Time Sensitive Course of Action Development and Evaluation

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ABSTRACT

The development of courses of action that integrate military with diplomatic, economic, and information operations (DIME) poses particular modeling challenges because the different instruments of national, multi-national, or international power operate often on different time scales. Timed Influence Net modeling is a Bayesian net variant that relates causes and effects and enables (a) the determination of alternative courses of action using alternative optimization algorithms and (b) the derivation of probability profiles which show graphically the changes over time of the probability of desired or undesired effects occurring. This provides useful information in selecting a course of action and assessing its risk. A university developed software application called Pythia has been used in the last few years to address issues in the planning of Information Operations, in analyzing the potential impact of counter-terrorism operations, and in coordinating humanitarian assistance. Multiple algorithms are embedded in Pythia to accommodate different causal assumptions. An example based on the development of information operations in conjunction with tactical operations in a province/sector where insurgents are active and destroying some of the infrastructure has been used as the basis for developing and analyzing alternative courses of action. The importance of the attitudes of the non-combatant local population on the probability of achieving the desired effects in a timely manner is illustrated. Sensitivity analyses show the impact of the relative timing of the various DIME related operations.

1.0 INTRODUCTION

Terrorist networks and the drug networks often overlap – with drugs providing financing for terrorist activities but the two are different in significant ways. A fundamental one is that, at the supply end, the drug network is tied to the land, to the places where the drug producing plants are cultivated and harvested. But a terrorist network does not need to have physical boundaries. The term transnational has been used to describe this property. While a terrorist network does have physical assets that must be located somewhere, these locations may be considered as temporal instantiations. For example, terrorist networks need to maintain training camps at some locations, but these locations can change rapidly from one country, region, or continent to another. There are other dissimilarities: the drug networks need to provide a consistent supply over time, they need to maintain elaborate transportation and distribution systems that are highly labor intensive, and they need to protect large money flows through the commercial banking system. Transnational terrorism, on the other hand, can move its physical nodes with relative ease; it needs only a small number of persons that are active at all times (the leadership and what one may categorize as mission managers); and the financial transactions can be reasonably small and highly distributed.

Transnational terrorist networks are hard to define in terms of geographical boundaries or through their physical assets. Therefore, the main objective in suppressing, if not destroying, transnational terrorism is to

Report Documentation Page

1. REPORT DATE **OCT 2010**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Time Sensitive Course of Action Development and Evaluation**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **George Mason University ECE Dept., MS 1G5 Fairfax, VA 20105 USA**	8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA564696. Human Modelling for Military Application (Applications militaires de la modelisation humaine). RTO-MP-HFM-202

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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT **SAR**	18. NUMBER OF PAGES **13**	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**			

attack and destroy not its system architecture but its operational architecture – its ability to conduct its operations in support of its goals. A terrorist network's operational architecture can be mapped into numerous system architectures. Our traditional attrition-based warfare is focused on destroying the system architecture of the adversary when the adversary is a state or a coalition of states or can be defined by geographical boundaries and fixed physical assets. In that case, the relationship (mapping) between the operational and system architecture is well known and well understood. The consideration of a well defined mapping between the operational and system architecture leads directly to concepts such as physical Centers of Gravity, prioritized target lists and the like. But, when we are faced with an adversary who is characterized primarily by an operational architecture that maps into many system architectures or to flexible and reconfigurable system architectures, we need to change the way we look at things and the way we model them.

Thus instead of focusing on the servicing of a well defined a priori target list, we focus on the effects that we wish to achieve on the adversary's behavior and in the non-combatant population within which the adversary operates.. The target list still exists and includes both hard and soft targets: from weapons systems, to C2 nodes, to leadership nodes, to infrastructure nodes, to the contents of communications. But the target list is only an intermediate construct, a means to an end, that can change rapidly as the effects we wish on the adversary are being achieved or not. Indeed, the list of possible actions we can take is now much larger as it includes all instruments of national (or coalition) power: political, military, or humanitarian; physical or ideological. The availability of all instruments gives us much flexibility in trying to achieve the desired effects and to avoid undesirable ones. But it also makes the Course of Action (COA) problem and the subsequent planning problem much harder. There are now many alternatives, many choices. The choice of a set of actions, their sequencing, and their time phasing become a problem in their own right.

COA Problem: Select from the set of all actions those subsets that will yield with high probability the effects we wish to achieve (including low probability for undesirable effects). Take into consideration constraints associated with specific actions or combinations of actions. Then sequence the actions in each subset and time-phase them. The result is a set of alternative COAs. When the selected COA becomes a plan, the operational aspects are mapped to system aspects. The operational nodes are instantiated by physical nodes with a time and a location associated with them.

Influence Net (IN), a variant of Bayesian Networks (BN), been used since 1994 [1], [2], [3] for modeling cause-and-effect relationships among variables of a domain. The construction of an IN requires a subject matter expert (SME) to model the parameters of the domain − random variables − as nodes in a network. The arcs (or directed edges) in the network represent the cause-and-effect relationships between the random variables. The nodes in an IN and their interdependencies may represent the inter effects between political, military, economic, social, infrastructure, and information (PMESII) factors present in an area of interest. The strengths of these dependencies are captured in terms of a small (i.e., linear) number of influence constants (as opposed to an exponential number of conditional probabilities in a BN). The IN approach was developed in recognition of the fact that most domain experts and situation analysts do not think in terms of conditional probabilities (as required for a BN) while relating affecting and effect variables in a domain. The INs provide an intuitive elicitation, update, and merge interface to an underlying BN that only requires specification of qualitatively described individual influences between each pair of an affecting and an affected variables. The approach then combines these individual influences to calculate the aggregate effect of multiple affecting variables on an effect variable in terms of conditional probability values of a resulting BN.

Wagenhals and Levis [3] have added a special set of temporal constructs to the basic formalism of Influence Nets. The Influence Nets with these additional temporal constructs are called Timed Influence Nets (TINs). A fully specified TIN model is characterized by the causal relationships between propositions and the values of

the parameters, i.e., strength of influences, and temporal delays associated with these relationships. TINs have been experimentally used in the area of Effects Adversarial Modeling for evaluating alternative courses of actions and their effectiveness to mission objectives in a variety of domains, e.g., war games [4], and coalition peace operations. A number of analysis tools have been developed over the years for TIN models to help an analyst in solving problems of interest [5-7].

A case study based on a particular province in Iraq has been used to examine and test this approach. The case study demonstrated the development of a model of an adversary and the culture that can be used to assess various courses of action designed to achieve several high level effects. A timed influence net (TIN) was used to create executable models based on knowledge about the cultural environment that link potential actions with their timing to effects. Such models captured the rationale for courses of action and explained how various actions can achieve effects. Given a set of potential actions, the model was then used to determine the course of action that maximizes the likelihood of achieving desired effects as a function of time.

The rest of this paper is organized as follows. Section 2 gives a brief description of a TIN and describes a process that can be used for developing a model and using it for course of action analysis. Section 3 describes the case study and how a specific objective along with detailed data about the cultural environment was used to create and analyze a TIN. The rationale and thought processes that were used to determine the content of the TIN are described first, followed by a description of how the TIN was used in a layered analysis process to examine various courses of action to determine their impact on the overall effects over time. Section 4 provides some observations and conclusions.

2.0   TIMED INFLUENCE NETS

When an adversary in imbedded within a culture and depends upon elements of that culture for support, the effects of physical actions may influence not only the adversary, but the individuals and organizations within the culture that can choose to support, be neutral, or oppose the adversary. Thus, the effects on the physical systems influence the beliefs and the decision making of the adversary and the environment in which the adversary operates. Because of the subjective nature of beliefs and reasoning, probabilistic modeling techniques such as Bayesian Nets and their Influence Net variant have been applied to these types of problems. .

Influence Nets (IN) and their Timed Influence Nets (TIN) extension are abstractions of Probabilistic Belief Nets also called Bayesian Networks (BN) [8, 9]. BNs and TINs use a directed acyclic graph representation where nodes in the graph represent random variables, while the edges between pairs of variables represent causal relationships. These random variables can represent various elements of a situation that can be described in a declarative statement, e.g., X happened, Y likes Z, etc.

While mathematically Influence Nets are similar to Bayesian Networks, there are some key differences. BNs suffer from the often intractable task of knowledge elicitation of conditional probabilities. To overcome this limitation, TINs use CAST Logic [10], a variant of Noisy-OR [11, 12], as a knowledge acquisition interface for eliciting conditional probability tables. This logic simplifies knowledge elicitation by reducing the number of parameters that must be provided. TINs are appropriate for modeling situations in which the estimate of the conditional probability is subjective, e.g., when modeling potential human reactions and beliefs, and when subject matter experts find it difficult to fully specify all conditional probability values.

To construct and use a TIN, the following process has been defined. It is illustrated in Fig. 1:

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1) Determine the set of desired and undesired effects expressing each as a declarative statement that can be either true or false. The point of view taken is that of the adversary. For each effect, define one or more observable indicators that the effect has or has not occurred.

2) Build an Influence Net that links, through cause and effect relationships, potential actions to the desired and undesired effects. Note that this may require defining additional intermediate effects and their indicators.

3) Transform the IN to a TIN by incorporating temporal information about the time the potential actions will occur and the delays associated with each of the arcs and nodes.

4) Use the TIN to compare different sets of actions in terms of the probability of achieving the desired effects and not causing the undesired effects. Use the optimization algorithms to obtain the five best courses of action

5) Use the TIN to experiment with different timings for the actions to identify the "best" COA based on the probability profiles that each candidate generates. Determine the time windows when observation assets may be able to observe key indicators so that assessment of progress can be made during COA execution.
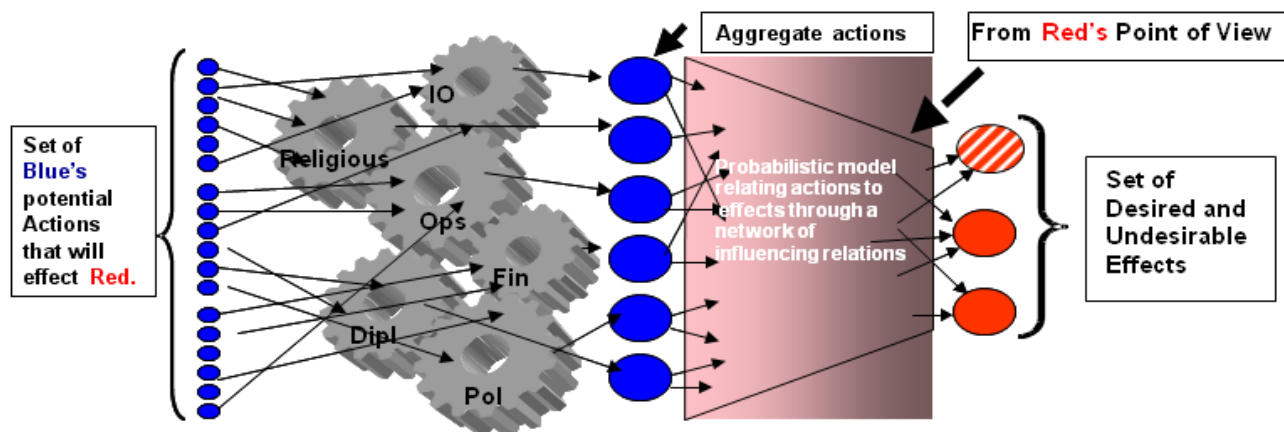

Figure 1: Modeling multiple types of actions to effects.

In building the TIN, the modeler must assign values to the pair of parameters that show the causal strength (usually denoted as g and h values) for each directed link that connects pairs of nodes. Each non-root node has an associated baseline probability that must be assigned by the modeler (or left at the default value of 0.5). It represents the probability that the random variable will be true in the absence of all modeled influences or causes. The CAST logic is based on a heuristic that uses these quantified relationships and the baseline parameter to compute the conditional probability matrix for each non-root node. Finally, each root node is given a prior probability, which is the initial probability that the random variable associated with the node (usually a potential action) is true.

When the modeler converts the IN into a TIN (step 4), each link is assigned a corresponding delay that represents the communication delay. Each node has a corresponding delay that represents the information processing delay. Figure 2 shows a partially specified TIN. Nodes B and E represent the actionable events (root nodes) while node C represents the objective node (leaf node). The directed edge with an arrowhead

between two nodes shows the parent node promoting the chances of a child node being true, while the roundhead edge shows the parent node inhibiting the chances of a child node being true. The inscription associated with each arc shows the corresponding time delay it takes for a parent node to influence a child node. For instance, event B, in Fig. 1, influences the occurrence of event A after 5 time units.

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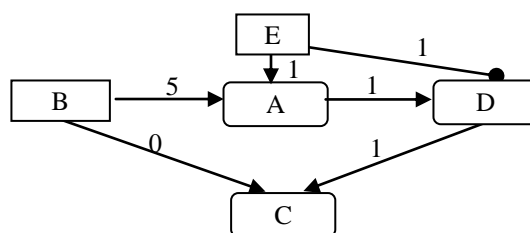

Figure 2: An Example Timed Influence Net (TIN).

The impact of a selected course of action on the desired effects is analyzed with the help of a probability profile. Consider the TIN shown in Fig. 2. Suppose the following input scenario is decided: actions B and E are taken at times 1 and 7, respectively. Because of the propagation delay associated with each arc, the influences of these actions impact event C over a period of time. As a result, the probability of C changes at different time instants. A probability profile draws these probabilities against the corresponding time line. The probability profile of event C is shown in Fig. 3.
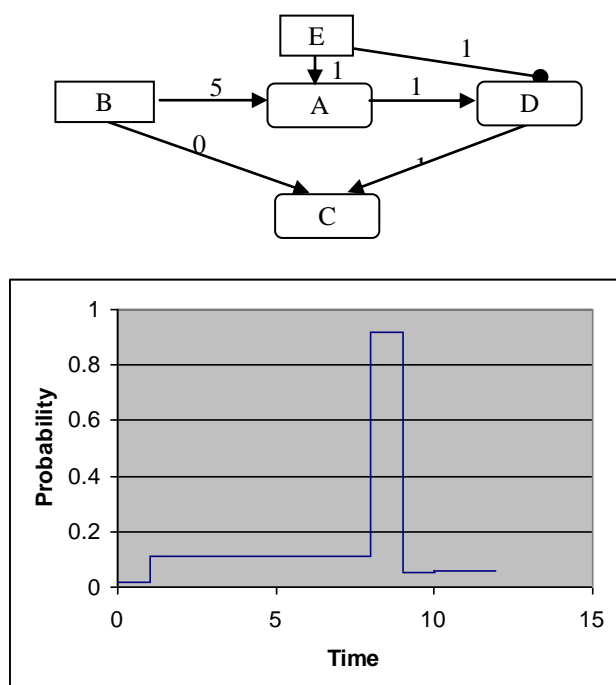
Figure 3: Probability profile for event C.

3.0   CASE STUDY

A case study was used to demonstrate the capability to develop and analyze courses of action. The specific issue that the case study addressed was stated as follows: given a military objective and a set of desired effects derived from statements of commander's intent, develop and analyze alternative courses of actions (COAs) that will cause those desired effects to occur and thus achieve the military objective. Specifically, the case study demonstrated the use of a TIN tool called Pythia that has been developed at George Mason University. This demonstrated the use of the tool to create knowledge about an adversary and the population that potentially supports or resists that adversary and the use of the TIN to analyze various COAs.

A scenario was chosen based on the problem of suppressing the use of Improvised Explosive Devices (IEDs) in a specific province of Iraq, denoted as province D in the year 2005.   Specifically, it is assumed that IED incidents have increased along two main east-west routes between the capital town C of the province and a neighboring country M. Both roads are historically significant smuggling routes.

There were hundreds of documents about Iraq in general and D province in particular that were reviewed to get a better understanding of the situation. The province includes substantial fractions of Kurdish, Shia, and Sunni populations as well as other minorities. It was noted that the northern route was in the predominantly Kurdish region and the southern route was in a predominantly Shia region. A dynamic tension existed between these regions particularly with regard to the flow of commerce (overt and covert) because of the revenue the flow generated. It was noted that some revenue was legitimate, but a significant amount was not and was considered covert. Increased IEDs in one region tended to suppress the trade flow in that region and caused the flow to shift to the other. Consequently, each region would have preferred to have the IEDs

suppressed in its region, but not necessarily in the neighboring region. The IED perpetrators needed support from the local and regional populations as well as outside help to carry out their attacks. The support was needed for recruiting various individuals to help manufacture the IEDs and to carry out the operations necessary to plant them and set them off. It was postulated that improving the local economy and the quality of the infrastructure services would reduce the local and regional support to the insurgents. Of course, this required effective governance and willingness on the part of the workers to repair and maintain the infrastructure that in turn required protection by the Iraqi security and coalition forces.

With this basic understanding, the following steps were taken to create the TIN. First the overall key effects were determined to be 1) IED attacks are suppressed on routes A and B (note these were modeled as separate effects because it may be possible that only one of the routes may have the IED attacks suppressed), 2) Covert economic activity improves along each of the two routes. 3) Overall overt economic activity increases in the region. 4) Insurgent fires are suppressed, 5) Local support for the insurgents exist and 6) Regional support for the insurgents exists. Nodes for each of these effects were created in the Pythia TIN modeling tool. It was noted that suppression of IED attacks on one route could have an inverse effect on the covert economic activity on the other, but each could improve the overall overt economic activity. The suppression of the insurgent fires positively affected both covert and overt economic activity.

The next step was to identify the key coalition force (Blue) actions that would be evaluated as part of the potential overall COA. To be consistent with the level of model abstraction the follow high level actions were considered: 1) Blue coalition forces (CF) exercise their standard Tactics, Techniques, and Procedures (TPPs) (including patrols, searches, presence operations, and the like). 2) Blue Coalition Forces actively conduct surveillance operations. 3) Blue CF actively conduct Information Operations. 4) Blue CF continue to train the local Iraqi security forces and police. 5. Blue CF broker meetings and discussions between various Iraqi factions (Green).

Of course, it is not possible to just connect these actions to the key effects and, therefore, several other sub-models were constructed and then linked together to produce the final model. These models include a model of the process the insurgents must use to conduct IED operations, a sub-model for the infrastructure and economic activity, and a sub model of the political and ethno-religious activities. In addition, it was recognized that the region was being influenced by outside sources, so these also were added to the model.

The sub model of the insurgent IED activities was based on the concept of how the insurgents develop an IED capability. They must have the IEDs, the personnel to carry out the IED operation, the communication systems to coordinate the operation and the surveillance capability to determine where to place the IED and when to set it off. Each of these in turn requires additional activities. For example, the personnel must be recruited and trained. The IEDs must be manufactured, and this requires material and expertise. Furthermore, the insurgents must be motivated to use their capability. Much of this capability relies on support by the local and regional population and funding and material from outside sources. The nodes and the directed links between them were added to the TIN model to reflect the Insurgents' Activities.

The economic and infrastructure sub-model included nodes for each of the main essential services: water, electricity, sewage, health, and education. It also included financial institutions (banks, etc.) and economic activities such as commerce and retail sales of goods. The nodes for the economic and infrastructure aspect of the situation were linked to the local and regional support as well as to the overall effect on the overt economic activity.

Of course, the economic and infrastructure services will not function properly without the support of the Political and Ethno-Religious entities in the region. Thus a sub-model for these factors was also included. To

do this, three facets of the region were considered: the religious activities including Shia, Sunni, and Kurdish (who are either Shia or Sunni) groups, political party activities (Shia, Sunni, and Kurdish), and the Shia, Sunni, and Kurdish activities within the government structure including the civil service and the police and law enforcement institutions. The nodes for all of these activities were created and appropriate links were created between them. Links were also created to other nodes in the model such as local and regional support of the insurgents, economic activity and infrastructure development.

Finally, the outside influences were added to the model. These include external support for the insurgents, anti-coalition influences from neighboring countries, and external financial support for the local government and the commercial enterprises of the region. All of these nodes were modeled as actions nodes with no input links. With this model design, analysts could experiment with the effects of different levels of external support, both positive and negative, on the overall outcomes and effects.

The complete model is shown in Figure 4. The model has 62 nodes, including 16 nodes with no parents, and 155 links.
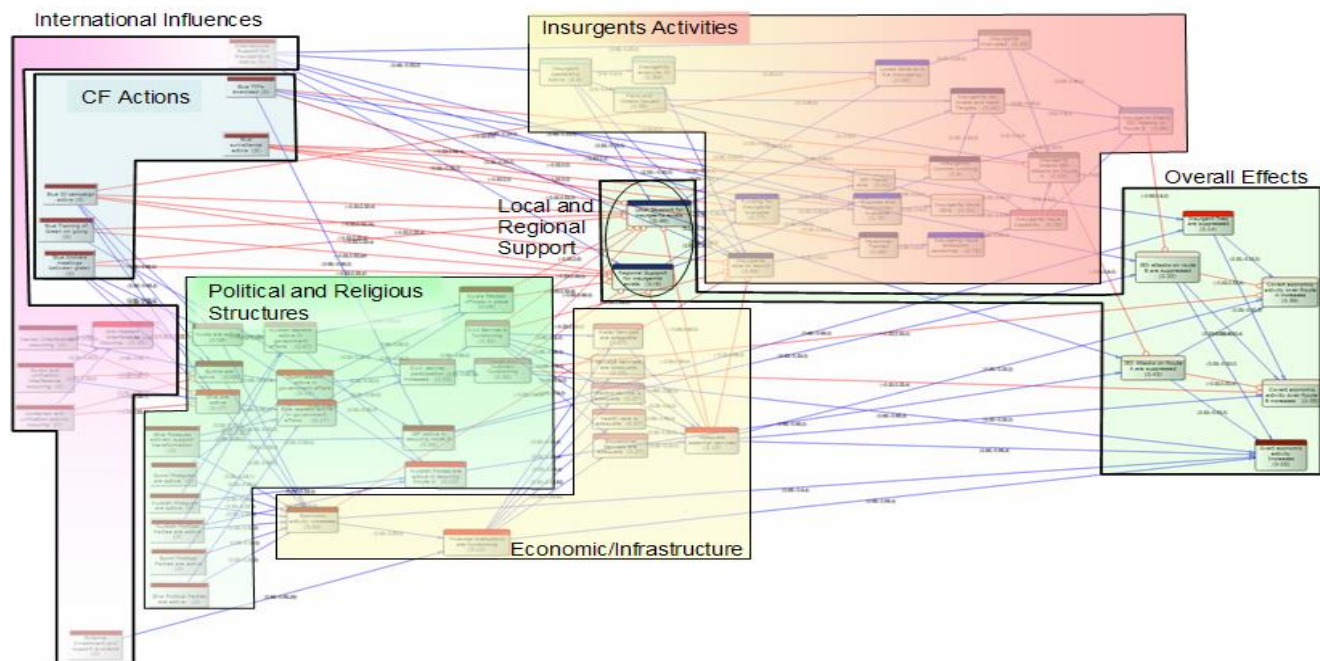

Figure 4: Complete model of the case study TIN.

Once the structure of the models was completed, the next step was to assign the values to the parameters in the model. This was done in two steps. First, the strengths of the influences (the g and h parameters on each link) and the baseline probability of each node were selected. This may seem like a daunting task given the subjective nature of the problem and the number of links and nodes. However, TINs and the Pythia tool limit the choices that can be made for these parameters. For each link, the model determines the impact of a parent node on a child node first if the parent is true and then if the parent is false. The choices range from very strongly promoting (meaning nearly 100%), strong (quite likely, but not 100%), moderate (50% or greater, but less than strong), slight (greater than 0% but not likely), or no effect. The modeler can also select a similar set

of inhibiting strengths ranging from very strongly inhibiting to no effect. The second set of parameters is the baseline probabilities of the node. These are set to a default value of 0.5 meaning that the probability of the node being true is 0.5 given no other influences or causes (we don't know). In many cases, the default value was selected.

At this point it is possible, if not prudent, to perform some analysis on the model to observe its behavior. We will describe this in detail shortly. The final step in creating the TIN model was to assign the temporal parameter values to the nodes and the links. The default value for these is 0. With all values set to 0 the model is identical to an ordinary Influence Net. The process for assigning the time delay values is similar to that for assigning the strengths of the influences and the baseline probabilities. For each link, the modeler determines how long it will take for the child node to respond to a change in the probability of the parent node. In some cases the change is instantaneous, so the default value of 0 is appropriate. In others, a time delay may be expected. Part of this process requires that the modeler establish the time scale that will be used in the model and thus what actual time length of one unit of delay is. Any unit of measure can be selected from seconds to days, weeks, months or even years. In this particular model each time delay unit was set to be one week. In setting the time delay of the arcs, it may also be useful to set the time delay of the nodes. Again the default value for this delay is 0. This delay represents processing delay. It reflects the concept that if there is a change in one or more of the parent nodes, once the child node realizes that the change has occurred, there may be some time delay before it processes this new input and changes its probability value.

Once the complete TIN was created, a validation of the model was undertaken. This was done by consulting with several subject matter experts who had been in the region and were familiar with the situation. Each node and link was checked to see if the node and the relationships to and from that node made sense. In short, we were confirming that the overall structure of the model made sense. Several suggestions were made and the changes were incorporated. Once the structure had been vetted, then the parameters were checked. This was done link by link and node by node. First the strengths of the influences were checked, then the baseline probabilities, and finally the time delays.

Once the TIN model was finished and validated, two levels of analysis were accomplished to demonstrate the utility of the approach. The first level is the logical level. This can be done without using the parameters because it only requires the structure of the model. At this level of analysis the model shows the complex causal and influencing interrelationships between Blue CF, the external influence, the religious and political factions, the adversary (Red), and the local and regional population (Green). This particular model shows that while Blue CF has some leverage, there are many other outside influences that also can affect the outcome of any actions that Blue may take. The model identifies these influences and how they may help inhibit the progress that is made as a result of Blue CF actions. Furthermore, the model shows relationships between the actions and activities of major religious and ethnic groups and effects on government activities (police, judiciary, public works and service, etc.). It shows the impact of the adequacy of government and public services on support of the insurgency. It captures the IED development, planning, and employment processes and the impact of the other activities, the status of public services, and coalition interventions on those processes. Finally the model captures interaction of IED attack suppression on two major trade routes (suppressing one route increases attacks on the other). In short, the model has captured Blue's understanding of a very complex situation and can help articulate concepts and concerns involved in COA analysis and selection.

The second level of analysis involves the behavior of the model. It is divided into a static quantitative and a dynamic temporal analysis. The static quantitative analysis requires the structure of the model and the non temporal parameters to be set. The temporal, time delay parameters should be set to the default value of 0.

This analysis enables one to compare COAs based on the end result of taking the actions in the COA. In the Province D model, four major COAs were assessed as shown in Fig. 5. This table has four parts, an Action stub in the upper left corner, the Action or COA matrix to the right of the Action stub, an Effects stub below the Action stub, and the Effects matrix adjacent to the Effects stub. In the COA matrix, the set of COAs that have been evaluated are listed with an X showing the actions that comprise the COA. The Effects matrix shows the corresponding effects as the probability of each effect.

Actions	Situation (COA) 1	Situation (COA) 2	Situation (COA) 3	Situation (COA) 4
International Interference	X	X	X	X
External Financial Support		X	X	X
CF TTPs and Surveillance		X	X	X
CF IO, training, brokering			X	X
Iraqi political and religious group participation				X
EFFECTS				
Local and Region Support for Insurgents Exists	0.97	0.92	0.26/0.36	0.22/0.14
IED Attacks Suppressed on Route A / B	0.17/0.15	0.31/0.34	0.67/0.68	0.85/0.74
Insurgent's fires suppressed	0.14	0.65	0.9	0.93
Public services adequate	0.12	0.39	0.39	0.55
Overt Economic Activity Increasing	0.02	0.08	0.31	0.89
Covert Economic Activity Increasing along routes A and B	0.37	0.50	0.56	0.57

Figure 5: Static Quantitative COA Comparison.

COA 1 was a baseline case in which only international interference and support to the insurgency occurs. There is no action from the Blue CF, no external financial support to the infrastructure and the economy, and the religious and political factions are not participating in the governance of the area. The overall effects are shown in the lower part of the matrix. The results for this COA are very poor. There is support for the insurgency and it is very unlikely that the IED attacks will be suppressed on either route. With an ineffective local government, the basic services are inadequate which encourages the support to the insurgency and there is little chance for economic increase.

COA 2 represents the case where external financial support is provided and the coalition forces are active both in presence operations and in conducting surveillance. However, Information Operations, training of Iraqi forces and workers, and brokering of meetings and agreement between Iraqi factions are not occurring. In addition, the political and religious groups are not participating in positive governance and support to civil service. In this case, there is some improvement compared to COA 1, but still there are many problems. Local support for the insurgents is still very strong, although there is some suppression of the IED attacks and insurgent fires due to the activities of the coalition forces. As a result there is some improvement in public services and an increase in covert and overt economic activity, due in part to the reduction in IED attacks and insurgent fires.

The third COA contains all of the actions of COA 2 plus the addition of coalition force information operations, training of Iraqi security and police forces as well as civilian infrastructure operations and significant brokering of meetings and agreements between the various Iraqi agencies and factions. The result is a significant improvement in the suppression of the IED attacks and insurgent fires due to the improved

capabilities of the Iraqi security and police forces and the significant drop in the local and regional support of the insurgents. There is also a significant improvement in the covert and overt economic activity. However, there is little change in the adequacy of the public services, due primarily to the lack of effective participation of the Iraqi governance function.

The last COA has all actions occurring. In addition to the activities of the previous three COAs, COA 4 includes the active participation of the Iraqi religious and political groups in the governance activities. It results in the highest probabilities of achieving the desired effects. While there is still some likelihood or local and regional support for the insurgents (0.22 and 0.14, respectively), many of the IED attacks are suppressed as are the insurgent fires. The result is significant increases in overt economic activity and moderate increase in the covert economic activity. Public services are still only moderately adequate, with room for improvement.

While the static quantitative analysis provides a lot of insight into the potential results of various COAs, it does not address the questions of how long it will take for the results to unfold or what should the timing of the actions be. The dynamic temporal analysis can provide answers to these types of questions.

Having created the TIN model with the time delay information, it is possible to experiment with various COAs and input scenarios. Figure 6 shows an example of COA and input scenarios that illustrate such an experiment. The second column of the Table in Fig. 6 shows a summary of the input nodes that were used in the experiment. They are divided into two types, those listed as Scenario and those listed as COA Actions. The scenario portion contains actions that may take place over which limited control is available. These set the context for the experiment. The second group contains the actions over which control exists, that is the selection of the actions and when to take them is a choice that can be made. The last column shows the scenario/action combinations that comprise the COA/Scenario to be examined. The column provides a list of ordered pairs for each Scenario Action or COA Action. Each pair provides a probability (of the action) and a time when that action starts. For example, the listing for the second scenario actions is [0.5, 0] [1.0, 1] which means that the probability of Country M and Country L interfering is 0.5 at the start of the scenario and changes to 1.0 at time = 1. In this analysis, time is measured in weeks.

The entries under the column labeled "COA 4a" mean that the scenario/under which the COA being tested is one in which there is immediate and full support for the insurgency (financial, material, and personnel) from international sources, and it is expected to exist throughout the scenario. The same is true for support from Country S. Countries M and L are modeled with the probability of providing support at 0.5 initially, but it immediately increases to 1.0 at week 1. All of the COA actions are assumed to not have occurred at the start of the scenario, thus the first entry of each is [0, 0]. The coalition force (Blue) actions start at week 1 with a probability of 1.0, meaning that all of the elements of Blue actions start at the beginning. With regard to religious activities, the Kurds begin at week 1 with probability 1.0. The Shia and Sunni have a probability of 0.5 starting at week 10 and then increase to 1.0, becoming fully engaged at week 20. In terms of political activity, the Kurds and Shia become fully active at week 1. The Shia become more likely to be active at week 10, fully active at week 20, then become less likely to be active at week 30 (probability 0.5) and then become fully active again at week 40. Finally, the External Financial support begins at week 26.

To see what the effect of this input scenario on several key effects, the model is executed and the probabilities of the key effects as a function of time are plotted as shown in Fig. 7. In the figure, the probability profiles of four effects are shown: IEDs are suppressed on Routes A and B and Local and Regional support for the Insurgents exists.

	Action	COA 4a: List [p, t]
Scenario Actions	Int'l Support to Insurgents	[1.0, 0]
	Interference by countries M and L	[0.5, 0], [1.0, 1]
	Interference by country S	[1.0, 0]
COA Actions	Blue TTPs activated	[0, 0], [1.0, 1]
	Blue Surveillance, IO, Training, Brokering	[0, 0], [1.0, 1]
	Shia and Sunni Religious Activity	[0, 0], [0.5, 10], [1.0, 20]
	Kurd Religious Activity	[0, 0], [1.0, 1]
	Kurd and Shia Political Activity	[0, 0], [1.0, 1]
	Sunni Political Activity	[0, 0], [1.0, 20], [0.5, 30], [1.0, 40]
	International Investment	[0, 0], [1.0, 26]

Figure 6: Dynamic Temporal Analysis Input.

Fig. 7 shows that the probability of suppression of the IED attacks on the two routes increases significantly under this scenario. This means that the number of IED attacks should decrease, more on Route A than on Route B. The improvement can be expected to occur more rapidly along Route A than along Route B by about 35 weeks or 8 months. Route A is the northern route that is controlled by the Kurds and Route B is the southern route controlled by the Shia and Sunni. This can be attributed to the rapid and steadfast political and religious activities of the Kurds as opposed to the more erratic activities of the others as modeled in the input scenario (Fig. 6). Also note that it is expected to take 80 to 100 weeks (nearly 2 years) for the full effect to occur. Fig. 7 also shows a significant decline in support for the insurgents both by the local and the regional populace with the local support decreasing more as the situation with respect to governance and services improves.
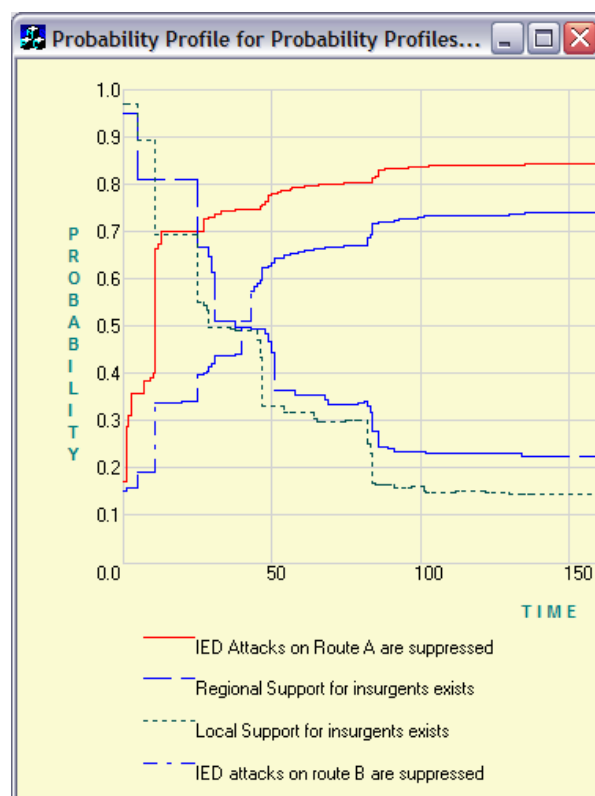

Figure 7: Probability Profiles of Scenario (COA) of Fig. 6.

Of course it is possible to examine the behavior of any of the nodes in the model, by plotting their probability profiles. This can increase the understanding of the complex interactions and dependencies that in the situation that have been expressed in the TIN model. The TIN model provides a mechanism to experiment with many different scenarios and COAs. Questions like what will happen if some of the Blue CF actions are delayed or what will happen if the Shia or Sunni decide not to participate after some period of time can be explored. By creating plots of the probability profile of key effects under different scenarios, it is possible to explore the differences in expected outcomes under different scenarios. This can be illustrated by changing the input scenario. Suppose that it is believed to be possible to get other countries or external organizations to reduce the support to the insurgents by some means, for example diplomatic or military action. It is postulated that we could reduce the likelihood of such support to about 50% but it will take 6 months to do this. The results can be modeled by changing the input scenario of Fig. 6. In this case the first line of Fig. 6 is changed from [1.0, 0] to [1.0, 0] [0.5, 26]. All of the other inputs remain the same. Figure 8 shows a comparison of effect of this change on the suppression on IED attacks along Route B. The reduction in international support for the insurgents at week 26 can cause a significant improvement in the suppression of the IED attacks along Route B (and a corresponding improvement along Route A, not shown). The improvement begins about 6 months after the reduction in international support or about 1 year into the scenario. Thus, decision makers may wish to pursue this option.
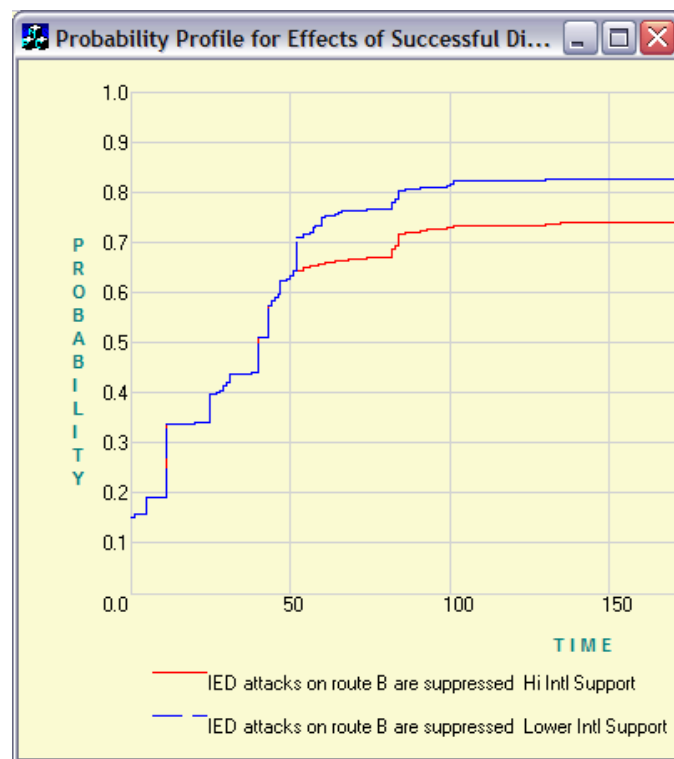

Figure 8: Comparison of the Effect of Different Scenarios.

4.0   OBSERVATIONS AND CONCLUSIONS

Creating TIN models of situations provides a representation of knowledge about a situation that is derived from an understanding of the capabilities of an adversary and the interactions and dependencies of that

adversary with the local and regional social, religious, and economic condition. Once created, the TIN model can be used to conduct computational experiments with different scenarios and COAs. In a sense, it provides a mechanism to assess various COAs based upon comparisons of the change in the probability of key effects over time

It is important to emphasize that the purpose of these models is to assist analysts in understanding the potential interactions that can take place in a region based on actions taken by one or perhaps many parties. It is not appropriate to say that these models are predictive. They are more like weather forecasts, which help us to make decisions, but are rarely 100% accurate and are sometimes wrong. To help deal with this uncertainty, weather forecasts are continually updated and changed as new data become available from the many sensors that make a variety of observations in many locations. Since these models cannot be validated formally, the appropriate concept is that of credibility. Credibility is a measure of trust in the model that is developed over time through successive use and comparison of the insights developed through the model and the occurrence of actual events and resulting effects.

The techniques described in this paper can make an important contribution to a variety of communities that need to evaluate complex situations to help make decisions about actions they may take to achieve effects and avoid undesired consequences. The approach offers at least three levels of analysis, a qualitative evaluation of the situation based on the graph that shows the cause and effect relationships that may exist in the environment, and two levels of quantitative evaluation. The first level of quantitative analysis is static, and shows, in a coarse way, what the likelihood of different effects occurring is given different sets of actions. The second quantitative level is dynamic and shows how the scenario may play out over time. The relevant aspect is that the approach allows the inclusion of diplomatic, information, military, and economic (DIME) instruments and highlights their cumulative effects.

The models can be used to illustrate areas of risk including undesired effects, and risks associated *with the amount of time* it will take to achieve desired effects. It should also be noted that these models are not likely to be created on a one time basis. It can be expected that the understanding of the situation will continue to evolve requiring updates or even new models to be created. Perhaps the best contribution is that the technique offers a standardized way to analyze and describe very complex situations.

During the ten years that such models have been applied to different domains and problems, a number of lessons have been noted.

The first lesson is that these models are best suited to addressing issues at the operational/strategic level and are unsuitable for the tactical level. At the tactical level, we need to expand the range of attrition-type combat models to include the influences of the whole spectrum of instruments of national power. A very difficult issue is the determination of the interactions among the various instruments. For example, what is the effect of a diplomatic initiative when coupled with information operations and should the latter precede, be concurrent or follow the former?

The second lesson is that consideration of temporal issues is critical to the understanding of effects based operations applied to transnational terrorist networks. While the results of conventional military operations focused on attrition may be well understood, it is very difficult (not enough data yet) to estimate how some of the non military actions will affect the future recruitment by the terrorist organization. Even issues such as persistence are not well understood and, certainly, not quantified yet.

The third lesson is a critical one. It is much too early to establish general purpose TIN models that can be applied to different circumstances by changing the contained data. It is not even clear that this is a desirable

approach or one that is technically sound for this class of problems. Rather, the way the technology and the tools are developing is to provide the analysts the capability to put together models (in a given domain about which the analyst is knowledgeable and for which SMEs are available) to address specific issues in the order of several hours. This approach has been tried successfully at the Global War games at the Naval War College in 2000 and 2001. At this time, the state of the art has taken two directions: (a) the development of template TINs for routine analyses and (b) the extraction directly from unstructured data using ontologies draft TINs that the analyst or modeler can then improve.

5.0   ACKNOWLEDGMENT

6.0   REFERENCES

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