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PRIMER FOR BUILDING FACTOR TREES TO REPRESENT SOCIAL-SCIENCE KNOWLEDGE

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ABSTRACT

Factor trees are relatively simple causal diagrams that indicate the many factors contributing to a phenomenon or effect at a snapshot in time. They consist of nodes and directional arcs (arrows) arranged in nearly hierarchical layers so that the effect can be seen as depending on a few high-level factors, but with those depending in turn on more detailed factors. This paper is a primer on building general and context-specialized factor trees; it includes subtleties and admonitions based on experience in several recent integrative studies on social science knowledge relating to terrorism, public support of insurgency and terrorism, and stabilization and reconstruction. It also discusses experiences with efforts to validate such conceptual models. Finally, the paper notes limitations and suggests supplementary methods.

1 INTRODUCTION

1.1 Background and Motivation

As RAND conducted a critical review of the scholarly social-science literature bearing on terrorism in 2008, it soon became evident that while the literature is quite rich, it is also fragmented and heterogeneous. The resulting book (Davis and Cragin 2009) bore the subtitle “Putting the Pieces Together.” In attempting the integration, we began with baby steps to maximize communication across professional boundaries and to limit goals to characterizing what is actually known or reasonably inferred, rather than merely speculated (Davis 2009). We sought to identify the primary *factors* contributing to terrorism because specialists are very good at identifying factors—especially when their knowledge is pooled. We then arrayed those factors graphically in approximate “factor trees” so that readers or viewers could–at a glance—see the many factors at work and how they relate to each other. This was conceptual modeling, and a contribution toward generalized theory, but deliberately simplified.

Even initial factor trees can be good straw men to elicit further expression of knowledge and to stimulate discussion. Expert viewers will quickly and vociferously point out omissions and ambiguities—precisely what is sought in collaboration and review. The iterated factor trees can be very useful as *thinking models*—i.e., conceptual models to structure reasoning and, as appropriate, to inform building more complete models, including computer models (e.g., by informing the identification of objects, attributes, and processes to be included).

The early factor trees were well received by scholarly and applied audiences, officials, and senior military officers. However, analysts attempting to build new factor trees encountered difficulties. Some asked for a simple, down-to-earth primer. The result, this paper sponsored by the Human, Social, Cultural and Behavioral Modeling Program (HSCB), evolved over the course of two years with the benefit of a study for the Office of the Secretary of Defense on social science informing stabilization and reconstruction (Davis 2011) and a study for the Joint Improvised Explosive Device Office (JIEDDO) on public support for insurgency and terrorism (Davis et al., forthcoming). RAND colleagues Kim Cragin, Todd Helmus,

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and Brian Jackson also completed studies on empirical work testing the factor trees of the earlier work on terrorism (Davis and Cragin 2009). Robert Sheldon and colleagues, working for the U.S. Marine Corps Combat Development Command, has used an interesting variant of factor trees in their work, which they call influence factor diagrams (IFDs), in part to elicit expert information for specific contexts.

1.2 Structure of the Paper

Section 2 describes the basic concepts of factor trees briefly, in part reviewing prior discussions for the sake of being self-contained. Section 3 goes on to discuss more subtle aspects, including conventions and points of common difficulty. Section 4 illustrates factor trees motivated by the recent studies. These demonstrate how factor trees can convey different *kinds* of knowledge and how they can be specialized for particular contexts and compared across contexts. Section 5 discusses validation efforts. Section 6 gives brief conclusions.

2 THE BASIC CONCEPTS

2.1 The Simplest Cases

In the simplest version (Figure 1a), a factor tree is laid out vertically with nodes connected by directional arcs (arrows) that point primarily upward. The top-most node D represents an effect (e.g., the propensity of someone to take an action). Lower-level nodes A, B, and C point to the top-most node, which means that they are factors contributing to that effect. They may themselves be effects of still lower-level factors as shown later.

As in Figure 1b, an arrow may bear a sign of +, -, or +/-; the absence of a sign means that a + sign applies. A positive arrow connecting two factors, say A and D, means that more of A will tend to mean more of D, and certainly not less. A negative sign means that the effect will tend to be reduced by more of the cause, but will certainly not be increased. A +/- sign implies that even the directionality of the effect is uncertain. In many instances, it is possible to avoid such an ambiguous influence by adding details—i.e., replacing an ambiguous influence with two or more factors with individually unambiguous influences.

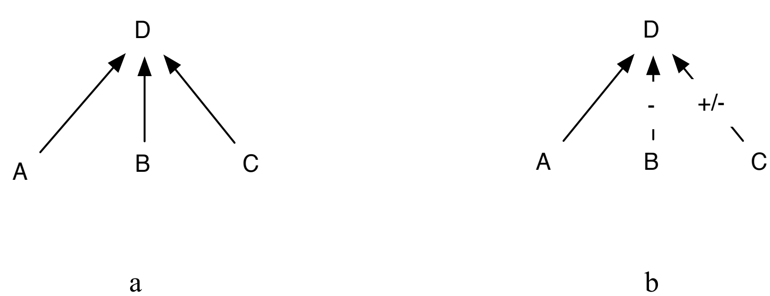


Figure 1: Simple Factor Trees

Unfortunately, it is not always possible to avoid the +/- ambiguities, especially in social science. One reason may be that we simply lack the information. For example, a particular leader may support or resist some activity when the time comes, but we don't yet know the leader's stance. A second reason may be that the phenomenon is afflicted by hidden variables with the result of apparent randomness.

The above discussion used the word "tend" because actual effects are context dependent. In Figure 1a, the effect of increasing A will depend on the values of B, C, and D (e.g., as in Figure 2). I have in mind that functional relationships will be semi-monotonic (non decreasing or non increasing). Although some articles in the social-science literature report inverted U-shapes, where an effect D first increases with A and then decreases, such findings are typically artifacts of hidden variables and relate to correlations rather than causality. For example, looking across many cases, countries with modest democratization may have more terrorism incidents than ones with none or very high levels. A reason is likely to be that many of the countries with limited democratization also have weak security apparatuses (a hidden variable of the analysis).

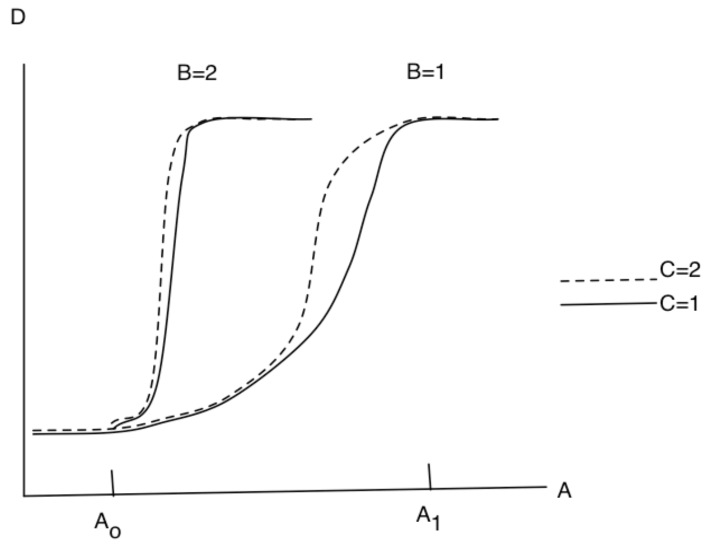


Figure 2: A Factor's Influence Depends on the Other Factors' Values

2.2 Approximate Combining Logic

We can sometimes add information on combining logic to the trees. To illustrate, suppose first that the nodes can have only binary values such as Yes, No. We can then add dashed, curved connector curves with "ands" or "ors" to indicate how factors tend to combine. Figure 3 shows several examples. If the factors are all binary, then in the leftmost figure, A, B, and C must all be present for the effect D to occur. In the middle figure, all that we know is that A, B, C, or some combination must be present. In the rightmost figure, C and *either* A or B must be present. If A, B, and C are all critical components, then they should be connected by "ands:" the absence of any one of them would mean that the effect will not happen. If they are substitutable for each other, then "ors" are appropriate. In political science such relationships are referred to in terms of "contingent" possibilities (George and Bennett 2005). Considerable social-science analysis can be done with binary logic or fuzzy-logic extensions (Ragin 2000; Ragin 1989).

An important generalization interprets the "ands" and "ors" by whether the values of the various factors are or are not above thresholds of significance. Thus, A, B, and C need not be binary. For the leftmost case of "ands" in Figure 3 there would be no significant effect unless *all* factors exceed threshold values. Thresholds are common in social phenomena (e.g., critical-mass effects). Analytically, use of thresholds sometimes allows us to treat effects of nonlinear phenomena with an initial filter (a *product* of factors) and subsequent linear-weighted sums. This can be used in social-science modeling (Davis 2006).

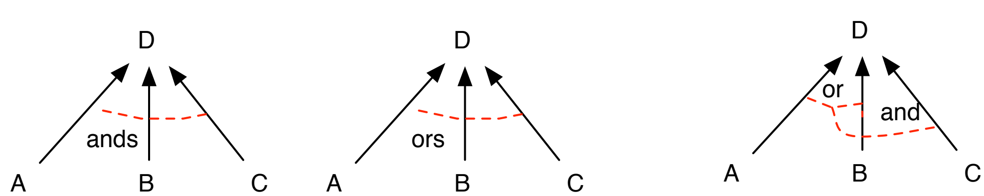


Figure 3: Factor Trees with First-Order Combining Logic

2.3 Feedback and Other Aspects of Dynamics

As most readers will appreciate, describing many systems of interest requires worrying about dynamics. Corresponding diagrammatic depictions can become complicated quickly, however. The elegant influence diagrams of System Dynamics (Forrester 1961; Sterman 2000), for example, may seem like a mere blur (or even a "fur ball") to those unfamiliar with them. For the sake of good two-way communication with heterogeneous audiences, including many social scientists with no background in system work, our factor trees normally suppress dynamics (by exception, feedbacks can be shown with backward pointing dashed arrows). The point is not to deny dynamic effects, but rather to focus attention on the causal influences in effect "now." Factor trees show factors at work at a snapshot in time. Technically, this is often reasonable because many aspects of a system's dynamics have effects over relatively long time scales and, thus, can be separable. A second reason is that the opposite case may apply: feedbacks may occur so quickly as to be not worth troubling about. If a system equilibrates quickly, we need not agonize about the processes by which it does so. This said, the argument is to deal with dynamics separately when possible, not to ignore them. But for the distracting effects of doing so, it would be good practice to annotate factor-tree charts with a footnote such as:

This diagram reflects causal influences at a snapshot in time. Significantly later values of factors may depend on earlier values of many other factors on the tree. That is, interactions over time may be many, significant, and highly cross-cutting.

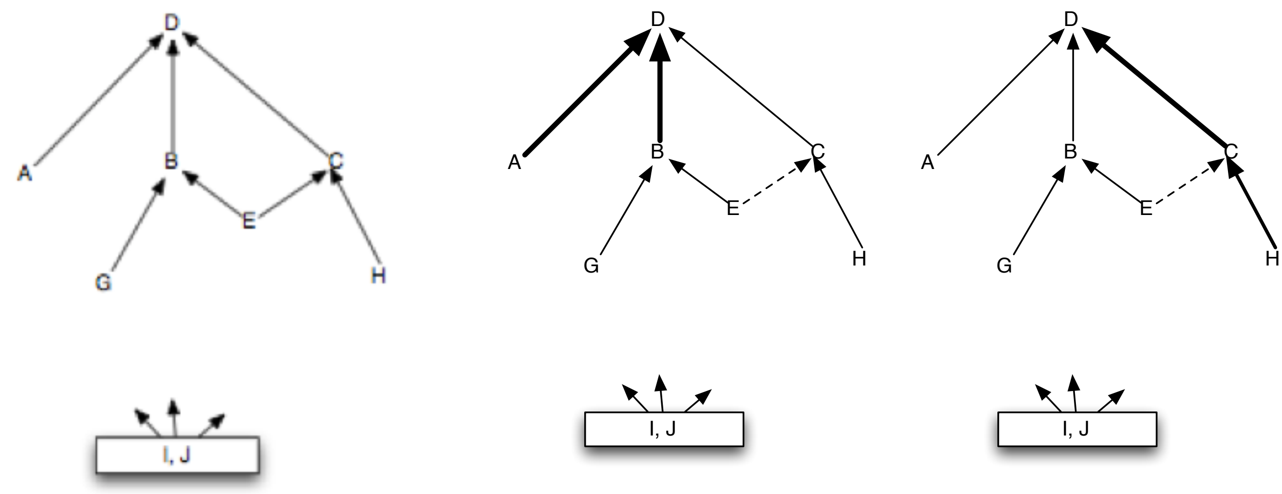
2.4 Imperfect Hierarchies and Unequal Influences

The term "factor tree" arose because we aspired to diagrams that were approximately hierarchical: such diagrams are very useful for both analysis and discussion. The idea, in many strands of work, is that we need a high-level view of the whole (breadth), but to "understand" and stay out of trouble we also need the ability to drill down into detail ("zoom"). This is arguably a design principle for high-level decision support (Davis, Shaver, and Beck 2008). It is especially feasible with hierarchical decomposition, whether in social science or, say, systems engineering.

Significantly, factor trees need not be purely hierarchical and seldom can be in a rigorous description: the real world being modeled is just too complicated. In Figure 4a, E influences both B and C, thereby making the "tree" a bit bushy. In addition, there may be some factors I and J that influence many or all of the higher-level factors. These are like "global variables" in programming, and are shown at the bottom of the factor tree in one or more boxes.

Often, the factors influencing an effect are not equally important and it may be possible to make useful qualitative distinctions. Figure 4b illustrates this for two different cases (i.e., different contexts, as when one is discussing issues in one country or another), one in which A and B are much stronger influences on D than is C; and one in which C is the much stronger influence. In both cases, D depends ultimately on A,G,E, and H; but E's effect on D is small except through its influence on B. If the linkage of E to C is ignored, then the diagram is strictly hierarchical except for the global variables I and J. As in multiresolution modeling generally, approximations are liberating (Davis 2003).

If the cross-branch interactions are too numerous, or the global factors too dominating, the concept of the factor tree becomes dubious. Some systems are best depicted differently (e.g., social-networks systems or hub-and-spoke systems). Fortunately, many complex systems in the real world are "nearly decomposable" with important hierarchical features (Simon 1981). Even highly networked systems often have hierarchical features.



a b (for two different cases or contexts)

Figure 4: Approximately Hierarchical Trees for Different Cases

3 WHAT CAUSES DIFFICULTY? SUBTLETIES AND ADMONITIONS

In the course of the last 2-3 years, my colleagues and I have had numerous opportunities to use factor-tree methods, and to engage with analysts in other organizations who have also adopted the methods. Not surprisingly, a number of puzzles and complications arose, and some things that seemed intuitively obvious at first proved less obvious to others. What follows are suggestions based on that experience.

3.1 Distinguishing between General and Specific Factor Trees

The factor trees that I had in mind in our original work (Davis and Cragin 2009) were intended to be relatively general—a kind of "general theory lite." A major purpose was to incorporate factors and causal pathways that were usually discussed separately and narrowly. Any such general depiction, however, will necessarily be abstract. This is very satisfying to some, but not to those who would prefer to see only those factors applying in a specific context of interest and with those factors expressed as concretely as possible (e.g., referring to a particular strength of a particular tribe in a particular region and time).

What has been confusing, sometimes, is how the general and specific relate to each other. A factor tree intended to be general will include factors that do not apply in some of the specific contexts of interest. A general factor tree, then, may be good as a *starting point* for a context-specific application (a kind of template). When used as a starting point, the intention is that the factor tree indicate what factors to look for, i.e., what kinds of factors *might* be important in the particular context. In an application, it might quickly be concluded that only a subset are in fact significant, at which point the factor tree could be simplified in scope but made more concrete in other respects. The general factor tree, however, can also be seen as suggesting what additional factors could in the future *become* important for the particular context. That is, it may help anticipate changes, recognize them when they occur, head off possibilities before they become troublesome, and recognize and exploit positive opportunities. It is for such reasons that general theory is powerful and fundamentally different in kind from what is often called "theory," but is actually something far more narrow (what might be called a "theory-oid" by analogy with "factoid").

My caution here, then, is that even those who are focused on a particular context and need a high degree of specificity to operate can benefit greatly from working back and forth between relatively more general and relatively more specific conceptual models.

3.2 What Factor Trees Are Not

One of the most common errors in trying to use factor trees is to confuse them with other graphical methods. Factor trees are *not stock-flow diagrams* in the sense of System Dynamics, although they are related to what System Dynamics calls causal loops (Sterman 2000) and most factors are akin to "stocks" in system dynamics. As suggested by its name, System Dynamics emphasizes dynamics (especially feedbacks) and broad system views. Factor trees suppress dynamics and may pertain to only one "module" of phenomena.

Factor trees are also not the influence diagrams of *Bayesian-net or influence-net models*, where the nodes are characterized by probabilities or probability distributions (Rosen and Smith 1996; Wagenhals, Levis, and Halder 2006). Ordinarily, the factors are characterized only by quantity or degree. This said, there is an intellectual relationship between the two methods and much of the thinking that goes on in factor-tree work could be carried over into Bayesian-net or influence-net modeling. Indeed, both the current work with factor trees and early influence-net modeling drew upon my own multiresolution qualitative modeling of decisionmaking in the early 1990s (Davis and Arquilla 1991) as cited in the Rosen-Smith article.

Factor trees are most decidedly not *decision-analysis* trees. The nodes are not decision points with branches corresponding to different decision outcomes. Those who are familiar and comfortable with decision trees may find themselves trying to twist factor trees into that kind of representation. Doing so is a mistake although, as shown later, the factors affecting a decision can readily be shown and the top-most node (the "effect") can be something like the likelihood of a particular decision.

Factor trees are not strategies-to-task (STT) decompositions of the sort used in defense work (Kent and Simons 1991), but they may have a significant intellectual relationship. An STT diagram has an objective or strategy at the top. It then identifies all of the component actions to be taken (or the corresponding subordinate objectives), and the components of those, recursively, until—at the lowest level—it identifies concrete "tasks" to be accomplished, such as closing an airfield or mining a maritime choke point. This said, many STT constructs can be mapped into corresponding factor trees by reconceptualizing objectives and subordinate objectives as variables with quantity or degree. For example, if the military mission to be accomplished is expressed as a verb, such as "Halt an invading army," and if the STT construct identities different organizational submissions and tasks, the problem can be reconceptualized as a factor tree with "Depth of the invader's penetration before being stopped" as the top node, which would be determined by factors such as the defender's resources and capabilities, operational strategy, command and control, and execution effectiveness. A computational model for assessing related capabilities can described with what is essentially a factor tree, with many levels (Davis, McEver, and Wilson 2002).

For social scientists, another type of confusion arises because social scientists are steeped in statistical methods where a "model" is typically a regression equation used to infer correlations among variables observed in data. That is often very different from representing causality, although the gap can be narrowed using econometric methods if the data is rich and the experiments controlled (Angrist and Pischke 2009). Nonetheless, even econometricians think about causality differently than I do in this paper because they tend to be data-driven rather than theory-driven. Causality is a deep issue in science, mathematics, and the philosophy of science (Pearl 2009; Dowe 2008). In some systems work, the concept of causality is weakened because of feedbacks: ultimately, everything is related to everything. In that case, we may wish to see causality as something more local in time than fundamental.

3.3 Admonitions for Those Building Factor Trees

People using factor trees will find their own way, but the following items constitute some advice.

3.3.1 The Importance of Words

Factor trees are fundamentally mechanisms for communication. Their success or failure depends on the words used to identify the factors. It is crucial in factor-tree work to name the nodes carefully and with a premium on intuitive concepts. Some of the attributes of such naming include:

- Brevity
- Pointedness (e.g., "revenge" rather than "ill feelings," if revenge is really the point)
- Nouns rather than, say, the verbs that might be used in a decomposition identifying actions
- Plain-language terminology in preference to specialized jargon or academese

Unfortunately, many words that we think to use have multiple meanings, sometimes in conflict with each other (antagonyms), some with insidious baggage. A factor such as "room for compromise" might suggest something good, or—to other people—the potential for the abandonment of principles. Using "fundamentalist beliefs" as a factor can usefully highlight the role of black-and-white thinking and related intolerance, but such a name could be offensive to some. A compromise in that case might be "Fundamentalism and active intolerance." It would convey the point that most of those holding fundamentalist beliefs do not actively seek to deny others their own beliefs, or to interfere with their lives.

3.3.2 Distinguishing Factor Trees from Decompositions

A source of much difficulty in building factor trees has been the tendency to confuse factors with components. The syntax to remember is that of a function. In Figure 1, D is a function of the factors (independent variables) A, B, and C. It might also be the case that D can be broken down into components. These might represent, for example, geography, gender, age, or ethnicity. The problem here is that, if one starts showing "components," diagrams can quickly become cluttered and more confusing than helpful.

Some guidance here is

- When discussing factors, think of them in terms of "contribute to" or "are independent variables determining," rather than "is a part of."
- Do not distinguish between components unless the distinction needs to be highlighted.
- Do not distinguish between components that change by the same processes (albeit with different parameter values).
- Think of the factors as multi-dimensional arrays.

This last item may remind readers of the virtues of specialized modeling systems such as *Analytica* (Lumina Corporation), which encourage thinking and modeling in terms of arrays, rather than scalars. Just as the beauty of Newton's Laws, Maxwell's equations, or Einstein's general relativity theory are evident only when such notation in used, so also the fundamental character of many policy-analytic and social-science phenomena are best understood by using such arrays (Morgan and Henrion 1992). A military example is illustrated in Davis, McEver, and Wilson (2002). Unfortunately, this chunking does not come easily in most programming languages, even if it is permitted.

3.3.3 Comprehensiveness of Factor Sets (Factors versus Bulleted Items)

Although there are no laws governing use of factor trees, it is good practice to assure that the factors affecting a given node are as "complete a set" as possible. If one can think of some factors, but it is clear that they are merely what is coming to mind at the moment, then it is better to list them as bulleted items rather than as nodes. This has the practical benefit of allowing a factor tree to show some familiar items without undercutting the intellectual integrity of the whole. The bulleted items are examples, and can be tailored to particular audiences if need be, but the node structure should have rigor and staying power.

How do we know what is "comprehensive?" One way is to cheat, by adding a factor "other." That is actually preferable to conveying the misimpression that a set of factors is complete when one knows it is not. More seriously however, there is no formula for assessing completeness in subjects such as social science. Consider, however, the old wisdom that concluding guilt of murder requires demonstrating motive, opportunity, and means. Are there other things that ought to be required? Perhaps, but this set has proven itself over centuries (perhaps millennia) as a good approximation of a complete set of criteria. Section 4 gives examples of factor trees and readers can muse about whether the factors at a level appear to be rather complete.

3.3.4 Reading Left to Right and Dealing with Overlaps

Some natural factors have potentially overlapping scope. A mechanism for dealing with this potential problem economically is constructing and reading the factor trees left to right so that a factor's scope is regarded as picking up only considerations not covered by the preceding factors (those to the left). As an example, two factors might be "enthusiasm for group" and "inspiration by group's leader." If these were shown side by side, the latter would be interpreted as the incremental additional inspiration associated with the leader rather than the group (the reverse ordering might be more appropriate in some cases). This approach conveys a sense of causality or precondition from left to right, which can be useful as part of a narrative that accompanies a factor tree. In a sense, it also builds in some dynamics unobtrusively.

4 EXAMPLES FOR DIVERSE APPLICATIONS

The purpose of this section is to illustrate how factor trees have been used for what are really very different purposes, although with overlaps. The examples are based on finished studies.

4.1 Alternative Causal Pathways to Terrorism

The factor-tree methodology was developed for a study reviewing the social science relevant to understanding terrorism and counterterrorism (Davis and Cragin 2009). The study included a comprehensive literature survey, but then had the challenge of integrating results in an understandable way, despite major differences across the scholarly community and even more differences within the communities involved with strategy, policy, and counterterrorism operations. A particularly insidious problem was the tendency of many toward single-factor explanations, as when it was asserted—for a time—that "the problem" was the madrasas that teach violent jihad, that "the problem" was Islam, or that "the problem was irrationality." Serious scholars of terrorism knew better and counseled against such would-be explanations, but their answering questions with "Well, it depends" were sometimes not appreciated. Our study sought to be both synthetic and analytic. An important virtue of factor trees is that they can juxtapose *alternative* causal pathways—i.e., what political scientists call equifinality (George and Bennett 2005).

4.1.1 Root Causes of Terrorism

The first factor tree appearing in our study addressed root causes of terrorism, a subject fraught with controversy. Figure 5 from a chapter by Darcy Noricks was our way of pulling together the many different streams. The factor tree has three levels of detail, with some cross-cutting factors and even some global factors. It also has some "and" conditions and some "or" conditions. The top level of the tree implies that, to a first approximation, the root-cause likelihood of terrorism depends on the culture countenancing violence, having grievances, and having mechanisms to organize and support those who might be willing to use terrorism. At lower levels, the combining rules are all shown as of the "or" variety. The reason for countenancing violence might be cultural, ideological, political (as in response to repression of an illegitimate regime), foreign occupation, or some combination. All of the higher-level factors could be affected by a low capacity for governance, among other things (one of the global variables below). Globalization is shown as a cross-cutting factor affecting economics, modernization, and social instability.

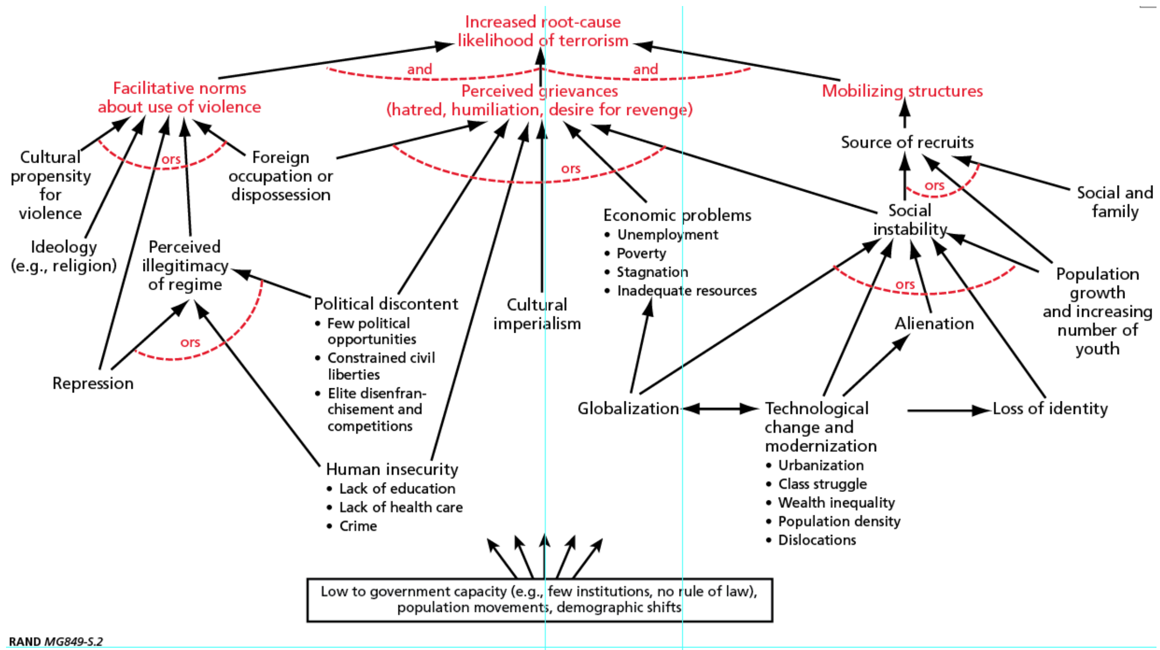


Figure 5: Root Causes of Terrorism

The point here is that instead of taking sides in the debate about whether "the problem" is the culture, economics, globalization, or whatever, the enlightened view is that the propensity for terrorism can depend on any or all of them. To be sure, in a particular place at a particular time, some influences may be stronger than others, but no one explanation applies generally The narrative that accompanied this factor tree included the observation that grievances exist in all societies. Terrorism, however, is seldom the result. There has to be a willingness to use terrorist violence and, as a practical matter, there needs to be a mechanism, such as an organization with the competence to plan and execute operations. This is not always true (yes, there are lone wolves), but it is usually true: most people who might have the grievances and willingness lack the opportunity, knowledge, or competence.

Referring back to Section 3, we might ask whether the factors at the second level are "comprehensive." They are intended to be, at least when supplemented by global variables such as those in the bottom box. They are probably not as comprehensive as intended, but they are certainly not ad hoc.

One of the rules mentioned above is, however, violated in the tree: the phrase "facilitative norms about use of violence" is unquestionably an example of academese. Compromises occur in collaborative writing and did in the case of this factor tree.

4.1.2 Motivations in Terrorism

A second use of factor trees in the same volume was a summary depiction of what causes individuals or groups to participate in terrorism. Figure 6, from a chapter by Todd Helmus, shows the factor tree for individual willingness to engage in terrorism. Some of the factors relate strongly to perceptions, needs, and even passions. They may, however, be affected by global factors such as a charismatic terrorist leader (Osama bin Laden was the obvious example early in this decade, inspiring many youths to join the violent jihad). As another observation, some terrorists are motivated by religious or otherwise ideological considerations, but others are motivated by very different matters, such as the excitement of joining other young men in taking risky "heroic" actions. These different motivations, then, are different causal pathways. One of the topics discussed with this factor tree was an ongoing academic debate between terrorist experts who argued that many terrorists arise from actions of a "bunch of guys getting together" (Sageman 2008) and others arguing that there was much more top-down recruiting than the others recognized (Hoffman, 2008). In fact, *both* mechanisms can be observed and it is not good science to pick "the most popular explanation." There are temptations to do so in social science, however, because simple explanations ("ultimately, it's about such-and-such") often gain attention.

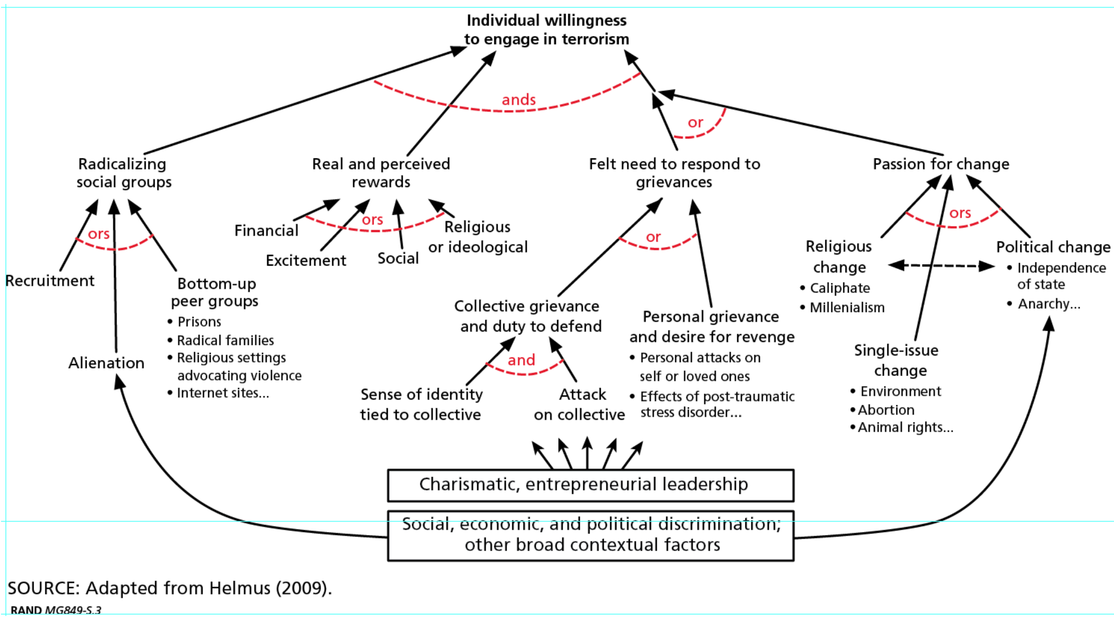


Figure 6: Individual Motivations for Terrorism

4.2 Factors in Decisions

Although factor trees are not decision trees, they can be used to illuminate what goes *into* decisions.

4.2.1 Behavior of Terrorist Organizations

Figure 7, from a chapter of the same study by Brian Jackson, shows the factors believed to influence the decision making of a terrorist *organization*. Jackson was drawing from a multidisciplinary literature on decision making as well as such information as could then be obtained about terrorist decision making itself. Although the model was based largely on rational-actor theory, it also allows for "irrationalities" due to, e.g., misperceptions, dissension, and lack of information. Some of the items highlighted by Jackson are often not mentioned in discussions of how terrorist organizations make decisions, although they are well grounded. One is that such organizations worry about resources, not just money, but also, e.g., their supply of people with specialized skills (bomb-making?) and know-how. They also worry about the consequences on the proposed action on group cohesiveness: will the proposed act inspire the organization or cause it to splinter? In reality, major debates go on within terrorist organizations.

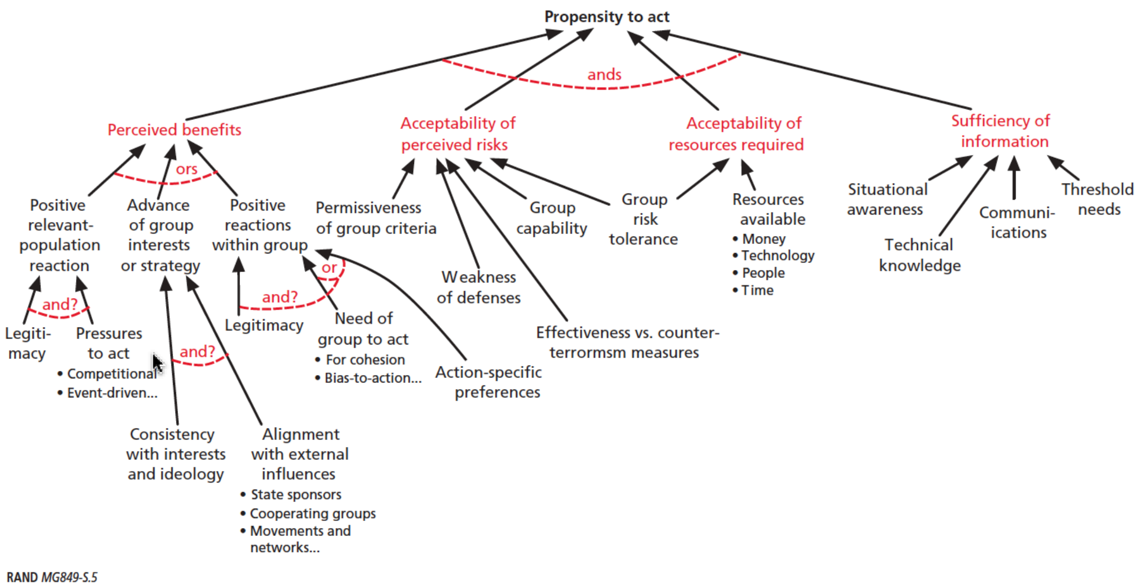


Figure 7: Factors in Terrorist-Organization Decision Making

4.2.2 Insurgent Decisionmaking on Peace and War Decisions

Figure 8 comes from a chapter by Christopher Chivvis and me in a more recent study on the social science of stabilization and reconstruction (Davis 2011). It reduced a great deal of discussion in the literature to a matter of a relatively easy-to-understand decision. In a post-conflict situation in which intervenors are hoping that insurgents will negotiate, the insurgents may be driven by a superficially rational-analytic decision: is it "smart" to negotiate or go back to war? As the figure indicates, the matter is actually not simple. Real people are not economists who believe that the rational decision is that which maximizes the expected future utility. Instead, they worry not just about the expected outcome (i.e., the mean of a distribution if the outcome could be described probabilistically), but about the upside opportunities and downside risks (Davis, Kulick, and Egner 2005). Negotiation might mean peace and prosperity, or it might mean that the last hope of their cause would be dashed as the dominant power reneges on promises. Going back to war might possibly lead to glorious victory, but it might instead mean utter annihilation. Further, real people are affected by greed, exhaustion, and other beyond-rational considerations. Experienced negotiators understand these matters, even if they do not usually express them in analytic ways.

In viewing this tree, the reader should note our attempt to have factors at a level be comprehensive. We have factors not just for best estimate judgments, but for perceived upside opportunities and downside risks. We also include explicitly a set of factors relating to beyond-rational considerations. Is this complete? Perhaps, perhaps not, but it is surely much more so than the usual model dealing only with so-called rational-analytic reasoning based on maximizing expected utility. Note also that bulleted items are mere examples, and almost obviously not complete sets.

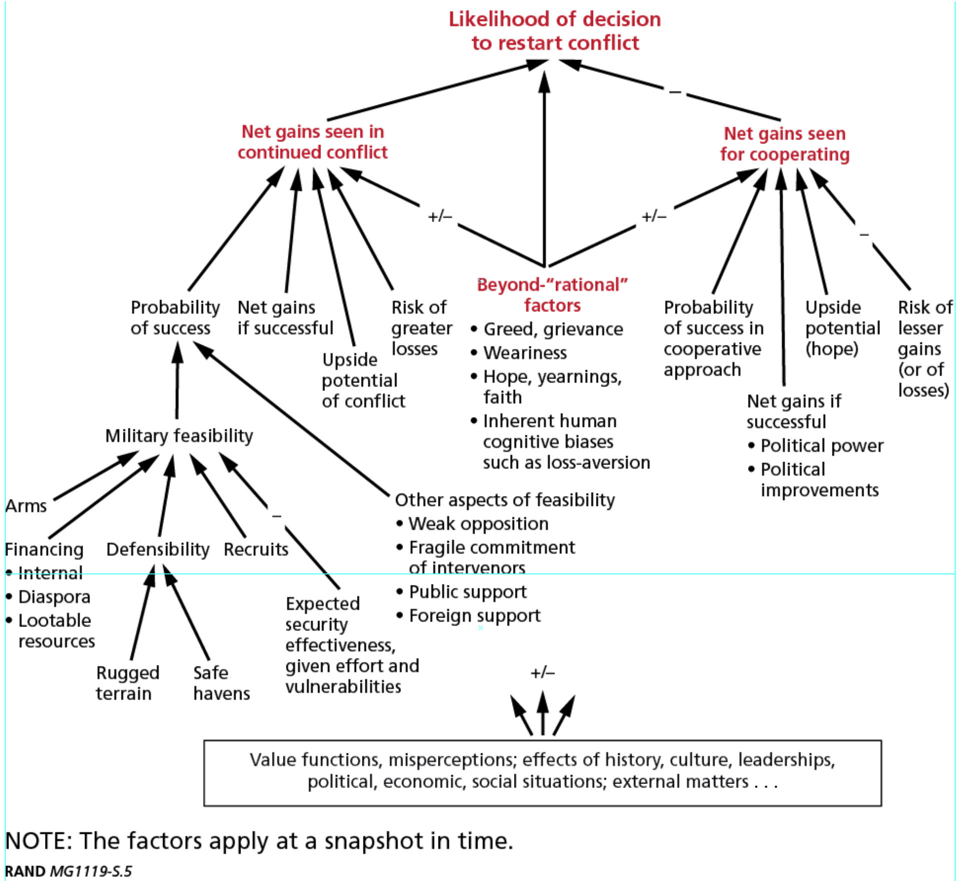


Figure 8: Decision on Whether To Go Back To War

4.3 Factor Trees To Show Crucial Distinctions and Components

Although I usually advise against using factor trees to discuss components, there are exceptions. Two examples are worth mentioning briefly. Figure 9 shows a factor tree from a chapter by Elizabeth Wilke, me, and Christopher Chivvis on achieving trust and cooperation in a post-conflict environment that includes a great deal of anger and bitterness. Here the narrative that goes with the picture is that it is crucial to distinguish between the kind of trust that comes from pragmatic calculations and the kind of trust that comes from personal relationships. The former may be shallow and even cynical, but may be quite feasible to achieve and effective. For example, a given faction may trust another faction because it sees that it is the other faction's interest to cooperate, especially if third-party intervenors are present to help assure that assessment of interests. There is nothing naïve about that. In contrast, the aspiration of building deeper relations-based trust is one to be realized over years or even decades, and may simply not come about. The chapter's story, then, is that attending to social issues is a crucial element of stabilization and reconstruction, that progress is achievable, but that the shorter-term payoffs will likely come from finding and exploiting opportunities where interest will overlap. This is not just sensible, but well grounded in empirical social science. The factor tree dramatizes the distinction between types of trust—i.e., by distinguishing between components of trust.

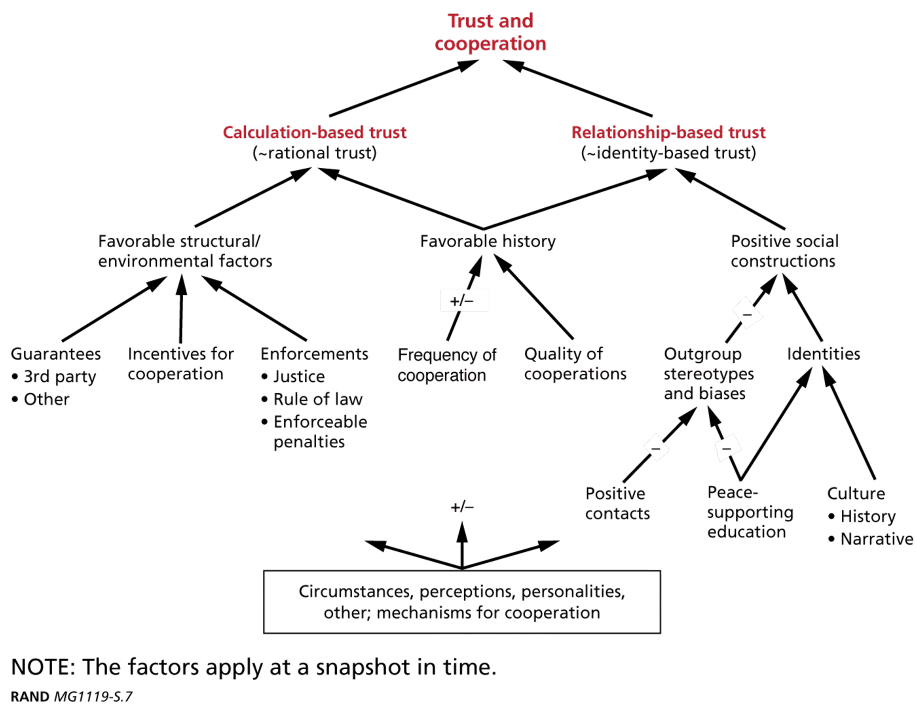


Figure 9: Factor Trees Merely Highlighting Distinctions or Components

5 VALIDATION AND LIMITATONS

5.1 Validation

If factor trees are to be seen as conceptual models, how can they be evaluated, or even "validated?" Validation of social-science models is not like validating physics models, for many reasons that should be obvious. Nonetheless, much can be done. In our recent study on public support for insurgency and terrorism (Davis et al., forthcoming), and in work by colleagues, we concluded that much can be done with case studies relating to validation and simultaneous theory improvement. The approach taken in the case studies, however, is a combination of testing and theory development, along the lines urged by the late Alexander George, who pioneered systematic case-study approaches (George and Bennett 2005). Key elements in our approach were as follows:

Tentative Confirmation of Factors. Empirical information can indicate whether the factors identified in the conceptual models appear to be at work in real-world cases as judged by, e.g., polls, accounts by reporters interviewing members of the public, the study of diaries and records, the voluminous writings of insurgent leaders, and so on. If the factors show up, this is useful incremental confirmation, although not proof. If the factors arise in a way conveying roughly the same narrative as the conceptual model, then the sense of confirmation is enhanced.

Tentative Confirmation Regarding Causality and Necessity. As discussed earlier, factor-tree models are causal models; they distinguish between sets of factors that are all necessary (at least in a first approximation) for an effect to occur and those that may be individually sufficient. Empirical information can provide tentative confirmation on both of these matters. The accumulation of such confirmations encourages confidence, especially if—once again—the empirical work also supports the causal explanations that are being given.

Falsification and Supplementation. If factors arising in such empirical information are not in the conceptual models, then the models are, in a sense, falsified—a key element of science. The "in a sense" phrase applies because there is no shame in having a model that does well in most respects but needs to be improved with additional factors—so long as, over time, the number of factors does not continue to grow without bound. The primary downside is that doing so entangles model-building and testing—something unavoidable at this stage of research. In one study my colleagues and I did a fair amount of supplementing, particularly as regards the mechanisms that factions use in attempting to influence public support. That is, although the empirical work confirmed the factors we had identified, it suggested that some of the causal paths were better depicted with different lower-level arrangement of factors. Most notably, we concluded that in understanding insurgency it is often more apt to highlight the factor of *identity* in the causal chain of motivation than to try to disentangle influences of religion, culture, nationalism, and tribalism.

Similarly, if the narratives reported from empirical sources describe cause-effect relationships differently than do the models, then this might be another type of falsification (if the empirical sources' narrative is credible), as would be evidence that a factor shown by the model as necessary is often not necessary. Such evidence can motivate refinements in the evolving model.

5.2 Limitations of the Factor-Tree Approach

As mentioned at the outset, factor trees convey a snapshot view of causal factors at work. They do not describe dynamics (except in subtle ways). Further, they inevitably reflect the author's perspective or preferred representation. Some natural supplements to factor trees are qualitative influence diagram and case tables (Davis 2011, Chapter 8). More ambitious, of course, would be building models that run, i.e., models that specify the algorithms by which factors combine and thus provide some predictive capability (Davis 2006), although that should be understood only in the sense of better understanding the odds of different developments, with considerable attention paid to remaining humble.

6 FINAL OBSERVATIONS

Much has been learned about using factor trees over the last 2-3 years, and also how to think about validating them as conceptual models. My judgment, and that of colleagues, is that they have proven quite useful. As experienced modelers and analysts would expect, however, they prove to be *one* useful tool in a tool kit, especially for social science, but other tools are essential as well—and sometimes better.

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