COVID-19: Exposing the need for emergency management to invest in systems thinking

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Abstract

The COVID-19 pandemic exposed numerous challenges in the emergency management (EM) response system. When confronted by the media, many public information officers (PIOs), emergency managers, public health officials, and politicians stated that the challenges COVID-19 presented were simply unforeseeable. This article contends that had EM employed a systems-thinking approach, it would have been better able to anticipate many of the evolving challenges of COVID-19. Reasons for EM not fully embracing systems thinking are discussed, including the perception that it is complex and mainly a theoretical construct. The article then attempts to dispel these beliefs by first demonstrating how many systems-thinking concepts are already embedded in the EM ethos and then by illustrating the application of system concepts in the context of the COVID-19 response. The article concludes by suggesting that EM explore the utility of System Evaluation Theory (SET) for systematically applying systems-thinking concepts in designing and adapting EM systems.

COVID19: Exposing the need for emergency management to invest in systems thinking

Progression, the ability to problem solve, is a core emergency management (EM) principle.[1] While progression is critical in any hazard, it was arguably one of the most important principles in managing the COVID-19 pandemic. Each day the COVID-19 pandemic taxed municipalities, counties, states, and the federal EM systems with new challenges. When confronted by the media during the countless daily public briefings as to why the United States was caught off guard, many public information officers (PIOs), emergency managers, public health officials, and policymakers nationwide commented that many of these problems were simply unforeseeable. The purpose of this paper is to suggest that a) many of these challenges were predictable, many pandemic plans accurately predicted the health and economic challenges, and the inability to foresee these problems was a result of EM not consistently viewing the challenges through the appropriate problem-solving lens—namely, a systems-thinking lens.

The father of general systems theory was a biologist, Ludwig von Bertalanffy,[2] who defined a system as a "complex of interacting elements." Ackoff later added that the interacting elements work together "to achieve an ascribed purpose."[3] The ascribed EM purpose, or goal, is to create "the framework within which communities reduce vulnerability to hazards and cope with disasters."[1] To meet this goal, EM must create a framework fit for purpose; it must tailor a system to meet the unique demands of each hazard. Tailoring a system begins with a hazard analysis in which the unique risks are identified.[4] The challenge is to then identify the correct capability requirements, that is, the combination of agencies and resources, or system elements, to meet the identified risks.[5] The emergency support functions (ESFs) are an example of trying to match agencies and resources to meet the unique hazard demands.[6] Anticipating the hazard demands and structuring a system to address these challenges typically occurs as part of the preparedness EM phase.[7]

Within the response and recovery phases the focus is on understanding how to make real-time system modifications, by adding, removing, or adjusting system elements to meet the evolving threats. To be able to construct and adapt systems to meet evolving threats requires that EM think critically about the utility of its approaches.[8,9,10] However, the COVID-19 pandemic exposed a fundamental problem in our EM system: a relatively poor ability to predict a novel situation. Albert Einstein is responsible for the quote, "We cannot solve our problems with the same level of thinking that created them." If EM is to avoid replicating the mistakes exposed in the COVID-19 pandemic, then it must engage in what Argyris termed double-loop learning.[11] Double-loop learners reflect on whether the approach with which they are comfortable is in fact the correct approach. Double-loop learners always ask why they are doing things the way they are doing them. Those working in EM are masters of single-loop learning, or having the ability to apply what they learned to help manage emergencies: "Doing things right."[11] For most hazards, the current EM core capabilities and approaches are proven successful. However, in any profession there comes a time when the approach learned doesn't produce the expected results. Argyris notes that,

> Put simply, because many professionals are almost always successful at what they do, they rarely experience failure. And because they have rarely failed, they have never learned how to learn from failure. So whenever their single-loop learning strategies go wrong, they become defensive, screen out criticism, and put the "blame" on anyone and everyone but themselves. In short, their ability to learn shuts down precisely at the moment they need it the most. (p. 6)

It is the author's experience that the majority of those in the EM are single-loop learners. However, when things do not go according to plan they do not blame others. The EM emphasis on continual quality improvement, combined with the altruistic nature of those attracted to EM, creates a culture of people who are always willing to explore better ways of practicing EM.

Given the inefficiencies and ineffectiveness of the EM system exposed in COVID-19,[12] reflection is needed to determine whether is there a better approach to constructing and adapting EM systems to meet the challenges that hazards present. Therefore, the question is whether we are, in fact, "doing the right thing." Since the EM challenge is to bring together and coordinate the correct combination of system elements to address a hazard, it seems that an approach better fit for purpose should also be grounded in systems thinking.[13]

Systems thinking is simply defined as a way of thinking about systems.[14] Systems thinking applies system concepts to help understand system dynamics. There is ample evidence that system concepts are already embedded in the EM ethos; the challenge is to raise this thinking from the subconscious to the conscious. For example, one foundational system concept germane to the EM context is interdependence. Interdependence focuses on understanding how elements are connected and work with each other to meet the system's purpose.[3] The EM principles of comprehensiveness, integration, coordination, and collaboration are embodied in the system concept of interdependence. Further, reference to the term *system,* or *systems*, is made over 300 times in the Target Capabilities List,[15] 18 times in the Crosswalk of Target Capabilities to Core Capabilities,[16] and 21 times in the Homeland Security and Exercise Evaluation Program (HSEEP) handbook.[17] The system references in these documents pertain to different system types, such as transportation, electrical, command, and so forth, and not necessarily systems thinking. Indeed, the use of the Incident Command System (ICS) recognizes the importance of coordinating many interdependent elements (e.g., planning, logistics, operations, finance, communications) to meet the demands of the hazard.

When one takes this evidence together, there is no doubt that the need to understand systems lies at the heart of EM. Therefore, the challenge is not to change the EM culture per se, but rather to make systems thinking explicit; to bring system concepts to the forefront of the EM approach. Thus, what is now *sporadic* systems thinking can become *systematic* systems thinking.

A review of the EM training and certification courses could not identify a single course dedicated to the topic of systems thinking. One explanation as to why systems thinking is not *explicitly* taught is that, on its face, it appears too complex. As Ackoff notes, this belief may stem from the perception that "We [systems thinkers] are an introverted profession. We do most of our writing and speaking to each other."[18] Indeed, even the authors of the relatively few articles devoted to systems thinking in the EM literature acknowledge it to be complex and largely theoretical.[19,20,21] Reinforcing this point is a recently published causal-loop diagram showing the interaction between numerous social and psychological elements as it relates to the COVID-19 spread.[22] While the accuracy or explanatory power of the causal-loop diagram is not being questioned, its predictive utility is uncertain and at first blush is overwhelming.[18] In short, its utility may never be appreciated because of its complex presentation. If systems thinking is to be embraced as *the* EM critical thinking tool, then we must make its application simpler and easier to understand.

This article aims to dispel the perceptions that system concepts are complex and of limited utility, by illustrating their application in the COVID-19 response. For each system concept a definition is first provided, followed by examples how each concept manifested itself in the COVID-19 pandemic response. The intent of these illustrative examples is to demonstrate that systems-thinking concepts are not complex, are easily applied, and are of tremendous utility in meeting the challenges of constructing and adapting EM systems to meet the demand characteristics of a hazard. It is hoped that these examples will persuade EM leadership regarding the utility of systems thinking and to make appropriate investments in developing systems thinkers to mitigate the likelihood of repeating similar mistakes in future hazards.

System Concepts and the COVID19 context

System Boundaries

Almost every discussion of systems thinking begins with boundaries. This is because the universe is one enormous interconnected system, but our current mental and technological capacity restricts our ability to understand only smaller subsystems. Therefore, defining the system boundaries to which one is referring, or analyzing, is important for establishing a common frame of reference. By definition, when boundaries are drawn, certain perspectives will be included and others omitted.[23] Knowing the perspectives being included or excluded affects the system understanding.[23]

In the EM context, defining boundaries consists of two dimensions: the hazard boundaries and the EM system boundaries. Knowing the hazard's boundaries is to understand its scope. The scope is critical in determining the size of the response system: the extent to which the response can be handled locally, and/or whether additional county, state, or federal support is needed.

There are at least two criteria needing to be considered when defining the hazard boundaries. The first is a chronological boundary, defined by when the hazard starts and ends. Each hazard will have its unique response triggers. These triggers should rely on information from a credible source and aligned to the hazard, such as in the National Hurricane Center monitoring hurricanes. In the COVID-19 pandemic, the response was triggered by an awareness of an impending public health crisis, both globally by the World Health Organization (WHO) and nationally by the Centers for Disease Control (CDC). In the county in which the author resides, the end of the response is declared by the chief medical officer (CMO). What made the pandemic so challenging, unlike an earthquake, hurricane, or flood, is that the intensity (i.e., the unknown number of asymptomatic carriers) and end date of the disease were undefined.

The second criterion is the hazard's geographical boundary. For hazards such as flood, earthquakes, tornadoes, and so forth, the boundaries are defined by the towns, counties, and states affected by the hazard. In the case of the COVID-19 response, the boundaries began in Wuhan, China, and continued to expand until the disease spread to the entire world, a true pandemic. Thus, like the timeline boundary, the COVID-19 geographical boundary knew no limits. It is this fact that makes the lack of a nationwide stay-at-home order inexplicable. Permitting the citizens of any one state or county to freely congregate and/or move about (e.g., Florida spring break. Mardi Gras, church services) undermined the attempt to reduce the nationwide disease spread.

When the hazard boundaries are understood the EM system must create an organizational and structural boundary commensurate to the hazard scope. This includes the agencies and resources needed to be coordinated to match the hazard's duration and geographical reach. For smaller incidents, like an apartment fire, the EM structural boundary may consist of just a few single agencies operating under an ICS. As the duration and affected area increases, such as the California wildfires or more recently the Australian bushfires, the structural boundaries may be expanded to include additional agencies, along with county and state EM systems.

When the hazard boundaries are finite and small, it is possible for the system to draw on surrounding resources for assistance, for example through a variety of mutual aid agreements. As the hazard boundary grows, available EM resources from outside the structural boundary naturally diminish. In the case of COVID-19, the pandemic had neither time nor geographical boundaries. As a result, the EM structural boundaries were commensurately broad, employing multiple agencies across multiple jurisdictions both nationwide and worldwide, many of whom had never coordinated together. Given that the COVID-19 pandemic had no boundaries, it was predictable that there would be very few, if any, available resources from outside any one EM system boundary. In effect, any mutual aid agreements would be deemed useless. Local, county, state, or federal EM officials trained in systems thinking would have arrived at this inevitable conclusion when the first COVID-19 cases were reported outside of China and community transmission confirmed. The documented shortage of needed personal protective equipment (PPE) and treatment equipment (e.g., ventilators)[12] could have been prevented or at least mitigated because production could have been initiated much sooner by each system at a local, county, or state level (e.g., using local 3D printers to construct PPE face shields; fashion designers to make PPE masks, etc.). The failure to anticipate this inevitability sooner led to lost time in securing sufficient PPE and necessary medical equipment, directly contributing to the loss of life.

Renger suggests that one way to define the EM structural/organizational boundary is by leveraging an understanding of the ascribed system goal.[24] In the case of COVID-19, the public health goal of "flattening the curve," that is, slowing the disease spread, was adopted by many EM systems as the common goal (see Figure 1). Understanding that the curve represents the EM system boundary beyond which there is no capacity to treat sick people requiring hospitalization was a critical factor in helping the EM response predict an impending problem and implement appropriate public health mitigation strategies, such as stay-at-home orders and social distancing.

Many countries operationalized the goal of flattening the curve by closing their international borders. In so doing they began acting as closed, rather than open, systems. Open systems exchange information, energy, or material with their environment. Biological and social systems are inherently open systems, while mechanical systems may be open or closed. The relatively closed system has rigid, impenetrable boundaries. The economic consequences of adopting a closed-border strategy became immediately evident. This is another example of how two important system concepts—boundaries and open versus closed systems—were operating and can have an impact upon EM decision making.

Insert figure 1 about here

System Elements

The EM challenge is to construct a system consisting of the necessary elements to match the hazard demands. The EM system elements must work integratively to achieve the system goals (e.g., "flattening the curve"). In the EM context, the system elements are the agencies, people, technology, equipment, and so forth needing coordination.

Renger suggested that one way to decide which elements to include in the EM system is to use the system goal as an inclusion/exclusion decision-making criterion.[24] Therefore, building on the example above, the challenge was to identify, engage, and coordinate those elements sharing in the goal of "flattening the curve." Common sense suggests that the coordination of public health, secondary, and tertiary care agencies was critical to meeting this goal. However, other agencies that share in this goal might not be immediately obvious. Fortunately, additional boundary guidance can be found in the form of the ESFs. ESF #8, the public health and medical services support function, identifies the public health and medical agencies needed but also identifies agriculture safety and security, food safety and security, worker safety and security, behavioral health care, and so forth as important functions. The ESFs also provide a list of corresponding agencies capable of providing this support.

System Relationships

After system elements are identified, it is necessary to understand how each is expected to operate and, perhaps more importantly from a systems-thinking perspective, how the elements are intended to interact with each other. To evaluate system efficiency and effectiveness, it is important to first know how the system elements are intended to interact and then compare this to how it is actually performing.[25]

In the EM context, the system concept of relationships is operationalized as agency standard operating procedures (SOPs) and/or joint standard operating procedures (JSOPs). The author has 25 years of working with prevention, secondary, and tertiary healthcare systems. In the case of COVID-19, response hospitals were a major partner. Hospitals typically have very detailed SOPs, or workflows. In a litigious, life-and-death environment, detailed SOPs are the norm rather than the exception. However, the COVID-19 response also included volunteer agencies to coordinate, for example, the transport of vulnerable populations to a Point of Dispensing (POD) for vaccination. These agencies typically do not have any written SOPs, and if they do the SOPs are seldom of sufficient detail to be useful for training purposes or to evaluate whether the response is being executed with fidelity.

As evidenced by the HSEEP building-block approach, the importance of agencies having written emergency response plans (ERPs) and practicing together with the intent purpose of adjusting their individual plans is well understood. However, in the author's experience, too often ERPs are incomplete and do not contain the detail as to how agencies are supposed to interact. The memorandums of understanding (MOUs) that are in place often do not detail the agreement engagement triggers or the steps both parties need to take to operationalize the agreement. EM must insist that agencies work out this level of detail before a response, and evidence of such cooperation must be made a condition for inclusion as a system element. To do anything else, to allow even one agency not to comply, jeopardizes the functioning of the entire system.[3]

During the EM preparedness phase, significant resources are invested in understanding the system boundaries, coordinating the elements, and defining the relationships. In the Australian EM context, this is referred to as defining the system arrangements, a term more conducive to the system concept of relationships.[26] Once the initial system is defined, the HSEEP building-block approach is applied to systematically test the system's efficiency and effectiveness. The results of this testing lead to improvement plans and corrective actions to better define the system boundaries (e.g., a different trigger), elements (e.g., additional agencies), and relationships (e.g., revised SOPs).

However, where the rubber meets the road is during a real-world event. Despite all its preparation, the EM system will be required to make real-time corrections to the boundaries, elements, and relationships to accommodate changing hazard demands. The inability to recognize when the system needs to be adjusted can have catastrophic consequences. Fortunately, there are many systems-thinking concepts that can be brought to bear to help analyze and better predict needed system adjustments, including feedback loops, cascading failures, reflex arcs, waste, and shock. These are discussed in the sections that follow.

Feedback loops

> A feedback loop is the part of a system in which some portion (or all) of the system's output is used as input for future operations. Each feedback loop has a minimum of four stages. During the first stage, input is created. During the second stage, input is captured and stored. During the third stage, input is analyzed and during the fourth stage, the insight gained from analysis is used to make decisions.[27]

Feedback loops are perhaps one of the most frequently employed and vital EM system concepts. EM systems are continually monitoring the hazard, analyzing the data collected, disseminating it, and using it to drive decision making. For example, in the COVID-19 response, the World Health Organization (WHO) was the trusted source for monitoring and reporting the spread of COVID-19 as it moved along the pandemic periods and phases, from animal to human transmission.[28] As the pandemic neared the United States, the Centers for Disease Control (CDC) joined the WHO in providing critical pandemic data and public health countermeasures. The feedback from these two sources should have served as a key early warning system providing the time necessary for EM to begin standing up their response systems.

Renger suggested that feedback loops should be evaluated using six criteria.[29] The first is that the feedback loop be closed. If the information being relayed is not received, then it cannot be acted upon. The importance of ensuring that feedback is transmitted and received is one reason that EOC managers are encouraged to engage in regularly scheduled operational period and situational update briefings.

Second, the feedback must be deemed credible. The CDC's crisis and emergency risk communication (CERC) for infectious disease outbreaks states that for information to be deemed credible, the message must be delivered honestly and supported with scientific information.[30] Further, the CERC guidance specifically warns against making "promises about anything that is not yet certain, such as the distribution of vaccines or medications" and "to be right," the latter referring to accurate messaging.[30] There are countless examples of where the White House, state, and public health messaging was contradictory and where all parties initially underplayed the significance of the COVID-19 impact on our nation.[31,12] The consequence of this contradictory messaging was that it undermined the credibility of all parties. It also points to the importance of letting subject-matter experts and trained Public Information Officers (PIOs) maintain message control. The impact of such messaging on controlling the disease spread and ultimately the number of deaths cannot be known, but it is indisputable that such messaging was a contributing factor to Americans' failure to heed early public health recommendations for social distancing and to their spreading of COVID-19.[32]

Third, the feedback must be deemed relevant if it is to be used. Examples of relevant feedback in the COVID19 response included data on the number of cases and deaths made available at the national, state, and county levels.[33,34] The ability to partition the data by region allowed different parts of the EM response system to tailor their response timing.

Fourth, the feedback must be timely. Feedback delays could render the information useless and result in decisions that no longer fit the current situation. One problem early in the COVID-19 response was the availability of laboratories to process test results. For example, early in the response, COVID-19 screening results in Arizona were sent to the state laboratory, which took up to six days to process them.[35] The delay in feedback affected decision making at the individual and system levels. Essentially, individuals who were positive, but did not receive confirmation of this, could have continued to spread the disease for up to six days. The delay in screening results meant that the EM system was always behind in its understanding of the disease's prevalence and therefore, by definition, was always playing catch-up in its decision making. As New York governor Andrew Cuomo stated in one of his COVID-19 press briefings, "We've been behind this virus from day one," and "You don't win playing catch-up."

Fifth, feedback must be sufficiently frequent. The feedback frequency must match the hazard's pace. Although the lack of test availability made it difficult to know exactly how fast COVID-19 was spreading, it is safe to say from the Italian and Spanish data that there was sufficient forewarning of rapid transmission. On the positive side, the CDC provided near real-time updates to its website regarding the number and location of new cases as well as the death rate. Thus, although data input was constricted by test availability and processing time, it appears the dissemination mechanism was able to keep pace.

Finally, the feedback must be specific. The less specific it is, the more the feedback remains open to interpretation by the receiver. In the COVID-19 pandemic there were numerous instances where the phrase "shelter in place" was used interchangeably with the guidance to "stay at home." These are two different concepts. "Shelter in place" is a stricter and more desperate measure, indicating that people should not leave their home at all costs, such as in the case of an active shooter. "Stay at home" orders still permit citizens to leave their homes for essentials, such as food and medicine.

The EM system also relies on feedback loops to ensure that internal processes are completed with fidelity. For example, a successful EOC requires numerous information exchanges, often every minute, within and between sections. As Henty notes, these feedback loops are designed "to input suggestions, solve problems and identify any issues that might prevent productivity."[37] Renger notes that these feedback loops can be found in agency SOPs and JSOPs and come in the form of "hand-offs," situational briefings, and so on.[29] The challenge, as described earlier, is the degree to which COVID-19 responding agencies have detailed SOPs, which is in fact highly variable. Without mapping the SOPs "from start to finish, … there is no way of seeing the process as a whole."[37] Therefore, EM must be more forceful in insisting that those agencies being coordinated in a response write SOPs to the finest possible level of detail. While all coordination of all interdependent EM system elements is key to success, the failure of just one system element can be catastrophic.

Cascading failures

Because system elements are interdependent, a problem occurring in one part of the system can be passed onto other parts of the system. This domino effect, or chain reaction, is termed a cascading failure.[38] The importance of this system concept cannot be understated. In the midst of disaster and when one is under duress, the tendency is to focus on the symptoms of a problem rather than the root causes.[39] The system concept of cascading failures broadens the problem solver's perspective to examine whether upstream system dependencies are at the root cause of the problem. For example, Renger & Granillo applied systems thinking to evaluate a Point of Dispensing (POD).[40] POD stations are deliberately sequenced to ensure maximum throughput. It was discovered that the back-up at any one station, for example at the vaccinations station, was often attributable to an upstream problem, for example security not controlling parking.

The COVID-19 pandemic provides many examples of where the system concept of cascading failures was used as a predictive decision-making tool and, conversely, where the failure to understand downstream dependencies led to devasting results. For example, there was daily discussion about "flattening the curve," a reference to a social distancing strategy designed to slow the spread so as to prevent and/or mitigate a surge on hospital resources.[41] The system concept of cascading failures had great predictive power. Epidemiological projections were forecasting the number of expected cases. Based on these projections it was possible to predict the downstream consequences of the case surge, including the shortage of hospital beds, life-saving equipment, and staff. The social distancing and stay at home orders were deliberate upstream strategies brought to bear to avoid a cascading failure. This is a wonderful example of implicitly understanding system interdependence and implementing system-wide upstream strategies to prevent a downstream problem.

However, EM must become more deliberate about its systems thinking so that it can systematically harness the power of system concepts. Embedded in the numerous pandemic influenza plans reviewed for this article are repeated references to cascading failures as a result of a pandemic, such as school closures. Social distancing strategies dictate the closing of schools and other points of gathering. This mitigation strategy caused predictable domino effects throughout our entire social and economic system. When schools closed, many parents then had to stay at home because they didn't have childcare support. This contributed to a workforce shortage, placing significant strain on those who remained. Some parents who were forced to stay at home were not paid, risking missing mortgage or rent payments and having to ration food supplies.[42] This caused individual and economic stress. By closing schools, internet services became overwhelmed. By closing schools, many children no longer received the only meal on which they depended for their daily nutritional intake.[43] Through a systems-thinking lens, the plethora of cascading events caused by just this one mitigation strategy were foreseeable. There are many other examples of cascading failures, such as the increased hospital surge caused by conflicting messaging.[12] Applying systems thinking during the prevention and protection phases could have helped EM work with the community to develop a series of pandemic countermeasures.

Reflex arcs

In simple terms, a reflex arc is the human body's mechanism for responding more efficiently to a stimulus by bypassing the need to send the signal to the brain for processing.[44] In organizational structures, reflex arcs are operationalized by limiting the need to pass everything to the top of the chain for approval (i.e., micromanaging) and allowing as many issues to be dealt with and resource-allocation decision making to occur at the lowest operational level (i.e. by frontline workers). This concept is referred to in strategic management as achieving "strategic consistency, [while] maintaining operational flexibility."[45]

The parallel concept in EM can be found in the understanding of the ICS and the concept of span of control. To improve efficiency, it is understood that no single ICS position can oversee all aspects of the EM system. The ICS structure empowers each section (i.e., planning, operations, logistics, and finance) to directly deal with issues for which they are responsible and not suffocate the IC with logistical, operational, or financial details.

In the COVID-19 response there were many examples of reflex arcs, some of which created efficiencies, others inefficiencies. One example of a reflex arc designed to create efficiencies, but with ethical consequences, occurred when some hospitals considered standing do not resuscitate (DNR) orders.[46] The purpose of a standing order is to expedite patient processing, negating the need for delays caused by waiting for physician referrals. A positive example of a medical system reflex arc is an automated referral for women presenting with breast cancer symptoms so they can receive diagnostic services sooner, thereby improving cancer survival rates. Unfortunately, the surge caused by COVID-19 placed a premium on medical equipment and forced hospitals to consider a standing DNR order.[46] The standing order being considered was a way to save staff time, preserve PPE, and free up medical equipment by not providing care to those patients whose status seemed irreversible.

A second example of a reflex arc occurred when there was an impasse between the federal government and state governors regarding Strategic National Stockpile (SNS) requesting and shipping responsibilities,[47] although "Ultimately … the federal government is responsible for making the decision to deploy all or portions of the SNS."[48] Given the impasse, governors began bypassing FEMA in an attempt to secure and coordinate PPE and medical supplies. This led to 50 states essentially competing for the same set of resources, driving up the price of the PPE and medical supplies. Governor Cuomo referred to this as essentially like "being on e-bay."[36] The lack of clarity regarding the JSOP resulted in 50 state reflex arcs, in this case creating massive system-wide inefficiencies.

Finally, a positive example of where a reflex arc improved efficiency was observed in several states, including Arizona, Illinois, and Michigan. When feedback loops were being discussed above, the problem of COVID-19 screening test results was provided as an example of feedback delays contributing to disease spread. The solution by one Arizona county was to contract directly with local laboratory services, thereby bypassing the state laboratory.[35] This bypass resulted in test results being returned in one to two days, rather than a week.

Having EM personnel fluent in systems thinking could help foresee when reflex arcs might be deliberately implemented to improve system efficiencies and/or to assess whether spontaneously occurring reflex arcs are helpful or harmful.

System shock

Shock is a body's defense response:

> In medical terms, shock is the body's response to a sudden drop in blood pressure. At first, the body responds to this life-threatening situation by constricting (narrowing) blood vessels in the extremities (hands and feet). This is called vasoconstriction and it helps conserve blood flow to the vital organs.[49]

COVID-19 placed our EM system in shock. The pandemic exhausted our resources and response capacity. In the COVID19 pandemic, resources were prioritized to the "hotspots," which were initially large urban centers like New York City, Chicago, New Orleans, and Los Angeles. By virtue of "being first," these places were able to lay first claim to outside resources, like PPE and medical equipment. They essentially became the human heart and brain. By definition, states that were affected later by the disease spread had less access to these resources. In essence, the mountain west and Midwest states were the extremities suffering the consequences of vasoconstriction. These "extremity" states were in a unique position in that they had more time to prepare than other states, but they were less likely to receive help. EM armed with systems thinkers in these states might have realized this dilemma sooner and begun seeking local solutions to meet their resource needs.

As noted in the earlier discussion of boundaries, many countries began operating as closed systems when they decided to close their borders. Therefore, EM must also understand that closed systems are vulnerable to entropy: the gradual decline of a system into disorder.[50] Operationalized, entropy might manifest itself as hoarding of PPE, for example, as in various system elements (e.g., schools, funeral homes, etc.), in the interest of self-preservation, underreporting PPE available for sharing with other system elements (e.g., private hospitals).

In the COVID-19 context, the timeline to disorder is likely tied to the time it takes to require herd immunity, which is where approximately 60% of the population is infected and has recovered.[51] The key to fighting against the force of entropy is awareness and intervention by EM leaders. Regular inputs of energy and resources are also key to long-term success. Renewal and reinforcement are required to maintain the health of the EM system. To counter entropy effects, "booster shots," or resources, from outside systems are needed on a regular basis. However, additional resources will not likely be available from a source outside the system, given that each EM system is engaged in its own survival battle. It is also doubtful that a closed system tending toward entropy and chaos will be able to anticipate and deal with additional challenges, such as a second, simultaneous disaster.

Cross-cutting system concepts

There are several system-wide cross-cutting influences including leadership, training, and information technology. These system influences must be present if a system is to operate efficiently and are often part of the root cause when it does not.

Leadership

The quality of federal and state leadership is an ongoing political hot button. In an attempt to ensure that this article's message is heard, examples of good and poor leadership are deliberately omitted. Clearly, leadership is central to any systems functioning and success.[52] Effective leaders have compassion, vision, and integrity, and they facilitate cooperation. In our current environment, EM leaders must find a way to park their own political ideology and navigate around those who are unable to do so. These leadership qualities are essential to system elements pulling in the same direction.

In the COVID-19 pandemic, it was evident that leadership conflicts created challenges for EM. There were numerous systems that needed to coordinate and cooperate, including school systems, political systems, transportation systems, communication systems, medical systems and so forth. In an emergency response these system leaders must relinquish some of their autonomy to work together efficiently and effectively. This happened with varying degrees of success. This speaks to the failure of the EM system to meaningfully engage not just agencies but also systems and their respective leaders in the prevention and protection phases. Trust must be developed between system leaders for the EM system to be effective. This requires a dedicated commitment to practicing together regularly under simulated stress conditions to develop these relationships. The leaders of these systems must be sufficiently engaged to work through the forming, storming, and norming phases so that when the response arrives they can focus on performing.[53] An annual half-day table-top exercise, for example, is unlikely to be of sufficient duration to work through the stages of relationship building needed to perform. It is the difference between listing an agency in a plan and enlisting it.

Training

Each EM system element, whether it be a person or a machine, must understand what to do and how to do it. A system needs all elements to succeed, but just one failed element can bring the system crashing down.[3] EM's commitment to training is evidenced by the hundreds, if not thousands, of training courses, utilization of the HSEEP building-block approach, and the emphases on developing SOPs, ERPs, MOUs, and Job Action Sheets (JAS) to guide system execution. However, a dedicated commitment to systems-thinking training is notably absent.

Information technology

It is a fact that our EM systems are technology-dependent. EM depends on telephones, notification systems, web platforms, social media secure servers, fax machines, copiers, and so forth.[54] Failures in technology can affect feedback loops, cause system waste, precipitate cascading failures, and contribute to system shock. Given the importance of IT, EM should consider the merit of adding an EOC section dedicated to this function.

Discussion

Evidence of systems thinking in EM can be found in its basic principles, core documents, and training materials. However, the explicit use of systems thinking in EM is currently, at best, sporadic and haphazard. Systems-thinking concepts need to be raised from the EM subconscious to its conscious. Further, systems-thinking concepts must be systematically applied to better understand how EM systems need to be initially structured and then predict how they will need to be adapted during a real-world event.

Renger developed a framework for organizing system concepts for evaluation purposes.[24] System Evaluation Theory (SET) consists of three steps to guide practitioners in the application of system concepts: defining the system, evaluating system efficiency, and evaluating system effectiveness. SET was developed in the emergency response environment, specifically for improving response to sudden cardiac arrest in a rural setting. Thus, it is directly applicable to the EM context. First, systems are defined using the system concepts of boundaries, elements, and relationships. This step mirrors the challenge faced by EM during the prevention and protection EM phases. Second, system concepts such as feedback loops, cascading failures, reflex arcs, system waste, and system shock are used to understand how to improve system efficiency.[25,38,55] Applying these concepts is critical to meeting the challenges EM faces during the mitigation, response, and recovery EM phases. Third, the system concepts of wholeness, emergence, and synergy are used to evaluate system effectiveness. Using these system concepts is key in the EM context, both for understanding the extent to which the overall mission was met and for being consistent with the HSEEP principle of creating a no-fault environment to foster continual improvement.[17]

This article has illustrated several systems-thinking concepts with the intent of altering the perception that systems thinking is complex and mostly theoretical. Some readers may criticize the examples as being Freudian in nature: they have explanatory power but no predictive power. It is important, however, that readers realize that this article was written *during* the

COVID-19 pandemic. The examples of the failure to appreciate the COVID-19 system boundaries, cascading failures, and system shock had not yet fully played out at the time of writing, so readers will be able to make their own value judgments about the predictive utility of systems thinking. Certainly, applying systems thinking isn't a guarantee that all the challenges that hazards present will be predictable, but the systematical application of system concepts will significantly increase the opportunity to foresee them.

While building systems-thinking core capabilities is encouraged across the entire EM sector, systems thinkers are most critical in system planning.[19] During the preparedness phase all system elements (e.g., agencies) should be challenged to understand how they interact as part of the system and appreciate the impact their SOPs have on other system elements. In the response and recovery phases, the COVID-19 examples demonstrate the need to be able to anticipate how a hazard is unfolding. Within the ICS and EOC structures, this responsibility falls on those in the planning section. A planning section armed with systems thinkers would be more likely to have anticipated many of the outcomes. Of course, central to the success of any systems-thinking initiative is leadership that appreciates, encourages, supports, empowers, and funds systems thinking itself.

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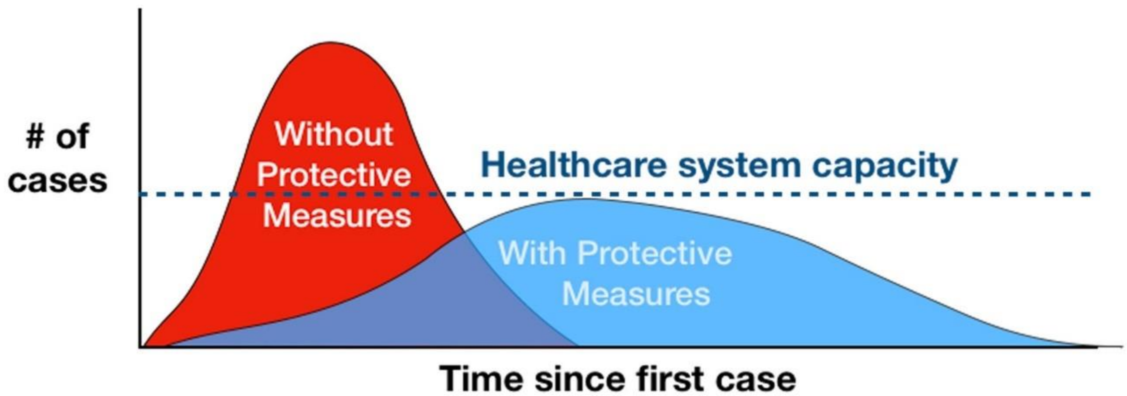
Figure 1. Flattening the curve[56]



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