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TECHNICAL REPORT

A Computational Model of Public Support for Insurgency and Terrorism

A Prototype for More-General Social-Science Modeling

Paul K. Davis • Angela O'Mahony

Prepared for the Office of the Secretary of Defense

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Summary

Overview

This report is part of a longer-term research agenda that began with a 2008–2009 RAND study reviewing and integrating social-science knowledge related to counterterrorism. That study used qualitative conceptual causal models called "factor trees" to show compactly all the different factors contributing to various aspects of terrorism at a slice in time and how the factors relate to each other qualitatively. That work reflected a considerable base of social-science knowledge. In the 2009–2011 period, the factor trees were subsequently tested and refined in empirical studies; they were also used in a variety of applications.

This report describes a next step. Going beyond the conceptual and qualitative, we have specified and implemented a prototype *computational* model (PSOT) for just one of the earlier factor-tree models, that addressing public support of terrorism and insurgency. The earlier model is extensively discussed in Davis, Larson, et al., 2012. The factor tree itself is shown in Figure S.1. Our prototype seeks to describe, as a function of contributing factors, the extent to which a nation's public supports an ongoing insurgency and its use of terrorism. The support may involve, for example, sympathy, approval, material contributions, sheltering from the government, or direct participation in insurgent operations. Public support is a complicated aggregation because "the public" is often heterogeneous with numerous disputing factions. Moreover, public support is not a purely "rational" behavior predictable with a stable utility function.* We undertook building a computational model with trepidation because characterizing the mathematics of how factors *combine* required going well beyond the established science base.

Approach. Our approach to modeling is systemic and causal, rather than statistical as in much social science. In contrast to most computational modeling, we emphasize transparency and explicit treatment of uncertainty. We *routinely* show model results as a function of parameters, thereby making results contingent on contexts and assumptions. This is quite different from the norm of constructing a single model treated as though it were "correct," constructing an approved database for all the input assumptions, running the model, and reporting the results as a point prediction (perhaps with minor sensitivity testing). That is, it is different from treating the model as an "answer machine."

Static Versus Dynamic. Factor trees and our prototype model are aggregate-level static models intended to (1) sharpen and clarify knowledge elicitation; (2) improve the coherence of discussion assessing and diagnosing a situation; and, more qualitatively, (3) to improve the ability to reason about how change in the situation can come about and what factors might

* Such issues and subtleties are discussed in Davis, Larson, et al. (2012). They are not repeated here.

be correspondingly influenced. These models are not themselves dynamic; that is, they do not predict changes over time, although they do provide a partial language for discussing change. As discussed in Davis, Larson, et al. (2012), we urge users of these static aggregate-level models to complement them with influence-diagram and system-dynamic methods that focus on time dependence, and with models that delve more deeply into faction-level dynamics within a complex society. The aggregate-level static models, however, are very useful first steps in themselves, especially to aid higher-level reasoning.

Character of Report. This report is inherently technical, analytic, and even mathematical: After all, it explains and documents a computer model. Nonetheless, our intent has been to maintain close contact with the social-science phenomena and understandable qualitative theory, rather than becoming lost in mathematical and programming details. We intend that the report's primary concepts be accessible to a broad range of readers, while also providing the rigorous detail necessary for modelers and analysts.

Finally, we emphasize that the report describes a prototype model illustrating concretely a new approach. The prototype model itself should be seen not as a definitive end point, but rather as a serious straw man to be reviewed, debated, and improved upon.

The Research Challenges

The conceptual factor-tree model for the prototype is shown in Figure S.1. If an arrow points from one variable (factor) to another, it means that more of the former tends to increase the latter if the influence is positive (the + sign is omitted by default). If the arrow bears a negative sign, then more of the former tends to decrease the latter. If the arrow bears a "+/–" sign, then even the direction of the influence is uncertain.

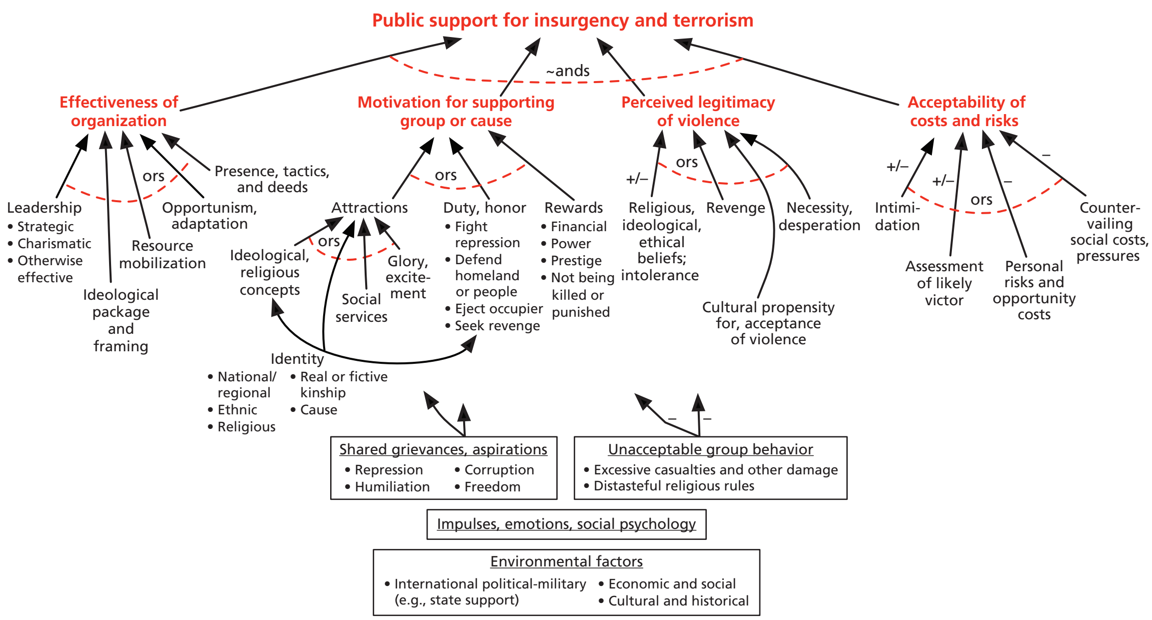
The tree includes tens of factors, but they are arranged in layers because most factors have their effect through higher-level factors. Technically, this is multiresolution modeling; it also reflects the way humans routinely reason.

In Figure S.1, the highest-level factors are connected by "~ands," implying that the top-level effect depends to a first approximation on *all* of those factors being present. In contrast, the lower-level factors are combined with "ors" (implying that the higher effect depends on some combination of the lower-level effects, with no one of them being necessary). For a particular country at a particular time, the influences in a factor tree may have influence arrows of varied thickness to indicate that some are more important than others (not illustrated in Figure S.1).

Some factors, shown at the bottom of the figure, are cross-cutting. For example, if the United States were drawn into a new war in the Middle East, that would probably affect the subsequent values of numerous factors in the tree itself. Some of these cross-factors can be seen as environmental; others relate to culture and emotions.

Building a computational model based on a factor tree posed numerous challenges, as summarized in Table S.1. This list guided our research. The challenges were in four blocks, as indicated by shading in the table: (1) defining the factors and their values; (2) defining how to reflect cryptic factor-tree "and" and "or" relationships, ambiguous influences indicated by +/– signs, and the varied significance of influences sometimes indicated by arrow thickness (illustrated in the text, but not Figure S.1); (3) dealing with uncertainty about factor values and combining rules, and showing results of exploratory analysis across uncertainties; and

Figure S.1
Conceptual Model for Public Support of Insurgency and Terrorism



NOTES: Applies at a snapshot in time. Current factor values can affect future values of some or all other factors.
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Table S.1
Challenges and Issues

Challenge	Issues
Define factors and factor values	How many values are sufficient? How can soft and fuzzy variables be reasonably defined?
Define “and” connections mathematically	How rigid should the relationship be? How can uncertainties be reflected?
Define “or” connections mathematically	How many alternative functional relationships are needed?
Define ambiguous and conflicting influences (+/– signs) mathematically	What does the ambiguity mean? How can it be represented?
Represent implications of line thickness in factor trees	How should relative importance of factors be understood and represented in the model?
Represent uncertainty of factor values	Should this be done by giving ranges of parameter values or by using probabilistic methods?
Represent structural uncertainty of combining relationships	Should this be done with alternative models, structural parameterization, or both?
Build model for exploratory analysis under uncertainty	How should far-reaching exploratory analysis be accomplished? When should probabilistic methods be used?
Assess “confidence” of nominal factor-value estimates and of model outputs	How should this best be accomplished?
Implement model in understandable high-level language	What language? How can the model be made transparent, comprehensible, and easy to re-implement (a form of reuse)?

(4) implementing the model in a computer program in which substantive content is transparent, comprehensible, and as language-independent as possible so as to facilitate model re-use, model composition, or rapid reprogramming.

Our Solutions to the Challenges

An important element of the research was identifying logical/mathematical relationships to express the intended social-science knowledge and uncertainty. For the problem treated by the prototype—and hopefully for a broader class of social-science problems—we found a minimal set of mathematical building-block methods that seemed sufficient. We present these methods as hypotheses to be reviewed and tested empirically by methods of social psychology and political science. Briefly, the methods we suggest are as follows.

Defining Factors and Their Values

It is often comfortable and natural when discussing social issues to use qualitative values such as "Very Low" or "Very High," so we constructed much of PSOT's interface accordingly. In doing so, we had to keep track of whether, e.g., a "Very High" influence was positive or negative. Values within the model are represented numerically on a continuous scale from –10 to 10, but a discrete set of corresponding qualitative values can be used instead, with 1, 3, 5, 7, and 9 corresponding to Very Low, Low, Medium, High, and Very High (with the influences being either positive or negative). A truncated set can be used with 3, 5, and 7 corresponding to Low, Medium, and High. Precisely what these values *mean* depends on the particular problem, but they must be approximately "equally spaced" rather than merely indicating relative order. To establish meaning, we take the common qualitative social-science approach of defining by example using short narratives. How values can be estimated by convenient measurements is a general and context-dependent challenge outside the scope of this report. In particular settings, a given factor's value may be well approximated by something as concrete as polling results, but in other cases that same class of data will be misleading or unavailable.

Combining Relationships

Factors Combining by "~and" Relationships. How should we represent an "~and" relationship? If factors were binary, with values of 1 (present) or 0 (not present), the mathematics would be as in elementary logic. However, with factors that can have values such as Low, Medium, or High, the issue becomes more subtle. We represent approximate "and" relationships with *thresholded* linear weighted sums, which allow for such nonlinearities as critical-mass phenomena. In this approach, the higher-level effect (e.g., public support) is assessed as small unless all of the contributing factors reach or exceed their threshold values, in which case a linear weighted sum can be used. If all thresholds are set to their least-demanding levels, the relationship reduces to a simple linear weighted sum.

Factors Combining with "or" Relationships. We found it sufficient to distinguish between two starkly different kinds of "or" relationships:

1. Primary Factors: The effect depends on the largest factor, with possible adjustment by a second factor.

2. Thresholded Linear Weighted Sums: Factors that exceed their threshold are combined linearly; using thresholded linear weighted sums allows for both dilution and reinforcement.

Which is most apt will be context-dependent, but one or the other will be sufficient in a wide range of contexts. That is, the mathematical toolkit need not be too large.

Factors with Ambiguous Influence (+/– signs). Factor trees use +/– to indicate that the directionality of an influence is uncertain. We distinguished between two very different reasons:

1. Stochastic Behavior: The influence's sign is effectively random because the underlying factors in conflict are unknown, unobservable, rapidly changing, or some combination.
2. Conflicting Influences: The influence is the result of two or more understandable conflicting lower-level influences, such as might occur when two population factions have opposite positions on an issue (in the prototype effort, we did not consider larger numbers of factions). Enough may be known to represent these and to estimate their resolution.

We reflect effective randomness by considering the input to be uncertain and either showing results for both cases (deterministic analysis) or treating the factor probabilistically. For conflicting influences, we use a function that assumes that the stronger of the sub-influences *largely* determines the result, but with the degree of domination controlled by an uncertain parameter.

Again, we emphasize that there is no single "correct" mathematical function for these several combining relationships. The actual combined effect will depend on context and sometimes on microscopic history. For example, in a particular situation, the dominant faction's perspective may altogether dominate because recent bad blood between leadership factions has made any other outcome untenable. The opposite could also occur, where personal relations and recent history makes compromise appropriate and feasible. Sometimes, but only sometimes, will experts know enough about such matters to make reasonable conjectures about which algorithm is more apt.

The toolkit of combining relationships that we settled on can be regarded as hypotheses about combining relationships to be tested in psychological research and case studies, both to determine the adequacy of the choices we provide and to better understand when one applies rather than another (e.g., When are threshold effects stronger and weaker? When does the strongest factor altogether dominate?).

Representing Uncertainty

We designed PSOT for exploratory analysis under multidimensional uncertainty (i.e., analysis that shows results for all combinations of the relevant factor values). We prefer to do exploratory analysis deterministically—establishing a discrete range of plausible values for each input, running all the possible combination cases, and then looking for patterns indicating what combinations of factor values lead to results that are good, bad, or indifferent. The analyst and decisionmaker can then make judgments about the relative plausibility of the different domains before reaching conclusions or taking actions. This approach has been used by RAND in many studies over the past two decades in connection with planning for adaptiveness and robust decisionmaking.

We also use an alternative approach that characterizes each input with a probability distribution and generates a probability distribution for results. This is sometimes appropriate and valuable, but can obfuscate causal relationships and be seriously misleading if correlations are ignored. If there are numerous uncertain factors, then it is sometimes best to use the hybrid approach of treating the most important of them deterministically while treating the others stochastically.

When probabilistic methods are appropriate, we use several methods:

Stochastic Functions. For probabilistic work, we used triangular distributions and Monte Carlo sampling. The triangular distribution represents asymmetric uncertainties, is readily understood by non-mathematician experts, and connects well to a "most likely" value. The analyst may increase the uncertainty range beyond what experts suggest because empirical evidence indicates that experts routinely underestimate the probability of low-probability events.

Correlations. It is incorrect to assume independent probabilities for many of the factors appearing in models such as ours. Attempting to model correlational details among numerous variables, however, would not be justified by the available knowledge and would complicate both interaction with experts and analysis. Thus, we adopted a parametric approach correlating a bundle of factors with a single variable parameter. This is sufficient to assess the significance of correlations to results.

Assessing Confidence. Uncertainty analysis can generate not only "expected value" or "mean" results, but also confidence intervals. Those can be based on deterministic or probabilistic calculations, as above. The inputs for the estimates may be made at different levels of detail. Confidence estimates are often more trustworthy and humbling if based on holistic expert judgment or historical information, rather than detailed calculations reflecting only specific known uncertainties.

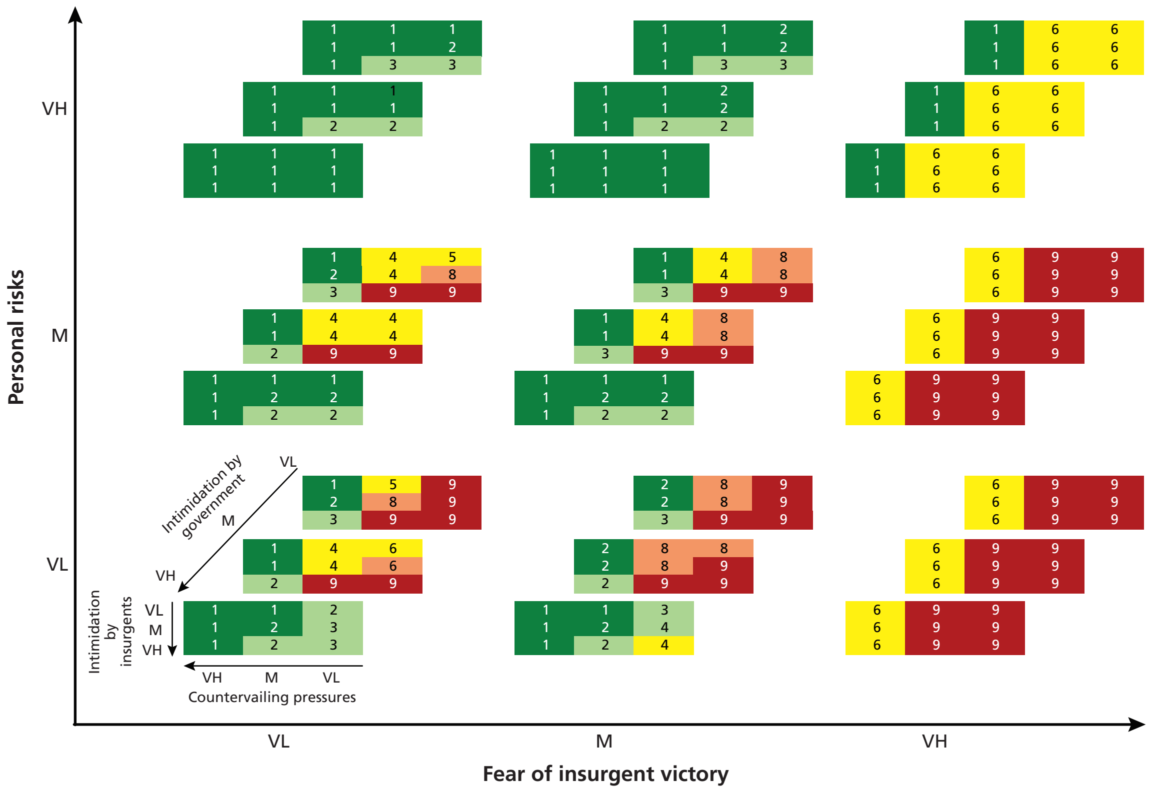
Implementation

We wanted to implement the model in a way that would permit substantive review, re-use, and composability (using the model in combination with others). With this in mind, we used the high-level programming language Analytica. The model's content can be largely comprehended without dealing with programming issues. The model is expressed visually (in influence diagrams) and, at the next level of detail, in a relatively simple syntax closely tied to mathematics rather than procedural programming. The result is intuitive for those with some background with vectors, matrices, and arrays. This tie to mathematics also makes the model especially suitable as a specification model available to researchers generally.

Exploratory Analysis to Understand Context- and Assumption-Dependency

Our study reports model building rather than analysis, but we illustrate exploratory analysis over uncertainty. Figure S.2 shows PSOT results for the extent to which "the public" will regard the costs and risks of supporting the insurgency and its terrorism as acceptable. That is, what combinations of factors would create a net sense of unacceptable costs (such factors are colored green in Figure S.2, because they are good from the counterinsurgency perspective) or low costs (shown in red)? Results are shown as a function of five factors: (1) intimida-

Figure S.2
Illustrative Exploratory Analysis: How Public Support for Insurgency Depends on Five Uncertain Factors



NOTES: The numbers shown are the values used internally in PSOT. Because low acceptability of costs and risks is good for the counterinsurgent side, the colors for 1, 3, 5, 7, and 9 are green, light green, yellow, orange, and red, respectively.
RAND *TR1220-S.2*

tion by the insurgents, which raises acceptability of support by making it dangerous to *not* support the insurgency; (2) intimidation by the government; (3) fear that the insurgents will win; (4) countervailing social pressures (e.g., the urgings of family respected leaders not to provide support; and (5) other personal costs of support. Figure S.2 reflects the Primary Factors approach mentioned above.

Such a depiction can help in diagnosing the seriousness of a situation, discussing what factors must be changed to move to a better situation, and assessing the relative leverage of factors (which may or may not be subject to influence). The model, then, is not about prediction, but about improved diagnosis and reasoning. It can be especially valuable in dampening enthusiasms when one factor is subject to influence but the net effect is unlikely to be significant, or in suggesting approaches in which moderate influence on two or more factors may have synergistic favorable effects.

Conclusions and Next Steps

The prototype effort demonstrated the potential for markedly improving representation of social-science knowledge, eliciting knowledge from subject-matter experts, dealing with uncertainty, and working on the components of more or less composable models. Next steps should include the following:

- Experimentation *using* the prototype model for reviews, substantive discussion, knowledge elicitation, and exploratory analysis for particular applications, such as understanding data from Afghanistan, Iraq, or Yemen.
- Working with government offices to create efficient processes for exposing such models to peer review by the scholarly and operational communities, after which revised versions could be considered as vetted "modules" for model composition.
- Building analogous "specification models" for other aspects of terrorism, insurgency, and irregular warfare. Each could be used on its own or become a module in more comprehensive system models.
- Extending the methods to other social-science domains.

Social science is notoriously difficult—and, as the cliché goes, much "harder" than the hard sciences. Nonetheless, social science contains extraordinary amounts of knowledge. Our report is one step in the process of learning how to better represent that knowledge in increasingly rigorous, albeit often qualitative and uncertainty-sensitive, systemic models.

As a final comment, an enormous amount of information has been gathered over the past decade regarding both insurgency and terrorism. However, it has not come together well, and the potential exists for the information to vanish with time and new priorities. If the knowledge is to be captured and expressed coherently, before memories fade and data disappear, models like PSOT could prove quite valuable because they can be individually understood, reviewed, debated, and put on the shelf (while maintaining their flexibility and treatment of uncertainty).