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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. The article contends that had EM deliberately and systematically engaged in systems thinking; it would have been better able to anticipate and respond to many of the challenges. Reasons for EM not fully embracing systems thinking are discussed, including the perception that it is complex and theoretical. This article 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 principles in the context of the COVID-19 response. This article concludes by recommending EM invest in training to encourage the systematic application of system principles in emergency preparedness and response.

Key words: COVID-19, systems thinking, EM systems

By any standard, the emergency management (EM) pandemic response was a failure, with over ¼ million and counting dead Americans.[1] If we are to avoid repeating this catastrophe, then we must engage in the continual improvement process to understand the root causes of the response failure, formulate lessons learned, and take necessary corrective actions.[2]

Undoubtedly, some of the pandemic response failure can be attributed to factors at play in any response such as a lack of leadership, training, failure to prepare/practice, interagency coordination challenges, and so forth.[3] However, one pandemic-specific explanation was that EM had relatively little experience upon which to draw in responding to such a large-scale event. The pandemic's sheer magnitude dwarfed other large-scale responses such as hurricanes, floods, and earthquakes; something not experienced since the 1918 pandemic.[4]

While there is no substitute for experience, research suggests an understanding of the response principles underpinning hazards such as an earthquake or flood is necessary to being able to solve a new or unfamiliar scenario, like a pandemic.[5] Based on a review of the available pandemic response literature and the author's real-time evaluation of the pandemic response at the county level, it is the author's conclusion that a major factor contributing to the inability to better predict and solve the pandemic challenges was the failure to systematically apply the systems-based principles underpinning all responses: that is EM did not engage in systems thinking.[3,6-8]

> Systems thinking is defined as "literally a system of thinking about systems."[9(p2)]
>
> A system is defined as "an integrated whole whose essential properties arise [emerge] from the relationship [interdependence] between its parts."[10(p142)]

At its core, systems thinking is about understanding relationships.[9] There is ample evidence that understanding the importance of relationships is already embedded in the EM ethos. For example, establishing memorandums of understanding and/or agreement (MOUs/MOAs) to ensure smooth interagency coordination is a common EM practice. The recognition of the need to coordinate with other agencies is also inherent in the Homeland Security Exercise and Evaluation Program (HSEEP) building

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block structure, which is intentionally designed to move agencies from working independently, eg, workshops and drills, to working collaboratively, eg, tabletop, functional, and full-scale exercises.[2] Indeed, the fundamental EM principles of comprehensiveness, integration, coordination, and collaboration, and the Incident Command System (ICS) embody the essence of systems thinking.[11]

Given the evidence that systems thinking is an inherent part of the EM culture, the question is why these principles were not applied in the pandemic response? It seems reasonable to posit that one explanation for the knowledge and application transfer failure is that EM personnel were simply unaware of the system principles underpinning a response and/or how to use them to better predict and solve challenges. The challenges EM faced are analogous to an elite athlete experiencing a performance setback. Elite athletes develop fine-tuned motor programs through repeated practice.[12] When competing, these motor programs are executed as needed, automatically and subconsciously. When an athlete's performance suffers, it is sometimes necessary to reintroduce consciousness into an unconscious act.[13] EM is like a fine-tuned athlete, reliably executing what is learned through repeated practice. However, in the pandemic, its performance suffered. Therefore, the purpose of this article is to show how the application of systems principles that underpin all EM response could have helped EM better prepare and respond to the pandemic. In doing so, this article hopes to remind EM of the importance of systems thinking in emergency preparedness and response.

ILLUSTRATING SYSTEM PRINCIPLES IN THE COVID-19 CONTEXT

Many system principles have their origins in general systems theory (GST).[14] Although developed in biology, the GST principles have been successfully applied in numerous disciplines such as engineering, medicine, psychology, and information technology.[15] This article now illustrates the application of these robust system principles in the EM context, specifically to the pandemic response. The system principles discussed later are not exhaustive but will hopefully serve to illustrate the value system principles can bring to better predict and solve EM response challenges.

System parts

> System parts include a set of plans, resources, authorities, agencies, and their associated human resources.[3]

Examples of the system parts in the pandemic response include—but are not limited to law enforcement—emergency medical services, hospitals, volunteers, laboratory services, personal protective equipment (PPE), medical equipment and supplies, military personnel, and county, state, and federal EM agencies. Author et al.[16] suggested that one way to decide which system parts to include are to use the system's essential property as an inclusion/exclusion decision-making criterion. For example, in the pandemic, the response system's essential property, or goal, was to save lives by reducing and containing the disease spread. It seems logical to posit that public health, secondary, and tertiary care agencies share this goal. However, other agencies that share this goal might not be immediately obvious, such as agriculture safety and security, food safety and security, worker safety and security, behavioral healthcare, and so forth. Fortunately, additional guidance about which system parts might need to be coordinated was developed by FEMA in the form of emergency support functions as part of the National Response Framework.[17,18]

System part interdependence and emergence

> Each part of the system, when it effects the system, is dependent for it effect on some other part. In other words, the parts are *interdependent*.[19]

> The essential, or defining, properties of any system are properties of the whole which none its parts have. That is, the essential system property *emerges* as a result of the interdependencies between system parts.[19]

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After the system parts needed to mount a response are identified, it is necessary to understand how each is expected to operate.[9] In EM, this is operationalized by requiring each agency to develop an emergency response plan (ERP) and detail their standard operating procedures (SOPs), for example, by using a discussion-based exercise like a workshop.[2]

Once individual agency SOPs are completed, it is necessary to understand how to coordinate them with other agencies.[3,9,20] That is, it is necessary to detail the interdependence between system parts. The pandemic response requires the coordination of numerous agencies to stop the disease spread and save lives. For example, law enforcement and the military must coordinate to help secure smooth transport of Strategic National Stockpile (SNS) shipments. Other examples include the coordination of volunteers and health professionals to conduct wide-scale COVID-19 testing, which then state and private labs analyze, and the results of which are used to inform response strategies, eg, contact tracing and public health messaging.

Ideally, as many of the interdependencies as possible should be defined and detailed in the preparedness phase through the use of tabletop, functional, and full-scale exercises.[2] The interdependencies are then operationalized through interagency Joint Standard Operating Procedures (JSOPs), MOUs, and MOAs.

The extent to which interdependencies between key response system parts were documented pre-pandemic varied significantly. For example, a review of available pandemic plans found many were still incomplete, eg, still containing placeholders for needed information, had not been exercised in almost a decade, and either had missing or incomplete JSOPs, MOUs, and/or MOAs.[8] There was also considerable variation between system parts, that is response agencies, in the level of SOP and ERP detail. For example, hospitals typically have very detailed SOPs, or workflows. However, other response agencies, like those that are volunteer based, do not typically have written SOPs. The lack of detailed SOPs complicates the response and recovery efforts.[21,22] Since response failure is likely to occur between the "seams",[3] EM must insist that (a) agencies detail their interdependencies during the preparedness phase and (b) provide evidence of so doing before being included in the system response. Without mapping these interdependencies "from start to finish, . . . there is no way of seeing the process as a whole."[23]

With the exception of the Crimson Contagion pandemic exercise, there is little evidence that exercising occurred with the frequency or intensity needed at the state and county levels, and that the lessons learned from national and statewide exercise were incorporated into local pandemic plans.[24] Therefore, EM must be more forceful in insisting agencies work out the details of their coordination during the preparedness phase. While the coordination of all interdependent EM system parts is a key to success, the failure of just one system element can be catastrophic.[25]

In summary, the interdependence and emergence principles explain *why* it is essential that response system parts and their coordination be detailed during the preparedness phases. The failure of EM to document and practice this to the level of detail needed meant that the essential system property of saving of lives by slowing or stopping disease spread did not emerge.

System boundaries, and open and closed systems

> A system boundary separates the created system from its environment.[26]
>
> An open system is one in which energy can be transferred between the system and its surroundings.[27]
>
> A closed system is one that cannot transfer energy to its surroundings. Closed systems are susceptible to entropy.[27]
>
> Entropy is a measure of the disorder of a system. As a system becomes more disordered, the lower its energy and the higher its entropy become.[27]

Most, if not all hazards, are demarked by time and geography. In some cases, the hazard boundaries

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are clear and finite, like in a train derailment. The hazard begins when a train leaves the rails and ends when the line is reopened. The boundaries are also defined by the geographical area covered by the wreckage and spill. For example, a two-mile radius might be appropriate for an oil spill, while a hundred-mile radius might be appropriate if the spill results in a dangerous plume.

In EM, knowing the hazard's boundaries is to understand its scope. Understanding the scope, in turn, is critical to determining the required response level. When the time and geographical hazard boundaries are finite, like in a train derailment, flood, or earthquake, it is possible for the EM response system to draw on surrounding resources for assistance, for example, through a variety of mutual aid agreements. That is, in fact, how the system is designed.[18]

The pandemic boundaries were far greater in scope than other hazards to which EM is accustomed. The pandemic began on December 31, 2019 with a report from the World Health Organization (WHO) on an outbreak in Wuhan, China. The outbreak continued to spread across the world, impacting every country on earth and has no definitive end date.[28] In short, the pandemic had no geographical boundary and no known time boundary! This fact has important implications for EM response. As noted in the pandemic plans, all public health agencies were required to complete,[29] and in the Crimson Contagion After Action Report,[24] when the hazard boundary encompasses the entire country, it is unlikely that any one jurisdiction can expect to receive support from another jurisdiction. In systems' terminology, the pandemic boundaries forced open systems, where there is an exchange of information, energy, or materials, to become closed systems. Closed systems do not exchange information; they are isolated and vulnerable to entropy: the gradual decline of a system into disorder.[30]

There were many examples of the chaos caused by the pandemic boundaries forcing open systems to become closed systems. States and the federal governments were competing against each other for the same PPE on world market. Governor Cuomo referred to this as essentially like "being on e-bay."[31,32] At the local level, agencies were hoarding PPE by deliberating underreporting what was available for sharing with other system parts.[8]

If the local, county, state, or federal EM officials had been trained in systems thinking, they would have been better able to anticipate the inevitable impact of the pandemic boundaries on receiving outside resources. The shift from operating as an open to a closed system was foreseeable and inevitable as soon as the first COVID-19 cases were reported outside of China and community transmission confirmed: that is as soon as it was known there would be no finite hazard boundary. As it was, local and county response systems failed to recognize this fact and lost valuable time to engage local resources to secure and stock pile needed PPE and treatment equipment, eg, ventilators.[8,33]

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.[34] The purpose of feedback is to input suggestions, solve problems and identify any issues that might prevent productivity.[23]

The feedback loop is arguably the most frequently employed and vital system principle in EM response. Examples of feedback loops in the pandemic included EOC situational briefings, public information officer briefings, information of the disease spread on government websites, and so forth. Author[35] suggested that feedback loops be evaluated using six criteria: closing the loop, credibility, relevance, timeliness, frequency, and specificity.

> 1. *Closing the loop*. 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

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and situational update briefings. In the pandemic response, there were numerous examples of where the failure to close feedback loops between state and county EOCs, and within the county EOC, resulted in unnecessary response delays, such as the receiving and shipping of PPE.[8]

2. *Credibility*. The pandemic illustrated well the consequences of when feedback credibility is questioned. The 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. However, credibility of these agencies was undermined by political agendas.[36,37] Thus, many EM agencies were conflicted on what guidance to follow, creating confusion, and system inefficiencies. Furthermore, feedback credibility continues to be a major reason why face covering mandates are not universally implemented—a countermeasure that could have saved at least 100,000 American lives.[38]

3. *Relevance*. Feedback must be deemed relevant if it is to be acted upon. Examples of relevant feedback in the pandemic response included data on the number of cases and deaths made available at the national, state, and county levels as well as by zip code and census tract.[1,39] The ability to partition these data by region provided the opportunity for different EM systems across the country to tailor their response.

4. *Timeliness*. COVID-19 can spread very quickly. Timely feedback is critical in a quickly evolving scenario to allow EM to make necessary response adjustments. One problem early in the COVID-19 response was the availability of laboratories to process test results. For example, early in the response, all COVID-19 tests in Arizona were sent to the state laboratory. The state laboratory was overwhelmed by the surge and tests took up to 6 days to process.[40] This delay in test results had disastrous effects. Individuals who tested positive, but did not receive timely test results, could have been spreading the disease for up to 6 additional days. The delay in screening results meant that the EM system was always behind in its understanding of the disease's prevalence and incidence. Therefore, by definition, EM 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."[31]

5. *Frequency*. Although the lack of test availability early in the US response made it difficult to know exactly how fast COVID-19 was spreading initially, Italian and Spanish data provided sufficient forewarning of rapid transmission. The rapid transmission made it imperative that updates were provided more frequently. Recognizing this reality, the CDC provided near real-time updates to its website regarding the number and location of new cases as well as the death rate.[1]

6. *Specificity*. The less specific the feedback, the more it remains open to interpretation by the receiver. In the COVID-19 pandemic, there were numerous instances where the lack of feedback specificity

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created confusion. For example, the phrases "shelter in place" and "stay at home" were used interchangeable, as they were the terms "social distancing and physical distancing." These are very different concepts with different implications on behavior.

Cascading failure

> Because system parts are interdependent, a problem occurring in one part of the system can be passed onto other parts of the system. This chain reaction, or domino effect, is termed a cascading event. The consequences of a problem are usually observed downstream, while the source is said to be upstream.[16]

The importance of the cascading failure system principle in EM cannot be overstated. In the midst of disaster and when decision-makers are under duress, the tendency is to focus on the symptoms of a problem rather than the root causes.[41,42] However, the cascading failure principle broadens the problem solver's perspective to examine whether upstream system dependencies are at the root cause of the problem.

The cascading failures' principle is well illustrated by the sequence of downstream events following the decision to implement the school closure mitigation policy. When schools closed, many parents then had to stay at home because they did not have childcare support. This contributed to a healthcare workforce shortage, placing significant strain on those who remained. Some of these workers subsequently reported in sick. Many parents who were forced to stay at home were not paid, risking missing mortgage or rent payments and having to ration food supplies.[43] This caused psychological and economic stress. Additionally, by closing schools, internet services became overwhelmed, often shutting down access completely to students trying to engage in remote learning,[44] and children no longer received the only meal on which they depended for their daily nutritional intake.[45]

An example of where an understanding of the cascading failure principle helped mitigate the disease was in the "flattening the curve" strategy (Figure 1).[46] Based on epidemiological projections, hospitals recognized a surge in COVID-19 cases would overwhelm the capacity of the hospital systems. Upstream mitigation strategies such physical distancing strategies and stay at home orders were implemented to slow the disease spread and the downstream surge on hospital resources.[46] This is an excellent example of how an understanding of interdependence between system elements was be used to predict and mitigate a pandemic challenge.

Reflex arcs

> 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.[48]

In organizational structures, reflex arcs are operationalized by limiting the need to pass everything to the top of the chain for approval, ie, micromanaging, and allowing as many issues to be dealt with and resource-allocation decision-making to occur at the lowest operational level, ie, by frontline workers. In management circles, this is sometimes referred to as achieving "strategic consistency, [while] maintaining operational flexibility."[49]

In EM, the reflex arc principle is embedded in the ICS. 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, ie, planning, operations, logistics, and finance, to directly deal with issues for which they are responsible and

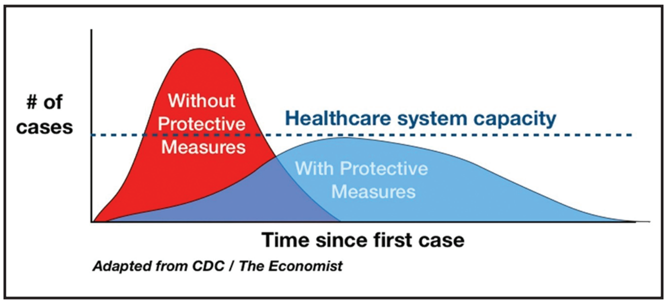

Figure 1. Flattening the curve. ***Source*****: Roberts.[47]**

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not suffocate the incident commander with logistical, operational, or financial details.

In the pandemic response, there were many examples of reflex arcs, some of which created efficiencies and 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.[50] Unfortunately, the surge caused by COVID-19 placed a premium on medical equipment and forced hospitals to consider a standing DNR order.[50] The standing DNR order was a way to save staff time, preserve PPE, and free up medical equipment by discontinuing life-saving 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 SNS requesting and shipping responsibilities.[51] Given the impasse, governors began circumventing FEMA in an attempt to secure and coordinate PPE and medical supplies. However, these bypasses 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."[31]

Finally, a positive example of where a reflex arc improved efficiency was observed in several states, including Arizona, Illinois, and Michigan. Counties in these states offset the delays in receiving COVID-19 test results from the state laboratory by contracting directly with local laboratory services.[40] This bypass resulted in test results being returned in 1-2 days, rather than a week.

System shock

> 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.[52]

The pandemic placed our EM response system in shock, exhausting our resources and response capacity. As a result, resources were prioritized to the "hotspots," which were initially large urban centers such as 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. However, the EM response in these states also failed to capitalize on the approximately 9 extra months of lead time they were afforded and were caught unprepared by a surge in cases and hospitalizations.[1]

Cross-cutting system influences

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 at the root cause when it does not.[20]

Leadership. Leadership is central to any systems functioning and success.[53] 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 parts pulling in the same direction.

In the pandemic, it was evident that leadership conflicts created challenges for EM. There were numerous systems that needed to cooperate and coordinate, 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. The level of collaboration and coordination occurred with varying degrees of success.[8,54] Trust is the foundation for improving interagency collaboration and

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coordination. This requires a dedicated commitment during the preparedness phases to work through the forming, storming, and norming phases so that when it is time to respond the focus is on performing.[55] In many instances, this did not happen.[8,54]

Information technology. EM systems are technology-dependent for their success.[3,20] Telephones, notification systems, web platforms, social media secure servers, fax machines, copiers, and so forth are all necessary for successful collaboration and coordination.[56] 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.

Training. A system needs all parts to succeed, but just one failed element can bring the system crashing down.[25] Central to this success is that people must be trained what to do, when to it, where to do it, how to do it, and why it needs to be done. 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 to guide system execution. However, a review of EM training courses could not find a single course dedicated to systems-thinking.

DISCUSSION

System principles form the foundation of all EM response. Despite the county, state, and federal pandemic influenza plans correctly forecasting many of the challenges,[29] the EM response was reacting and playing catch-up. The EM had understood the system principles underpinning these plans and engaged in systems thinking they could have been better prepared and able to anticipate many of the pandemic challenges: to act rather than react.

Trying to convince EM to invest in systems thinking, training should not be a bridge too far. This is because evidence of systems thinking can be found in the EM basic principles, its practice, and in many of its core documents. Thus, the challenge is to help increase the awareness of the system principles being tacitly applied and make them a deliberate part of the decision-making process. One major challenge in bringing systems thinking into the EM mainstream is that it is perceived as complex and largely theoretical.[57-59] This article aimed to dispel these perceptions by illustrating their application in the COVID-19 response.

Some readers may criticize the examples as being Freudian in nature, that is, they have explanatory power but no predictive power. It is important, however, that readers realize that this article was written *during* the *start* of the COVID-19 pandemic. The only updates to the article occurring until the time of publication was to the actual American death count attributable to the 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 is not a guarantee that all the hazard's challenges will be predictable, but the systematic application of system principles will significantly increase the opportunity to foresee challenges. To assist with the systematic application of system principles, Author[20] developed systems evaluation theory (SET). SET was developed in the emergency response sector to accomplish three necessary steps for improving preparedness and response: define the response system parts, their interdependencies, and their emerging essential system property.[9,20] Jackson et al. also provide a four-step framework for improving response reliability, but the system principles upon which the analyses rests are not clear from the published work.[3]

While building systems-thinking capabilities is encouraged across the entire EM sector, systems thinkers are most critical in response preparation and planning.[57] During the preparedness phase, the importance of the interdependence principle must be made salient by challenging all system parts, eg, agencies, to explain how they interact as part of the system and the impact their SOP has on other system parts. In the response and recovery phases, systems' principles are applied to anticipate how a hazard is

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unfolding. A planning section armed with systems thinkers would be more likely to have anticipated many of the pandemic challenges. Of course, central to the success of any systems-thinking initiative is leadership that appreciates, encourages, supports, empowers, and funds systems thinking.

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 by the COVID-19 pandemic, then it must engage in double-loop learning.[60] Double-loop learners reflect on whether the approach with which they are comfortable is in fact the correct approach. It will take time and resources to develop competent and capable systems thinkers, but it is an investment EM cannot afford to forgo.

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