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**INVESTIGATING THE COMPLEXITIES OF
NATIONBUILDING: A SUB-NATIONAL
REGIONAL PERSPECTIVE**

THESIS

Matthew JD Robbins, Captain, USAF

AFIT/GOR/ENS/05-16

**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY**

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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AFIT/GOR/ENS/05-16

INVESTIGATING THE COMPLEXITIES OF
NATIONBUILDING: A SUB-NATIONAL
REGIONAL PERSPECTIVE

THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Operations Research

Matthew J. Robbins, BS

Captain, USAF

March 2005

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INVESTIGATING THE COMPLEXITIES OF
NATIONBUILDING: A SUB-NATIONAL
REGIONAL PERSPECTIVE

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Abstract

Stabilization and reconstruction operations are necessary to secure and maintain the peace in the aftermath of conflict. The complexities of nation-building involve many different but interrelated systems and institutions. The basic structure of a country may or may not remain; its political, economic, and judicial systems, cultural, educational, medical, and military institutions, and critical infrastructure all vitally contribute to the overall progression of stability and prosperity. Understanding the significance of the dynamic relationships between the forces in play during stability and reconstruction operations is paramount to the successful conclusion of such missions. The system dynamics model proposed in this research functions as a support tool allowing decision-makers and analysts to investigate different sets of decision approaches at a sub-national, regional level. Concentration on the regional level allows for specific identification and investigation of potentially troublesome regions, providing the model-user with more detailed information concerning the internal dynamics prevalent within the area of operations. Construction of two different measures via logistic regression, a probability of stabilization success and a probability of stabilization failure, provide indication as to the successful execution of stabilization and reconstruction operations. The proposed model is a general construct, widely adaptable to a variety of post-conflict nation-building scenarios. The model is notionally demonstrated using Operation Iraqi Freedom as a test case.

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INVESTIGATING THE COMPLEXITIES OF NATIONBUILDING: A SUB-NATIONAL REGIONAL PERSPECTIVE

I. Introduction

Background

As declared by the President of the United States in the September 2002 National Security Strategy, the most formidable challenge to freedom and peace in the upcoming century will no longer involve large scale conflicts between rival nation-states; rather it is the ambitions and destructiveness of global terrorist organizations. As affirmed by the president, the United States will actively seek out and destroy these terrorist organizations regardless of their location (Bush, 2002: 5).

The primary tenet of the United States national security strategy elucidates American determination to act preemptively, if necessary, in exercising the right of self-defense against purveyors of global terrorism (Bush, 2002: 6). Therefore, denying support and sanctuary to terrorists across the globe where enabling conditions for terrorism prevail is a primary driver for future military conflicts. The potential threat to the national security of the United States posed by these failing states which are inadvertently or actively providing safe harbor to global terrorist organizations provides a galvanizing motivation to explore the complexities involved in “convincing or compelling states to accept their sovereign responsibilities” (Bush, 2002: 6).

A question remains, however; with what frequency will the US find itself involved in sub-national and transnational conflicts within these failed states and why?

Dr Thomas Barnett, in his book *The Pentagon's New Map; War and Peace in the*

Twenty-First Century (2004) and other outlets offers one rationale providing context for the currently prevailing geopolitical situation. In particular, in an article written for the National Intelligence Council's 2020 project titled *Does the US Face a Future of Never-ending Subnational and Transnational Violence?* Barnett (2004) directly addresses the concerns surrounding failed states.

Barnett (2004:2) suggests a capitalist economic worldview drives global interdependency forward, subtly forcing states to continually integrate economically, politically, culturally, and on other levels into a core global whole. A connectivity is thus developed between functioning parts of the global community as globalization extends throughout the world. Those areas that do not connect into this global economy (for various reasons) are often found to be the areas where security problems arise (failed states). Barnett (2004:2) emphasizes what the President's National Security Strategy contended, that the world has moved rapidly from a Cold War/global nuclear war era through a transitional phase, where rogue states were deemed the most problematic to global stability, to the now prevailing geopolitical situation whereby transnational non-state actors are the drivers of worldwide disruptions to peace. For a variety of reasons these non-state actors (terrorist networks) will continually be found in failed states, with those states typically being unattached to the global community.

Barnett (2004:3) defines state failure as:

a state is 'failing' if it either cannot attract or build itself the connectivity associated with globalization's progressive advance or if it essentially seeks to retard or deny the development of such connectivity out of desire to maintain strict political control over its population.

As mentioned, terrorist networks seek out the failed states for a variety of reasons. Regimes in failed states often do not have full control over its own territory (e.g., Somalia, Afghanistan) allowing groups to arrange agreements with local leaders and set up operations without fear of a national government response. Failed states often experience political turmoil which is then exploited by the terrorists to create a supportive and friendly environment (e.g. Sudan and potentially other sub-Saharan African states in the near future). Failed states are often ruled by authoritarian regimes offering limited support to terrorist networks (e.g. Iran's support of Hezbollah, Liberia's offer of sanctuary in return for cash). Barnett suggests an underlying rejectionist ideology amongst the terrorist leadership fighting against the "reality of globalization's progressive advance into traditional Islamic societies" as driving rationale behind the current geopolitical situation (Barnett, 2004:4). The terrorists are individuals motivated to fight this "assault" on traditional values. They view the failed states as bases from which to strike back against the powers of globalization, the chief of which is the United States.

Barnett also discusses the future integration of disconnected regions into the global economy, arguing that the disconnected regions lack technological, social, economic, and political connectivity to the global economy. Since the Cold War it is in these regions that most of the internal and terrorist violence occurs. The four disconnected regions are: Southwest Asia/Greater Middle East, Asia Pacific, Sub-Saharan Africa, and the Caribbean Rim/Central America/Northern Andes region (2004:6). When examining these regions from a historical context it is not difficult to see the current problems stem from, in part, national boundaries drawn with imperialistic intentions as the primary consideration. In particular for the Middle East, the Sykes-Picot

Treaty implemented at the conclusion of World War I could be argued as a root cause of many of the present day problems due to the ethnic fractionalization resulting from the politically motivated determination of national borders. The historical backdrop of the disconnected regions complements the rationale put forth by Barnett. As for nation-building as US national policy, Barnett directly states the continuing and pressing need for nation-building as the US seeks to rehabilitate and reintegrate the failed states into the global economy. In fact, in his book Barnett expounds a controversial vision of a US military force-shaping evolution necessary to successfully conduct the potentially numerous upcoming nation-building operations.

The stabilization and reconstruction (S&R) operations addressed in this study focus primarily on the aftermath of military operations executed to forcibly compel a state to alter its policy on terrorism. Whether the state was actively hostile or simply incapable of policing itself is irrelevant; direct military action is assumed to have occurred. A myriad of different political paths could lead to such a stabilization and reconstruction effort and, sadly, as discussed above, there appears to be definitive potential for future nation-building operations.

By design, the model developed is general in nature; it fits the middle-state of a particular S&R situation and does not directly factor in the geopolitical events leading up to that particular situation. More specifically, the model does not consider phase I, II, or III (partially) operations directly. The conditions resulting from actions taken in these phases are captured by the initial states and growth rates of the variables within the model, though the model could be viewed as spanning the overlap of phase III and phase IV operations to the end of phase IV.

Phasing operations is a basic tenet of campaign planning (DoD, 2001: III-18). Although a commander has leeway to establish actual phases as necessary, the typical four phases used to organize the full spectrum of combat and non-combat operations are: deter/engage (I), seize initiative (II), decisive operations (III), and transition (IV) (DoD, 2001: III-19). Planning and conducting a campaign in phases allows commanders and staffs to visualize and think through the entire campaign in terms of forces, resources, time, space, and purpose (DoD, 2001: III-18), thus providing a progressive advantage to the forces using phased operations. It is also acknowledged that “phases may be conducted sequentially or concurrently and may overlap” (DoD, 2001: III-18).

The major assumption of this study presupposes a successful military operation that removes a hostile or ineffective (and terrorist enabling) leadership from power. With such a condition existing, the victor finds itself transitioning between phase III and phase IV. Remnants of the hostile regime must be confronted while simultaneously a multitude of civil affairs tasks must be completed. It should be noted that depending on the historical time period of the post-conflict operation, S&R operations have been labeled as occupation, peacekeeping, and peace enforcement and can be found referenced as such in the literature.

Stabilization and reconstruction operations are necessary to secure and maintain the peace in the aftermath of conflict. Many factors shape the outcome of S&R operations including: the amount of damage inflicted on the state’s infrastructure, non-combatants killed or injured (along with the associated perception management

problems), and the effects of a long term military campaign on neighboring states' stability (Transforming for Stabilization and Reconstruction Operations, 2003: 21).

The important overarching goals driving the success of stabilization and reconstruction operations are:

1. Establishment of security – defined as the suppression or destruction of the indigenous elements resisting the emergence of a new society (politically driven insurgents) or promoting instability for economic reasons (criminally driven insurgents)
2. Establishment of law and order (justice and reconciliation)
3. Maintenance of critical infrastructure (social and economic well-being)
4. Establishment of an effective interim government constituted from the indigenous population

All four driving goals must be pursued concurrently because of their heavy interdependence (Transforming for Stabilization and Reconstruction Operations, 2003: 29). These four main goals are mentioned repeatedly by experts within the peacekeeping and reconstruction communities as paramount to success (World Bank: 2004, United Nations/World Bank: 2003, Rand: 2003, Feil: 2002, US DoD: 2004, CSIS/AUSA: 2002). Arguably, the key factor is that of establishing security as it is an enabler for the other factors. Degradation of security increases pressure on stabilization and reconstruction operations as pressure for a coalition withdrawal increases. Insurgent elements violently opposing intervention directly inhibit mission success across the spectrum of coalition activities; “terrorist or insurgent elements are always engaged in obtaining popular support on their home ground and abroad by attacking military targets in areas where

Americans are intensely unpopular” (Transforming for Stabilization and Reconstruction Operations, 2003: 29). Finding and defeating these insurgent elements is critical to overall mission success.

The systems dynamics model developed in this study functions as a support tool allowing decision-makers and analysts to investigate different sets of decision approaches at a sub-national regional level. Of specific import is resource allocation management. The proposed model is a general construct, widely adaptable to a variety of post-conflict nation-building scenarios.

Study Focus

A wide array of security, economic, infrastructural, geographical, sociological, cultural, and historical complexities reflect the ongoing status of S&R operations within the area of operations (AOR). This study expands the current system dynamics model proposed by Richardson (2004) to capture the various aspects of the S&R effort as it progresses.

Richardson demonstrated the viability of applying system dynamics modeling techniques (which will be subsequently discussed) to an S&R effort, allowing the statistical analysis of various potential macro level policy choices. This study develops a deeper, broadened model, the Stabilization and Reconstruction Operations Model (SROM). The SROM allows for a more detailed analysis of the S&R effort than the earlier work done by Richardson.

The SROM is a sub-national region based construct as opposed to the nation based model put forth by Richardson. This allows the end-users of the model to identify potential problem regions within the state, test a wide variety of policy options on a

national or regional basis, determine suitable courses of action given a specified set of initial conditions, and determine resource allocation methods that best improve overall country or regional stability. The different policy options are simulated at the sub-national regional level, providing higher fidelity solutions to the end-user. Analysis of S&R operations via the SROM provides decision makers insight into policy driven scenarios, affording them the opportunity of having different policy options modeled, simulated, and the outcomes analyzed.

The SROM can be used to analyze the importance of the controllable factors affecting ongoing S&R operations. By changing different factor levels such as troop numbers, the region of troop deployments, troop deployment schedules, indigenous security forces training schedules, levels of indigenous popular support, initial number of insurgents, civil-military operations in terms of aid money disbursed, and other such level values included within the model, the factors' relative significance and impact to the success or failure of the particular instance of nation-building may be investigated. Decision-makers and analysts are thus provided a tool able to assist in determining appropriate courses of action in stabilization and reconstruction at a regional level within a nation.

While this model extends the scope of the Richardson model, limitations remain in regard to the proper determination of the relationships among the state variables. Investigating potentially successful courses of action in terms of policy decisions can only be accomplished at the regional level. An excellent goal would be to narrow the focus to the city level, but acquiring the necessary level of data remains in doubt with this being true even at the regional level.

Summary

Justification for the relevance of this thesis effort in the context of the global war on terror (denial of failed states as safe havens for enemy activity) has been presented to the reader. Creation of a sub-national regional level system dynamics model has been identified as the approach used to gain insight into the complexities of nation-building. Chapter II reviews the relevant literature as it applies to nation-building. Chapter III discusses the development and construction of the general stabilization and reconstruction operations model (SROM). Demonstration of the model using Operation Iraqi Freedom as a test case is presented in Chapter IV. Significant insights, recommendations, and suggestions for future work are then offered in Chapter V.

II. Literature Review

This chapter examines specific literature for direct application within the stabilization and reconstruction model (SROM). Each area focuses on determining the relationships and rates of change between necessary level values incorporated into the model. Typically, each area covers an entire sub-model within the SROM architecture. This literature review serves to provide a background context for the reader and to justify the reasoning behind values and relations that are used to define the aforementioned level values and associated rates of change. The exact specifications for each will be discussed in detail in Chapter III. This chapter concludes with a discussion on the analytical methodology used to evaluate the importance of various level values and the associated meaning regarding policy implications.

System Dynamics

Nation-building is an ambitious and difficult foreign policy undertaking. Few national undertakings are as complex, costly, and time-consuming as reconstructing the governing institutions of foreign societies (Pei and Kasper, 2003: 1). Any model constructed to simulate the nation-building process must be able to accurately represent the inherent dynamics of the situation. The basic structure of a country may, or may not, remain; its political, economic, and judicial systems, cultural, educational, medical, and military institutions, and critical infrastructure all vitally contribute to the overall progression toward stability and prosperity. The country's many interdependent systems lend themselves to study via a system dynamics model and indeed, as mentioned in Chapter I, Richardson demonstrated the viability of the concept.

System dynamics, with its underlying principles of interdependent systems has its roots in systems of difference equations and differential equations (Forrester, 1980: Sec 3.3). Common principles such as feedback loops, time delays, levels, and rates are used to describe each of the individual systems, which when taken together, describes a larger, target system of interest. By investigating the levels and rates associated with the individual systems a better understanding of the whole system can be achieved.

The Richardson model used *national* level systems to model the nation as a whole. The SROM consists of sub-national regional systems together modeling regions within the country. A region's systems are then integrated with other regions' systems as appropriate. In addition to this narrowing of focus, the individual systems within each region are further refined. In some cases, such as critical infrastructure and population characteristics, the systems are expanded dramatically over those in Richardson's original model. In other cases, such as criminal, insurgent, and coalition military activity, the systems are entirely revamped. These changes allow a higher fidelity investigation into the relative significance of different sets of decision approaches at a sub-national regional level.

Criminal Activities

The attendant socioeconomic problems within a state recovering from a major violent political transition such as a militarily enforced regime change necessarily involve a transient period of lawlessness and rampant criminal activity. In seeking to more accurately capture the characteristics of this period within the nation-building paradigm, a more thorough review of criminal activity and the associated criminal statistics was conducted.

When constructing a system dynamics model, identifying the important level values and their rates of change is of particular importance. In the context of law enforcement the SROM is concerned with police, police training rates, performance levels of police (arrest rates), criminals, crime rates, and the associated demographic and cultural conditions affecting each of these areas. Together these elements represent a region's criminal culture and the capacity of the society to mitigate the negative effects of that culture.

Some basic questions need to be addressed. How many police are typically appropriate for a given number of citizens? How many police are required to maintain law and order given a certain amount of criminal activity? What is the typical murder rate for a given crime rate? What effect does unemployment have on the crime rate? Does economic growth have a significant impact? What about the urbanization level? A study conducted by Niskanen for the Cato Institute presents a statistical analysis of the relation between crime rates and public safety resources and provides tentative solutions to many of the questions raised above (1994: 1).

Niskanen attempts to answer many of the questions posed above. He first discusses a "supply of crimes" (1994:6), the key variable in part of his study. To provide the "supply of crimes" a model of criminal activity is put forth. It should be noted that there are psycho-social models of criminal activity as well as economic models. Both types of model attempt to model criminal behavior in order to better understand it. Niskanen focuses on the economics of crime and acknowledges many contributors to the economics of crime literature to include: foremost Becker (1968), then Erlich (1973), Craig (1987), Trumbull (1989), and Tauchen, Witte, and Griesinger (1993). Niskanen

states the central hypothesis of the extended Becker rational choice economic model of crime:

the crime rate is expected to be a negative function of the probability and expected severity of criminal sanctions, a positive function of returns to criminal activity, a negative function of returns to legal activity, and a positive function of the share of the population that may have a relative tolerance of or preference for criminal activity. (Niskanen, 1994: 6)

The coefficients of the significant predictor variables in Niskanen's regression provide solutions to the aforementioned questions. The data used in Niskanen's study will first be discussed, followed by his results.

The data used in Niskanen's study set the demographic and cultural conditions. The data comes from the Statistical Abstract of the United States (1993) and reflects the crime and related conditions by state, in the US, for the calendar year of 1991. It is from this data set that certain assumptions for the SROM are derived. Niskanen lists the minimum, average, and maximum violent and property crimes committed per 100,000 citizens. The minimum, average, and maximum number of police per 10,000 citizens are also listed (1994: 6). From these numbers certain generalities can be assumed for use within SROM. These relationships are detailed in Chapter III under the law enforcement sub-model description.

The criminal relationships used in the SROM drawn from Niskanen's study are based on data from a peaceful, stable United States. It would be reasonable to question the use of relationships derived from such data. However, Fajnzylber, Lederman, and Loayza note the difficulty in carrying out cross-country studies; the most notable problems being that of mismeasurement and underreporting (2000: 3-4). They further

note that “underreporting is widespread in countries with low quality police and judicial systems and with poorly educated populations” (Fajnzylber *et al*, 2000:3-4).

Examination of their cross-country summary statistics reveals that the homicide rate of the United States is over twice as much as the homicide rate for the Middle East region (Israel, Jordan, Egypt). Thus, the US data indicates a much higher homicide rate than that of the Middle East, but the Middle East probably underreports. In view of these facts, it was deemed reasonable to assume the relationships derived from the United States data are plausible for use in a post-conflict stabilization and reconstruction scenario, especially considering that when applicable, the data used will be from maximums or doubled averages.

The Niskanen study allows the determination of certain rates of change between level values. Niskanen finds that, “as expected, an increase in legal economic opportunities reduces the crime rate” (1994: 9); a one percent increase in unemployment increases violent crime by nine percent. A second useful determination is that of the urban effect. A one point increase in a state’s urbanization level increases both the violent and property crime rate by 0.9 percent (Niskanen, 1994: 10). Niskanen’s rationale suggests a higher productivity rate for criminals relative to police within highly urbanized metropolitan areas. Another very important find is that economic growth reduces many problems; an increase in per capita income reduces violent and property crime by a proportional amount. It is suggested that an economic growth strategy may be more effective in reducing crime than a public safety strategy, especially if unemployment is decreased among the male youth (Niskanen, 1994: 13). A similar strategy is worthy of consideration in the nation-building context.

Niskanen's study goes on to identify many more significant conditions affecting the crime rate in a state. These include the percentage of single mothers (crime up), the percentage of minorities (crime up), and the percentage of church goers (crime down). While interesting, these findings are beyond the scope of this model and indeed their direct application to a failed state paradigm may be limited considering the inherent cultural and economic differences between populations.

While Niskanen addressed many of the questions concerning crime, others remain. Fajnzylber *et al* (2000) analyze the determinants of national crime rates across countries and over time using an economic model of crime. So while Niskanen examined statewide crime rates within the US, Fajnzylber *et al* examine crime across different nations where the shared cultural and economic characteristics of the indigenous people may bias the proclivity for criminal activity within a nation. The stated objective of Fajnzylber *et al* in their paper, "What Causes Violent Crime?," is to gain insight into the social and economic causes of worldwide violent crime (2000: 1).

Fajnzylber *et al* follow the Becker rational choice cost-benefit theory of crime and choose the explanatory variables for their study accordingly. The basic Fajnzylber *et al* model considers the lagged crime rate, the economic growth rate, income per capita, income inequality, and average education. Additionally, they include four extensions: deterrence factors (number of police and presence of death penalty), presence of illegal drug industry, demographics, and cultural issues (geographic region and religion). Fajnzylber *et al* acknowledge that measurement error makes it difficult to compare crime rates across countries (due to underreporting, varying confidence in police, social stigma,

and so forth) but contend that the associated bias is reduced by their selection of the types of crime modeled and the econometric methodology employed (2000: 3).

The Fajnzylber *et al* results provide additional evidence that economic variables successfully capture criminal behavior and account for criminal inertia as well.

Specifically, the identified variables were: economic growth, inequality, and past crime rates (2000: 23). As for economic growth rate, Fajnzylber *et al* report that a one point increase in the GDP growth rate decreases the murder rate by 2.4 percent (2000: 18).

Fajnzylber *et al* also contend that there is clear evidence that violent crime is self perpetuating (criminal inertia); the coefficient of the lagged dependent variable (crime rate) is positive and significant across all model variations.

Fajnzylber *et al* offer two rationales by which past crime breeds future crime; criminal behavior and law enforcement performance. First, the cost of performing criminal activity declines with the passing of time as criminals become more efficient in their trade (learning curve), the moral loss of breaking the law is reduced by committing the crime and by interacting with other criminals (criminal culture). Second, law enforcement failures (arrest and/or conviction rates) reduce the criminals' perception of apprehension, a factor in the choice to commit crime (2000: 18). The implication here is that besides the increased incapacitation of criminals due to additional police, more police will deter criminals due to the increased perception of apprehension (conversely, in the presence of a breakdown in society and withdrawal of police, more crime will occur). In addition, once there are fewer criminals, criminal inertia will have less of an impact; a culture of law and order must be established to further assist in mitigating the

effects of crime. Not surprisingly, the establishment of law and order is one of the primary goals for stabilization and reconstruction operations.

Some basic questions still remain unanswered (typical arrest rates, murder rates, and deterrence rates). Levitt (1995), attempts to determine the difference between incapacitation effects and deterrence effects on crime rates. Levitt acknowledges Becker as the initial purveyor of the economic model of crime and explains why deterrence is the most important factor within that model (1995: 3). If the cost of committing the crime is too high, according to the model, then the criminal will not commit the crime; the criminal is deterred.

In implementing his study Levitt uses a panel of US city-level arrest data from 1970 to 1992 for the seven index crimes. The crime rates per 100,000 people for each of the index crimes are given, as are the associated arrest rates for the crimes (Levitt 1995: Table 1). The proportion of crimes (how many murders on average, relative to robbery or burglary, and so forth) is of particular import. From these summary statistics certain useful rates can be determined, including typical arrest rates and murder rates.

Levitt found a negative correlation between arrest rates and crime rates which is noted to be consistent with the economic model of crime and the predicted effects of incapacitation and deterrence. Levitt was able to break the coefficients for each of the index crimes into incapacitation and deterrence effects (1995: Table 7). This dichotomy is particularly useful for the SRM because it indicates the number of criminals deterred per arrest; the calculations are shown in Chapter III under the law enforcement sub-model description.

Levitt provided a rough estimate of the number of crimes committed per criminal per year. This value, fifteen, is taken from prisoner self reports (1995: 28). From his work Levitt estimates that the “reduction in index crimes associated with an additional person-year of incapacitation ranges from 5.1 to 8.2,” depending on the type of crime committed (1995: 27). The values calculated for the incapacitation effect are of the same order of magnitude as the criminal self-reports, giving Levitt further positive feedback supporting his work. The small discrepancy is explained as resulting from multiple perpetrators involved in a single crime and replacement effects as one criminal immediately replaces the newly incarcerated criminal. The number of crimes committed per criminal per year is useful in calculating a rough estimate of the crime rate within a region given the number of criminals. Of course, if more nation specific data is available, it should be utilized.

A key issue is the effect of crime on society. Bourguignon (1999: 3), Tullio and Quarella (1998), and Bejarano (2003: 49-50) each discuss the negative costs to a country’s GDP due to criminal activity. Bejarano suggests a natural crime rate inherent to any economy as a function of income per capita and the capacity of the judicial system to keep criminal activity constrained (2003: 44). Failure of the judicial system to adequately protect a society from criminal action will allow increased criminal activity resulting in economic erosion. This economic erosion is typically measured by economists as a 1% to 2% loss of GDP annually (Tullio and Quarella: 15, Bejarano, 49); if the crime rates are high enough the effect might reach as high as 7% (Bourguignon, 50).

Bejarano's paper is of particular interest for this thesis because of its focus on Colombia. Colombia's murder rate (as of 1995) was 72 per 100,000 people. A myriad of factors explain why it is so high, approximately 2.5 times higher than the Latin America average of approximately 28 per 100,000 people. These factors include numerous anti-government insurgent groups, an entrenched drug trafficking industry, and an ineffective judicial system. Tullio and Quarella parallel these findings in their study of southern Italy, where ineffective government, poor judicial practices, and extensive organized crime all contribute to poor growth in GDP. Bejarano, utilizing the work of Londono (1996: 7), suggests that Colombia's extremely high murder rate points to an annual GDP loss of 5% compared to the 2% loss suffered by other countries in the Latin American region (Bejarano, 2003: 49-50).

The theoretical justification of why crime affects economic growth so negatively should be discussed. Tullio and Quarella suggest that crime affects an economy much as taxation does except that there is no return on capital in terms of services provided (1998: 10). A society must redirect resources from productive uses to fight crime. Whether the public sector protects society by raising taxes to increase public safety activities or the private sector spends capital to protect its investments, resources are spent to combat the negative criminal effects. Organized crime, criminal gangs, insurgent groups, and simple criminals effectively accomplish a redistribution of resources due to their criminal activity (Tullio and Quarella, 10). Besides the wasted funds combating criminal elements, direct criminal activity harms the economy as well; murder, robbery, kidnappings, extortion, protection fees, and ransom demands are perpetrated against corporations and citizens, breeding a culture of lawlessness, fear, and insecurity

(Bejarano, 2003: 49-50). This culture threatens property rights, discourages accumulation of capital, and generally hurts the capitalistic entrepreneurial spirit. Law abiding entities will seek out different locales because there is no incentive to invest in the unstable area in question (Tullio and Quarella). As previously mentioned, a criminal inertia exists, and so once the law enforcement establishment has been weakened the effort required to return the area to a reasonable level of security will be markedly increased. As far as direct application in the SROM, Bejarano's implication that a natural baseline murder rate of 28 per 100,000 citizens results in a 2% decrease in GDP was used to assess the criminal effect on the economy in a stabilization and reconstruction operational context. Any civilian death rate higher than the baseline will result in a further reduction of the GDP growth rate (Bejarano, 2003: 49-50).

Overall, Niskanen, Fajnzylber *et al*, Levitt, and Bejarano provide detailed quantitative criminal characteristics justified by statistical analysis of regressions based on real world data sets and modeled using the extended Becker economic model of crime. The results obtained from the review of the criminal activity literature are used in defining rate relationships among the law enforcement level values of the SROM and are detailed, as appropriate, in the next chapter. While not all of these figures are from failed nations, they do provide approximations based on the open literature. As better data becomes available, the relations can be improved.

Insurgent Activities

An unfortunate reality facing US and coalition allies attempting to rebuild a country is the likely existence of the preconditions for insurgency. Not surprisingly, the conditions necessary for insurrections are often found in failed states. This is especially

true after military action is taken to remove the previous regime. Steven Metz (2003: 28) identifies the “raw material” for insurgency: “anger, resentment, alienation, frustration, a unifying ideology”. Additionally important is access to resources, particularly arms and money. Again, a failed state will likely be rife with these necessary conditions.

In his article “Insurgency and Counterinsurgency in Iraq” Metz discusses the situation in Iraq. In recognizing the importance of achieving success in Iraq, he notes that Iraq is a test case in helping the Arab world become more open, economically and politically. Metz specifically states:

the conflict there will help determine whether the world continues its difficult and uneven movement toward a global system based on open governments and economies or fractures into a new bipolarity. (Metz, 2003: 26)

Metz further identifies the Middle East region as the most resistant to the US global vision. Interestingly, Metz’s thoughts parallel the points made by Barnett, outlined in Chapter I.

Generally an insurgency begins with the failure of the state to address the needs of the people. Some problems that Metz lists are: “social or regional polarization, sectarianism, endemic corruption, crime, radicalism, or rising expectations” (2003: 26). A population is even more unforgiving when it is a foreign power failing in support of the people; even the mere presence of foreign troops often exacerbates sensitive situations (Metz, 2003: 26). Thus, it is a narrow window in which a nation-building operation must operate. The issues identified as problematic when executing stability and reconstruction operations need to be recognized and incorporated into any model attempting to realistically simulate a nation-building incidence. Some crucial concerns are further outlined by Metz and are germane to the discussion here.

One concern is the existence of a security vacuum in the time immediately following the overthrow of the previous regime. The allowance of lawlessness breeds a culture of chaos and disorder within the nation and makes the eventual establishment of order more difficult (Metz, 2003: 27). Reconstruction projects and economic assistance, both instrumental in the rebuilding of the country, are harmed by the lawlessness. Additionally, this period can witness severe looting and destruction of critical infrastructure within the country which will again slow rehabilitation efforts. Metz feels the importance of infrastructure cannot be overstated (Metz, 2003: 27). It will be addressed more fully later in this chapter.

Not surprisingly, insurgents hinder the nation-building effort on many fronts. Insurgents directly attack coalition troops, guarantors of security. They hurt economic recovery by driving away efforts to disburse aid funds. Reconstruction projects are attacked, harming the rebuilding of infrastructure. Once the indigenous people take part in their own future and begin to fill in the ranks of security forces (police, civil defense, and army) within the country, the insurgents attack them as well. As has occurred in past insurgencies, the insurgents may even attack civilian populace bases seen as collaborating with the “enemy” (the US and its coalition partners).

An examination of the relevant information contained in the Brookings Institution “Iraq Index” (2005), which provides summary information on a range of activities inside Iraq since the declared end of major combat operations (1 May 2003), bares out the above stipulations concerning insurgent actions. The data presented by the Brookings Institution is the primary source in determining the number of daily insurgent attacks in this study. This calculation results from the development of a regression model using the

Brookings Institution data. The number of daily insurgent attacks is a function of the number of insurgents, a quadratic effect resulting from the one month lagged number of insurgents, and a moving average of the coalition troops casualty rate.

Besides successfully modeling the actions of insurgents, a significant issue concerns the recruitment of insurgents. If the insurgents are able to replace their combat losses quicker than coalition forces can capture or eliminate them, than the insurgency will grow. It is of primary importance that the dynamics involving recruitment of additional insurgents be correctly modeled. Unfortunately, the extent of specific open source literature addressing this topic is minimal. However, various literature on violent conflict leads to a number of insights.

“Greed and Grievance in Civil War” authored by Collier and Hoeffler (2001) discusses the causes of civil war. Rebellion is typically explained by the grievances of the rebels such as income inequality, poor political rights, and ethnic and religious divisions amid society. In addition, rebellion may be explained by opportunities for rebellion. Collier and Hoeffler test which set of conditions provides more explanatory power, grievance or economic viability (greed). They develop a set of explanatory variables that proxy greed and grievance to then determine which set of variables most accurately explain the onset of rebellion. A data set of 78 large civil conflicts dating from 1960 to 1999 was used to facilitate their study.

In discussing the opportunity for rebellion, a host of categories can be described. The first of which is the extent of rebel finance. This rebel income can be derived from a primary commodity export (such as oil, diamonds, and so forth), foreign diasporas, or neighboring hostile governments. The SROM assumes that conditions are such that

sufficient financing exists for the insurgency. Further support from outside the AOR is modeled by the infiltration of foreign insurgents.

Collier and Hoeffler go on to discuss the cost of recruiting. The cost of recruiting new insurgents may be related to the income foregone by enlisting in the insurgency (2001: 4). This reasoning complements the extended Becker economic theory of crime whereby legal economic opportunities raise the cost of crime and thereby forces a decline. Collier and Hoeffler suggest three proxies for foregone income: income per capita, male secondary schooling, and the growth rate of the economy. All three of these variables are found to have a significant and substantial effect on the reduction of conflict (2001: 16). Within the SROM, the growth rate of the economy has an impact on the recruitment of insurgents, directly and also indirectly by reducing the pool of potential insurgents through the reduction of the number of unemployed.

As far as grievance is concerned, Collier and Hoeffler use four measures: ethnic or religious hatred, political repression, political exclusion, and economic inequality. For the SROM, the concern here is with ethnic and religious hatred (though the other measures should certainly be addressed in future studies), as they are widely thought of as a primary cause of civil conflict (2001: 6). Used widely in conflict analysis literature, an ethnic-linguistic fractionalization (ELF) index score can be generated from the population distribution inside a nation or region. This index score indicates the extent to which the population is fractionalized into many different groups. Specifically, the index score is the chance that two people within the region do not belong to the same ethnic (or religious) group and is thus a simple measure of diversity within a culture. A value of

zero indicates the society is completely homogenous whereas a value of one indicates a completely heterogeneous society (Collier and Hoeffler, 2001: 32).

Besides the fractionalization of a society as a proxy for ethnic tension, Collier and Hoeffler discuss another proxy adapted from Esteban and Ray (1994), polarization. The argument here is that polarization is a better measure of inter-group tension than simple diversity. The ultimate goal of these grievance measures is to accurately capture the inter-group hatreds that ultimately lead to civil strife and conflict.

In their work “On the Duration of Civil War”, Collier, Hoeffler, and Soderbom (2001) revisit the civil war topic but this time in the context of determining the conditions necessary for the end of the conflict; or put another way, to determine the conflict drivers. In this paper the authors find that ethnic fractionalization is a significant determinant in the length of the conflict. In fact, both ethnic fractionalization and its square are highly significant and Collier *et al* note that the duration of conflict reaches its maximum when the index score is approximately half (2001: 10). This implies that conflict is most likely when there are just a few large ethnic or religious groups rather than many small groups or a single dominant group.

When discussing insurgent recruiting, an important factor remains. The influence of the media is typically regarded as quite substantial. Indeed it is important, to the coalition effort and that of the insurgents as well. As previously mentioned, insurgent elements are always engaged in obtaining the popular support of the indigenous people to further their political and military goals (Transforming for Stabilization and Reconstruction Operations, 2003: 29). Thus, developing “a uniform, consistent message that supports a political strategy with attainable political-military objectives is vital” to

undermining an insurgency (Transforming for Stabilization and Reconstruction Operations, 2003: 25). A consistent, compelling message is important. Besides the synergistic effect on coalition operations across all stabilization and reconstruction elements, human relations are crucial to winning the peace. “To be successful the United States must gain trust and create a state in which the citizens of an ‘occupied’ nation feel that their condition is improved and that they have hope for the future” (Transforming for Stabilization and Reconstruction Operations, 2003: 101-102). Communications between coalition forces and the indigenous population are necessary to “bridge cultural differences, establish trust, deliver our message, and counter disinformation about our intent” (Transforming for Stabilization and Reconstruction Operations, 2003: 102).

A major insurgent methodology is the spreading of misinformation to damage the credibility of stabilization and reconstruction forces. A biased mass media only exacerbates the problem. In *Changing Minds Winning Peace* the research panel came to an insidious conclusion: “we were also told that if America does not define itself, the extremists will do it for us” (2003: 8). It is self-evident that the US must embrace public diplomacy as a tool to positively influence the perceptions of certain target audiences and in terms of the battle for indigenous popular support, mass media can act as the main communication vehicle for the insurgent and terrorist elements. Which side makes the most impact on the target audience (potential insurgent recruits) and how does the impact make its presence felt in terms of the recruitment rates? Examination of relevant marketing literature, in particular consumer behavior, provides some interesting information and allows the development of a proxy measure for use in the SROM.

Especially constructive for the SROM media influence effect is the Theory of Reasoned Action (TRA). The main premise of Ajzen and Fishbein's (1980) Theory of Reasoned Action is that a person's intention is the main predictor and influencer of attitude. If a person intends to do something then they will more than likely do it. If they do not intend to take action (engage in a certain behavior) then they will more than likely not do it (Ajzen and Fishbein, 1980). This implies the existence of a seemingly behavioral inertia. The Theory of Reasoned Action suggests two main influencers of intention; the attitude towards the behavior and subjective norms relating to the behavior.

The attitude towards the behavior derives from the person's previous attitude toward the behavior. The Theory of Reasoned Action contends that people consider the implications of their actions before they decide to engage or not engage in a given behavior. An attitude forms about the overall decision and the behavior central to the decision (Ajzen and Fishbein, 1980).

The second suggested main influencer of a person's intentions is "subjective norms." The subjective norms come from a person's belief of how certain specific, important individuals or groups regard the contemplated action or inaction concerning the behavior, to include the perceived motivation driving the person's action or inaction (Ajzen and Fishbein, 1980). What outside influencers will think of the decision and how important these outside influencers are to the decision maker play a vital role in the subjective norms. For many it is rare to make an important life decision quickly without consulting close and valued sources. People want to feel that they have made the most educated and best decision for themselves. The SROM must model these media effects.

Based on the current population support level values within the SROM a predisposed portion of sub-groupings of a population (e.g. within Iraq - Sunnis not supporting coalition reconstruction and stabilization activities, Shiites not supporting coalition reconstruction and stabilization activities, and so forth) are more likely to join the insurgency based on a personal attitude towards the insurgency (TRA) and friends, family, clergy, tribal, and/or others attitudes toward the insurgency (TRA- subjective norms). If those individuals that are predisposed to favoring the insurgency have not yet committed to active membership because of their own concerns or because of the thoughts and influences of those around them, then it is contended here that media, especially a biased media (e.g. Al-Jazeera) will reinforce the insurgency-friendly view and push some of those individuals on the edge from inactive support of the insurgency to an active, violent role in the insurgency. A baseline rate is established and modified by the market penetration of insurgency friendly media and the prevalence of that particular medium within the AOR.

Lastly, it should be noted that media influence extends beyond the bounds of the SROM. Media affects the perceptions of the coalition population base which can influence the political situation at home and thereby alter the situation in the nation-building AOR. Additionally, media influence could potentially affect the morale of coalition troops as well as dynamically impact indigenous security forces recruiting efforts within the AOR. Currently, these effects are beyond the scope of the model, but the far reaching effects of the media are acknowledged.

The aggregation of these various sources, to include certain aspects of the criminal activity research, provides a foundation for a theoretical measure in which the

insurgent recruitment rate within a region is determined by the many different economic, demographic, military, and geopolitical factors. The insurgent recruit rate is a function of the perceived military success of the insurgency, the population diversity within the region and the country, the polarization of the population sub-groups (nationally and regionally), the presence of foreign troops as an aggravating factor, the growth of the economy in terms of GDP per capita and unemployment changes, an urbanization effect, the percentage of unemployed males, media influence, and the support of the population sub-groups for the coalition stabilization and reconstruction effort. Each of these factors modifies a baseline recruitment rate, affecting each of the population subgroups in a different manner according to their support of the coalition effort. The detailed equation is explained fully in Chapter III under the insurgent and coalition military sub-model, insurgent recruit rate subsystem.

Social and Economic Developmental Framework

One of the four major focus areas identified by experts within the peacekeeping and reconstruction communities, the social and economic well-being of a society is an important determinant of stabilization and reconstruction operational success. Rand corporation notes that reconstructing a nation's economy is not sufficient for success by itself; nation-building is about political transformation not economic viability (2003: xix). While an excellent point, and a consideration that must be kept in mind, the implicit suggestion contends that political transformation (and thus mission success) will heavily depend on the economic and social development of the post-conflict state. The society must have its social and economic needs addressed; if not, coalition forces risk ever increasing hostility from the indigenous population. For example, in the *Iraq Needs*

Assessment it is stated that the macroeconomic prospects for Iraq depend heavily on security, functionality of basic utilities and services, and the expansion of the oil and private sectors (2003: 6). A poor, starving, sick, homeless, uneducated, and/or jobless populace will be much more inclined to join insurgency forces should such living conditions continue for an extended period of time. Collier's study of renewed conflict potential in post-conflict society also recognizes the importance of an improving economy. Collier states that a lack of economic opportunity increases the risk of conflict and suggests four proxy measures by which to capture this effect: per capita income, male secondary school enrollment, per capita income growth, and population growth (2000: 7).

The Center for Strategic and International Studies (CSIS) and the Association of the United States Army (AUSA) published a task framework for post-conflict reconstruction. In it the social and economic pillar is defined:

Social and economic well-being addresses fundamental social and economic needs; in particular provision of emergency relief, restoration of essential services to the population, laying the foundation for a viable economy, and initiation of an inclusive, sustainable development program. (2002: 3)

In their framework CSIS/AUSA identify many key aspects of nation-building that should be addressed; with specific regard to the social and economic well-being of a society, the many areas include: assisting refugees and internally displaced persons, food security, public health, shelter, education, social safety net (pensions), economic development strategy, physical infrastructure, employment generation, financial market reconstitution, economic legal reform, and investment (2002: 12-16). The SROM addresses food security, investment in terms of aid, public health in terms of potable

water, job creation, and overall economic development (with respect to rehabilitation of critical infrastructure and determination of GDP). The SROM assumes a complementary level of progression in the areas not directly modeled. Chapter V addresses those areas which should be considered in extended versions of the model.

A nation's critical infrastructure refers not only to just the physical domain. It encompasses many of the services, institutions, and people (like those named above) necessary for the functionality of the nation to carry forward. The President's Commission on Critical Infrastructure Protection (PCCIP) defines an infrastructure as:

a network of independent man-made systems and processes functioning collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services (PCCIP, 1997: 3)

These increasingly complex infrastructure systems directly impact the security, economic prosperity, and social well being of the state. Any model hoping to accurately capture the dynamic process of nation-building must include the nation's infrastructure systems.

While much of the literature identifies and discusses the need for development of the infrastructure as an enabler of economic growth and prosperity (and hence political stability), the specifics of the discussion often ignore the interdependency of the many differing yet linked infrastructure systems. When examining the rehabilitation or the growth of a nation's critical infrastructure the various systems' interdependency must be considered in any developmental plans.

Identifying, understanding, and analyzing these interdependencies can be problematic. The magnitude and complexity of the infrastructure systems only increases this difficulty (Rinaldi, Peerenboom, and Kelly, 2001: 12). Rinaldi *et al* suggest six

dimensions for describing infrastructure interdependencies. These dimensions are comprised of the various interrelated factors and system conditions that can affect infrastructures and include: infrastructure characteristics, state of operation, type of interdependencies, environment, and coupling and response behavior (Rinaldi *et al*, 2001: 12). These dimensions are formulated so as to represent all the different manners and degrees to which infrastructures can interrelate. Identifying the dimensions in which the infrastructures interrelate allows application of the appropriate associations and links to the different infrastructure systems. Rinaldi *et al* define dependency as “a linkage or connection between two infrastructures, through which the state of one infrastructure influences or is correlated to the state of the other” (2001: 12). For the SRM, this dependency entails matching various supported infrastructure level values and their rate changes with the appropriate level values of supporting infrastructures. Infrastructures can support multiple infrastructures and in turn be supported by many. This interlocking of infrastructure systems can be thought of as a system of systems. Rinaldi *et al* state that

Infrastructures are frequently connected at multiple points through a wide variety of mechanisms, such that a bidirectional relationship exists between the states of any given pair of infrastructures; that is, infrastructure I depends on j through some links, and j likewise depends on I through other links. (2001: 14)

When examining a system of infrastructures, it is important to realize that the extent of the interdependencies increases the complexity of the overall national system. Put another way, the overall complexity of the national level infrastructure system is “characterized by multiple connections among infrastructures, feedback and feedforward paths, and intricate, branching topologies” (Rinaldi *et al*, 2001: 14). Analyzing the behavior of a single system in isolation will yield flawed results; thus, analysis of a

system of multiple infrastructures must be accomplished in a “holistic” manner (Rinaldi *et al*, 2001: 14). It is readily seen that system dynamics lends itself naturally to the study of infrastructures. As for SROM application, an excellent graphic depiction of six basic infrastructures and their interdependencies provides a guiding template (see Figure 2.1 from Rinaldi *et al*).

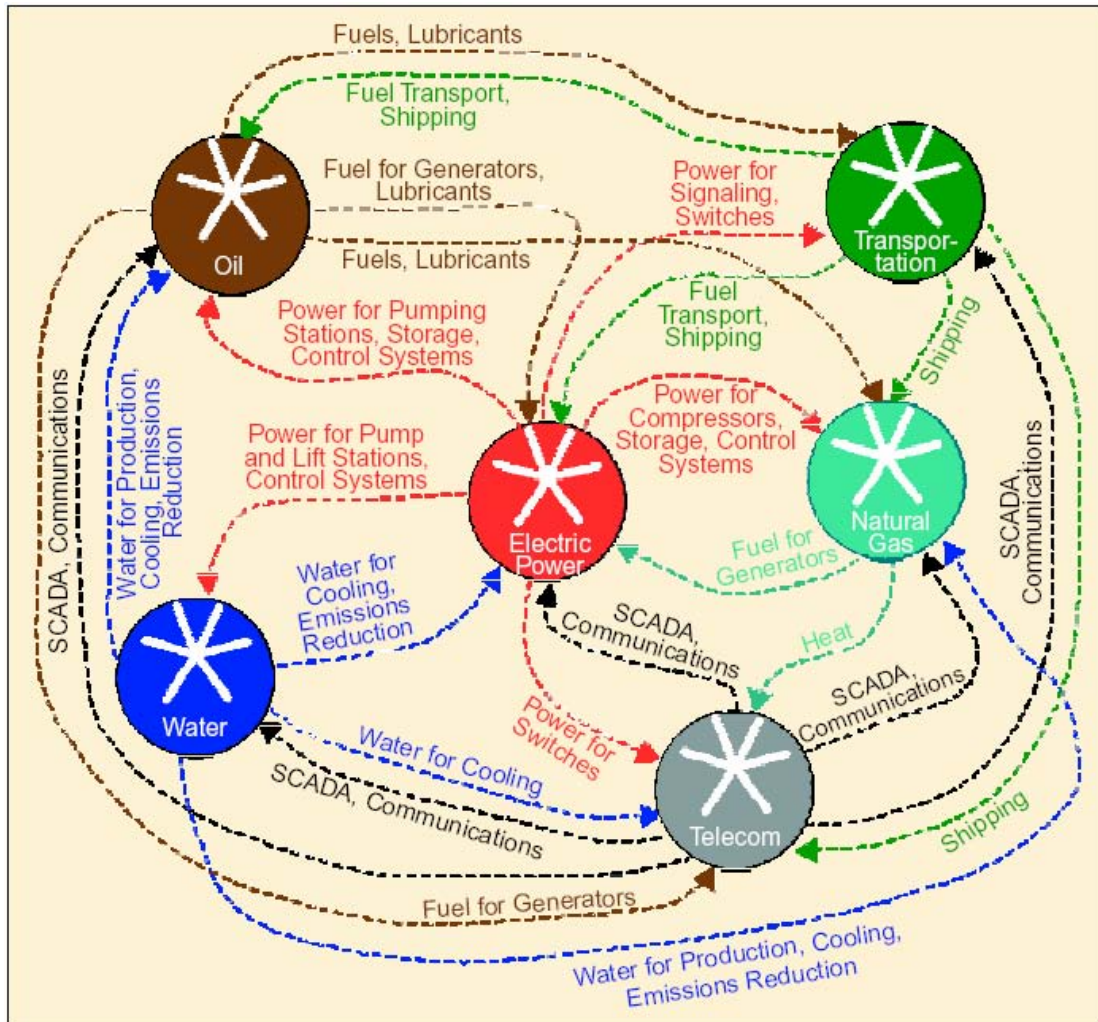


Figure 2.1 Example of Infrastructure Interdependencies (Rinaldi *et al*, 2001: 15)

Again, the importance of national infrastructure systems cannot be overstated; any model hoping to accurately capture the dynamic process of nation-building must include

these systems. “What happens to one infrastructure can directly and indirectly affect other infrastructures, impact large geographic regions, and send ripples throughout the national and global economy” (Rinaldi *et al*, 2001: 16). An excellent depiction of the effects of the 2001 California power disruptions are shown in Figure 2.2 from Rinaldi *et al* and illustrate many of the concepts discussed concerning the propagating effects disruptions in one infrastructure can have on interdependent infrastructures; the higher the dependency, the higher order of effect.

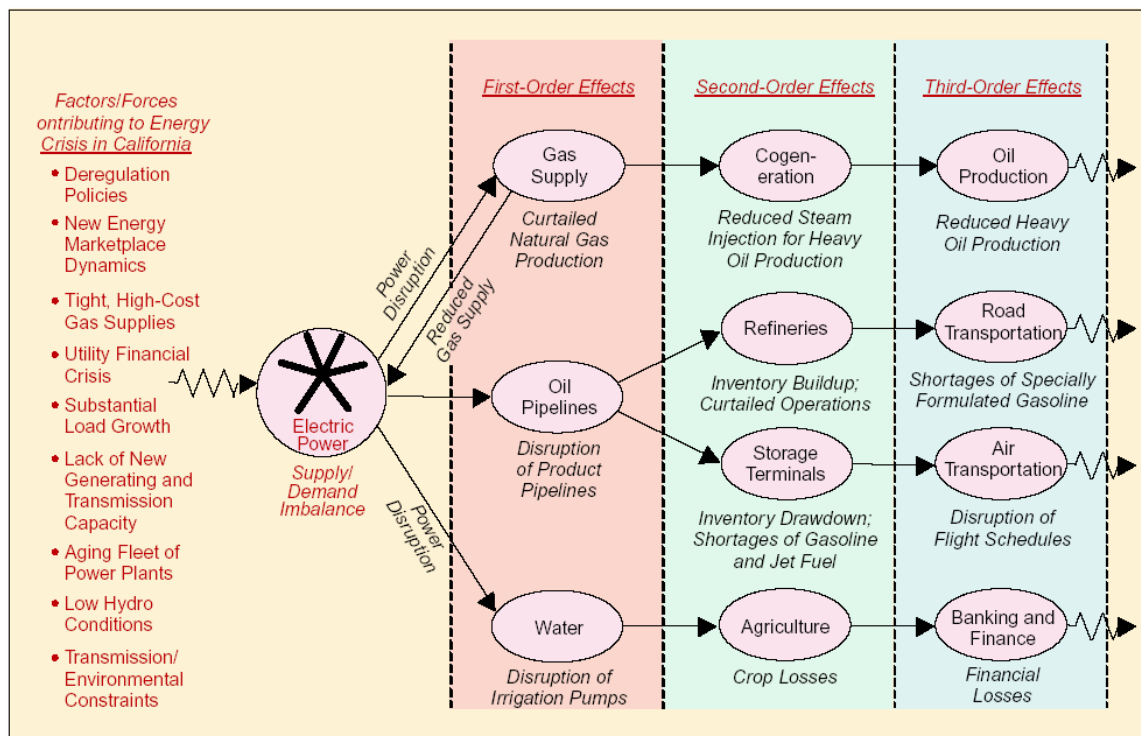


Figure 2.2 Example of 2001 Electric Power Disruption (Rinaldi *et al*, 2001: 19)

Given projected operational capacities of different infrastructures within the incident AOR, the SROM can provide analysis of limiting factors and assist in identifying areas for improvement within the nation-building context. This is achieved

by properly modeling the effects of infrastructure disruptions resulting from disparate growth between dependent infrastructures and/or damages suffered from insurgent attacks.

Response Surface Methodology

With a functioning model providing results, a method for analyzing the data must be chosen. In general terms, response surface methodology (RSM) is “a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes” (Myers and Montgomery, 2002: 1). Used extensively in industry, RSM typically involves the investigation of the influence of several process variables on some performance measure or quality characteristic of a product or process (response variable). In graphical terms, the n process variables form an n -dimensional hyperplane with the experimenters, scientists, or engineers typically seeking the maximization or minimization of that hyperplane with respect to a single (or multiple) response variables. More specifically, RSM is defined as:

The field of response surface methodology consists of the experimental strategy for exploring the space of the process or independent variables, empirical statistical modeling to develop an appropriate approximating relationship between the response and the process variables, and optimization methods for finding the levels or values of the process variables that produce desirable values of the responses. (Myers and Montgomery, 2002: 3)

In many studies, the underlying relationship between the response variable and the process variables is known exactly (such as chemical or engineering processes and physical principles). The RSM model in such a situation would be written as

$y = g(x_1, x_2, \dots, x_n) + \varepsilon$, where some function g of the n process variables plus the error ε

in the system together produce the response variable y . In many other studies, such as this one, the exact underlying mechanism is not fully understood. This lack of understanding results in the RSM model becoming $y = f(x_1, x_2, \dots, x_n) + \varepsilon$, where the function f is an approximation of the unknown function g . The function f is typically a first order or second order polynomial derived from least squares regression analysis (Myers and Montgomery, 2002: xiii). The second order model is widely used for a variety of reasons to include flexibility, ease of parameter estimation using the method of least squares, and real past experiences validating its use (Myers and Montgomery, 2002: 8). The model is expressed as $\eta = \beta_0 + \sum_{j=1}^n \beta_j x_j + \sum_{j=1}^n \beta_{jj} x_j^2 + \sum_{i < j=2}^n \sum \beta_{ij} x_i x_j$ and reflects the inclusion of first order main effects, effects from interactions between the quadratic effects, and the main effects (Myers and Montgomery, 2002: 8).

Myers and Montgomery suggest that typical application of RSM is accomplished in three phases. Phase zero of the RSM study involves the screening experiment. Generally a study begins with selection of the factors or variables most important to the response of interest. Usually an experiment is conducted to filter down from many factors to just the important ones. In phase one, now that the important variables are identified, the current settings of the process variables are tested to examine the nearness to the stated desired goal or optimum. These settings are then adjusted utilizing the method of steepest ascent. This method is concerned with exploring the response surface in the search of improved response. Phase two begins when it is determined that phase one has led to a result near the goal. A second order model is then typically used to obtain a more precise model of the response surface at this near optimum area (Myers and Montgomery, 2002: 10-11).

Applying RSM to the SROM primarily involves phase zero. This phase identifies the important factors within the SROM and provides general indication of priority selection in terms of troop deployment levels, aid disbursement, and infrastructure rehabilitation schedules and priorities within the nation-building context. While not directly utilized in this study, many of the experimental investigations permitted by the SROM would be best handled using RSM.

Summary

This chapter presented relevant background literature to the reader in order to provide a context for the construction of the different sub-models with the SROM. The literature review focused primarily on criminal activity, insurgent activities, and critical infrastructure relationships. The relevant literature provided direct numerical relationships based on empirical studies or when absent empirical research, much of the rationale for many notional relationships. Chapter III presents the framework and direct application of the concepts discussed in this chapter.

III. Methodology

The stabilization and reconstruction model (SROM) represents the complex, multi-faceted, and interdependent system of systems comprising the daily functionality of a nation. Feedback loops, time delays, levels, and rates are the mechanisms used to describe each of the individual systems, which when viewed in the aggregate, describes the larger, national system of interest. By investigating the interactions of the levels and rates associated with the individual systems in each region, a better understanding of the national system is achieved. Any model constructed to simulate the nation-building process must be able to accurately capture the inherent dynamics of the situation.

This chapter outlines the structure of the general purpose SROM, providing an overview and discussion of the key relationships and level values applied in the model. Due to the large scope of the model, a hierarchical sub-national regional approach was taken in its construction. The general purpose SROM consists of a national level functional sub-model and any number of regional sub-modules (Figure 3.1). The number of regions modeled depends on the specific analytical requirements of the scenario and area of interests.

A moment should be taken to provide the reader context in regard to the size of the SROM. Approximately 600 model parameters describe a single regional sub-module. About 50 model parameters describe the national level sub-model. The regional parameters function jointly with approximately 90 random variables. Together, the regional parameters and random variables represent the daily functioning of a single region, as expressed by a total of 87 level values and 193 rates of change. A three region

implementation of the SROM would then require approximately 1850 parameters, 270 random variables, and approximately 850 associated level values and rates of change.

Each region is tied to the national level sub-model, which tracks national level values and rates of change that affect all the regions in the model. Each region functions as its own aggregate system, but does not function autonomously; a region may be tied to other regions based on the nature of the established interdependent relationships between the regions. For economy of presentation only one specific functional sub-model, the insurgent and coalition military sub-model, is fully discussed within this chapter. An overview of the remaining functional sub-models is presented in this chapter. Each sub-model is then more fully developed in the appendices.

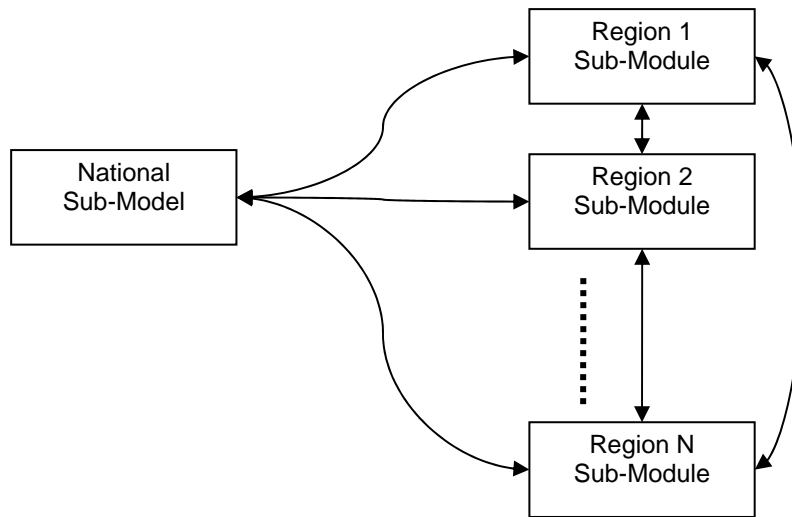


Figure 3.1 SROM National Level View

National Level Sub-Model

The national level sub-model consists of those real or abstract level values that necessarily function at a national level. Any system requiring management on a national scale and thereby directly involving multiple regions should be incorporated within the

national sub-model. In addition to those level values and rates of change at the national level, it should also be noted that there are numerous constants (model parameters) affecting the model on a national scale; these constants can have a far reaching impact and are listed in the appendices along with their definitions. The national level values and rates of change are given in Table 3.1.

Table 3.1 National Level Values and Rates of Change

Level Value	Rates of Change (RoC)	Units
National Power Grid	Regional Power Generation	MegaWatt hours
	Regional Power Consumption	
National Primary Commodity GDP	Commodity Export Payment Received	US\$
National Aid Disbursement	National Aid Disbursement Rate Change	millions US\$
National Refined Oil Products Storage	Regional Refined Products Production	liters, tonnes
	Regional Refined Products Consumption	

The national power grid level value tracks the power generation capability of all generators connected to the national grid. The combined power generation of the nation is then distributed as directed by national policy (national policy is set via constants). This aggregation captures the general functionality of power distribution in a nation. A single region of the country may generate all the electrical power and must be allowed to transmit this power to other regions. Additionally, power can be imported into the national grid via different regions. The imported power is subject to the regional limitations of the power transmission system before being passed into the pool of available national power. It is also of note that islands of power can exist; each region has the capability, if needed, to utilize stand alone generators that serve only regional demand and are not connected to the national power system. A model user could feasibly coordinate generator capacity rates of change within a region to represent power capacity being disconnected from the national grid to support only regional or local demand.

The national primary commodity GDP level value can be construed as a single commodity or multiple commodities ranging from crude oil, diamonds, coal, natural gas, minerals, and so forth. The modeling of a primary commodity may be needed to estimate the country's GDP on an aggregated national level. When it is impractical to model the economy of the country via its individual regions, it becomes necessary to represent the primary commodity's contribution to national GDP at the national level. This share of GDP is then assumed to be equally disbursed among the differing regions. If this is not true, the disbursement balance could be modified.

As an example of this level value consider the export of crude oil. When present, the petroleum sector often represents a large share of a country's GDP; for governments heavily reliant on oil revenue for funding, disruption becomes quite problematic (UN/World Bank, 2003: v-x). The health of the economy is driven by the operations of the petroleum industry; the profits of the petroleum industry are redistributed among the country's regions in terms of infrastructure improvements, industry expansion, social programs, job creation, and other economic advancements (UN/World Bank, 2003: v-x). In the SRM, successful operation and growth of the primary commodity industry keeps the GDP of each of the regions high, translating into a higher GDP per capita and increased job growth in that region.

The rate of change of the primary commodity GDP results from the combination of many factors. Successful exportation depends heavily on the condition of the country's critical infrastructure and the level of violence afflicting it. For instance, the extraction of crude oil in one region may be proceeding with little problem, but in the neighboring region the interregional pipeline transporting that crude oil to the export

terminal could be in poor shape due to neglect, malfunction, or sabotage. The export flow would thus be heavily reduced, thereby reducing GDP revenues and harming national programs dependent on those revenues.

Aid is very important to a stabilization and reconstruction effort. Initial aid funds replace the vacuum that may exist due to a war induced shut down and subsequent restart of the main industries within a country. Successful aid disbursement via reconstruction and rehabilitation efforts will temporarily buoy the economy of the country (UN/World Bank, 2003: v-x). In the SROM, aid is disbursed based on a national contribution to GDP. The rate of change associated with aid is exogenous to the model, though actual disbursement is affected by the level of violence within a region (the impact of violence on GDP was mentioned in Chapter II; the exact equation associated with the reduction of GDP due to violence is detailed in the economic component subsystem block of Appendix G, the critical infrastructure sub-model appendix).

Refined oil products are important to citizens for their driving, cooking, and heating needs; they keep the transportation industry and the electrical power industry supplied with fuel and they are essential for the normal functioning of a modern economy (Rinaldi *et al*, 2001: 15). After production of refined products at the regional level the products are first made available to regional users; the remaining balance of available supply is then tracked at a national level, though storage is kept local (this local storage is abstract; storage is not defined specifically within any region). Keeping the supply management of surplus refined products at the national level allows an assumed equal access to the products by any region tied to the national level storage level value. Any

retrieval will cause a demand on the transportation infrastructure within the demanding region.

It should be noted that at the national level, both the level values and the associated rates of change are affected by local regional conditions; thus, their realization depends on the many different prevailing conditions within the specific region of realization. For instance, should heavy insurgent activity within a region extensively reduce the capability of the region to receive power from the national grid (reduction of power transmission capacity due to destruction of power substations, transformers, transmission lines, and so forth) then that region's share of the national grid is unrealized and will be redistributed to regions with the capacity to receive the power. The factors affecting these values are discussed further in the appropriate sub-models where their effects are realized.

Regional Level Sub-Module

The SROM can theoretically consist of any number of regions which when taken in the aggregate functionally represents the country or area of interest. Regions may be defined in a manner deemed most conducive to the analytical objectives. Whether this is due to geography, population ethnicity, or economic situation the characteristics of the region (population, population distribution, non-primary commodity GDP, critical infrastructure levels, critical infrastructure growth/rehabilitation rates, and so forth) as defined in the model, are very important and should be carefully considered.

The *Post Conflict Reconstruction Task Framework* developed by the Center for Strategic and International Studies (CSIS) and the Association of the United States Army (AUSA) provides an excellent guiding conception of the important aspects involved in

the stabilization and reconstruction of a nation (2002: 12-16). The many level values and rates of change selected to collectively represent the complexities of regional behavior can be categorized into six different functional areas (Figure 3.2, Figure 3.3). (Note that in Figure 3.3, the shaded areas indicate people susceptible to insurgent attack.) These areas complement the four driving pillars of nation-building discussed in Chapter I.

A SROM may consist of any number of regional sub-modules. Within each regional sub-module a total of six functional sub-models represent the daily functioning of the individual region. As mentioned earlier, for brevity's sake only one of the six functional sub-models will be reviewed in full detail in this chapter; the other sub-models will be briefly reviewed here and then detailed in its associated appendix. The insurgent and coalition military sub-model is explained in detail in the forthcoming pages. To provide the reader full context however, the general description of the demographics sub-model is provided first.

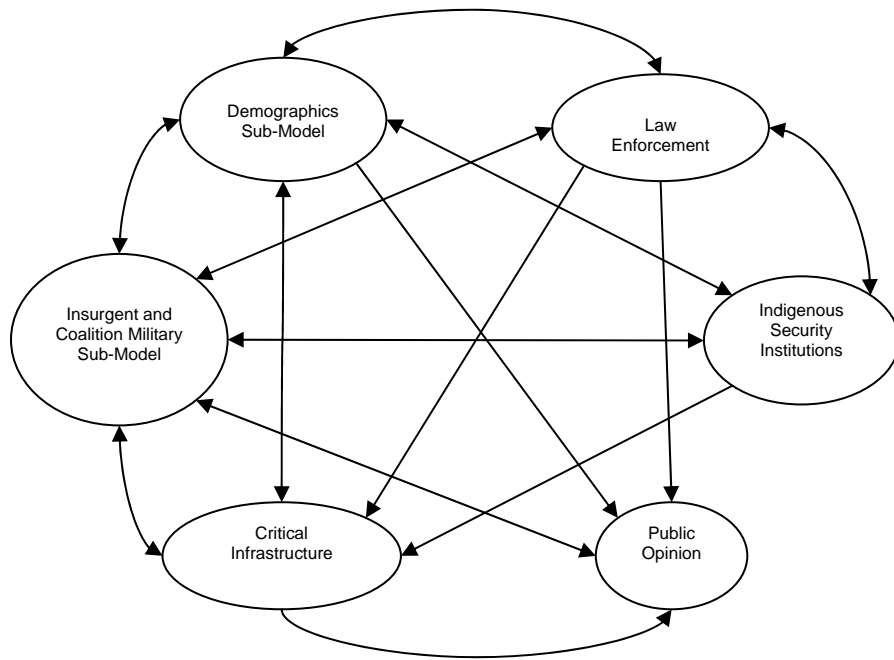


Figure 3.2 Regional Level Sub-Module

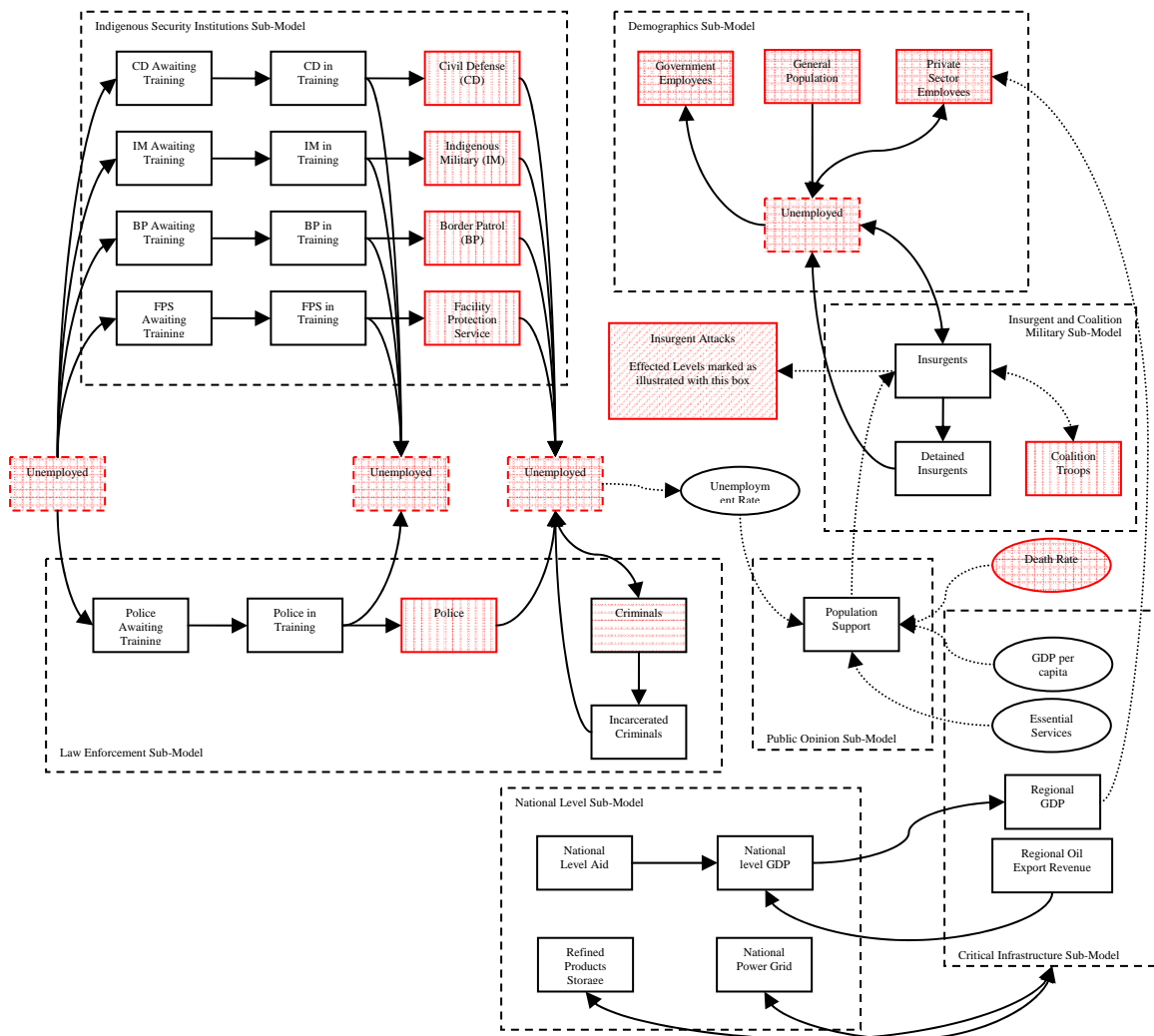


Figure 3.3 Conceptual Diagram of Regional Sub-Module

Demographics Sub-Model

The demographic level values and rates of change represent the flow of indigenous people to and from varying life activities as prescribed by the dynamic, developing situation occurring throughout the regional model. Within the SRM, the indigenous population of the region is divided into twenty-seven categories (level values). Throughout the simulation run time of the model, individuals move back and

forth amongst these twenty-seven categories as determined by the conditions prevalent in the model. Those individuals within the model that die are permanently removed from the model. The four level values within the demographics sub-model and their associated rates of change are listed in Table 3.2. The sign changes associated with the rates of change indicate the direction of the flow of indigenous persons to or from a particular level value. A positive sign represents an increase, whereas a negative sign indicates a decrease.

The demographics sub-model manages the flow of indigenous persons amongst many of the twenty-seven possible level values available. It tracks the growth of the general populace (expressed via the birth and death rate) and the movement of individuals into and out of the workforce (including criminal and insurgent lifestyles) via the unemployed level value. Government employees and the private sector are also distinctly labeled and followed.

The general population level value consists of the young, the elderly, and those of proper age who do not work. Most population demographic statistics include the birth and death rate which then reflects the population's growth. Additionally, a certain percentage of the general populace continuously reaches a level of maturity such that they then join the workforce. Concurrently, a certain percentage of the population will retire and leave the workforce. This (typically) results in a net positive daily flow of indigenous persons flowing from the general population level value into the unemployed level value.

In the SRM, it is assumed that retirees move instantaneously through unemployed status to the general populace with an available unemployed person

Table 3.2 Demographics Sub-Model Level Values and Rates of Change

Level Value	Rates of Change	Units
General Population	+ Natural Birth Rate	Indigenous Persons
	- Natural Death Rate	
	- Deaths from Crime	
	- Deaths from Insurgency Collateral Effects	
	- Deaths from Direct Insurgent Attack	
	- Population Entering Workforce	
Unemployed	+ Population Entering Workforce	Indigenous Persons
	- Deaths from Crime	
	- Deaths from Insurgency Collateral Effects	
	- Deaths from Direct Insurgent Attack	
	- Government Employee Hire Rate	
	± Private Sector Hire Rate	
	- Police Awaiting Training Recruit Rate	
	+ Police in Training Washout Rate	
	+ Police Attrition Rate	
	- CD Awaiting Training Recruit Rate	
	+ CD in Training Washout Rate	
	+ CD Attrition Rate	
	- IM Awaiting Training Recruit Rate	
	+ IM in Training Washout Rate	
	+ IM Attrition Rate	
	- BP Awaiting Training Recruit Rate	
	+ BP in Training Washout Rate	
	+ BP Attrition Rate	
	- FPS Awaiting Training Recruit Rate	
	+ FPS in Training Washout Rate	
	+ FPS Attrition Rate	
	± Criminal Recruitment Rate	
	+ Incarcerated Criminal Release Rate	
	± Insurgent Recruitment Rate	
Government Employees	+ Government Employee Hire Rate	Indigenous Persons
	- Deaths from Crime	
	- Deaths from Insurgency Collateral Effects	
Private Sector Employees	- Deaths from Direct Insurgent Attack	Indigenous Persons
	± Private Sector Hire Rate	
	- Deaths from Crime	
	- Deaths from Insurgency Collateral Effects	
	- Deaths from Direct Insurgent Attack	

immediately filling the opening position – this unemployed person is then immediately replaced by a person from the general populace thus reflecting no change in the level

values. This effectively reduces the percentage of people entering the workforce on a daily basis and is done for simplicity's sake. (If a future scenario required, this assumption could be relaxed with a modicum of additional programming.)

The unemployed are monitored as legitimate jobs are obtained from the government, the private sector, and the various security forces; whereby they then leave unemployed status. As the individuals proceed through training, they might washout or quit, and once again become unemployed. If the economy worsens individuals will be fired and again move to the unemployed level value. Additionally, the unemployed can become criminals or insurgents and pursue an illegal lifestyle.

In the SROM, the government only hires. It is assumed for the sake of stability that civil service jobs will not be given and then removed within the timeframe of the model. Government employees may be killed as the result of violence in the region, but the model will then hire more people until the stated manning goal is met. As mentioned above, retirees are assumed to be immediately replaced by an unemployed person, who in turn is immediately replaced by a person from the general populace.

The SROM assumes the private sector hires and fires based upon the strength of the economy. Richardson (2004) successfully utilized what is referred to as "Okun's Law" in his model. According to Richardson, in Okun's paper "Potential GNP: It's Measure and Significance" Okun found that:

in the postwar period, on the average, each percentage point in the unemployment rate above four percent has been associated with about a three percentage decrement in the real gross national product (Okun, 1962: 2).

This relationship is then used as a broad macroeconomic assumption in the model whereby as GDP per capita increases (decreases), unemployment decreases (increases). Thus, as the economy grows stronger, unemployed persons flow into the private sector and as the economy weakens, private sector employees flow into the unemployed level value.

Besides managing the flow of people within the above four categories, the demographics sub-model calculates the unemployment rate, the labor force percentage, and the total regional population. These three functional values are used in calculating rates of change for level values in other sub-models.

The unemployment rate, a function of all four level values in the demographics sub-model, appears in rate of change equations for the criminal recruit rate (law enforcement sub-model), the insurgent recruit rate (insurgent and coalition military sub-model), and the popular support unemployment effect rate of change (public opinion sub-model). The unemployment rate is also used in the popular support limiter function (public opinion sub-model).

The labor force percentage, a function of all four level values in the demographics sub-model, is used in conjunction with the unemployment rate to form the popular support limiter function (public opinion sub-model). This function places a ceiling on how high the popular support in a region can rise. Popular support is limited by the number of unemployed people. The assumption is that unemployed people are unlikely to directly support the coalition.

The regional population, again a function of all four level values in the demographics sub-model, is used in calculations for the insurgent recruit rate (insurgent

and coalition military sub-model), the level of violence effect rate of change (public opinion sub-model), and rates of change within multiple subsystems within the critical infrastructure sub-model to include: the refined products demand function, the electrical power demand function, the transportation food demand function, the water demand ratio function, and calculation of regional GDP per capita.

Insurgent and Coalition Military Sub-Model

The movement and flow of indigenous persons is important because coalition forces are essentially concerned with stopping the flow of people into the insurgent category. Indeed, a primary utilization of the SRM is to explore the different policy avenues by which to better achieve a slow down and subsequent stopping of indigenous persons flowing into the insurgent level value. It is within the insurgent and coalition military sub-model that insurgent activities, recruitment, deaths, and capture are calculated. The level values and rates of change for the insurgent and coalition military sub-model are displayed in the following table.

Table 3.3 Insurgent and Coalition Military Sub-Model Level Values and Rates of Change

Level Value	Rates of Change	Units
Insurgents	+ Insurgent Recruit Rate	Indigenous Persons
	+ International Insurgent Recruit Rate	
	- Insurgent KIA or Detained Rate	
	± Interregional Insurgent Movement	
Coalition Troops	+ Coalition Troops Arrival Rate	Coalition Troops
	- Coalition Troops Departure Rate	
	- Coalition Troop Casualty Rate	
	± Coalition Troops Interregional Movement Rate	
Detained Insurgents	+ Insurgent KIA or Detained Rate	Indigenous Persons
	- Detained Insurgent Release Rate	

There are three level values in the insurgent and coalition military sub-model. The table lists each of the rates of change that affect them. The first of the three level values explained here represents the number of insurgents actively operating against coalition and indigenous security forces. An insurgent is defined as a “member of a political party who rebels against established leadership” (JP 1-02, 2001: 260). There are a total of four different rates of change that affect the number of insurgents present in a region. In turn, the level of insurgents affects the rates of change of level values throughout the region though the functional determination of the number of insurgent

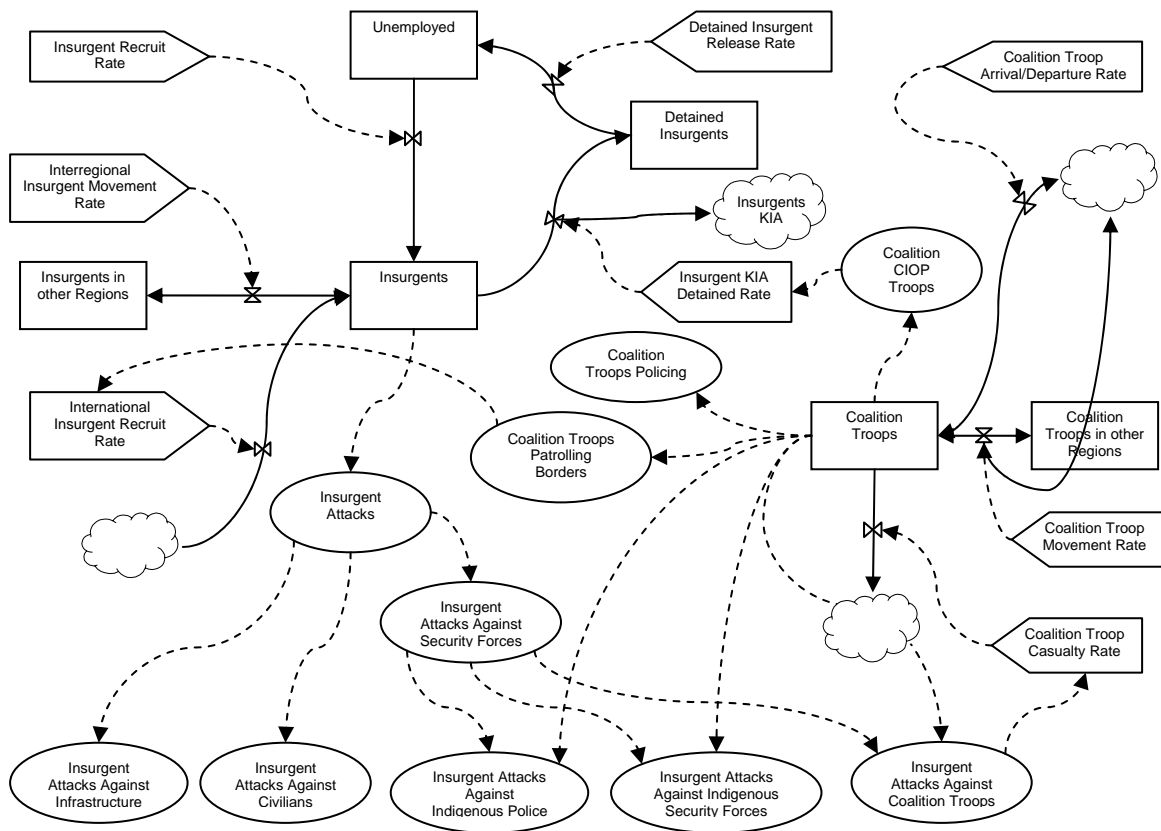


Figure 3.4 Insurgent and Coalition Military Sub-Model Systems Dynamic Flow Chart

attacks. The systems dynamic flow chart (Figure 3.4) illustrates the basic relationships involving the insurgent level value as well as those for the coalition troops and detained insurgents level values.

Calculation of the insurgent recruit rate is of vital importance to this model. As a tool to analyze potential policy decision sets, it is imperative to properly capture the elements contributing to the rise and fall of insurgent personnel. As mentioned in Chapter II, the aggregation of various sources, to include certain aspects of the criminal activity research, provides a foundation for a theoretical measure in which the insurgent recruitment rate within a region is determined by the many different economic, demographic, military, and geopolitical factors.

The insurgent recruit rate is a function of the perceived military success of the insurgency, the population diversity within the region and the country, the polarization of the population sub-groups (nationally and regionally), the presence of foreign troops as an aggravating factor, the growth of the economy in terms of GDP per capita and unemployment changes, an urbanization effect, the percentage of unemployed males, media influence, and the support of the population sub-groups for the coalition stabilization and reconstruction effort. Each of these factors modifies a baseline recruitment rate, affecting each of the population subgroups in a different manner according to their level of popular support of the coalition effort.

The following equations specify the insurgent recruit rate:

- 7 day moving average Loss Exchange Ratio, $LER(t) = \frac{1}{7} \sum_{i=1}^7 \frac{CoalitionKIA_{t-i}}{InsurgentKIA_{t-i}}$.

Days that see insurgent military success will involve higher coalition KIAs relative to insurgent KIAs resulting in a higher LER and thereby a more

successful recruiting effort in the near term. Note that LER(t) must have a ceiling to limit its impact on days when the LER could be extraordinarily large. The higher the ceiling, the larger a recruiting day insurgents are allowed to have.

- National adapted ethno-linguistic fractionalization (ELF) score, $ELF_{Nat} =$

$$1 - 3.5 \cdot \left[0.5 - \sum_{i=1}^P NatPopDist_i^2 \right]^2, \text{ where } NatPopDist \text{ is the national population}$$

proportions for P sub-groups. $NatPopDist$ must sum to one. ELF_{Nat} is a constant throughout the simulation run time. The basic ELF index score is often used to measure the population diversity within a country. “It measures the probability that two randomly drawn individuals from a given country do not speak the same language” (Collier *et al*, 2001: 32). For the purposes of this study it is then adapted based on the results of Collier *et al* where it was found that the risk of continued conflict is highest when the ELF is approximately 50 on a scale of 0-100 (2001: 11). Collier *et al* go on to note that increasing or decreasing the ELF to its extremes results in an eight-fold reduction in the probability of continued conflict. This essentially means that a population is most at risk for internal conflict when it has two large, nearly equal population sub-groups. Risk is lessened when a single large population group dominates the country or when there are many small subgroups present with no dominating ethnic group.

- Regional adapted ethno-linguistic fractionalization score, $ELF_{Rg} =$

$$1 - 3.5 \cdot \left[0.5 - \sum_{i=1}^P RgPopDist_i^2 \right]^2, \text{ where } RgPopDist \text{ is the regional population}$$

distribution for P sub-groups. This regional index score is analogous to the national score.

- National adapted polarization score, $Pol_{Nat} =$

$$1 - \frac{\left[\begin{array}{c} \sum_{j \neq i}^P NatPopDist_{i=1}^{2.6} \cdot NatPopDist_j \\ \sum_{j \neq i}^P NatPopDist_{i=2}^{2.6} \cdot NatPopDist_j \\ \vdots \\ \sum_{j \neq i}^P NatPopDist_{i=P}^{2.6} \cdot NatPopDist_j \end{array} \right]}{\sum \left[\begin{array}{c} \sum_{j \neq i}^P NatPopDist_{i=1}^{2.6} \cdot NatPopDist_j \\ \sum_{j \neq i}^P NatPopDist_{i=2}^{2.6} \cdot NatPopDist_j \\ \vdots \\ \sum_{j \neq i}^P NatPopDist_{i=P}^{2.6} \cdot NatPopDist_j \end{array} \right]},$$

where P is the number of sub-groups in the population.

The basic polarization concept seeks to further differentiate population sub-groups. It is explained as follows: “Polarization is related to the alienation that individuals and groups feel from one another [with] such alienation fuelled by notions of within-group identity” (Duclos, Esteban, and Ray, 2003: 1). The polarization score intends to capture the tension and hostility present in population sub-groups feeling marginalized by the other sub-groups.

Though not incorporated in the current model, a worthwhile extension to the polarization score would be the inclusion of an inter-group hostility matrix in the above equation that would modify one sub-group’s polarization score based on the presence of a disliked subgroup. Currently, each sub-group’s like/dislike for other subgroups is equal. The adaptation of the polarization score involves using the complement of the proportion of polarization held by each population

sub-group. This creates a score ranging from zero to one with the more polarized sub-groups being near one.

- Regional adapted polarization score, Pol_{Rg} . Analogous to the national adapted polarization score except using the regional population sub-group proportions.
- Coalition troops aggravation factor, $CTAF(t) = A \cdot \frac{CoalitionTroops_t}{RgPopulation_t}$, where A =

100 is the aggravation constant. Each coalition troop present in the region at time t counts as 100 troops. This modified total of troops is then divided by the regional population to determine a troop presence aggravation score. Generally speaking, the more troops in the region, the more agitated the indigenous population becomes; the insurgent recruit rate thereby increases. This factor is notional and should be explored further.

- GDP per capita growth effect, $GDPpcapGEff(t) = 1 + 2.4 \cdot \left[1 - \frac{GDPpcap_t}{\frac{1}{7} \sum_{i=27}^{33} GDPpcap_{t-i}} \right]$.

For every 1% increase in the current GDP per capita (relative to the 27-day lagged, 7-day moving average GDP per capita) there is a corresponding 2.4% decrease in insurgent recruits. This relationship is taken from the results of Fajnzylber *et al* where the increase in GDP per capita resulted in a 2.4% drop in violent crime (1998: 18). This relationship fits into the economic model of crime whereby a portion of potential criminals/insurgents is not willing to forgo the loss of increased wages or the opening of a newly created, legitimate job.

- Unemployment effect, $UnempEff(t) = 1 - 9 \cdot \left[\frac{1}{7} \sum_{i=27}^{33} UEmp_rate_{t-i} - UEmp_rate_t \right]$. For every 1% decrease in the current unemployment rate (relative to the 27-day lagged, 7-day moving average unemployment rate) there is a corresponding 9% decrease in insurgent recruits. This relationship is taken from the results of Niskanen where the decrease in the unemployment rate resulted in a 9% drop in violent crime (1994). This relationship fits into the economic model of crime whereby a portion of potential criminals/insurgents is not willing to forgo the loss of increased wages or the opening of a newly created, legitimate job.
- Urban effect, $UrbanEff = 1 + 0.9 \cdot (RgUrbanRate - UrbanEffCon)$, where $RgUrbanRate$ is the regional urbanization rate. This value remains constant for the region throughout the simulation. This relationship is also taken from Niskanen where his regression analysis of crime statistics determined that for every 1% increase in the urbanization rate over the regression mean, 0.80, the violent crime rate increased by 0.9%. The urban effect constant, $UrbanEffCon$, is set to 0.80. The more urban a society, the more crime. This thought is then adapted to insurgency.
- The male effect, $MaleEff = \text{constant}$. This value reflects the expectation of the proportion of the workforce, region-wide, that is male. Many regression crime studies, including Niskanen's, find that more males typically indicate more crime. That relationship is applied here by using the number of male unemployed as part of the pool of potential insurgent recruits. A related area that should be addressed

in future versions of the SROM is that of age. The insurgent recruit rate could be modified to reflect different rates for different ages.

- Non-supporting population vector, $NonSupPop(t) = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} - \begin{bmatrix} PopSup(t)_1^{2.6} \\ PopSup(t)_2^{2.6} \\ \vdots \\ PopSup(t)_p^{2.6} \end{bmatrix}$. Each

sub-group's non-supporting portion of the population is affected by the above mentioned factors. The portion of each sub-group that supports coalition efforts is not part of the pool of potential recruits.

- Insurgent inertial effect, $InertiaEff(t) = Inert_{eff} \cdot \frac{1}{7} \sum_{i=27}^{33} Insurgents_{t-i}$, where $Inert_{eff}$

= 1/1000 is the inertia effect constant. For every 1000 insurgents (the 27-day lagged, 7-day moving average number of insurgents) present on a given day an extra one person joins the insurgency. Fajnzylber *et al* find an inertial effect for criminal activity (1998: 18); this is adopted for insurgent activity, intending to capture the momentum of an insurgency due to the absence or eradication of the rule of law and the rise of a criminal/lawless culture.

- Deterrence effect, $DeterEff(t) = D_{eff} \cdot \frac{1}{7} \sum_{i=1}^7 InsurgentsKIADetained_{t-i}$, where D_{eff}

= 1/100 is the deterrence effect constant. For every 100 insurgents killed or detained on average in the past 7 days, one insurgent decides to quit. This relationship is adapted from the results of Levitt who found a deterrence factor for crime based on arrests made (1995, table 7).

- Media effect, $MedEff(t) =$

$$\sum \left[\frac{1}{365} MedPen \cdot NegMed \cdot MedEffBaseline \cdot UnempRate_t \cdot \right.$$

$\left. (1 - PopSup_t) \cdot RgPop_t \cdot RgPopDist \right]$, where $MedPen$ is the market penetration of the influencing medium in terms of proportion of population, $NegMed$ is the market share of the biased, insurgency reinforcing media, and $MedEffBaseline = 1/1000$ is the notional annual baseline rate in which the predisposed population actively joins the insurgency. The male, unemployed, non-supporting portions of each population subgroup combine to form the pool of potentially predisposed individuals already leaning toward active support of the insurgency. This relationship is based on the premise of Ajzen and Fishbein's (1980) Theory of Reasoned Action (discussed in more detail in Chapter II), which is often used in consumer behavior research.

- Baseline insurgent recruit rate, $BaselineIRR = \text{constant}$. This value, typically set at $1/10000$, is the daily number of disaffected, non-supporting people actively joining the insurgency.

Together, these equations form the average insurgent recruit rate, $avgIRR(t) =$

$$\sum \left[(LER_t + ELF_{Nat} \cdot ELF_{Rg} + Pol_{Nat} \cdot Pol_{Rg} + CTAF_t) \cdot GDPpcapGEff_t \cdot UnempEff_t \cdot \right. \\ \left. UrbanEff_t \cdot MaleEff_t \cdot BaselineIRR \cdot RgPopDist \cdot NonSupPop_t \right] + InertiaEff_t \\ - DeterEff_t + MedEff_t$$

The functional value $avgIRR(t)$ is then used as the expectation of the insurgent recruit rate, $IRR(t)$. A random variable distribution should be selected by the model user as deemed appropriate for the modeled situation.

The next rate of change affecting the insurgent level value is the insurgent KIA-detained rate. This rate is a function of the number of coalition troops performing

counter-insurgency operations (CIOP), as well as the number of active duty indigenous police, civil defense, and military personnel. Troop type CIOP effectiveness is also a factor. The insurgent KIA-detained rate of change is given by the following equation:

$$\begin{aligned} \text{InsurgentKIADetained}(t) = & \text{CIOPApprehensionPercent}_t \cdot \text{Insurgents}_t \cdot \\ & \frac{\% \text{CIOP} \cdot \text{CTroops}_t \cdot \text{Eff}_{\text{CTroop}} + \text{Police}_t \cdot \text{Eff}_{\text{Pol}} + \text{CivilDefense}_t \cdot \text{Eff}_{\text{CD}} + \text{IndMilitary}_t \cdot \text{Eff}_{\text{Mil}}}{\text{CIOPEffectivenessFactor}} \\ & + \text{InsurgentsKIADetainedFromTips}(t). \end{aligned}$$

The %CIOP constant is the proportion of coalition troops actively conducting CIOP. The Eff constants indicate the effectiveness of the troop type with respect to CIOP (allowing for variations among troops trained for a specific function versus those dragooned into a mission other than their primary MOS). The CIOPEffectivenessFactor is the number of effective troops needed to capture on average CIOPApprehensionPercentAvg percent of the insurgents on a daily basis. This average is used as the expectation of a random variable, with distribution chosen by the model user. Using

CIOPApprehensionPercentAvg as the expectation, the random variable

CIOPApprehensionPercent_t is then generated on a daily basis for use in the equation.

AvgInsurgentsKIADetainedFromTips(t) is calculated by the following equation:

$$\left[\sum \text{RgPopDist} \cdot \text{PopSup}_t \cdot \text{Pop}_t \right] \cdot \frac{1}{\text{PopPerTip}} \cdot \frac{1}{\text{InsurgentsPerTip}} \cdot \text{InsurgentsKIADetPerTip}$$

This equation represents those insurgents killed or apprehended as a result of pro-coalition popular support. As popular support grows, more of the population is willing to provide intelligence to coalition forces. As would be expected, insurgents transiting into a coalition friendly region will find difficulties because the host population does not support the insurgency. The coalition-supporting population will provide more intelligence to the security institutions, resulting in increased death or apprehension of the

insurgents. The more insurgents present in the region, the more tips that can be generated. On average, a certain number of insurgents will be caught for every tip provided. The calculated expectation is then used in the generation of random variable $InsurgentsKIADetainedFromTips(t)$ that is used in the calculation for the number of insurgents KIA or detained.

The $InsurgentKIADetained(t)$ equation creates a relationship such that at time t for every group of $CIOPEffectivenessFactor$ number of troops actively fighting the insurgency, a randomly distributed proportion of insurgents are captured or killed. The insurgents killed or detained are then split again by an $InsurgentKIAUncertainty$ random variable that places a certain proportion in the KIA category and the rest in detained status. A random portion of those detained are released after a random length of time. If these values are known exactly, they can be entered as constants instead of parameters of random variables. This is true of any relationship defined in the SROM.

The international insurgent recruit rate represents the influx of foreign insurgents into the region. This rate is a function of the amount of active duty border patrol, number of coalition troops patrolling the border, their respective associated effectiveness, and the daily expectation of incoming foreign fighters. The applicable equations are as follows:

$InternationalInsurgentRecruitRate(t) =$

$$\frac{BPEffectFactor}{\left(BP_t \cdot BP_{eff} + \%CTroopPolicingBorder \cdot CTroops_t \cdot CTroop_{BorderEff} \right)^2 + BPEffectFactor} \cdot InternationalInsurgentInflux_t$$

$InternationalInsurgentInflux_t$ is a random variable based on a chosen expectation parameter (and corresponding distribution) and represents the number of foreign insurgents attempting to cross into the region at time t .

$$BPEffectFactor = \frac{BPTroopsNeeded^2}{\frac{1}{1 - BPDeterPercent} - 1}, BPTroopsNeeded \text{ is the number of troops}$$

required to stop *BPDeterPercent* percent of the foreign insurgents attempting to cross into the region.

The fourth rate affecting the insurgent level value represents the movement of insurgents to and from other regions. This functionality exists in order to capture the dynamic movement of insurgents between regions. A region with a large number of insurgents that is successfully executing an insurgency may export insurgents to other regions in the country, seeking to cause problems in those regions. Likewise, a region where coalition forces are successfully eradicating insurgents may cause many of the remaining insurgents to flee that region to one in which the insurgency is in better shape. Different rule sets can be applied to what essentially is an offensive and defensive insurgent capability. These conditional rule sets are applied to simulate a dynamic insurgency that responds to ongoing operational conditions in its environment.

The interregional insurgent movement rate is expressed with the following equations: $OffMovRate(t) = OffMovRatePercent \cdot Insurgents_t \cdot I_{Off}$, where *OffMovRatePercent* is the percentage of insurgents that leaves the region daily, *Insurgents_t* is the number of insurgents at time *t*, and *I_{Off}* is an indicator function that turns on/off based on the necessary conditions for movement. $I_{Off} = 1$ when $30DayMovAvgDeathRate(t) > OffCondFactor * AcceptableDeathRate$, 0 otherwise. The indicator function goes high when the violence meets a certain threshold (a multiple of the model-terminating acceptable death rate). Modification of this multiple affects the level at which insurgents will transfer out. The higher the multiple, the smaller the

number of insurgents that transfer out, since more are required to stay in the region to meet the required level of violence. As stated, the *OffMovRatePercent* value determines the alacrity with which insurgents transfer regions. The equation

$DefMovRate(t) = DefMovRatePercent \cdot Insurgents_t \cdot I_{Def}$ is analogous to $OffMovRate(t)$,

with the exception of the condition as expressed by the indicator function. For the defensive movement, insurgents transfer out of the region when the current insurgent level drops to a certain percentage of the maximum insurgent level ever achieved. $I_{Def} =$

$$1 \text{ when } \frac{insurgents_t}{\max(insurgents_i), i = [0, t)} < DefMovThreshold, 0 \text{ otherwise.}$$

Together then, the interregional insurgent movement rate, $IIMR(t) =$

$$OffMovRate(t) + DefMoveRate(t) - \sum_{j \neq i}^R IIMR_{ij}(t), \text{ where } \sum_{j \neq i}^R IIMR_{ij}(t) \text{ is the total number}$$

of insurgents flowing into the current region i via other regions' prescribed movement rates.

Only one functional relationship is directly impacted by the insurgents level value, the calculation of the daily number of insurgent attacks. The number of daily insurgent attacks is determined by the following equation: $InsurgentAttacks(t) =$

$$\frac{1}{A}(Insurgents_t) + \frac{1}{B} \left(\frac{1}{7} \sum_{i=27}^{33} CTroopCasualtyRate_{t-i} \right) + \frac{1}{C} \left(Insurgents_t^2 - \frac{1}{7} \sum_{i=27}^{33} Insurgents_{t-i} \right)$$

, where A is the number of insurgents required for a single daily attack, B is the number additional attacks per coalition casualty (momentum effect from successful insurgent operations), and C is the insurgent differential effect. The last term is best explained in this manner: any 30 day period seeing a large surge in the number of insurgents will see a correspondingly higher surge in the number of insurgent attacks. Likewise, any sudden

change in the insurgent level value will reduce the number of insurgent attacks. Different interpretations of this phenomenon can be made and are not detailed here. This equation was derived from a regression analysis accomplished for this study using open source data on the Iraq insurgency provided by the Brookings Institution (17 Dec 2004: 11-13).

In the model the *InsurgentAttacks(t)* value is partitioned into three categories: attacks against security forces, attacks against infrastructure, and attacks against civilians. These proportions are assigned by the model user to best reflect the targeting patterns used by the insurgents. The attacks against security forces are further partitioned into attacks against coalition forces, indigenous police, civil defense, and indigenous military. This is subsequently discussed.

The second of the three level values in this sub-model is the coalition troop level value. It represents the total number of coalition troops operating in the region and is affected by four rates of change (Table 3.3).

The first two rates of change are the troop arrival and departure rates. These values are set by the model user to allow troops exogenous to the model to enter or depart at a prescribed simulation time t . No condition inside the model interferes with the arrival or departure of coalition troops. Once the exogenous troops actually flow into the coalition troops category they can then be affected by the prevailing conditions in that region. When troops depart, they are removed from the model entirely.

The third rate of change affecting coalition troops is the casualty rate. The equation for the casualty rate, $CTroopCasualtyRate(t) =$

$InsurgentAttacksAgainstCTroops_t \cdot CTroopCasualtiesPerAttack$, where

$InsurgentAttacksAgainstCTroops_t$ is a proportion of the total number insurgent attacks

occurring at time t . $CTroopCasualtiesPerAttack$ is a random variable chosen by the model user to most accurately reflect the nature of hostilities in the region.

Concerning $InsurgentAttacksAgainstCTroops_b$, this value is calculated as a weighted proportion of the total number of the security forces in the country, including the indigenous forces. This weighted proportion is used to ensure a dynamic response by the insurgents. For instance, early in a nation-building incident coalition forces will typically comprise the vast majority of security forces in a region and as such will be the targets of nearly all insurgent attacks. However, as indigenous security forces stand up, they too will become targets. The weighted proportion leaves the model user an option to bias attacks against coalition forces. For example, if the force structure in the region were the following: 50,000 coalition troops, 10,000 police, 20,000 civil defense, and 20,000 indigenous military, then the non-weighted proportions of insurgent attacks against the respective services would simply be: 0.50, 0.10, 0.20, and 0.20. A coalition troop bias factor (e.g. of 1.5) would make it appear as if there were more coalition troops (e.g. 75,000) than are actually present; the coalition troops would then receive a higher proportion of the insurgent attacks with the indigenous troops receiving a reduced proportion. As coalition troops are drawn down or move out of the region, and/or indigenous security forces become active, the insurgents will direct more attacks against the indigenous security forces.

The fourth rate of change affecting the coalition troops level value is the coalition troop movement rate. This rate of change is analogous to the insurgent movement rates of change. Given a certain prescribed condition, coalition troops in one region will move

to other regions. The conditions required to allow movement will typically involve regional stability and safety considerations.

The equation $CTroopMovRate(t) = CTroopMovRatePercent \cdot CTroop_t \cdot I_{Mov} - \sum_{j \neq i}^R CTroopMovRate_{ij}(t)$ describes the coalition troops movement rate of change in region i with the first term representing outbound flow and the second representing all coalition troops moving from other regions into the current region. I_{Mov} is the indicator function such that $I_{Mov} = 1$ when the safety/stability measure is less than a predetermined threshold ($90DayMovAvgDeathRate(t) < AcceptableDeathRate$), 0 otherwise.

Besides just having a required violence level, another condition could involve the manning level of the indigenous security forces. The $CTroopMovRatePercent$ is the daily proportion of coalition troops that transfer out of the region. The destination point of the transfer is a matter of policy. The troops typically will be sent to the region with the highest violence level, though conceivably they could be sent home as well. The model terminates when all regions have a 90 day moving average death rate below the acceptable violence level.

The third and last level value in the insurgent and coalition military sub-model is the detained insurgent level value. This level value represents the number of insurgents currently being held by coalition forces and is obtained by splitting a proportion of the previously described $InsurgentKIADetainedRate(t)$ into two flows; one for insurgents killed (leaves model) and one for insurgents detained. Typically, a random variable (with parameters assigned as deemed appropriate by the model user) is generated for use as the proportion.

The detained insurgent level value is affected by only one rate of change. The detained insurgent release rate is determined by taking an appropriate percentage of the incoming detained insurgents, holding them for an appropriate process time, and then releasing them back into the unemployed category. The percentage of incoming detainees that are to be released is a random variable with an appropriately selected distribution. Likewise, the amount of time the released detainees are held is a random variable with an appropriately selected distribution. The following equation describes the rate of change: $DetainedInsurgentReleaseRate(t+wait) = DIReleasePercent(t) \cdot InsurgentDetainedRate(t)$, where *wait* is the holding time random variable. (This equation involves a time delay.)

The insurgent and coalition military sub-model represents the activities and interactions of the insurgents, coalition troops, and detained insurgents level values. Their associated rates of change and functional applications were described in detail above. The important contribution of this sub-model is the generation of the insurgent attacks that impact all the other sub-models within its region.

Indigenous Security Institutions Sub-Model

The indigenous security institutions sub-model contains the level values of four indigenous security institutions. The four security institutions set apart from each other by virtue of their training, manning, equipment, and ultimately in the effective execution of their selected security roles. It is not necessary to limit the security institutions to a certain number, but their relationships to other level values and rates of change within the model should be considered and have some basis. Examination of the coalition stabilization and reconstruction efforts in Iraq allows some relationships to be formed

(Brookings Institution, 2005: 11-14). The exact nature of recruiting rates, training rates, attrition rates, casualty rates, criminal interaction, and insurgent interaction between the various indigenous security institutions will vary from scenario to scenario. The general form of the SROM therefore outlines only rudimentary relationships that are subject to the conditions of a particular instance of nation-building.

There are three level values representing the various stages of training and development for each of the four security institutions (Table 3.4). The first tiers represent those indigenous individuals that were successfully recruited into a security service and await training. These level values are increased by a recruit rate, moving those in an unemployed status to awaiting training status. The factors affecting recruit rates currently remain exogenous to the model and are thus expressed as distributions chosen by the modeler to best capture the dynamic of the situation. Future improvements of the model might hope to include GDP per capita, unemployment rate, level of violence, and popular support mechanisms among others.

Table 3.4 Indigenous Security Institutions Sub-Model Level Values and Rates of Change

Level Value	Rates of Change	Units
Civil Defense (CD)	+ CD Training Graduation Rate - CD Casualty Rate - CD Attrition Rate	Indigenous Persons
CD in Training	- CDTraining Graduation Rate - CD in Training Washout Rate + CD in Training Training Rate	Indigenous Persons
CD Awaiting Training	+ CD Awaiting Training Recruit Rate - CD in Training Training Rate	Indigenous Persons
Indigenous Military (IM)	+ IM Training Graduation Rate - IM Casualty Rate - IM Attrition Rate	Indigenous Persons
IM in Training	- IM Training Graduation Rate - IM in Training Washout Rate + IM in Training Training Rate	Indigenous Persons
IM Awaiting Training	+ IM Awaiting Training Recruit Rate - IM in Training Training Rate	Indigenous Persons
Border Patrol (BP)	+ BP Training Graduation Rate - BP Casualty Rate - BP Attrition Rate	Indigenous Persons
BP in Training	- BP Training Graduation Rate - BP in Training Washout Rate + BP in Training Training Rate	Indigenous Persons
BP Awaiting Training	+ BP Awaiting Training Recruit Rate - BP in Training Training Rate	Indigenous Persons
Facility Protection Service (FPS)	+ FPS Training Graduation Rate - FPS Casualty Rate - FPS Attrition Rate	Indigenous Persons
FPS in Training	- FPS Training Graduation Rate - FPS in Training Washout Rate + FPS in Training Training Rate	Indigenous Persons
FPS Awaiting Training	+ FPS Awaiting Training Recruit Rate - FPS in Training Training Rate	Indigenous Persons

Once in the awaiting training status, the indigenous individuals wait until a class becomes open. When classes do become available, with a frequency represented by the associated training rates, the individuals leave awaiting training status and move into training status. These movements consist of discrete, class size blocks of trainees. The class sizes, training speeds, and resultant troop effectiveness rates are all potential policy rule sets that the model could explore. Once in training, the classes suffer an attrition rate

represented by a random variable with a distribution appropriately chosen by the model user to reflect the dynamic of the situation. For instance, in Afghanistan, many trainees completing the government security training immediately return to their respective warlords. This phenomenon effectively signifies trainee attrition since the graduating trainees do not enter into active duty for the government security force. Given such a scenario, the attrition rate for that particular Afghanistan security institution should reflect the reality of the situation. Trainees who washout are sent back into the unemployed category. Trainees who graduate from their class are moved into the associated active duty level value of their particular indigenous security institution. After a prescribed down time for the teaching cadre to reconstitute themselves, a new class can then begin.

The active duty level values tier of the various indigenous security institutions is where the large structural differences lie. The civil defense could be labeled the busiest of the institutions. In the general SROM, the civil defense level value functionally impacts the rates of change for both criminals (criminal apprehension rate) and insurgents (*InsurgentKIADetainedRate(t)*). As currently modeled the indigenous military functionally impacts only the insurgents (*InsurgentKIADetainedRate(t)*). The border patrol functionally impacts the infiltration rate of international insurgents into the region by reducing the number of successful foreign insurgent infiltrations. The facility protection service functionally impacts the stability of the region's critical infrastructure by limiting the number of successful insurgent infrastructure attacks. Each of the security services suffer from an associated attrition rate. These rates are modeled using a random

variable with a distribution representative of the situation. Future versions of the SROM should attempt to include casualty rates and popular support as attrition mechanisms.

The ability and degree to which these indigenous security institutions can successfully execute these missions remains scenario dependent and the model parameters reflecting the service's attributes should be carefully selected. For instance, the capability of the civil defense to fight crime may be rated lower than its ability to fight the insurgents. The effectiveness parameter could further be set with the knowledge in mind that inadequate training time and poor equipment further limits the security institution's capability to perform its various missions.

Additionally, in future versions of the SROM elite commando brigades could be modeled as a separate indigenous security institution with longer training times and higher effectiveness ratings. The brigades could also be modeled to allow a dynamic flow between regions as occurs with coalition troops.

Law Enforcement Sub-Model

The law enforcement sub-model focuses on violent criminal activity and the efforts made by the coalition to reduce crime. The law enforcement sub-model contains an indigenous police subsystem and a criminal subsystem. The criminal activities section of Chapter II detailed many of the driving themes within this sub-model; the crime rate in a region is a function of the number of criminals present. Based on empirical studies of crime data, certain basic relationships are surmised and then represented in this sub-model. The five level values and their associated rates of change are shown in the table below.

Table 3.5 Law Enforcement Sub-Model Level Values and Rates of Change

Level Value	Rates of Change	Units
Police	+ Police Training Graduation Rate - Police Casualty Rate - Police Attrition Rate	Indigenous Persons
Police in Training	- Police Training Graduation Rate - Police in Training Washout Rate + Police in Training Training Rate	Indigenous Persons
Police Awaiting Training	+ Police Awaiting Training Recruit Rate - Police in Training Training Rate	Indigenous Persons
Criminals	± Criminal Recruitment Rate - Criminal Apprehension Rate - Criminal vs Criminal Death Rate	Indigenous Persons
Incarcerated Criminals	+ Criminal Apprehension Rate - Incarcerated Criminal Release Rate	Indigenous Persons

The police subsystem functions in a manner analogous to any of the four indigenous security institutions discussed in the previous section. Indigenous police are recruited from the unemployed at a random rate (appropriately chose by the model user) and flow from the unemployed level value into the police awaiting training level value. When a class becomes available and there are enough persons awaiting training, those individuals then flow into the indigenous police in training level value. While in training, the trainees washout at a prescribed random rate. Upon successful completion of the class, the remaining police in training for that class flow into the active duty indigenous police level value where they have an immediate impact on functions involving the indigenous police.

The indigenous police level value is reduced by an attrition rate, represented by a random variable appropriately chosen by the model user, and by a police casualty rate. The police casualty rate is a function of the number of insurgent attacks and the proportion of active police in the region relative to the other indigenous security forces and coalition troops; it represents the losses inflicted upon the police due to fighting with

insurgents. The indigenous police level value functionally impacts the rates of change for criminals (criminal apprehension rate) and insurgents (*InsurgentKIADetainedRate(t)*). Its impact on those rates is further modified by an associated effectiveness rate.

Criminals are a destabilizing force in a region. Bourguignon (1999: 3), Tullio and Quarella (1998), and Bejarano (2003: 49-50) each discuss the negative costs associated with a high crime rate. In the SROM, the number of criminals present in a region determines the region's crime rate; the more criminals in a region, the more murders, violence, theft, and overall disruption to the normal functioning of society. The criminal activities literature reviewed in Chapter II led to the determination of the criminal recruit rate and the criminal apprehension rate. The criminal recruit rate represents the flow of unemployed people into the criminal lifestyle and should capture the dynamic conditions prevalent in the region that encourage or discourage criminal behavior. The criminal apprehension rate represents the rate at which policing forces in the region successfully capture and imprison criminals; those apprehended flow from the criminals level value into the incarcerated criminals level value.

As mentioned in Chapter II, several basic questions need to be addressed. How many police are typically appropriate for a given number of citizens? How many police are required to maintain law and order given a certain amount of criminal activity? What is the typical murder rate for a given crime rate? What effect does unemployment have on the crime rate? Does economic growth have a significant impact? What about the urbanization level?

The criminal recruit rate and criminal apprehension rate are calculated from the answers to the questions posed above. Empirical relationships found in the criminal

literature are used to construct these rates of change. Causes of crime are continuously investigated by many professional and academic sources and it should be noted that the relationships utilized here are based upon the general research of a few researchers that may or may not be specifically applicable to different model scenarios. Model parameters should be adapted to best represent the nation being modeled. The components used to calculate the criminal recruit rate and the criminal apprehension rate are shown in the table below.

The criminal level value is of vital concern. Criminal activity contributes greatly to violence in a region. This violence induced instability greatly reduces the economic prosperity of the region. The criminal activities literature review addressed many of the reasons why this is so. In the SROM, the criminal murder rate (a function of the number of criminals) is combined with the deaths caused from the insurgent activity to obtain the overall death rate in the region. This death rate is the primary measure by which the model measures the progress of the coalition stabilization and reconstruction effort.

The fifth level value in the law enforcement sub-model is the incarcerated criminal level value. It represents the criminals that have been apprehended by the policing forces. Thus the apprehension rate directly feeds this level value. A random number (again, the distribution of the random variable should be selected as appropriate) of criminals are released daily from incarceration back into the unemployed flow of people. Future versions of the model should attempt to incorporate more of the criminal justice system to include conviction rates, holding rates, and prison capacities.

Table 3.6 Criminal Rates of Change Description

Criminal Recruit Rate	Description	Numerical Relationship	Source
Unemployment Effect (Expectation Used)	For every 1% increase in unemployment rate, a 9% increase in crime occurs	$9 * (\text{CurrentUnEmp} - \text{LaggedUnEmp}) * \text{Criminals}$	Niskanen (1994)
Criminal Inertia Effect (Model Parameter Constant)	Notional - on a daily basis, for every 10,000 criminals present, an additional 1.75 new criminals are recruited	$(1.75/10000) * \text{Criminals}$	Fajnzylber et al (1998)
GDP per capita Effect (Expectation Used)	For every 1% increase in GDP per capita, a 2.4% decrease in crime occurs	$(\text{lagged GDP} / \text{current GDP} - 1) * 2.4 * \text{Criminals}$	Fajnzylber et al (1998) Table 1 Column 3
Baseline Criminal Recruit Rate (Model Parameter Constant)	Replenishes the assumed criminal losses due to arrest and deterrence (assuming full police strength)	$(\text{Daily Arrest Rate} + \text{Daily Deterrence Rate}) * \text{Urban Effect} * \text{Criminals per 100k} * \text{Initial Regional Population} / 100k$	Bejarano (2003)
	Assume natural crime rate of Cv violent + Cp property = crimes per 100k citizens annually	$Cv + Cp = 2453 + 8315 = 10768$	Niskanen (1994) Table 2 maximum column
	Assume Crimes per Criminal per year Criminals per 100k citizens	15 $10768 / 15 = 717.87$ criminals per 100k citizens	Levitt (1995: 28)
	For every 1% increase in urbanization rate over 0.80, a 0.9% increase in crime occurs.	$\text{Urban Effect} = 1 + 0.9 * (\text{regional urban rate} - 0.8)$	Niskanen (1994)
Criminal Deterrence Rate (Expectation Used)	The Criminal Deterrence Rate is a function of the Criminal Apprehension Rate. For every 1 criminal apprehended 1.26 criminals on average are deterred and return to unemployed status.	$\text{Deterrence Ratio} = \text{Daily Deter Rate} / \text{Daily Arrest Rate} = 1.2606$	Levitt (1995)
Criminal Apprehension Rate	Description	Numerical Relationship	Source
Criminal Apprehension Rate (Expectation Used)	Policing forces manning level of 78 Police per 100 Criminals (from Police Demand Ratio) is required to achieve a daily arrest rate of 0.1846/365	$\text{Daily Arrest Rate} * (\text{Indigenous Police} + \text{Civil Defense} + \text{Coalition Troops Policing}) / \text{Police Demand Ratio}$	
	Assume Required Police per 100k citizens	560	Niskanen (1994) Table 2 double average column
	Assume Arrest Rate of 0.1846 yearly	$\text{Daily Arrest Rate} = 0.1846/365$	Levitt (1995) Table 1
	Assume Deter Rate of 0.2327 yearly	$\text{Daily Deter Rate} = 0.2327/365$	Levitt (1995) Table 1
	Police Demand Ratio	$560 / 717.87 = 0.78$	
Criminal Death Rate	Description	Numerical Relationship	Source
Criminal Death Rate (Random Variable)	Notional - A specified proportion of crime caused deaths are assumed to be criminal vs criminal death	$\text{Avg Criminal Death Rate} = (1 - \text{Sum}(\text{Crime Death Proportions Vector})) * \text{Homicides per Criminal per day} * \text{Criminals}$	
	Crime Death Proportions Vector represents the proportion of crime induced death against the unemployed, government employees, private sector employees, and general population -> it must sum to less than one with any remaining proportion indicating crimina	$[\text{CDeathUnEmp}, \text{CDeathGovt}, \text{CDeathPriv}, \text{CDeathGenPop}]$	
	Criminal Homicide Rate is the percentage of crimes committed that are murders Homicides per Criminal per day	0.0032 $\text{Criminal Homicide Rate} * \text{Crimes per Criminal per year} / 365$	Levitt (1995) table 1 maximum column

Public Opinion Sub-Model

The public opinion sub-model represents the indigenous population's overall general attitude concerning the coalition stabilization and reconstruction effort. Often times the feelings and behavior of the populace is difficult to predict, though not impossible. The Center for Strategic and International Studies' (CSIS) Post-Conflict Reconstruction (PCR) project is one of many organizations attempting to develop measures to gauge the nation-building progress from the perspective of the indigenous people. In *Capturing Iraqi Voices* the CSIS PCR project experts indicate how they have traveled to Kosovo, Iraq, Sudan, and Sri Lanka to conduct research for several influential reports, each of them accomplished in order to better understand the effects of ongoing reconstruction operations in the country (CSIS, 2004: 2). In *Progress or Peril*, the extended follow up report to *Capturing Iraqi Voices*, the CSIS PCR project team details its full Iraqi popular perception report in five distinct areas: security, governance and participation, economic opportunity, services, and social well-being (2004: 1). Not surprisingly, the focus of the research parallels the nation-building goals of the coalition.

For the purposes of this model however, a single popular support measure is used; the popular support level value consists of a percentage score for each population sub-group in the nation, representing the proportion of that particular sub-group that supports the coalition stabilization and reconstruction effort. This measure could be construed as a weighted composite of each of the important areas within the nation-building context. Determination of the initial popular support measures for each of the sub-groups is difficult, especially if no reliable polling sources are available to the model user. It is for

this reason, that the initial popular support level values should be considered as a factor in any study conducted using this model.

The popular support level value and the four associated rates of change are listed in the table below.

Table 3.7 Public Opinion Sub-Model Level Values and Rates of Change

Level Value	Rates of Change (RoC)	Units
Popular Support (vector of P length) P = number of population subgroups in the nation	Unemployment Effect RoC Level of Violence Effect RoC Essential Services Demand Ratio Effect RoC GDP per capita Effect RoC	Percentage Points

Examination of the trends revealed by various opinion methodologies (media, official, polls, and interviews) sheds light on what the populace views is important (CSIS, 2004 and IRI, 2004). The International Republican Institute (IRI) poll conducted in Iraq in September and October of 2004 found that the following four areas concerned ordinary Iraqis most: unemployment, crime, infrastructure, and national security. Of these four, crime was labeled as the most important. Not surprisingly, the important areas are encompassed within the four principal components of nation-building identified by the stabilization and reconstruction subject matter experts. The SROM represents the concerns of the population through the rates of change affecting the popular support level value.

The four rates of change affecting the popular support level value are: the unemployment effect, level of violence effect, essential services demand ratio effect, and the GDP per capita effect. The unemployment effect addresses unemployment such that as unemployment decreases (increases) popular support increases (decreases). The specific mathematical relationship used for this rate of change is notional and requires further investigation.

The level of violence effect addresses the crime and national security concerns of a population. The violence within a region, as measured by the number of daily indigenous deaths, is an excellent barometer for stability. The level of violence effect decreases popular support when the number of deaths due to crime, insurgency, direct insurgent attacks, and indigenous casualties is above a specified tolerable threshold. The level of violence effect increases popular support when the violence is below the tolerable threshold. The specific mathematical relationship used for this rate of change is notional and requires further investigation. Since the model runs almost entirely in a time when violence is high, this effect will constantly be pushing popular support down.

The essential services demand ratio effect addresses the population's infrastructure needs in terms of food, water, power, and availability of refined products. If the weighted average demand ratio is above a specified tolerable threshold there is an increase in popular support, otherwise there is a decrease. Any of these demand ratios can be weighted according to the particular importance of the service. A demand ratio is a percentage score conveying the amount of a particular product or service provided to the population relative to the amount demanded by the population. For instance, if the power infrastructure provided 18 hours of service on a given day, the power demand ratio for that day would be 0.75. If the tonnage of food demanded for delivery required 18,000 tonnes of transport capacity daily but the transport infrastructure could only handle 9,000 tonnes, the food demand ratio would be 0.50. The specific mathematical relationship used for this rate of change is notional and requires further investigation.

The GDP per capita effect addresses wages, salaries, consumer prices, jobs, and general economic health. As GDP per capita increases (decreases), popular support

increases (decreases). The specific mathematical relationship used for this rate of change is notional and requires further investigation.

Critical Infrastructure Sub-Model

Chapter II discussed at great length the significance of a nation's critical infrastructure on stabilization and reconstruction efforts. The critical infrastructure sub-model represents a region's portion of the national infrastructure. It is the largest of the six sub-models, containing 58 level values and 90 associated rates of change. The sub-model consists of five subsystems: crude oil industry, electrical power generation and distribution, transportation, water, and economic. Due to the scope and complexity of constructing an adequate model of a region's critical infrastructure, a conceptual diagram of the SROM critical infrastructure sub-model has been provided for the reader (Figure 3.5). With the aid of Figure 3.5 a general description of the entire sub-model is provided to the reader. Note that the shaded areas indicate component subsystems that are susceptible to insurgent attack.

It should be noted that the SROM may be adapted to different stabilization and reconstruction scenarios. An industry contributing a substantial amount of money to the national GDP should be incorporated into the SROM. For instance, if a country's production and export of a commodity (e.g. oil, steel, coffee) accounts for 80% of its GDP and insurgent elements within the country are actively attempting to destroy or impair that industry (to hinder stabilization and reconstruction efforts), then the production, transport, and export of that commodity should be modeled since the successful operation of the industry has such a large impact on the health of the economy (and hence stabilization and reconstruction efforts).

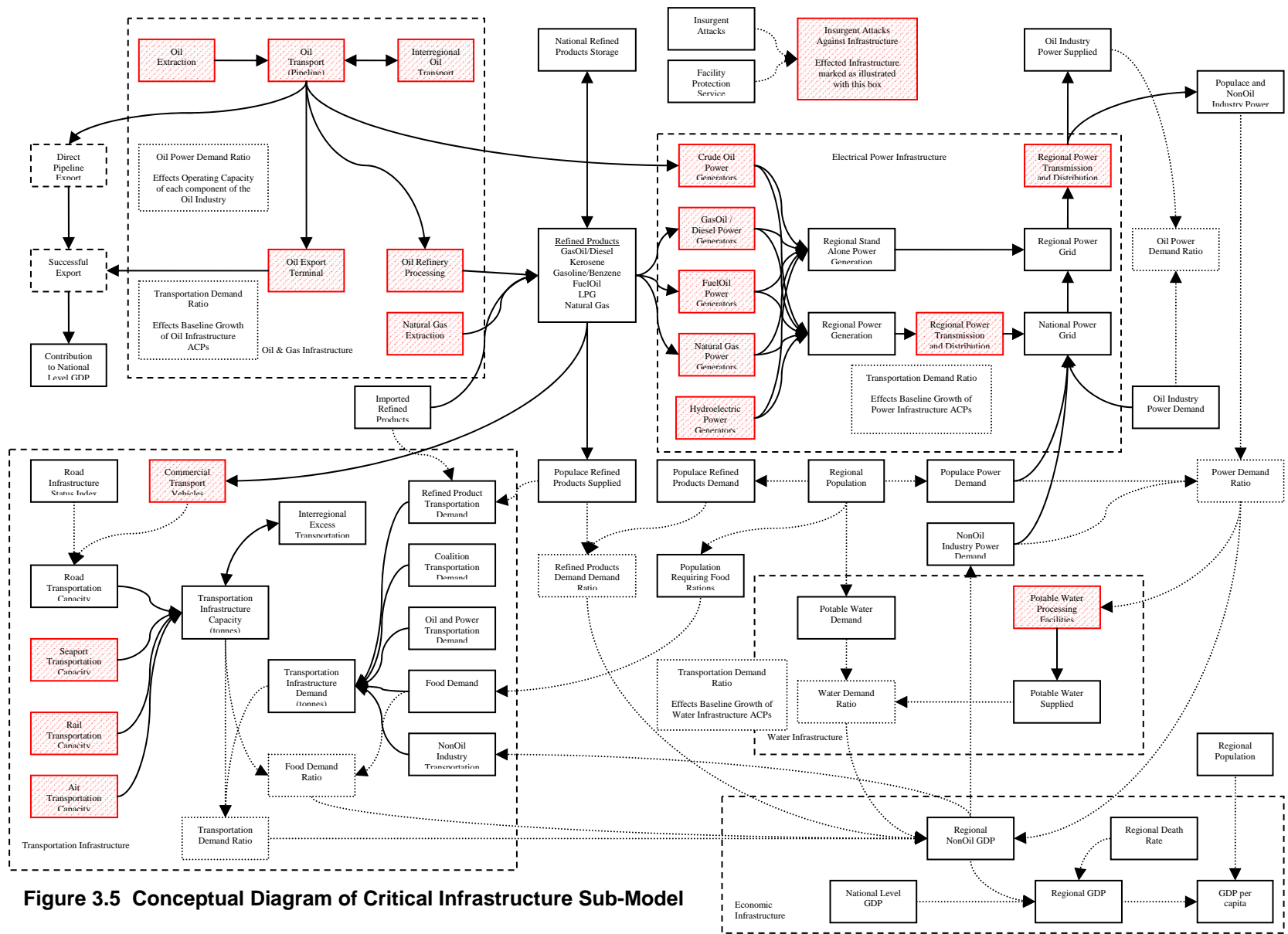


Figure 3.5 Conceptual Diagram of Critical Infrastructure Sub-Model

The crude oil infrastructure is important to many countries because it is a major source of fuel. In the SROM, regional crude oil is first extracted and then moved to the regional oil transport (pipeline) component of the oil infrastructure subsystem. From the pipeline system there are various destinations available. The oil could be transported to regional oil refineries where a refining process occurs that yields different refined oil products. The oil could be transported to regional oil export terminals where the oil is loaded into ships (or perhaps trucks) for export. The oil could be exported directly out of the country via pipeline. Successful exportation of crude oil is assumed to be sold based upon a model parameter constant price per barrel of oil with all revenue attributed to the national level GDP. (This national level GDP is shared by all the regions in the country.) Finally, for refining or export purposes, oil could be transported to another region in the county via an interregional pipeline. Insurgents can attack every aspect of the oil industry: oilfields, oil pipelines, oil refineries, and oil export terminals.

The natural gas extraction component is also included within the oil infrastructure subsystem. Much of a country's natural gas production could come from non-associated gas which the Society of Petroleum Engineers defines as the "natural gas produced from a reservoir that does not contain significant quantities of crude oil (2005)." The natural gas extraction component models the operations of the non-associated natural gas surface processing facilities. The natural gas produced is transported via pipeline to join the regional production of refined products.

Associated gas, which the Society of Petroleum Engineers defines as the "natural gas produced with crude oil from the same reservoir, (2005)" may account for much of the country's natural gas production. Depending on the capability of the associated

surface processing facilities, a large amount of natural gas could be processed. In the SROM, associated gas is modeled as a function of the barrels of crude oil refined. As the crude oil is sent to refineries, collocated natural gas processing plants are able to siphon off the associated natural gas. In the model this is accomplished by setting a natural gas refined yield to the appropriate amount, then converting the partial barrels of crude to cubic feet of natural gas. The natural gas then joins the rest of the refined products produced at the refinery. If a particular country flares all associated gas because it lacks the processing capabilities, the natural gas yield would be set to zero, indicating the lack of associated natural gas production.

Refinery operations consist of processing crude oil to produce differing refined products which are then used within different functional areas of a society and economy. *Platt's Guide to Petroleum Specifications* provides excellent, detailed information on refinery processing yields. There are many crude oil yield formulas for use with different crude oils, refining regions, and refining configurations. Platt's offers the following pertinent information:

The normalization process involves calculation of the yield of a given refined product as a volume fraction of the total volume of refined products, excluding the refinery fuel gas produced. The amount of refinery fuel gas produced varies dependent upon the refinery classification (topping, cracking), the refining location, and the crude oil being processed. (Platt's, 1999: 34)

Yields within the model should be selected to best represent the true realization of the refinery yield. The model is such that the refineries in different regions can be set to have different yields. For instance, one region's refineries could concentrate on production of gasoline and diesel while another concentrates on fuel oil and kerosene.

The chosen yields should best reflect the true potential of the refineries. Platt's also notes that the refining process consumes approximately 5% of the fuel feedstock, depending on the type of refining (topping, cracking) and type of crude oil (Platt's, 1999: 35).

The six refined product categories modeled in the SROM are gas oil/diesel, kerosene, gasoline/benzene, fuel oil, liquid petroleum gas (LPG), and natural gas. After the refined products are produced they are offered as fuel to many different sources: the generators in the electrical power infrastructure subsystem (gas oil/diesel, fuel oil, and natural gas), population consumption for heating, driving, and cooking (kerosene, gasoline/benzene, and LPG), and vehicles in the transportation infrastructure (diesel). Any remaining regional fuel is then forwarded for keeping in the national refined products storage level value. Of note, due to the difficulty in storing large amounts of natural gas it is assumed in this model that excess natural gas is converted to LPG. Physically, no refined products storage is modeled. The assumption is that all available regional surpluses are kept in storage tanks collocated with refining process facilities and are available for transport to other regions as demand requires.

The electrical power infrastructure subsystem consists of five different types of generators based upon the type of fuel used to spin the turbines: crude oil, gas oil/diesel, fuel oil, natural gas, and hydro-electric. Each of the generator types has two categories of generator, those that contribute to the national grid and those considered stand alone (contribute power only to the region). The amount of power generated and delivered is constrained not only by the operational generating capacity of the generators but also by the available fuel and the condition of the region's transmission and distribution component. The regional transmission and distribution component affects the amount of

power that can be exported from the region as well as the amount of power delivered to users in the region. Insurgent attacks can be made against both the generation and the transmission components of the subsystem.

The users of power place a demand on the national power grid. The population, non-oil industry, and the oil industry all are modeled as having dynamic demands on the regional grid and through it the national grid. As the population grows, so too does its demand for power. Based on country power consumption by sector data, a rough estimate of population demand in terms of megawatt-hours per capita can be calculated. Also of consideration, typical load characteristics (usage patterns) indicate a seasonal variation whereby the winter minimum load can be as low as 70% of the summer peak load (Sadiq and Al Taie, 2003: 9). Thus, a seasonal demand modifier is used in the model to more accurately depict the seasonal changes in electricity. Sadiq and Al Taie note that in Iraq the industrial base load varies the least; the largest seasonal variation in demand comes from residential customers operating their air conditioners in the summer heat. This seasonal variation is also mentioned in the report issued by the US-Canada Power System Outage Task Force concerning the August 14th, 2003 blackout in the northeastern US and southeastern Canada (2003: 5).

The non-oil industry demand is based upon the regional non-oil GDP. Thus, as the economy grows through the expansion of commerce and industry, as reflected by the regional non-oil GDP, so too does its demand for electricity. Based upon a country's power consumption by sector data a rough estimate of megawatt-hours per million US dollars of GDP can be estimated. Thus, a growing economy must have its power needs met to realize full growth potential. This concept is put forth in the Joint Iraqi Needs

Assessment (UN/World Bank, 2003, vi and 59). If power requirements are not met, then the economy does not grow as fast and actually may decline. The model uses the power demand ratio to facilitate this concept. If the power demand ratio equals one, then the populace, non-oil industry, and oil industry are receiving 24 hours of service at their required load levels. A ratio of 0.67 would indicate only 16 hours of service is being provided.

Moving to the transportation infrastructure, it is modeled as four distinct modes of transport providing capacity measured in tonnes. The modes of transport are road, sea, rail, and air. It should be noted that the coalition *military* transport is not modeled, though the coalition can place a demand on the transportation infrastructure. The model only considers indigenous transport capacity. Insurgent attacks disrupt transportation infrastructure.

Road transportation consists of a fleet of vehicles that provide the actual available tonnage capacity for movement of goods and supplies within the region. Insurgent attacks and criminal activity can destroy commercial transport vehicles. The actual condition of the system of roads and bridges that make up the physical infrastructure is measured using a road infrastructure index score. This score ranges from zero to one and represents a penalizing factor on the available tonnage capacity provided by the fleet of commercial transport vehicles. This concept is used to allow the model user to represent the problems arising from bridges being out or certain roads being out of service.

For instance, if the road infrastructure index was set at 0.80 and the region had 100 vehicles each with an average capacity of 29.5 tonnes, then the actual available tonnage supplied to regional demand would be $100 * 29.5 * 0.8 = 2360$. The region has

effectively lost 590 tonnes (20%) of its vehicle transport capacity because of poor road infrastructure. This could indicate long queues at fuel distribution stations, long queues at customs checkpoints, or longer routes due to bridges being down. At any given time, if 20% of the region's vehicle fleet is stuck in customs as it seeks to import food, then this effectively reduces the available capacity and the road infrastructure index should be set to approximately 0.80. The road infrastructure index level value is notional and should be used to reflect improvements or problems that occur with the road infrastructure such as it affects the available transport capacity.

Any excess regional trucking capacity is offered for use by other regions that may be experiencing shortfalls. The trucking industry places a demand upon and consumes diesel. Regional production of diesel is used first and if demand is not met, the national refined products surplus of diesel, if any, is consumed. The availability of fuel affects the available trucking transport capacity. The number of liters of diesel consumed daily by each truck is a model parameter and can be set to appropriately reflect the fuel consumption in the region.

The seaports in a region are extremely important as much of the bulk cargo arriving in a country could come by sea. Conversely, the region could have no access to the sea and the seaport capacity would be zero. For a seaport, the number of functional berths, condition and presence of loading/unloading equipment, manning levels, power requirements, security, rail connections, tugboats, and basic harbor characteristics all impact the daily tonnage capacity of the seaport (UNJLC, 27 Aug 2004: 1-6).

The rail transportation capacity is determined by the number of functioning engines, the availability of rolling stock, and the number, condition, and location of the

rail lines. The total available internal transport capacity provided by rail is added to the regional total.

The capacity of airports is determined by its size, number of inbound flights, cargo terminal conditions, fuel availability, and perimeter security. Air transport typically will not be very large relative to trucking and sea transport and as such currently does not contribute a large effect to the model. However, later versions could incorporate more of the positive factors associated with air cargo, such as the quick arrival of precious or emergency cargo.

The total regional transportation capacity supplied over the capacity demanded gives the transportation demand ratio. The transportation demand ratio affects the baseline growth of availability capacity percentages (ACP) (which is subsequently discussed) representing the impact of slowed delivery of reconstruction supplies to various industries. The transportation demand ratio also directly affects the food demand ratio.

The amount of food rationing required by the population is an unchanging model parameter. (Later versions should consider making the percent of the population requiring food rationing a level value that could perhaps slowly be reduced as reconstruction progresses.) A rough estimate of the tonnes of food per person on food rationing can be determined by examination of the gross food requirement estimates made by subject matter experts. Used with the regional population, this estimate then drives the transportation demand for the delivery and distribution of food.

The model has a food delivery priority control whereby transportation capacity food demand is satisfied before any other. Use of this control ensures a priority for food

delivery. Otherwise, the food demand will be pooled with the demands of the other industries and be subjected to the general transportation demand ratio as an indicator of how much food is being delivered to the populace who needs it.

The industries and activities placing a demand on the transportation infrastructure include the movement of refined products (including imports), coalition requirements, oil and power industry, non-oil industry, and food rationing system.

The water infrastructure is represented by the total potable water accessible to the population. The water demands of population typically represent essential basic needs such as preparation of food and personable hygiene. These activities sustain life and reduce disease. The water infrastructure subsystem measures capacity in terms of liters of potable water provided daily. A per capita demand is utilized to measure the success of the water infrastructure in providing adequate resources. A typical per capita demand is 5-15 liters per day per person though the minimum amount necessary to sustain life is about 2.5 liters per day (Health Disaster Management, 2002: 80). Similar to the other demand ratios, the water demand ratio is the ratio of water supplied to water demand and is an indicator of how well the populace is doing with regard to water services.

The last infrastructure subsystem represents the regional economy. The economic subsystem contains the regional non-oil GDP level value, its only one. This regional non-oil GDP measures the strength of the non-oil economy in the region and directly impacts the power demand for the region based on the amount of GDP represented. In the model, an assumed growth rate is set by the model user. To achieve this growth rate, the average demand ratio of the five essential services must equal one.

For instance, if a regional non-oil GDP was 1000 million US\$ and the specified non-oil growth rate was 30% then the following situations might occur: should the demand ratios of the essential services indicate a healthy, smoothly running infrastructure with an average demand ratio of 0.90 then the daily equivalent non-oil GDP would be $1000 * 1.30 * 0.90 = 1170$. The 1170 equivalent then increases the non-oil GDP to 1000.5 for the day. The next day, assuming the same average demand ratio, the equation would be $1000.5 * 1.30 * 0.90 = 1170.6$, increasing the non-oil GDP to 1001.

If the average demand ratio dropped to 0.50, indicating poor realization of essential services, then the non-oil GDP would be adversely affected. Consider the following equation, $1000 * 1.30 * 0.50 = 650$. The 650 equivalent then decreases the non-oil GDP to 999.04. As mentioned previously, a society's essential services must be adequately provided to meet the economic growth expectations (UN/World Bank, 2003, vi and 59). The concept is realized through the use of the average demand ratio.

In addition to the effect that essential services have on an economy, the security of the region is of significant consequence as well (UN/World Bank, 2003, vi). It is no surprise that increased violence harms an economy, but how much damage is done to the economy? Review of the criminal activities literature revealed estimates that are used in the SROM. As introduced in Chapter II, Bejarano's implication that a natural baseline murder rate of 28 per 100,000 citizens results in a 2% decrease in GDP will be used to assess the criminal effect on the economy in a stabilization and reconstruction operational context (Bejarano, 2003: 49-50). Any civilian death rate higher than the baseline will result in a further reduction of the GDP growth rate.

Revisiting the sample non-oil GDP equations discussed above, the effect of violence is now considered. With a non-oil GDP of 1000, an assumed growth rate of 30%, and an average demand ratio of 0.90, the equation was $1000 * 1.30 * 0.90 = 1170$. Consider that due to insurgency and extensive criminal activity, the death rate in the region is 100 per 100,000 citizens. This is 3.57 times more than the baseline level of 28 per 100,000 citizens causing a loss of $3.57 * 2\% = 7.14\%$ of GDP. (This loss applies not only to the non-oil GDP but to the national level GDP as well.) The resulting effect on non-oil GDP is illustrated with the following equation: $1000 * 1.30 * 0.90 * (1 - 0.0714) = 1086.4$. Non-oil GDP still grows to 1000.2, but the growth was reduced due to violence. Of course with scenario specific data, these figures could be adjusted.

In addition to the regional non-oil GDP, the region receives the national level GDP (consisting of aid and oil money) which is then added to its own regional GDP. Before the realizing the national level GDP, the incoming GDP is subjected to the violence effect that is prevalent in that region. Once the national level GDP is appropriately reduced it is then combined with the regional non-oil GDP to give the regional GDP. In this way, regions with different levels of violence receive different disbursements of the national level GDP. Relatively quiet regions will suffer less of a loss than regions with higher violence. The higher loss reflects the problems associated with violence-afflicted reconstruction projects, collateral war damage due to insurgency, and general lack of disbursement of government monies due to ongoing hostilities and instability.

The manner in which the operational status and capacities of the numerous subsystem components are modeled is now discussed.

The operating capacity of each of the various subsystem components is modeled using two level values. The first is the available capacity percentage (ACP), a percentage value ranging between zero and one that indicates how much of the particular component's installed capacity is available at simulation time t . Using this value in conjunction with the component's capacity gives the component's current operating capacity. For instance, if a region's near term oil field extraction capacity is about 500,000 barrels per day (bbl/d) and the condition of the equipment, manning level, electrical power, industrial water availability, transportation infrastructure's effective delivery of supplies, and security is such that the ACP is 0.25, then that region's daily crude oil production would be 125,000 bbl. If at the start of a stabilization and reconstruction operation a particular region's oilfields were undamaged by conflict, sabotage, or looting its ACP would undoubtedly be high, indicating its relatively rapid capability to return to normal operating conditions.

The ACP concept is used throughout the critical infrastructure sub-model and requires a more detailed discussion. The baseline growth of an ACP represents the ability of infrastructure reconstruction elements to enact repairs given the local conditions (transportation delivery of supplies, manning levels, power availability, and so forth). A typical ACP growth rate might be $1/180$, indicating that it would take approximately 6 months (180 days) to effectively repair the infrastructure component in question, given a starting ACP of zero. If the component in question is more difficult to repair, such as a long interregional oil pipeline, than the ACP growth rate might be set to $1/730$ to indicate an approximate estimated repair time of two years. The ACP baseline growth rate is an

expectation with the model user selecting an appropriate distribution that reflects the variation expected in the daily rehabilitation progress.

It should also be noted that the ACP should be thought of as the near term reconstruction/repair capability of a particular component system. Any major refurbishing or overhauls such as the arrival of 500 megawatts (MW) worth of electrical generating capacity or the opening of a new 750,000 bbl/d oilfield should be reflected in the appropriate capacity growth rate of change.

As just noted, the capacity level values found throughout the critical infrastructure sub-model should be construed as the attainable short term goals for a particular component's reconstruction. Any major change to the component's capacity that a model user wishes to represent can be accomplished by setting the component's capacity rate of change accordingly. For example, should a region's seaport be undergoing dredging operations with an expected completion time of 18 months, then use of the seaport capacity rate of change would be appropriate. The ACP reflects a gradual, continuous growth in capacity whereas the capacity rate of change represents large discrete jumps in operating capacity. Together, the versatility of the two level values and their rates of change allow the model to represent a wide spectrum of possible scenario developments.

The insurgent attack effect affects many of the sub-model's ACP level values and represents a successful insurgent attack against infrastructure. Many of the subsystems' components are susceptible to attack. Those that can be attacked are marked with stripes in Figure 3.4.

The exact distribution of the insurgent attacks against infrastructure is expressed as a pair of branching random variables in the model (e.g. first which subsystem, then

which component). The distribution of attacks should be set to reflect the targeting strategies of the insurgents (e.g. 0.40 oil industry, 0.30 power industry, 0.20 transport, 0.10 water). Of further note, the distributions of attacks could be modified to test the different outcomes resulting from different enemy courses of action. If insurgent elements were to repeatedly attack power transmission lines, what would occur? This is the type of question that could be further explored with the model.

In addition to the distribution of insurgent attacks against infrastructure, the subsequent impact of the attacks needs to be correctly specified. Each attack causes a percentage loss in the ACP level value of a particular capacity (the exception being transport vehicles where actual vehicles are destroyed or stolen). The attack effect is a random variable with a distribution chosen that best reflects the level of damage that could be inflicted. The attack effect distribution should be chosen with the ACP growth rate and the capacity in mind. For instance, if an ACP was currently at a value of 1.00 and an insurgent attack with an effect of 0.05 occurred the ACP would be reduced to 0.95. If this ACP was operating in association with the power transmission capacity of 100 megawatts then the current operational capacity would be 95 megawatts. If three attacks had occurred, the current operational capacity would be 85 megawatts.

Additionally, if the ACP baseline growth rate expectation was 1/100, then on average it would take 15 days to bring the operational capacity back to its full potential (from 85 MW to 100 MW). If the ACP baseline growth rate expectation was 1/365, then on average it would take approximately 55 days to bring the operational capacity back up to its full potential. Thus, the attack effect for each of the components in the critical

infrastructure sub-model should be carefully considered in relation to the particular ACP growth rate and capacity.

Interregional Interactions

The last section of this chapter discusses the way in which regions interact with each other. There are seven relationships that tie regions together into a single national system. Some are of more consequence than others.

The two that are of most consequence are the dynamic movement of coalition troops and insurgents. A particular region could be progressing forward in relative stability and prosperity until the arrival of large numbers of insurgents, spilling over from a nearby region that is experiencing severe problems due to insurgency. Different insurgent movement rule sets could be investigated in an effort to understand the effects such movement has on the overall stabilization and reconstruction effort. It would be interesting to note the effects on a region if insurgent movement rates were turned off. Disallowing insurgent movement between regions might reflect successful coalition cordon operations.

Similarly, a region could be in turmoil due to insurgency until a neighboring region is subdued, allowing the release of coalition troops from that region. The coalition troops arrive in the problem region, turning the tide of the insurgency and enabling peace on the region. The movement of coalition troops intends to capture the dynamic capability of coalition forces to respond to developing conditions within the model. A stable region with a large number of troops will not stand idly by as a neighboring region descends into chaos. Given a certain scenario, the movement conditions of the coalition troops can be investigated to find improved results.

In addition to the two movement interactions, each region shares the same national level GDP. Thus, the oil produced and exported in one region has an impact on the GDP of a non-oil producing region. This assumes and reflects a near equal disbursement of revenue and associated funds. The model user could investigate the effects of uneven distribution of oil wealth. If a certain region's stability precludes disbursement of oil wealth funds, its share of the national oil GDP could be adjusted. That region would then suffer in terms of regional GDP, job creation, and GDP per capita. To the detriment of the unstable region, the other regions would benefit from the increased share of oil wealth.

Each region shares a national power infrastructure. In this way, a region that generates much more electricity than it consumes, is able to export power to other regions, assisting in the operation and growth of their economies and the provision of essential services to other regions' populations. Analogous to the share of national level GDP, a region's share of the national power plays an important role in the development of infrastructure. Electricity has a wide ranging impact on a region's stability. Assuming that there is never enough generation compared to demand, proper distribution of power is vitally important to the overall stabilization and reconstruction effort. Investigating different national power shares for the differing regions allows the model user to investigate the impact of poor/good resource allocation management. This type of study could explain the ramifications of giving a disproportionate amount of power to one region, to the detriment of another.

The oil infrastructure is modeled such that one region may transport oil from its own region to a neighboring region. This might be done for refining purposes, export

purposes, or generator fueling purposes. Thus the production and transport of oil in one region might affect the refined products output in another region. If the crude oil feedstock provided to a refinery in a stable region is cutoff due to insurgent sabotage of a pipeline in an unstable region, the stable region will suffer problems unless steps are taken to alleviate the fuel supply problem (import of fuel, more FPS, more coalition troops and indigenous security forces, increased oil transport ACP baseline growth rate).

The refined products from an oil refining region may end up being transported back to an oil producing region for consumption (should that region lack adequate refining capacity based on its requirements). Thus, both regions' refined products demand ratio may increase because of this interaction, causing an increase transportation capacity through provided diesel, an improved economy through the refined products demand ratio, and higher popular support due to the essential services demand ratio.

The last interaction is the shared excess road transportation capacity. A region with an excess of trucks can loan out its trucking fleet to assist nearby regions in meeting transportation tonnage demands. A higher transportation demand ratio facilitates full realization of ACP growth for the oil, power, and water industries as well helping the non-oil economy.

Summary

This chapter described the general stabilization and reconstruction model (SROM). General overviews, descriptions, detailed equations, and corresponding rationale was provided. The model was constructed in a hierarchical manner that allows the investigation of a many, varying nation-building paradigms. A “course of action” approach to investigation could be employed to investigate the consequences of regional

stabilization and reconstruction policies and strategies. The areas of investigation can involve: modifying indigenous security training rates, allocation of aid disbursement, coalition CIOP efforts (troop allocation) given limited manning, infrastructure development priorities given limited funds or capability, indigenous troop effectiveness given training times, criminal arrest rates, criminal release rates, power generators scheduled maintenance cycles, and so forth as required.

On a broad scale, as an exploratory effort, the probability of achieving peace and the probability of failing the stabilization and reconstruction effort (given a set of input factor levels) can be calculated. This type of macro measure can be used as a rough measure for determining the probable level of success for a nation-building effort well before such an effort is actually attempted.

A note of caution is required, however. Systems dynamics models are difficult to verify, validate, and accredit. Caution should be used when conducting an analysis with a model that has not been fully verified, validated, and accredited. That said, however, if the purpose of the analysts is insight, the SROM does give the decision maker a tool to investigate stabilization and reconstruction actions. The ultimate decision, of course, will remain with the appropriate decision maker.

Chapter IV discusses a notional test case used to illustrate the utility of the SROM.

IV. Implementation

This chapter serves to illustrate the utility of the stabilization and reconstruction model (SROM). The scope of the model prohibits the full investigation of all the potentially meaningful factors affecting the outcome of a nation-building scenario. Nonetheless, many key factors are identified and tested using the SROM. Two measures are constructed that provide the probability of stabilization success and the probability of stabilization failure, given a certain set of factors. The scenario used for the illustration of the SROM is based on Operation Iraqi Freedom (OIF).

Operation Iraqi Freedom effected the forceful removal of the Iraqi Baathist regime from power. The majority of phase III operations was considered to be complete on 1 May 2003 and thus for the purposes of the SROM, 1 May 2003 is the start date of stability and reconstruction operations (simulation start, $t = 0$). As previously mentioned, the nation-building process often overlaps the final two phases of campaign level operations resulting in the concurrent execution of both phase III and phase IV operations within the Operation Iraqi Freedom AOR. Based on the best available open source information, the model parameters are chosen to represent the state of the Iraqi AOR on 1 May 2003.

For this particular implementation of the SROM the model parameters are set to reflect the prevailing regional conditions within Iraq, to include: population, population sub-group distributions, population growth rates, regional non-oil GDP, number of police, power infrastructure capacities, oil refinery operations, training class schedules, seaport tonnage capacity, importation of refined products, water requirements, food requirements, electricity demand, and so forth. Factors of interest are investigated to

determine their relative significance to the outcome of the stabilization and reconstruction mission. Explanation and discussion of the results are provided in the following sections.

Model Implementation

General top level model features must first be considered before any specific numerical characterizations can be implemented. An extremely important facet of the SROM is the definition of the regions (in terms of their module characteristics). The geographical, political, religious, or ethnic based partitions chosen to make up a region can significantly impact the course of model development and the results. The aggregation of smaller partitions into larger regions will also make a definitive impact on the development of the larger region due to the newly prevailing characteristics. Determination of the regional characteristics must be considered carefully.

It is worthwhile to reiterate that the SROM was constructed, in part, to investigate the factors that significantly affect the successful execution of stabilization and reconstruction operations and as discussed in Chapter I, the conditions typically associated with such operations will contribute towards failure of the mission. Determination of the regional characteristics should reflect the potential or realized level of violent discord occurring within the regions of the incident nation.

Consider the notional test case for Iraq. In this implementation of the SROM there are three regions representing Iraq. The northern region represents the five northernmost governorates in Iraq: Dahuk, Erbil, Sulaymaniyah, Ninewa, and Tameem. These five regions were selected in an effort to capture the ethnic tension existing in Ninewa and Tameem between the Sunni Arabs and Kurds. The selection methodology suggested here is to include contentious provinces where two large, distinct population

sub-groups coexist. This method of selection leverages the research of Collier, Hoeffler, and Söderbom (2001) where it was found that societies with multiple, large population sub-groups were most at risk for conflict. If the northern Iraq region was chosen to contain only the Kurdish governorates Dahuk, Erbil, and Sulaymaniyah its population characteristics would reflect a near homogenous block of the ethnic Kurd population sub-group. The regional characteristics would then most likely keep the region relatively free of problems (barring significant problems in other areas and assuming the Kurds are pro-coalition), but any inter-group tension between Kurds and Sunnis in Ninewa and Tameem would not be adequately captured by the model if they were placed in a region that masks the effects. Selection of the regional characteristics must be made with the intent of capturing prevailing, relevant indigenous population inter-group dynamics. The regional breakdown for the OIF scenario is detailed in Table 4.1.

Table 4.1 OIF Scenario Regional Breakdown by Governorate

Region		
North	Center	South
Dahuk	Anbar	Basrah
Erbil	Babylon	Missan
Ninewa	Baghdad	Muthanna
Sulaymaniyah	Diyala	Najaf
Tameem	Kerbala	Qadissiya
	Salah al-Din	Thi-Qar
		Wassit

Of course, a different scenario could dictate a different grouping than the one used in this illustration.

Another topic concerns the selection of the population sub-groups. This selection depends on the driving goals of the study being accomplished. Generally, consideration should be given to population sub-groups that make up more than 5-10% of a nation's population. If a population sub-group is deemed of small consequence due to its relative

national size, or due to political factors not portrayed by the model, then those particular sub-groups are marginalized and will contribute little to the model's outcome. In the OIF scenario, there are four population sub-groups: the Shia, the Sunni, the Kurds, and others; in this illustration the smaller population sub-groups (Turkoman, Yezidi, and Assyrian/Chaldean) are aggregated due to their limited impact.

Actual determination of a region's population sub-group proportions can be problematic due to lack of data. For the OIF scenario, the regional populations were calculated by extrapolation of the 1997 Iraq Census figures (as reported by the United Nation's Humanitarian Information Centre (HIC) for Iraq; HIC Map reference 027) with an assumed annual population growth rate of 3%. Once the estimated 2003 population data was calculated, it was a simple matter of addition to determine the model's regional populations. Gross calculation of the population sub-groups proportions was then accomplished via examination of religious and ethnic thematic maps such as the ones in Figure 4.1. The resulting estimations are shown in Table 4.2.

Table 4.2 OIF Scenario Regional Population Characteristics

	Region			National Total
	North	Center	South	
Population	6,755,600	12,255,000	7,313,800	26,324,000
Population Sub-Group Proportion				
Shia	0.00	0.74	0.917	0.60
Sunni	0.645	0.24	0.073	0.19
Kurd	0.225	0.01	0.00	0.17
Other	0.13	0.01	.01	0.04

Discussion of the regional population characteristics used in the OIF implementation provides a necessary overview for better understanding of the experimental results.

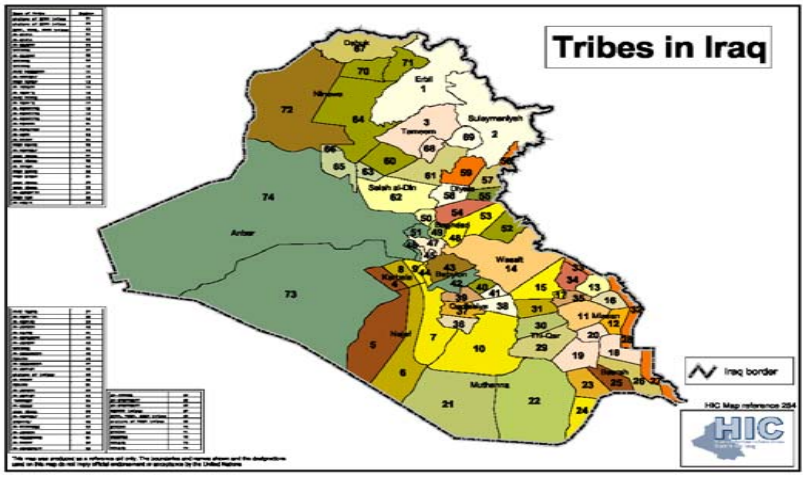
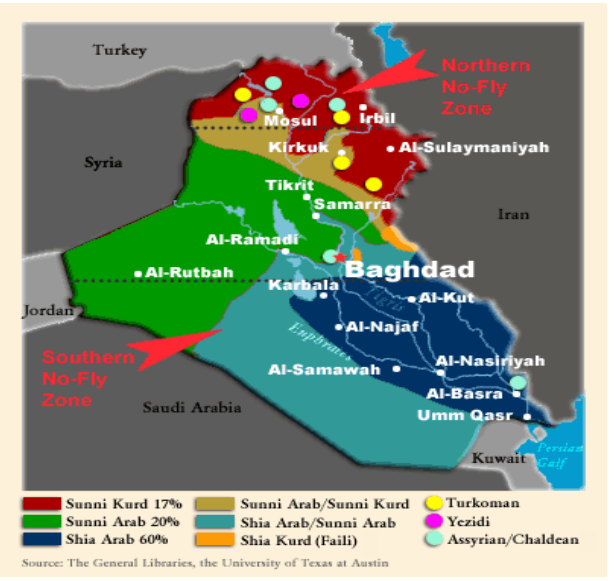
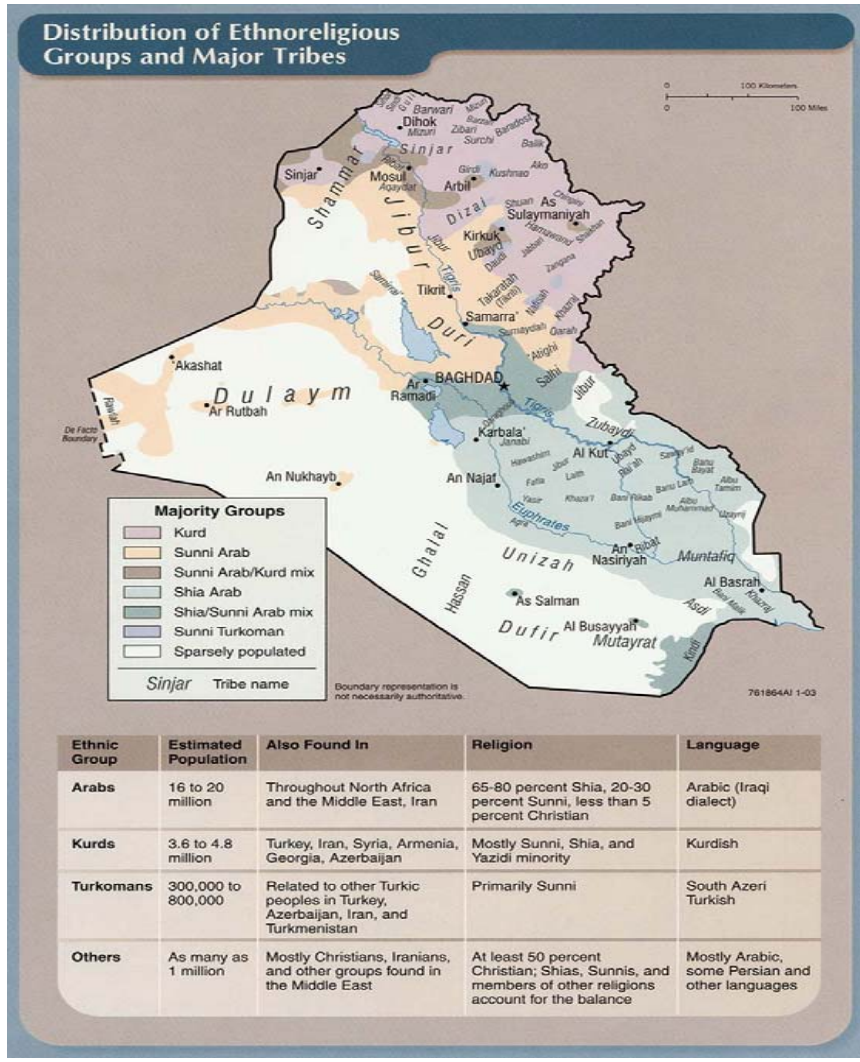


Figure 4.1 Iraqi Thematic Maps

Table 4.3 OIF Scenario Regional Infrastructure Model Parameters

Infrastructure		Region											
Oil and Gas		North				Center			South			National Total	
Oil Production (bbl)	[Capacity	1.0 mbbbl	0%	1/270		None			2.0 mbbbl	0%	1/270	N. & S.	3.0 mbbbl
Initial APC APC Growth]		Kirkuk, Bai Hassan, Jambur, Khabbaz, Ajil							Rumaila, W. Qurnah, Az Zubair, Misan/Buzurgan, Majnoon, Jabal Fauqi, Abu Ghurab, and Luhais				
Non-Associated Natural Gas Production (cubic feet)		50.0 mcf	0%	1/365	Al-Anfal	None			None				50.0 mcf
Oil Transport (bbl)		1.4 mbbbl	0%	1/270		1.4 mbbbl	0%	1/270	2.8 mbbbl	0%	1/270		
Oil Refinery (bbl)					None	410,000 bbl	50%	1/270	150,000 bbl	0%	1/270		560,000 bbl
Oil Export Terminal (bbl)					None				1.6 mbbbl	0%	1/180		1.6 mbbbl
Oil Export Pipeline (bbl)		1.4 mbbbl	0%	1/270					None				1.4 mbbbl
Notes		Crude Produced in the North flows from the Oilfields to northern crude oil power generators and then to the Refineries in the South. Remaining crude flows back from the South into the North and then to Export.				Crude Produced in the North provides fuel for crude oil power generators and crude feedstock to the Baiji and Doura Oil Refineries. Refined Products are first made available to regional demand then forwarded to national storage			The South generally operates independent of the other two regions because of the non-operational status of the Iraqi Strategic Oil Pipeline. All crude not refined or consumed as fuel for power generation is exported via the Basra and Khor al-Amaya termin				
Power													
National Power Share (percentage)		25%				40%			35%			100%	
Power Generation (MW)		2521 MW				2317 MW			1260 MW			6098 MW	
Power Transmission (MW)		3212 MW				10438 MW			3019 MW			16,669 MW	
Transportation													
Road Transport (tonnes)		2200 trucks at 29.5 tonnes each = 64900 tonnes				5000 trucks at 29.5 tonnes each = 147500 tonnes			1100 trucks at 29.5 tonnes each = 32450 tonnes			244,850 tonnes	
Sea Transport (tonnes)		None				None			19,200 tonnes 75% 1/730			19,200 tonnes	
Rail Transport (tonnes)		200 tonnes	100%	1/180		200 tonnes	100%	1/180	200 tonnes	100%	1/180		600 tonnes
		Rail is unique in that ACP must = 1 for Rail Capacity to function				Rail is unique in that ACP must = 1 for Rail Capacity to function			Rail is unique in that ACP must = 1 for Rail Capacity to function				
Air Transport (tonnes)		10 tonnes	100%	1/180		10 tonnes	100%	1/180	10 tonnes	100%	1/180		30 tonnes
Economic													
National Population Share		0.2566				0.4655			0.2778			1.00	
Regional Non-Oil GDP share of national population)	(based on	770 million US\$				1397 million US\$			770 million US\$			3000 million US\$	
Oil GDP on share of national population)	(based	3079 million US\$				5586 million US\$			770 million US\$			12000 million US\$	

A national GDP of 15000 million US\$ is assumed, of which 80% is contributed by the oil sector. (Calculated from

Besides the regional population demographics, a region's infrastructure heavily influences the successful progression towards stability. The US Energy Information Administration's (EIA) *Iraq Country Analysis Brief* (November 2004) provided general information concerning the operational capacities of the Iraqi oil and gas industry. The Iraq Electricity Sector Report (Sadiq and Al Taie, 2003) provided general information concerning the operational capacities of the Iraqi power sector. Transportation capacities for each of the regions were calculated from reports by the United Nations Joint Logistics Centre's (UNJLC) *Iraq Bulletin No. 6 of 2004*. This information is summarized in Table 4.3.

Again, due to economy of presentation, the model's hundreds of parameters are not detailed within this chapter. Each of the seven appendices (one for each of the functional sub-models and the national sub-model) lists not only a description of the general functional sub-model parameters and relationships, but also the associated values used within the OIF scenario.

Once all the model parameters are appropriately set, the identified experimental factors are tested. These factors include the level of popular support among the Shia, Sunni, and Kurds for the coalition stabilization and reconstruction effort across all regions, the initial number of coalition troops in each of the defined regions, the initial number of insurgents in each of the regions, and the rate of infrastructure development across all regions. It should be noted that the focus of this experiment was of a geophysical intent. That is, the factors were chosen to measure the importance of the allocation of resources in terms of coalition troops and reconstruction effort (infrastructure growth rate), amid differing levels of popular support for the coalition

effort (popular support and insurgent levels), given the selected regional characteristics. The coalition troop and insurgent factors are implemented within the different regions so that their importance can be measured relative to the regions in which they are realized. The specifics of the experiment are subsequently discussed.

Experiment

The experiment conducted for this study utilized a 2^{10-3} one-eighth fractional factorial design. The resolution of the design (V) allows the main effects and two factor interactions to be tested without confounding aliases with higher order interactions. A single replication of the design takes 128 runs. In addition to the 128 factorial design points, each replication contained two center runs to allow testing for the presence of curvature. Four replications were accomplished, totaling 520 observations.

The design consisted of 10 factors (Table 4.4), with combinations of each factor being tested at a Low and High level as determined by the design matrix, X .

Table 4.4 OIF Scenario Design Factors

Factor	Low	High
X1: Shia Support	0.40	0.80
X2: Sunni Support	0.10	0.40
X3: Kurd Support	0.60	0.90
X4: Troops in North	30,000	90,000
X5: Troops in Center	30,000	90,000
X6: Troops in South	30,000	90,000
X7: Insurgents in North	2,000	14,000
X8: Insurgents in Center	2,000	14,000
X9: Insurgents in South	2,000	14,000
X10: Infrastructure Growth Rate	0.75	1.25

The Iraqi population sub-group's support for coalition stabilization and reconstruction efforts was determined through the examination of various Iraqi polling studies. The polls used were those reported in the Brookings Institution Iraq Index (February 2004). Gauging the response of an indigenous people towards militarily

enforced regime change *a priori* can be problematic. The Iraqi polls were conducted after completion of offensive OIF operations, but were used as rough indicators of the sentiment of the Iraqi people towards the coalition effort (on 1 May 2003).

Examination of many of the polls reported in the Brookings Institution *Iraq Index* led to the data seen in Table 4.4. Note that Shia support is marginal to high, Sunni support is low, and Kurd support is high. These ranges are meant to characterize the different possible *initial* levels of Iraqi support for the coalition stabilization and reconstruction effort. Their relative ranges should be kept in mind as results are reported. Subsequent experiments could very easily change the factor levels to more accurately reflect the reality of Iraqi public opinion.

In each of the three regions, the initial coalition troop levels are set to 30,000 or 90,000. A major assumption that should be noted concerning troop levels is that for this experiment no reinforcements are assumed to transfer into Iraq from outside the model. Each region had to be stabilized with the forces in Iraq at the start of the model. Coalition troops were allowed to dynamically move between regions if their initial region became stable (regional death rate < 43 per 100,000 persons) with the additional constraint that only up to half of the original number of troops in the region could transfer to other regions. If each of the regions contained the highest number of troops, there would be a total 270,000 troops in Iraq. Conversely, at the low levels, there would be a total of 90,000 troops in Iraq. These levels were chosen with the real number of coalition troops in mind (typically ranging from 150,000 to 175,000 troops – Brookings Institution *Iraq Index*, 25 Feb).

Again, for each of the regions, an initial insurgent level value was set to a low and high level. The low level was 2,000 regional insurgents (6,000 nationally when all regions are set at the low value) and the high level was 14,000 regional insurgents (42,000 nationally when all regions are set at the high value). As with the coalition troop factor levels, the insurgent levels were chosen with the best real open source approximation in mind (typically 15,000 to 20,000 insurgents nationwide – Brookings Institution *Iraq Index*, 25 Feb). It should be noted that once the simulation begins insurgents have the capacity to transfer to different regions (assuming the regional death rate $> 3 \times 43 = 129$ per 100,000 persons).

The infrastructure growth rate factor modifies (multiplicatively) the rate at which regional infrastructure is reconstructed. Specifically, the factor modifies the baseline growth rate of the available capacity percentage (ACP) for every component subsystem in the oil, power, transportation, and water subsystems. Thus, at the low level of 0.75 the infrastructure ACP growth rates for all infrastructure systems (across all regions) inhibits the progress of reconstruction. At the high level of 1.25, reconstruction progresses more rapidly.

Consider the reconstruction efforts for the Basrah oil refinery, in the SROM South region of Iraq. The ACP growth rate for the southern region = $\frac{1}{270}$, indicating that from cold start-up, the refinery would take, on average, 270 days to reach full capacity (150,000 bbl/day). When the infrastructure growth rate factor is low the refinery ACP effectively becomes $\frac{1}{360}$, indicating it now takes approximately a year to reach full

capacity. At the high level, the ACP becomes $\frac{1}{216}$, indicating it now takes 216 days to reach full capacity.

The goal of the experiment is to investigate the factors that significantly affect the successful execution of stabilization and reconstruction operations (nation-building). Two experimental responses facilitate the construction of two different measures, a probability of stabilization success and a probability of stabilization failure. These two measures are constructed using logistic regression. Besides the two Bernoulli responses, the day of stabilization (or failure) and the total number of coalition casualties are recorded. The summary statistics of these two responses prove insightful as well. The experimental response measures are shown in Table 4.5.

Table 4.5 OIF Scenario Experimental Responses

Response
Y1: Stabilization
Y2: Failure
Y3: Days Until Event
Y4: Coalition Casualties

The criteria used to judge the outcome of the model results can be set as deemed appropriate by the model user. For the OIF scenario, Y_1 , the successful completion of the stabilization and reconstruction effort, occurs when the annual (unnatural, violent) death rate of each of the regions drops below 43 per 100,000 persons. This rate was selected as the terminating threshold because it is the highest state-wide (District of Columbia) murder rate in the United States (Brookings Institution, 25 Feb: 10). The failure of the stabilization and reconstruction effort, Y_2 , occurs when coalition casualties inside Iraq reach 50% of the total initial coalition troop strength. Y_3 represents the day when stabilization (Y_1) or failure (Y_2) occurs.

If stabilization or failure does not occur within an allotted 1500 days (a little over 4 years) then both Y_1 and Y_2 remain at zero. These occurrences reflect an unresolved nation-building effort that if given more time *may* have resulted in stabilization or failure occurring. However, due to practical timing considerations, a cutoff had to be established.

Before examining the results, some intuitive predictions are discussed. Each of the factors was chosen because of their perceived importance to the success of the stabilization and reconstruction effort. Undoubtedly, some will be more important than others. Interestingly, some will be more important to establishing peace, as compared to mission failure.

Shia support should be of vital consequence to the results. This is due to the fact that Shia comprise 60% of the national population. Should Shia popular support decrease too low, it is assumed it will have a negative consequence on stabilization.

Sunni support will be important as well due the factor levels being so low. The low values intend to capture the unhappiness of the Sunni population with the coalition effort. This is not surprising as the minority Sunni had held power over the other population sub-groups through a police state. The lower support values of the Sunni should prove significant to the establishment of peace.

The Kurdish support level values capture the high level of support the coalition received from the Kurds. Ongoing support will of course depend on the dynamic development of situations in the SROM. The Kurdish support factor may be of limited significance due to the relatively high levels of support. The Kurd low level (0.60) is well above the high for the Sunnis (0.40). As such, even when low, the Kurds are still

relatively pleased with the Iraqi situation. In any future experiments, were the Kurdish position reevaluated, its factor levels could be altered to investigate the consequence of alienating the Kurds.

The coalition troop levels may or may not be significant. There may be interactions between the troop levels and the insurgent levels. Obviously, more troops should increase the odds of success; by how much and in what region is unknown.

High insurgent level values should negatively affect the odd of success and positively affect the odds of failure. The more insurgents present in a region, the more casualties and damage to infrastructure they can cause.

The infrastructure growth factor should be extremely influential as well. The quicker reconstruction occurs, the quicker essential services are restored, the happier the public becomes; the quicker jobs are created, the wealthier the Iraqis become, the less people turn to crime and insurgency, the lower the death rate, and the quicker stability occurs. Conversely, slower reconstruction would decrease the odds of success and increase the odds of failure.

A last cautionary note before the discussion of the results: the experimental design matrix leads to combinations of factors that may not be realistic or plausible, but, are indeed feasible. Furthermore, the model assumptions concerning no reinforcements must also be considered when interpreting the results. (If additional troops were to be added, an experiment could be designed to test the effect.) The design matrix facilitates the statistically valid investigation of the nation-building factor space and necessarily involves the realization of these doubtful design points.

For instance, the situation whereby all factor levels are low except the insurgent factor levels amounts to an extremely unfavorable position for the coalition. The troop factor levels are such that only 90,000 troops are in country. The population sub-groups are as unhappy as possible, there are 42,000 insurgents operating in the country, and reconstruction is slow. The deployment of only 90,000 troops in the face of such negative conditions is doubtful. This recipe for disaster would typically result in failure. However, in order to better understand the nation-building factor space, the unfavorable design point just described must be examined. Investigation of the factor space (to the extent possible) provides the insights this study seeks.

Results

A logistic nonlinear regression model is used to analyze the Y_1 and Y_2 responses of the SROM. A multiple logistic regression model must be used for these responses because of their dichotomous nature. Special problems arise when a response variable is a Bernoulli (binary) variable: nonnormal error terms, nonconstant variance, and constrained responses (Neter, Kutner, Nachtsheim, Wasserman, 1996: 569-570). In such cases, a normal error regression model which assumes that the error terms are normally distributed is inappropriate. A logistic regression model is used in this study.

Consider a simple linear regression model:

$$Y_i = \beta_0 + \beta_1 X_1 + \varepsilon_i \quad \text{where } Y_i = 0, 1$$

Since $E\{\varepsilon_i\} = 0$, the following is true:

$$E\{Y_i\} = \beta_0 + \beta_1 X_1$$

With Y_i being a Bernoulli random variable the following can be stated about the probability distribution (Neter *et al*, 1996: 568):

Y_i	Probability
1	$P(Y_i = 1) = \pi_i$
0	$P(Y_i = 0) = 1 - \pi_i$

Thus, the probability that a response $Y_i = 1$ is π_i and the probability that $Y_i = 0$ is $1 - \pi_i$. By definition of a random variable expectation the following is obtained:

$$E\{Y_i\} = 1 \cdot (\pi_i) + 0 \cdot (1 - \pi_i) = \pi_i$$

Equating the above equation with the expectation of the simple linear regression model:

$$E\{Y_i\} = \beta_0 + \beta_1 X_i = \pi_i$$

Thus, the mean response $E\{Y_i\} = \beta_0 + \beta_1 X_i$ as provided by the response function is the probability that $Y_i = 1$ given the factor level is X_i (Neter *et al*, 1996: 568).

Due to the problems arising because of the binary nature of Y_i , the above model is considered unreasonable. Neter *et al* state “both theoretical and empirical considerations suggest that when the response variable is binary, the shape of the response function will frequently be curvilinear” (1996: 570). Thus, a modified response function is used to form an appropriate model, the (sigmoidal) form:

$$E\{Y\} = \frac{\exp(\beta_0 + \beta_1 X_1)}{1 + \exp(\beta_0 + \beta_1 X_1)}$$

The response function expectation can then be stated as:

$$E\{Y\} = [1 + \exp(-\beta_0 - \beta_1 X_1)]^{-1}$$

From the method of maximum likelihood, the parameters of the logistic response function can be estimated (Neter *et al*, 1996: 574). The simple logistic regression model can be stated as:

$$E\{Y_i\} = \pi_i = [1 + \exp(-\beta_0 - \beta_1 X_i)]^{-1}$$

Where Y_i are Bernoulli random variables with expected values $E\{Y_i\} = \pi_i$. In this study, the X_i levels are not constant; as such, $E\{Y_i\}$ is a conditional mean, given the values of X_i and is better stated as $E\{Y_i | X_i\}$.

The simple logistic regression model is easily extended to the multiple logistic regression model. Using the following notation:

$$\beta_{p \times 1} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_{p-1} \end{bmatrix} \quad X_{i,p \times 1} = \begin{bmatrix} 1 \\ X_{i1} \\ X_{i2} \\ \vdots \\ X_{i,p-1} \end{bmatrix}$$

the multiple logistic regression model can be stated as:

$$E\{Y_i | X_i\} = \pi_i = \left[1 + \exp(-\beta^T X_i) \right]^{-1}$$

A numerical search procedure is required to find the maximum likelihood estimates for the regression coefficients (β). The Newton-Raphson (gradient) numerical search method is used in this study. Formal chi-square goodness of fit tests are used to test the significance of the overall model and each of the individual regression coefficients.

The results of the OIF scenario are presented in Table 4.6 and Table 4.7.

General examination of the model parameter coefficients in terms of their signs and magnitudes provides some initial information. Those factors with **negative** signs **increase** the probability of a successful (failed) stabilization occurring within the first four years (the main effects that contribute to stability (failure) are bolded). The factors with low levels of significance are shaded. Effects with a p value less than 0.10 were

Table 4.6 OIF Scenario Logistic Reduced Model Fit for Y₁

Nominal Logistic Fit for Y1: Stable					
Parameter Estimates					
Term	Estimate	Std Error	p value	Lower 95%	Upper 95%
Intercept	-0.964	0.478	0.0436	-1.984	-0.097
X1: Shia Support	-3.608	0.566	<.0001	-4.871	-2.636
X2: Sunni Support	-6.427	1.071	<.0001	-8.897	-4.659
X3: Kurd Support	-1.216	0.324	0.0002	-1.918	-0.629
X4: Troops in North	-2.029	0.472	<.0001	-3.065	-1.184
X5: Troops in Center	-1.763	0.451	<.0001	-2.768	-0.970
X6: Troops in South	-0.754	0.301	0.0123	-1.400	-0.190
X7: Insurgents in North	1.994	0.495	<.0001	1.139	3.102
X8: Insurgents in Center	2.901	0.547	<.0001	1.946	4.101
X9: Insurgents in South	4.443	0.891	<.0001	2.957	6.474
X10: Infrastructure Growth Modifier	-3.818	0.608	<.0001	-5.195	-2.767
X1: Shia Support*X2: Sunni Support	-1.968	0.511	0.0001	-3.100	-1.066
X2: Sunni Support*X7: Insurgents in North	1.458	0.423	0.0006	0.698	2.368
X2: Sunni Support*X8: Insurgents in Center	1.618	0.388	<.0001	0.919	2.463
X2: Sunni Support*X9: Insurgents in South	2.792	0.575	<.0001	1.786	4.053
X2: Sunni Support*X10: Infrastructure Growth M	-2.089	0.475	<.0001	-3.117	-1.241
X3: Kurd Support*X6: Troops in South	-0.933	0.348	0.0074	-1.673	-0.299
X3: Kurd Support*X8: Insurgents in Center	0.950	0.405	0.019	0.175	1.806
X6: Troops in South*X9: Insurgents in South	0.920	0.407	0.0237	0.136	1.778

Table 4.7 OIF Scenario Logistic Reduced Model Fit for Y₂

Nominal Logistic Fit for Y2: Failed					
Parameter Estimates					
Term	Estimate	Std Error	p value	Lower 95%	Upper 95%
Intercept	3.628	0.473	<.0001	2.803	4.679
X1: Shia Support	2.699	0.357	<.0001	2.063	3.475
X2: Sunni Support	1.332	0.269	<.0001	0.849	1.920
X4: Troops in North	1.023	0.242	<.0001	0.579	1.541
X5: Troops in Center	0.367	0.198	0.0637	-0.014	0.767
X6: Troops in South	0.389	0.213	0.0676	-0.027	0.812
X7: Insurgents in North	-1.334	0.275	<.0001	-1.923	-0.837
X8: Insurgents in Center	-2.066	0.417	<.0001	-2.993	-1.331
X9: Insurgents in South	-3.647	0.449	<.0001	-4.647	-2.860
X10: Infrastructure Growth Modifier	2.302	0.313	<.0001	1.745	2.990
X1: Shia Support*X7: Insurgents in North	-0.804	0.226	0.0004	-1.280	-0.385
X1: Shia Support*X8: Insurgents in Center	-1.198	0.318	0.0002	-1.889	-0.623
X2: Sunni Support*X8: Insurgents in Center	-0.875	0.257	0.0007	-1.431	-0.409
X4: Troops in North*X9: Insurgents in South	-0.599	0.234	0.0106	-1.098	-0.166
X6: Troops in South*X9: Insurgents in South	0.620	0.221	0.005	0.201	1.072
X7: Insurgents in North*X8: Insurgents in Center	0.758	0.254	0.0028	0.294	1.301
X8: Insurgents in Center*X9: Insurgents in South	1.049	0.389	0.0071	0.355	1.916
X8: Insurgents in Center*X10: Infrastructure Growth Modifier	-0.536	0.299	0.073	-1.186	0.012

kept in the reduced model, though their impact is limited and ambiguous (shaded entries have a 95% confidence interval that includes zero). The inclusion of many significant interaction terms in the stability regression model precludes direct interpretation of individual parameter estimates. The two response functions derived from their respective logistic regression coefficients (Table 4.6 and 4.7) facilitate numerical interpretations by evaluating the functions at different factor levels (Table 4.8 and 4.9):

Table 4.8 Factor Effects on P(S|X)

P(Successful Stabilization)						
Popular Support	Decrease			Increase		
	0.10	0.05	0.01	0.01	0.05	0.10
X1: Shia Support	-0.4224	-0.2084	-0.0375	0.0346	0.1421	0.217
X2: Sunni Support	-0.689	-0.4886	-0.0932	0.0771	0.2332	0.2709
X3: Kurd Support	-0.1857	-0.0878	-0.0165	0.0159	0.0734	0.1312
Initial Troop Strength	Decrease			Increase		
	20,000	5,000	1,000	1,000	5,000	20,000
X4: Troops in North	-0.3199	-0.0724	-0.0137	0.0133	0.0623	0.1863
X5: Troops in Center	-0.2766	-0.0624	-0.0119	0.0116	0.0547	0.1708
X6: Troops in South	-0.1106	-0.0258	-0.0051	0.005	0.0244	0.0886
Initial Insurgency Strength	Decrease			Increase		
	5,000	2,000	1,000	1,000	2,000	5,000
X7: Insurgents in North	0.2086	0.1121	0.0613	-0.0711	-0.1497	-0.3916
X8: Insurgents in Center	0.2432	0.1494	0.0857	-0.1061	-0.2247	-0.5344
X9: Insurgents in South	0.2668	0.1963	0.1222	-0.1683	-0.3503	-0.6631
Infrastructure Growth	Decrease			Increase		
	0.10	0.05	0.01	0.01	0.05	0.10
X10: Infrastructure Growth Modifier	-0.3611	-0.174	-0.0315	0.0295	0.1252	0.1996

$P(S | \mathbf{X})$ is the probability of successfully stabilizing all regions in the Iraqi AOR within the first 1500 days (approximately four years). $P(F | \mathbf{X})$ is the probability of failure in the stabilization and reconstruction effort such that coalition forces sustain 50% casualties within the first 1500 days (it is assumed that coalition forces would then withdraw).

Table 4.9 Factor Effects on P(F|X)

P(Stabilization Failure)						
Popular Support	Decrease			Increase		
	0.10	0.05	0.01	0.01	0.05	0.10
X1: Shia Support	0.067	0.0237	0.0036	-0.0032	-0.0125	-0.019
X2: Sunni Support	0.0348	0.0139	0.0023	-0.0021	-0.0091	-0.0151
X3: Kurd Support	0	0	0	0	0	0
Initial Troop Strength	Decrease			Increase		
	20,000	5,000	1,000	1,000	5,000	20,000
X4: Troops in North	0.024	0.0047	0.0009	-0.0008	-0.004	-0.0126
X5: Troops in Center	0.0069	0.0016	0.0003	-0.0003	-0.0015	-0.0055
X6: Troops in South	0.0074	0.0017	0.0003	-0.0003	-0.0016	-0.0058
Initial Insurgency Strength	Decrease			Increase		
	5,000	2,000	1,000	1,000	2,000	5,000
X7: Insurgents in North	-0.0172	-0.0091	-0.005	0.0062	0.0139	0.0488
X8: Insurgents in Center	-0.0211	-0.0127	-0.0074	0.0102	0.0243	0.1034
X9: Insurgents in South	-0.0246	-0.0181	-0.0116	0.0206	0.0563	0.3309
Infrastructure Growth	Decrease			Increase		
	0.10	0.05	0.01	0.01	0.05	0.10
X10: Infrastructure Growth Modifier	0.0367	0.0145	0.0024	-0.0022	-0.0094	-0.0154

Both of the tables (Tables 4.8 and 4.9) were generated using their respective logistic regression response functions. Each entry was generated by stepping the indicated factor level (by the indicated amount and direction) away from the baseline center of the factor space (Table 4.10).

Table 4.10 OIF Scenario Baseline Factor Space Center

Factor	Center
X1: Shia Support	0.60
X2: Sunni Support	0.25
X3: Kurd Support	0.75
X4: Troops in North	60,000
X5: Troops in Center	60,000
X6: Troops in South	60,000
X7: Insurgents in North	8,000
X8: Insurgents in Center	8,000
X9: Insurgents in South	8,000
X10: Infrastructure Growth Rate	1

At the baseline, $P(S|X) = 0.724$ and $P(F|X) = 0.026$. Thus, given the factor levels indicated in Table 4.10, the coalition has a 72.4% chance of achieving stability within the first 1500 days and conversely has a 2.6% chance of failure. Generation of the entries for

Tables 4.8 and 4.9 assumes all other levels remain at their center levels, with the table entries indicating the deviations from their respective baseline probabilities, $P(S|X) = 0.724$ and $P(F|X) = 0.026$.

Examination of specific factor conditions could easily be accomplished by evaluating the proper logistic regression response function at the factor levels of interest. The reader should also realize that the characteristics of the response surface could very easily change as different combinations of factor levels are investigated. Of further interest, it should also be noted that factor effects are non-linear. For instance, an increase of 5,000 troops in the North increases $P(S|X)$ by 0.062 whereas 20,000 additional troops increases $P(S|X)$ by 0.186.

Examination of the results reinforces intuitive generalizations. Increasing popular support for the coalition, increasing the initial number of troops in a region, and increasing the infrastructure growth modifier all increase the probability of successfully completing the stabilization and reconstruction mission. Not surprisingly, increasing the initial number of insurgents within the regions decreases the probability of success. Conversely, decreasing popular support for the coalition, decreasing the initial number of troops in a region, decreasing the infrastructure growth modifier, and increasing the initial number of insurgents within the regions all increase the probability of failing the stabilization and reconstruction mission.

The degree to which the factors affect the two opposing measures provides the interesting insight. The level of Shia popular support and Sunni popular support substantially impact the probability of success. Increasing Shia popular support by 0.10 increases $P(S|X)$ by 0.217 while increasing Sunni support by the same increases $P(S|X)$

by 0.2709. Conversely, decreasing Shia popular support by 0.10 decreases $P(S|X)$ by 0.4224 while decreasing Sunni support by the same decreases $P(S|X)$ by 0.689. It is clear that keeping the majority population sub-group happy increases the chance for success. Alternately, attempting to gain the support of the most troublesome population sub-group pays dividends as well. Indeed, it is interesting to note that Sunni support is more important in attempting to successfully stabilize Iraq, whereas in regard to failing, it is important to have the support of the majority Shia; definitely an intuitive yet discerning result.

The support of the Kurds while important is not as substantial as the other population sub-groups. It is important to remember however that the Kurds support was ranged between 0.60 and 0.90. (Any presumed drop below 0.60 would be cause for concern as such an occurrence was not modeled.) Analyzing aspects of popular support emphasizes the importance of focused resource allocation strategies. For example, the reduction of Kurdish support from 0.75 to 0.65 is not nearly as significant as the reduction of Sunni support from 0.25 to 0.15 (-0.186 versus -0.689). Additionally, the level of Kurdish support has negligible effect on the probability of failure. The implication here is that the North will not be the key region that determines whether or not the overall stabilization and reconstruction mission fails. General priorities could be developed from similar SROM enabling analysis.

Initial regional troop strength has more of an impact in the North and Center regions. The specifics of why this is true remain uncertain; though the fact that the troublesome Sunni are concentrated mostly in the Center and North is a likely root cause. It is also seen that regardless of region, the absence of troops has a more substantial

impact than the presence of troops (for the North, -0.320 versus 0.186) emphasizing the utility and importance of having the right number of troops. Given troop manning limitations, finding a general estimate of a troop threshold where diminishing returns begin would be helpful; knowing that the addition of another 20,000 soldiers in a region is not likely to increase the probability of success (due to a variety of causes) assists planning staffs with order of battle and deployment considerations.

The number of initial insurgents has more of an impact in the South. This may speak to slower training rates or a more fragile infrastructure. But more likely it speaks to the lack of a large Sunni insurgent recruiting pool in the South. Barring an initial lack of Shia popular support (which would create an insurgent recruiting pool) a successful insurgency would require an initial cadre to cause problems and create the chaos that would then enable an insurgency to take root. Thus, the number of initial insurgents in the South is more significant than in the other regions, suggesting the South is the key region in Iraq. These results suggest that any insurgency in the South should be given consideration for operational priority. *A priori* identification of the critical region(s) gives commanders and staffs more information on which to base troop manning priorities.

The infrastructure growth modifier also substantially impacts the probability of success and the probability of failure. The significance and magnitude of the infrastructure growth modifier coefficient suggests it has the third highest impact on stabilization success, behind Sunni support and insurgents in the South. With respect to stabilization failure, again it is third, behind insurgents in the South and Shia support. The significance of this factor denotes the importance of early and rapid integration of

phase IV with phase III operations. Phase IV planning should not be neglected; proper integration saves time and lives; poor integration costs time and lives and potentially lead to mission failure.

Given the scope of the model, not all variables have been analyzed in this illustration. Further studies would do well to include the national power share percentage for each region, the amount of national aid disbursed to the country, indigenous troop training rates for each region, indigenous troop effectiveness levels, dynamic reinforcement of coalition troops, and an extended time window (>1500). Each of these factors should be of significance to the outcome of stabilization success or failure.

Simple summary statistics from the experiment are provided for further perspective. During model execution, the event day in which stabilization or failure occurred was recorded (Y_3). The two histograms (Figures 4.2 and 4.3) show the results.

Of the 520 experimental observations, 215 resulted in stabilization success. The average number of days required to achieve stabilization success was 697. Of the 215 successes, 75% occurred after 500 days. (Note: the large number of observations at 100 is due to a minimum days in country constraint; no success was allowed before 100 days.) Of the 520 experimental observations, failure occurred 159 times; the average number of days until failure was 340. Approximately 90% of the failures occurred before 400 days.

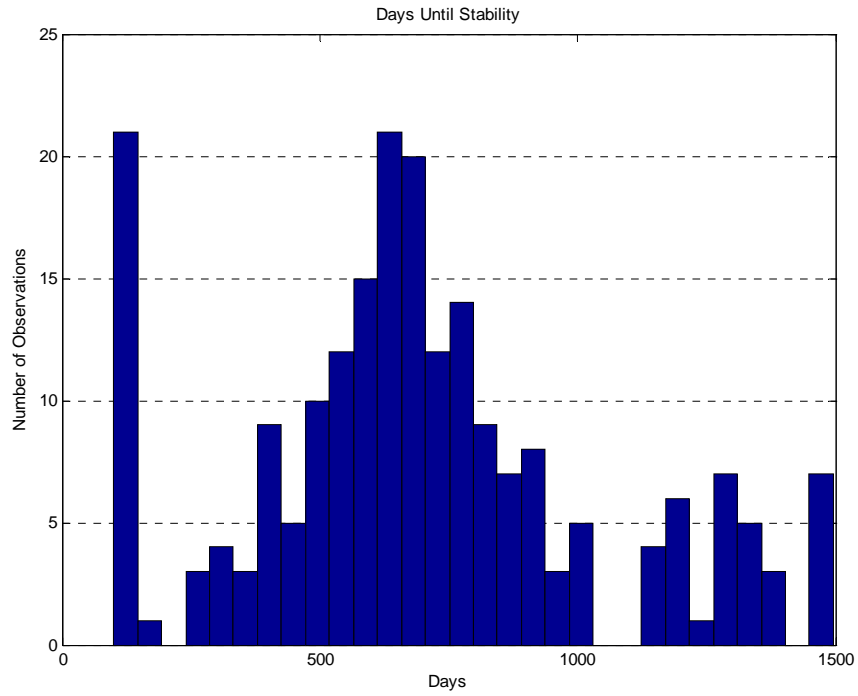


Figure 4.2 OIF Scenario Days Until Stability Histogram

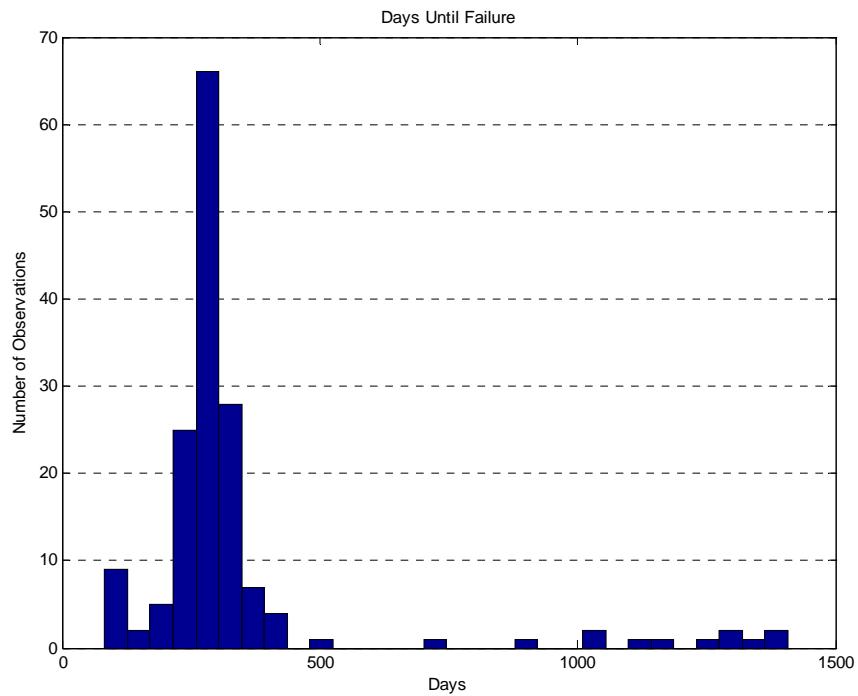


Figure 4.3 OIF Scenario Days Until Failure Histogram

The summary statistics suggest that the danger period for failure is within the first 400 days, which bodes well for the current coalition effort in Iraq. It should be noted that of the 520 observations, 146 resulted in a non-decision. Stability was not achieved within 1500 days, but neither did coalition forces suffer the heavy casualties that would lead to the conjectured total withdrawal of forces. If given more time these no-win, no-loss observations may have ended well for the coalition. Examination of the casualty counts associated with those design runs would give some indication as to the level of success the ongoing operations is attaining. In future studies, given more time, the model could run for as many days as necessary. Model growth parameters would have to be appropriately modified to reflect the longer run time, but running the SROM out to 7 or even 10 years is a viable option.

As implied above, the fact that most stabilization failures occurred before 400 days bodes well for the ongoing coalition effort in Iraq. In an effort to match a scenario design run with the current real situation, the experimental data was searched. Data points with similar casualty counts (Y_4) were found; one was selected, with two of the resulting graphs of the model level values shown as illustration for the reader. It should be noted that these results are based on ongoing operations. It is possible a turning point event (e.g. a Tet offensive) has not yet occurred. The current data used would not capture such a turning point event.

For the particular design parameters selected, the coalition achieves stability in 833 days, suffering 14,283 casualties. The southern region started off in the best shape before suffering a setback around day 300. A heavier rate of violence then afflicted the region before it was brought under control again by day 450. The northern region was

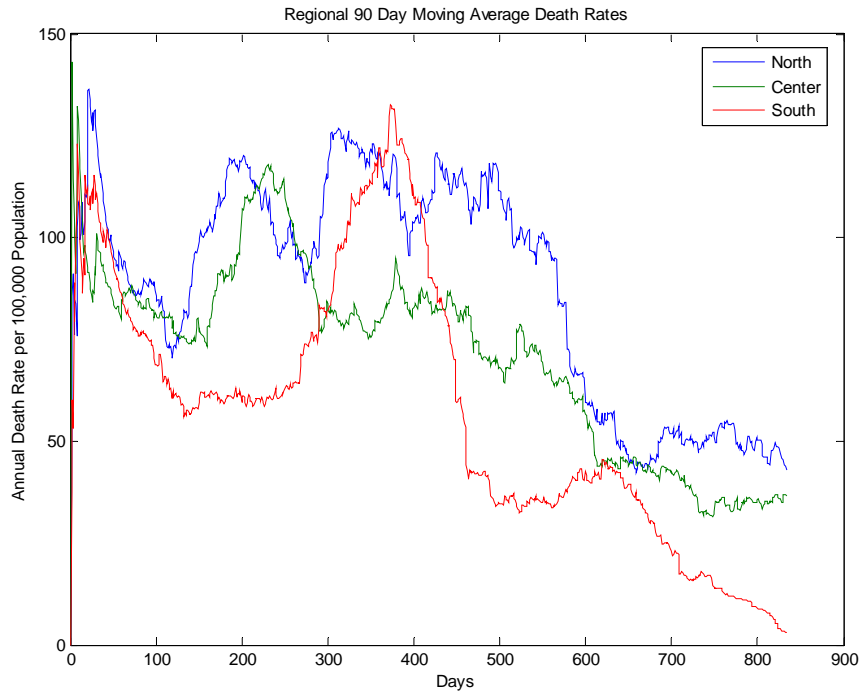


Figure 4.4 OIF Scenario Regional Death Rates

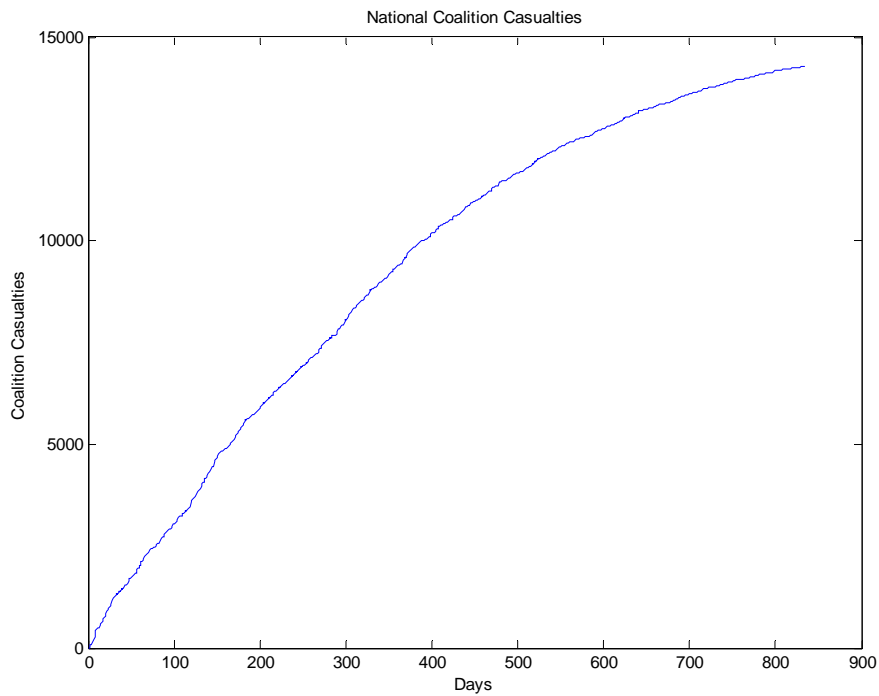


Figure 4.5 OIF Scenario Total Coalition Casualties

the most problematic in this run, remaining the most violent region for nearly the entire time. The central region, while appearing relatively less violent caused the same number of coalition casualties as in the north, due to its larger population. Analysis of other design points can be conducted.

Summary

This chapter served to illustrate the utility of the stabilization and reconstruction model (SROM). A notional Operation Iraqi Freedom scenario provided the backdrop for the illustration of the model's uses. A number of important factors were identified and tested. Two measures were constructed that give the model user an indication of the probability of stabilization success or failure. These measures were then used to investigate the complex interactions occurring in the model. Of course while they do offer insights, due to the limitation of open source data, these results should not be directly compared to current operations. The notional scenario was used only to illustrate the utility of the SROM, not provide actual analysis of current operations.

The insights resulting from such SROM scenarios could be used to investigate different friendly and enemy courses of action. The model can provide general solutions to questions plaguing commanders and support staffs. In particular, resource allocation strategies involving the prioritization of one region or population sub-group over another. In the OIF scenario there were only three major population sub-groups. If there had been fourteen sub-groups, it would have been interesting to see which held the most significance in determining success and/or failure and then take the appropriate actions. It should also be noted, that if a particular scenario has data that refines or alters the

relationships in the model, the relationships can be easily modified to best represent the reality of the situation.

While the SROM is good step forward in providing decision-makers a tool for investigating the complexities of nation-building, there remain many facets that require addressing. Chapter V discusses many of the recognized areas for further study.

V. Conclusions

The stabilization and reconstruction operations model (SROM) proposed in this study allows the user to more precisely investigate the multi-faceted process that is nation-building. The complexities of nation-building involve many different but interrelated systems and institutions. Understanding the significance of the dynamic relationships between these systems and institutions is paramount to the successful conclusion of stabilization and reconstruction missions. The system dynamics model proposed in this research allows decision-makers and analysts to investigate different sets of decision approaches at a sub-national, regional level.

The utility of the SROM encompasses:

- Identification of critical regions before boots hit the ground (insurgent effectiveness); this allows commanders and staffs to more efficiently allocate troop strengths for phase IV operations. Knowing which region is most susceptible to insurgency allows for a more effective prioritization. Important questions can be addressed: should more troops be moved to the north or to the south? Where would the additional troops be most effective?
- Identification of popular support thresholds; this allows commanders and staffs to assess the consequences of alienating or pandering to different population sub-groups. Knowing which sub-group's support contributes most towards stability (or failure) allows establishment of a more effective resource allocation policy. Where should the new water plant, hospital, school, power generator, and so forth be built?

- Investigation of indigenous security forces application; determining the rapidity of training, recruiting numbers, duty effectiveness, and stationing locations of indigenous security forces facilitates the development of a more measured and reasoned counter insurgency policy.
- Investigation of reconstruction alacrity; this could involve investigating which region has priority (relating to identification of critical regions) or given limited resources, determining which infrastructure system should be given priority. Assessing the effects of establishing power a full six months earlier is one application in this area. Another could involve the opening of a seaport three months ahead of schedule. Conversely, assessing the negative effects of failing to rehabilitate oil refineries would be of valuable information. Other problem areas that could require investigation: failure of food imports arrive, a neighboring country closes its border, determining which regional distribution of the national power supply. The relative importance of the affected population sub-groups should be considered as well (critical regions).

As seen, the SROM is a multi-faceted tool that permits the modeling and investigation of the many differing complex systems existing within the nation-building paradigm. However, there are many areas requiring further research. The SROM does not account for all of the important national systems. Many of the areas requiring consideration have been identified for further study. Not surprisingly, these are the same areas repeatedly mentioned in the post-conflict reconstruction literature. The *Post Conflict Reconstruction Task Framework* gives a general description and rationale for

many of the required additional areas (2002); the four areas parallel the four overarching “pillars” described in Chapter I: security, law and order, critical infrastructure, and governance.

Within a security context, there are various additions that could be made to the SROM. This includes modeling an indigenous commando force, a special forces group that moves dynamically between regions. Tracking paramilitary foreign security personnel as a level value would also be of benefit. Tying the recruitment rate of each of the indigenous security institutions to popular support and perhaps GDP per capita should be investigated. If the population no longer supports coalition efforts, recruiting the required number of security personnel would be problematic. Attrition rates should become more dynamic. The expectations driving the attrition rates should be influenced by popular support and casualty rates. Additionally, indigenous troop effectiveness should be dynamic. As indigenous troops become more experienced, receive better equipment, or are provided better training, their effectiveness should be affected.

In a law and order context, a more detailed review of the judicial process could be accomplished. This would allow more accurate modeling of conviction rates and criminal justice processing procedures. Not having the proper number of judges or prison facilities could adversely affect the rule of law in a region. This would allow the development of a criminal culture which should then be reflected with a higher number of criminals.

Critical infrastructure has many areas for expansion and improvement. Of potentially significant concern, and not addressed in the SROM, is the presence of internally displaced persons (IDP). Refugees are a burden on a society, especially one

emerging from a failed or pariah state status. At the least, IDPs place a demand on resources, in terms of food, water, medicine, and other aid. At worst, IDPs could be exploited for insurgent recruiting purposes.

Food security is very important. This version of the SROM assumes if the transportation capacity allows delivery, then food is delivered. Future versions should consider directly modeling food storage bins, having population demand decrease food supplies as the agriculture sector and food imports increase supplies.

Public health should be modeled as well. This would include modeling the numbers and effectiveness of hospitals in a region. The presence of hospitals would have a positive impact on popular support while also decreasing population death rates.

Public housing may be a concern in a scenario AOR. If the population does not have enough shelter, public health may fall, crime may rise, and popular support may falter as well. Before people worry about jobs, they worry about a place to house their families.

Public education should also be addressed. Conflict studies have found a relationship between the number of students enrolled in higher education and GDP per capita (Collier, 2000 and Collier and Hoeffler, 2001). The implication is that increasing the number of enrolled students will assist in enriching a society's economy. Higher numbers of enrolled students removes individuals from the labor force (unemployed level value), more accurately representing the population's occupation status. As for youth education, increasing the number of grade schools should positively impact popular support.

Modeling a region's economy can be difficult. Future versions of the SROM could focus on a more accurate depiction of a country's economic workings. Partitioning a country's GDP into basic categories and then dynamically attaching these GDP sectors to a region's electricity, industrial water, oil, refined products, and transportation infrastructure would be a significant step forward. The GDP sectors would also directly impact job creation and the provision of certain services. For instance, meeting public housing demand requires the proper functioning of construction sector. This construction sector would hire workers to meet demand but may be limited by the operational capacity of the transportation sector to provide raw materials. The agricultural sector should be significant as well; progress in this sector not only provides new jobs but helps the society meet its own food requirements. However, economic effects on local agriculture must be carefully judged. Well intentioned food aid can have the unintended effect of driving out local agricultural production. Telecommunications should certainly be included in future versions of the SROM. A final thought would be to perhaps include black market activities. The development of an illegal drug trade may be of particular relevance to certain nation-building scenarios.

The impact of non-governmental organizations (NGO) should be considered as well. Given a certain tolerable level of violence (and political factors exogenous to the model) NGOs may contribute to the coalition stabilization and reconstruction effort. This contribution may come in the form of food distribution, medicine and health aid, water distribution, and other areas of infrastructure growth.

In a governance and participation context, further research should be done to examine indigenous popular support. Currently, the homicide rate, unemployment, GDP

per capita, and essential services (electricity, water, food, refined products) all affect a population's support for the coalition stabilization and reconstruction effort. Public health, housing, and education could be included as well. The weightings given to each area requires further research. Additionally, the impact of elections could be modeled as a discrete jump in popular support (subject to necessary security conditions). Other important transitional or milestone events could be modeled as popular support modifications. These discrete events that can have a profound impact on scenario progression lead to a discussion on perturbations.

Many of the random variable distributions used in the OIF scenario utilized an exponential distribution in an attempt to capture the characteristics of a perturbation. It is quite feasible for the model user to manually shut down an infrastructure component subsystem (e.g. power generation) in a region and examine the fallout such an action would cause. Such an endeavor might be useful in examining the cascading effects such perturbations may cause to the collective national infrastructure system (periodic power outage is a current problem). Such specific catastrophic events can naturally occur in the SROM. The sequence of events causing such a perturbation would be the occurrence of a large of number of attacks coupled with a high damage amount per attack. This would cause an available capacity percentage (ACP) to drop to zero. The SROM models perturbations in this manner. Future versions could easily provide further perturbation utility by inserting additional random variables that can dynamically model the total collapse of key nodes within a critical infrastructure.

Each of these enhancements might be considered. Inputs from the appropriate authorities as to which are most critical at the time should assist in the solution of

options. The SROM allows a wide array of scenarios and analysis to be conducted. The current version can be fitted to a number of situations. Future versions can extend the current version in order to more accurately represent the daily functioning of stabilization and reconstruction operations within a country.

The SROM attempts to accurately represent a complex system of systems which when taken in the aggregate, portrays the daily functioning of newly nascent nation. The sub-national regional approach to modeling the nation-building phenomenon provides analysts a tool for clearer examination and understanding of the dynamic forces involved in stabilization and reconstruction. Such awareness then provides the basis for coalition actions that lead to increased probability of success. The overarching drive is to attain mission success while minimizing the cost in lives, resources, and time.

Appendix A. Directions for Appendices

These appendices describe the Operation Iraqi Freedom (OIF) scenario application of the stabilization and reconstruction operations model (SRROM). The appendices serve as a guide for any reader wishing to navigate the OIF SRROM discussed in Chapter IV.

The OIF SRROM was created with the use of MATLAB's Simulink software package. Thousands of blocks were required for proper construction of the relationships in the SRROM. These blocks are organized into subsystems, sub-models, and sub-modules. For new users to the software, specific directions are needed. (See <http://www.mathworks.com/support/>)

It is assumed that MATLAB and the associated Simulink toolbox have been installed on the user's computer. After opening the MATLAB software, *simulink* should be typed at the MATLAB command prompt; the Simulink library browser window will open. The user should then use the File menu to Open the OIF SRROM .mdl file.

Opening the OIF SRROM reveals three regional sub-modules and the national level sub-model. The regional sub-modules are organized as discussed in Chapter III. Within the individual sub-models and subsystems, the blocks are color coded to give the user immediate information about the blocks' function. Green indicates the block represents a level value. Yellow indicates the block is a display scope that when opened, displays the value of the attached signal over time. Red indicates a rate of change, e.g. the signal modifies or changes the value of a green block. Magenta indicates the attached signal is a function of a level value. Finally, light blue indicates a model parameter, changeable by the model user.

The light blue blocks are most numerous and show the user the manner in which the different model parameters impact the signals (level values or rates of change) attached to them. Double-clicking on any of the light blue blocks opens a menu with an associated model parameter. The parameters in the OIF SROM are listed by sub-model in the subsequent appendices. The associated values are loaded into the model at the start of a simulation run. Where applicable, the parameters in the following appendices are described, as are sources for the values used.

Regarding Simulink, it should be noted that the user can right-click on any of the blocks and select help; a detailed explanation of that block is then provided.

Appendix B. National Sub-Model

```
% Model Wide Parameters
national_population = 26.324e6; % from UN/World Bank Joint Iraqi Needs
    Assessment p59
nat_pop_dist = [0.6 0.19 0.17 0.04]'; % national population
    distribution - multiple sources - not exact
ELF_national = 1-3.5*((1-sum(nat_pop_dist.^2))-0.5).^2; % modified
    national ethno-linguistic fractionalization score, Collier et al
K = 1; % polarization constant = 1 -> magnifies polarization
Polarization_nat_setup = (K*(sum(nat_pop_dist.^(2.6)*nat_pop_dist',2)-
    diag(nat_pop_dist.^(2.6)*nat_pop_dist')));
Polarization_nat = 1-Polarization_nat_setup./
    sum(Polarization_nat_setup); % proportion of polarization held by
    each population sub-grouping
urban_effect_constant = 0.8; % Threshold where urbanization negatively
    effects crime and insurgent recruiting -> from Niskanen
national_labor_force_percent = 0.3074; % from UN/World Bank Joint Iraqi
    Needs Assessment
population_entering_workforce_annually = 0.012*0.5; % percent of
    population joining unemployed from nonlabor population -> from
    CIA World Factbook: Iraq, adjusted (by 0.5) for an assumed rate
    of retirement
population_death_rate = 5.66/1015; % percent of population leaving
    model from general population - from CIA World Factbook: Iraq
population_birth_rate = 33.09/1015; % percent of population entering
    model to general population - from CIA World Factbook: Iraq

init_national_refined_products_daily_populace_demand = [3e6 15e6 18e6 0
    4e3 0]'; % assumed approx 15e6 diesel consumed by trucking
    industry
liters_per_bbl = 158.984;
tons_per_bbl = 0.136; % this is actually tonnes per bbl
cf_per_bbl = 5658.53;
tonnes_per_liter = tons_per_bbl/liters_per_bbl;
diesel_seasonal_demand_modifier = [1 1 1 1]';
kerosene_seasonal_demand_modifier = [0.51 0.67 1.2 0.67]';
gasoline_seasonal_demand_modifier = [1.1 1 0.9 1]'; % gasoline demand
    spikes somewhat in the summer and drops in winter -> notional
fueloil_seasonal_demand_modifier = [1 1 1 1]';
LPG_seasonal_demand_modifier = [1 1 1 1]';
NaturalGas_seasonal_demand_modifier = [1 1 1 1]';
seasonal_demand_modifier_times = [50 141 233 324].';
    % assumes model begins on May 1, thus 50 days after sim begins,
    summer starts during summer, kerosene demand drops 49% to 7.7 ML
    and goes on to spike in the winter with an increase of 20% over
    average (15ML) to 18 ML -> from DoD working papers brief 23Feb04
inf_baseline = Factor(10); % infrastructure baseline modifier

% National Level Submodel
national_init_refined_storage = 5*[18e6 15e6 18e6 10e3 4e3 eps]'; % eps
    is a very small number, very close to zero
national_refined_storage_capacity = 30*[18e6 15e6 18e6 10e3 4e3 eps]';
    % total of 30 days of stock available for storage
national_initial_oil_GDP = 12000e6; % in US$
```

```
price_per_bbl_oil = 32; % $/bbl - assumed constant throughout
simulation run
national_initial_aid_GDP = 0; % in millions of US$ -> aid increases
determined from IMF Iraq Country report (2004)
national_aid_GDP_increases = [2000 0 2200 1200];
national_aid_GDP_increase_times = [30 365 730 1095];
national_aid_GDP_decreases = [1200];
national_aid_GDP_decrease_times = [1460];
```

Appendix C. Indigenous Security Institution (ISI) Sub-Model

```
input.ISI.CD.training_attrition_rate_parameter = [.00 .25 .5];  
    % between 0 and 50% (mode of 25%) of class will not complete  
    training  
input.ISI.CD.training_class_length = 21; % days required to complete  
    training  
input.ISI.CD.training_class_downtime_between_classes = 7; % days  
    required for school/cadre to reconstitute  
input.ISI.CD.max_training_classes = 1; % maximum number of concurrent  
    training classes allowed in this region  
input.ISI.CD.init_training = 0; % initial people in training  
input.ISI.CD.init_CD = 0; % initial active duty civil defense  
input.ISI.CD.attrition_rate_parameter = [.00 .10 .20]/365; % Cordesman,  
    US Policy in Iraq p17 - active duty attrition  
input.ISI.CD.init_awaiting_training = 0; % initial recruits awaiting  
    training  
input.ISI.CD.training_class_size = 1000; % class size  
input.ISI.CD.recruit_rate_parameter = [0 50 100]; % number of  
    unemployed recruited per day  
input.ISI.CD.goal = 61904*input.national_manning_percentage; % regional  
    goal - based on region's share of national population  
    % manning goal numbers come from Brookings Institution Iraq Index  
    % class sizes and training cycles are set to match reported  
    manning levels for the Iraqi security organizations  
  
input.ISI.IM.training_attrition_rate_parameter = [.00 .25 .5];  
input.ISI.IM.training_class_length = 60;  
input.ISI.IM.training_class_downtime_between_classes = 30;  
input.ISI.IM.max_training_classes = 1;  
input.ISI.IM.init_training = 0;  
input.ISI.IM.init_IM = 0;  
input.ISI.IM.attrition_rate_parameter = [.00 .10 .20]/365;  
input.ISI.IM.init_awaiting_training = 0;  
input.ISI.IM.training_class_size = 1000;  
input.ISI.IM.recruit_rate_parameter = [0 50 100];  
input.ISI.IM.goal = 36462*input.national_manning_percentage;  
  
input.ISI.BP.training_attrition_rate_parameter = [.00 .25 .5];  
input.ISI.BP.training_class_length = 60;  
input.ISI.BP.training_class_downtime_between_classes = 7;  
input.ISI.BP.max_training_classes = 2;  
input.ISI.BP.init_training = 0;  
input.ISI.BP.init_BP = 0;  
input.ISI.BP.attrition_rate_parameter = [.00 .10 .20]/365;  
input.ISI.BP.init_awaiting_training = 0;  
input.ISI.BP.training_class_size = 1000;  
input.ISI.BP.recruit_rate_parameter = [0 50 150];  
input.ISI.BP.goal = 29360*input.national_manning_percentage;  
  
input.ISI.FPS.training_attrition_rate_parameter = [.00 .25 .5];  
input.ISI.FPS.training_class_length = 3;  
input.ISI.FPS.training_class_downtime_between_classes = 7;  
input.ISI.FPS.max_training_classes = 3;  
input.ISI.FPS.init_training = 0;  
input.ISI.FPS.init_FPS = 0;
```

```
input.ISI.FPS.attrition_rate_parameter = [.00 .10 .20]/365;  
input.ISI.FPS.init_awaiting_training = 0;  
input.ISI.FPS.training_class_size = 500;  
input.ISI.FPS.recruit_rate_parameter = [0 250 500];  
input.ISI.FPS.goal = 73992*input.national_manning_percentage;
```

Appendix D. Law Enforcement (LE) Sub-Model

```
% Police Subsystem
% similar to indigenous security institutions in appendix C
input.LE.Pol.training_attrition_rate_parameter = [.00 .25 .5];
input.LE.Pol.training_class_length = 60;
input.LE.Pol.training_class_downtime_between_classes = 7;
input.LE.Pol.max_training_classes = 2;
input.LE.Pol.init_training = 0;
input.LE.Pol.init_Pol = 5000;
input.LE.Pol.attrition_rate_parameter = [.00 .05 .10]/365;
input.LE.Pol.init_awaiting_training = 0;
input.LE.Pol.training_class_size = 1500;
input.LE.Pol.recruit_rate_parameter = [0 225 450];
input.LE.Pol.goal = 142190*input.national_manning_percentage;

% Crime Subsystem
input.LE.crime.initial_criminals = 48.5e3; % set to reflect a natural
      crime rate of 10768 crimes per 100,000 annually, from Niskanen
input.LE.crime.initial_incarcerated_criminals = 0;
input.LE.crime.Pol_effectiveness = 1; % indigenous police effectiveness
      against crime
input.LE.crime.CD_effectiveness = 0.9; % civil defense effectiveness
      against crime
input.LE.crime.CTroop_policing = 0.1; % percentage of coalition troops
      policing
input.LE.crime.CTroop_effectiveness = 1; % coalition troop
      effectiveness against crime
input.LE.crime.crimes_per_criminal_per_year = 15; % from Levitt 1995
input.LE.crime.criminals_per_100k =
      (2453+8315)/input.LE.crime.crimes_per_criminal_per_year; % from
      Niskanen
input.LE.crime.required_police_per_100k = 560; % from Niskanen Table 2
      (double average)
input.LE.crime.police_demand_ratio =
      input.LE.crime.required_police_per_100k/input.LE.crime.criminals_
      per_100k; % number of police required to arrest one criminal
input.LE.crime.daily_arrest_rate = 0.1846/365; %from Levitt 1995 table1
input.LE.crime.daily_deterrence_rate = 0.2327/365; % from Levitt 1995
      table 1
input.LE.crime.deterrence_ratio = 1.2606; % from Levitt 1995, for every
      1 criminal apprehended, 1.26 criminals are deterred and return to
      unemployment status
input.LE.crime.urban_effect = (1+0.9*(input.demo.percent_urban-
      urban_effect_constant)); % from Niskanen, for every 1% increase
      in urbanization, over the urban_effect_constant, crime increases
      by 0.9%
input.LE.crime.baseline_criminal_replenishment_rate =
      (input.LE.crime.daily_arrest_rate +
      input.LE.crime.daily_deterrence_rate)*input.LE.crime.urban_effect
input.LE.crime.baseline_criminal_recruitment_rate =
      input.LE.crime.criminals_per_100k/100000*input.LE.crime.baseline_
      criminal_replenishment_rate*input.demo.init_population;
      % baseline recruit rate replenishes those criminals assumed to be
      caught or deterred when police is at its full strength
```

```

input.LE.crime.criminal_inertia = 1/10000; % notional - criminal
    culture - FLL and Niskanen discuss criminal inertia
input.LE.crime.GDP_per_capita_lag_center = 4;
input.LE.crime.GDP_per_capita_growth_effect_constant = 2.4; % from FLL
    - for every 1% increase (decrease) in GDP per capita, there is a
    2.4% decrease (increase) in the number of criminals
input.LE.crime.unemp_effect_lag_center = 4;
input.LE.crime.unemp_effect_constant = 9; % from Niskanen - for every
    1% decrease (increase) in unemployment, there is a 9% decrease
    (increase) in the number of criminals
input.LE.crime.daily_criminal_release_rate = [0.5*8.2474e-4 8.2474e-4
    1.5*8.2474e-4]; % from Travis et al -> 8.2474e-4 = 1600/1940000 -
    based on numbers of prisoners released daily from US prisons
input.LE.crime.criminal_homicide_rate = 0.0032;
    % percent of crimes committed that are murders -> from Levitt
    1995 table 1 max column
input.LE.crime.homicides_per_criminal_per_day =
    input.LE.crime.criminal_homicide_rate*
    input.LE.crime.crimes_per_criminal_per_year / 365; % this value
    times the criminal level gives the daily number of murders
    committed

```

Appendix E. Insurgent and Coalition Military (ICM) Sub-Model

```
input.ICM.init_CTroops = Factor(4); % initial coalition troops
input.ICM.init_insurgents = Factor(7); % initial insurgents
input.ICM.death_rate_mov_cond_factor = 3; % if death rate is above 3
    times the acceptable death rate (model_terminating_death_rate)
    then insurgents will move to neighboring region with least
    insurgents
input.ICM.offensive_movement_rate = 0.01; % daily, 1% of the region's
    insurgents will transfer to neighboring region if death rate
    condition met
input.ICM.offensive_insurgent_move_control = 1;
    % 1 = insurgents will transfer regions offensively
    % 0 = insurgents will not transfer regions offensively
input.ICM.insurgency_failing_mov_cond_factor = 0.15;
input.ICM.defensive_movement_rate = 0.05; % daily, 5% of the region's
    insurgents will transfer to neighboring region when current
    insurgents number only 15% of the all time maximum number of
    insurgents in the region
input.ICM.defensive_mov_rate_min_cond = 500;
input.ICM.CTroop_movement_rate = 0.05;
    % when 90 day mov avg death rate below 43, 5% daily of coalition
    troops in current region will transfer to the region with the
    highest death rate
input.ICM.stop_CTroop_movement = 0.5;
    % CTroops will not transfer below half-strength of original
    regional value
input.ICM.population_per_tip = 50e3;
input.ICM.insurgents_per_tip = 10e3;
input.ICM.insurgents_kia_detained_per_tip = 0.3;

% Coalition Troops Deployment & Return Subsystem
input.ICM.CTDR.CTroop_arrival_schedule_times = [0]; % arrival times
input.ICM.CTDR.CTroop_arrival_schedule_troops = [0];
input.ICM.CTDR.CTroop_departure_schedule_times = [0]; % departure times
input.ICM.CTDR.CTroop_departure_schedule_troops = [0];

% Coalition Troop Casualties & Insurgent Attacks Subsystem
input.ICM.CTCIA.init_CTroop_KIA = 0;
input.ICM.CTCIA.CTroop_KIA_percent = [0 0.096 0.192];
input.ICM.CTCIA.init_CTroop_casualties = 0;
input.ICM.CTCIA.avg_casualties_per_insurgent_attack = 4/3*[0 0.4443
    0.8886];
input.ICM.CTCIA.insurgents_per_daily_attack = 400;
input.ICM.CTCIA.daily_casualty_rate_inertia_effect = 2;
input.ICM.CTCIA.insurgent_differential_effect = 3000;
input.ICM.CTCIA.CTroop_casualty_inertial_center = 30; % +3 days on
    either side of center -> 7 day window
input.ICM.CTCIA.insurgents_inertial_center = 30; % +3 days on either
    side of center -> 7 day window
input.ICM.CTCIA.light_casualty_percentage = [0.19 0.39 0.59]; %
    percentage of casualties returning to service
    % after treatment for minor injuries -> from strategypage.com
input.ICM.CTCIA.light_casualty_service_return_delay = [0 3 6];
```

```

% Civilian Collateral Deaths Subsystem
% derived from regression of Brookings Institute for Insurgent Attacks
and Insurgents KIA or Detained
input.ICM.CD.civilian_collateral_insurgent_attack_effect = 10;
% For every ~10 Insurgent Attacks on a given day, the average
number of daily civilian deaths increases by 1
input.ICM.CD.civilian_collateral_insurgent_KIA_Detained_effect = 20;
% For every ~20 Insurgents Killed or Detained, the average number
of daily civilian deaths increases by 1
input.ICM.CD.civilian_collateral_deaths_uncertainty = [0.75 1 1.25];
input.ICM.CD.init_civilian_collateral_deaths = 0;
input.ICM.CD.avg_deaths_per_insurgent_attack_civ = [0 10 20];

% International Insurgent Subsystem
% Number of Troops Patrolling Border necessary to stop 50% of
infiltration
input.ICM.II.BP_max_percent_deter_attack = 0.5;
input.ICM.II.BP_effectiveness_constant = 32e3*
input.national_manning_percentage;
input.ICM.II.international_insurgent_infiltration_rate = 1;
input.ICM.II.BP_effectiveness = 1;
input.ICM.II.CTroop_patrolling_border_percent = 0.025;
input.ICM.II.CTroop_border_effectiveness = 1;

% Insurgent Killed or Detained Subsystem (IKD)
input.ICM.IKD.init_detained_insurgents = 0;
input.ICM.IKD.init_killed_insurgents = 0;
input.ICM.IKD.insurgent_KIA_uncertainty = [0 0.25 0.5];
input.ICM.IKD.counter_insurgency_effect_parameter = 15000;
% Number of Troops necessary for 0.15% of insurgents to be killed or
% apprehended daily
input.ICM.IKD.counter_insurgency_apprehension_avg = 0.0015;
input.ICM.IKD.CTroop_counter_insurgency_percent = 0.4;
input.ICM.IKD.CTroop_CIOP_effectiveness = 1;
input.ICM.IKD.IM_CIOP_effectiveness = 0.75;
input.ICM.IKD.CD_CIOP_effectiveness = 0.6;
input.ICM.IKD.Pol_CIOP_effectiveness = 0.5;
input.ICM.IKD.detained_insurgent_holding_time = [90 150 210];
input.ICM.IKD.detained_insurgent_release_rate = [0 0.10 0.20];

% Insurgent Attack Direction Subsystem (IAD)
input.ICM.IAD.percent_attacks_all_troops = [0.78 0.84 0.90];
input.ICM.IAD.percent_attacks_civilians = [0 .02 .04];
input.ICM.IAD.percent_attacks_CI = [0 .02 .04];
input.ICM.IAD.CTroop_insurgent_attack_bias = 1.5;
% Insurgent preference to attack coalition troops over and above
CTroop's relative proportion to that of indigenous security forces

% Indigenous Security Forces Casualties (ISFC) Subsystem
input.ICM.ISFC.avg_casualties_per_insurgent_attack_Pol = [0 7.1 10.6];
input.ICM.ISFC.avg_casualties_per_insurgent_attack_CD = [0 8.6 12.9];
input.ICM.ISFC.avg_casualties_per_insurgent_attack_IM = [0 8.6 12.9];
% from Cordesman Table

```



```

% Insurgent Recruit Rate
input.ICM.IRR.LER_center = 4; % ±3 days on either side of center -> 7
    day window
input.ICM.IRR.baseline_recruit_rate = 1/10000;
input.ICM.IRR.CTroop_presence_aggravation_factor = 100; % 1 troop
    counts for 100 people for determining troop concentration
input.ICM.IRR.ELF = 1-3.5*((1-sum(input.demo.pop_dist.^2))-0.5).^2; %
    modified regional ethno-linguistic fractionalization
input.ICM.IRR.polarization_setup =
    (K*(sum(input.demo.pop_dist.^(2.6)*input.demo.pop_dist',2)-
    diag(input.demo.pop_dist.^(2.6)*input.demo.pop_dist')));
input.ICM.IRR.polarization = 1-input.ICM.IRR.polarization_setup./
    sum(input.ICM.IRR.polarization_setup);
input.ICM.IRR.baseline_recruit_rate = 1/10000;
input.ICM.IRR.urban_effect = 1 + 0.9*(input.demo.percent_urban-
    urban_effect_constant); % from Niskanen
input.ICM.IRR.GDP_per_capita_growth_effect_constant = 2.4; % from FLL
input.ICM.IRR.unemp_effect_constant = 9; % from Niskanen
input.ICM.IRR.inertia_effect = 1/1000; % for every thousand insurgents
    1 new recruit per day
input.ICM.IRR.insurgents_kia_detained_lag_center = 7;
input.ICM.IRR.death_capture_effect = 1/100; % for every hundred dead or
    captured insurgents 1 less recruit per day
input.ICM.IRR.media_penetration = 0.577; % from 17 Feb 04 DoD brief
    (central sat TV)
input.ICM.IRR.negative_media_share = 0.25; % Notional
input.ICM.IRR.media_effect = input.ICM.IRR.media_penetration*
    input.ICM.IRR.negative_media_share*1e-3/365;

```

Appendix F. Demographics (demo) Sub-Model

```
input.demo.init_general_population = input.demo.init_population*(1-
    national_labor_force_percent);
input.demo.init_unemp_rate = 0.35; % Actual rate will be biased
    slightly higher
input.demo.init_govt_emp_rate = 0.10; % case made on p.5 of UN/World
    Bank Joint Iraqi Needs Assessment
input.demo.init_private_emp_rate = 0.55;
input.demo.init_unemp_persons =
input.demo.init_unemp_rate*input.demo.init_population*
    national_labor_force_percent-input.ICM.init_insurgents-
input.ICM.IKD.init_detained_insurgents-
input.LE.crime.initial_incarcerated_criminals-
input.LE.crime.initial_criminals;
input.demo.init_govt_emp =
    input.demo.init_population*input.demo.init_govt_emp_rate*national
    _labor_force_percent-input.LE.Pol.init_Pol-input.ISI.BP.init_BP-
input.ISI.IM.init_IM-input.ISI.CD.init_CD-input.ISI.FPS.init_FPS;
input.demo.init_private_emp = input.demo.init_population*
    input.demo.init_private_emp_rate*national_labor_force_percent;
input.demo.crime_deaths_percentage = [0.08 0.08 0.08 0.7]; % crime
    deaths for Unemp, Govt, Private, & General ** Left over
    percentage is for criminal vs criminal deaths
input.LE.criminals_crime_deaths = 1-
    sum(input.demo.crime_deaths_percentage); % criminal deaths due to
    criminal infighting
input.demo.collateral_deaths_percentage = [0.1 0.1 0.1 0.7]; %
    collateral deaths due to insurgency for General, Unemp, Govt, &
    Private ** Sums to one
input.demo.private_sector_GDP_job_growth_effect = -0.4; % Private
    sector job growth/decline due to GDP
    % +1%(+2.5%) GDP Growth = -0.4%(-1%) Unemployed Okun's Law
input.demo.additional_govt_jobs_needed = 0.25; % additional jobs needed
    by govt as percentage of INITIAL number of govt employees
input.demo.govt_hiring_goal =
    input.demo.additional_govt_jobs_needed*input.demo.init_govt_emp;
input.demo.govt_hiring_goal_time_required = 180;
input.demo.govt_hiring_avg = input.demo.govt_hiring_goal/
    input.demo.govt_hiring_goal_time_required;
input.demo.govt_hiring_rate_parameter = [0 input.demo.govt_hiring_avg
    2*input.demo.govt_hiring_avg];
input.demo.insurgent_attack_deaths_percentage = [0.1 0.1 0.1 0.7]; %
    insurgent caused deaths for Unemp, Govt, Private, & General
input.demo.primary_death_rate_mov_avg_length = 7;
input.demo.death_rate_mov_avg_length = 30;
input.demo.terminating_death_rate_mov_avg_length = 90;
```

Appendix G. Critical Infrastructure (CI) Sub-Model

```
input.CI.insurgent_infrastructure_attack_dist = cumsum([0.5 0.20 0.20
0.10]); share of infrastructure attacks on oil, electrical,
transportation, & water
input.CI.FPS_max_percent_deter_attack = 0.5;
input.CI.FPS_effectiveness_constant = 88e3*
input.national_manning_percentage;
% Number of Troops Guarding Infrastructure necessary to stop 50%
of insurgent attacks
input.CI.FPS_troop_effectiveness = 1;
input.CI.foreign_security_contractors = 5e3;

% ***** Oil Infrastructure Subsystem *****
input.CI.oil.insurgent_oil_attack_dist = cumsum([0.10 0.20 0.50 0 0
0.20]); percentage of oil infrastructure attacks on extraction,
regional pipeline, inter-reg pipeline, refinery, export
terminals, refined products transport

% Oil Extraction -> Regional Oilfields (Oil Wells, etc)
input.CI.oil.init_oil_extraction_efficiency = 0;
input.CI.oil.oil_extraction_efficiency_baseline_growth_rate =
inf_baseline*1/270; % 270 days until 100% when starting at 0%
efficiency
input.CI.oil.init_oil_extraction_capacity = 1.0e6; % Northern Oilfields
% Kirkuk, Bai Hassan, Jambur, Khabbaz, Ajil
input.CI.oil.oil_extraction_capacity_increase_times = [0 0];
input.CI.oil.oil_extraction_capacity_increases = [0 0];
input.CI.oil.oil_extraction_capacity_decrease_times = [0];
input.CI.oil.oil_extraction_capacity_decreases = [0];
input.CI.oil.init_oil_extraction_storage = 0;
input.CI.oil.oil_extraction_storage_capacity = 1.0e6;
input.CI.oil.insurgent_attack_extraction_effect_oil = [0 .10 .20];
input.CI.oil.extraction_power_demand = 0.004; % MWhrs/bbl
% -> from EIA Petroleum Supply Annual 2003 Vol 1, table 46,47
% -> assumed half as intensive as refinery operations (.008)
input.CI.oil.extraction_trans_effect = 1;

% Natural Gas Extraction -> Regional Non-Associated Gas Reservoirs
input.CI.oil.init_NG_extraction_efficiency = 0;
input.CI.oil.NG_extraction_efficiency_baseline_growth_rate =
inf_baseline*1/365;
input.CI.oil.init_NG_extraction_capacity = 50e6; % cf/d al-Anfal
input.CI.oil.NG_extraction_capacity_increase_times = [0];
input.CI.oil.NG_extraction_capacity_increases = [0];
input.CI.oil.NG_extraction_capacity_decrease_times = [0];
input.CI.oil.NG_extraction_capacity_decreases = [0];
input.CI.oil.NG_extraction_power_demand = 7.0690e-007; % MWhrs/cf
% Converted from Oil Extraction Requirements
input.CI.oil.init_NG_extraction_storage = 0;
input.CI.oil.NG_extraction_storage_capacity = 100e6; % cf/d
input.CI.oil.insurgent_attack_extraction_effect_NG = [0 .10 .20];
input.CI.oil.natural_gas_extraction_trans_effect = 1;
```

```

% Regional Oil Pipeline(s), transports oil from any Regional Production
Facilities
input.CI.oil.init_oil_transportation_efficiency = 0;
input.CI.oil.oil_transportation_efficiency_baseline_growth_rate =
    inf_baseline*1/270;
input.CI.oil.init_oil_transportation_capacity = 1.4e6;
input.CI.oil.oil_transportation_capacity_increase_times = [0];
input.CI.oil.oil_transportation_capacity_increases = [0];
input.CI.oil.oil_transportation_capacity_decrease_times = [0];
input.CI.oil.oil_transportation_capacity_decreases = [0];
input.CI.oil.insurgent_attack_trans_effect = [0 .12 .24];
input.CI.oil.regional_pipeline_power_demand = 0.002;
input.CI.oil.regional_pipeline_trans_effect = 1;

% Interregional Oil Pipeline(s)
input.CI.oil.init_interregional_oil_transportation_efficiency = 0;
input.CI.oil.interregional_oil_trans_eff_baseline_growth_rate =
    inf_baseline*1/270; % 270 days until 100% when starting at 0%
efficiency
input.CI.oil.init_interregional_oil_transportation_capacity = 1.4e6;
input.CI.oil.interregional_oil_transportation_capacity_increase_times =
    [0];
input.CI.oil.interregional_oil_transportation_capacity_increases = [0];
input.CI.oil.interregional_oil_transportation_capacity_decrease_times =
    [0];
input.CI.oil.interregional_oil_transportation_capacity_decreases = [0];
input.CI.oil.insurgent_attack_interreg_trans_effect = [0 .12 .24];
input.CI.oil.interregional_pipeline_power_demand = 0.002; % Notional -
gross estimation from EIA
input.CI.oil.interregional_oil_pipeline_trans_effect = 1;

% Regional Refinery Capability
% can be fed from interregional pipelines, regional pipelines, or both
% [Diesel Kerosene Gas FuelOil LPG NaturalGas]
input.CI.oil.oil_refinery_refined_production_yields = [0.29 0.19 0.24
    0.17 .05 .02]; % note that Natural Gas added to reflect
production of associated gas
% from -> Platt's Description on crude oil yields -> can be
altered to reflect different production schemes
% yields should sum to 0.95 = one minus .05 for refinery
consumption
input.CI.oil.oil_refinery_refined_production_per_bbl =
    input.CI.oil.oil_refinery_refined_production_yields(1:3)*
    liters_per_bbl % Diesel, Kerosene, and Gas output in terms of L
input.CI.oil.oil_refinery_refined_production_per_bbl(4) =
    input.CI.oil.oil_refinery_refined_production_yields(4);
% FuelOil output remains in terms of bbl
input.CI.oil.oil_refinery_refined_production_per_bbl(5) =
    input.CI.oil.oil_refinery_refined_production_yields(5)*
    tons_per_bbl; % LPG output in terms of metric tons
input.CI.oil.oil_refinery_refined_production_per_bbl(6) =
    input.CI.oil.oil_refinery_refined_production_yields(6)*cf_per_bbl;
% NaturalGas output in terms of cubic feet (cf)
% If all daily NG production converted to LPG ->
227.4e6/cf_per_bbl*tons_per_bbl = 5465.4 tons

```

```

input.CI.oil.init_oil_refinery_capacity = 0; % bbl of crude
input.CI.oil.init_oil_refinery_efficiency = 0;
input.CI.oil.oil_refinery_efficiency_baseline_growth_rate =
    inf_baseline*1/365; % 365 days until 100% when starting at 0%
    efficiency
input.CI.oil.oil_refinery_capacity_increase_times = [0];
input.CI.oil.oil_refinery_capacity_increases = [0];
input.CI.oil.oil_refinery_capacity_decrease_times = [0];
input.CI.oil.oil_refinery_capacity_decreases = [0];
input.CI.oil.oil_refinery_production_time = 3; % days to produce
    refined products (distillation process)
input.CI.oil.refinery_production_variance = [0.90 1 1.1]; % triangular
    distribution showing uncertainty
input.CI.oil.insurgent_attack_refinery_effect = [0 .10 .20];
input.CI.oil.refinery_pipeline_power_demand = 0.008; %MWh/bbl -> from
    EIA (2003)
input.CI.oil.refined_oil_products_import = 0.23*[3e6 3e6 6e6 0 2e3 0]';
    % percentage comes from UNJLCL Iraq Bulletin No.6 (23% import into
    North)
input.CI.oil.oil_refinery_trans_effect = 1;

% Refined Products Demand Subsystem
input.CI.oil.NG_to_LPG_conversion_time = 1; % gas-to-liquid conversion
    process delay, days
input.CI.oil.refined_products_trans_effect = 1;

% *** Export Terminal Subsystem ***
input.CI.oil.init_oil_exportation_efficiency = 0;
input.CI.oil.oil_exportation_efficiency_baseline_growth_rate =
    inf_baseline*1/180;
input.CI.oil.init_oil_exportation_capacity = 0; % from EIA country
    analysis brief
input.CI.oil.init_oil_exportation_storage = 0;
input.CI.oil.init_oil_exportation_storage_capacity = 0; % guesstimate
input.CI.oil.oil_exportation_capacity_increase_times = [0];
input.CI.oil.oil_exportation_capacity_increases = [0];
input.CI.oil.oil_exportation_capacity_decrease_times = [0];
input.CI.oil.oil_exportation_capacity_decreases = [0];
input.CI.oil.oil_exportation_storage_capacity_increase_times = [0];
input.CI.oil.oil_exportation_storage_capacity_increases = [0];
input.CI.oil.oil_exportation_storage_capacity_decrease_times = [0];
input.CI.oil.oil_exportation_storage_capacity_decreases = [0];
input.CI.oil.insurgent_attack_terminal_effect = [0 .10 .20];
input.CI.oil.export_terminal_power_demand = 0.003;
input.CI.oil.export_terminal_trans_effect = 1; % 1st order effect

% ***** Electricity Infrastructure Subsystem *****
input.CI.electric.insurgent_elec_attack_dist = cumsum([0.7*3/36
    0.7*6/36 0.7*12/36 0.7*7/36 0.7*8/36 .3]); % distribution of
    attacks against diesel, crude, fuel oil, natural gas, and hydro
    generation, last entry concerns transmission and distribution
    subsystem
input.CI.electric.national_power_share = 0.25; % share of national
    power grid (MWhrs) that region draws upon

```

```

% Electricity Generation
input.CI.electric.insurgent_attack_electric_gen_effect = [0 .10 .20];
input.CI.electric.elec_gen_maint_modifier = [1 1 0.80 1]';
input.CI.electric.elec_gen_maint_modifier_times = [50 141 233 324]';
input.CI.electric.init_imported_elec_generation = 0; % MWhrs 60 Syria
      80 Turkey see transmission subsystem for import control
input.CI.electric.imported_elec_generation_increases = [30*24 110*24];
      % Power from Syria and Turkey
input.CI.electric.imported_elec_generation_increase_times = [150 180];
input.CI.electric.imported_elec_generation_decreases = [0];
input.CI.electric.imported_elec_generation_decrease_times = [0];

% Diesel/GasOil Fuel Generators
input.CI.electric.init_elec_gen_efficiency_diesel = 0.25;
input.CI.electric.elec_gen_eff_baseline_growth_rate_diesel =
      inf_baseline*1/730;
input.CI.electric.init_elec_gen_capacity_diesel = 130; % MW
input.CI.electric.elec_gen_capacity_increase_times_diesel = [0];
input.CI.electric.elec_gen_capacity_increases_diesel = [0];
input.CI.electric.elec_gen_capacity_decrease_times_diesel = [0];
input.CI.electric.elec_gen_capacity_decreases_diesel = [0];
input.CI.electric.fuel_requirement_diesel = 118.3; % L diesel/MWhr
      generated -> from US/Canada Blackout Study Appendix p111...
      4/128*1/42*158.984*1000
input.CI.electric.init_fuel_storage_capacity_diesel = 400e3;
input.CI.electric.init_fuel_storage_diesel = 200e3;
input.CI.electric.fuel_storage_capacity_increase_times_diesel = [0];
input.CI.electric.fuel_storage_capacity_increases_diesel = [0];
input.CI.electric.fuel_storage_capacity_decreases_diesel = [0];
input.CI.electric.fuel_storage_capacity_decrease_times_diesel = [0];
      % stand alone generators are detached from national grid
input.CI.electric.init_stand_alone_gen_efficiency_diesel = 1;
input.CI.electric.init_stand_alone_gen_capacity_diesel = 0;
input.CI.electric.stand_alone_gen_eff_base_growth_rate_diesel =
      inf_baseline*1/30;
input.CI.electric.elec_sa_capacity_increase_times_diesel = [0];
input.CI.electric.elec_sa_capacity_increases_diesel = [0];
input.CI.electric.elec_sa_capacity_decrease_times_diesel = [0];
input.CI.electric.elec_sa_capacity_decreases_diesel = [0];
input.CI.electric.transportation_gen_effect_diesel = 1;

% Crude Fuel Generators
input.CI.electric.init_elec_gen_efficiency_crude = 0.25;
input.CI.electric.elec_gen_eff_baseline_growth_rate_crude =
      inf_baseline*1/730;
input.CI.electric.init_elec_gen_capacity_crude = 224; % MW
input.CI.electric.elec_gen_capacity_increase_times_crude = [0];
input.CI.electric.elec_gen_capacity_increases_crude = [0];
input.CI.electric.elec_gen_capacity_decrease_times_crude = [0];
input.CI.electric.elec_gen_capacity_decreases_crude = [0];
input.CI.electric.fuel_requirement_crude = 0.5883; % bbl crude oil/MWhr
      generated conversions vary depending on the type of crude oil &
      energy conversion -> from
      http://www.spe.org/spe/jsp/basic/0,,1104_1732,00.html
      % 1/(5.8e6*1055.059*1e-6/3.6*1e-3) = 0.5883
input.CI.electric.init_fuel_storage_capacity_crude = 50e3;

```

```

input.CI.electric.init_fuel_storage_crude = 20e3;
input.CI.electric.fuel_storage_capacity_increase_times_crude = [0];
input.CI.electric.fuel_storage_capacity_increases_crude = [0];
input.CI.electric.fuel_storage_capacity_decreases_crude = [0];
input.CI.electric.fuel_storage_capacity_decrease_times_crude = [0];
    % stand alone generators are detached from national grid
input.CI.electric.init_stand_alone_gen_efficiency_crude = 1;
input.CI.electric.init_stand_alone_gen_capacity_crude = 0;
input.CI.electric.stand_alone_gen_eff_base_growth_rate_crude =
    inf_baseline*1/30;
input.CI.electric.elec_sa_capacity_increase_times_crude = [0];
input.CI.electric.elec_sa_capacity_increases_crude = [0];
input.CI.electric.elec_sa_capacity_decrease_times_crude = [0];
input.CI.electric.elec_sa_capacity_decreases_crude = [0];
input.CI.electric.transportation_gen_effect_crude = 1;

% FuelOil Generators
input.CI.electric.init_elec_gen_efficiency_foil = 0.25;
input.CI.electric.elec_gen_eff_baseline_growth_rate_foil =
    inf_baseline*1/730;
input.CI.electric.init_elec_gen_capacity_foil = 707; % MW
input.CI.electric.elec_gen_capacity_increase_times_foil = [0];
input.CI.electric.elec_gen_capacity_increases_foil = [0];
input.CI.electric.elec_gen_capacity_decrease_times_foil = [0];
input.CI.electric.elec_gen_capacity_decreases_foil = [0];
input.CI.electric.fuel_requirement_foil = 0.5427; % bbl/MWahr generated
    % from Platt's  $1/(6.287e6*1055.059*1e-6/3.6*1e-3) = 0.5427$  bbl
    fuel oil/MWahr
input.CI.electric.init_fuel_storage_capacity_foil = 50e3; % bbl of
    fuel oil
input.CI.electric.init_fuel_storage_foil = 0;
input.CI.electric.fuel_storage_capacity_increase_times_foil = [0];
input.CI.electric.fuel_storage_capacity_increases_foil = [0];
input.CI.electric.fuel_storage_capacity_decreases_foil = [0];
input.CI.electric.fuel_storage_capacity_decrease_times_foil = [0];
    % stand alone generators are detached from national grid
input.CI.electric.init_stand_alone_gen_efficiency_foil = 1;
input.CI.electric.init_stand_alone_gen_capacity_foil = 0;
input.CI.electric.stand_alone_gen_eff_base_growth_rate_foil =
    inf_baseline*1/30;
input.CI.electric.elec_sa_capacity_increase_times_foil = [0];
input.CI.electric.elec_sa_capacity_increases_foil = [0];
input.CI.electric.elec_sa_capacity_decrease_times_foil = [0];
input.CI.electric.elec_sa_capacity_decreases_foil = [0];
input.CI.electric.transportation_gen_effect_foil = 1;

% Natural Gas Generators
input.CI.electric.init_elec_gen_efficiency_NG = 0;
input.CI.electric.elec_gen_eff_baseline_growth_rate_NG =
    inf_baseline*1/730;
input.CI.electric.init_elec_gen_capacity_NG = 800; % MW
input.CI.electric.elec_gen_capacity_increase_times_NG = [0];
input.CI.electric.elec_gen_capacity_increases_NG = [0];
input.CI.electric.elec_gen_capacity_decrease_times_NG = [0];
input.CI.electric.elec_gen_capacity_decreases_NG = [0];

```

```

input.CI.electric.fuel_requirement_NG = 3000; % cf/MW hr generated
% -> from US/Canada Blackout Study Appendix p.111... 3*1000
input.CI.electric.init_fuel_storage_NG = 0;
input.CI.electric.init_fuel_storage_capacity_NG = 46e6;
input.CI.electric.fuel_storage_capacity_increase_times_NG = [0];
input.CI.electric.fuel_storage_capacity_increases_NG = [0];
input.CI.electric.fuel_storage_capacity_decreases_NG = [0];
input.CI.electric.fuel_storage_capacity_decrease_times_NG = [0];
input.CI.electric.init_stand_alone_gen_efficiency_NG = 1;
input.CI.electric.init_stand_alone_gen_capacity_NG = 0;
input.CI.electric.stand_alone_gen_eff_base_growth_rate_NG = 1/30;
input.CI.electric.elec_sa_capacity_increase_times_NG = [0];
input.CI.electric.elec_sa_capacity_increases_NG = [0];
input.CI.electric.elec_sa_capacity_decrease_times_NG = [0];
input.CI.electric.elec_sa_capacity_decreases_NG = [0];
input.CI.electric.transportation_gen_effect_NG = 1;

% Hydroelectric Generators
input.CI.electric.init_elec_gen_efficiency_hydro = 0.5;
input.CI.electric.elec_gen_eff_baseline_growth_rate_hydro =
    inf_baseline*1/365;
input.CI.electric.init_elec_gen_capacity_hydro = 660; % MW only river
    flow restricts generating capacity (water supply exogenous to
    model)
input.CI.electric.elec_gen_capacity_increase_times_hydro = 0;
input.CI.electric.elec_gen_capacity_increases_hydro = 0;
input.CI.electric.elec_gen_capacity_decrease_times_hydro = 0;
input.CI.electric.elec_gen_capacity_decreases_hydro = 0;
% stand alone generators are detached from national grid
input.CI.electric.init_stand_alone_gen_efficiency_hydro = 1;
input.CI.electric.init_stand_alone_gen_capacity_hydro = 0;
input.CI.electric.stand_alone_gen_eff_base_growth_rate_hydro =
    inf_baseline*1/30;
input.CI.electric.elec_sa_capacity_increase_times_hydro = [0];
input.CI.electric.elec_sa_capacity_increases_hydro = [0];
input.CI.electric.elec_sa_capacity_decrease_times_hydro = [0];
input.CI.electric.elec_sa_capacity_decreases_hydro = [0];
input.CI.electric.transportation_gen_effect_hydro = 1;

% Electricity Transmission Subsystem
input.CI.electric.init_elec_trans_eff = 0.75;
input.CI.electric.elec_trans_eff_baseline_growth_rate =
    inf_baseline*1/270;
input.CI.electric.init_elec_trans_capacity = 3112*24; % MWhrs
input.CI.electric.elec_trans_capacity_increases = [0];
input.CI.electric.elec_trans_capacity_increase_times = [0];
input.CI.electric.elec_trans_capacity_decreases = [0];
input.CI.electric.elec_trans_capacity_decrease_times = [0];
input.CI.electric.trans_line_power_loss_percent = [.05 .07];
input.CI.electric.insurgent_attack_electric_trans_effect = [0 .12 .24];
input.CI.electric.transportation_trans_effect = 1;
input.CI.electric.power_import_grid_control = 1;
% 1 => imported power joins national grid
% 0 => imported power only available for regional consumption

```



```

% Electricity Demand Subsystem
input.CI.electric.population_demand = 0.0027; % MWhr per capita per day
input.CI.electric.non_oil_industrial_demand = 18.5; % MWhr per non-oil
    GDP million dollars
input.CI.electric.oil_industrial_demand_priority = 1;
    % 1 = oil industry receives full priority
    % 0 = even distribution among populace, industry, and oil
input.CI.electric.pop_demand_uncertainty = [.9 1 1.1];
input.CI.electric.industrial_demand_uncertainty = [.9 1 1.1];
input.CI.electric.pop_demand_seasonal_modifier = [0.25 0.75 41];
input.CI.electric.non_oil_demand_seasonal_modifier = [0.05 0.95 41];
    % sine wave depicting seasonal demand -> amplitude = 0.25, center
    bias = 0.75 and initial phase bias = 41 days => time begins May
    1, (t = 0) and since day 50 is summer we need to subtract 41 from
    the period of 91.25. Wave begins with an upslope toward 1 for
    summer (day 50), dropping to 0.75 in fall (day 141), then dips to
    0.5 (day 233) in winter before rising again

% ***** Water Infrastructure Subsystem *****
input.CI.water.baseline_growth_rate = inf_baseline*1/365;
input.CI.water.init_percent_capacity_available = 0.25;
input.CI.water.insurgent_attack_effect = [0 .10 .20];
input.CI.water.init_potable_water_capacity = 150e6; % Mliters/day
input.CI.water.demand_per_capita = 15;
input.CI.water.potable_capacity_increases = [0];
input.CI.water.potable_capacity_increase_times = [0];
input.CI.water.potable_capacity_decreases = [0];
input.CI.water.potable_capacity_decrease_times = [0];
input.CI.water.trans_effect = 1;

% ***** Transportation Infrastructure Subsystem *****
input.CI.transport.insurgent_attack_dist = cumsum([0.75 0 0.2 0.05]);
    % attack distribution on road, seaport, rail system, and airports

input.CI.transport.road_init_tractor_trucks = 2200;
input.CI.transport.vehicle_capacity_increases = [200 200 200 200 200];
input.CI.transport.vehicle_capacity_increase_times = [180 365 545 730
    1095];
input.CI.transport.vehicle_capacity_decreases = [0];
input.CI.transport.vehicle_capacity_decrease_times = [0];
input.CI.transport.road_trailer_tonnage = 0.5*15+0.5*44;
    % This assumes 50% of the trucking fleet is 15 tons and the other
    50% is of the 44 ton variety (50 tonne trailer - max allowable
    load = 44 tonnes)
input.CI.transport.road_init_infrastructure_index = 0.75; % notional
    % congestion delay idleness factors resulting from a variety of
    factors including transport route closed, bridge out, poor road
    quality, customs delay
input.CI.transport.road_infra_index_increases = [0.05 0.1];
input.CI.transport.road_infra_index_increase_times = [365 730];
input.CI.transport.road_infra_index_decreases = [0];
input.CI.transport.road_infra_index_decrease_times = [0];
input.CI.transport.road_insurgent_attack_effect = [0 1 2]; % each
    insurgent attack against trucking takes down 0 to 2 trucks
input.CI.transport.road_criminal_effect_uncert = [0.5 1 1.5];

```

```

input.CI.transport.road_crime_effect_factor = 1/40000; % 1 truck-
    jackings per 40000 criminals daily
input.CI.transport.diesel_required_per_vehicle = 1800; % liters per
    truck per day -> assumes 15e6 of 18e6 (80%) diesel demand per day
    used by trucking industry % 15e6/8300 = 1800

input.CI.transport.seaport_init_availability = 0;
input.CI.transport.seaport_availability_growth = inf_baseline*1/730;
input.CI.transport.seaport_init_capacity = 0; % tonnes
input.CI.transport.seaport_capacity_increases = [0];
input.CI.transport.seaport_capacity_increase_times = [0];
input.CI.transport.seaport_capacity_decreases = [0];
input.CI.transport.seaport_capacity_decrease_times = [0];
input.CI.transport.seaport_insurgent_attack_effect = [0 .10 .20];

input.CI.transport.rail_init_availability = 1;
input.CI.transport.rail_availability_repair = inf_baseline*1/180;
input.CI.transport.rail_insurgent_attack_effect = [0 0.12 0.24];
input.CI.transport.rail_init_capacity = 200; % tonnes per day
input.CI.transport.rail_capacity_increases = [0];
input.CI.transport.rail_capacity_increase_times = [0];
input.CI.transport.rail_capacity_decreases = [0];
input.CI.transport.rail_capacity_decrease_times = [0];

input.CI.transport.air_init_availability = 1;
input.CI.transport.air_availability_repair = inf_baseline*1/180;
input.CI.transport.air_insurgent_attack_effect = [0 0.10 0.2];
input.CI.transport.air_init_capacity = 10; % tonnes per day
input.CI.transport.air_capacity_increases = [50 50];
input.CI.transport.air_capacity_increase_times = [365 540];
input.CI.transport.air_capacity_decreases = [0];
input.CI.transport.air_capacity_decrease_times = [0];

input.CI.transport.refined_oil_products_import =
input.CI.oil.refined_oil_products_import;
input.CI.transport.init_oil_power_demand = 4e3; % tonnes per day
input.CI.transport.oil_power_demand_increases = [0];
input.CI.transport.oil_power_demand_increase_times = [0];
input.CI.transport.oil_power_demand_decreases = [0];
input.CI.transport.oil_power_demand_decrease_times = [0];
input.CI.transport.init_coalition_demand = 2e3; % tonnes per day
    % note: this is coalition demand on non-military transport
    services only
input.CI.transport.coalition_demand_increases = [0];
input.CI.transport.coalition_demand_increase_times = [0];
input.CI.transport.coalition_demand_decreases = [0];
input.CI.transport.coalition_demand_decrease_times = [0];
input.CI.transport.refined_oil_products_import(1:3) =
input.CI.oil.refined_oil_products_import(1:3)*tonnes_per_liter;
    % daily regional import, rough estimate of weight for diesel,
    kerosene, and gasoline/benzene
input.CI.transport.food_demand_per_capita = .0011; % tonnes per day per
    person on Food Rations -> from 530e3 tonnes of food per month
    needed for 60% of national population -> from 23 Feb 04 Iraq
    Update Brief
input.CI.transport.percent_population_on_food_ration = 0.60;

```

```

input.CI.transport.commercial_demand_per_NonOilGDP = 10.83; % 10.83
    daily tonnes per NonOil GDP million dollars % calculated from
    UNJLC bulletin 6 figures on import tonnage
input.CI.transport.food_delivery_priority_control = 0;
    % 1 = food tonnage demand satisfied before any commercial and
    fuel shipping
    % 0 = food demand treated equally

% *****
% Economic Subsystem
input.CI.econ.init_NonOil_GDP = 770; % in millions of US$
input.CI.econ.NonOil_GDP_growth = 0.35; % expected annual growth if
    essential services demands are met -> from IMF Iraq report
input.CI.econ.violence_GDP_reduction_factor = [28 .02];
    % from Bejarano -> a murder rate of 28 per 100k corresponds to a
    loss of 2% GDP annually

```

Appendix H. Public Opinion (PO) Sub-Model

All parameters affecting popular support are notional.

```
% *****  
% Public Opinion Sub-Model  
input.PO.init_population_support= [Factor(1) Factor(2) Factor(3) .75]';  
    % popular support percentages for the three major population sub-  
    groups, Shia, Sunni, Kurd - the "Others" sub-group always starts  
    at 0.75  
input.PO.baseline_acceptable_civilian_death_rate_annually = 43/100e3;  
input.PO.civilian_death_effect_constant = 150; % for every 1 person  
    killed over the acceptable level of violence, 100 supporters lost  
input.PO.GDP_per_capita_factor = 0.1; % one percent rise in GDP per  
    capita corresponds to a 0.1 increase in popular support relative  
    to the current popular support  
input.PO.demand_ratio_weights = [1 1 1 1];  
    % importance weighting factor for demand ratios  
    % Power, Water, Food, Refined Products Demand  
input.PO.baseline_demand_ratio = 0.75; % for essential services demand  
    ratios - above baseline, popular support increases - below  
    baseline, popular support decreases  
input.PO.unemp_eff_constant = 4; % Notional - for every person removed  
    from (put on) unemployment 4 people support (don't support)  
    coalition efforts
```

Note that region2 and region3 are not shown in these appendices.

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