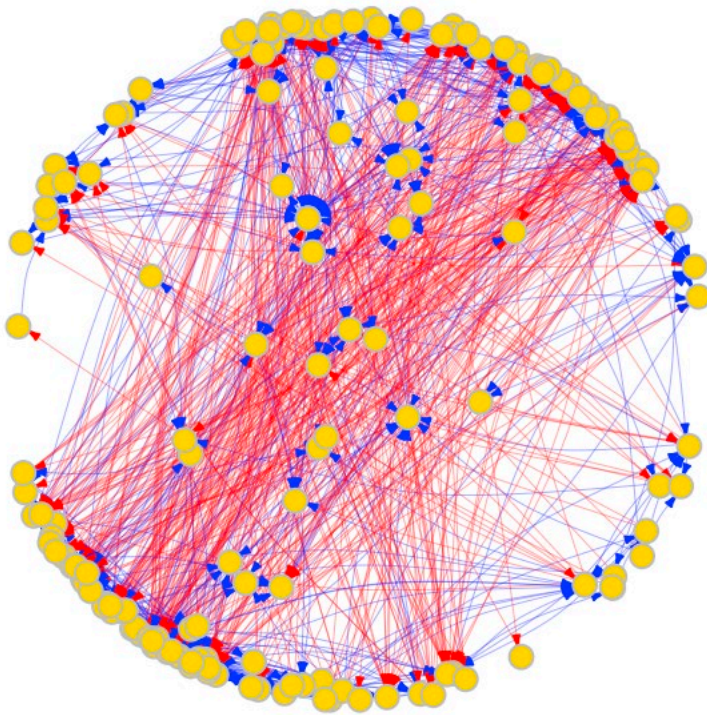


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AFRICOM Exploitable Conditions Model (AECM) Network Analysis Report



Dr. Lawrence A. Kuznar, NSI, Inc.

Produced for the Strategic Multilayer Assessment (SMA) Office (Joint Staff, J3)

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Cover image: AFRICOM Exploitable Conditions Model (AECM) network

Table of Contents

NSI Project Team	2
Executive Summary	4
The Key Drivers of Change in the African System.....	4
Operational Implications.....	4
Introduction.....	6
The AECM Network Analysis Model	6
Centrality Analysis of the AECM Network Model.....	7
Drivers in the AECM system.....	7
Receivers of Influence in the AECM System	9
First Through Third-order Effects.....	10
The AECM Strength of Government Institutions Ecosystem.....	13
The AECM Terrorism Ecosystem.....	14
Conclusion: Operational Implications of the AECM Network Analysis.....	15
Counterterrorism Efforts Appear Critical.....	15
Beware Government Repression	15
Strengthening Government Institutions is Central to Everything	16
Appendix: Glossary of AECM Node Definitions.....	17
Appendix: Centrality Metrics	20
References.....	22

Executive Summary

The physical, social, political, economic, and cultural systems that comprise the operational environment interact in complex ways. The Strategic Multilayer Assessment (SMA) *Anticipating the Future Operational Environment (AFOE)* project models this complexity with special relevance to US national security concerns. The AFOE team constructed a generic *Global Exploitable Conditions Model (GECM)* that captured this complexity as a system of nodes (or variables) and edges, which are the relationships between nodes. The generic model was then tailored to the specifics of the USAFRICOM AOR as the *African Exploitable Conditions Model (AECM)*. This report describes a network analysis of the AECM that provides insight into important conditions and dynamics that impact USAFRICOM's mission objectives.

The Key Drivers of Change in the African System

- **Terrorism.** Owing to its many direct and indirect connections to other influential nodes in the AECM system, terrorism is positioned to be a prime driver of disruption and, overall, the strongest influencer across the system. Many of the cascading effects that start with terrorism directly undermine USAFRICOM's enduring objectives and US interests on the continent.
- **Violent conflict.** As represented in the AECM, three conflict nodes—civil conflict, communal violence, and interstate conflict—are also positioned to have wide-ranging negative influence on the USAFRICOM AOR.
- **Economic growth & development** is positioned to have both a major influence on the system and to receive a lot of influence from the system. This suggests that increases in economic growth & development beget more economic growth & development, and vice versa.
- **Governance.** The strength of government institutions and adherence to rule of law each have the greatest number of paths by which they can influence the AECM system. Each pathway is an avenue for influencing a node; therefore, the more pathways that emanate from a node, the more potential influence that node can have on the system.
- **Corruption.** Corruption in government and by influential people has a strong dampening effect on economic growth and development as well as the strength of government institutions.
- **Humanitarian crises,** when they occur, are strong shocks to the AECM system through direct effects on well-being (physical, psychological, food security, employment) and indirect effects on influential nodes such as strength of government institutions and economic growth and development. Conversely, strong government institutions buffer against humanitarian crises and provide resilience to states.
- **Gender inequality** is positioned to have a significant and wide-ranging impact on the AECM system.

Operational Implications

Counterterrorism Efforts Appear Critical

Because of terrorism's position as a key driver in the AECM system, we assess that investments in counterterrorism (CT) appear to be well-founded. Terrorism can impact many nodes that are involved in key USAFRICOM concerns, including political stability, civil conflict, and humanitarian crises, in addition to terrorism itself.

Beware Government Repression

Government repression is in a position to reduce terrorism. However, if government attempts to repress terrorist activities include use of state terror and physical torture, it can have the reverse effect. US-sponsored CT efforts and military security cooperation should place a premium on professionalism and respect for the rule of law in host nation security forces.

Strengthening Government Institutions is Central to Everything

Strengthening government institutions also has the potential to improve conditions like economic growth and development, food security, and to decrease gender inequality and has wide-ranging effects on many parts of the model. It is key to addressing USAFRICOM concerns including political stability, civil conflict, humanitarian crises, and terrorism. However, because of the reinforcing effects of many of these nodes, efforts that impact any of them positively could have corresponding ripple effects on the others. However, strengthened government institutions could be easily counteracted if political stability, civil conflict, humanitarian crises, and terrorism are not also addressed.

Introduction

This report is part of the multi-phase SMA *Anticipating the Future Operational Environment (AFOE)* project intended to inform Joint Staff and Combatant Command (CCMD) decision makers, planners, analysts, assessors, and operations staff about challenges to US international influence (i.e., strategic competition). The original inspiration for this project was research conducted by the TRADOC G-2 that identified twenty-four global “exploitable conditions” that could impact US-China-Russia strategic competition (Burns et al., 2019). Phase I of the AFOE project concentrated on decomposing the 24 conditions into subsystems of elements, called nodes, that drove these conditions and exploring the connections between the nodes. The result was the *Global Exploitable Conditions Model (GECM)*, which is a conceptual model of the interrelationships among the nodes of these subsystems (Kuznar, 2022; Popp, 2022). Phase II of the AFOE project involved tailoring the generalizable GECM to the concerns of specific CCMDs. USAFRICOM was the first Command to which the GECM was applied. The first step of the tailoring involved researching the particulars of how the GECM nodes relate to one another in the USAFRICOM AOR, resulting in the *African Exploitable Conditions Model (AECM)* (see Lindquist, 2023). The conceptual model forms a de facto network of influences that can be analyzed with graph theoretic methods to gain insights into how the position of nodes in the network gives them the *potential* to either influence, or be influenced by, the system represented by the network. This report presents the network analysis of the AECM.

The AECM Network Analysis Model

In the process of tailoring the GECM to the African continent, relationships between the nodes were coded into an edgelist that recorded the direction (which node influenced another node) and whether the influence was positive or negative.¹ This edgelist provides the basic data to create a graph representation

of the network of influences represented by the AECM. The full, tailored network consists of 165 nodes and 992 connections. Figure 1² illustrates the level of structure and interconnectedness of the AECM network. Understanding how nodes are positioned to influence this system requires both analysis of the system as a whole and focusing on the ecosystem of influences around individual nodes of interest.

It is important to note that network analysis assesses the structural properties of a network and therefore identifies how nodes are *positioned* to influence the system. Actual influence depends on the flows of influence between nodes and how those flows percolate through the system. For instance, information operations are positioned to influence political stability, but only if they are

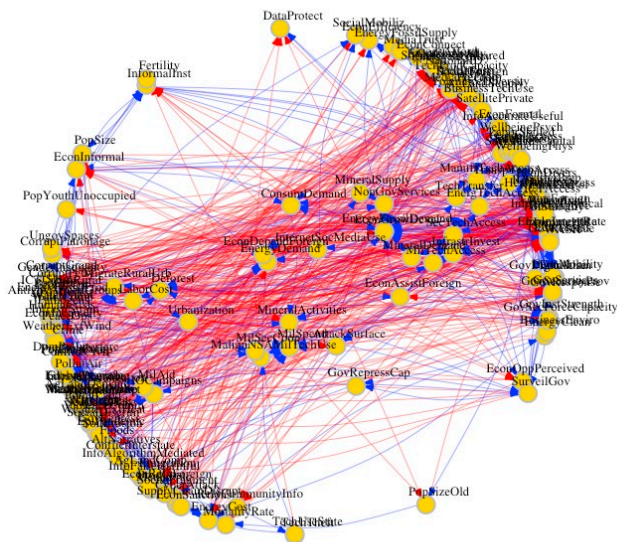


Figure 1. AECM network graph

¹ The edgelist is available by contacting Dr. Allison Astorino-Courtois (aastorino@nsiteam.com) or Ms. Mariah Yager (mariah.c.yager.ctr@mail.mil).

² This figure was produced with the Frichterman-Reingold algorithm, which places the most central nodes in the middle of the graph and less connected nodes on the periphery of a circle.

conducted effectively. However, an important first step in the analysis of a system is to identify nodes that are positioned to have leverage in a system. The following section provides analysis of the AECM system overall. This is followed by focused analyses on two influential nodes in the system: terrorism and the strength of government institutions. Nodes in the system are printed in bold and their definitions specific to the AECM are footnoted the first time a node is mentioned.

Centrality Analysis of the AECM Network Model

Centrality metrics measure a node's connectedness in the system and thus its potential to impact, or to be impacted by, the system. Impacts *on* the system measure downstream effects and, therefore, identify drivers in the system. If these nodes can be influenced, then they represent key leverage points. If they cannot be influenced, then they represent drivers that must be monitored. If a node is indicated as highly impacted *by* the system and it is of national security concern, then decision makers should consider whether the nodes that impact it can be influenced or if not.

Ten network analysis centrality metrics were used to assess a node's connectedness within the AECM model (see [Appendix: Centrality metrics](#) for a detailed description of the metrics). To analyze the system, node centrality scores are reported in two ways: representing outward influence³ (i.e., the node's impact on other nodes in the system) and/or inward influence⁴ (i.e., how a node is affected by the system). Metrics for outward and inward influence were created by adding the standard deviations above the mean for each metric. This created a score of 1–6, with higher scores indicating greater potential influence in the system.

Note: **Bold font** is used to indicate a node in the AECM.

Definitions are footnoted the first time a term is used and are also found in [Appendix: Glossary of AECM Node Definitions](#)

Drivers in the AECM system

Nine nodes scored 3 or higher for outward influence on the system, as shown in (Figure 2 on the next page). Out of the 165 nodes in the AECM system, **terrorism**⁵ had the highest outward influence score. In other words, it is positioned to have the greatest influence on the AECM system due to its many direct effects on other nodes, some of which are themselves highly connected as well as its numerous indirect effects. This finding may be particularly relevant to USAFRICOM since countering violent nonstate actors is one of its enduring objectives (Townsend, 2022). The outward centrality of **terrorism** is somewhat paradoxical since the tactical impact of a terrorist act is usually minor and limited to one or a few locations (Lutz & Lutz, 2005; O'Neill, 2005). However, populations and their governments often have strong

³ The network metrics used to measure outward influence were outdegree, Kleinberg's hub centrality, and the sum of 1st – 3rd order effects, see [Appendix: Centrality metrics](#).

⁴ The network metrics used to measure inward influence were indegree and Kleinberg's authority centrality, see [Appendix: Centrality metrics](#).

⁵ Terrorism is defined as the unlawful use of violence or threat of violence, often motivated by religious, political, or other ideological beliefs, to instill fear and coerce individuals, governments, or societies in pursuit of terrorist goals.

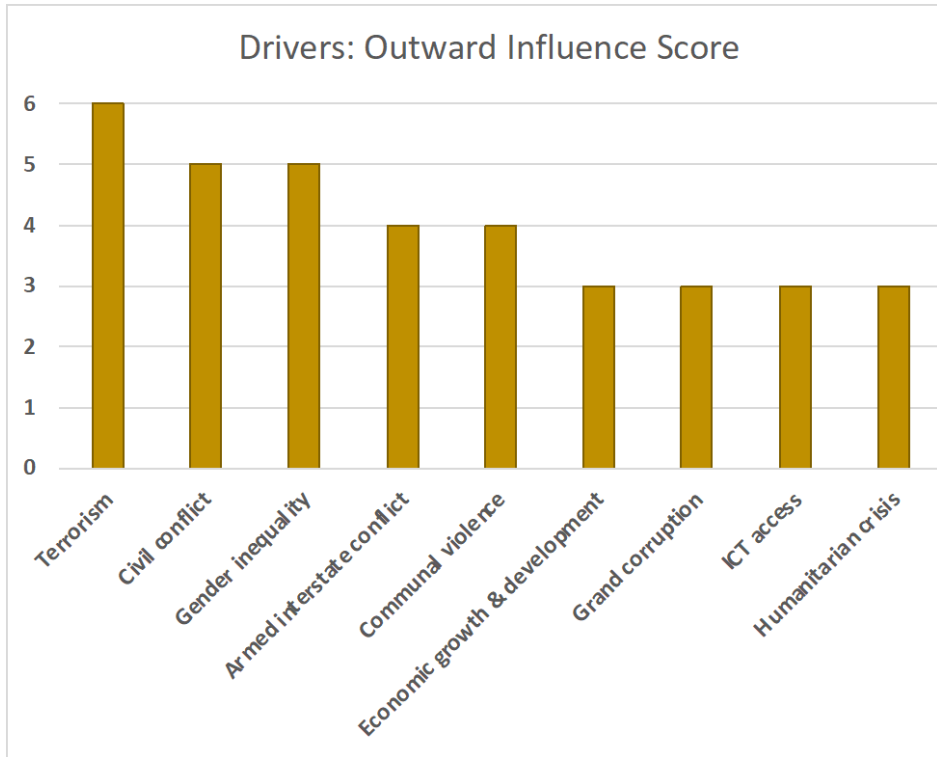


Figure 2. Network drivers in the AECM Sahel system. Nodes listed are ≥ 3 standard deviations above the mean for at least one outward influencing metric.

reactions to terrorist acts, enabling terrorists to have much greater impact on societies than their numbers, or the material effect of their actions, may warrant (Lustick, 2006).⁶ The AECM model appears to capture these disruptive impacts.

Conflict and violence impact a number of USAFRICOM's most critical concerns. Both are associated with political instability, which can lead to political crises, as well as

population

migration and **humanitarian crises**. **Civil conflict**⁷ and **communal violence**⁸ –violent disruptions that emanate from within a country— as well as interstate, or **state-based armed conflict**,⁹ are also positioned to have significant influence on the AECM system.

Humanitarian crises¹⁰ can have natural (e.g., **droughts**, **floods**, cyclones, earthquakes), human (e.g., **internal conflict**), or combined natural and human causes (United States Department of the Army, 2008). When these crises occur, they are positioned to have profound impact on the system, especially through

⁶ Lustick (2022) has also suggested that the prominence of terrorism in social science models may be due to the attention it has received from researchers; much is known about it; therefore, more connections can be made than for other more poorly known nodes.

⁷ Civil conflict is defined as the intensity and scope of a violent conflict between a state and one or more organized non-state actors in the state's territory. Includes conflicts in which additional, external actors, state or non-state, may also become involved.

⁸ Communal violence is defined as instrumental use of violence by people who identify themselves as members of a social group, defined by their differences of religion, ethnicity, language, or race group, against another social group or individual members of a social group in society (e.g., "race riots").

⁹ State-based armed conflict is defined as the intensity and scope of a conflict between the military forces of two or more national governments triggered by 1) incompatible positions regarding the state's type of political system government composition and/or 2) aims to change the state control of a certain territory.

¹⁰ Humanitarian crises are risks of a singular event or series of events that cause(s) sufficient human, physical, economic, and/or environmental damage to overwhelm a community's capacity to respond.

their impacts on other nodes that are highly connected such as **psychological health and well-being**¹¹ and **gender inequality**.¹²

Economic growth and development¹³ and **Information and Communications Technology (ICT) access**¹⁴ are also positioned to have influence on the AECM system, often through direct effects on nodes such as **employment, household income**,¹⁵ and **access to education and training**.¹⁶ **ICT access** is growing rapidly in Africa (Chin, Callaghan, & Ben Allouch, 2019; Kuznar, 2023), and other studies in the AFOE USAFRICOM project indicate that growing access to the internet dramatically raises the consumption of foreign disinformation, which fuels political polarization (Kuznar, 2023).

Grand corruption¹⁷ is another node that has a greater than average outward effect on the Sahelian system and plays a role in undermining the **strength of government institutions**, which in turn is positioned to influence many other nodes in the system. **Corruption** often emerges as a factor in empirical studies of state fragility, **political instability**, and **terrorism** (Bjorvatn & Farzenegan, 2015; Kuznar & Day, 2021).

The prominence of **gender inequality** as a driver speaks to the potential impact of restricting opportunity for half of a society's population. The network analysis of the AECM reflects the results of empirical studies demonstrating that when women's creativity and labor is unrestricted, economies flourish, politics democratizes, and societies become more peaceful (White House, 2022).

Receivers of Influence in the AECM System

Eight nodes out of the 165 in the full AECM were particularly well-positioned to receive strong influence from the system (inward influence score ≥ 3) (Figure 3). Most of these concern the physical or psychological conditions of the population, including **physical health and well-being**,¹⁸ **psychological health and well-being**, **food/nutrition security**,¹⁹ **water quality, sanitation, & hygiene (WASH)**,²⁰ and

¹¹ Psychological well-being is defined as the extent to which individuals are able to find enjoyment and happiness in life, develop resilience to challenges, and feel optimistic about the future, not merely the absence of mental illness, disability, or dysfunction.

¹² Gender inequality is defined as the extent to which women and men and girls and boys do not have equal conditions, treatment, or opportunities for realizing their full potential, human rights and dignity, and for contributing to (and benefiting from) economic, social, cultural, and/or political development.

¹³ Economic growth & development is defined as level of increase or improvement over time in the (inflation-adjusted) market value of the goods and services produced by an economy and/or quality improvements, innovations, and transitions in economies. It includes both the overall size of the economy (growth) as well as the introduction of new goods and services, risk mitigation, or dynamics of innovation and entrepreneurship that positions an economy on a higher growth trajectory, for example by moving from a subsistence agriculture-based economy to one that is manufacturing- and/or service-based.

¹⁴ ICT access is defined as proportion of the population with access to communication technologies including but not limited to smartphones, radio, television, computers, internet, social media, and traditional media.

¹⁵ Household income is defined as the value of the combined income sources of all members of a particular household.

¹⁶ Access to education & training is defined as the ability for individuals to access and afford the type and level of education and/or training necessary to ensure employment.

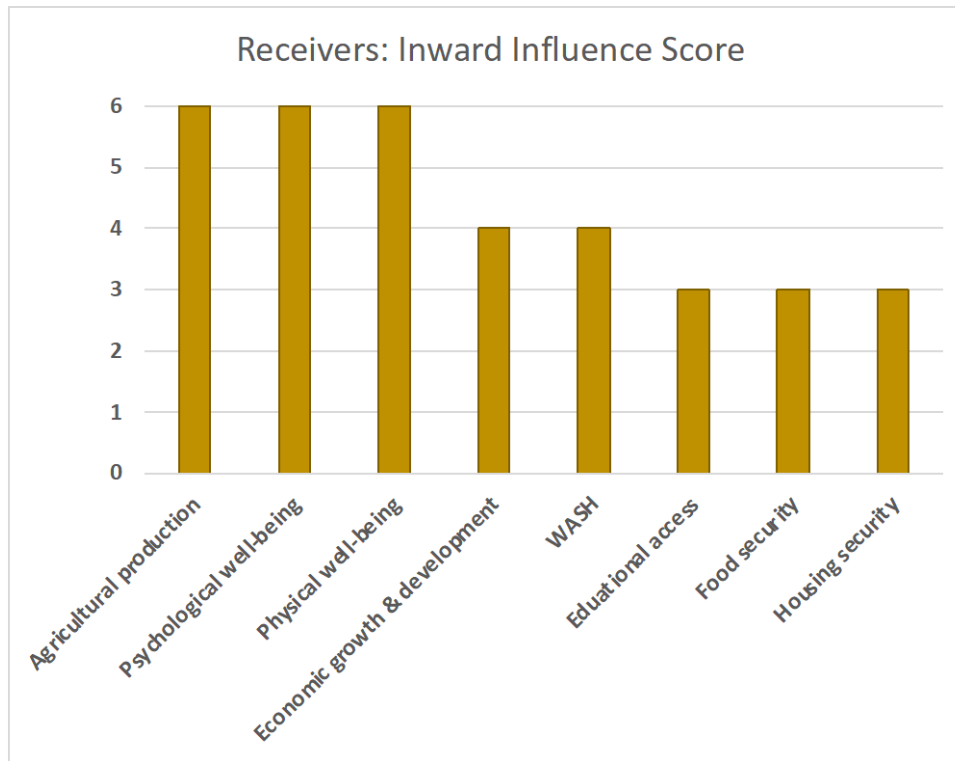
¹⁷ Grand corruption is defined as abuse of high-level power that benefits the few at the expense of the many and causes serious and widespread harm to individuals and society. It often goes unpunished. This includes activities like state capture, political corruption, and administrative corruption.

¹⁸ Physical health and well-being is defined as the extent to which individuals are able to maintain a quality of life that allows them to function well, and get the most out of our daily activities, without undue fatigue or physical stress. Physical well-being includes not only the absence of disease or infirmity, but the presence of factors that improve quality of life, such as adequate sleep, nutrition, physical activity, and relaxation.

¹⁹ Food/nutrition security is defined as the proportion of a population who have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life.

²⁰ Water quality, sanitation, & hygiene (WASH) is defined as the extent to which the population in a given area has reliable access to sufficient potable water, sanitation, and hygiene.

housing security.²¹ **Agricultural production**²² is also positioned to receive more influence than average from the system as measured by direct and indirect effects from other nodes and is itself key to guaranteeing food security in the agrarian economies of most African countries. **Access to education and training**, important for providing **skilled labor**,²³ also is impacted more than average by direct and indirect effects through other nodes in the AECM system.



Economic growth and development is both a primary driver and a primary receiver of influence from the system; it ultimately has a recursive, reinforcing effect on itself. The result is that, holding everything equal, increases in African **economic growth and development** could compound beyond an initial uptick. Conversely, recession or failures of **economic growth and development** in Africa can generate downward spirals with negative impact well beyond the

Figure 3. Network receivers in the AECM Sahel system. Nodes listed are ≥ 3 standard deviations above the mean for at least one outward influencing metric.

initial losses.

First Through Third-order Effects

Examining n^{th} order effects provides a means of measuring the potential magnitude and sign (positive or negative) of effects of one node upon another. Only first through third-order effects are examined here for two reasons. First, research on complex systems indicates that the influence of a node on any system diminishes rapidly beyond second-order effects (Williams et. al., 2002) indicating that third-order effects are most likely sufficient to capture meaningful downstream effects of one node upon another in most systems. This is corroborated in the AECM where the correlation between first and second-order effects is 0.700, between second and third-order effects is 0.747, and between third and fourth-order effects is 0.975. In other words, the correlation asymptotically reaches 1.000 after fourth-order effects, and thus no additional information is added. Second, the mean distance between nodes in the AECM system is

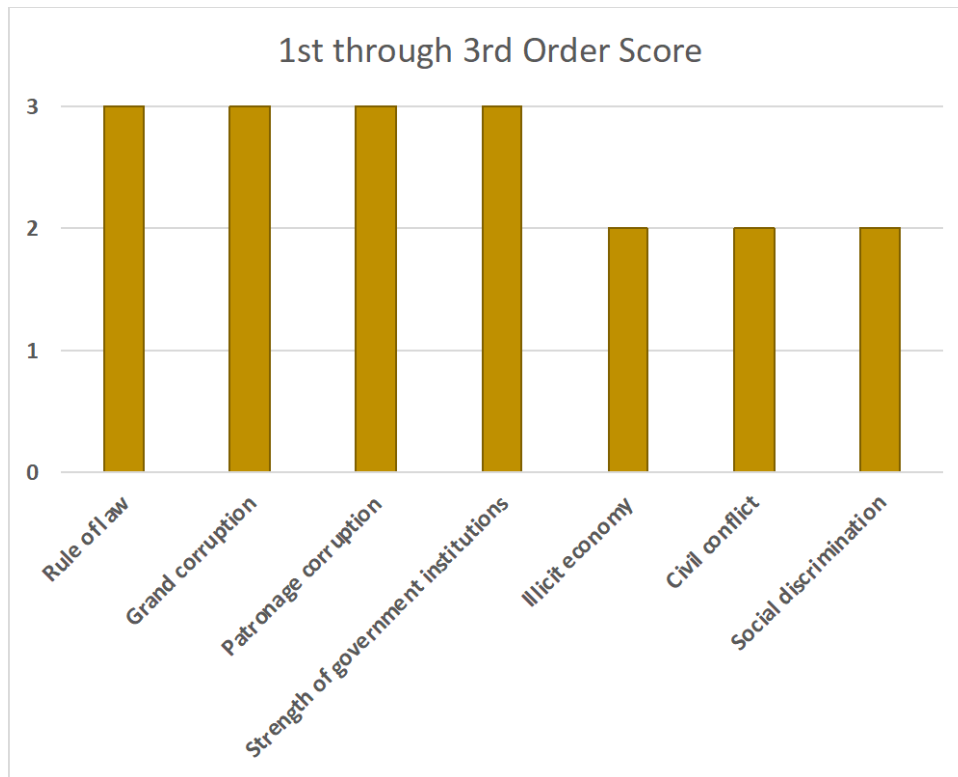
²¹ Housing security is defined as the proportion of the population with access to housing that is affordable relative to household income, and stable over time.

²² Agricultural production is defined as the amount of human-usable products (including food, animal feed, and non-food products) extracted from cultivated plants or animals, including production from farming, aquaculture, small scale horticulture.

²³ Skilled labor is defined as the number of people in a given country with modern technical skills, especially STEM, who can contribute to the work force. This includes professional occupations that require technical training or tertiary level education.

between three and four degrees of separation ($m = 3.27$ degrees) indicating that third-order effects capture the average connectedness between nodes.

Using network analysis to examine some of the strongest first to third-order effects in the system helps to illustrate how some individual nodes can drive others. The net positive or negative effect of first to third-order pathways between two nodes is a measure of these potential downstream effects.²⁴ The scoring system used for all centrality measures was used for these effects as well to provide an easy identification of the most influential nodes. In addition, the net first to third-order effects of each node on other individual nodes were normed to the strongest connection—which was the **strength of government institutions on psychological health & well-being**—to permit easy comparison of nodes’ ream effects *relative to one another*.²⁵ For example, a normed first to third-order effect of 0.33 has one-third as many net first to third-order pathways than one with a value of 1.0. Effects larger than 0.143 (two



standard deviations above the mean) are statistically significant at the 0.05 level and effects larger than 0.200 are statistically significant at the 0.01 level.²⁶

The network analysis indicates that the greatest net first- to third-order effects involve governance as represented by **strength of government institutions** and the **rule of law**;²⁷ factors that undermine these pro-governance nodes include **grand corruption, patronage**

Figure 4. Nodes with greatest net 1st - 3rd order effects in the AECM system

²⁴ This net effect is measured by multiplying an initial adjacency matrix measuring direct effects between nodes by itself times the n^{th} order of interest (in this case, the 3rd order) and summing the results for each of the orders.

²⁵ The absolute number of pathways is a function of the size of the network and in itself is not informative. The first to third-order effects are normed by dividing the number of pathways between two nodes by the maximum number of pathways that exists between two nodes in the network, yielding a measure of relative potential influence.

²⁶ The mean normed first to third-order relationship was 0.029 with a standard deviation of 0.057.

²⁷ Rule of law is defined as a government’s establishment, maintenance, and support of a durable system of laws and institutions—supported by norms and community commitment—that deliver accountability, just law (i.e., law that is clear, publicized, stable, and ensures contract and property rights), open government (i.e., the law is adopted, administered, and adjudicated in an accessible, fair, and efficient way), and accessible and impartial justice (i.e., justice is delivered in a timely fashion by competent, ethical, and independent representatives with adequate resources to perform their duties).

corruption,²⁸ and the **illicit economy**,²⁹ and disruptive social conditions such as **civil conflict** and **social discrimination**³⁰ (Figure 4).

Examining the **strength of government institutions** and **grand corruption** illustrates how indirect first through third order effects can percolate throughout the system³¹ and the near opposite effects these two nodes have on many key nodes (Figure 5).

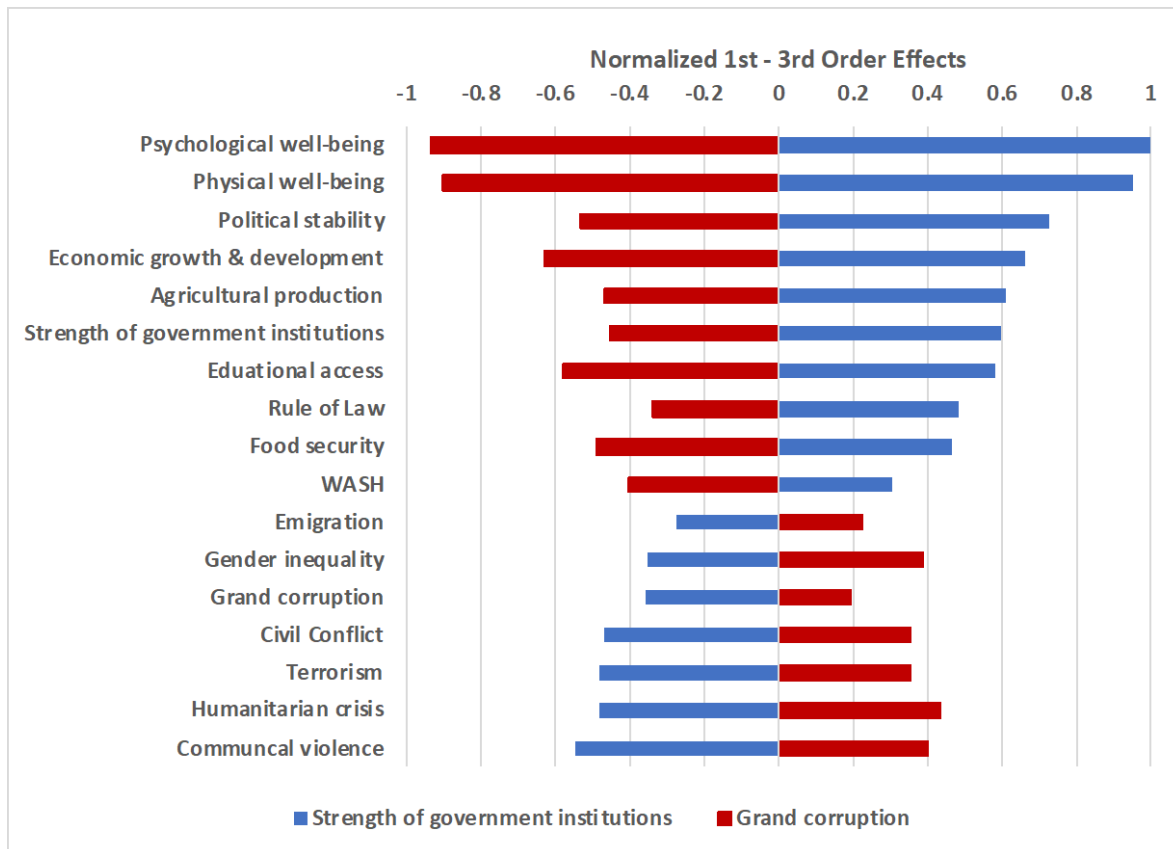


Figure 5. Normalized first through third order effects of strength of government institutions and grand corruption on key nodes in the Sahelian system

Strength of government institutions and **grand corruption** have numerous pathways through which they can influence food-related nodes such as **agricultural production** and **food security**. In general, the stronger government institutions like the courts, property rights, and transportation are, the more effective will be **agricultural production**, whereas **grand corruption** undermines these institutions. Nodes

²⁸ Patronage corruption refers to the prevalence of the use of state resources by an incumbent politician or leader to reward and incentivize individuals for their political support.

²⁹ The illicit economy is defined as the amount of market activity (the trading of goods or services) conducted in a manner contrary to the laws or regulations of the government in power, especially the buying and selling of forbidden or banned goods and services. It includes but is not restricted to trafficking in people, arms, drugs, wildlife.

³⁰ Social discrimination is defined as the extent to which individuals receive differential treatment based on their membership in a particular societal group (note: this excludes purely sex/gender discrimination).

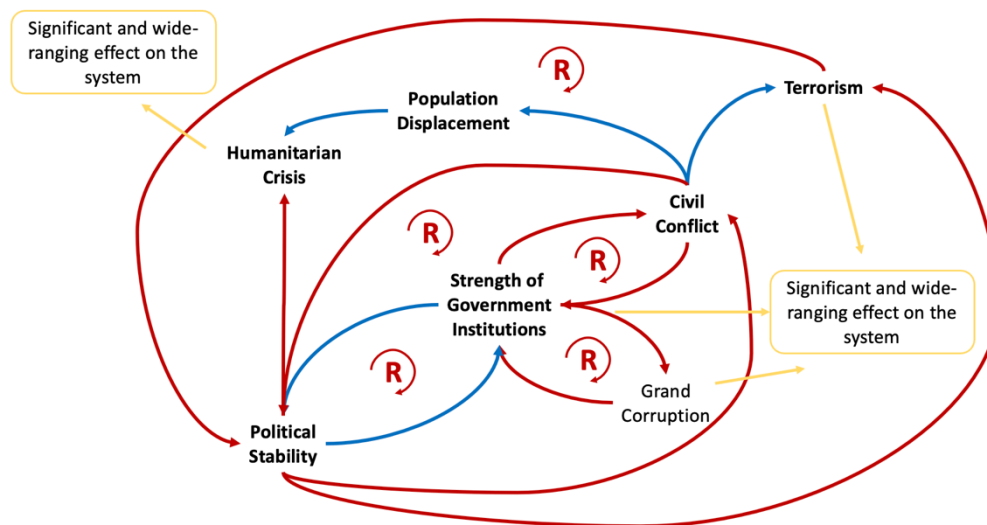
³¹ Rule of law and patronage corruption have nearly identical effects as strength of governing institutions and grand corruption respectively.

associated with human well-being such as **educational access**³² and decreasing **gender inequality** also can be influenced positively in many ways by the **strength of government institutions**, the opposite being the case for **grand corruption**. Strong institutions also can enhance **political stability**.³³ The analysis also shows strong governing institutions to be essential for **economic growth and development** while **grand corruption** acts to undermine it. Finally, both the **strength of government institutions** and **grand corruption** are positioned to influence themselves positively through many indirect pathways as well. They have a tendency to accelerate change in themselves through indirect effects flowing across the system.

Centrality metrics identify the nodes positioned to have the greatest influence in a network. However, tracing their effects through the network requires more detailed analysis. Two nodes, **strength of government institutions** and **terrorism**, are examined to provide a more detailed picture of some of the network dynamics in the AECM system.

The AECM Strength of Government Institutions Ecosystem

As noted, **strength of government institutions** is positioned to be a particularly influential node in the AECM system by virtue of its centrality in the network. An ecosystem around this node was constructed by extracting nodes with high centrality to which it is connected, and then high centrality nodes connected to them. For simplicity, only other nodes with high centrality were included in this analysis to illustrate how a network of nodes around them may influence one another. Figure 6 illustrates the complex connections between AECM nodes that form an ecosystem of influences around **strength of government institutions**.



The first key observation is that the **strength of government institutions** is involved in three key direct reinforcing loops in the AECM model, as well as having stronger than average effects on the AECM system in other ways. Reinforcing loops create snowballing

Figure 6. Strength of government institutions ecosystem. Blue lines = positive relationship, red lines = negative relationship. Nodes in bold are common to the strength of government institutions and terrorism networks described in this report.

³² Educational access is defined as the ability for individuals to access and afford the type and level of education and/or training necessary to ensure employment.

³³ Political stability is defined as the degree to which the politics, leadership, and governance of a state or region are predictable, and there is continuity in the political/legal institutions and rules within a state, irrespective of regime type. It is associated with a low probability that a nation's government will be overthrown by unconstitutional or violent means.

effects in which a node's influence recursively affects itself, thereby setting in motion a cycle of acceleration (Meadows, 2008). When these cycles are desirable, they are often referred to as *virtuous*, and when they are undesirable, they are referred to as *vicious cycles* creating negative runaway effects. Reinforcing loops have the potential to increase rapidly, if not exponentially. These reinforcing effects can create flare-ups or, in extreme cases, transformations of the whole system. Because of its involvement in three reinforcing loops, strengthening government institutions can set in motion virtuous cycles if, for example, **grand corruption** and **civil conflict** decrease, and **political stability** is enhanced, all of which reciprocally should strengthen government institutions. Conversely, a decrease in any of these nodes can spark cascading vicious cycles between them, driving the system to political and social chaos. Furthermore, there is a reinforcing relationship between **political stability** and **civil conflict**, which if activated in a negative direction, is positioned to further fuel those vicious cycles. The reinforcing loops between these nodes create an engine for change since their reciprocal effects can drive exponential changes in one another and therefore the entire system.

The engine of reinforcing loops between **strength of government institutions**, **civil conflict**, **political stability**, and **grand corruption** is positioned to impact other nodes of interest to USAFRICOM. For instance, **humanitarian crises** can be sparked by **population displacements**³⁴ as a result of **civil conflict** in the AECM model. **Humanitarian crises**, in turn, are positioned to have stronger than average impacts on the AECM system, primarily through indirect effects on the system. However, **political stability** buffers against **humanitarian crises**. **Terrorism** is also directly influenced through **civil conflict**, and itself is in a reinforcing loop with **political stability**. Recall that **terrorism** is positioned to have the greatest driving effect in the AECM system. Therefore, the **strength of government institutions**, **civil conflict**, **political stability**, **grand corruption** engine is in a position to fuel **terrorism**, which then can have powerful effects on the rest of the AECM system due to its stronger than average effects. Examining the terrorism ecosystem provides further insight into how the network of AECM influences can impact the dynamics of key USAFRICOM concerns.

The AECM Terrorism Ecosystem

Several key relationships in the **terrorism** ecosystem are illustrated in Figure 7. As already noted, **terrorism** has a reinforcing relationship with **political stability**, and **political stability** and **civil conflict** are also in a reinforcing relationship, which can fuel **terrorism**. Also, **political stability** and **strength of government institutions** are in a reinforcing loop, which means that when they have positive effects on one another, they can buffer against **terrorism**, but when they are in decline, they can be another engine that fuels **terrorism**. **Terrorism** is in a balancing loop with **government repression**.³⁵ *Balancing loops* return nodes to a steady state and can act as buffers in a system (Meadows, 2008). Some degree of **government repression** is statistically associated with the suppression of **terrorism** (Asal & Brown, 2022).³⁶ Both political stability and government repression are positioned to increase the **strength of government**

³⁴ Population displacement is defined as the proportion of a population forced from their homes or places of habitual residence as a result of, or in order to avoid, the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters.

³⁵ Government repression is defined as the actual or threatened use of force by the government of a state, against an individual or groups within that state, for the purpose of deterring activities perceived to be challenging to the state. It includes activities such as harassment, bans, mass arrests, outlawing of political organizations, and/or torturing or disappearing individuals.

³⁶ Note that this relationship is nuanced. If repression involves political state terror, it can have the opposite effect and actually increase terrorism (Kornblith, 2005).

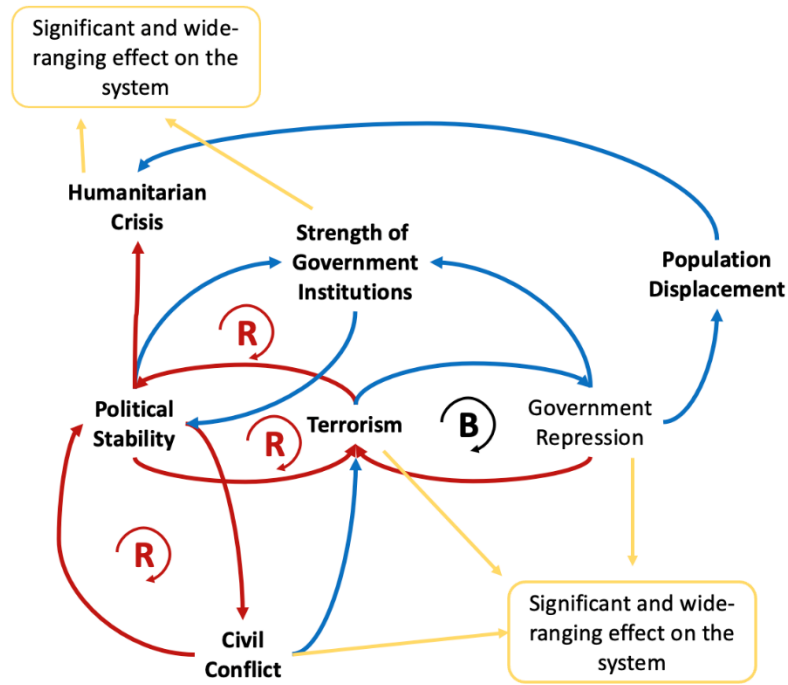


Figure 7. Terrorism ecosystem. Blue lines = positive relationship, red lines = negative relationship. Nodes in bold are common to the strength of government institutions and terrorism networks described in this report.

institutions, and **political stability** decreases **humanitarian crises**. However, **government repression** is a known contributor to **population displacement** (Giménez-Gómez, Walle, & Zergawu, 2019) in Africa, which can create **humanitarian crises**. Therefore, **government repression** has contradictory influences on stability in the AECM system. Note that there are an additional four nodes with the potential to significantly impact the system within two degrees of separation from **terrorism**, enabling it in turn to have strong effects on the rest of the AECM system.

Conclusion: Operational Implications of the AECM Network Analysis

SMA research does not make policy recommendations but is intended to inform policy and aid planning, assessments, and operations. The network analyses presented in this paper cover only a fraction of the dynamics that exist in the AECM system. This section reviews some of the operational implications implied by these analyses.

Counterterrorism Efforts Appear Critical

Because of terrorism’s position as a key driver in the AECM system, investments in counterterrorism (CT) appear to be well-founded. **Terrorism** is positioned to be the most influential node in the AECM system, impacting many nodes that are involved in key USAFRICOM concerns, including **political stability**, **civil conflict**, and **humanitarian crises**, in addition to **terrorism** itself.

Beware Government Repression

Government repression is positioned to reduce **terrorism**. However, if government attempts to repress terrorist activities include use of state terror and physical torture, it can have the reverse effect. US-sponsored CT efforts and military security cooperation should place a premium on professional conduct in the provision of security and respect for the **rule of law** in host nation security forces.

Strengthening Government Institutions is Central to Everything

Owing to its many pathways of influence and its involvement in reinforcing relationships with other key nodes, strengthening government institutions is very important for impacting key USAFRICOM concerns including **political stability, civil conflict, humanitarian crises, and terrorism**. Because of the reinforcing effects of many of these nodes, efforts that impact any of them positively could have positive ripple effects on the others. However, because of the tight connections between these nodes, it is important to consider that positive change in the strength of government institutions could be easily counteracted if these related nodes are not also addressed. Specifically, key reinforcing nodes for strengthening government institutions include a politically stable environment as well as the absence of **civil conflict, terrorism, and grand corruption**. Any efforts to strengthen governing institutions should holistically address these as well. Strengthening government institutions is also positioned to improve conditions like **economic growth and development, food security, and to decrease gender inequality**.

Appendix: Glossary of AECM Node Definitions

AECM Node	Definition
Access to education & training	The ability for individuals to access and afford the type and level of education and/or training necessary to ensure employment.
Agricultural production	The amount of human-usable products (including food, animal feed, and non-food products) extracted from cultivated plants or animals, including production from farming, aquaculture, small scale horticulture.
Civil conflict	The intensity and scope of a violent conflict between a state and one or more organized non-state actors in the state's territory. Includes conflicts in which additional, external actors, state or non-state, may also become involved.
Communal violence	Instrumental use of violence by people who identify themselves as members of a social group, defined by their differences of religion, ethnicity, language or race group, against another social group or individual members of a social group in society (e.g., "race riots").
Economic growth & development	Level of increase or improvement over time in the (inflation-adjusted) market value of the goods and services produced by an economy, and/or quality improvements, innovations, and transitions in economies. Includes both the overall size of the economy (growth) as well as the introduction of new goods and services, risk mitigation, or dynamics of innovation and entrepreneurship that positions an economy on a higher growth trajectory, for example by moving from a subsistence agriculture-based economy to one that is manufacturing- and/or service-based.
Educational access	The ability for individuals to access and afford the type and level of education and/or training necessary to ensure employment.
Food/nutrition security	The proportion of a population who have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life.
Gender inequality	The extent to which women and men, girls and boys do not have equal conditions, treatment, or opportunities for realizing their full potential, human rights and dignity, and for contributing to (and benefiting from) economic, social, cultural, and/or political development.
Government repression	The actual or threatened use of force by the government of a state, against an individual or groups within that state, for the purpose of deterring activities perceived to be challenging to the state. Includes activities such as harassment, bans, mass arrests, outlawing of political organizations, and/or torturing or disappearing individuals.
Grand corruption	Abuse of high-level power that benefits the few at the expense of the many and causes serious and widespread harm to individuals and society. It often goes unpunished. This includes activities like state capture, political corruption, and administrative corruption.
Household income	The value of the combined income sources of all members of a particular household.
Housing security	The proportion of the population with access to housing that is affordable relative to household income, and stable over time.

Humanitarian crises	Risks of a singular event or series of events that cause(s) sufficient human, physical, economic, and/or environmental damage to overwhelm a community's capacity to respond.
ICT access	Proportion of the population with access to communication technologies including but not limited to smartphones, radio, television, computers, internet, social media, and traditional media.
Illicit economy	The amount of market activity (the trading of goods or services) conducted in a manner contrary to the laws or regulations of the government in power, especially the buying and selling of forbidden or banned goods and services. Includes but is not restricted to: trafficking in people, arms, drugs, wildlife.
Patronage corruption	The prevalence of the use of state resources by an incumbent politician or leader to reward and incentivize individuals for their political support.
Physical health and well-being	The extent to which individuals are able to maintain a quality of life that allows them to function well, and get the most out of our daily activities without undue fatigue or physical stress. Physical well-being includes not only the absence of disease or infirmity, but the presence of factors that improve quality of life, such as adequate sleep, nutrition, physical activity, and relaxation.
Political stability	The degree to which the politics, leadership, and governance of a state or region are predictable, and there is continuity in the political/legal institutions and rules within a state, irrespective of regime type. Associated with a low probability that a nation's government will be overthrown by unconstitutional or violent means.
Population displacement	The proportion of a population forced from their homes or places of habitual residence as a result of, or in order to avoid, the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters.
Psychological well-being	The extent to which individuals are able to find enjoyment and happiness in life, develop resilience to challenges, and feel optimistic about the future, not merely the absence of mental illness, disability, or dysfunction.
Rule of law	A government's establishment, maintenance, and support of a durable system of laws and institutions—supported by norms and community commitment—that deliver accountability, just law (i.e., law that is clear, publicized, stable, and ensures contract and property rights), open government (i.e., the law is adopted, administered, and adjudicated in an accessible, fair, and efficient way) and accessible and impartial justice (i.e., justice is delivered in a timely fashion by competent, ethical, and independent representatives with adequate resources to perform their duties).
Skilled labor	The number of people in a given country with modern technical skills, especially STEM, who can contribute to the work force. This includes professional occupations that require technical training or tertiary level education.
Social discrimination	The extent to which individuals receive differential treatment based on their membership in a particular societal group (note: this excludes purely sex/gender discrimination).
State-based armed conflict	The intensity and scope of a conflict between the military forces of two or more national governments triggered by 1) incompatible positions regarding the state's type of political system government composition, and or 2) aims to change the state control of a certain territory.

Terrorism	The unlawful use of violence or threat of violence, often motivated by religious, political, or other ideological beliefs, to instill fear and coerce individuals, governments or societies in pursuit of terrorist goals.
Water quality, sanitation, & hygiene (WASH)	Water quality, sanitation, & hygiene (WASH)The extent to which the population in a given area has reliable access to sufficient potable water, sanitation, and hygiene.

Appendix: Centrality Metrics

Ten centrality metrics were used to assess the relative connectivity of each node in the full GECM system (Table 1). Guides to these metrics and their underlying algorithms are found in Bonacich (1987), Kleinberg (1998), and Wasserman and Faust (1994). Outdegree and indegree measure the direct, first order effects between nodes. Betweenness measures the extent to which a node joins other nodes. Closeness measures a node’s accessibility to all other nodes. Eigenvalue centrality is one of the most often used centrality metrics; it measures the degree to which a node is central based on its connection to well-connected nodes. For instance, if one has only a few friends, but they each have many friends, one would be well-connected in a network of friends.

The next four metrics are variants of eigenvalue centrality designed to assess the directionality and strength of influence in a network. Kleinberg authority centrality measures the extent to which other nodes link to it and is therefore a measure of how other nodes can potentially influence it. Kleinberg hub centrality measures the extent to which a node points toward well-connected nodes and is therefore a measure of how much information (i.e., influence) it sends throughout a network. Bonacich’s alpha centrality takes into account the extent to which nodes are exogenous (i.e., have influence on other nodes). Bonacich’s power centrality is based on a node’s connection to poorly connected nodes; the power centrality score is high if the node is connected to “weak” nodes with few connections because it dominates the weakly connected nodes. The Bonacich centrality metrics may not be capturing the directionality of influence in the GECM and AECM networks in a manner appropriate to the kinds of nodes in these networks, which are influences of an operational environment versus individuals influencing other individuals and so are treated as general centrality metrics. The final centrality metric considered is 5th order effect, or a measure of the number and sign (positive or negative) of effects a node has five steps away. This is another measure of a node’s “downstream” or outdegree effect on other nodes.

Table 1. Centrality metrics used to analyze node importance

METRIC TYPE	CENTRALITY METRIC	DEFINITION
General centrality	Betweenness	The number of times a node acts as a bridge along the shortest path between two other nodes.
	Closeness	Average length of the shortest path between a vertex and all others; weights must be positive.
	Eigenvalue centrality	Measure of the influence of a vertex; measures a vertex’s degree and those of its neighbors and so on.
	Bonacich’s alpha centrality	Eigenvalue centrality plus external influence (i.e., authority imbued from outside) on nodes. The alpha weight was set to 1, and all nodes were considered potentially exogenous, as were the default values
	Bonacich’s power centrality	Based on the notion that being connected to others that are not well-connected makes one powerful because these other actors are dependent on you. One begins by giving each actor an estimated centrality equal to their own degree, plus a weighted function of the degrees of the actors to whom they were connected. An "attenuation factor" indicates the effect of one's neighbor's connections on ego's power. Where the attenuation factor is positive (between zero and one), being connected to neighbors with more connections makes one powerful. This is a straightforward extension of the degree centrality idea. Bonacich also had a second idea about power, based on the notion

		of "dependency." If ego has neighbors who <u>do not</u> have many connections to others, those neighbors are likely to be dependent on ego, making ego more powerful. Negative values of the attenuation factor (between zero and negative one) compute power based on this idea.
Impact on the system	Outdegree	Number of direct links to other vertices.
	N th order effects	N th order effects are those n steps away from a node. A measure of the number of possible nth order effects of one node upon another is given by raising the adjacency matrix of 1 st order connections by the nth power. The 3 rd order was used to ensure that a thorough consideration of downstream effects of one node upon another were fully considered.
	Kleinberg's hub centrality	Authorities contain information, hubs point to information. It is measured by the eigenvector of $A \cdot t(A)$ where A is the adjacency matrix.
Impacted by the system	Indegree	Number of nodes with a direct link to a node.
	Kleinberg's authority centrality	Authorities contain information; hubs point to information. It is measured by the eigenvector of $t(A) \cdot A$ where A is the adjacency matrix.

These centrality metrics were binned into those that represent general centrality (betweenness, closeness, eigenvalue, Bonacich's alpha, Bonacich's power), those that represent impact *on* the system (outdegree, Kleinberg's hub centrality), and those being impacted *by* the system (indegree, Kleinberg's authority centrality).

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