definition follows (note the similarity to definitions of systems thinking):

> A sociotechnical system stresses the holistic, interdependent, integrated and inseparable relationship between humans and machines and fosters the shaping of both the technical and the social conditions of work in such a way that both the output goal of the system and the needs of workers are accommodated. (Manuele, 2013, p. 58)

When safety practitioners offer a recommendation to improve a facet of an operational risk management system, they should apply macro thinking to determine how application of the recommendation may also affect other operational aspects.

Applied macro thinking takes a holistic approach to analysis that focuses on the whole of a system and its parts at the same time and the way a system's parts interrelate. Macro thinking contrasts with an analytical process that addresses a technical or social aspect of a system separately (micro thinking) without considering the relationship of that aspect to the system as a whole.

To further understand systems thinking (macro thinking), safety practitioners must understand and include the human interface of the process they advise. When promoting macro thinking and having a balanced sociotechnical operation, the organization should understand that:

•technical and social systems are inseparable, integral and interrelated parts of a whole;

•changes made in one process may have an effect on others;

•an organization's needs and employees are not well served if, when resolving a risk situation, the subject is considered narrowly and in isolation rather than as a part of an overall operating system.

This article emphasizes the importance of considering the entirety of the processes and the probable human interfaces within those processes, as well as their interdependence when an organization discusses and resolves risk-related problems.

How to Get It Done: Safety Practitioners as Change Agents

This author has discussed OSH professionals' role as culture change agent (Manuele, 2015). Safety practitioners may find it an appropriate guide as they encourage managements to adopt macro thinking concepts. Excerpts from that article follow.

> Overcoming management systems deficiencies occurs only by modifying the way things get done—that is, only if an organization's culture is changed with respect to its system of expected performance. Thus, the safety professional's overarching role is that of a culture change agent. (Manuele, 2015, p. 38)
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> An organization's safety culture, which is a subset of its overall culture, derives from decisions made at the governing entity level (e.g., board of directors, group of owners) and at the senior management level that result in acceptable or unacceptable operational risk levels. Outcomes of those decisions could be positive or negative. Safety is culture driven, and management establishes the culture. An organization's culture is translated into a system of expected performance that defines the staff's beliefs with respect to what management wants done. (Manuele, 2015, p. 39)
>
> A change agent is a person who serves as a catalyst to bring about organizational change. A change agent assesses the present, is controllably dissatisfied with it, contemplates a future that should be, and takes action to achieve the culture changes necessary to achieve the desired future. (Manuele, 2015, p. 40)

As change agents, safety practitioners should first study and become thoroughly familiar with the premises of macro thinking, and apply them in all that they do. Then they should persuade management of the benefits of adopting macro thinking and develop a convincing exhibit to support their proposal. Internal incident investigation reports can likely provide supporting data to help this cause. Exhibits should include examples of how application of macro thinking would have resulted in identifying more pertinent causal factors.

If such initiatives are successful, a safety practitioner should seek opportunities to make similar presentations to senior management. If unsuccessful, safety practitioners can still demonstrate their knowledge when they advise on hazards and risk situations. As they participate, safety practitioners can think macro and take a holistic approach. Safety practitioners take on the role of change agent by championing macro thinking. Doing so will be educational, over time, for many employees.

Incident Investigation & Causation: Introducing the Five-Why Problem-Solving Technique

Dekker (2006) makes the following astute observation, which is worthy of consideration by anyone involved in incident investigations:

> Where you look for causes depends on how you believe accidents happen. Whether you know it or not, you apply an accident model to your analysis and understanding of failure. An accident model is a mutually agreed, and often unspoken, understanding of how accidents occur. (p. 81)

Safety practitioners must recognize the fact that they apply an accident model as they participate in and give advice for incident investigations, and that they are obligated to provide advice based on a sound thought process that considers the reality of hazards, the risks that derive from them and the relative management system deficiencies.

Unfortunately, an overabundance of incident causation models and discussions about them exist. For example, Toft, Dell, Klockner, et al. (2012), comment on 13 accident causation models. Sklet (2002) discusses 14 incident investigation techniques, some of which are not identical to those noted by Toft, Dell, Klockner, et al. These are two examples of such collections; however, others exist.

As safety practitioners become change agents and promote macro thinking, they should be certain that the causation model they endorse appropriately encompasses the premises that many incidents have multiple causal factors and that most causal factors are systemic.

This author purposely avoids proposing a complicated causal factor identification system because such a system would not likely be accepted by management. Safety practitioners should become familiar with the five-why system for problem solving and use it as they apply macro thinking in their work, perhaps beginning with incident investigations. There are many reasons for this recommendation:

1) Within the practice of safety, significant improvement in causal factor determination is needed.

2) The five-why system for problem solving has long been used with great success.

3) It is easy to learn and apply.

4) It fits well with macro-thinking concepts.

5) If successfully adopted, the five-why system would:

•significantly improve investigation quality;

•lead to determining the reality of systemic causal factors;

•help determine the absence, inappropriateness, misuse or nonuse of barriers;

•evaluate the human interfaces of the process in which the incident occurred;

•provide information about when risk assessments should be made.

6) Because of its structure, the five-why technique promotes:

•involvement of individuals in the investigation group who are close to the work performed;

•critical, systematic and collaborative thinking;

•meaningful discussion that can lead to agreed-on causal factors.

7) Use of the five-why technique helps determine whether causal factors are complex enough to merit using additional investigation systems.

Applying the Five-Why Problem-Solving Technique

Three examples of applying the five-why technique are presented here (they first appeared in Manuele, 2016). Purposely, these examples are rather ordinary and not overly complex. They pertain to real-world operational situations.

The author has made adjustments and extensions in the examples to assist in identifying micro and macro thinking. These examples illustrate the thought and inquiry process used in application of the five-why technique.

Example 1

An incident's written description says that a tool-carrying wheeled cart tipped over while an employee was trying to move it. She was seriously injured. The causal factor was recorded as "Employee did not move the cart correctly." This statement demonstrates micro thinking. The following illustrates using the five-why technique to inquire further.

1) Why did the cart tip over?
We now realize that the carts are tippy because the diameter of the casters is too small. This has happened several times but there was no injury and we didn't make any reports.

2) Why weren't the previous incidents reported?
We didn't recognize that a serious injury could occur when the cart tipped over.

3) Why is the diameter of the casters too small?
They were made that way in the fabrication shop.

4) Why did the fabrication shop make carts with casters that are too small?
They followed the dimensions given to them by engineering.

5) Why did engineering give fabrication dimensions for casters that have been proven to be too small?
Engineering did not consider the hazards and risks that would result from using small casters.

6) Why did engineering not consider those hazards and risks?
It never occurred to the designers that small casters would create hazardous situations.

Causal/contributing factors: Hazard was not recognized by operations personnel; failure to report hazardous incidents; and design of the casters resulted in hazardous situations.

All of the preceding, beginning with the enumerated items, and the following demonstrate macro thinking.

Conclusion: I [the department manager] have made engineering aware of the design problem. In that meeting, emphasis was given to the need to additionally focus on hazards and risks in the design process. Also, engineering was asked to study the matter and has given new design parameters to fabrication: triple the caster diameter. On a high-priority basis, fabrication is to replace all casters on similar carts. A 30-day completion date for that work was set.

I have also alerted supervisors to the problem in areas where carts of that design are used. I have advised supervisors that when deciding whether to report an incident not resulting in injury, their decision should be on the side of being extra cautious. I also advised them to instruct all personnel who use the carts to use two people to move the carts until larger casters are placed on the carts. I have asked our safety director to alert her associates at other locations of this situation and how we are handling it.

Example 2

Operations personnel express concern about injury potential because of conditions that develop in a metal forming machine when the overload trip actuates. This is an example of how the five-why technique and macro thinking can be used to resolve hazard/risk situations before an incident occurs.

The safety director met with the supervisor who is directly responsible for the work.

1) Why are you concerned?
The electrical overload trip actuates very often when we use this forming machine. It gets risky when it stops in mid-cycle and the work that has to be done to clear the partially formed metal adds risks that our employees think are more than they should have to bear. Occasionally, that's okay. Often is too much.

2) Why does the overload trip actuate?
This is a new problem for us. We rarely had the overload trip actuate. It started after a new order for metal was received. We are told that the purchasing department thought that it got a very good deal from a metals distributor, but it turns out that what was delivered did not meet our specifications. This metal is not as malleable and workable, and the metal former struggles in the forming process. So, the overload trip actuates. Maintenance is furious with us because we have to call on them as often as we do.

3) Why can't the amperage for the overload trip be increased for this batch of metal?
Our engineers say they don't want more power fed into this machine.

4) Why do you have to call on maintenance so often?
The rule here is that no overload trip is to be reset without a review of why it tripped and clearance from maintenance.

5) Why haven't you recommended to your operating manager that he arrange a get together with the engineer and the maintenance manager to decide on what must be done to resolve the overload trip problem for this batch of metal?
That's not easy for me to do at my level. But it would be good if you could find a way to get that done.

Possible causal/contributing factors: Overexertion; machine actuating when cleaning the partially formed metal; fall potential; partially formed metal being hazardous in the handling process.

Conclusions: Management resolved this risk-related problem by involving the purchasing department as to future purchases; operations; engineering; and maintenance (macro thinking). It is often the case that risk reduction actions require participation by several interrelated functions and the application of macro thinking.

And of interest, the supervisor did not feel free to discuss a hazardous situation with the person to whom he reports.

Example 3

Description of incident: Machine operator fell and broke a hip.

Causal factors: Oil on the floor.

Corrective actions: Cleaned floor.

Note: The foregoing was the entirety of what was entered in the incident investigation report for the description, causal factors and corrective action. The entries represent micro thinking. The incident investigation form contained four signatures indicating approval. Further inquiry followed.

1) Why was there oil on the floor?
A gasket leaked.

2) Why did the gasket leak?
Bearings are worn on this machine and when it is overstressed, it vibrates a lot and the vibration loosened the joints.

3) Why is the machine overstressed?
When production is at full capacity, which is often, this machine just barely meets the demand.

4) Why haven't the bearings been replaced?
We sent a work order to maintenance on two occasions with no response.

5) Why hasn't maintenance responded?
We have been through two expense reductions and maintenance is short of staff. They prioritize work orders and ours have not reached sufficient priority status.

6) Why hasn't the machine been replaced with one that can handle production at full capacity?
That has been discussed at our department meetings, but we haven't been able to get approval.

Causal/contributing factors: Leaking gasket; worn bearings; inability of maintenance to respond to work orders on a timely basis because of understaffing; and management running a machine beyond its capacity (macro thinking).

Conclusion: Management has been alerted to what happened at this machine and the potential problems we could have with other machines that are overstressed and not being properly maintained. The injured employee is not responding well to treatment and workers' compensation claim costs for the cracked hip are estimated at $400,000. Additions have been made to the maintenance staff. Our department head submitted a capital expense request to replace the machine with one that has a larger capacity, which has been approved. Our location manager has asked all department heads to submit data on all machines that are overstressed when operations are at full capacity.

Conclusion

The author promotes adopting the premises on which systems/macro thinking is based for the practice of safety. That would add immensely to the content and effectiveness of what safety practitioners do. Now that more entities are initiating activities to further improve on the prevention of serious injuries and fatalities, macro thinking about processes and the interrelations between the elements within a process would additionally identify the reality of causal factors. Preferably, for all incidents but particularly for incidents that result in serious injuries or fatalities, systems/macro thinking should be applied with respect to the interaction and interplay of elements within a process before adverse events occur.

If safety practitioners promote adoption of systems/macro thinking concepts they should be prepared to participate in a major culture change. Also, they have a responsibility to bring to executives' attention any management systems deficiencies that may be uncovered, some of which may relate to decisions made at the executive level. **PSJ**

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