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Course of Action Analysis in a Cultural Landscape Using Influence Nets

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Abstract—**Since 1992 the nature of military operations has changed. The type of objectives that the military has to address has expanded well beyond those of traditional major combat operations. As military operations become other than conventional war – whether against transnational terrorist threats or conducting stabilization operations – the need to broaden the focus of models that support effects based planning and operations has become critical. One major present weakness is the absence of socio-cultural attributes in the models used for course of action selection and effects based planning. This paper illustrates an approach that enables analysts to evaluate a complex situation in which an adversary is embedded in a society from which it is receiving support. The paper describes a layered modeling approach that enables the analysts to examine and explain how actions of the military and other entities may results in desired or undesired effects, both on the adversary and on the population as a whole, and shows several techniques for comparing contemplated courses of action.**

Index Terms—Influence Nets, Bayesian Nets, Effects-Based Operations, Cultural Environment

I. INTRODUCTION:

Two challenges are addressed: (a) the need to understand how actions taken by the military or other elements of national power may affect the behavior of a society that includes an adversary and non adversarial elements, and (b) the need to be able to capture and document data and knowledge about the cultural landscape of an area of operations that can be used to support the understanding of the key issues, beliefs, and reasoning concepts of the local culture so that individuals that are new to the region can quickly assimilate this knowledge and understanding.

The first challenge relates to capabilities that enable the analysis needed to conduct focused effects based planning and effects based operations. Models to support Effects Based Operations developed to date relate actions to effects on the adversary [1]. Such models can be quite effective in informing the comparison of alternative courses of action provided the relationships between potential actions and the effects are well understood. This depends on the ability to model an adversary's intent and his reactions and identifying his vulnerable points of influence. But as the nature of Blue's military operations goes well beyond the traditional major combat operations, there is the need to anticipate the effects of actions not only on the adversary (Red), but also on the local population which may support or oppose that adversary. Such support may depend in part on the actions taken by Blue.

The second challenge involves the need for new personnel to rapidly assimilate the local knowledge needed to analyze the local situation and to analyze and formulate the effects based plans and operations. Data about a culture exists in many forms and from many sources including historical reference documents, observations and reports by intelligence analysts, and unclassified (and unverified) sources such as the internet. The data is often incomplete and partially incorrect and includes contradictions and inconsistencies. Analysts, particularly those new to an area of operation who are responsible for formulating courses of action, are hard pressed to quickly develop the necessary understanding of the cultural factors that will effect the behavior of the adversary and the society in which it is embedded.

A case study based on a particular province in Iraq has been used to examine and test an approach to these challenges. 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) modeling technique was used that enables analysts to create executable (probabilistic) models based on knowledge about the cultural environment that link potential actions with their timing to effects. Such models capture the rationale for courses of action and explain how various actions can achieve effects. Given a set of potential actions, the model is 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 formal description of a TIN and describes a process that can be used 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 comments.

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II. Timed influence nets

Several modeling techniques are used to relate actions to effects. With respect to effects on physical systems, engineering or physics based models have been developed that can predict the impact of various actions on systems and assess their vulnerabilities. When it comes to the cognitive belief and reasoning domain, engineering models are much less appropriate. The purpose of affecting the physical systems is to convince the leadership of an adversary to change its behavior, that is, to make decisions that it would not otherwise make. However, 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 cultural environment in which the adversary operates. Because of the subjective nature of belief and reasoning, probabilistic modeling techniques such as Bayesian Nets and their influence net cousin have been applied to these types of problems. Models created using these techniques can relate actions to effects through probabilistic cause and effect relationships. Such probabilistic modeling techniques can be used to analyze how the actions affect the beliefs and decisions by the adversary.

Influence Nets (IN) and their Timed Influence Nets (TIN) extension are abstractions of Probabilistic Belief Nets also called Bayesian Networks (BN) [2, 3], the popular tool among the Artificial Intelligence community for modeling uncertainty. BNs and TINs use a graph theoretic representation that shows the relationships between random variables. 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.

Influence Nets are Directed Acyclic Graphs where nodes in the graph represent random variables, while the edges between pairs of variables represent causal relationships. 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, INs use CAST Logic [4, 5], a variant of Noisy-OR [6, 7], 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. INs 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.

The modeling of the causal relationships in TINs is accomplished by creating a series of cause and effect relationships between some desired effects and the set of actions that might impact their occurrence in the form of an acyclic graph. The actionable events in a TIN are drawn as root nodes (nodes without incoming edges). Generally, desired effects, or objectives the decision maker is interested in, are modeled as leaf nodes (nodes without outgoing edges). In some cases, internal nodes are also effects of interest. Typically, the root nodes are drawn as rectangles while the non-root nodes are drawn as rounded rectangles. Figure 1 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.

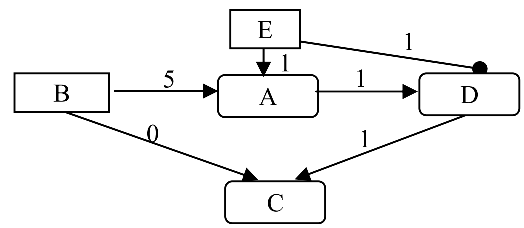

Fig 1. An Example Timed Influence Net (TIN)

Formally, a TIN is described by the following definition.

Definition 1 Timed Influence Net (TIN)

A TIN is a tuple $(V, E, C, B, D_E, D_V, A)$ where
V: set of Nodes,
E: set of Edges,
C represents causal strengths:
$E \rightarrow \{ (h, g) \text{ such that } -1 < h, g < 1 \}$,
B represents Baseline / Prior probability: $V \rightarrow [0,1]$,
D_E represents Delays on Edges: $E \rightarrow Z^+$
(where Z^+ represent the set of positive integers),
D_V represents Delays on Nodes: $V \rightarrow Z^+$, and
A (input scenario) represents the probabilities associated with the state of actions and the time associated with them.
$A: R \rightarrow \{([p_1, p_2, \ldots, p_n],[[t_{11},t_{12}], [t_{21},t_{22}], \ldots,[t_{n1},t_{n2}]])$
such that $p_i = [0, 1]$, $t_{ij} \rightarrow Z^*$ and $t_{i1} \leq t_{i2}$,
$\forall\ i = 1, 2, \ldots, n$ and $j = 1, 2$ where $R \subset V \}$
(where Z^* represent the set of nonzero positive integers)

The purpose of building a TIN is to evaluate and compare the performance of alternative courses of actions. 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. 1. 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. 2.

To construct and use a TIN to support effects based operations, the following process has been defined.

1. Determine the set of desired and undesired effects expressing each as a declarative statement that can be either true

or false. For each effect, define one or more observable indicators that the effect has or has not occurred.

2. Build an IN 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.

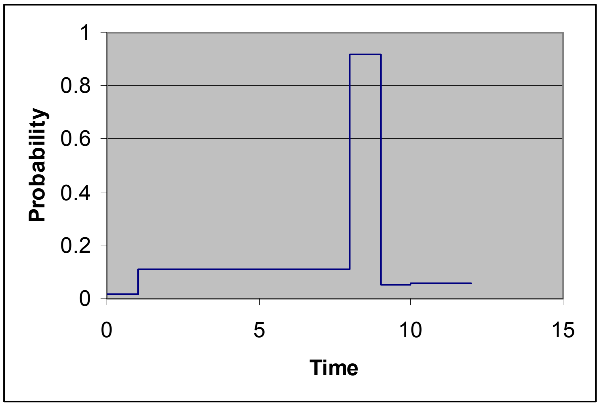

Fig 2. Probability Profile for Node C

3. Use the IN to compare different sets of actions in terms of the probability of achieving the desired effects and not causing the undesired effects.

4. 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.

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.

6. Create a detailed execution plan to use the resources needed to carry out the COA and collect the information on the indicators.

7. Use the indicator data to assess progress toward achieving the desired effects.

8. Repeat steps 2 (or in some cases 1) through 7 as new understanding of the situation is obtained.

In building the IN, 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 d (where $d \geq 0$) that represents the communication delay. Each node has a corresponding delay e (where $e \geq 0$) that represents the information processing delay. A pair (p, t) is assigned to each root node, where p is a list of real numbers representing probability values. For each probability value, a corresponding time interval is defined in t. In general, (p, t) is defined as

$$([p_1, p_2, \ldots, p_n], [[t_{11}, t_{12}], [t_{21}, t_{22}], \ldots, [t_{n1}, t_{n2}]]),$$

$$\text{where } t_{i1} < t_{i2} \text{ and } t_{ij} > 0 \ \forall\ i = 1, 2, \ldots, n \text{ and } j = 1, 2$$

The last item is referred to as an input scenario, or sometimes (informally) as a course of action.

To analyze the TIN (Step 5), the analyst selects the nodes that represent the effects of interest and generates probability profiles for these nodes. The probability profiles for different courses of action can then be compared.

III. Case Study

A case study was used to demonstrate a capability to address the two challenges described in the introduction. The challenge was to create (demonstrate) a capability to allow rotating and in-country forces to easily and quickly access data and knowledge about the cultural landscape of their area of operations that can be used to support their understanding of the key issues, beliefs, and reasoning concepts of the local culture. The specific need 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. The use of TINs was the approach taken. 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. 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 because of the revenue the flow generates. 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 prefer 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 a willingness on the part of the workers to repair and maintain the infrastructure that in turn requires 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 trained and in order to get the personnel they must be recruited. 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 for 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 3. The model has 62 nodes, including 16 nodes with no parents, and 155 links.

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.

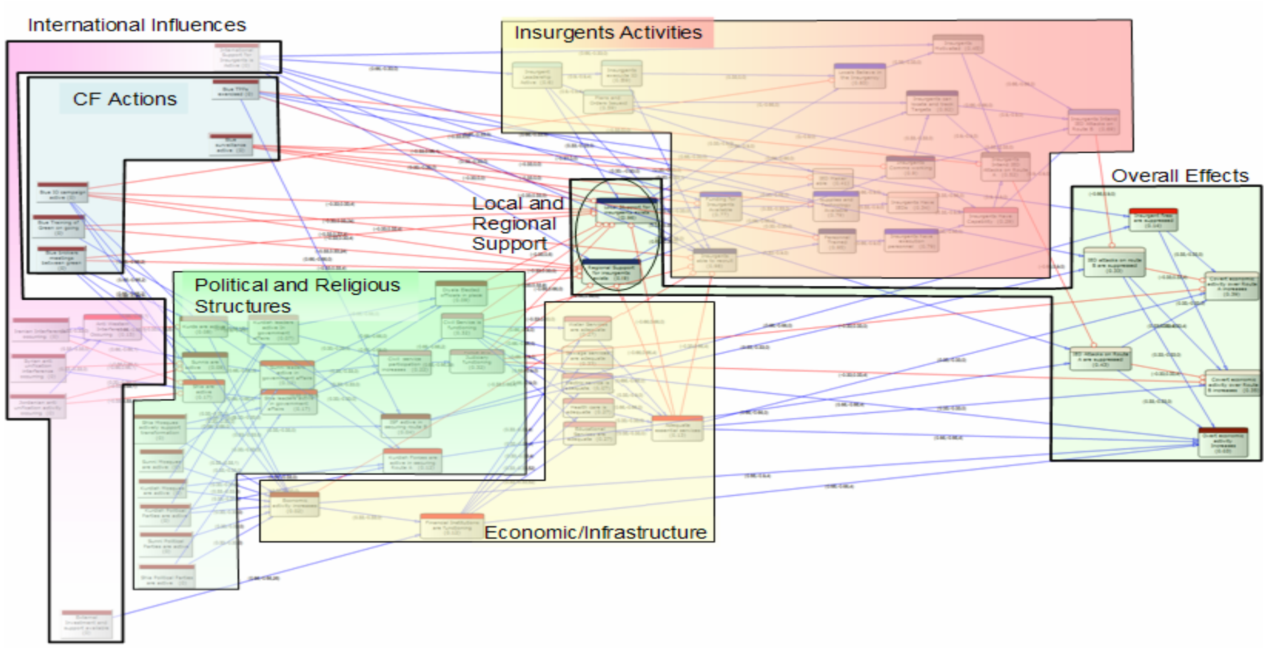

Fig. 3 Complete TIN Model

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. 4. 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

Fig. 4 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. Fig. 5 shows an example of COA and input scenarios that illustrate such an experiment. The second column of the Table in Fig. 5 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.

	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]

Fig. 5 Dynamic Temporal Analysis Input

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. 6. 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.

Fig. 6 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. 5). Also note that it is expected to take 80 to 100 weeks (nearly 2 years) for the full effect to occur. Fig. 6 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.

Of course it is possible to examine the behavior of any of the nodes in the model, by plotting their probability profiles.

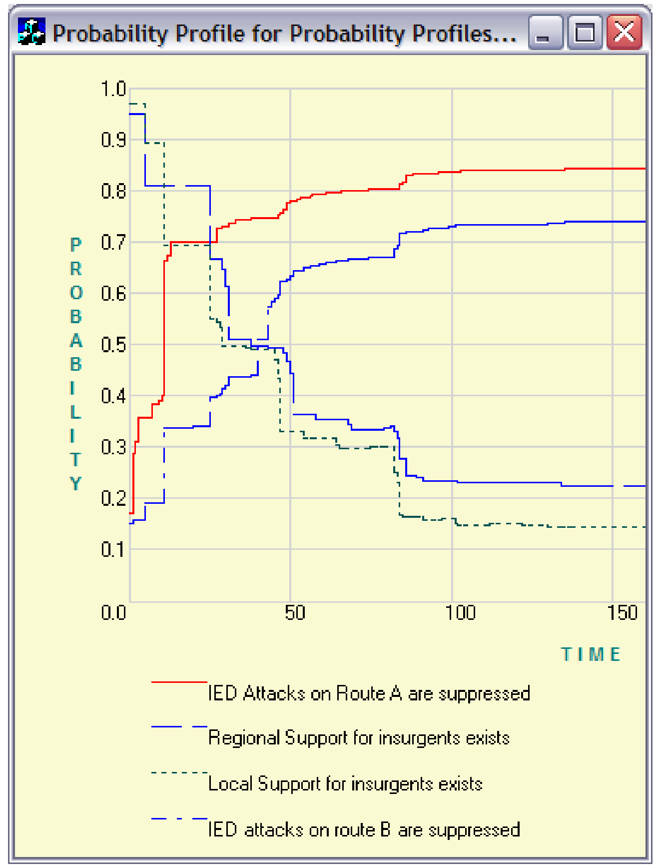

Fig. 6 Probability Profiles of Scenario (COA) of Fig. 5

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. 5. In this case the first line of Fig. 5 is changed from [1.0, 0] to [1.0, 0] [0.5, 26]. All of the other inputs remain the same. Fig. 7 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.

IV. Observations and Comments

Creating TIN models of situations appears to help address the two challenges described in the beginning of this paper. It 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 be comes 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.

We believe that 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, a coarse way, what the likelihood of different effects occurring are 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.

This modeling approach can provide analysts with a rich vehicle for explanation and computational experimentation with COAs so that important recommendations can be made to the decision makers. 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 standard way to analyze and describe very complex situations.

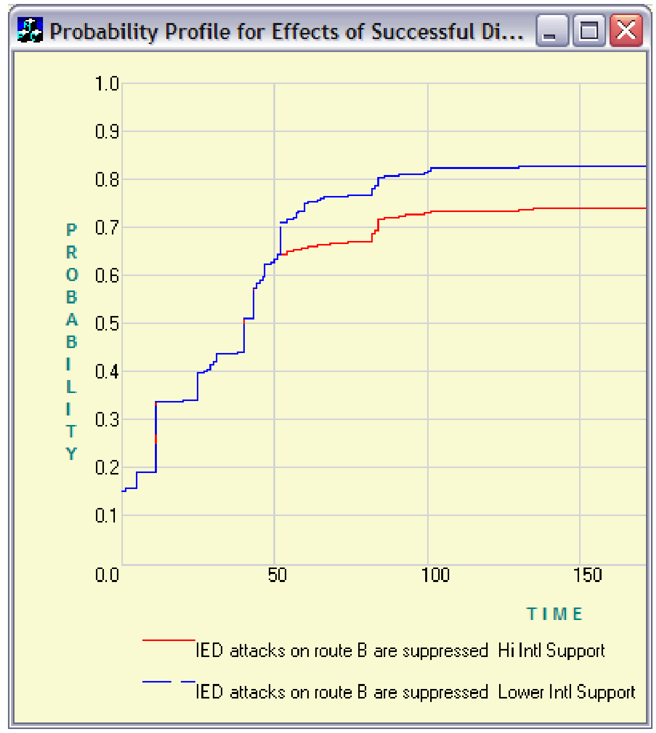

Fig. 7 Comparison of the Effect of Different Scenarios

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