SANDIA REPORT
SAND2004-4745
Unlimited Release
Printed September 2004

Modeling Conflict: Research Methods, Quantitative Modeling, and Lessons Learned

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a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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Abstract

This study investigates the factors that lead countries into conflict. Specifically, political, social and economic factors may offer insight as to how prone a country (or set of countries) may be for inter-country or intra-country conflict. Largely methodological in scope, this study examines the literature for quantitative models that address or attempt to model conflict both in the past, and for future insight. The analysis concentrates specifically on the system dynamics paradigm, not the political science mainstream approaches of econometrics and game theory. The application of this paradigm builds upon the most sophisticated attempt at modeling conflict as a result of system level interactions. This study presents the modeling efforts built on limited data and working literature paradigms, and recommendations for future attempts at modeling conflict.

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Acknowledgements:

The authors would like to thank Christopher Butler, Assistant Professor of Political Science at the University of New Mexico for his contributions to this report.

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1. Background

Because it is difficult to conduct experiments in interstate conflict, many analyses of interstate conflict consist of qualitative 'storytelling' approaches that use narrative analysis based on case studies to explain factors related to conflict. However, modeling and simulation can be important tools for understanding how and why human groups engage in conflict. This background discussion describes some of the standard approaches to international conflict modeling in the social sciences and explores the potential role for system dynamics as a modeling tool in conflict studies.

What is conflict? Since the purpose of this exercise is to examine data driven models of conflict we revert to the definitions given by the Correlates of War (COW) project [1]. There are several data sets provided by the COW project that represent conflict.

The COW project provides data on Inter-, Extra- and Intrastate disputes, Table 1. Data collection is restricted to states that are members of the "interstate" system.[2] Ideally, a model should have explanatory power for all three.

Table 1. War Types from the Correlates of War (COW, 2004)

Data set	**Description**
Inter-State War	1 = Interstate war
Extra-State War	2 = State conflict with a colony
	3 = State conflict with a non-state actor
Intra-State War	4 = Civil war for control of central government
	5 = Conflict over local issues
	6 = Inter-communal conflict

In addition, the Militarized Interstate Disputes data sets "… provides information about conflicts in which one or more states threaten, display, or use force against one or more other states…".[3] This statement, and the supporting categorization, constitutes the working definition for conflict used in this study.

The COW[4] project has 10 categories of datasets that may be appropriate for use in modeling the system dynamics of conflict, Table 2. A dynamic hypothesis addressing how each set of data explicitly affects conflict remains in progress.

[1] There are several data sets available. COW project is in electronic form and easily downloadable.
[2] See Cederman (1997) for a description of the nation state as a unit of analysis.
[3] COW, 2004. Specific website as of September 16, 2004, http://cow2.la.psu.edu/
[4] COW, 2004. Specific website as of September 16, 2004, http://cow2.la.psu.edu/

Table 2. Correlates of War Project Data Sets (COW, 2004)

COW Data Sets	
State System Membership	Territorial Change
Inter-, Extra-, and Intra- State War	Direct Contiguity
Militarized Interstate Disputes	Colonial/Dependency Contiguity
National Material Capabilities	Intergovernmental Organizations
Formal Alliances	Bilateral Trade

Modeling conflict between nations in a quantitative manner is a challenging, yet fruitful exercise to understand the robustness of potential policy effects. Political scientists, especially in quantitative international relations, frequently use models to examine aggregate human behavior, including conflict. For example, Snidal (2004) gives a good description of the use of formal methods in international relations, especially quantitative international relations. As he states, "A model is nothing more than a "simplified picture of a part of the real world" (Snidal, pp. 227). He goes on to say that formal (i.e. mathematical) models have special advantages since they "push research toward tightly specified descriptions and arguments" in contrast to storytelling approaches.

Modeling and simulation have gained new popularity in the wake of the terrorist events in the United States on 9/11/2001 as tools for exploring social problems, but as early as 1969,[5] modeling had become a popular approach,[6] practiced by some of the leading institutions and researchers[7] of the time, and different approaches to the *simulation* of international conflict were being compared.[8] At that time, Alker and Brunner (1969) examined the three leading simulations of the time and concluded that:

> We learn by doing, by operating our theories to discover their surprising implications, and by our own experiences, even if they are artificial ones. Increased understanding leading to eventual transformation of the violent interchanges, which are characteristic of reality in contemporary international relations, requires greater use of idealized, artificial representations of reality. (p. 110).

In 1973, Dennis Meadows wrote, that while extending the Global Model[9], "It has become clear that a global model based upon data already available can provide insights

[5] Alker and Brunner, 1969.
[6] Simulation was also used for global modeling, see Chadwick *Simulation & Gaming*, Vol. 31, No. 1 (March, 2000), pp. 50-73.). Chadwick opines that the widely criticized *Limits to Growth*, a system dynamics approach to world modeling, instigated the rise in world models after 1971.
[7] Political Military Exercise (PME) from the RAND Corporation, Inter-Nation Simulation (INS) from Northwestern University, and Technological, Economic, Military, Political Evaluation Routine (TEMPER) from The Raytheon Company.
[8] Ironically, Alker from MIT seemed to be unaware of the groundbreaking work in system dynamics occurring at the same institution.
[9] Meadows was referring to the World3 model, the basis for The Limits to Growth.

into the general nature of the factors limiting growth and an overall context for discussions and investigations about specific aspects of global problems." Meadows [10] explains his modeling team research hierarchy with Figure 1. Essentially, Meadows states that the determinants of global conflict drive and are driven by the dynamics of global equilibrium. Global equilibrium in turn is determined by the interaction of natural resources, pollution, food, capital, and population. For a further explanation of issues relating to conflict and the dynamics of a global equilibrium see Sprinz and Wolinsky-Nahmias (2004).

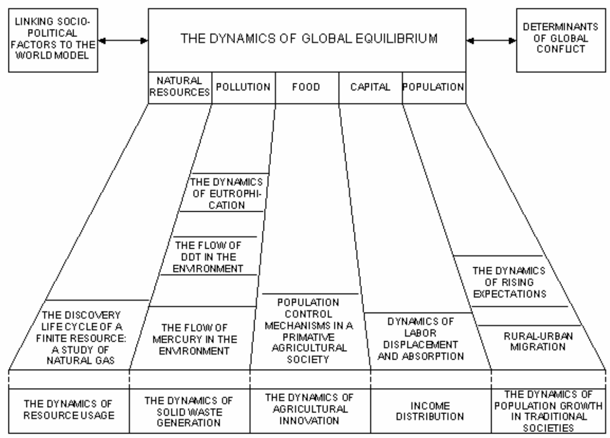

Figure 1. The Hierarchy of Research (Adapted from Meadows, 1973)

Most quantitative international relations models rely on some form of regression analysis to identify key variables in explaining conflict. We follow Kadera[11] in arguing that they are not dynamic. Kadera laments that the incorporation of pseudodynamic features into statistical models has not proved satisfying. As she also points out,[12] one of the key strengths of narrative or 'storytelling'[13] approaches is the "idea of *change* over *time*."[14] It is the attempt to capture change over time that makes an approach dynamic.

Unlike most regression analysis, system dynamics models are designed to address the issue of change over time, which was one reason that applying it to the issue of international conflict was appealing. Secondly, since 1983 there has been a proliferation of datasets in the area of quantitative international relations. The availability of these broader and more detailed datasets (than any previously available) triggered our attempt to construct a systems dynamics model to gain insight into international conflict. Like other quantitative international relations (IR) approaches, our attempt concentrated on individual nation states and dyads, although we develop a fuller model of conflict than the regression approaches favored by political scientists.

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[10] Meadows, 1973.
[11] Kadera, 2001
[12] Kadera, 2001, Chapter 2.
[13] Organiski, The Stages of Development (1958) and Morgenthau, Politics among Nations (1978).
[14] Kadera, 2001, pp. 14

1.1 Verification and Validation Issues

Criticism will always arise concerning the verification and validation of models of this type applied to this problem domain. As Ruloff[15] states,

> There are considerable difficulties in verifying a complex mathematical model. But *objections* against computer-simulation stressing on these difficulties are partly based upon wrong assumptions concerning the *objectives* of this method. We do not aim at long-term forecasts, but rather at gaining insight into the *typical behavior* of a social system, a behavior resulting from the system's numerous parts interacting in a characteristic way. (p. 118)

Sterman[16] devotes an entire chapter to validation and model testing. Models cannot be verified or validated, for as Box (1979, p. 202) said, "All models are wrong, some models are useful." Instead of focusing on the goodness of a model, we propose that studying its limitations is a more reasonable approach to preventing its misuse.

2. Team Membership Skill Sets

Developing a system dynamics model for use in analyzing interstate conflict requires expertise in the social and political sciences as well as systems dynamics modeling. Appropriately, the team includes modelers and social scientists:

- Len Malczynski works in the Office of the Chief Economist and specializes in developing systems dynamics models for nontraditional applications
- Peter Kobos, an ecological economist in the Office of the Chief Economist who develops systems dynamics models
- Paul Rexroth, a nuclear proliferation analyst who develops models for nuclear material control and proliferation risk
- Gerald Hendrickson, a political economist in the National Security and Arms Control division with experience in strategic studies
- Laura McNamara, an anthropologist at the Cooperative Monitoring Center whose research focuses on computational modeling of social science problems

3. Explanation of Dynamic: What Does Dynamic Mean?

Dynamic systems are complex arrangements of entities, in which the system itself emerges as a property of interaction among lower level (not necessarily simple)

[15] Ruloff, 1975a
[16] Sterman, 2000

components. As the components change, they influence the behavior of the system itself – which, in turn, can influence the behavior of the components. Dynamic systems can be extremely complex and may join elements across multiple levels of analysis. System behavior is unpredictable and difficult to predict or control. Examples include organisms, ecological systems, cities, and the global economy.

3.1 What is System Dynamics Modeling?

A dynamic model is one that is *flexible in its assumptions and can self-regulate over the simulation period.* 'Systems thinking' and 'systems dynamics modeling' is a specific kind of dynamic modeling. The term refers to a paradigm for simplifying, representing, and modeling the real world, in order to generate insight about the range of behaviors that emerge from interactions among the connected elements. Systems dynamics modeling and analysis began at Massachusetts Institute of Technology in the 1950s, where researcher Jay Forrester identified systems analysis as a means to help business managers understand the flows of goods and materials through supply and distribution chains. It has since been applied to problems of urban planning, national economic cycles, energy planning, and other areas of socioeconomic policy analysis.

Systems dynamics begins with the recognition that the behavior of social systems is far more difficult to predict and control than that of physical systems. The goal of systems dynamics modeling is to develop a useful abstraction of real socioeconomic systems, focusing on the relationships that link concepts together, and to use this abstraction to simulate the development and behavior of the interrelated elements over time. A good systems dynamics model can provide insight into processes, patterns of change, and possible paths of system evolution.

Systems dynamics models the world as a network of *flows* (of information, items, a substance, people) and *stocks*, or holding areas where flows accumulate. Stocks are like a bathtub with a faucet and a drain; as water (the flow) enters the tub, the tub fills; when the drain is opened, the water leaves the tub (outflow) and the tub empties. A systems dynamics model usually has many such stocks connected by feedback loops that channel the flow cyclically through the system. Equilibrium is reached when entry and exit rates are equalized across the system; however, rarely are real-world systems in equilibrium, as rates of inflow and outflow differ across stocks. *Systems dynamics allows the modeler to vary the parameters of different stocks to assess how imbalance in one area impacts the rest of the system.* Insights generated from the model can be used to formulate plans and policies to effect change in the real-world system.

Variables that might be of other interest to us include people, money, and weapons. Each of these variables has a unique unit (number of people, dollars, and number of weapons). For each, there are different stocks and different flows. Stocks for people might be broken down into demographics and institutions. Demographic stocks would include youth, working age, and elderly cohorts. Institutional stocks might include productive employment, education, and military service. Flows of people would include births, deaths (natural, by disease, and violence), recruitment into different institutions, retirements, and changing institutions. Figure 2 illustrates a simple “mainstream” model of society looking down into different stocks. People enter the system at left by being born, growing up, going to school, getting a job, retiring, and exiting the system at right at death. The unemployed box indicates at least the transition from school to work, also captures the loss of work, possible re-schooling, and getting a new job. Such a simple model could also include feedback loops in which, for example, the number of people schooled depends on the number of educators available and the excess become immediately unemployed. Even this simple feedback loop could inhibit economic development in the sense that the number of unemployed could overload the system.

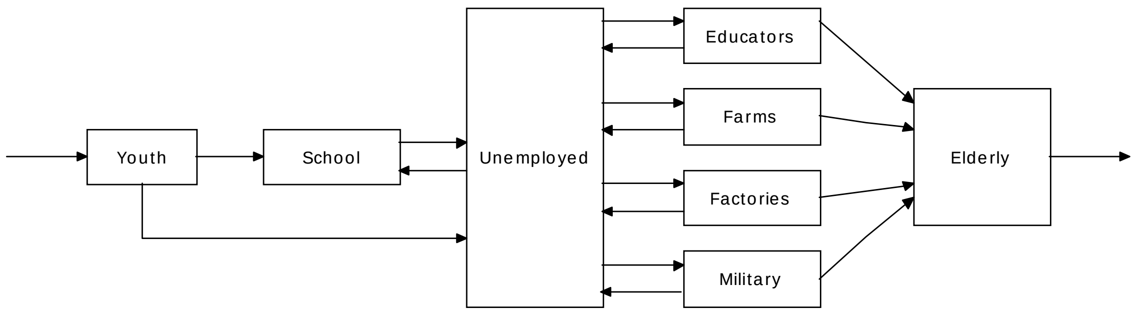

Figure 2. Illustrative Stock and Flow Diagram of a Simplified Society

Systems dynamics models represent reality as a structured network of cause-and-effect relationships. Hence, it is possible to construct a useful systems dynamics model at a gross level and gain insight into the system’s possible evolution, even when individual system elements are poorly understood. Moreover, the metaphor of stocks and flows can be used to conceptualize a wide range of structures: for example, one could construct a demographic model using age categories as the stocks and people as flows.

4. Use of System Dynamics Models in Decision Making

While systems dynamics research, originally made popular by Forrester[17] (1971) in efforts to model industrial processes in factories, its use has spread to include teachers in the classroom, scientists at research institutions and policymakers in government. The key driver for this spread is the way these models seemingly reduce complexity through interactivity. It is this same trait that gives a system dynamics model of conflict the potential to improve the level of analysis about activities of interest across the globe.

[17] See Forrester (1958) for the first publication addressing system dynamics.

Simulation exercises are often found in the university classroom with most introductory textbooks in 'systems' disciplines (i.e. biology, economics, etc.) now including simulation software to supplement the book's written material. The use of system dynamics models in this context is a natural fit for teaching complex material. These models create an interactive representation of the academic discipline's state of knowledge about any given topic. The interactivity clearly allows students to gain better intuition about complex material in a shorter amount of time as novices can iterate through numerous "what if" scenarios in a single setting.

The connection with real world data and the knowledge of important relationships makes this kind of model useful to policymakers. Due to the breadth of topics that must be considered in any oversight area, policymakers often do not have enough time to gain the expertise that is required for them to make the best choices between sets of policy options. Expert advice often fills the gap, but there is often no permanent 'leave behind' the policymaker can use as they consider their options by themselves. System dynamics models[18] can fill this gap and may provide greater value-added to the decision maker because they focus on avoiding unintended policy consequences.

5. Previous System Dynamics Work in the Area of International Conflict

There have been some previous efforts to apply the system dynamics approach to the international state system, but the methodology is not widely recognized as a core tool in the quantitative IR toolbox. Forrester himself was interested in applying systems dynamics approaches to international relations. For example, in his World Dynamics model, Forrester (1971) implied that conflict was and important factor but included no specific treatment of international conflict as measured by wars or other aggressive acts.

The first mention of dyadic conflict analysis using the system dynamics paradigm is found in Ruloff (1975a). In his computer simulation modeling work, Ruloff developed a dynamic system formulated in difference equations to integrate theories of conflict between nations. The goal was to develop a complex model that determined how the level of armament, perceived defense capabilities, reaction to hostile actions, tension, perceived security, and fear influence an overall degree of conflict. In Ruloff's model, tension between countries may only lead to outright conflict with some external factor including variables beyond the country's control (e.g., "anti-foreign riots or sabotage") or pressure faced by the country's decision makers (e.g., perceived security according to a rank of incongruence (Ruloff, 1975a, p. 112)).

[18] The term 'model' has been thrown about carelessly. A model, of course, can simply exist on paper. It can be a functional form in econometrics, a causal loop diagram, or an experimental design in game theory. More appropriately, the system dynamics paper *model* is operationalized via a software model to which one adds an *interface,* thus producing an *application*.

Ruloff's model determined that deterrence mechanisms (in the form of an arms race) are more effective at reducing conflict escalation than mediation (tension reduction). Indeed, his model indicated that conflict escalation is very difficult to stop once underway. However, under conditions of conflict, dampening effects, such as mediation efforts, may help to reduce the severity and duration of conflict. Moreover, in the presence of great losses to both countries, mediation can lead to good results (i.e., the development of cooperative interactions between countries).

The next early attempts to use the system dynamics paradigm in social science research are found in Hanneman (1988). Simulation analysis, according to Hanneman (1988) involves three distinct and separate activities. One of these activities specifies that simulation analysis can be used to analyze and construct theories. In this vein, he states, "We are attempting to build an understanding of an artifact by experimentally subjecting it to known stimuli and observing the consequences" (Hanneman, 1988, p. 86). He presents a model of an arms race escalation as an illustrative use of system dynamics simulation modeling.[19]

More recently, Wils et al., (1998) developed a system dynamics model called the "Threats to Sustainability" model. In this work, the authors attempted to identify and address necessary (but perhaps not sufficient) conditions that may lead to internal or external conflict in various individual countries across a range of socio-economic levels. The authors used the theory of lateral pressure developed by Choucri and North (1975), which posits that as a population's needs for technology and natural resources in a country are not sufficiently met, pressure will develop to help meet these needs. Wils et al. (1998) expanded this theory to additionally posit that technology can moderate the intensity of resource use, thus moderating internal stresses induced by resource shortages.

To explore this theory, Wils et al. (1998) used a system dynamics analysis model that included several key or 'master' variables, such as changing levels of population, technology, resources, military force, and trade and bargaining. The model examined several countries in the Organization for Economic Co-operation and Development (OECD) as well as several not in the OECD. Each country was treated independently, and there was no explicit conflict between countries. Rather, the level of conflict was a level of stress developing from the interactions between the 'master variables'. Figure 3 illustrates the general framework of the Wils et al., (1998) model.

[19] See Coyle, et al. (1999) for a review of system dynamics modeling in the defense area.

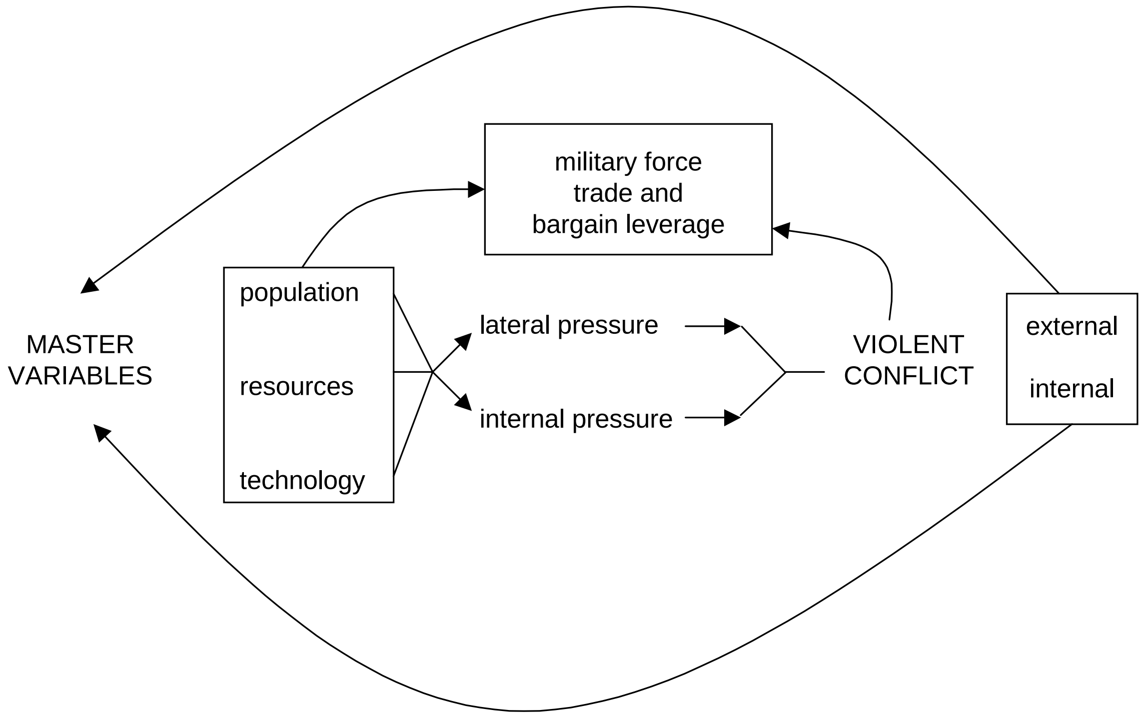

Figure 3. The General Structure of the Threats to Sustainability Model (Adapted from Wils et al., 1998).

Like Ruloff (1975a), Wils et al. (1998) find that conflict, once started, escalates easily and is difficult to dampen.

6. Quantitative Conflict Modeling Efforts

As we discuss below, this “Threats to Sustainability” model provided a starting point for the current modeling effort. Although the Wils et al. (1998) model evolved from a well founded theory and provides a solid foundation for a system dynamics investigation, in its published form, it exhibits many limitations. The formulations used for levels of population, technology, resources, and military strength were all simplistic. This was appropriate for a scoping model whose intent was to set out the basic relationships between these parameters. It was the intent of this project to go beyond some of the limitations of the Wils et al. (1998) model, providing greater flexibility and fidelity in a platform on which the effect of model assumptions and data treatment could be manipulated. This would allow one to gain insight into the nature and validity of the theory presented in Wils et al. (1998).

Overall, the modeling efforts in this SAND report loosely follow the structure illustrated in Figure 3. The model includes variables that may contribute to conflict potential for a given country. The first effort was to develop a close-to-true copy of Wils et al.'s (1998) in Powersim Studio 2003. This was a non-trivial task given the significant differences between the dynamic simulation software Vensim used in Wils et al. (1998), and the software used for this study (Powersim Studio 2003). Also, the limited description of the input datasets used by Wils et al. (1998) demonstrates the challenging nature of conflict modeling.

From the basic Wils et al.'s (1998) framework, we considered the aspects of the model that warranted extension or elaboration. The first area was the treatment of population. One area of particular interest for the group was demographics. The Wils et al. (1998) model extrapolated population data based on arbitrary estimates from current trends. The demographics model described in section 6.1 of this report was chosen to provide the population versus time data figures. Calculation of the population through the demographics model provides two advantages. First, it allows the user to take advantages of the most currently available data on population patterns providing better confidence in the prediction of populations into the future. Second, it allows the user to experiment and observe the effects of changes in the assumptions related to demographic change.

The Wils et al. (1998) model uses the Gross Domestic Product (GDP) or purchasing power parity as a surrogate for the single master variable; the level of technology. Technology plays two direct roles in the model. As the level of technology rises, so does the requirement for some resources to fuel it, creating external pressure. On the other hand, it can reduce reliance on specific resources, such as land for producing food, resulting in a reduction in internal pressure. GDP, and thus the technology level, is also used in the model as a contributor to military force. The current study sought to provide more flexibility and fidelity in the treatment of technology. To address this issue, the degree of electrification was substituted for a single percent of GDP as the measure of technology. It was proposed that future model developments could include decomposing the technology variable into various aspects that have different affects on an overall level of technology. For instance, some technological development is directed toward military strength, contributing to pressures that affect conflict. Additionally, other pressures, such as the relative level of communications, would likely reduce pressures related to conflict. Sustained external pressure or conflict, though depleting resources, may lead to greater military technology gains.

The levels or resources in the Wils et al. (1998) model are represented by the total land area of the country under consideration. As the current model progresses, the relative level of resources could be replaced with a more rich set of components that may include arable land, water, mineral deposits, fuel sources, and climate. The feedback from conflict on each type of resource could be considered separately.

The Wils et al. (1998) model assumes that military capabilities (expenditures) are a constant percent of GDP. In the current Powersim Studio model, actual military expenditures and personnel from the Correlates of War project dataset are used for the initial conditions. In the future, an advanced military capabilities model may be developed that takes into account such things as the relative level of military technology between countries, nuclear capabilities, and missile technologies.

First, the Studio model included only the four initial countries of interest (India, Pakistan, the United States, and China) for the purposes of illustration. These countries were chosen because of the timely nature of changes occurring in these countries. India and Pakistan, for example, are in an ongoing period of occasional friction. The United States and China, however, were chosen due to their relatively large economic, geopolitical, resource use and demographic size as compared to most other nations. Also, these four countries had available and relatively complete datasets. Ideally, this modeling effort would focus on a multitude of countries across economic, geopolitical and other measures. Next, the country-specific data for population, gross domestic product (GDP), total energy, total energy used for electricity, military expenditures, and total military personnel was collected from various sources[20]. Where possible, the model includes this data in the mathematical framework Wils et al. (1998) developed. Additional work is necessary to determine where in the software, for example, the military data should be installed. One proposal was to link military expenditures per military personnel (a surrogate metric for how financially intensive the military personnel are) to a type of military power secondary variable (secondary in the sense that it is not one of the original, 'master variables' outlined in the Wils et al. (1998) work).

6.1. Additional Branches of a Conflict Model

The model based on the Wils et al., (1998) work also builds on the Meadows (1973) work. The latter indicated population is a component of a global equilibrium. To address this issue, an illustrative population demographics model was developed. Largely methodological, this model illustrates the growth within age cohorts by sex as they relate to the overall population totals.[21] These modeling efforts were performed with varying degrees of success due to data limitations for India, Pakistan, the U.S. and China. Figure 4 illustrates the results of the demographics model relative to total population forecasts from the U.S. Bureau of the Census (2004).[22]

[20] Population data, U.S. Bureau of the Census (2004); GDP, BEA (2004); total energy and total energy used for electricity, IEA, (2002a, 2002b); military expenditures, CWP, 2004; total military personnel, CWP, 2004. See Appendix A.

[21] This model is based on one developed by Linard (2004).

[22] The model employs the U.S. Bureau of the Census (2004) data to begin the model simulation. The discrepancy between the model's forecasts and the total population figures reported by the U.S. Census (2004) are due to the varying growth rates (births, deaths, migration) within the age cohort and sex-specific levels of the model for each country.

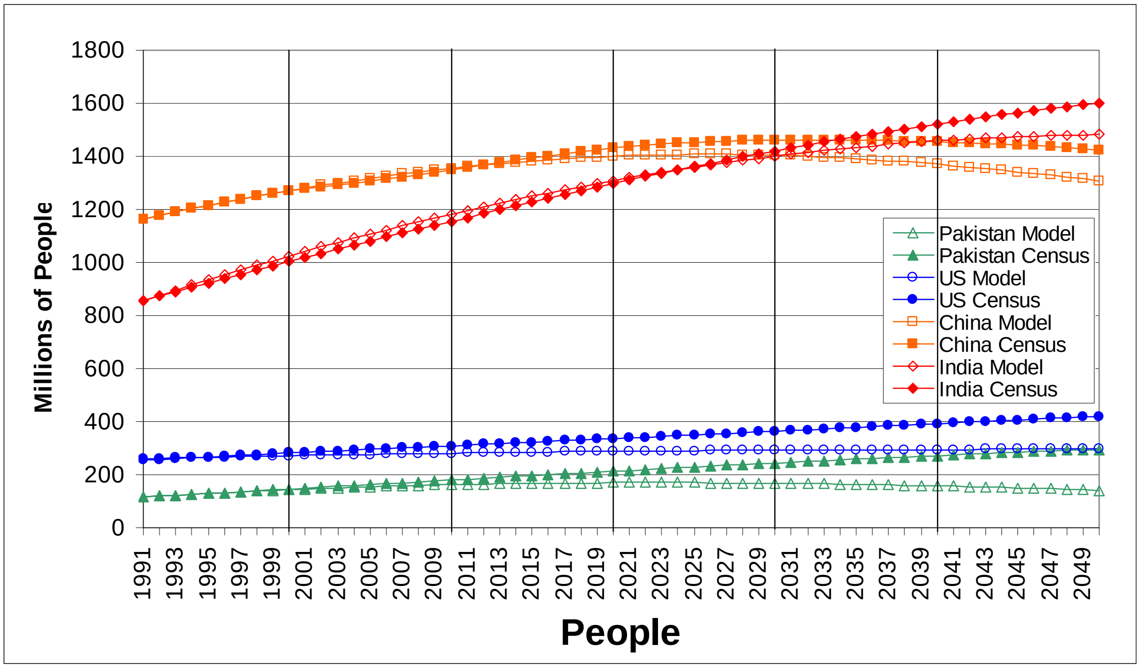

Figure 4. Population Cohort Model Illustrative Results (1991-2050)

Additionally, Figure 5 illustrates the population cohort model interface for Pakistan. The India, U.S. and China models have similar interface components in the model. The latter three models lack age cohort and sex-specific detail, but are reasonably accurate at the aggregate population levels as illustrated by Figure 4.

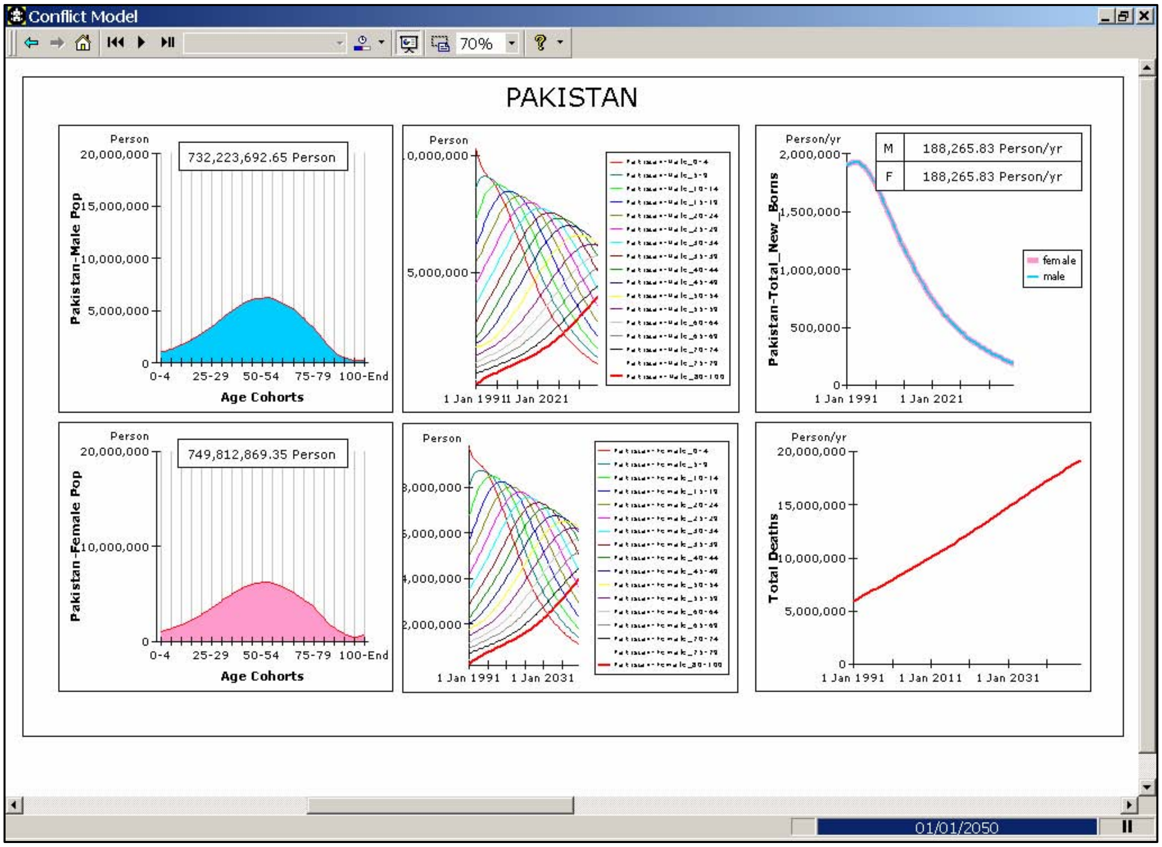

Figure 5. Population Cohort Model for Pakistan (1991-2050)

Figure 5 illustrates the age cohort projections for Pakistan by sex between 1991 and 2050. The top row shows the male population by age cohort, total population, by cohort growth, and by deaths. The second row shows the female population by age cohort, total population, by cohort growth, and by deaths. The Pakistan population model, as well as those for the other three countries, uses a static mortality rate.[23] Forecasts of the mortality rates across countries would improve the age and sex-specific cohort projections.

[23] The mortality rate for Pakistan uses 1988 rates due to data limitations.

The following several figures illustrate the data collected for the modeling efforts based on Wils et al. (1998). Figure 6 shows the large differences between the gross domestic product (GDP) of the four countries.

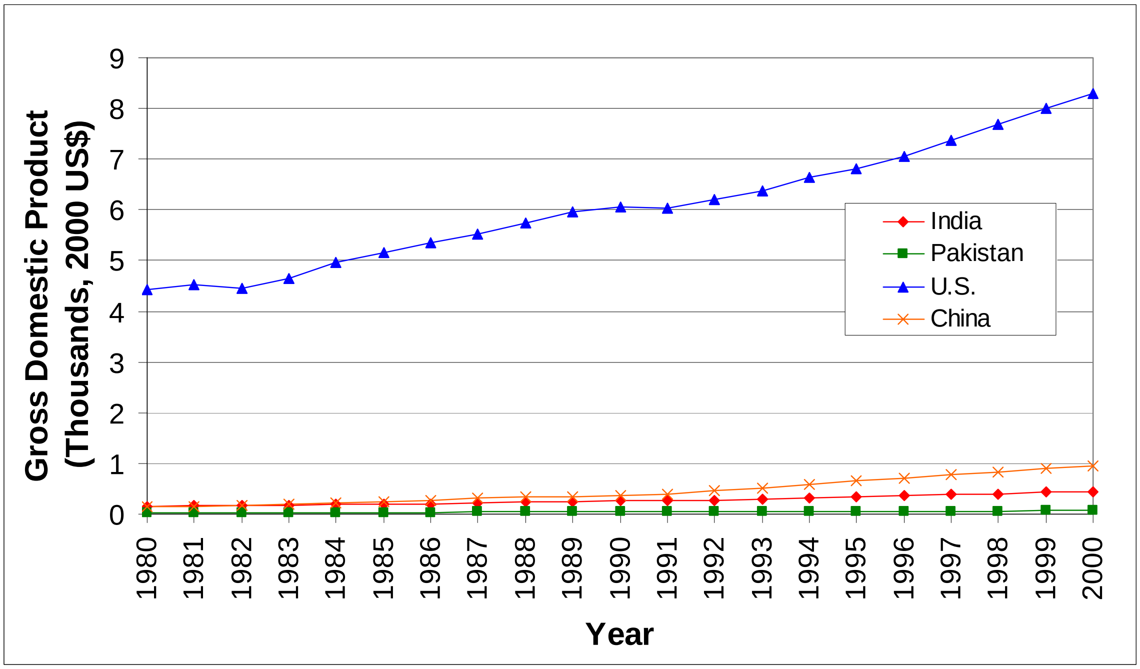

Figure 6. Gross Domestic Product for India, Pakistan, the U.S. and China (EIA, 2002; BEA, 2004)

Figure 7 illustrates the total energy used in the four countries to produce electricity.

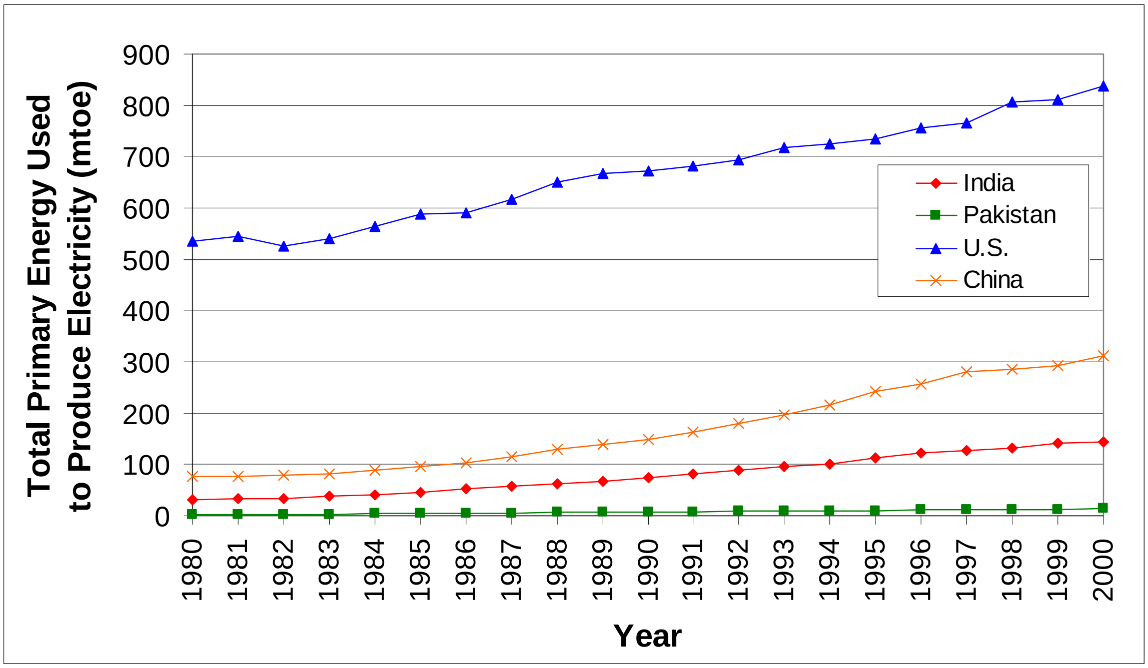

Figure 7. Total Primary Energy Used to Generate Electricity in India, Pakistan, China and the U.S. (IEA, 2002a, 2002b)

Figure 8 illustrates the total military expenditures for the four countries.

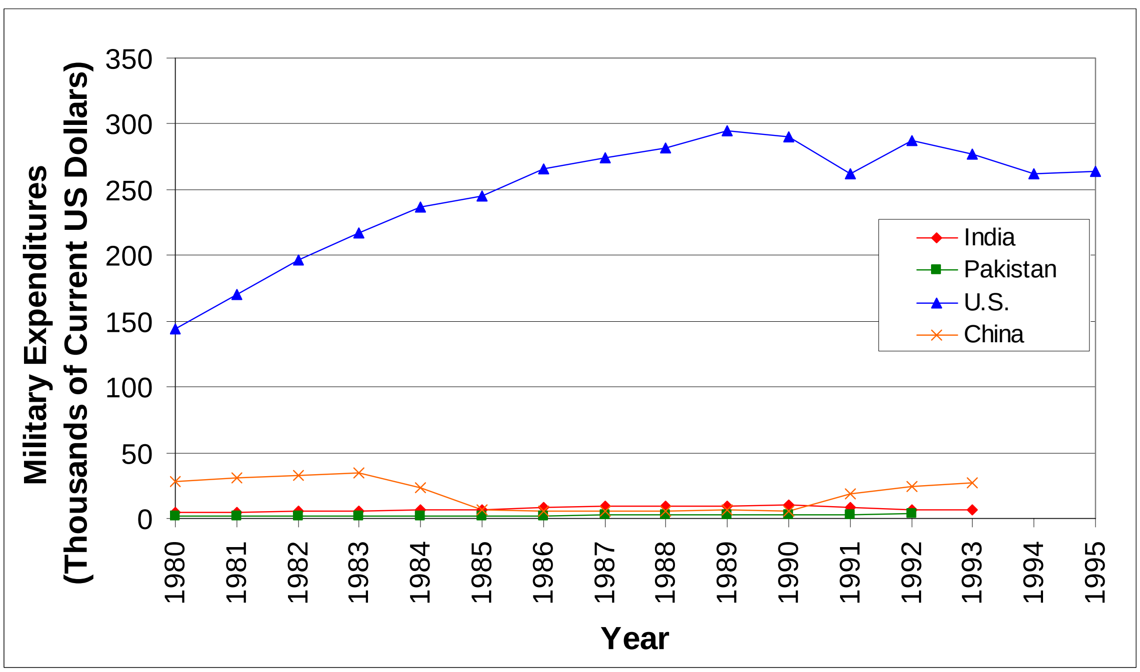

Figure 8. Total Military Expenditures for India, Pakistan, the U.S. and China (COW, 2004)

Figure 9 illustrates the number of people in the military for the four respective countries.

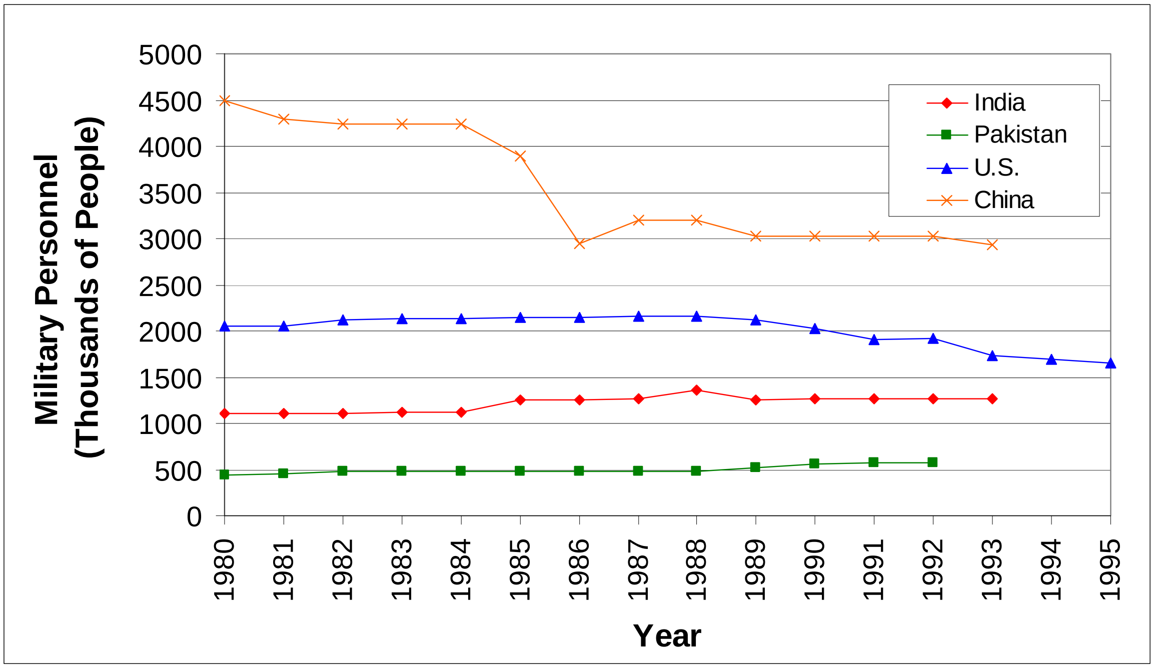

Figure 9. Total Number of Military Personnel in India, Pakistan, the U.S. and China (COW, 2004)

7. Conclusion and Further Work

System dynamics modeling, the chosen methodological approach upon which the research is based, is intended to develop a useful abstraction of real socioeconomic systems, focusing on the relationships that link concepts together, and to use this abstraction to simulate the development and behavior of the interrelated elements over time. We relied upon previous work to develop useful abstractions of conflict and tried to operationalize those abstractions using a system dynamics software tool.

In some sense, this research is a defense of the methodology, system dynamics, applied to the specific problem domain of international conflict. There have been attempts in the past that have not become part of the mainstream methodologies used by scholars of international relations. That mainstream is occupied by econometric and game theoretic approaches. However, the widespread availability of quantitative international data sets has not triggered a move toward system dynamics approaches to modeling international conflict. Correspondence with two authors[24] that previously applied system dynamics to conflict revealed that both have moved on to other areas of research. Interestingly, the international relations area of research never widely adopted

[24] Email from Dieter Ruloff, and a phone conversation with Annababette Wils.

system dynamics as an analytical tool. This lack of popularity likely stems from the prevalence of contradictory findings in the mainstream quantitative international relations literature on conflict (Beck, 2000), as well as a backlash to prior efforts (i.e. the Limits to Growth model). System dynamics is not taught in international relations programs[25] as is econometrics and game theory.

The current modeling attempts demonstrated the complexity in format, and time coverage available of the quantitative international relations data sets. Additionally, this research explored and developed a modeling methodology for conflict largely as a proof of the concept. The literature offers a multitude of variables purportedly explaining why conflict arises. The final modeling efforts demonstrate the need to further develop the methodological connection between variables that may affect conflict in a modeling environment.

We believe the data collection, hypothesis selection and the software issues related to building a interactive model in this study highlight the state-of-the-art with respect to system dynamics modeling applied to conflict modeling. Future analysis could examine additional causal links between military spending, the application of technology, demographic transition issues, sector specific resource distribution, and other factors that affect relative levels of conflict.

[25] A cursory review of web published syllabi from major universities had no mention of the key system dynamics articles related to international relations.

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Appendix A: Data Collected for the Conflict Modeling Efforts

- Population Data

U.S. Bureau of the Census. (2004). International Data Base. August 13, 2004. Dates, 1950 – 2050, http://www.census.gov/ipc/www/idbnew.html

- Gross Domestic Product

Energy Information Administration (EIA). (2004). International Energy Annual 2002, Table Reposted: June 25, 2004, B.2 World Gross Domestic Product at Market Exchange Rates, 1980-2002. August 23, 2004, Dates: 1980 – 2002, http://www.eia.doe.gov/emeu/international/other.html

- GDP Deflator

Bureau of Economic Analysis (BEA). (2004). Current-Dollar and "Real" Gross Domestic Product. August 24, 2004. http://www.bea.doc.gov/bea/dn/gdplev.xls

- Military Expenditures

Correlates of War Project (COW). (2004). Data Sets. Singer et al., (1972). July 20, 2004. http://www.umich.edu/~cowproj/dataset.html

Dates: India, 1950 – 1993
Pakistan, 1950 – 1992
U.S., 1950 – 1995
China, 1950 - 1993

- Total Energy, Total Energy for Electricity

International Energy Agency (IEA). (2002). Energy Balances of Non-OECD Countries. 1971 – 2000. TPES, Total Primary Energy Supply. OECD/IEA, Paris, France.

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- Military Personnel

Correlates of War Project (COW). (2004). Data Sets. Singer et al., (1972). July 20, 2004. http://www.umich.edu/~cowproj/dataset.html

Dates: India, 1950 – 1993
Pakistan, 1950 – 1992
U.S., 1950 – 1995
China, 1950 – 1993

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