# Understanding & Modeling State Stability: Exploiting System Dynamics


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*Abstract*—The potential loss of state stability in various parts of the world is a source of threat to U.S. national security. Every case is unique, but there are common processes. Accordingly, we develop a system dynamics model of state stability by representing the nature and dynamics of 'loads' generated by insurgency activities, on the one hand, and by articulating the core features of state resilience and its 'capacity' to withstand these 'loads', on the other. The problem is to determine and 'predict' when threats to stability override the resilience of the state and, more important, to anticipate propensities for 'tipping points', namely conditions under which small changes in anti-regime activity can generate major disruptions. On this basis, we then identify appropriate actionable mitigation factors to decrease the likelihood of 'tipping' and enhance prospects for stability.


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## 1. INTRODUCTION

The potential loss of state stability in various parts of the world is a major source of threat to U.S. national security. While every case is unique, there are common processes tending toward instability. In its Preface, *The 9/11 Commission Report* states: "*We learned that the institutions charted with protecting …national security did not understand how grave this threat can be, and did not adjust their policies, plans, and practices to deter or defeat it*" [1: xvi]. Given current realities and uncertainties, "better preparedness" can be achieved by identifying, controlling and managing the linkages and situational factors that fuel hostilities and undermine stability and cohesion.

Over the course of six months from April to October (2005), researchers from MIT and elsewhere worked with DARPA[3] to develop computational social science models for understanding the nature of state stability as well as propensities for state failure and collapse. The MIT team developed a system dynamics model to understand and represent sources and consequences of stability, as well as ways in which the potential for disruptions could be reduced, managed or mitigated. In this report, we review the way in which we have modeled (and 'predicted') how and when threats to stability tend to override the resilience of the state and to undermine its overall capabilities and performance. More specifically, we isolate the 'tipping points' – conditions under which small changes in anti-regime activity can generate major disruptions – and then seek to identify appropriate actionable mitigation factors to reduce the potential for 'tipping' and enhance prospects for stability.

## 2. BACKGROUND AND CONTEXT

We begin by placing the key issues in context, first by noting insights from the social sciences and then by highlighting some key system dynamics modeling features.

### *2.1 State Stability*

The stability of a state is a process, in that states can be at different stages of 'stability' and subject to different pressures toward instability. There are multiple modes of fragility as well as different paths toward a range of 'end


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[3] Defense Advanced Research Projects Agency

points'. It is well known that studies of state stability (and fragility) are closely connected to a wide range of issues in the social and the computational sciences such analyses of civil war, political mobilization, social disturbances, institutional development (or lack thereof), economic performance, social cohesion, ethnic violence and a range of issue areas that bear directly on the resilience of states and their capabilities, as well as on the pressures upon the state and the types of threats to its integrity and stability.

One of the most recognizable indications of state instability is the onset of civil war. While it may be impossible to predict an individual catalyst for a civil war, there are many elements that make a state predisposed towards the breakout of civil war. For instance, time and again we have seen that the most likely states for civil war are those states that have recently undergone another war, states whose neighbors are involved in civil war, and states that are economically weak [2]. However, many social scientists and policy-makers identify the best device for preventing civil war as democracy [3; 4]. Yet, on a global basis, Siegle, Weinstein and Halperin show that the evidence regarding which comes first, democracy or development, is still contentious [5]. By the same token, Hegre, et al. show that the greatest likelihood of civil war is not in a state which is the least-democratic, but rather civil war is much more likely to break out in a state which is semi-democratic [6].[4] Our approach to state stability takes this divergent perspective into account, but adopts a rather different approach.

Given the wide range of contentions regarding sources and consequences of state stability, an initial step is to define the core proposition in order to render precision and direction for the computational and modeling strategy. The proposition is this:

> *A state is stable to the extent that its resilience (capabilities) is greater than the load (or pressures) exerted upon it.*

Embedded in a high level model of state stability, this proposition helps guide formulation of the system dynamics model.

Social scientists in general, and political scientists in particular, are in general agreement regarding the nature of the state, its fundamental features, and its generic attributes – irrespective of specific manifestations or characteristics shaped by time or location. Rooted in the basic contributions of Aristotle's *Politics* all states consist of, and are governed by, a complex body of relationships and institutions framed and guided by a constitution [7]. Many centuries later, Almond and Powell put forth a formal approach to state capacities by defining a set of specific capabilities (namely, extractive, regulative, responsive, distributive, and symbolic) [8]. These points support our premise that a state is stable to the extent that the loads or pressures upon it can be managed by its prevailing capabilities or performance capacities.

### *2.2 System Dynamics*

System dynamics is an approach for modeling and simulating (via computer) complex physical and social systems and experimenting with the models to design policies for management and change [9]. The core of the modeling strategy is representation of system structure in terms of *stocks* and of *flows*. In this connection, *feedback* loops are the building blocks for articulating the dynamics of these models and their interactions can represent and explain system behavior.

Created by Jay Forrester, system dynamics modeling (SDM) has been used as a method of analysis, modeling and simulation for almost 50 years. SDM has been used for a wide range of purposes, such as to capture the dynamic relationship of energy and the economy [10], to model the world petroleum market over a period of thirty decades [11], to explore dynamics of economic growth [12] to analyze the environmental implications of international trade [13], to understand supply-chain management [14], to analyze different policies for nation-building [15], to model software development [16], and to examine the intricacies of the air force command and control systems [17].

SDM offers unique capabilities to contribute to social science, economics, or political science modes of analysis. SDM recognizes the complex interactions among many feedback loops, rejects notions of linear cause-and-effect, and requires the analyst to view a complete system of relationships whereby the 'cause' might also be affected by the 'effect'. SDM enables analysts to uncover 'hidden' dynamics. Moreover, SDM allows the analyst an increased level of flexibility as SDM utilizes both conceptual understanding as well as empirical data collection. As Forrester explains, "the first step [in SDM] is to tap the wealth of information that people possess in their heads. The mental data base is a rich source of information about the parts of a system, about the information available at different points in a system, and about the policies being followed in decision making". [18: 5]. The modeling process in system dynamics translates these elements of causal logic into systems of difference equations and differential equations [19]. Empirical analysis is also used to explain the relationships between individual elements in the overall system. By understanding the dynamics of a state system, including interactions among actors, actions, structures and processes in complex environments, one can better identify how to reinforce state capabilities while diminishing the loads and pressures exerted upon it.

[4] This one-dimensional scale was originally constructed by Ted Robert Gurr in conjunction with the Polity project. Visit http://www.cidcm.umd.edu/inscr/polity/ for the complete dataset.

## 3. Modeling State Stability

### 3.1 Overview of Process

For modeling purposes, the first step is to define the *overall domain* and system of elements tending toward state stability and the sources of instability. This high level view is used for framing purposes, consistent with dominant lines of thinking in the social sciences. The value of system dynamics is that it also provides a method for empirical model grounding as well as policy crafting. Next is to select and 'drill down' to the most important, sensitive and *short-term processes* that shape the more immediate threats to stability and enhance the propensities for instability. The task after that is to formulate a computational *system dynamics model* for simulation, and 'predictive' purposes based on empirical data and observable cases. Drawing upon data from two real-world cases, we developed and then used the SDM model to make further predictions about insurgency recruiting, recognize different policy implications, and make informed policy decisions based upon empirical measurements.

### 3.2 The High-Level Diagram

The first step in identifying our operational approach to modeling state stability is to define the key system-features and to create a high-level causal loop diagram that captures the key elements of the system in question including the major feedback loops. Unlike in traditional social science, in this diagram there is no one 'dependent variable' that reflects the overall stability status of the state; rather there are a whole range of potentially significant joint dependencies (and feedback dynamics) that capture overall system behavior and performance over time.

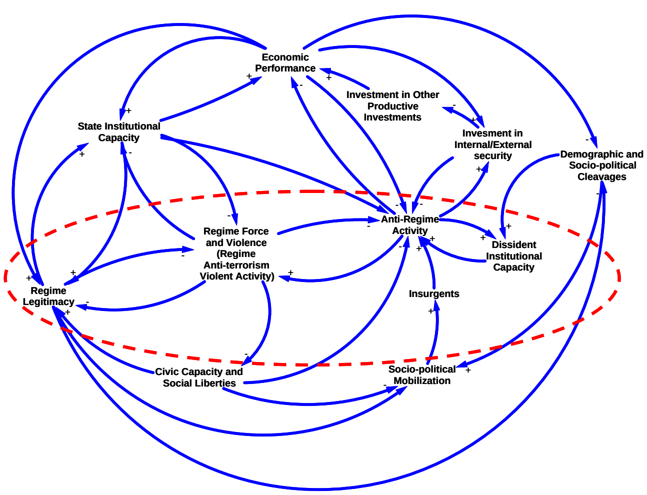



**Figure 1**. High-Level Diagram of State Stability. (Circled section signals the segments for detailed system dynamics modeling)

Figure 1 presents the High-Level Diagram of overall state stability. We seek here only to define broadly the *overall domain* as well as the *SDM model focus* (encompassed within the dashed lines). In this diagram, the arrows show causal relationships between variables. A plus sign (+) indicates that a change in the first variable (at the tail of the arrow) causes a change in the second variable (at the head of the arrow) in the same directions. A minus sign (-) indicates that a change in the first variable causes a change in the second variable in the opposite directions. A path that begins at any variable and traces from arrow to arrow to returns to the original variable forms a feedback loop.

In many cases, there were large bodies of literature that described each of the key relationships. Framed thus, we sought only to reflect some of the most dominant sets of relationships reflected in the literature, by way of developing an integrated device for representing the complexities of underlying dynamics.

### 3.3 Drilling Deeper

In Figure 1, the dotted line delineates several elements in the High-Level Diagram. that we chose as the place to start the modeling process. Choosing to analyze these sets of systems also yielded three other important benefits. First, we sought to determine how system dynamics could best be applied to capturing and understanding state stability. Analysis of system dynamics is strongest when applied to situations where long-term ramifications are usually hidden by short-term drivers. We wanted to choose a case where this would be especially pronounced. Second, our goal was to develop a model that would yield results in the short run: that is, we wanted to be able to make predictions based upon the internal logic of the model and to be able to use the model to explain the strengths and weaknesses of different policy options. Third, we sought to focus on a specific set of system-features that would best illustrate the contributions of system dynamics and demonstrate the broad value of social science. Based on all these considerations we elected to focus on modeling the dynamics of dissident and insurgent recruiting given the resilience of the state and its capacity to manage anti-regime activities.[5] This focus on insurgency-vs.-state-resilience would become our Proof of Concept Model.

[5] Many of these subjects were saved in case we had the opportunity to pursue future modeling. They ranged from analyzing instances of famine and food shortage to the mobilization and propagation of fundamental terrorism.

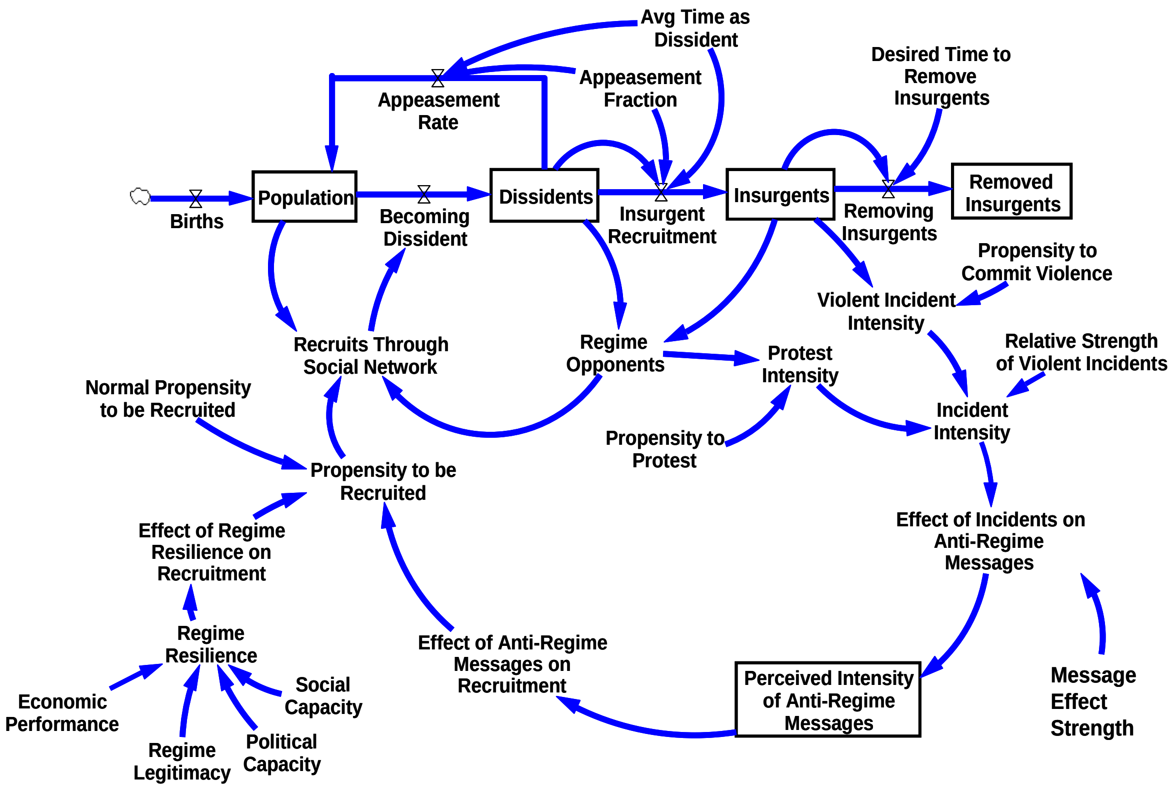



**Figure 2.** Conceptual Model of Insurgent Activity and Recruitment (Simplified)

*3.4 Developing Proof of Concept Model*

The starting point for modeling the potential growth of dissidents and insurgents was recruiting. We considered and sought to represent the different causes and effects of such recruiting. Model formulation was done in four, often interactive, stages. First, we began with a thorough and comprehensive literature review in order to familiarize ourselves with the key terms and to capture the current state of understanding of insurgent recruitment. Second, we interviewed relevant personnel: in our case, we turned to military experts, country analysts, and scholars for further insight. Third, we used existing empirical work to explain relationships that would be true for all states. In this sense, we made our model generic. Fourth, we finalized the overall model specification by incorporating country-specific information for two test cases: Country A and Country B.[6] Country-specific information came from personnel, online newspapers, databases constructed by government organizations, non-governmental organizations, and experts. Throughout the process, we considered how different policies would affect the dynamics of the model.

[6] One of the requirements for the DARPA contract was that all teams make real predictions for two countries. Thus Country A and Country B represent two existing countries.

## 4. Proof of Concept Model

Below we present the SDM state stability model, beginning first with an overview of the entire system and structure, and then addressing key components sequentially.

### *4.1 System and Structure - Overview*

The model shows the sources and consequences of insurgent recruiting, constrained and limited by the resilience of the regime and the extent to which the state can manage anti-regime activities. To simplify, of the many actions that insurgents chose to perform in order to undermine regime legitimacy, we model those associated with stimulating, producing and circulating anti-regime communications. Anti-regime messaging and communication are thus major mechanisms for increasing insurgent recruitment and for mobilizing opponents to the regime. The context in which these activities occur is partly shaped by the regime. The state's capacities and the resilience of the regime operate such as to counter insurgency recruitment. Figure 2 shows the conceptual structure of our Insurgent Recruitment Model.

The logic of the model can account for many known patterns of insurgent recruiting. The model as represented in Figure 2 was developed drawing upon the social science literature and earlier studies in the computational social sciences, as well as "by tapping into the wealth of information that people possess in their heads" [18].[7], The formulated model includes about 140 equations. The remainder of this section looks at each component of the model, one at a time, and seeks to articulate the basic logic as the behavior of the system 'unfolds,' so to speak.

### *4.2 Sources of Insurgents*

We begin with the assumption that, in any given state with a given number of people, there are some peaceful anti-regime elements (dissidents) and there are some violent anti-regime elements (insurgents). Thus, we divide the population into three stocks, labeled Population, Dissidents, and Insurgents, and shown as rectangles in Figure 3. The model shows transitions from one stock to the other with icons resembling pipes and valves. People in the general population may become dissidents and after some time these dissidents may become insurgents. There are two direct ways to curb this transition, however. First, dissidents might become appeased by the state and return to the general population. A peaceful regime change or a policy change may placate these dissidents into regime supporters. Alternatively, dissidents who become insurgents can be removed from the system by the state. This could occur through arrests, detentions, or state violence. These approaches to reduce dissidents and insurgents are shown as the "Appeasement Rate" and "Removing Insurgents," respectively, in Figure 3.

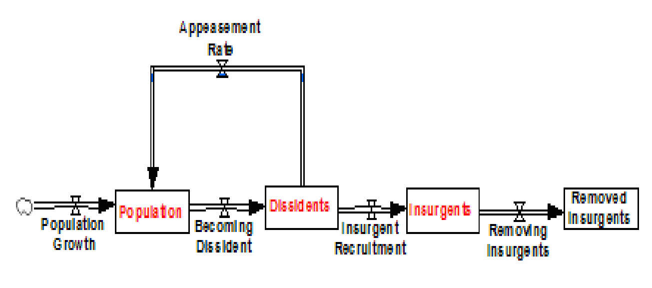



**Figure 3**. Overview of Conflict Model

However, there are notable other conditions affecting the Population-to-Insurgent flows. There are several different elements that can affect the transition of a normal member of society to a dissident to an insurgent. Figure 4 introduces the next level of complexity. For example, when considering the component of removing insurgents, we must also consider the removal effectiveness, the indicated force strength, and the desired time to remove insurgents in order to assess how well insurgents are removed. Even though several of these variables are exogenous to our model, they can nonetheless be affected by different policy levers that will affect the overall system.

[7] For literature used to justify the model, please contact the authors. We also relied heavily upon interviews, news sources, and databases.

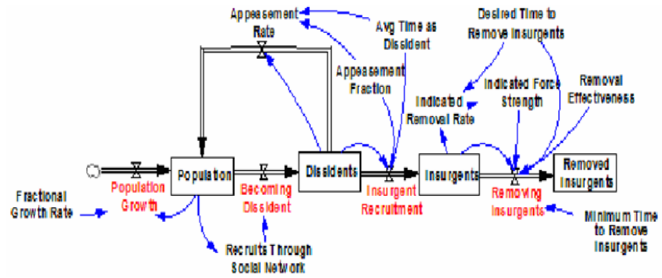



**Figure 4.** Ways to Affect the Population-to-Insurgent Flow

### *4.4 Anti-Regime Messaging and Flow of Communication*

In Figure 5, we expand the model to show that dissidents and insurgents generate anti-regime messages through anti-regime incidents. Such incidents include protests, targeted attacks, or even civil war. 'Messages' include both formal and informal communications between individuals in a regime. An anti-regime message based upon an intense incident might proclaim that the regime violently cracked down on *innocent* protestors, or that the regime can no longer effectively handle insurgent movements in a certain part of the country and is therefore incapable of controlling the state. Messages of this sort can undermine the legitimacy of the regime and represent one form of loads on state capacity.

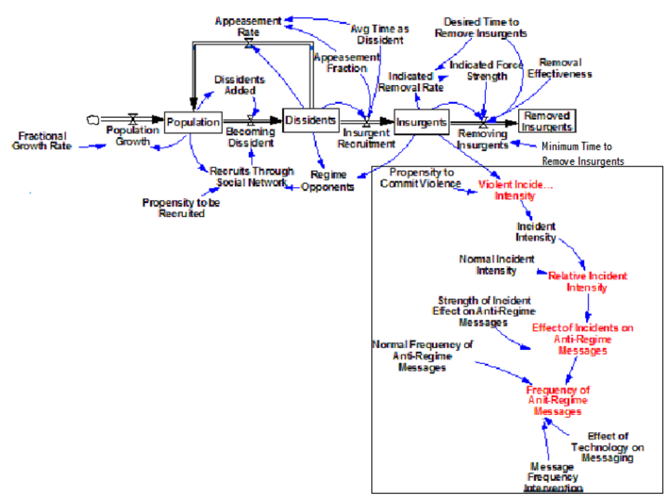



**Figure 5.** Message Production Generated by Dissident and Insurgent Incidents

Once again, there are many policy options available for limiting the flow of anti-regime messages. Such options are often utilized, in countries as diverse as France, (which imposed curfews on its citizens to quell riots in October and November of 2005), and Thailand (where the South has been in a state of martial law since March of 2005). At the same time, we recognize that perceptions may be different from actual behavior. Accordingly, in Figure 6, we take into account the perceived intensity of anti-regime messages and the relative frequency of anti-regime messages.

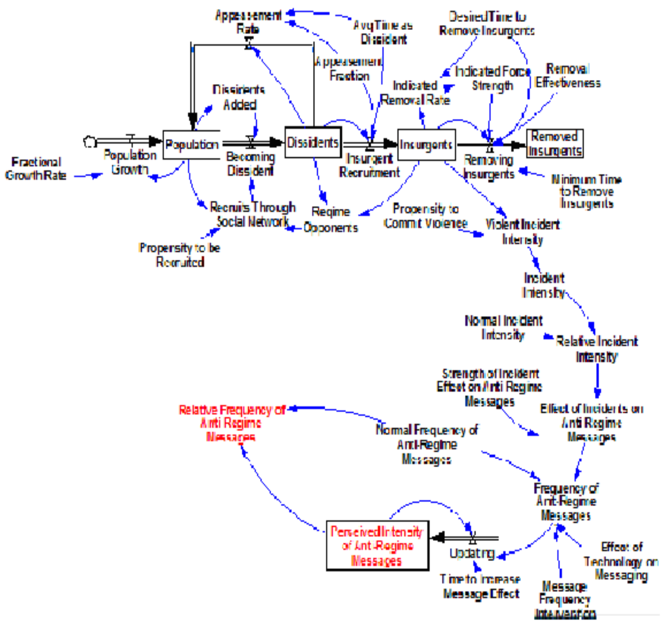



**Figure 6**. Accounting for Perceptions

*4.5 Regime Resilience*

The critical constraint on insurgency expansion is the resilience of the state. The SDM model represents state resilience through an empirically derived function of key determinants, as indicated in the social science literature. Specifically, we draw upon economic performance, regime legitimacy, political capacity, and social capacity, as shown at the lower left of Figure 7, to compute the aggregate regime resilience, via the relationship:

$$Regime\_Resilience_t = \alpha_t * \beta_t * \gamma_t * \delta_t * \varepsilon_t$$

Polity Index: $\alpha_t = |Polity_t / Polity_{1980}|$

Civil Liberties Index: $\beta_t = Civil\_Liberties_t / Civil\_Liberties_{1980}$

GDP Index: $\gamma_t = (GDP_t / Population_t)/(GDP_{1980} / Population_{1980})$

Employment Index: $\delta_t = Emp\_per\_Capita_t / Emp\_per\_Capita_{1980}$

Literacy Index: $\varepsilon_t = Literacy_t / Literacy_{1980}$

The effects of anti-regime messages on dissident recruitment are taken into account, as shown in Figure 7. Considering our earlier discussion of capacities versus loads, regime resilience can be considered as a measure of the long-term capacities of a state.

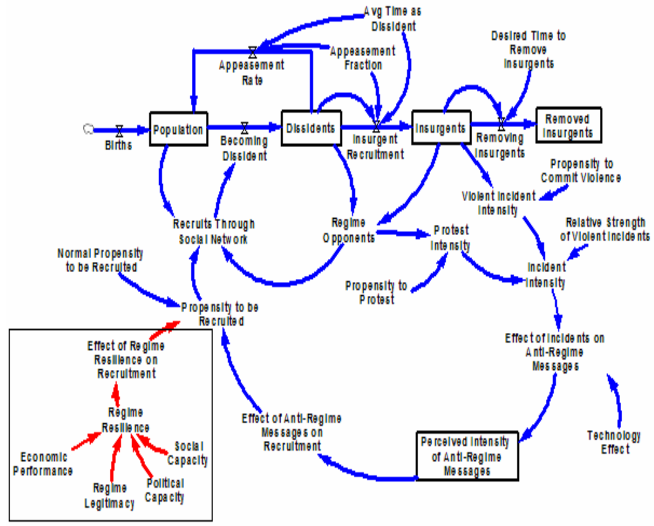



**Figure 7**. Regime Resilience in Computational Terms

The literature notes that the resilience of a state is inversely related to the occurrence of civil war. We find empirical support for this relationship when comparing the state resilience function to the determinants of civil war as determined by Hegre et al. [6]. Hegre, et al. looked at all occurrences of civil wars across the world over the last several decades. They were able to produce a measure that determines the likelihood of a civil war breaking out. As we would expect, for the case of Country A, the Relative Risk of Civil War drops precipitously as the computed Resilience index rises, as shown in Figure 8. This suggests that insurgent movements are being contained from further breakouts at the national level.

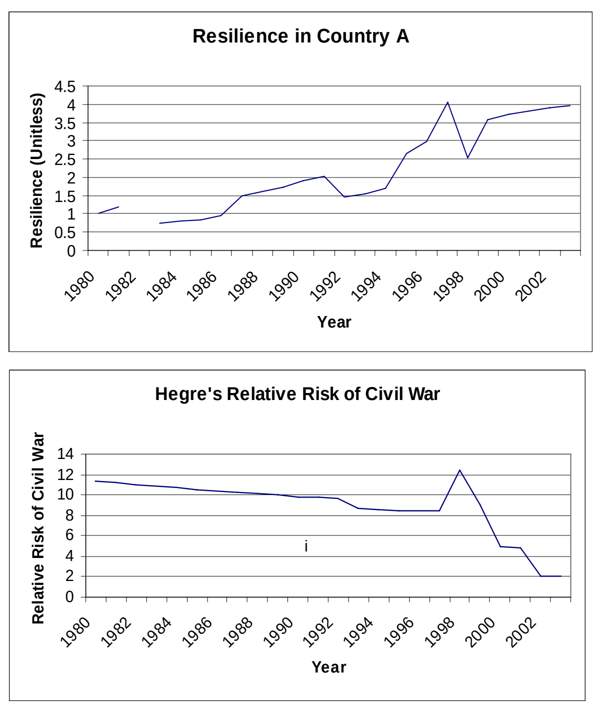



**Figure 8.** Regime Resilience vs. Relative Risk of Civil War

*4.6 Review of Loads-vs.-Resilience*

Regime resilience can mitigate against insurgent recruitment, thereby reducing a load on the stability of the system. For example, when the economy is doing well or when the regime is perceived as having increased legitimacy, the likelihood of an individual becoming a dissident or an insurgent becomes much smaller. The focus of the loads and capacities of the system are highlighted in Figure 9.

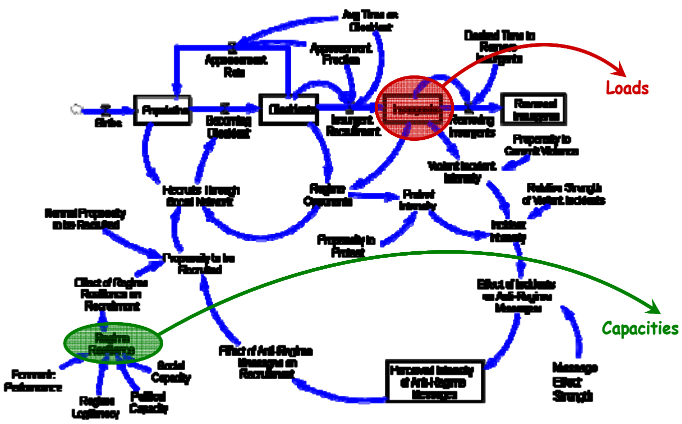



**Figure 9**. Identifying Loads and Capacities

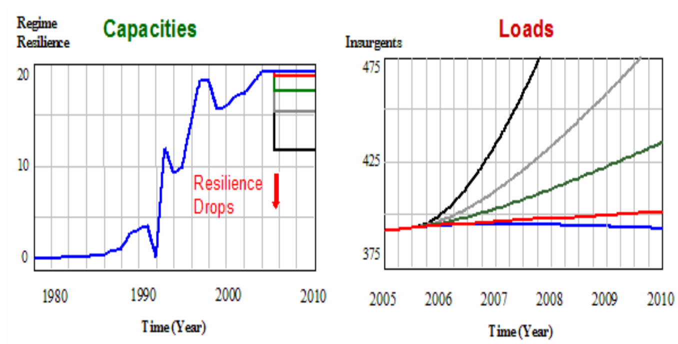
Re-examining the usage of policies specifically designed to stem message flows through reductions in civil liberties, we see that in the short-term such policies can reduce the messaging capabilities but in the long-term such policies can undermine the social capacity of a state and will therefore undermine the regime resilience. As a result, while there are fewer avenues for messages to circulate, these messages are more effective at converting individuals into dissidents and insurgents as individuals are less happy with the regime. Therefore the state and the regime should be wary of enforcing short-term controls with deleterious effects and should instead create and foster policies focused on improving the capacities of the state, which in turn will balance the loads.

## 5. RESULTS OF PROOF OF CONCEPT MODEL

We show here two sets of SDM results, namely (a) illustrations of tipping points and (b) examples of some policy prescriptions.

*5.1 Tipping Point Caused by Reduction in Regime Resilience*

Recall that we are interested in identifying tipping points at which the loads on the system exceed the capacities to manage the loads. At such points, regime resilience will no longer be able to 'fend off' insurgency behavior. In Figures 10a and 10b, we present the regime resilience and the corresponding insurgents that are generated by reductions in the state capacity. Specifically, these figures show the resulting growth in insurgency with various changes in long-term state capacities (known as Regime Resilience in the model). These figures are based upon observations, estimates, and predictions in a specific region of Country A, where insurgency has fluctuated for the last several years.




**Figures 10a and 10b.** Capacities and Loads

As one can see from Figure 10, initially small declines in the capacities of the state produce small increases in the number of insurgents, i.e. the load on the system. But, at some point, further declines in the capacities, produce dramatic increases in the projection of insurgent growth – thus a 'tipping point.'[8] This shows the critical nature of choosing the correct policy prescriptions required for state stability.

*5.2 Policy Alternatives: Removing Insurgents vs. Reducing Anti-Regime Messages*

Using SDM, we can compare different policy alternatives. In Figure 11, we identify two policy prescriptions:

(1) the state might become better at removing insurgents, and

(2) the state might improve its ability to respond to anti-regime messages, dampening the message strength.

Earlier, we identified that controlling the circulation of anti-regime messages (through curfews and other civil liberty limitations) would reduce the number of anti-regime messages in the short-term. Considering the broader system, we see that a policy prescription which encourages choking messages through the suppression of liberties would undermine regime resilience, and in the long run, such a policy prescription would cause more harm than good. Increasing the 'Regime Voice' is different. It implies that the strength of the anti-regime messages might become diluted in an acceptable fashion.

[8] The numbers presented in Figures 10a and 10b on the axes are based upon a specific case study., The true value of system dynamics does not come from empirical statements such as "if you reduce the economy 10%, you will increase insurgents by 10%," but rather "if the economy drops, one can expect to see an increase in insurgents, and based upon previous situations, if something is not done to re-establish the capacities, the state may tip into an unsustainable situation."

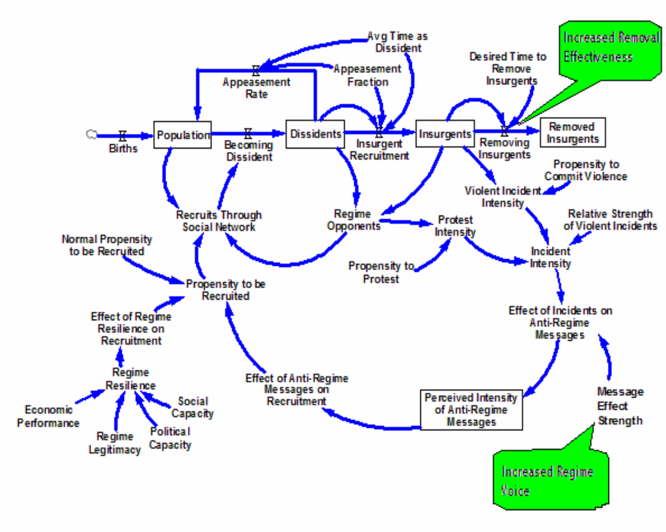



**Figure 11.** The Potential Effects of Increased Removal Effectiveness (Intelligence Sharing) versus Weakening the Message Strength (Moderate Rhetoric)

For example, one such way to increase the regime voice is to sponsor a public campaign against the insurgents (to undermine their legitimacy). As we recently observed in Jordan in November of 2005, as a result of extreme terrorist acts by Al Qaeda, the state was able to garner public sentiment. That can become a very successful method for controlling anti-regime elements. There are many ways that states can increase the regime voice to counter the threats. In Figure 11, we compare the results of changes in each of these inputs.

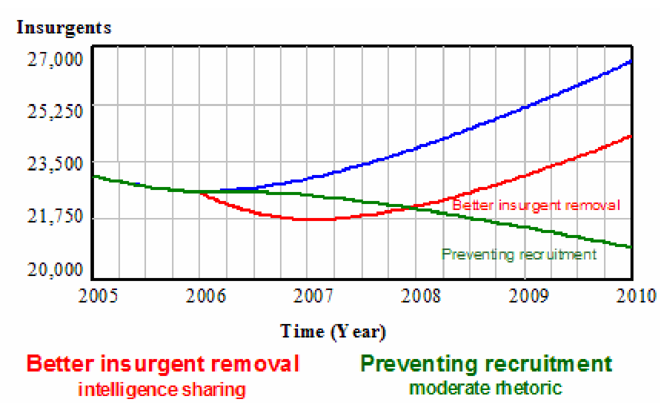



**Figure 11.** Increasing the Regime Voice vs. Increased Removal Effectiveness

The upper line shows the expected growth in insurgents if no action is taken. Both of the proposed actions produce a reduction from this projected growth. However, as the figure shows, although the use of better insurgent removal policies does reduce the number of insurgents at any given time relative to the base case, the basic trajectory is not changed and insurgents do continue to grow. On the other hand, when the state focuses on preventing recruitment through improving rhetoric, insurgent recruitment slows and insurgent levels actually decline, as shown as the lowest line.

## CONCLUSION

This research focused on particular segments of an overall modeling strategy designed to help better understand the sources and consequences of state stability. We hope to create an integrative computational model, one that addresses all of the key features of the High Level Diagram. Such an effort would enable us to integrate the dynamics of insurgency and dissidence within a more detailed and realistic representation of overall stability – all of the key loads vs. the entire major capacities. In this paper, we illustrated the underlying interplay between critical elements that can produce useful predictions, and we have shown that system dynamics can yield fruitful results for policy prescriptions, in this case on combating insurgent recruitment.

The strength of SDM lies in being able to understand, recognize and compare both short-term and the long-term effects of different elements on other elements, as well as the effects of different relationships on other relationships, while simplifying such complex dynamics. Framing elements in such a model will garner key insights from non-traditional information sources. Scholars have been analyzing states, security, policy decisions, and nation-building for years: the military planners and policy analysts could gain insights from such work, much as the SDM modeling initiatives reported in this paper have benefited from interactions with, and contributions of, our collaborators in this project. Finally, the combination of SDM and social science is a natural marriage in the nature of computational social sciences: There is a long history of understanding states as complex systems in the social sciences, and understanding the dynamics of the systems involved in a state may produce the most robust predictive value for planning.

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