Modeling Stability and Reconstruction Operation Using SEAS*

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ABSTRACT

Humanitarian aid and assistance is considered a critical tool for development and reconstruction. Challenges are posed by recurring disasters such as armed conflicts; droughts, hurricanes, and earthquakes; high numbers of internally displaced persons and returning refugee;, contested terrains; and competing regional and international influences. In this paper we present a computational model for simulating the dynamic interplay between humanitarian and developmental aid and its linkages to the nation building process in a war ravaged region of the world, namely, Afghanistan. We use the SEAS-VIS platform to construct a Virtual Afghanistan represented by a physical landscape), and autonomous, adaptive and cognitive agents consisting of individuals, organizations, institutions, and infrastructure. We use VA to analyze the robustness of policy choices under different scenarios. Our results indicate that in the presence of moderate levels of criminal and terrorist activities, a Minimalist Approach to Stability and Reconstruction Operation may provide a better return on investment than a Maximalist Approach.

INTRODUCTION (1)

Recent rise in intra-nation conflict and subsequent multi-nation peace building efforts has contributed to a proliferation of literature on various strategies for successful achievement of post-conflict peace-building goals. Varying in scope and funneled by ideological convergence of scholars, policy makers, and local implementers, conflict mitigation, resolution and reconstruction aims at identifying and supporting structures that help strengthen and solidify peace in a war torn region. Scholars and practitioners agree that post-conflict operation requires a holistic approach, a combination of military and non-military actions to stabilize and reconstruct a weak/failing state. According to Barakat and Hoffman [1995], 'reconstruction as the first step in a long-term recovery process, entails economic, social, and psychological readjustment, that is, the full range of integrated activities and process that have to be initiated in order to reactivate the development process that has been disrupted by conflict; restoration of the physical infrastructure and essential government services; institution building to improve the efficiency and effectiveness of existing institutions; the structural reform of the political, economic, social and security sectors.'

Debate, however, rages over exact strategies for implementation that may best suit the context. Over the years, numerous policy options have been advanced ranging from a minimalist (emergency relief) to a maximalist approach (aid with wider political and social objectives) as well as bottom up (for example Somalia where humanitarian aid was given without addressing the political cause of the disaster) or a top down (for example Cambodia where aid intervention were conditional on democratization and rule of law) effort

[Goodhand 2004; Chong 2002; Barakat and Deely 2001]. Debate also ranges over the timing, content, and sequencing of development and reconstruction efforts. Needless to say one of the reasons for such debate is a paucity of literature on the actual impact of various peace-building models (Goodhand 2004). The later is largely due to the daunting challenge of gathering relevant data from the 'real world' cases which in turn is context and time dependent. This difficulty thus extends to policies and intervention programs that are rarely based on empirical evidence of optimal solutions. International aid community is also faced with various challenges that mitigate coordination of aid such as theft of goods, and attack on convoys. Real life cases are serious risks to the local implementers who often lack the necessary information that can help avoid precarious security situations in various areas.

Computational experimentation using agent based modeling (ABM) is a new integrative approach with the promise to overcome the risk of learning in the real world. In this approach one builds a 'synthetic' environment that mirrors its counterpart in the real world. This 'third way of doing science' as eloquently stated by Axelrod (2003), is a 'virtual' interactive system that creates artificial autonomous agents that mimic the behavior patterns of their counter-part in the real world. These behavioral patterns of individuals and groups or interaction between the two are based on theoretical models that are either directly encoded or observed as emergent behavior make assumptions more visible and verifiable. According to Lustick [2004], the advantage of ABM is not that it eliminates stipulated parameter values, but that every stipulation is noted and that there are no unrevealed or hidden assumptions. Following are key distinguishing features of computational experimentation approach:

- virtual experiments can be conducted in an environment in which consequences of decisions can be measured and analyzed;
- multiple theories from various specialized disciplines can be integrated for a comprehensive understanding of underlying phenomenon;
- agents can be represented with multiple decision strategies ranging from rational and non-rational;
- heterogeneous actors can be modeled who can modify their behavior during the course of the simulation; and
- seamless and interchangeable integration of human and software agents can be facilitated to provide both breadth and strategic sophistication (Buodriga and Obaidat 2004; Chaturvedi et al. 2005; Sawyer 2003).

In this paper we present a computational model for simulating the dynamic interplay between aid and its linkages to the peace building process in a war ravaged region of the world, namely Afghanistan. Our goal is to integrate various socio-psychological and organization behavior models to assist in understanding the effectiveness of intervention strategies, specifically in understanding *what types* of intervention at *which particular time* can affect the various dimensions of peace building. The rest of the paper is organized as follows: Section 2 discusses the stability and reconstruction operation, especially addressing the issues of refugees and internally displaced people; Section 3 highlights the main features of Synthetic Environments for Analysis and Simulation (SEAS); Section 4 presents the environment configuration, parameterization, and calibration process; Section 5 describes the experiments and results; and Section 6 concludes the paper.

STABILITY AND RECONSTRUCTION OPERATION (2)

Though the scope can vary on a case by case basis, stability and reconstruction operations is a broad brushed approach to stabilizing and reconstructing conflict-ridden regions and/or regions devastated by endemic poverty and natural disasters. According to USAID, stability and reconstruction operation consists of three interrelated objectives:

- Stability that is advancing a degree of stability and personal security for affected individuals sufficient enough to assure their survival and be able to engage in basic economic activity. These include micro interventions such as humanitarian assistance such as food, water, shelter and a secure environment for the people as well as an environment conducive to the repatriation of Internally Displaced Persons and refugees, and more often than not diplomatic, political, and military interventions to bringing warring parties to agreement.

- Reform that is addressing issues of institutional reform thereby increasing state's effectiveness and legitimacy.

- Capacity that is developing capacity of institutions and infrastructure fundamental to advancing lasting recovery. Capacity building targets developing institutions at the local, regional and national levels.

While the first objective may be short term, reform and capacity building are considerable undertakings requiring long-term commitment and resources from aid agencies.

In recent years agencies have undertaken various mix of approaches to ensure maximum success. Two dominant approaches are the minimalist aid versus the maximalist effort. According to Goodhand (2004) the maximalists argue that aid should be consciously used as an instrument of peace building. It should be comprehensive strategy with the goal of providing a mixture of humanitarian, rehabilitation and development assistance that would in turn affect the behavior of various actors. Minimalists question the broadening of the aid's mandate and assume a clear distinction between humanitarian aid and development goals.

While normative debate is extensive, scholars agree that there is clearly a lack of empirical evidence that would support either of these methods. Due to the paucity of real world examples, challenges of data collection, issues with level of analysis and time frames, and measurement gaps, very little is known about the linkages between aid and the dynamics of violence, as well as its direct linkages with development and state-building.

SYNTHETIC ENVIRONMENT FOR ANALYSIS AND SIMULATION (SEAS) (3)

Synthetic Environments for Analysis and Simulation (SEAS) (Chaturvedi et al. 2004, 2005) provides an agent-based framework that is unbiased to any specific school of thought, scenario, model, or system paradigm.

SEAS COMPUTATIONAL INFRASTRUCTURE

It leverages enabling information technologies and computational architectures, such as grid computing, service oriented architecture and resource virtualization, to decouple model and data representation, implementation, execution, and control and data flows. SEAS computational infrastructure consists of two major components, SEAS Computational Engine and SEAS Extensible Net Assessment (SEAS xNA). These technologies enable SEAS to be a highly scalable, configurable, portable, and persistent environment wherein a wide range of large scale, complex problems can be studied in a holistic manner.

SEAS COMPUTATIONAL ENGINE

The technical architecture of SEAS is presented in Figure 1. The key components of SEAS are Virtual Execution Environment (VEE), SEAS Virtual Model Repository (SVMR), and Dynamic Resolution Manager (DRM). VEE enables researchers and analysts to configure a unique execution environment for their own requirements. Many such environments run simultaneously for different scenarios and courses of actions analysis.

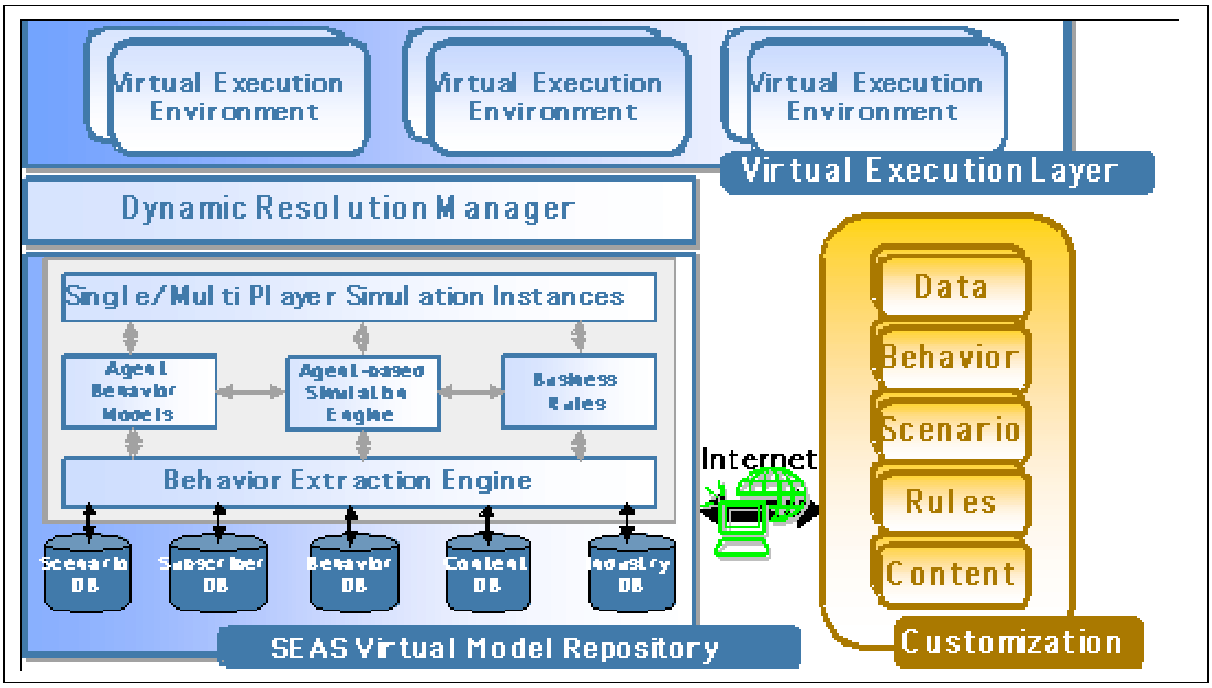

Figure 1: Technical Architecture of SEAS.

SEAS' Virtual Model Repository (SVMR) is a warehouse consisting of validated simulations, models, and model-components at varying levels of resolution, data, and inter-model coupling relationships. These essential elements can be selected, sustained, and appropriately combined to build any desired simulation through conformance to model and XML standards.

Each component is validated before committing it to SVMR to ensure an accurate representation of the behavior of its real-world counterparts, and for a specific level of simulation detail.

SEAS has a software zoom capability, called Dynamic Resolution Manager (DRM). Simulations can be presented at varying levels of fidelity. With a user-friendly graphical interface, different data sets can be selected and the information presented enhanced via DRM. Supported by the ability to accept live inputs, such as real-time sensor data or other databases, DRM allows simulated environments to be organized hierarchically for various levels of access and analysis. Information can be easily displayed and readily transitioned from one focus to another using detailed modeling, such as engineering level modeling, to aggregated strategic, theater, or campaign-level modeling.

SEAS EXTENSIBLE NET ASSESSMENT (SEAS xNA)

SEAS uses a knowledge base, called Extensible Net Assessment (xNA), to represent a synthetic environment in ontological form. The database is constructed from a variety of sources and perspectives, including proprietary databases, specific databases developed by analysts and public domain information gathered through web spiders. Information in xNA is tagged with the perspective, source, and period of time for which the information is valid. A runtime experiment is instantiated for a specific calendar date using a slice of knowledge from xNA, representing the state of the environment at the specified time. Models employed by SEAS in the active environment capture the emergent behavior of entities imported from xNA. Additional simulations and components are integrated with the synthetic environment enabling cross-disciplinary interaction with the knowledgebase. Selected types of changes that occur within the simulation runtime are persisted back into xNA, tagged with the excursion from where the knowledge originated.

SEAS MODELING FRAMEWORK

SEAS is a computational infrastructure designed to support plurality of thought. In other words, alternative points of view, modeling disciplines, schools of thought, representation schemes, and mathematical abstractions can be meaningfully implemented and integrated. SEAS modeling framework incorporates approaches to both, forward and inverse, classes of problem domains. It models fundamental human behavior theories from psychology, neuroscience, and economics as forward problems and complex emergent phenomena such as groups and organizational behaviors, societies, economies, nation states, and international systems as inverse problems. SEAS is an integration of millions of agents operating within a synthetic environment which allows it to take advantage of diverse theories for parameterization and estimations. In addition, the large number gives “real world like,” high degree of diversity in starting conditions and can be viewed as massively large numbers of experiments done in parallel. This enables SEAS the requisite degrees of freedom for analysis which otherwise would have required hundreds of runs.

SEAS agents emulate the attributes and interactions of individuals, organizations, institutions, infrastructure, and geographical decompositions. Agents join together to form networks from which evolve the various cultures of the world's population. Intricate relationships among political, military, economic, social, information and infrastructure (PmESII) factors emerge across diverse granularities. Statistics calculated from the simulation are then used to provide measurable evaluations of strategies in support of an effects-based approach to operations (EBAO) decision making.

The fundamental agent categories in SEAS are the individuals, organizations, institutions, and infrastructure (IOIIG). The population agents of these fundamental types form higher order constructs in a fractal-like manner where sufficient detail exists at multiple levels of focus, from world constructs to individuals. Higher order constructs include political systems (type of government, political parties/factions), militaries (soldiers, institutions, branches of service), economic systems (formal banking networks and black-market structures), social systems (tribes, religious groups, neighborhoods) and information systems (print, broadcast, internet).

Agents representing individuals are used to model the populace in the synthetic environment. Individual agents are categorized into citizen and leader agents. An individual's well being is based on a model consisting of eight fundamental needs: basic, political, financial, security, religious, educational, health, and freedom of movement. The desire and perceived level of each of the well being categories are populated taking into account the socio-economic class of the individual the agent represents.

Citizen agents are constructed as a proportional representation of the societal makeup of a real nation. A citizen agent consists of a set of fundamental constructs: traits, well being, sensors, goals, and actions. The traits of citizen agents, such as race, ethnicity, income, education, religion, gender, and nationalism, are configured according to statistics gathered from real world studies. Dynamic traits, such as religious and political orientations, emotional arousal, location, health, and well being, result during simulation according to models that operate on the citizen agents and interactions they have with other agents. The traits and well being determine the goals of a citizen agent. Each citizen agent "senses" its environment, taking into account messages from leaders the citizen has built a relationship with, media the citizen subscribes to, and other members in the citizen's social network. Each citizen agent's state and goals can change as a result of interactions the citizen has with its environment. A citizen agent can react to its environment by autonomously choosing from its repertoire of actions. Additionally, a citizen agent's set of possible actions can change during the course of the simulation, such as when a citizen agent resorts to violence. Traits, well-being, sensors, and actions together determine the behavior of the citizen agent.

Leader agents have additional traits over citizen agents and can have an influence level within their organizations and institutions. A leader agent can take specific stances on key economic, political and social issues and can influence citizen agents to take on the leader's attitudes, thereby altering the political and social climate in an attempt to promote the leader's goals. A leader agent that leads a specific organization is also able to leverage its organization's resources. On the other hand, citizen agents can elect leaders to places of position and replace former leaders.

Clusters of citizen and leader agents form organizations. Citizen agents voluntarily join organizations due to affinity in perspective between the citizens and the organization. An organization agent's behavior is based on a foundation consisting of the desires of the organization's leaders and members. Organizational leadership constantly seeks maintenance and growth of the organizational membership by providing tangible and intangible benefits, and citizens subscribe based on a perceived level of benefit that is received from the organization. Additionally, through inter-organization networks, attitudes and resources may be shared among organizations. Through these internal and external interactions, organizations cause significant changes in perception and attitude change and become core protagonists of activism in the model. In turn, an organization exercises its power through the control over its resources and its ability to procure and maintain its resource base.

Institution agents are represented as 'governmental entities' such as the army, police, legislature, courts, executive, bureaucracy, and political parties—entities that are able to formulate policies that have legal binding, and have more discretionary resources. SEAS models institutions as structures that are products of individual choices or preferences, being constrained by the institutional structures (i.e. an interactive process). Institutions are like formal organizations with an additional power to influence the behaviors of members and non-members.

Media agents also play a significant role in providing information to other agents in the form of reports on well-being and attitudes. Media organizations consist of television, radio, newspapers, and magazines. The media make choices of what information to cover, who to cover, what statements to report, what story elements to emphasize and how to report them. Incidents are framed on well-being components, and formalized in a media report. Media is able to set the agenda for domestic policies as well as foreign policy issues. Citizens subscribe to media organizations based on their ideological bend. Media organizations act primarily to frame the issues for their audiences in such a way that they increase their viewership as well as their influence.

Agents emulate the behavior of the entity it represents via the possible engagement options available to that agent and the environment that it is operating within. In essence, the agent intelligence represents the possible exchanges between the agent's attributes and traits, on the one hand, and the agent's environment comprised of a host of other dissimilar agents, on the other hand. The rules of engagement are known for any class of agents and are configured for a particular experiment. This intelligence consists of seven "behavior primitives" that describe the range of possible actions: initiate, search, decide, execute, update, communicate and terminate. Specific algorithms are used to describe the intensity of particular classes of agent intelligence and to affect the agent behavior with respect to external stimuli.

Agents interact with the environment and respond, that is take actions, to exogenous variables that may be specified by human agents or players in the environment as well as inputs from other agents. This is implemented with the introduction of inputs and outputs that each agent possesses. Inputs consist of general "environmental sensors" as well as particular "incoming message sensors." The incoming message sensors are singled out by each agent as agents have the ability to query messages from the environment discriminately. The agent also possesses ports characterized collectively as "external actions" that allow the agent to submit its actions or messages to the environment. Finally, the agent possesses an internal set of rules classified as "internal actions" that result in the agents "external actions" on the basis of the sensor inputs as well as the traits/attributes and intelligence structure of each agent.

Algorithms, which are differentiated for a specific type of agent, are embedded into each agent to create a decision-making ability. These algorithms enable up to five decision-making characteristics, depending on the nature, or sophistication, of each agent. These characteristics are: (a) adaptation by relating events (desired and un-desired) to actionable events through cause and effect relationships; (b) course of action (COA) selection, sequencing, and timing actions that would achieve desired effects and suppress undesired effects in a timely manner; (c) sensing to determine the indicators of effects and what and when to look for these indicators; (d) evaluation by determining metrics by which measures of performance and effectiveness can be formulated so that COAs can be compared; and (e) self-regulation as plans that implement selected COAs unfold and sensors provide the state of indicators, calculate the degree of success and determine if changes should be made to the COAs.

CONFIGURATION, PARAMETERIZATION, AND CALIBRATION FOR VIRTUAL AFGHANISTAN (4)

Afghanistan lends itself as an example of a multi-year multi-nation humanitarian intervention effort with the ultimate goal of ‘nation-building.’ Toward the end of 2001, Afghanistan was one of the poorest nations in the world manifested with little or no surviving infrastructure, failing economy, repressed populace, internecine warfare, a refugee crisis of immense proportions and the criminalization and deligitimization of the state (Cramer and Goodhand 2002). NATO led reconstruction efforts in collaboration with several NGOs have targeted a whole spectrum of nation-building efforts such as institution building, reconstruction of economy and critical infrastructure, provision of security and humanitarian aid, helping repatriation of refugees and internally displaced people.

According to the Internal Displacement Monitoring Center report (2005) IDPs and refugee crisis is one of the most enduring problems facing Afghanistan and the aid agencies. Repatriated IDPs find integration difficult or impossible due to unresolved property disputes, lack of an environment fostering stable income, and ethnic resentments. Refugee camps have become sites of rebel leaders (Taliban) who use them as bases to recruit and train individuals, control and replenish the supplies and launch incursions into the country. Idleness in the camp has increased resentment amongst the refugees fostering ideological extremism. To date reports on progress remain mixed (Bellamy and Williams 2005). UNHCR reported thousands living in displacement, mainly in Zer-e-Dasht and Panjwai in Kandahar province, Mukhtar in the Helmand province, Masalakh in Herat province and many more in smaller camps bordering Pakistan. Water shortages, poor sanitation conditions, and high insecurity remain major impediments to camp stability. We use this backdrop to analyze the impact of various intervention measures.

Virtual Afghanistan is a full synthetic environment that allows human-in-the-loop (HITL) players to interact with a broad range of actors in a strife torn region of the world, including coalitions of forces, non-government organizations (NGO), local government agencies, terrorist networks, media outlets, internally displaced persons (IDPs), and local administrations. The synthetic world is designed so that the outcomes of players’ actions emerge much like they do in the real world.

The VA scenario investigates the impact that well being of internally displaced persons (IDP) can have on the coalition’s objectives. Approximate locations of a number of IDP camps are indicated in Figure 2. The coloring in the map indicate areas of risk with respect to stability and terrorist activity, (blue is low risk, yellow is medium, and red is high). Though the population of the IDP camps is much smaller than the population of the country of interest, health and security issues within IDP camps can require military resources, influence the effectiveness of NGOs, and sway world public opinion.

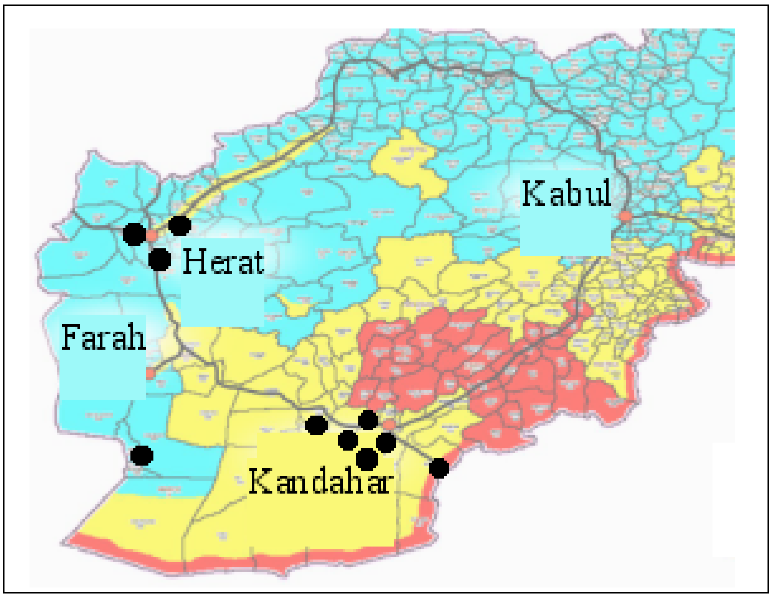

Figure 2: The Virtual Afghanistan.

Virtual Afghanistan (VA), in the experiment, is represented by a physical landscape (G), and autonomous, adaptive and cognitive agents consisting of individuals (I), organizations (O), institutions (I), and infrastructure (I). VA is represented by 47000 citizen agents, 19000 refugee agents, 208 infrastructure agents, 17 named organizations, 29 named leaders, and 2 institution agents as shown in Figure 3. We build five southern provinces of Afghanistan—Zabol, Uruzgan, Helmand, Nimroz and Kandahar at a much finer granulatity. These five provinces were chosen as they have proven to be the most unstable and dangerous with areas controlled by warlords, factional infighting, and maximum refugee flows.

Representative organization and leader agents were chosen that could reflect the religious, ethnic, tribal and ideological fragmentation in Afghan society. For example, Uzbek warlord General Abdul Rashid Dostum, Pashtun warlord Gulbuddin Hekmatyar, and Governor of Herat Ismail Khan are some of the prominent leaders while Hezb e-Wahdat, Hezb e-Islami, and Jamiat e-Islami are examples of various organizations. For many of the SEAS models used in the experiment, a day tick temporal granularity was used, capturing international alliances, media broadcasts, and changes in the economy, for example. Within the country of interest, a one-to-one-thousand sampling of agents to people was used to represent the population.

Fine-grained models are employed to address the health and security issues surrounding Refugee/IDP camps. Within a Refugee/IDP camp, an hourly temporal granularity is used to capture health crises and crowd violence that can result from basic needs not being met and ethnic or class differences within a camp. In an IDP camp, each inhabitant is individually modeled as an agent. The following section describes one of the classes of models and the calibration processes in detail.

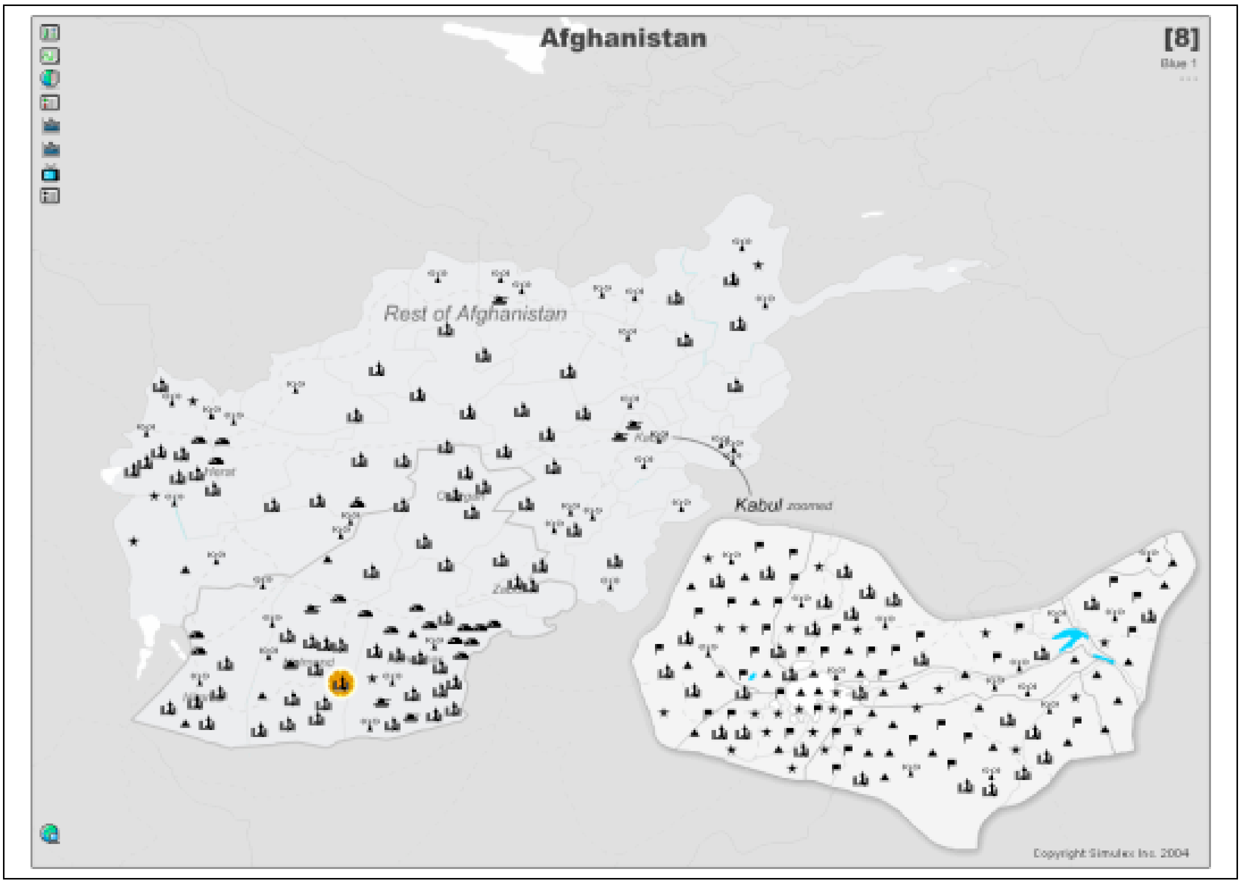

Figure 3: Modeled PMESII Nodes in Virtual Afghanistan.

MODEL DETAILS

As discussed in the previous section, many models representing PmESII elements of Afghanistan are implemented, configured, and calibrated. Exemplars of agents, models, inputs, and outputs are described below.

- *Refugees/IDP*. These agents are special cases of citizen agents. There are three "income" classes for IDP/Refugees: Elite, Middle, and poor. The 'elite class' refugees represent a small group who manage to secure power and additional goods for themselves, often at the expense of others. The 'middle class' refugees are those who do somewhat better than the majority of people, but have not secured the power or additional goods that the elite refugees have. The 'poor class' refugees comprise a majority of the population of the community, are the weakest and most exploited.

- *Refugee Agents Details*. The traits modeled in each IDP agent include religion, ethnicity, income, social networks, and ideology. Information reaches the agents via traditional media sources and rumors spread by other agents. A refugee agent's behavior is primarily driven by his/her well being.

- *Sickness Model*. Refugees can be in one of four states: Healthy, Sick outside the Medical Center, Sick Inside the Medical Center, and Dead. Refugees remain in a particular state for a minimum of one time step, representing one hour. Every agent can query each time step to see if they remain in their current state or transition to another state.

- *State: Healthy*. This is the default state for agents. Agents remain in this state until they become sick and transition to "Sick Outside" state. The probability that an agent will become sick is a non-linear function, $f(\mathit{Basic\ Needs}, \mathit{Food\_Water}, \mathit{Sanitation})$, of the refugee's current perceived Basic Needs level, the community Sanitation level, and the community Food/Water level.

- *State: Sick Outside the Medical Center*. When an agent becomes sick, they enter this state and are assigned a number, , from a triangular distribution that represents the number of time steps in which they will die if they are unable to enter the medical center. Again, the agent checks with each time step its health status as a result of his/her ability or inability to obtain medical attention. If they are still alive, agents can attempt to enter the medical center and transition to 'Sick Inside.' If the medical center has exceeded its capacity, the agent is forced to remain in 'Sick Outside.'

- *State: Sick Inside the Medical Center*. When agents enter the medical center they are assigned a number that represents the number of time steps in which they will become well again and transition to Healthy. The number of time steps until they become healthy is a non-linear function, , of a number from a triangular distribution, the community Medical Resources level, the community Medical Personnel level, and the community Security level. With each time step, an agent checks to see its survival status in the medical center. The probability of dying in the Medical Center is p = 0.0001 per time step. If not dead, they check to see if sufficient time has elapsed to become healthy eventually transitioning to the Healthy state.

- *State: Dead*. Once an agent dies, it is removed from the camp and undergoes no further processing.

- *Inputs:* Policy decisions and actions by governments and NGOs provide the inputs to the model. These are entered through SEAS Action Planner. Levels of Security, Food and Water, Medical Personnel, Medical Resources and Sanitation can take on values ranging from 1 to 10. The capacity of the medical clinic/hospital is also established a priori.

- *Outputs:* The outputs of the model include the numbers of healthy, ill and dead refugees. Also the number of ill refugees being treated by the clinic/hospital is calculated. These outputs ate displayed in SEAS Visual interface.

CALIBRATION PROCESS

The sickness model is calibrated using information from the United Nations Refugee Agency (UNHCR). In the proceeding paragraphs we present two steps of our calibration process, model calibration and intervention calibration.

MODEL CALIBRATION

Information from the UNHCR Standards and Indicators suggests that death rates for stable refugee camps should be < 1.5 per 1,000 populations each month, and death rates for refugee camps in an "emergency" state should be < 1 per 10,000 populations each day. Converted to the same units, stable: 1.5 deaths/1000 pop each month, emergency: 4.5 deaths/1000 pop each month. The death rates from the model reasonably approximate the data for the stable as well as the emergency conditions.

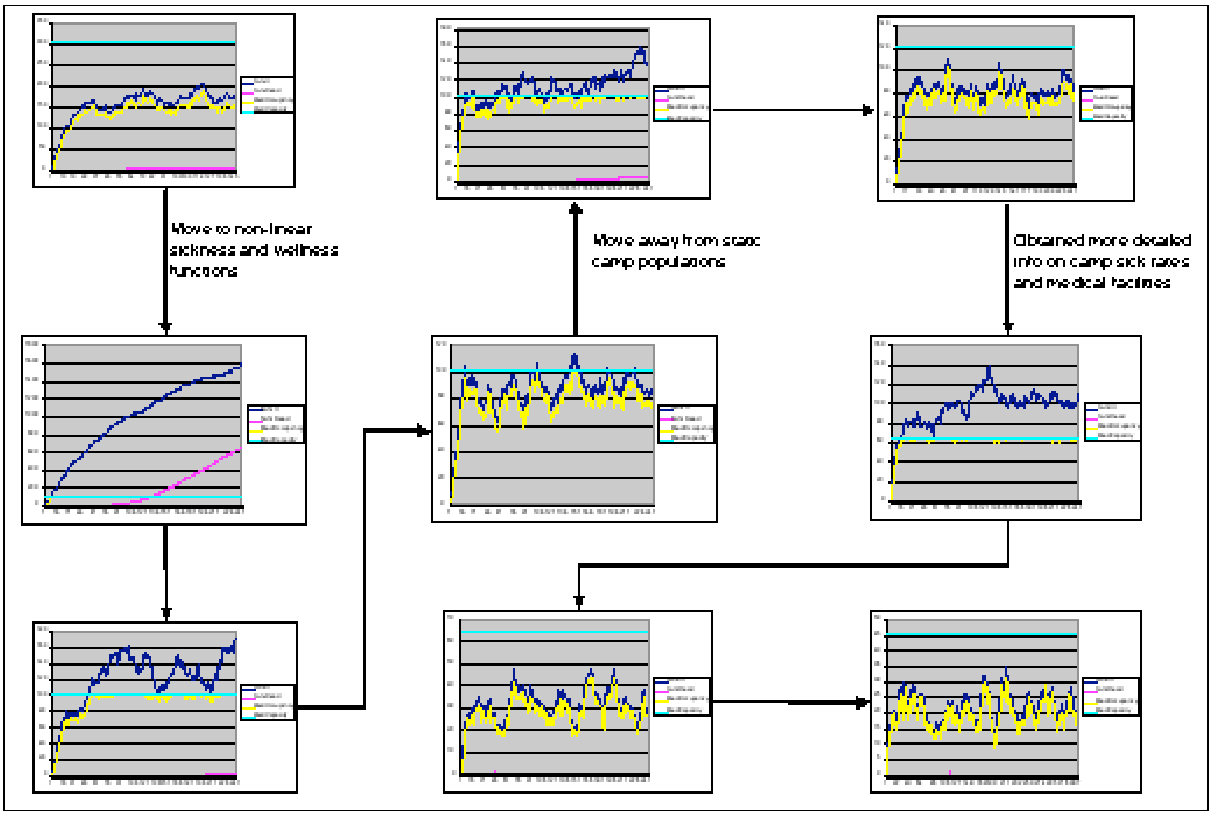

Figure 4: Model Calibration Process.

The UNHCR Standards and Indicators also provide insights into sick rates in the camps. In stable camps, the number of new visits to primary health facilities per person per year is 1.0 - 4.0. Note that this is the number of *new* visits and does not include follow-up visits, which will increase the number of visits per year. The standards, however, do not provide any information about follow-up visits. We assume that 75% of visits require a follow-up visit and 50% of those require a (second) follow-up visit giving us the number of visits per year as approximately 2.125 – 8.5. For camps in an "emergency" state, the standards suggest that the number of new visits per person per year is 3.0 – 5.0. Using the same assumptions about follow-up visits, we have approximately 6.375 – 10.625 visits per year.

As shown in Figure 4, we start by rough estimation of the parameters of the sickness model. These are linear approximation from the empirical data. We run the models and analyze the results. Next we introduce non-linearity to better match the historical time series data which provides better estimates. These steps assume that the size of the camp is constant. In the following phase of calibration we relax this assumption and allow new refugees/IDP to enter the camp. In the final step of calibration, we introduce sickness rates and medical facilities distribution and readjust the parameters to match the empirical data.

INTERVENTION CALIBRATION

Intervention calibration entails adjusting the responsiveness of the model taking into account the ranges of values for each relevant variable. Some of the variables may have direct impact on the observed metric while the other may have indirect impact. For example, while sanitation may be assumed to have a direct impact on number of sick, closure of supply route may have indirect impact. As shown in Figure 5, we perturb the PmESII values to get the distributions for sickness and wellness.

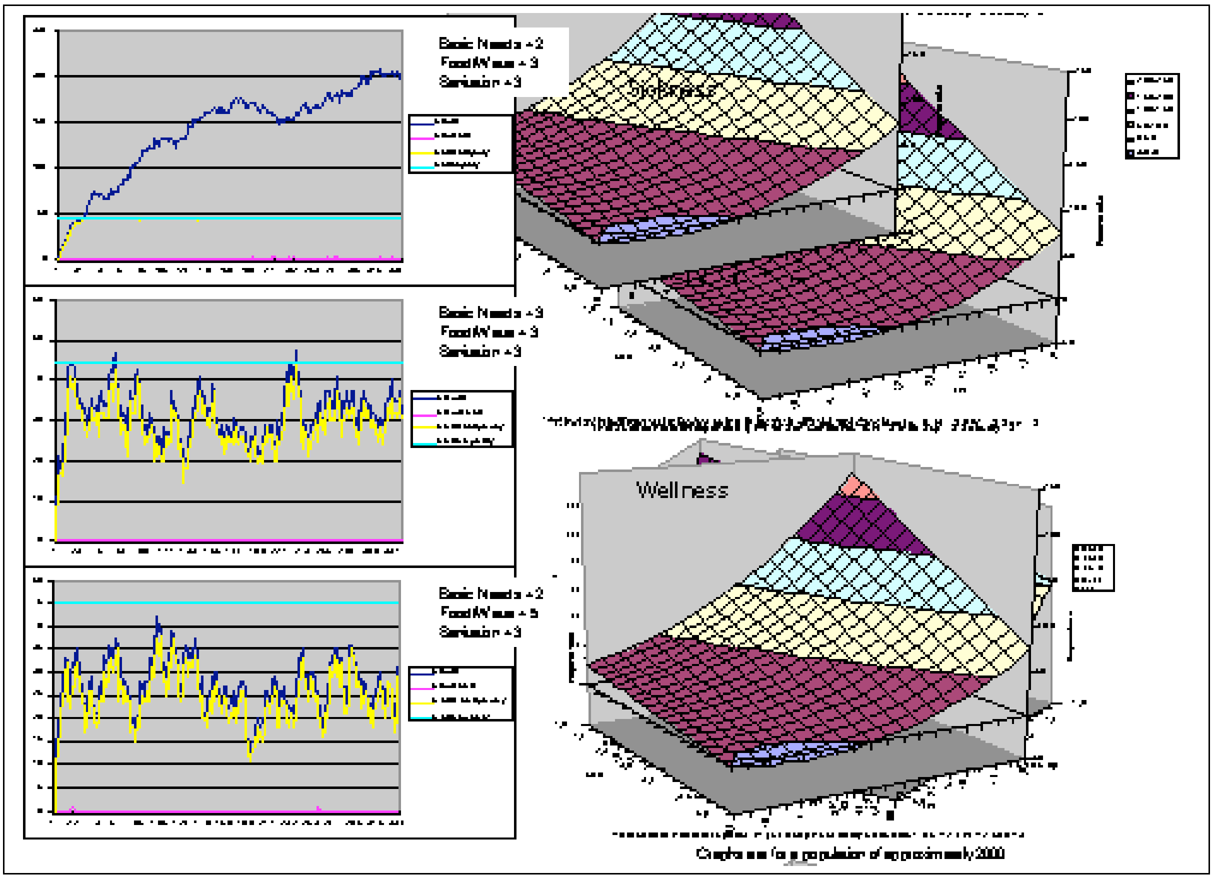

Figure 5: Intervention Calibration Process.

This process of model and intervention calibration is repeated for all models and the entire range of Diplomatic, Information, military, Economic (DImE) actions. We rely primarily on data to determine the response rates. Wherever data is not available we resort to well accepted theories from published reports in peer-reviewed journals. Obviously, there are bound to be areas were neither data nor theories exist. In such cases we make reasonable assumptions with the help of subject matter experts, assumptions that are transparent to the users.

TYPES OF INTERVENTION

By mixing and matching DImE actions on PmESII nodes and allocating different levels of resources, experimenters can create rich sets of intervention plans focusing on different aspects of stability and reconstruction operation. These plans can then be tested in SEAS-VIS environment and their impacts on different metrics can be measured, analyzed, and causality estimated. Because SEAS-VIS is set up in an n-sided interaction, each side in the environment has ability to take actions against each other. The availability of action sets and the resource to the sides are configured at the beginning of the experiment based on real world information. Whenever there is paucity of information, separate experiments can be set with different assumptions in order to get better estimation of resources. The following is a subset of all available actions in SEAS-VIS.

- *Engage (D):* This action is taken on an Organization or a Leader to diplomatically persuade the entity to support the actor. The resource level indicates the level of engagement.

- *Expand Diplomatic Relations (D):* This action is taken on an Institution to diplomatically persuade the entity to support the actor. The resource level indicates the level of engagement.

- *Issue Demarche (D):* This action is taken on an Institution or a Leader to internationally convey an objection to the entity's actions. The resource level indicates the level of objection.

- *Reduce Diplomatic Relations (D):* This action is taken on an Institution to internationally convey an objection to the entity's actions by reducing diplomatic relations. The resource level indicates the amount of reduction in diplomatic relations.

- *Threaten an Embargo (D):* This action is taken on an Institution to convey economic threat in the form of an embargo on the nation. The resource level indicates the level of threat.

- *Threaten Economic Sanctions (D):* This action is taken on an Institution to convey economic threat in the form of economic sanctions on the nation. The resource level indicates the level of threat.

- *Conduct Psychological Operation (I):* This action is taken on geography to indicate that the player is undertaking psychological operation in that geography. The resource level indicates the subset (designated by thirds) of the population targeted by the operation. This action is treated as an attempt by the player to persuade the citizens to align their attitudes with those of the player.

- *Media Campaign (I):* This action is taken on media to persuade it to convey information with a desired spin to its subscribers. The spin of the media campaign is set by the actions "Media Campaign: Opposing" and "Media Campaign: Supporting". It is assumed that the entity taking this action desires a positive spin attributed towards itself. The resource level indicates the extent of the media campaign influencing the number of subscribers that are likely to be aware of the campaign.

- *Disrupt Relief Activities (M):* This action is taken on geography to disrupt any relief activities that might be ongoing in that geography. The resource level indicates the level of disruption.

- *Disrupt Critical Infrastructure (M):* This action is taken on a geography to disrupt all infrastructure in the following sectors: Agriculture, Education, Health, Power, Transportation, and Water.

- *Protect Critical Infrastructure (M):* This action is taken on geography to protect all infrastructures in the following sectors to a level indicated by the resource level of the action: Agriculture, Education, Health, Power, Transportation, and Water.

- *Destroy (M):* This action is taken on infrastructure to damage it through the use of overt military means. The effect is permanent, and the resource level is indicative of the level of damage intended.

- *Disrupt (M):* This action is taken on infrastructure to disrupt its activities through the use of overt military means. The effect is temporary and ceases when the action is removed. The resource level is indicative of the level of disruption intended.

- *Kidnap (M) / Arrest (M) / Assassinate (M):* These actions are applicable to Leaders. Action is always successful without regard to the resource level. Media reports on the event and inter-organization communication influence citizen wellbeing, attitude and arousal.

- *Deploy Troops (M):* This action is taken on geography to indicate that military forces or militia affiliated with the player are present in that geography. The resource level indicates the level of troops.

- *Provide Relief Aid: XXXXX (E):*

  > Provide Relief Aid: Education (E)
  > Provide Relief Aid: Food (E)
  > Provide Relief Aid: Health (E)
  > Provide Relief Aid: Power (E)

> Provide Relief Aid: Sanitation (E)
> Provide Relief Aid: Telecommunications (E)
> Provide Relief Aid: Transportation (E)
> Provide Relief Aid: Water (E)

These actions are taken on geography to provide temporary relief to citizens in that geography. The resource level indicates the fraction of citizens that are targeted by this action.

- *Provide Resources to Local Security Institutions (E):* This action is taken on a geography to temporarily increase the level of local security forces in that geography. The resource level of the action indicates the level of resources provided.

- *Rebuild/Expand Critical Infrastructure (E):* This action is taken on a geography to rebuild all infrastructures in the following sectors: Agriculture, Education, Health, Power, Transportation, and Water. The resource level of the action indicates the level of effort expended in the rebuilding.

- *Provide Humanitarian Relief (E):* This action is taken on organizations and leaders to provide them with humanitarian relief for redistribution. The resource level indicates the amount of goods provided.

EXPERIMENTS AND RESULTS (5)

Once we have a calibrated synthetic environment, which in the steady state gives outputs that are consistent with the real world, we design different experiments to study the behaviors of the communities. In our experiment, we interject an earthquake to analyze the immediate and prolonged impact on the well-being of citizens in a specific locality as well as in the neighboring regions. Our intervention strategy consists of DImE actions that are taken by international and national aid agencies on PmESII nodes to mitigate the impact of the disaster. DImE actions taken by the Coalition Task Force are entered manually while actions taken by the anti-government factions and terrorist groups are automated. We create various action planners with minimalists and/or maximalist approaches to aid strategies.

EXPERIMENTS

We set up experiments to analyze the effects of two intervention strategies on the condition of refugee camps both in the immediate aftermath of the earthquake and in the following reconstruction period. The actions are injected two days after the simulated earthquake. The epicenter of the earthquake is located on the west side of Helmand, and subsequently the provinces of Nimroz and Helmand were most heavily affected. Sixteen refugee camps were modeled in Virtual Afghanistan, three of which were directly affected by the earthquake due to their proximity—Makaki (Nimroz, ~6000 refugees and IDPs), Mile 46 (Nimroz, ~10,000 refugees and IDPs), and Mukhtar (Helmand, ~22,000 refugees and IDPs).

SCENARIO 0 – BASELINE

Our first experiment simulates the effect of no intervention from the Coalition Task Force in conjunction with low criminal and terrorist activity from the Red groups. The baseline results are used to assess the impact of different intervention strategies in the aftermath of the virtual earthquake.

SCENARIO 1 – MINIMALIST APPROACH

Experiment 1 has a low level action aimed at bolstering security in refugee camps, aid/protect critical infrastructure in southern Afghanistan coupled with high level of aid to NGOs to support refugee camps within the provinces affected by the earthquake**.** There are medium levels of criminal and terrorist activities aimed at disrupting the relief effort.

SCENARIO 2 – MAXIMALIST APPROACH

In experiment 2 high levels of resources are allocated to the actions taken by the Coalition Task Force and are aimed at interdicting Red (adversarial) organizations, aid/protect critical infrastructure in southern Afghanistan, media campaign/psychological operations against Red entities. Criminal and terrorist activities are set at medium levels.

RESULTS

IMPACT OF INTERVENTION STRATEGIES ON SICKNESS AND DEATH

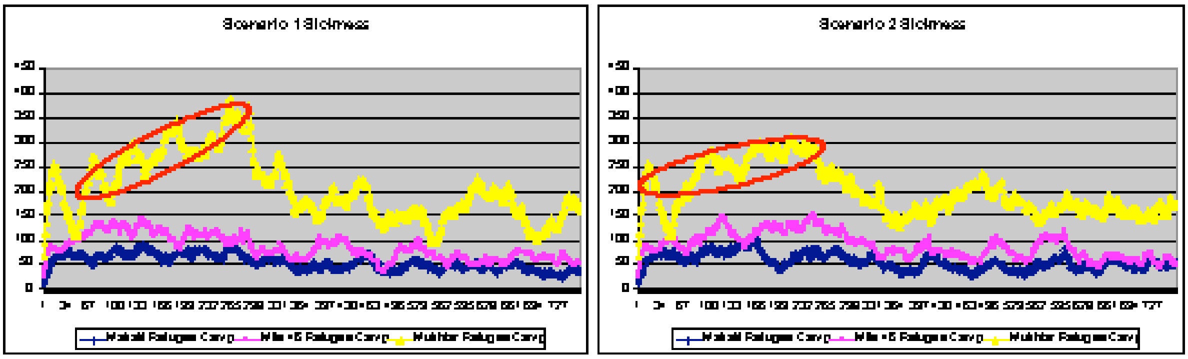

Figure 6: Impact of Intervention Strategies on Sickness Level in the aftermath of Earthquake.

As shown in Figure 6, the maximalist approach produces a larger reduction in the number of sick in the camp following the earthquake. However, because of the medium levels of criminal and terrorist activities, the return on the investment is low compared to the minimalist approach. Greater availability of resources increases criminal and terrorist activities as money, medical supplies, and food are siphoned off to black markets for profits. These profits in turn finance the criminal and terrorist activities. This cycle, in turn, has detrimental effect on the stability and reconstruction operation.

It is interesting to note that the main difference between the two strategies is in the peak levels of sickness in the affected camp and stabilizes at approximately the same level. This result has clear policy, humanitarian, and moral implications. These implications are more evident when we analyze the number of deaths in the camp as shown in Figure 7. Maximalist strategy reduces the number of deaths by 33% over the minimalist approach. The issue again is how the resource can be or should be allocated to mitigate the suffering of the affected populace.

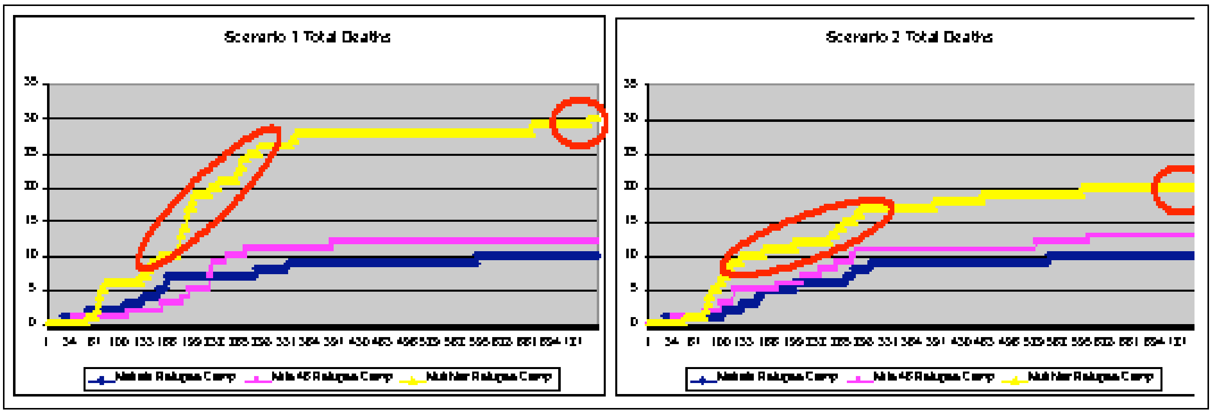

Figure 7: Impact of Intervention Strategies on the number of Deaths from Sickness in the aftermath of Earthquake.

IMPACT OF INTERVENTION STRATEGIES ON PUBLIC OPINIONS

As shown in Figure 8, the impact of intervention strategies on local to global public opinions is counter-intuitive. Maximalist approach actually does worse than the minimalist approach. Maximalist approach, over a longer period of time, increases criminal and terrorist activities resulting in decline in favorable public opinion, especially among the citizens of Afghanistan.

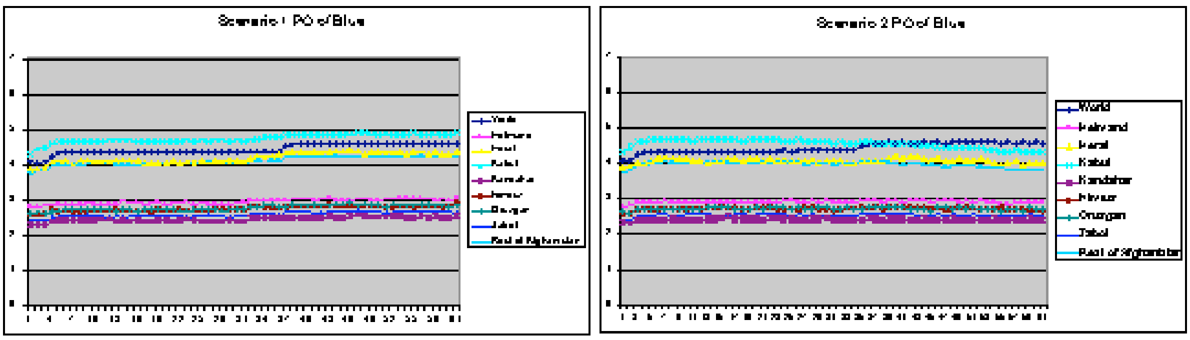

Figure 8: Impact of Intervention Strategies on Public Opinions.

CONCLUSION (8)

Humanitarian aid and assistance is considered a critical tool for development and reconstruction. Analysts agree that reconstruction is a long term holistic process that includes a full range of integrated activities such as restoration of physical infrastructure, building institutions and enhancing government capacity, reforming and/or transforming political, social, and economic sectors, and socio-psychological support to communities affected severely by the conflict ridden environment. Debate however ranges over the timing, content, and sequencing of development and reconstruction efforts. International aid community is also faced with various challenges that mitigate coordination of aid. Challenges are posed by recurring natural disasters such as drought and earthquakes, high numbers of internally displaced persons, and returning refugees, contested terrain, and competing regional and international influences.

In this paper we present a computational model for simulating the dynamic interplay between aid and its linkages to the peace building process in a war ravaged region of the world. Our goal is to integrate various socio-psychological and organization behavior models to assist in understanding the effectiveness of intervention strategies, specifically in understanding *what types* of intervention at *which particular time* can affect the various dimensions of peace building.

We use the SEAS-VIS platform to construct a Virtual Afghanistan represented by a physical landscape, and autonomous, adaptive and cognitive agents consisting of individuals, organizations, institutions, and infrastructure. Virtual Afghanistan is represented by 47000 citizen agents, 19000 refugee agents, 208 infrastructure agents, 17 named organizations, 29 named leaders, and 2 institution agents. We interject an earthquake to analyze the immediate and prolonged impact on the well-being of citizens in a specific locality as well as in the neighboring regions. Our intervention strategy consists of Diplomatic, Information, military, and Economic (DImE) actions that are taken by international and national aid agencies on Political, military, Economic, Social, Information, and Infrastructure (PmESII) entities to mitigate the impact of the disaster. We test various courses of actions with Minimalists and Maximalist approaches to aid strategies.

Our results indicate that in the presence of moderate levels of criminal and terrorist activities, a Minimalist Approach to stability and reconstruction operation may provide a better return on investment than a Maximalist Approach. However, the result should be accepted with caution. Given the dynamic nature of n-sided interests in an environment, each side adapts to the actions taken by the others to achieve their own goals. Coalitions and alliances are formed and disbanded; leaders emerge and lose favor; and same actions can have popular support at one time and may be viewed as coercive at another. As such, the definitions of “minimalist” and “maximalist” approaches change as situation changes.

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