Sociocultural Behavior Influence Modelling & Assessment: Current Work and Research Frontiers

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Abstract. A common problem associated with the effort to better assess potential behaviors of various individuals within different countries is the shear difficulty in comprehending the dynamic nature of populations, particularly over time and considering feedback effects. This paper discusses a theory-based analytical capability designed to enable analysts to better assess the influence of events on individuals interacting within a country or region. These events can include changes in policy, man-made or natural disasters, migration, war, or other changes in environmental/economic conditions. In addition, this paper describes potential extensions of this type of research to enable more timely and accurate assessments.

Keywords. DYMATICA, sociocultural modeling, geopolitical modeling, hybrid warfare

1. Sociocultural Behavior Assessments

The rise in the number of asymmetrical threats posed by various state and non-state actors, which use hybrid[3] forms of aggression as a means to achieve their end, has necessitated the expanded use of strategic messaging and other forms of diplomatic and societal persuasion. Because of the challenge associated with hybrid activities, it is recognized that the sole use of direct military power will often not achieve desirable results and could even lead to results contrary to long-term NATO intentions. With a greater focus on "soft power" actions to support behavioral change, such as inspiring certain pro-social attitudes of individuals within societies, NATO can institute influence operations that better inform and appropriately influence key audiences. This can occur by synchronizing and integrating communication efforts to deliver truthful, timely, accurate, and credible information. This concept of influence operations can be defined as "the coordinated, integrated, and synchronized application of national diplomatic, informational, military, economic, and other capabilities in peacetime, crisis, conflict, and post-conflict to foster attitudes, behaviors, or decisions by foreign target audiences that further U.S. [or any NATO state] interests and objectives" [1, p. 2].

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[3] Hybrid warfare conflicts typically involve some combination of covert military, political, economic, and social messaging activities to influence the population and ultimately the government of another nation.

The focus of influence operations has been used to build credibility and trust between organizations such as NATO and a targeted audience by countering adversary claims, leveraging positive NATO actions, as well as supporting local leaders that are believed to be credible and supported by the general populace. This type of influence can help shape the beliefs, attitudes, intentions, and ultimately the behaviors of the targeted audience so they are more amenable to NATO policies, or at least less hostile towards them. However, to help accomplish this, one should have insight regarding how individuals form decisions, express behaviors, and interact within state and non-state organizations. Furthermore, accurate characterizations of individuals within a state or non-state organization should represent the interaction between those under control, those influencing power, and external variables, such as government actions or global changes in the socio-political/economic climate.

1.1. Computational Modeling Example: DYMATICA

It is asserted here that the phenomena underlying sociocultural and geopolitical dynamics that drives stability and instability within countries has become understandable enough to pose testable hypotheses amenable to simulation [2]. This has led to many efforts that assess various aspects of these dynamics. To illustrate this point, the United States Department of Energy's Sandia National Laboratories (SNL) has developed a capability to allow analysts to better assess potential actions and counteractions of individuals interacting within state and non-state organizations. Called DYMATICA (DYnamic Multi-scale Assessment Tool for Integrated Cognitive-behavioral Actions), it is a computational approach to help decision makers better understand and anticipate likely responses and decision calculus of counties, groups, and individuals to political gamesmanship and socioeconomic situations. DYMATICA models are designed to simulate geopolitical, psychosocial, and economic phenomena subject to key physical constrains and conditions.

DYMATICA is designed to help organizations develop, understand, and compare likely effects of potential courses of action (COAs) under a variety of geopolitical scenarios and can help investigate attitudinal and behavioral reactions to NATO policies for a given country, group, or ethnic region. In this role, it supports hypothesis generation and COA development, analysis, and comparison, while accounting for uncertainty in the environment. DYMATICA is also designed to enable comparison and integration of views from multiple subject matter experts in a common, decision theory-based format. The specific objective of this effort is to develop a systems-level capability that allows analysts to better assess potential actions and counter-actions of individuals interacting within a country of interest before, during, and after an initiated event. Included in this assessment are considerations of the dynamics that drive stability and instability within countries. DYMATICA is designed to achieve this objective by providing a computational modeling structure that simulates interactions among individuals, groups, and societies. The data used to condition the model can originate from a large spectrum of sources including previous studies, subject matter expert (SME) guidance, surveys, observations, and public media. The models have represented a variety of topic domains and country regions from around the world, including countries from Africa, Asia, Europe, and South America. The assessment domain includes military and cyber activities, deception activities, deterrence activities, internal stability, migration, and propensity for aggressive behaviors. Funding organizations include the United States' (US) Department of Defense, the United Kingdom's (UK) Ministry of Defence, the intelligence community, as well as SNL through its internal laboratory-directed research and development program.

A typical DYMATICA assessment can demonstrate how different scenarios and COAs are likely to affect key outcomes (subject to a variety of causal hypotheses) over time. Depending on the situations of interest, these outcomes may be geopolitical (such as interactions between countries), at the group level (such as political leanings of various social groups, or tendencies of groups to engage in conflict or social unrest or to support NATO actions), and individual level (such as decisions made by leaders). Output can also be non-cognitive (such as resource availability or economic trends). Structural and parametric uncertainty can be incorporated to demonstrate the range of likely outcomes given a variety of potential circumstances. The time needed to develop these models are largely dependent on the questions being addressed, the level of detail desired, and the type of analysis. Receiving assessment results for a new, related question represented within an existing model could take minutes to days. Studies making heavy use of previous models may take a few weeks, while deep assessments involving new questions, further detail, and the modeling of new countries or assessment domains can take several months to a year.

1.2. DYMATICA Structure and Process

The DYMATICA structure and process is based on a specific combination of well-established psychological, social, and economic theories of decision making, as well as established techniques in knowledge elicitation, statistics, system dynamics modeling, uncertainty quantification, and sensitivity analysis. While computational social modeling is not an exact science, the goal is to improve understanding of likely outcomes in situations of importance to analysts, allowing for higher confidence in assessments. The process of developing a DYMATICA assessment model involves 10 main steps:

1. Develop key intelligence question with customer
2. Select scope and granularity of assessment with customer
3. Perform extensive literature review
4. Develop systems-level conceptual model (in diagram form) and prototypical models of interactions and influences
5. Perform systems-level and decision-level elicitation from experts
6. Develop dynamic, multi-scale computational model of PMESII-PT[4] influences
7. Run model with simple key feature
8. Falsify or retain, improve, move on
9. Analysis: scenarios, interventions, sensitivity, and uncertainty, risk
10. Dynamic visualization and delivery

The first step in the development process is to determine with the customer, the overarching question that is important to the customer and/or end user. This typically

[4] Acronym for Political, Military, Economic, Social, Information, Infrastructure, Physical Environment, and Time

involves working with various producers and consumers of information to craft the broad-level questions and sub-questions that DYMATICA will assess. The overarching question will help scope and constrain the model so that it is both tractable and useful. The next step is to determine the granularity for the assessments. This includes the time horizon (the complete span of time the model will simulate and assess, which could be several days to several decades) and the time resolution (the amount of simulated time for each assessment step, which could be simulated hours to months). In addition, from the overarching question it is determined what counties, organizations, and individuals will be included in the simulation.

Once the granularity is determined, an extensive literature search and review is performed. This task supplies the modeling team with enough information to properly ask SMEs specific questions related to the system of interest. This process leads to the construction of what is known as a causal loop diagram (CLD). The CLD is used to visualize potential interactions and influences between entities (groups, organizations, leaders) of interest and their environments. These diagrams are considered to be dynamic hypotheses of the structure underlying the system of interest. CLDs are used to elicit information from SMEs regarding interactions and influences. This process is typically iterative, with SMEs reviewing the CLDs and recommending modifications where needed. This process continues until the SMEs are satisfied with the CLDs.

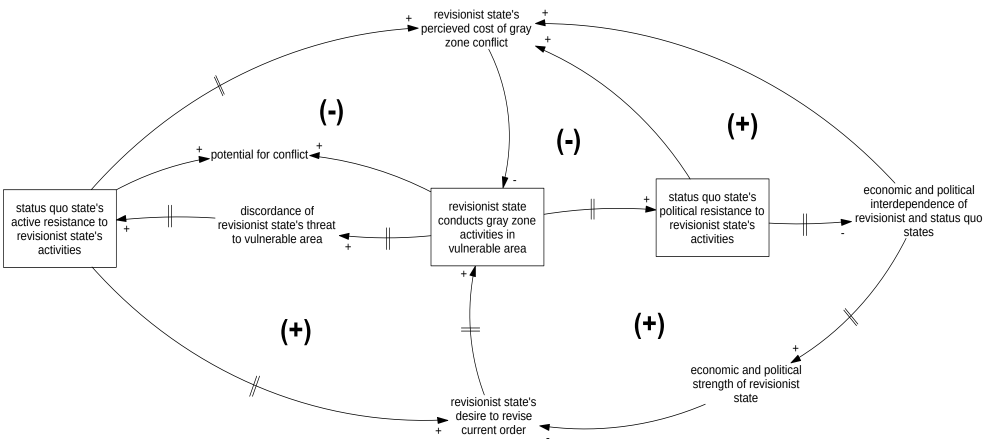

Figure 1: Causal loop diagram of high-level decision making about gray zone actions for proxy war

For example, Figure 1 shows a CLD that describes a power struggle between revisionist and status quo powers in proxy war. At the bottom of the diagram is the revisionist state's desire to revise the current order, which influences its decision to conduct gray zone activities in the vulnerable area. The status quo state's resistance to gray zone activities will increase the perceived cost of gray zone conflict, which may lead the revisionist state to reduce gray zone activities. However, Resistance from the status quo state is interpreted as a power struggle by the revisionist state, which increases their desire to revise the current order and subsequently increases their gray zone activities.

Through the process of creating CLDs and working with SMEs (and often with customers), we can determine if elements within the model would benefit from higher resolution representations. For example, if a population that is being modeled contains several key actors (such as political parties, religious/social groups, etc.) that drive a significant percentage of the interactions, a more detailed representation of these actors might prove useful. Higher resolution representations are structured via psychosocial and behavioral-economic theoretical models. The most prominent psychosocial theories represented in the higher resolution representation are the model of recognition-primed decision making (RPD) [3]; 2) the theory of planned behavior (TPB) [4]; 3) an extension of theory of planned behavior called the model of goal directed behavior (MGB) [5]; and 4) cognitive dissonance theory (CDT) [6]. The listed theories describe how people make decisions when faced with various situations. RPD focuses on how relatively quick decisions are made based on interpretations of external cues. The TPB focuses on how decisions are made based on prevailing attitudes, social norms, and perceived behavioral control, and mediated by intentions. The MGB extends TPB by adding emotional affect, desire, recency, and frequency variables. CDT focuses on how cognitive/behavioral discrepancies can affect views towards one's behavior. Integrating the described theories into a single framework can be achieved because each theory generally complements the others. That is, RPD (and other related theories) regard how stimuli affect cognitive appraisal via perceptions of the environment. Cognitive perceptions can then trigger specific attitudinal-emotional beliefs that will help frame the situational context. Social norms and the perception of behavioral control contribute to the desire (which we call motivation), and ultimately the intention, to perform some type of behavior (This conceptual structure is shown in Figure 2). This cognitive process is discussed indirectly in the TPB and is prominently featured in the MGB. Broader theories, such as prospect theory, complement these theories as well.

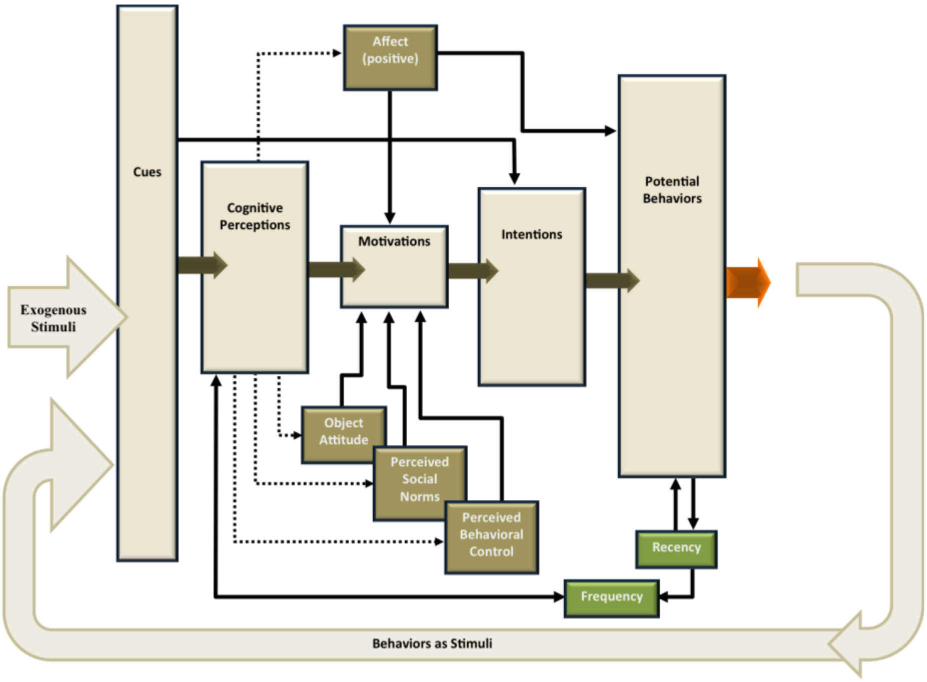

Figure 2. Conceptual diagram of the higher resolution, psychosocial (decision) model

1.3. DYMATICA Structure

The DYMATICA structure consists of a modeling framework, model simulators, and an analysis approach. The current structure allows for assessment of models across different domains (i.e., different countries, groups, individuals, and scenarios of interest). For example, Figure 3 shows a simplified conceptual representation of a hypothetical DYMATICA structure that involves the modeling of two interacting groups and several leaders. Exogenous inputs to the model (e.g., global economic factors and general population support) influence the dynamic interactions within and between the entities. Each simulated behavior is a function of psychological characteristics along with environmental and group dynamic factors. This enables the assessment of group behaviors as the groups react to other’s perceptions and world conditions.

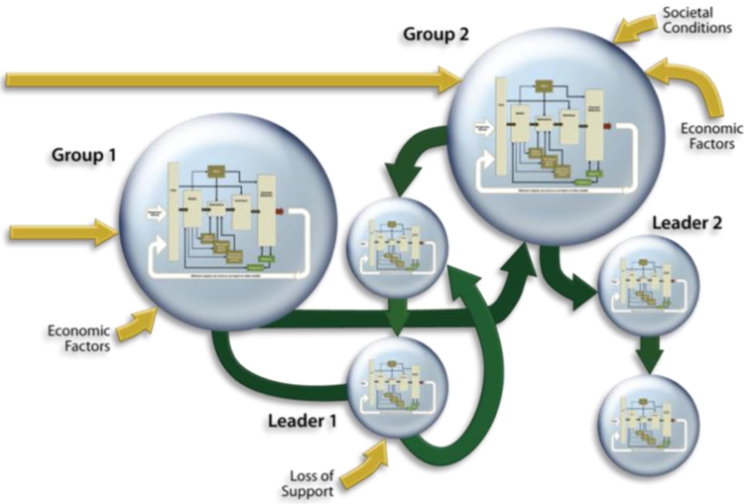

Figure 3. Conceptual diagram of the full systems view of a hypothetical application of DYMATICA

DYMATICA uses system dynamics modeling structure to simulate interactions between cognitive entities in the context of a problem of interest. An assessment begins with a scenario, often including an initiating event associated with certain cues. Cognitive entities interpret these cues as cognitive perceptions, determined by linear weighted sums of cues with coefficients based on the beliefs of each entity. Entities form expectations about their world based on their cognitive perceptions. The difference between expectations and perceptions is called discordance. Discordance is the normalized difference between perceptions and expectations. Each entity calculates an intention utility, or perceived benefit of taking the corresponding action, for each potential behavioral choice. Intention utilities are linear weighted sums of cognitive perceptions, expectations, and discordance, with weights determined by the entities' cognitive resources (perceptions, attitudes, perceived social norms, and perceived behavioral control). These weights are determined by SMEs, literature, or other data, and may be different for each entity. The model uses qualitative choice theory (QCT) [7] to select the intentions that each entity will pursue. This is based on a multinomial logit function that determines either the probability of selecting a specific behavior from a set (for individuals) or the fraction of people that will select that behavior (for groups). In situations where emotion affects the magnitude of an intention, the model determines amplification using a linear weighted sum of perceptions, expectations, and discordance. Weights for amplification equations are based on positive and negative emotions, and are determined by SMEs, literature reviews, or other data. Intention evaluations are multiplied by amplification to determine indicated behaviors of each entity. Actions, or physical realizations of behaviors, are delayed versions of these indicated behaviors. Both actions and world model outputs (which can also depend on actions) can act as cues for cognitive entities in subsequent time steps.

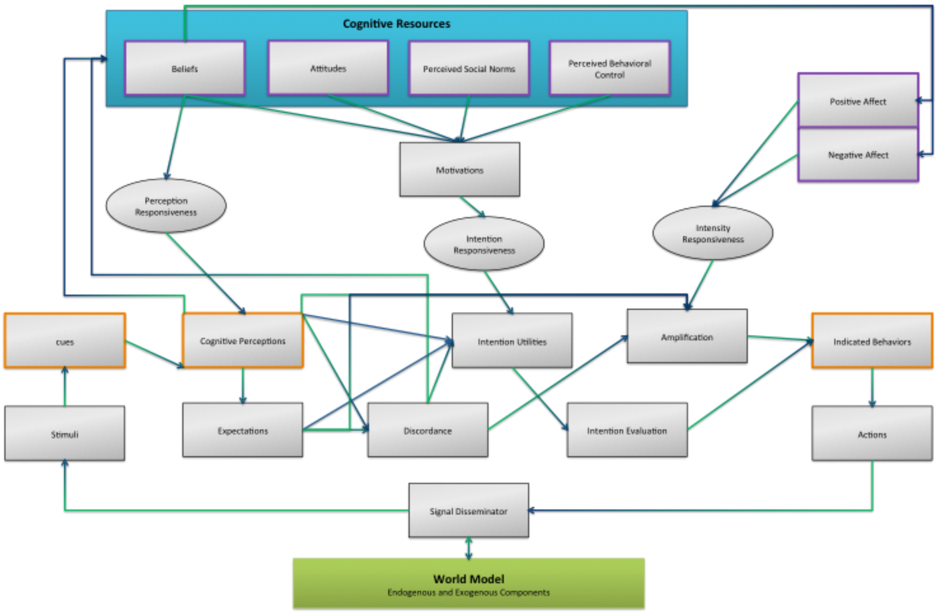

Figure 4: Overview of the DYMATICA structure

1.4. Knowledge Structure

Domain information within DYMATICA is represented within its 'knowledge structure.' One can think of a knowledge structure (KS) as scaffolding for the organization of socio-cognitive processes underlying decision-making, as well as the actual content of that knowledge with respect to a modeled individual, type of individual, or group of individuals (see Figure 5). Unlike a general database of information, a KS links cognitive information to the mathematical framework in a manner that is consistent with psychological, social, and behavioral economic theories of human decision-making. A KS describes the relationships that lead from the marshaling of relevant stimuli in the form of "cues" to the performance of probable behaviors of modeled entities. It incorporates very specific cognitive information such as cognitive perceptions, motivations, attitudes, emotional states, and potential behaviors associated with particular situations. Importantly, this information is structured in a manner that should reflect the processes underlying both highly deliberative and highly reactive human decision-making—taking into account behaviors associated with what is considered both "rational" and "irrational" thinking. This typically includes capturing specific biases, cultural thinking, general practices, and the frequency and recency of behaviors.

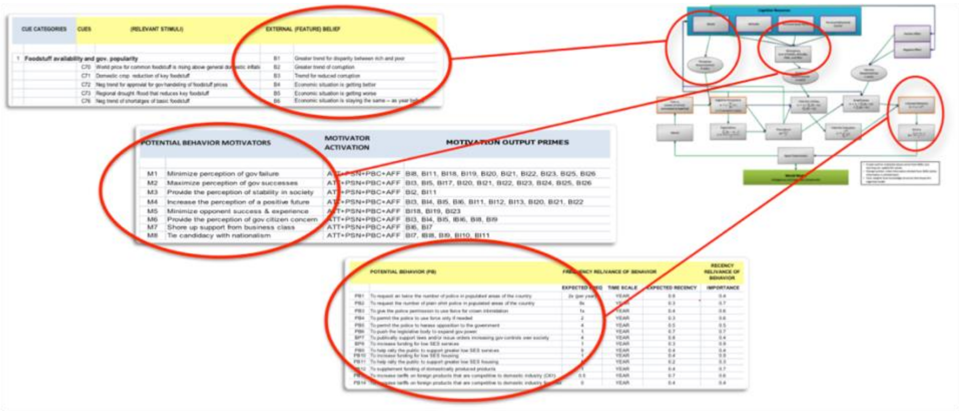

Figure 5. Example of a Knowledge Structure showing cognitive perception, motivation, and potential behavior information

Once the initial model is built, it is assessed to determine if the results are consistent with SME opinion and with current and previous observations of entity behaviors (if applicable). This process continues until all parties are confident that the output provides useful insight given the constraints of time, information, and scope. Results are dynamically visualized in a graphical user interface.

Uncertainty in the data is explicitly characterized where uncertainty quantification identifies uncertainty in model results. This process provides confidence intervals on the results of the model analyses that test interventions. By simultaneously performing uncertainty quantification for model parameters and potential interventions, DYMATICA can determine the portfolio of interventions that have the highest (quantified) probability of success despite uncertainty. DYMATICA can then perform sensitivity analyses to determine what minimal additional information is needed to maximally reduce uncertainty and further assure the proposed interventions produce the desired outcome throughout the time horizon of interest. Moreover, because the model is causal, decision-makers can reach back into detailed results of the simulation to independently evaluate the nuanced processes that caused the anticipated outcomes and find leverage points that would be maximally effective at altering these outcomes.

2. Assessment Examples

DYMATICA models have assessed different geopolitical and socio-cultural narratives regarding the internal perceptions of a country's status, capabilities, and hegemony over other countries within a region. This involves the modeling of PMESII-PT factors associated with a country's economic and military capabilities, as well as their self-perceptions, behavioral tendencies, and internal political dynamics. For example, the relationship visually described in Figure 6 might be associated with the question, "How do changes in economic circumstances, military capabilities, geopolitical positioning, and sociopolitical conditions affect a country's stability and ability to project power over the next ten years?" In this scenario, we might assess the dynamics within the country, such as the interactions and influences between political parties, the political leader, as well as other countries that are interacting with the country of interest. In addition, this assessment would need consider the current and protected economic situation, social and political dynamics, and the narratives that are active within this country. Furthermore, global economic, military, and geopolitical circumstances would also have an impact on the stability within this country. For example, if a more powerful non-NATO neighboring country started to actively use hybrid forms of aggression directed towards a less powerful NATO country, it could have large-scale impacts on the internal social, political, economic stability of that NATO country.

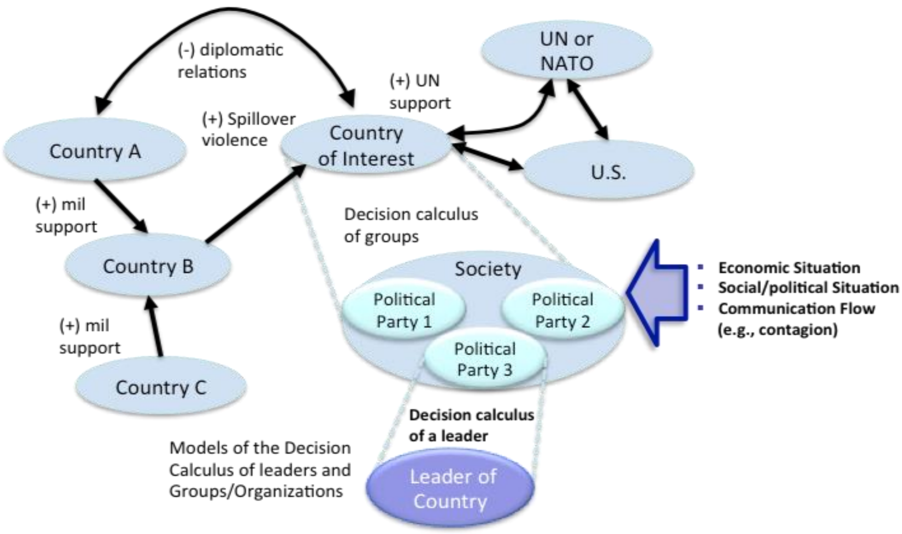

Figure 6. Example of the interactions within country and between other countries

In addition, DYMATICA models have assessed how (and when) perturbations within different indigenous and diaspora communities, logistical networks, and ecological systems (e.g., refugee migrations, disasters) could affect the behaviors of specific national and transnational violent extremist organizations (VEOs), societies, and governments over time. This involves modeling PMESII-PT factors associated with specific VEOs, including their economic and military capabilities, and their interactions with local societies and governmental organizations. Recent uprisings and social collapses within international areas of concern have highlighted the need to adequately anticipate likely changes in behaviors in response to shifts in beliefs and attitudes of a population, along with the emergence of economic, logistical, and ecological failures. As visually shown in Figure 7, the focus of this type of relationship could address such questions as, “How do VEOs influence various populations within certain regions? What type of activities could strengthen pro-Western government within a region? How can we better understand and anticipate the behaviors of VEOs over time?” Here, behaviors of the VEO of interest, as well as behaviors from other VEOs could help provide insight into future behaviors of the VEO. These assessments should also include the economic, social, and political dynamics within this community, as well as other factors such as gains and losses in resources, the flow of information, and impacts on living conditions due to changes in such things as climate, migration, and the like.

Figure 7. Example of the interactions within and between VEOs

3. Typical Assessment Results

DYMATICA assessments are tailored to fit the information needs of the customer. As shown in Figure 8, a DYMATICA assessment might include a number of parameters, such as country GDP which can change over time. These changes can be reflected in the model as parameter updates. For example, economic data updates can come for sources such as the International Monetary Fund or the World Bank. This type of assessment is meant to capture current and near-term conditions.

In addition, an analyst can use DYMATICA to better understand various geo-political and sociocultural landscapes if one or more conditions change. To accomplish this, analysts can use the model to adjust parameters to play out various “what if” scenarios. Modifiable parameters can be such things as changes in GDP, levels of military strength in specific areas, degree of aggressiveness in foreign policy, amounts and types of migration, and the like. As one or more of these parameters are adjusted, the results will dynamically change to reflect the scenario change. The visualization of this information is typically presented in a ‘freeware’ platform that is commonly available. This enables the assessments to be widely shared, but also can potentially constrain the richness and flexibility of the assessments to the limitations of that software.

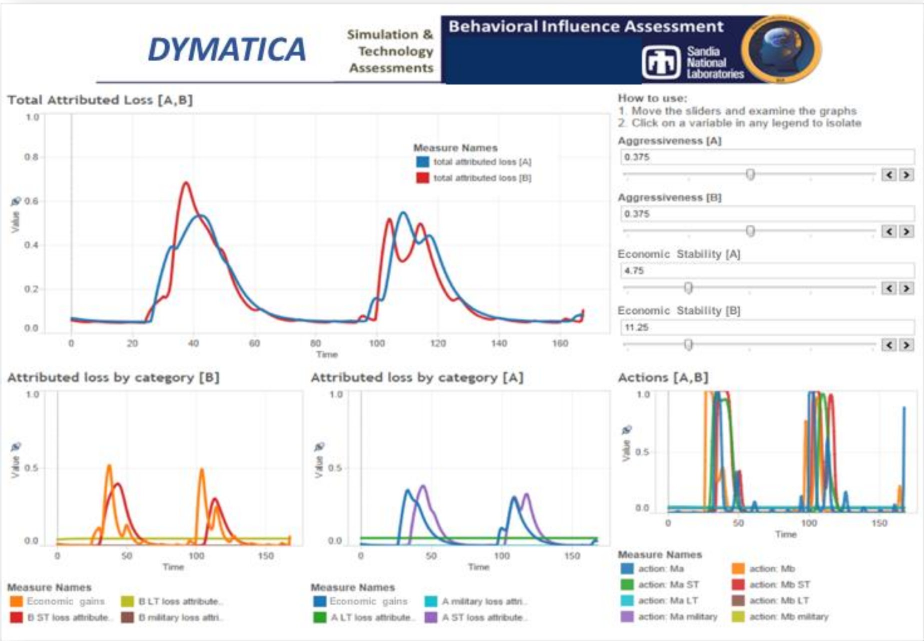

Figure 8. Example of a DYMATICA assessment output.

4. Research Frontier for Sociocultural Modeling

Because of the newness of this area, there are many opportunities to increase the utility of these types of assessment capabilities. For example, developing modeling approaches that enables quick construction of simulations concerning urgent customer questions is a current research direction. Presently, SNL is working to create pre-populated structures to use as starting points for new simulations with the goal of reducing production time. This type of work is designed to create generic models that would be quickly parameterized for specific countries to enable COA comparison and identification of regions at greatest risk for conflict, with the highest practical confidence. Resulting models could simulate countries and their interactions, which could be adaptable to specific instances and incorporate automatic validation exercises for assessing appropriate levels of model confidence. Another approach SNL is using to aid in rapid construction is in developing object-oriented models. An object-oriented structure would include pre-populated objects for characteristics relevant to decisions of interest. These structures would then be used as starting points for new simulations, reducing production time. The resulting simulations would be causal, allowing assessment of why outcomes occur, which will include key inter- and intra-country behavioral interactions.

An additional area of development is the advancement of novel forms of visualization that presents dynamic assessment outputs across multiple domains and scales. For instance, performing concurrent assessments of interactions between individuals, organizations, and geographical regions necessitate some type of multi-dimensional visualization. A visualization interface (perhaps using augmented or virtual reality) of this sort could support analysts' decision making by enabling them to visually zoom into a particular area of interest. As an example, the first level of visualization in Figure 9 provides slider bars that could adjust the parameterizations for specific conditions and actions represented within the model. The second level could provide specific assessment results for certain countries or groups of interests.

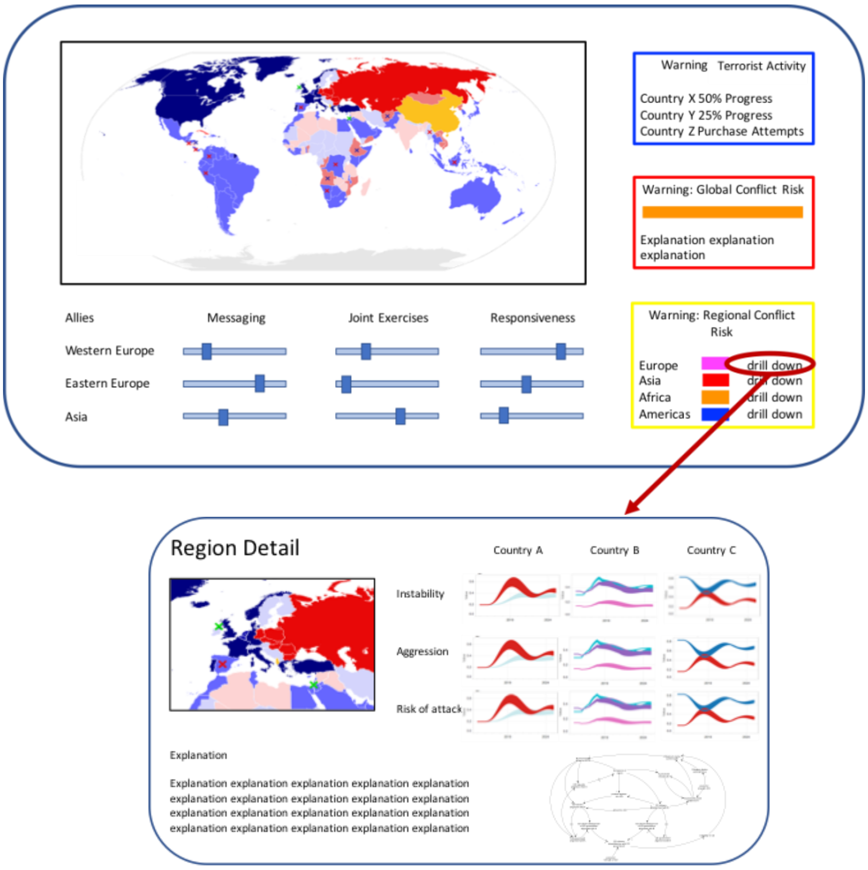

Figure 9. Example of a potential assessment output.

Moreover, additional validation techniques need to be developed that are specifically designed to improve model accuracy for these types of models. This includes better ways to identify and quantify uncertainties associated with data pertaining to model parameters, expert opinion, and open source data. Currently, SNL is developing "confidence management" methods that focus on uncertainty quantification (UQ) and sensitivity analysis (SA), as well as other validation metrics for these types of models.

UQ is being used to learn how uncertainty in inputs ultimately propagates through the model to affect results. By simultaneously performing UQ for model parameters and potential interventions, the framework can determine the portfolio of interventions within a range of probabilities of success, despite uncertainty.

The overall goal of this effort is to improve the understanding of likely outcomes in situations of importance to organizations such as NATO, allowing for higher confidence in such things as multi-domain COA development and comparison. While this type of work has great promise, as discussed above, more work needs to be done. With this in mind, current capabilities are currently able to quantifiably address intervention dynamics and unintended, higher-order consequences that enable analysts to better assess potential actions and counter-actions of countries of interest.

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