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ANALYSIS OF CHANGE IN POPULATION STANCE ON INFRASTRUCTURE USING A CULTURAL GEOGRAPHY MODEL FOR STABILITY OPERATIONS

by

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September 2009

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Operations in counterinsurgency (COIN) and stability, security, transition, and reconstruction (SSTR) require a cultural understanding of the population in which they are conducted. TRAC Monterey has embarked on the development of a stochastic, discrete-event simulation model called the Cultural Geography (CG) model, intended to aid the decision maker in understanding the effects of his actions on the local population. The simulation model incorporates theories in social science, along with data pertaining to a specific region, to demonstrate how the population's culture will influence their stance on issues relevant to the region. We conduct a preliminary investigation of the capabilities of the CG model. We use techniques in data mining and experimental design to determine the inputs or factors that have a significant effect on the output or results of the model. The methods we employ were able to aid in debugging the infrastructure portion of the CG model, and demonstrate the utility of efficient experimental design in developing and exploring simulations that represent human populations. Ongoing, in-depth explorations of CG and related models will be beneficial as these models are refined, and will help establish the class of questions for which they are suitable.

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EXECUTIVE SUMMARY

Operations in counterinsurgency (COIN) and stability, security, transition, and reconstruction (SSTR) require a cultural understanding of the population in which they are conducted. The center of gravity in irregular warfare is the population, and the U.S. and its partners must be able to operate as proficiently in this environment as they once were prepared to do conventionally during the Cold War. To do this effectively, the U.S. and its allies must implement all the tools and techniques available to aid their understanding of the cultural terrain. One approach to this very complex problem of human behavioral modeling is that posed by the modeling and simulation community.

TRAC Monterey has embarked on the development of a stochastic, discrete-event simulation model called the Cultural Geography (CG) model, intended to aid the decision maker in understanding the effects of his actions on the local population. Its development is rooted in the prevailing theories of social science, and implements the beliefs, value, and interests of the major demographic segments (age, education, tribe, and politics) in an area of operations to determine their stance with regard to these attributes on the relevant issues. We use this function of the CG model to quantify their change in stance on issues of relevance over the course of a year. This is an important first step toward using insights about the population's stance in course of action analysis.

The current unclassified scenario incorporates data collected on the Iraqi city of Amarah, located in Maysan Province, during the year 2008. This initial location was chosen due to the ample data available in the form of firsthand accounts, provided by the co-lead member of the CG development team at TRAC Monterey. The population of agents is made up of the indigenous peoples and the actors who are the government agents, insurgents, and coalition forces whose actions affect the population. The agent's narrative identities capture their beliefs, values, and interests on the relevant issues in the AO. The agents carry out actions in the simulation based on a theory of planned behavior, and pass messages about events in the scenario via a social network. The agents satisfy their basic needs from infrastructure objects that are represented by multi-server queues.

We use efficient experimental design techniques to explore the model's response to variations in the model's inputs. An understanding of the important factors and their interactions improves our knowledge of the simulation and, by extension, provides insights about the real-world situations it represents. These insights can help us to find more robust solutions, as well as to uncover new questions worthy of investigation.

We analyze the results using multiple regression methods, partition trees, and other graphical and analytic techniques to measure the population's change in stance on the issue of infrastructure. This prototype analysis explores the population by their stereotypes, demographic segments, and locations to draw insights on the most influential of these on the stance on infrastructure. For the version of CG under study, the demographic segments are defined as military and non-military age males, educated or uneducated males, four tribal affiliations, and three political party affiliations. TRAC Monterey identified these demographic segments as the most relevant to the issues of security, elections, and infrastructure in this area of operations.

We find that tribal affiliation is the strongest indicator of change in stance on infrastructure for the specified scenario over the course of the simulation's run, which represents one year. When combined with location, tribal affiliation becomes the dominant indicator of the agents' stances on infrastructure. We develop a statistical metamodel to further support this finding and demonstrate that if we are able to identify an agent's tribe and political affiliation, we can determine with some confidence the simulation model results regarding his change in stance on the issue of infrastructure.

Since this analysis is a preliminary investigation of the capabilities of the CG model and, specifically, of the issue of infrastructure, there are many more opportunities for research in CG that will aid the U.S. Army, the modeling and simulation community, and TRAC Monterey in its continuing development. A similar analysis could be applied to the remaining issues of security and elections to determine the demographic segments of importance. The methods employed during this research were able to aid in debugging the infrastructure portion of the CG model, and further proved the utility of efficient experimental design in developing and exploring complex simulation models of this type.

Ongoing, in-depth explorations of CG and related models will be beneficial as these models continue to be refined, and will help establish the class of questions for which these simulations representing populations and culture are suitable.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAH	Asaib Ahl al-Haq
ABM	Agent-Based Model
AO	Area of Operations
CG	Cultural Geography
COA	Course of Action
COIN	Counterinsurgency
CSV	Comma Separated Values
DoD	Department of Defense
DOE	Design of Experiments
IDFW	International Data Farming Workshop
IPB	Intelligence Preparation of the Battlefield
IW	Irregular Warfare
JAM	Jayesh al-Mahdi
MAMs	Military Age Males
MOE	Measure of Effectiveness
MAS	Multi-Agent System
NGOs	Non-Governmental Organizations
NOLH	Nearly Orthogonal Latin Hypercube
OMS	Office of Muqtada Al-Sadr
PMESII	Political, Military, Economic, Social, Infrastructure, Information
PSOM	Peace Support Operations Model
SIIC	Supreme Islamic Iraqi Council
SSTR	Security, Stability, Transition, and Reconstruction

TRAC	TRADOC Analysis Center
TRADOC	Training and Doctrine
USMC	United States Marine Corps

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I. INTRODUCTION

A. BACKGROUND

Current operations in Iraq and Afghanistan have identified a need for tools in Irregular Warfare (IW) that can aid the decision maker in achieving a better understanding of the effect of his actions on the local population. This is a recent change in doctrine for the U.S. Department of Defense (DoD), based on feedback and the hard lessons learned from current conflicts. The U.S. Army has taken this doctrine onboard and, in the latest revision to Army Field Manual 3-0, discusses the importance of the host population in stability operations for current and future conflicts. It states that "[w]ith the exception of cyberspace, all operations will be conducted 'among the people' and outcomes will be measured in terms of effects on populations" (Army Field Manual 3-0, 2008).

In support of this guidance, TRAC Monterey has developed an agent-based modeling platform that can be used to measure the population's change in stance on relevant issues. For this study of one version of the Cultural Geography (CG) model still under development, issues related to elections, infrastructure, and security are represented. The goal is not a model capable of predicting responses of the population to specific actions, but rather a tool useful for gaining insight into the effects that certain actions by other actors in the environment, such as coalition, government, and insurgent forces, have on the population. In the current unclassified scenario based in Al Amarah, Iraq, the population is partitioned into 48 different stereotypes based on age, education, political affiliation, and tribal affiliation to gain intuition about the effects that events have on these specific subgroups.

Previous studies have utilized other simulation modeling platforms in an attempt to model cultural geography, but were limited by the original purpose of the software's design. For example, PYTHAGORAS (version 2.0.0) allows for a rich, nuanced set of perceptions between the agents, but it was primarily built to function as a combat model. Ferris (2008) concludes that a major fault of an attempt to model cultural geography through PYTHAGORAS is an absence of a link between the agent's beliefs of the relevant issues and his position or stance on those same issues. Seitz (2008) determines that PYTHAGORAS is well-suited for military functions in stability operations, such as patrolling, and can even be used to model the effects of mass media and taxes for analysis. It is, however, unable to implement an effective social network representation.

The Cultural Geography model was designed and created by TRAC Monterey, from its inception, to be a social model that incorporates social network and human behavioral theory as cornerstones of its functions. It is far from a traditional combat model; instead, it is a human behavior representation that attempts to fill a large gap in the DoD's field of modeling and simulation.

B. RESEARCH QUESTIONS

The goal of this research is to observe the operations of the CG model, conduct debugging, suggest methods of analysis, and recommend improvements using the methods of experimental design and data mining. We will do this by observing the change in population stance on the issues of interest, and conduct experimentation with the model to gain a better understanding of the conflict ecosystem and the factors that most strongly influence the population subtypes as represented in the current scenario. Specifically, this research will address the following questions:

- For each stereotype, can the dominating influences be identified (tribal, political, educational, or age) with some certainty?
- What controllable factors could be manipulated to have the most substantial effects on the outcome of the model? Are there highly influential factors that are beyond the control of coalition forces?
- How sensitive is the civilian population to changes in infrastructure capacity?
- What techniques used during the conduct of the experiment are useful in ascertaining the model's performance?

C. BENEFITS OF THE STUDY

This research will support TRAC Monterey in the development of an appropriate methodology to use CG and other related models for investigating the various political, military, economic, social, infrastructure and information (PMESII) aspects of irregular warfare. Although not intended to be a complete investigation of the model's capabilities, this prototype analysis utilizes experimental designs and data mining techniques to show the benefits of their efficiency in exploring complex social simulation models of this nature. The efficiency of designs of experiments will provide us the ability to observe varying degrees of the response surface for verification and debugging as just two examples. Lastly, we intend to demonstrate the utility of the Cultural Geography model in the decision-making process.

D. METHODOLOGY

The scenario developed by TRAC Monterey utilizes data obtained on the populace of Al Amarah, Iraq, and was first employed during the March 2009 International Data Farming Workshop (IDFW). Experimentation during the workshop mainly addressed troubleshooting and verification; however, a brief analysis was also conducted of the 48 stereotypes to determine their stance on the relevant issues that provided a basis for the methodology of this research. This same scenario, with some modification, was utilized as the Cultural Geography (CG) model was improved by TRAC Monterey through its own efforts and by feedback from the analysis of the resulting output. Experimental design was utilized to determine how changes in various input factors affected the measures of effectiveness once the model was equipped for multiple simulation runs.

E. LITERATURE REVIEW

Though the United States military has traditionally resisted engaging in conflicts involving humanitarian assistance and stability, they are not a foreign concept. The conflicts in Vietnam, Somalia, Haiti, and Kosovo provided many of the lessons the U.S. armed forces needed to prepare for the battles we are now engaged in and will most likely confront in the foreseeable future. A rigid focus on conventional combat led to a failure by the Department of Defense to take the lessons learned during these campaigns and pen them into doctrine for future engagements. Our early struggles in these conflicts have forced a change in thinking and brought deficiencies in Irregular Warfare (IW) to the forefront.

The failure of the United States to utilize the “golden hour” after hostilities had ceased in Iraq in 2003 led to a rapid escalation of chaos in Baghdad, whereby criminal actions became rampant and the insurgency we now are fighting was born. The inability of the nation to shift its target from the enemy forces, the conventional center of gravity, to the populace, which became the new center of gravity when Iraq’s armies were defeated, aided in the creation of a completely different engagement. U.S. forces were now battling against insurgents for the “hearts and minds” of the populace, without any plan or idea of how to successfully do so.

Further, U.S. military forces were best positioned, though not adequate in numbers, to provide the Iraqis with stability and aid in the days following the end of major hostilities. Unfortunately, at the time of Operation Iraqi Freedom, the Department of Defense did not see this as a core mission of the U.S. armed forces. Not until the release of *DOD Directive 3000.05* in November 2005 were stability operations given priority comparable to combat operations. Until this time, the military’s sole mission was to win a conventional war and leave all else to other U.S. agencies.

Melillo (2006) states:

> While military planners prefer to view the postwar reconstruction as the purview of the State Department, the United Nations, and nongovernmental organizations, the unfortunate reality is that within the U.S. government, only the military possesses the expeditionary capability to deploy to austere (or war-ravaged) environments and sustain itself while providing the requisite assistance to restore order and promote U.S. interests. (p. 28)

1. Security and Reconstruction

The ability of the U.S. military to provide for its own security in post-conflict situations is a capability that is not inherent in most international organizations, non-governmental organizations (NGOs), or other private organizations, which have the expertise in stability and reconstruction. This is especially true in those military organizations that have units composed of military engineers. These units are able to effectively conduct reconstruction activities while simultaneously providing self-protection (Ryan, 2007). Often, the lack of security against the threat of attack by insurgents in post-conflict regions prevents international organizations, private groups, and NGOs from entering the areas of greatest need. The insurgents maintain their control of these afflicted areas through chaos and fear, thereby preventing goodwill from gaining a foothold. However, if security is established, the seeds of goodwill are given the opportunity to sprout and the populace can reap the benefits of peace, free markets, improved infrastructure, and self-governance.

While the military provides the force to establish security, it can use its supporting elements to begin the work of reconstruction. Conventional combat places infantrymen on the front lines to defeat the enemy, while combat service support elements are placed in the rear to support them. Now, in nontraditional warfare, combat service elements are brought to the front while being supported by the "trigger pullers." Intelligence, construction, public affairs, and the medical elements are those best suited to wage the new war. They must interact with the local populace at all levels of the existing social structure to determine the current needs and deliver the right product at the right place and time. They do this well, through their inherent capability to provide for their own protection.

The focus of military-led reconstruction should be in the realm of quick impact projects. These are rapid completion projects, which meet the immediate needs of the local populace. They should be arranged and coordinated through frequent contact with the leaders of the local community to ensure that they meet the needs of the people, and not the political needs of the community leaders or nation. According to McFate (2005), "Postconflict reconstruction is most effective when the rebuilt institutions reflect local interests, and do not impose external concepts of social organization" (p. 45). Quick-impact projects allow the military forces to make a positive impact on the local populace and gain their favor, thereby dissuading any allegiance to the insurgency and, therefore, improving stability. The public affairs or information operations element is vital in distributing the status of these projects to the local community as well as to the U.S. population. The locals must be frequently updated on the coordination between local leaders and the military, the current status of these projects, and the benefit these projects bring to the local community.

When the military is leading reconstruction efforts, it is able to create time and space for native capacity to grow within the existing capacity of the military's programs (Ryan, 2007). While these quick-impact projects are creating time and space, long-term projects can be undertaken. Hospitals, schools, police stations and fire stations can be built, while efforts to educate the professionals who bring life to these institutions can be initiated. The local community should be used to the maximum extent possible to participate in—or lead, if capable—these efforts. Where there is a lack of capability amongst the local populace, training should be conducted by the U.S. military component working the project to create a local capability. These initial efforts in reconstruction can only be realized through the security capability that is inherent to the U.S. military organization.

2. Intelligence

Since the goal of the U.S. military is to provide for the stability of a region, it must have a thorough understanding of the populace in which it is operating. In fact, according to Ryan (2007), this should be one of the highest intelligence priorities from the start of pre-deployment planning and throughout the conduct of operations. Cebrowski states that "the value of military intelligence is exceeded by that of social and cultural intelligence. We need the ability to look, understand, and operate deeply into the fault lines of societies where, increasingly, we find the frontiers of national security" (as cited in McFate, 2005, p. 47). A societal order of battle must be developed that identifies the families, tribes, or political groups that have the most influence amongst the population. This is a responsibility of the geographic combatant commander to include in his intelligence campaign as stated in *DOD Directive 3000.05.* These "targets of interest" then become the means through which stability is achieved. Their support aids in gaining the support of the larger populace and provides a measure of effectiveness whereby military actions can be gauged.

During the engagement, the gathering of intelligence must occur at all levels of interaction and be shared up and down the chain of command. Though primarily employed for force protection, Soldiers and Marines must be able to establish one-to-one relationships, which are key to intelligence collection and winning hearts and minds. The intelligence is used to mold and change the policies used by U.S. forces in reconstruction. It ensures that the correct projects are undertaken that will bring the most benefit, and deters any distracters. In support of this intelligence effort, *DOD Directive 3000.05* (Section 4.11) has stated that "stability operations skills, such as foreign language capabilities, regional area expertise, and experience with foreign governments and international organizations, shall be developed and incorporated into Professional Military Education at all levels." This places many experts in the field who are able to sense and interpret the mood of the population to actions by the coalition. Further, their collaborated reports improve the situational perspective of the command authority.

Simulation models can be utilized as part of the intelligence efforts. Knowledge of the population's centers of gravity in the form of influential tribes, families, and leaders—as well as their interests, values, and beliefs—can be built into models that represent the intended areas of operation. In this way, an analysis of the simulation model can be conducted to determine the effects of possible courses of action on the local population.

3. Conclusion

Following the completion of major hostilities, the U.S. military must be able to smoothly transition to provide for the security and stability of the local population if required to do so. Additionally, it must immediately begin the work of reconstruction until a secure environment exists whereby these responsibilities can be transferred to international organizations or NGOs. It must be prepared, however, to continue these tasks until such time as sufficient capacity and capability is established within the indigenous population where participation by other organizations is not possible.

Planning for stability and reconstruction must be undertaken during the preparation for war. Intelligence gathered on the local populace should be viewed with equal importance as intelligence gathered on enemy capability. McFate (2005) argues that although "know thy enemy" is one of the first principles of warfare, failure to understand the culture of the opponent has caused continuing suffering in our military operations. He states that "misunderstanding culture at a strategic level can produce policies that exacerbate an insurgency; can lead to negative public opinion at the operational level, and endanger civilians and troops at the tactical level" (McFate, 2005, p. 43). Support for the campaign must be quickly gained from the local populace and must then be utilized in the reconstruction efforts. The day Saddam's statue fell in Baghdad was perhaps the day the U.S. had the greatest support from the Iraqis. Unfortunately, the lack of knowledge about the indigenous culture and the delay in reconstruction caused a rapid erosion of that support and a quick escalation in resistance to eventual reconstruction efforts.

Finally, the theme of U.S. military efforts in stability and reconstruction is best stated by Colonel Michael R. Melillo, USMC: "The lessons learned in Iraq have shown that to be effective, the U.S. military must balance its well-developed ability to apply force with compassion and understanding of the local indigenous population" (Melillo, 2006, p. 33).

II. CULTURAL GEOGRAPHY MODEL FOR STABILITY OPERATIONS

A. BACKGROUND

The development of the Cultural Geography model at TRAC Monterey is an ongoing effort, which will continue as new purposes for the model are identified. The CG model underwent several iterations during this research to upgrade its functions and expand its utility. The description of the prototype model that follows is a brief glimpse of the methods used in its construction and the capabilities employed during the development of this thesis. Version 0.4.0 of the Cultural Geography (CG) model was utilized to create the data for analysis in Chapter IV, Section B, IDFW, and Version 0.4.3 for Chapter IV, Section C, Analysis of Infrastructure.

It is not our intent to completely define the operations or functions of the CG model. Further information about the CG model is available upon request from the developers at TRAC Monterey.

B. DESCRIPTION

The CG model is a discrete-event, stochastic, agent-based model (ABM) implemented in Java that uses Simkit 1.3.7 as the simulation engine. The CG model uses Jacques Ferber's multi-agent system (MAS) definition to represent Kilkullen's "conflict ecosystem" that exists in an IW setting (Kilkullen, 2007). Jackson and Alt (2009) briefly summarize the MAS as "consisting of the environment, agents, objects, a collection of operations that can be executed by agents and rules governing operations within the environment" (Conceptual Modeling Framework section, para. 1).

1. Scenario

The version of the CG model implemented for this work was composed by analysts from TRAC Monterey, from unclassified data, to create the environment referred from here on as an area of operations (AO). The size of the AO is dependent on the study questions, the quantity and quality of data available, and the degree of scope desired by the analysts. For this reason, the CG model is well suited for varying degrees of analysis.

The current scenario incorporates data collected on the Iraqi city of Amarah, located in Maysan Province, during the year 2008. This initial location was chosen due to the ample data available in the form of firsthand accounts, provided by the co-lead member of CG development team at TRAC Monterey. The population of agents is made up of the indigenous peoples and the actors who are the government agents, insurgents, and coalition forces whose actions affect the population. Since the goal is to understand the influences of the actors on the indigenous population, the concerted efforts are on gathering data to build the narrative identity for each agent in the population. This process is essential to the ability to study the relevant issues of the AO.

2. Data Development

The data developers at TRAC Monterey employed a process mirroring the techniques suggested by COL Peter R. Mansoor, U.S. Army, in counter-insurgency (COIN) intelligence preparation of the battlefield (IPB), to gather data on the AO (Figure 1).

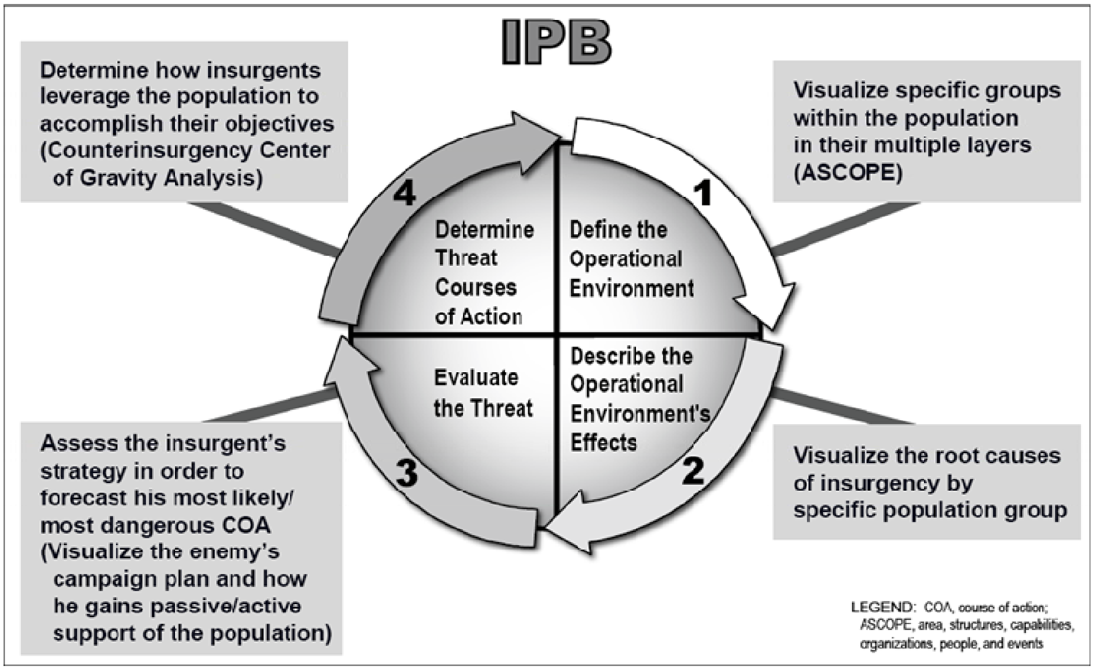


Figure 1. The Four Steps of COIN IPB (From Mansoor, 2007)

COL Mansoor proposes four steps in the IPB process applied by the data developers at TRAC Monterey in the following way:

- define the battlespace environment,
- describe the battlespace effects,
- evaluate the threat, and
- determine the enemy course of action (COA).

The model developers at TRAC Monterey then conducted a literature review consisting of doctrine, reports, key engagements, and firsthand accounts from the area under study to identify the relevant issues, influential actors, and prominent population cohorts. (Perkins, Pearman, & Jackson, 2009). This process was iterated over to ensure that the focus of the data collection efforts was towards a study of the relevant issues of the population in the designated AO.

An essential to the model as the data concerning the indigenous population, is the integration of current doctrine in the realm of stability operations (SSTR) and counterinsurgency. Perkins et al. (2009) state, "Doctrine provides overarching guidance about relevant information, operations potentially relevant to the civilian population, actions taken by coalition and insurgent actors, and identifies other potential groups that affect an area of operations" (p. 6). In summary, doctrine provides the objectives of U.S. forces with respect to a particular AO and attempts to qualitatively describe the possible repercussions of carrying out actions to achieve those objectives. The current Army doctrine for stability operations and counterinsurgency exists in the latest revisions of the Army Field Manual, FM3-07 and FM3-24, respectively.

3. Agent Description

The greatest service of the CG model rests in the information provided on the population's responses to actions by actors in the AO, to the infrastructure objects, and to the various events of the scenario. Their response, in the form of a change in stance on the relevant issues, is the measure used in this work and by the analysts at TRAC Monterey to gauge the model's operation as well as to provide the insights on the effects of the actor's actions. The identity of the indigenous agent is composed of two theoretical elements, which allow him to react and function within the model's environment. These two theories are the narrative paradigm and theory of planned behavior. These two theories are uniquely applied to each agent based on which of 48 distinct stereotypes applies to the agent. The description of each theory and its application to the chosen demographic segments follows.

a. Narrative Paradigm

An agent's narrative identity is the bridge between his beliefs, values, and interests, and his stance on the relevant issues. Dr. Walter Fisher's narrative paradigm describes this as the incorporation of an entities beliefs, values, and interests into a story, through which he evaluates the other stories of the world. An agent's narrative rationality is the basis for his evaluation. Fisher (1987) bases narrative rationality on three factors:

- narrative coherence—the story makes sense,
- narrative probability—the story is likely to have occurred from the listener’s perspective, and
- narrative fidelity—whether or not the stories people experience relate to what they know to be true in their own lives.

Perkins et al. (2009) add, “Knowledge of a population’s narrative identity enhances understanding of society’s core values and beliefs, which is essential to successful counterinsurgency and stability operations” (p. 14).

The tool used to capture an agent’s narrative identity in the CG model is the Bayesian belief network. Bayesian networks were chosen due to their ability to adequately model human causal induction (Tennebaum & Griffiths, 2001). Tennebaum and Griffiths argue that the human ability to make rapid decisions with very little information is based on a probabilistic process. Beliefs and interests are extracted from the narrative identities of the chosen demographic segments and anchored to nodes in the Bayesian network in order to determine how these various segments view the relevant issues. The values and beliefs of the demographic subtypes chosen for study by TRAC Monterey are included in Table 1.

Demographic	Beliefs and Interests
MAMs (age 15-29)	1. Government owes me a job with honor and power. (S,E,I) 2. Violence is ok. (S)
Males older than Military Age	1. Iraq should be a sovereign nation. (S,E) 2. Iranian ties ok for commerce. (S,I) 3. Outsiders not welcome. (S,E)
Educated	1. Fear of central government. (S,E) 2. More opportunity outside Iraq. (I) 3. Iraq is not secure. (S) 4. Not appreciated by the government. (E)
Uneducated	1. Living off the land provides a viable and respectable livelihood. (E,I) 2. Providing for family (preserving honor) worth risking life (Iraqi Army or insurgent participation). (S) 3. Government should improve infrastructure. (E,I)
Bani Lam	1. Opportunistic. No bounds regarding methods to accumulate wealth. (S,E,I) 2. Violence is not ok. (S). 3. Self-reliance necessary to resolve problems. (I).
Albu Durraji	1. Violence is ok. (S) 2. Outsiders not welcome. (S,E) 3. Supports local government. (E)
Al Suwaid	1. Iranian ties ok for commerce. (S,,I)
Albu Mohammad	1. Outsiders not welcome. (S,E) 2. Government should improve infrastructure. (E,I)
OMS (JAM)	1. Violence is ok. (S) 2. Outsiders not welcome. (S,E) 3. Willing to expand their mission to humanitarian and social priorities to achieve long-term political influence. (S,E,I) 4. Iranian ties ok for political gain. (S,E)
Dawa	1. Supports central government. (S,E,I) 2. Violence is not ok. (S)
SIIC (Badr Organization)	1. Iranian ties ok for political gain. (S,E) 2. Violence is ok. (S) 3. Believes establishing ties with US is ok. (S,E)
Legend: Letters next to the beliefs indicate that the belief is aligned with that issue. S=Security, I=Infrastructure, E=Elections.	

Table 1. Beliefs and Interests by Demographic Group (From TRAC Monterey, 2009)

The beliefs and interests of the various demographic segments in Table 1 were aligned by the study team at TRAC Monterey to the issues of security, infrastructure, and elections. The result was a Bayesian belief network for each agent that accounts for each of these issues. Figure 2 provides an example for the issue of infrastructure.

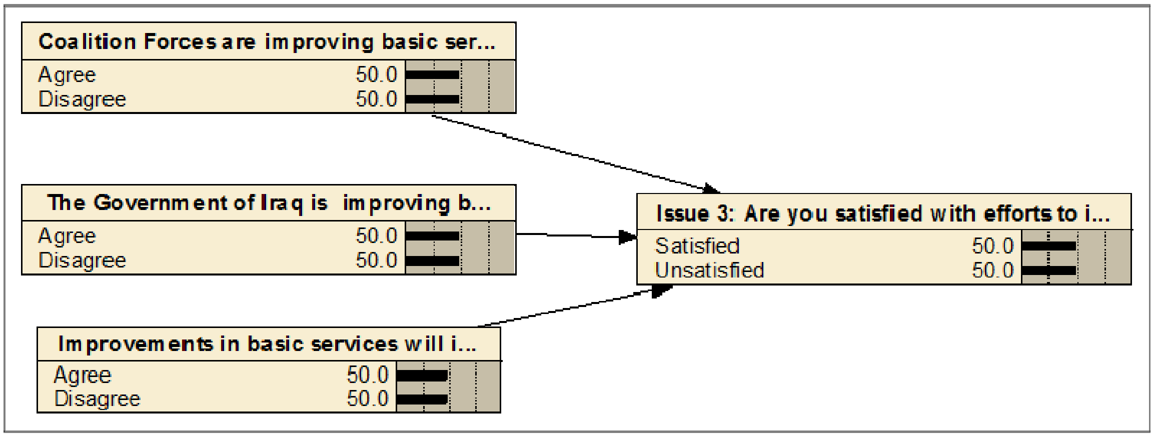


Figure 2. Beliefs Impacting Stance on Infrastructure (From TRAC Monterey, 2009)

The values in each Bayesian belief node quantify his beliefs and interests in terms of a probability on the particular issue in reference to his demographic profile. The overall probability of satisfaction (Figure 2) with the level of efforts in improvements in basic services provided by the infrastructure in Amarah is the result of a calculation utilizing Bayes' Theorem that uses the values of the previous three belief nodes as the variables. Thus the agent's entries for improvement of basic services by coalition forces, government of Iraq, and the belief that improvements in basic services will improve quality of life in Amarah will determine the agent's level of satisfaction on the efforts to improve basic services in the city of Amarah.

Further, the agents have similar Bayesian belief networks for the issues of security and elections, constructed with a comparable methodology to that for infrastructure.

b. Theory of Planned Behavior

Where an agent's narrative identity provides his rationale on the relevant issues, the theory of planned behavior provides a guide for his actions in the scenario. These actions include passing of messages to other entities in the social network or interacting with an infrastructure object to obtain goods and services. The theory of planned behavior in the CG model provides a method for an agent to carry out actions during the simulation according to his specific motivations. As with his narrative identity, these will be specific to each agent based on the composition of his stereotype.

Icek Ajzen's (1991) theory of planned behavior is implemented in the current version of CG. Jackson (2009) summarizes the theory of planned behavior as, "the relationship between an individual's attitude toward a behavior, the perceived social norms surrounding the behavior, and the individual's perception of their level of behavioral control and the formation of the individual's intention to take some action" (Applying Narrative To Model section, para. 15). The Bayesian belief network is again the chosen method of implementation of the theory of planned behavior for the CG model. An example of one Bayesian network that incorporates the theory of planned behavior is included in Figure 3.

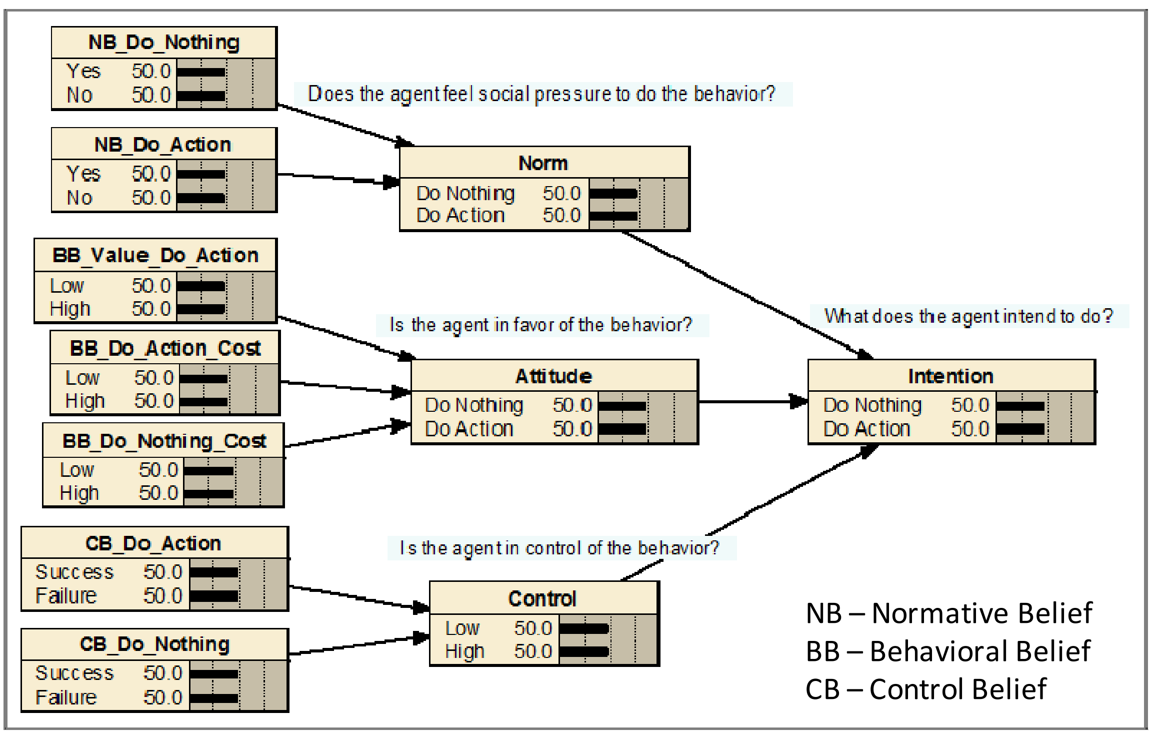


Figure 3. Theory of Planned Behavior Network for General Actions (From TRAC Monterey, 2009)

Thus far, the agent is able to quantify his stance on the relevant issues by virtue of this narrative identity. He is also able, through the theory of planned behavior, to take action based on his beliefs, values, and interests. The following discussion will present the means by which the agents in the model communicate.

c. Social Network

A social network within the CG model allows for communication among the agents of the population. Specifically, the agents are able to pass messages in the social network about events occurring within the scenario. Arcs in the network are characterized as affective ties. The strength of the affective tie is based on the concept of homophile, which is the affinity of an entity to interact with another based on a level of likeness. For the construct within the CG model, the strength of the tie is a distance between demographic dimensions instituted in the model based on Euclidean distance.

Messages are passed among members of similar tribal or political affiliation, as one example. The hierarchy can be constructed to account for members of the society who are perceived to be influential, such as political figures or tribal leaders. The ability of an agent to pass messages through the social network can be varied to account for repetition and the passage of time.

d. Infrastructure Objects

Infrastructure exists in CG as multi-server queues. The agents in the model are able to obtain goods and services from these objects based on direction from their theory of planned behavior profile. Acquisition or denial of goods and services is also used to update the agent's theory of planned behavior profile and therefore provide an input to their stance on the issue of infrastructure. Capacity provided by the multi-server queues can be reduced to account for damage due to attacks, or increased to account for improvements made by the government or coalition forces. Additionally, the infrastructure objects can be associated with a specific tribe or region. This allows a cost to be associated with the use of an infrastructure object by an agent from another tribe or region.

4. Model Output

As described above, the agent’s Bayesian belief networks are updated as the simulation runs as a function of the events in the scenario, the messages received through the social network concerning events, or the interaction with infrastructure objects. Their change in stance on a specified measure of effectiveness (MOE) is a function of the way in which their narrative identity weighs each event. Thus, it is possible to conduct a survey of these narrative identities, which exist in the 48 stereotypes. A run of the simulation is essentially a poll of the population on the selected MOEs over the course of one year. For the current version of CG, data recorders gather information on each agent each time there is a change in his stance, positive or negative.

III. DESIGN OF EXPERIMENTS

In this chapter, we will discuss the techniques used to conduct the experiment, the measures selected, as well as the reasoning for these choices.

A. MEASURES OF EFFECTIVENESS

The measures of effectiveness used for this analysis were chosen by TRAC Monterey due to their high degree of importance in the area of study. The three measures of security, elections, and infrastructure were selected due to the feedback received from a deployed analyst and the study team's detailed literature review. Though it is possible to change the measures of effectiveness in CG, it would require additional resources to build the applicable case files and Bayesian networks to support the study of another issue, as the population's narrative identities must be appropriately aligned with said issue. Therefore, we decided to continue to use the measures already in place in the current version of CG. A brief description of each of the measures follows.

1. Infrastructure

The issue of infrastructure is defined by the population's satisfaction with the current state of infrastructure and the outlook on near-term opportunities. Conversely, the issue is also defined by the population's belief that the current state of infrastructure and the methods to improve it are unsatisfactory. The ability to build and maintain infrastructure is vital to the growth and sustainment of a society.

2. Security

This issue relates to the adequacy of security in the area of study from the population's perspective. Security is provided by the host government and coalition forces. Any action taken by insurgent forces will be perceived by the population as a degradation in the level of security. For this scenario, the insurgents are characterized to be members of the prominent militia group, Jayesh Al-Mahdi(JAM), or the Asaib Ahl al-Haq (AAH) militia. Providing security for a region is a key tenet of current Army doctrine in stability operations.

3. Elections

The issue of elections is concerned with the population's opinion of its government. Further, the people desire that elections will provide them a voice for social justice. The issue of elections also provides the population's outlook on the fairness of elections and whether the results will produce a legitimate or illegitimate government from their perspective (Perkins et al., 2009). The legitimacy of the established government is crucial for stability, and is another critical tenet of current Army doctrine in counterinsurgency.

B. EXPERIMENTAL DESIGN

We use experimental design techniques to explore the model's response to variations in the model's input and then analyze the results for the affects of variations in these input factors. An understanding of the factors and their interactions improve our knowledge of the experiment and can help us to find more robust solutions as well as to uncover questions for further study (Sanchez, 2008). This is accomplished by creating a matrix consisting of columns of factors and rows of scenarios. Each scenario, or design point, is a row of values that contain the designated settings of the factors for that given scenario. The range of values of the factors is determined by the analyst or a third party as a feasible set of values. The matrix, referred to as the design of experiment (DOE), is then used to drive the simulation model and generate results. There are many ways in which the DOE can be implemented into a model. The details are often specific to the simulation model's existing interfaces and the computing language and format in which the model's code is written. The DOE implementation tool used for this research will be discussed in a forthcoming section.

Simulations are run on computers of varying processing power, but are typically matched appropriately for model complexity and processing requirements. The ability to harness the computational power of multiple processors, such as those found in clusters, is an added benefit when using experimental designs. Often, these resources provide the ability to conduct an experiment tens of thousands of times with very little additional expenditure. The additional information gained through the combination of computational power and efficient experimentation is invaluable. Hence, it is a goal of this technique to utilize the appropriate degree of computational potential available to conduct multiple replications of simulation models with stochastic characteristics, in order to be able to adequately explore the variability of the response surface.

In summary, the benefits of the experimental design approach are succinctly stated by Sanchez (2008) in “that a well-designed experiment allows the analyst to examine many more factors than would otherwise be possible, while providing insights that cannot be gleaned from trial-and-error approaches or by sampling factors one at a time” (p. 73).

1. Infrastructure Factors

Through discussion with the CG study team at TRAC Monterey, we decided to investigate the effects of infrastructure changes on the population’s perception of overall satisfaction with the level of efforts in improvements in basic services provided by the infrastructure in Amarah. The model contains several ways in which to influence perceived changes in infrastructure. Capacities of the infrastructure objects, rates of material transfer, or the rates of consumption of the population themselves can be varied to determine the overall effects of these changes to their stance on infrastructure. During debugging efforts of the infrastructure portion of the model, we determined that the initial and maximum transfer rates of the infrastructure objects were having a large affect on the population’s stance on the issue of infrastructure. For this reason, these two factors became the focus of further investigation.

The maximum transfer rate is defined as the maximum amount of consumable type, in this case fuel and food, that can be transferred to an agent per unit time per server. The initial transfer rate is the amount of fuel and food that can be transferred to an agent per unit time per server at the beginning of each replication. Each agent has a maximum capacity of fuel and food that they are able to hold, as well as a limit to the amount that they can obtain on each visit to the infrastructure object. Thus, the agent’s service time is dependent on the amount of time it takes to reach this limit.

The infrastructure objects themselves are composed of eight different commodities. They are fuel, food, water, electricity, communications, health, education, and legal. Constrained by the inability to utilize computer clusters in the model's current version due to limitations of the current Bayesian network implementation software, the decision was made to observe the commodities of fuel and food only. Each of the four tribes has its own unique infrastructure object to capture the agent's cost in receiving service from an infrastructure other than their own. Therefore, the final number of factors implemented in the DOE was 16, maximum and initial transfer rates for the commodities of fuel and food, across the four tribes, for a total of 2 x 2 x 4 = 16 factors.

The initial settings of the maximum transfer rates for fuel and food for all four tribes' infrastructure objects was set at 5000 units. This value was varied by 50 percent of the initial value for a range of 2500 to 7500 units. The initial setting of the initial transfer rates for fuel and food for all four tribes' infrastructure objects was set at 2500 units. This value was also varied by 50 percent for a range of 1250 units to 3750 units. The selection of 50 percent variation was through discussion with the CG study team at TRAC Monterey.

2. Nearly Orthogonal Latin Hypercube Design

The method of choice for the experimental design was the Nearly Orthogonal Latin Hypercube (NOLH). NOLH designs are flexible and efficient, making them suitable for experiments where there are many factors selected for consideration. The well-known space filling properties of the NOLH design is well suited for the exploration of complex response surfaces (Cioppa, 2002). Since the columns of the matrix are nearly orthogonal (meaning that the correlation between any two of the columns is very low), the analysis is greatly simplified in that it makes an easier identification of the impacts of the factors varied in the experiment. A multivariate scatterplot matrix of the design is depicted in Figure 4, which shows the space filling properties of the NOLH design for this DOE.

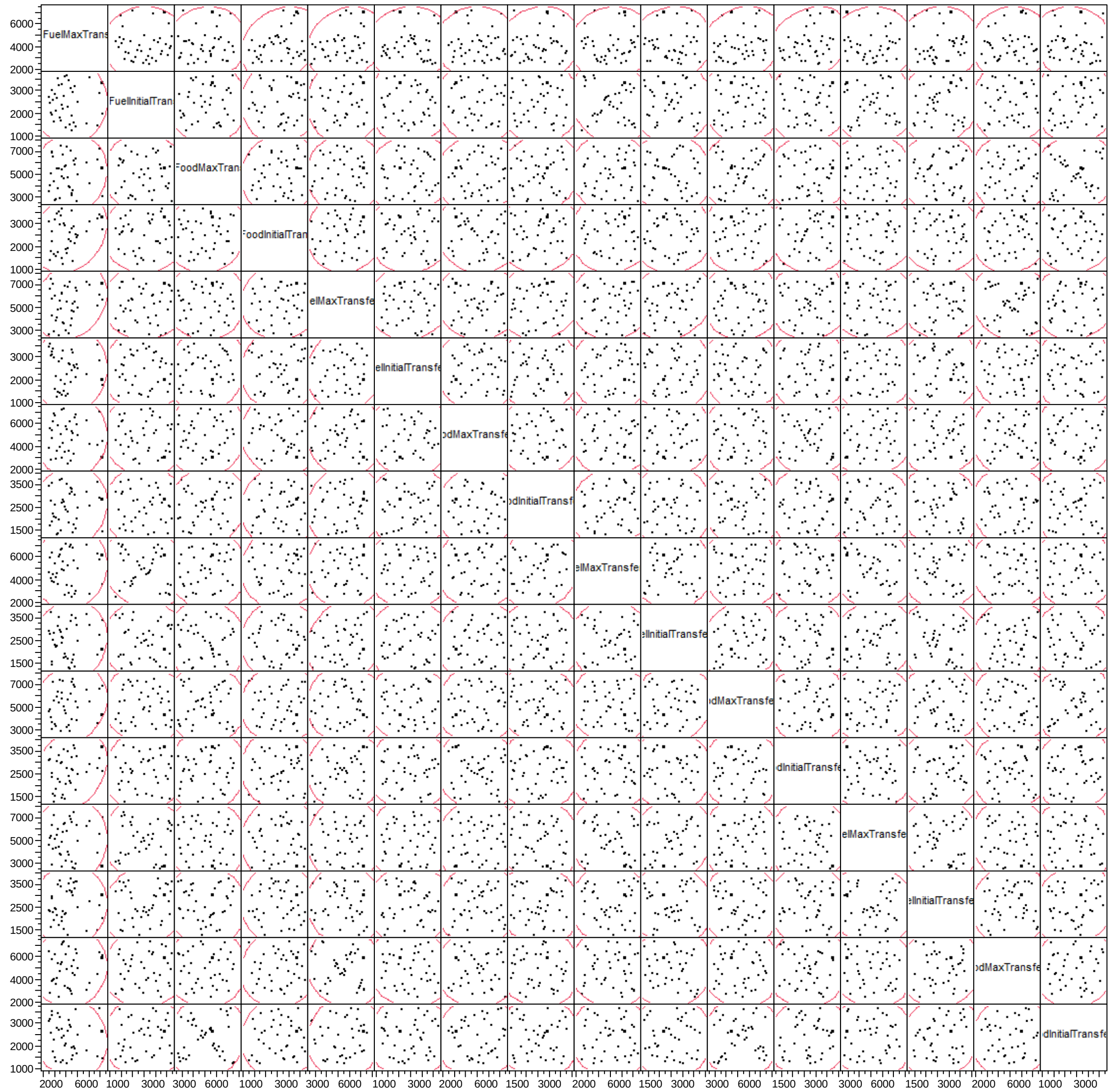


Figure 4. Multivariate Scatterplot Matrix for Infrastructure DOE

Experiments for this thesis were conducted utilizing the NOLHDesigns_v4.xls spreadsheet created by Professor Susan Sanchez (2005) based on the designs of Cioppa (2002) (see also Cioppa and Lucas, 2007). Further, the creation of the scenario files for each design point was created utilizing the DOE tool developed by TRAC Monterey, which incorporates the work of Sanchez, Cioppa, and Lucas (Pearman, 2009). This tool allows for the easy examination of CG scenario .xml files for factors, the ability to set upper and lower bounds for those factors, and the automatic creation of the smallest

NOLH capable of handling this number of factors. The DOE tool greatly simplified the process of creating an experiment for this work due to its ability to rapidly create scenario files for each design point. The DOE for this work consisted of 65 design points, created by the DOE tool in under one minute. Mr. Gerald Pearman of Augustine Consulting, Inc. executed the DOE tool based on our requests.

3. Computing

Runs of the 65 design points were conducted at TRAC Monterey on four standalone computers. As the CG model is still in development, we were unable to make runs on the computing clusters available on the campus of the Naval Postgraduate School, due to the incompatibility of the software in which the CG's Bayesian networks are written with the cluster environment. The developers at TRAC Monterey intend to resolve this issue in future CG versions through a software change that will, in turn, allow for a wider analysis of the effects of the many factors in the model on the response surface.

The runs were executed by the lead software developer of the CG model, Mr. Harold Yamauchi of Rolands & Associates Corporation. Each scenario, or design point, was replicated ten times for a total of 650 runs. The time of completion of each run was approximately 15 minutes but varied greatly, with some runs requiring nearly an hour to complete. The completion time for this experiment on four stand-alone computers was one week, counting scenarios that were rerun due to memory allocation errors in the first runs, which resulted in incomplete data. It was impossible to predict in which runs the memory allocation errors would occur, therefore, we allowed each of the batches to run to completion. We then identified the design points with incomplete information and reran them until they could be completed without error.

IV. ANALYSIS

A. BACKGROUND

We discuss the analysis portion as it occurred during two distinct time periods. The first portion of the analysis describes the results of the prototype run of the CG model for the International Data Farming Workshop (IDFW) held in March 2009 in Monterey, California. This aided in creating the methodology we used for the second portion of the analysis, which we conducted on the data to address the questions posed in Chapter I.

B. IDFW

The main intent of the prototype run of the CG model was to demonstrate a working model and observe and verify the output. Of the three MOEs of infrastructure, security and elections, the CG model only produced complete data for security and elections. A major obstacle to overcome in the first two days of the model simulation run was reduction of the data from the large file size, one to two gigabytes in comma separated value (csv) format. The simulation's output for each MOE includes the updated activity for each agent (for this case, 105 agents), from time zero to the end of the simulation run 365 days later. Although this is a discrete-event simulation, activity updates for each agent occur when there is a change in the agents' stance on the issue of infrastructure. Therefore, each agent has several line entries and the result is a dataset that can be several million lines long. Though the IDFW team wanted to implement a simple DOE for the prototype run, the model did not have this capability at the time of the first simulation runs.

1. Methods of Data Analysis for IDFW

S-Plus big data frames were used to sort and reduce the size of the data. The desired result was a file with one line for each agent that contained his delta, i.e., change in stance as a proportion on the specified MOE from time zero to the end of the simulation run at time 365. We further aggregated these data by taking the mean across all agents of similar stereotype. The final result was a 48 x 2 matrix, where each row contained the entity's stereotype and resulting change in approval on the issue of elections. A similar process was conducted on the data representing the security MOE. The team noted that the data on infrastructure were incomplete at the time of the IDFW. Correcting this deficiency required the installation of several case files on later versions of the CG model.

2. IDFW Data Results

In an effort to present an analysis of the data from the prototype run during the short week of the IDFW, several simplifications were made. Some of these simplifications were made by choice, and others were dictated by limitations on what the model was able to provide in its output. As the implementation of a DOE was not possible during IDFW, only ten replications on one design point were available for the analysis portion. Additionally, the data focused specifically on the effects of the scenario upon the 48 individual stereotypes without an in-depth analysis of the effects of the component subtypes.

Partition trees (Figure 5) were primarily used in the analysis of the results during the IDFW. One of the benefits of partition trees is their ability to easily communicate the results of data produced through many simulation runs. Partition trees use recursion to split the data into homogeneous subsets, based on the relationship between the response variable and the predictors. A limitation of this non-parametric tool is its poor ability to fit concise models if the response surface is continuous. Thus, we use the results of other techniques in the analysis of Section C to account for this constraint. Each leaf of the partition tree represents a result reached through previous condition. Therefore, the mean education of an agent (0.031), using the partition tree represented in Figure 5, is through the condition that he is also affiliated with the Dawa political party. Other leafs of the partition tree are read similarly. Further, the relative position of the nodes within the tree identifies the importance of the predictors to the response. For example (Figure 5), political affiliation is deemed to be more important to the model than age or education.

An insight gained from the partition tree in Figure 5 is the effect of the agent's political affiliation on the issue of elections. As previously stated, political affiliation is most important in determining an agent's stance on the issue of elections. Least important is the entity's tribal affiliation, indicated by the fact that it is not represented on the partition tree. The leaf farthest to the right shows that an educated entity from the Dawa political party has the greatest positive proportional change in stance (0.03) on the issue of elections during the given scenario. Though the changes in stance of the population and of the individual demographic segments are small at this level of experimentation, we see from Figure 6 that they are statistically significant (p-value < 0.05). Even at this level of analysis, the utility of the CG model is apparent because it shows that segments of the population have altered their stances differently based on their narrative identities.

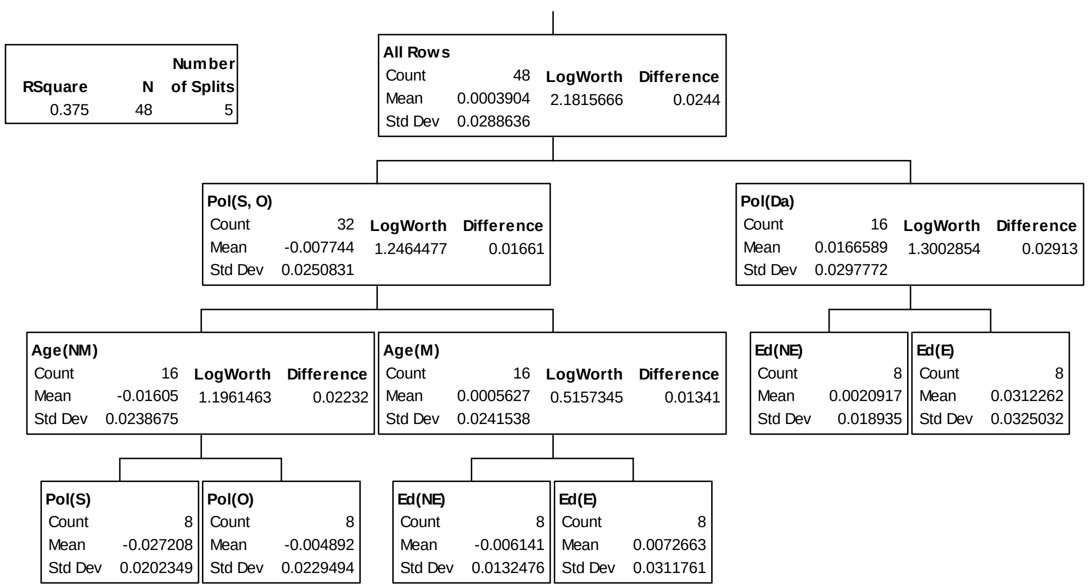


Figure 5. Partition of Stance on Elections Issue by Demographic Subtype (From TRAC Monterey, 2009)

Further study is required to correlate the events of the scenario to changes in stance of the individual agents. Additionally, new research could uncover events which affect specific portions of the population based on their demography. An experiment considering insurgent (red) and coalition or government (blue) rates of activity could be utilized as an aid to this analysis. By considering the time, frequency, and placement of events in the scenario, and comparing the results to a baseline with no added events, it would be possible to determine how those events affected the changes in stance on the relevant issues.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	0.01394717	0.003487	5.9476
Error	43	0.02520896	0.000586	**Prob > F**
C. Total	47	0.03915613		0.0007*

Figure 6. ANOVA of Mean Proportional Changes in Stance on Elections by Demographic Segment

For the issue of security, tribe is the most important factor. As in the case of elections, though the change in stance across the population and among the demographic segments is small, it is still significant (Figure 7) (p-value < .05). The partition tree in Figure 8 provides more details. Though there was generally a negative trend by all agents on the issue of security, the combination of the Suwaid, Mohammad, or Banni Lam tribes with a Dawa political affiliation showed a positive change in stance on the issue of security, though very small.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	1.3294541	0.443151	274.3868
Error	1046	1.6893535	0.001615	**Prob > F**
C. Total	1049	3.0188076		<.0001*

Figure 7. ANOVA of Mean Proportional Change in Stance on Security by Demographic Segment

The modest analysis of data on the elections and security MOE during the IDFW proved valuable in assessing the functionality of the prototype model. It also gave insights into the various demographic segments' responses to various events of the scenario, based on their change in stance, as well as to point out improvements for later versions of the model and propose new questions for further study. One question posed was how the addition of location tags to the agents in the model could help to provide insight into how messages travel through the social network, from those closest to events, to those furthest away from them.

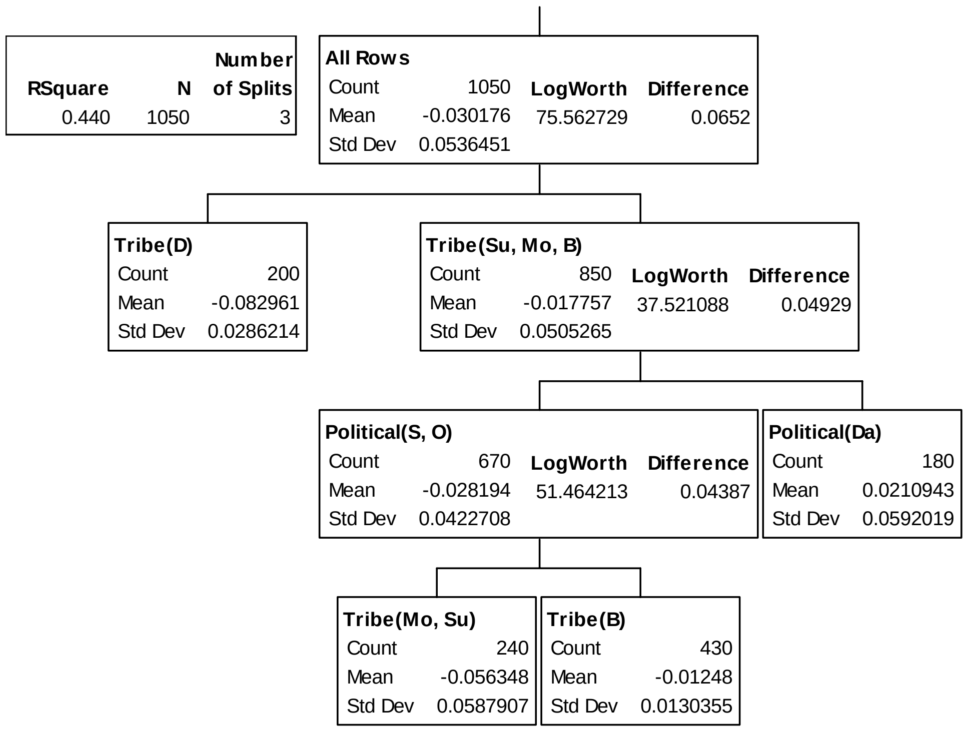


Figure 8. Partition of Stance on Security Issue by Demographic Subtype (From TRAC Monterey, 2009)

C. ANALYSIS OF INFRASTRUCTURE

In this section, we describe the detailed analysis of data produced by the model after the improvements identified during IDFW18 were implemented. This work is intended primarily to verify the model's functions, provide feedback to the developers on the model's progress, and provide initial insights about the questions posed in Chapter I. A benefit of this work is that many other questions for further study were uncovered as part of the analysis. These points of further study will be addressed in the concluding chapter.

A substantial improvement in the model's design from the prototype was the addition of location tags to each agent in the population as well as to the infrastructure objects (Figure 9). For further study, this information combined with that of Table 2 could help us to determine the relationships between the agents' locations and the locations of the infrastructure objects. The number and location of the infrastructure objects do not change over the course of the scenario. CG simulates an expansion of infrastructure by raising the rates at which goods and services are transferred to the agents, and portrays attacks on infrastructure by insurgents by reducing the same rates. This was another contributor to our reasoning in selecting the transfer rates for study. The market infrastructure type (Table 2) includes the commodities of fuel and food. The services infrastructure type includes the commodities of health, education, and legal. Finally, the structural infrastructure type includes the commodities of communications, electricity, and water. For the purposes of this research, we conducted our analysis on the commodities of fuel and food that are of the market infrastructure type. The market infrastructure objects represent an area where physical objects are exchanged for currency or other physical objects.

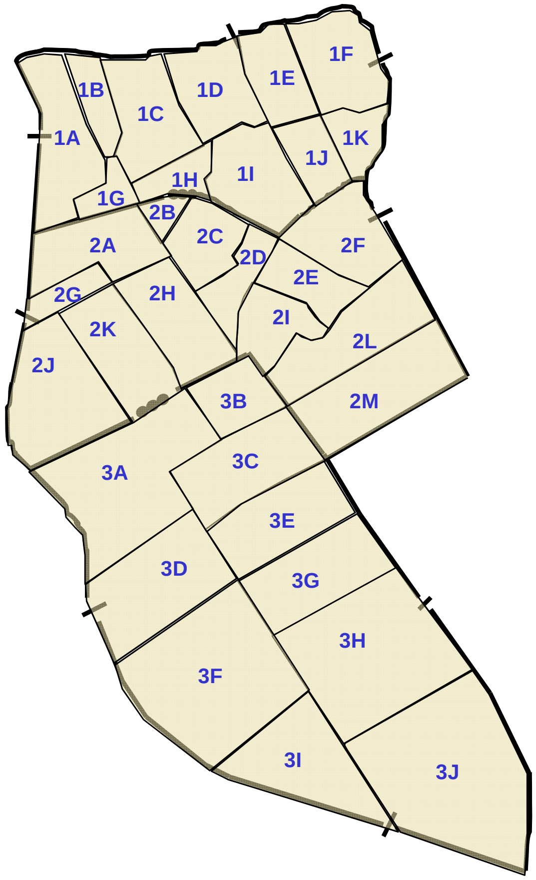


Figure 9. Location Identifiers for Amarah Scenario (From TRAC Monterey, 2009)

Analysis of the data utilizing this improvement enhances understanding of the demographic segment's response to the various events and objects in the simulation. It also aids in indentifying the locations in the area of operations which are most affected, as well as identifying how the interaction between location and demography affect the agent's stance on the issues in the AO.

Name	Type	Total Servers	Location
Infra_B_1	Market	7	Zone2A
Infra_B_2	Structural	3	Zone2B
Infra_B_3	Services	3	Zone2C
Infra_D_1	Market	2	Zone3A
Infra_D_2	Structural	1	Zone3B
Infra_D_3	Services	1	Zone3C
Infra_Su_1	Market	2	Zone1E
Infra_Su_2	Structural	1	Zone1F
Infra_Su_3	Services	1	Zone1E
Infra_Mo_1	Market	2	Zone1K
Infra_Mo_2	Structural	1	Zone1J
Infra_Mo_3	Services	1	Zone1K

Table 2. Infrastructure Name, Type, Number, and Location

1. Methods of Analysis

We continued to modify the methodology used in the analysis to improve the efficiency and speed the process to reach the point of analysis. This was a lesson learned from the week at the IDFW. To overcome the large data file sizes, a data mining tool named PAWS, formerly known as Clementine, was used to sort and format the data for analysis. An analysis stream was created for each of the three MOEs. This stream combined the agent data in one .csv file, with agent location data located in another .csv file. The desired format was similar to that for the IDFW. Each formatted file contained 1050 rows of data, which included the agent's identity by stereotype, location using the tags from Figure 9, and change in stance (delta) on the particular issue. The value of 1050 is the result of the 105 agents of the simulation, multiplied by the number of replications on that particular scenario. Thus, for this work there were ten replications for each scenario. This file was then exported via PAWS in .xls, or Excel, format. PAWS has the capability to conduct analysis on any data read into an analysis stream; however, this capability was not utilized for this work. This was mainly because the analysis required a simultaneous look at all of the scenarios in the design of experiments, and PAWS was used to reduce and format the data one scenario at a time.

The formatted Excel files were then joined on one worksheet. Since PAWS had formatted them similarly, it was a simple matter of pasting the deltas of each scenario into one file in preparation for the analysis portion. The tool used for analysis in this work was JMP. JMP is a statistical package that includes formatting, graphical analysis, and journaling, as just a few of its many functions. The author was introduced to JMP during the IDFW by the CG model co-lead, found the program intuitive to use, and well-suited to this type of analysis. Once imported into JMP, the data were further cleaned and manipulated to support the following analysis.

2. Overall Change in Stance on Infrastructure by Stereotype

Conducted first in the analysis was an examination of the stereotypes that exhibited the most change in stance on the issue of infrastructure. Figure 10 gives a broad overview of the stereotypes and their proportional change in stance on the issue of infrastructure. Of note are the eight stereotypes (circled in green) that display a consistently improving change in positive stance (delta) over all 6,500 replications (p-value < 0.05). These correspond to some of the smaller stereotypes, so the low variability is not an artifact of the number of agents within these stereotypes. As expected, there are also some stereotypes that exhibit deteriorating views of infrastructure throughout the implementation of the entire experimental design, although the average deltas for these stereotypes are more variable. The three stereotypes circled in red have the most negative reactions, on average.

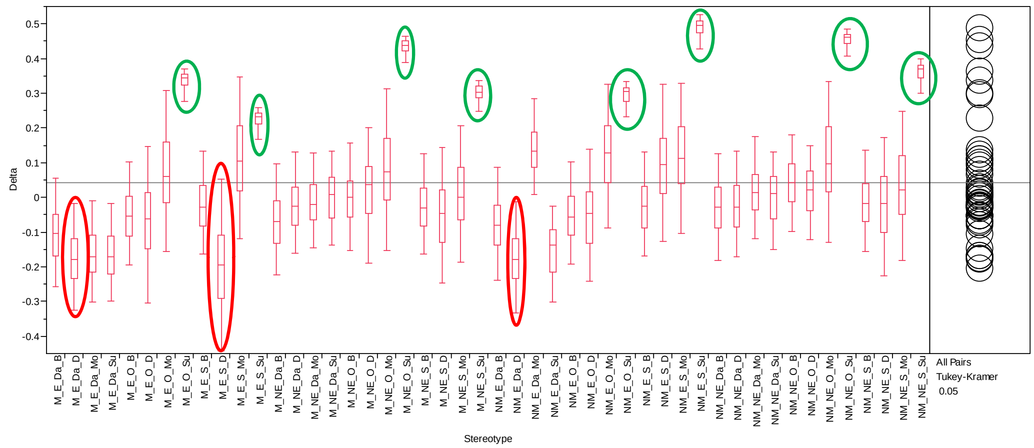


Figure 10. Proportional Change in Stance on Infrastructure by Stereotype

a. Change in Stance on Infrastructure by Demographic Segment

The next step in the analysis was to determine the demographic segments, or components, of the stereotype driving the change in stance on infrastructure. The stereotypes' composition of segments by age, education, political affiliation, and tribe are viewed individually to determine the segments of significant contribution. For this portion of the analysis, a partition tree shows the importance of the various demographic segments to the issue of infrastructure (Figure 11).

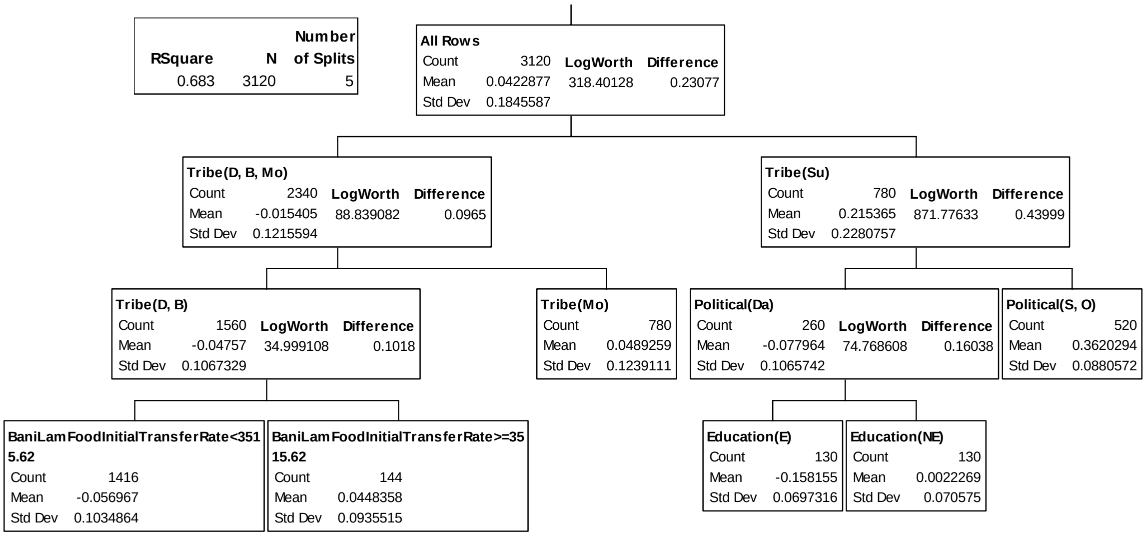


Figure 11. Partition Tree of Stance by Demographic Segments

First, we observe that the Suwaid tribe has an overall positive stance on infrastructure, with a mean positive change in stance of 0.21; when combined with the SIIC and OMS political affiliations, this is further improved to a mean of 0.36 positive change in stance on the issue of infrastructure. This coincides with what is seen in the analysis of stereotypes (Figure 10) where the eight stereotypes circled in green are composed of Suwaid tribal affiliation with SIIC or OMS political affiliation. From Figure 12, we see that on the issue of infrastructure, tribe is most important in determining the change in stance on the issue of infrastructure, while the initial transfer rates of the BaniLam food infrastructure objects are less important. Further (Figure 12), all other transfer rates and age are not important to determining an agent's stance on the issue of infrastructure. While age was seen to have some importance on the issue of elections (Figure 5), it plays no part in the issue of infrastructure. The conclusion of the analysis by stereotype is that tribal affiliation plays the greatest role on the issue of infrastructure.

Column Contributions

Term	Number of Splits	SS
Total	5	72.5788174
Tribe	2	35.9959112
Political	1	33.5563235
Education	1	1.67194813
BaniLamFoodInitialTransferRate	1	1.35463455
BaniLamFuelMaxTransferRate	0	0
BaniLamFuelInitialTransferRate	0	0
BaniLamFoodMaxTransferRate	0	0
DajiFuelMaxTransferRate	0	0
DajiFuelInitialTransferRate	0	0
DajiFoodMaxTransferRate	0	0
DajiFoodInitialTransferRate	0	0
SuFuelMaxTransferRate	0	0
SuFuelInitialTransferRate	0	0
SuFoodMaxTransferRate	0	0
SuFoodInitialTransferRate	0	0
MoFuelMaxTransferRate	0	0
MoFuelInitialTransferRate	0	0
MoFoodMaxTransferRate	0	0
MoFoodInitialTransferRate	0	0
Age	0	0

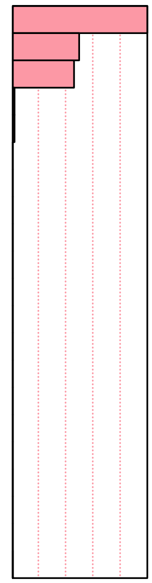
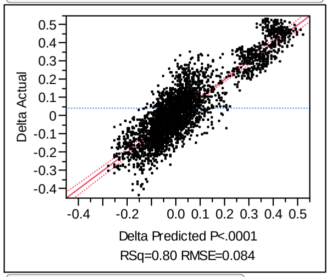


Figure 12. Contributions of Factors to Partition of Change in Stance on Infrastructure by Demographic Segments

b. Regression of Change in Stance on Infrastructure by Stereotype

A statistical metamodel of the change in stance on infrastructure by stereotype was created to determine the statistically significant factors, as well as to create a simpler model for that which is occurring within CG with regards to the issue of infrastructure. Figure 13 is the presentation of the regression model.

Actual by Predicted Plot



Summary of Fit

RSquare	0.795204
RSquare Adj	0.792745
Root Mean Square Error	0.084021
Mean of Response	0.042288
Observations (or Sum Wgts)	3120

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	37	84.48168	2.28329	323.4349
Error	3082	21.75738	0.00706	Prob > F
C. Total	3119	106.23906		0.0000*

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
				1.1002
Lack Of Fit	1834	13.443079	0.007330	Prob > F
Pure Error	1248	8.314298	0.006662	0.0335*
Total Error	3082	21.757377		Max RSq
				0.9217

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Political{Da-S&O}	-0.080814	0.001595	-50.65	0.0000*
Tribe{D&B&Mo-Su}	-0.107344	0.001764	-60.86	0.0000*
(Political{Da-S&O}+0.33333)*(Tribe{D&B&Mo-Su}-0.5)	0.0927884	0.001842	50.37	0.0000*
Tribe{D&B-Mo}	-0.048248	0.001842	-26.19	<.0001*
Age[M]	-0.025179	0.001504	-16.74	<.0001*
Education[E]	-0.022832	0.001504	-15.18	<.0001*
Education[E]*Political{S-O}	0.023157	0.001842	12.57	<.0001*
Education[E]*(Tribe{D&B-Mo}-0.25)	-0.022308	0.001842	-12.11	<.0001*
Education[E]*(Political{Da-S&O}+0.33333)	-0.017463	0.001595	-10.95	<.0001*
(BaniLamFuelInitialTransferRate-2518.03)*(SuFoodMaxTransferRate-5287.26)	-1.993e-8	1.838e-9	-10.84	<.0001*
(SuFuelMaxTransferRate-5049.28)*(SuFuelInitialTransferRate-2484.98)	-1.569e-8	1.45e-9	-10.82	<.0001*
Education[E]*(Tribe{D&B&Mo-Su}-0.5)	0.017523	0.001764	9.93	<.0001*
Age[M]*Political{S-O}	-0.018057	0.001842	-9.80	<.0001*
(DajiFoodMaxTransferRate-5028.85)*(DajiFoodInitialTransferRate-2537.26)	-2.423e-8	2.538e-9	-9.55	<.0001*
Education[E]*Age[M]	-0.013873	0.001504	-9.22	<.0001*
Political{S-O}	-0.012101	0.001842	-6.57	<.0001*
DajiFoodInitialTransferRate	1.625e-5	2.508e-6	6.48	<.0001*
(DajiFuelMaxTransferRate-5567.31)*(DajiFoodInitialTransferRate-2537.26)	1.5728e-8	2.459e-9	6.40	<.0001*
(DajiFoodMaxTransferRate-5028.85)*(DajiFoodMaxTransferRate-5028.85)	6.9282e-9	1.143e-9	6.06	<.0001*
Education[E]*Tribe{D-B}	-0.011207	0.002127	-5.27	<.0001*
BaniLamFoodInitialTransferRate	1.1427e-5	2.341e-6	4.88	<.0001*
(SuFoodInitialTransferRate-2665.26)*(MoFoodMaxTransferRate-5039.66)	-8.253e-9	1.703e-9	-4.85	<.0001*
Age[M]*(Tribe{D&B-Mo}-0.25)	0.0085692	0.001814	4.72	<.0001*
DajiFuelInitialTransferRate	1.0785e-5	2.471e-6	4.36	<.0001*
Tribe{D-B}	-0.008945	0.002127	-4.20	<.0001*
Age[M]*Tribe{D-B}	-0.008819	0.002127	-4.15	<.0001*
(SuFoodMaxTransferRate-5287.26)*(SuFoodMaxTransferRate-5287.26)	5.0209e-9	1.217e-9	4.13	<.0001*
SuFoodInitialTransferRate	1.0439e-5	2.559e-6	4.08	<.0001*
DajiFuelMaxTransferRate	-4.785e-6	1.208e-6	-3.96	<.0001*
BaniLamFuelMaxTransferRate	-5.334e-6	1.372e-6	-3.89	0.0001*
SuFuelInitialTransferRate	-1.04e-5	2.729e-6	-3.81	0.0001*
MoFuelMaxTransferRate	4.2886e-6	1.333e-6	3.22	0.0013*
MoFoodMaxTransferRate	-3.171e-6	1.178e-6	-2.69	0.0071*
SuFoodMaxTransferRate	2.2946e-6	1.202e-6	1.91	0.0564
DajiFoodMaxTransferRate	-2.012e-6	1.082e-6	-1.86	0.0629
BaniLamFuelInitialTransferRate	-3.454e-6	2.344e-6	-1.47	0.1408
SuFuelMaxTransferRate	1.6674e-6	1.132e-6	1.47	0.1409
Intercept	-0.001325	0.020792	-0.06	0.9492

Figure 13. Regression Metamodel of Change in Stance on Infrastructure by Stereotype

Factors were entered into the model to evaluate main effects and two-way interactions between all factors, and quadratic effects for the quantitative factors. Because of the large number of terms, there are not enough degrees of freedom to include them all in a single model. Instead, we used a stepwise approach to isolate the statistically significant terms. We reduced the list even further by manually removing interaction or quadratic terms that were statistically not significant. The model of Figure 13 was then created with the resulting statistically significant terms. As with the prior results, the terms consisting of the demographic segments (particularly tribe and political affiliation) were the most important to the model. The model is able to account for 79 percent of the variability in the change in stance on infrastructure. This provides some additional insights about how the changes in the stances viewed by stereotype are related to the demographic segments of the agent's stereotype. Of note (Figure 14) is the fact that of the 16 infrastructure factors selected for study, only Albu Durraji food maximum transfer rate is significant in affecting the response, though its influence is small when compared against the demographic factors (Figure 15).

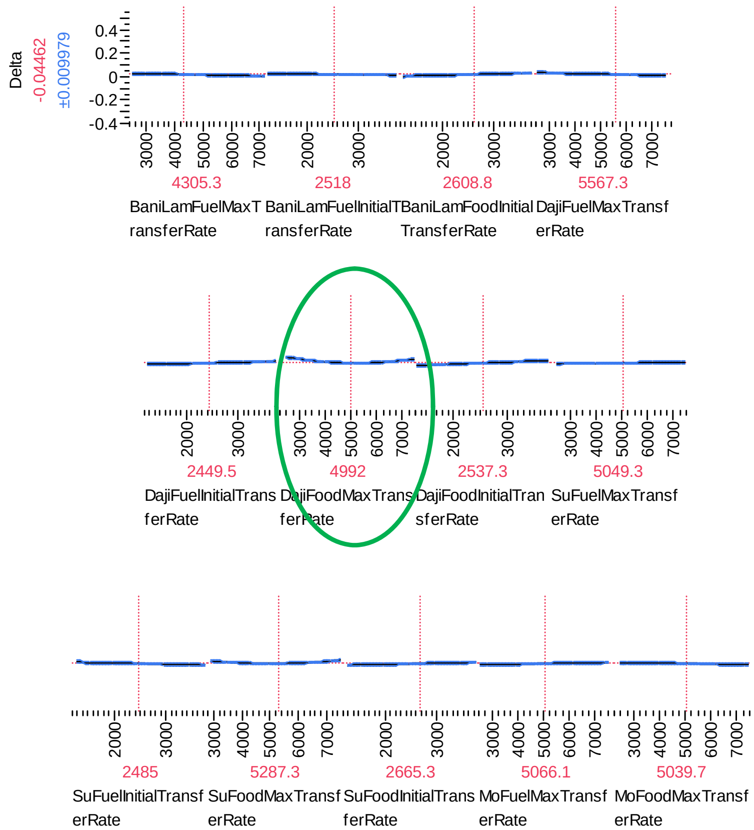


Figure 14. Prediction Profiler of Infrastructure Factors on Response of Change in Stance on Infrastructure

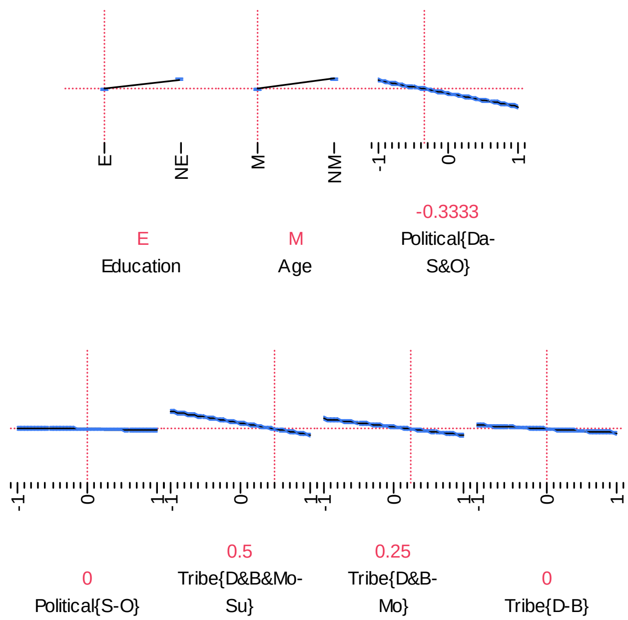
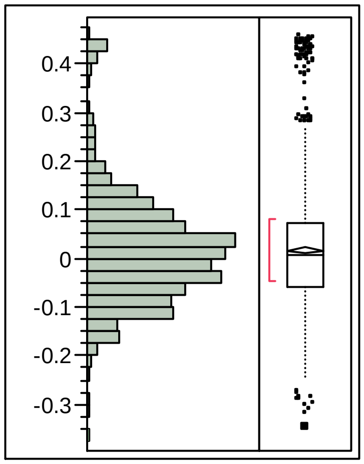


Figure 15. Prediction Profiler of Demographic Factors on Response of Change in Stance on Infrastructure

3. Overall Change in Stance on Infrastructure by Location

Next is the analysis by location, to discover how the agents responded in their change in stance based on their location in the area of operations. First, consider the broad overview of the distribution of deltas across the region depicted in Figure 16.



Moments

Mean	0.017093
Std Dev	0.1182116
Std Err Mean	0.0025146
upper 95% Mean	0.0220241
low er 95% Mean	0.0121618
N	2210

Figure 16. Distribution of Changes in Stance by Location

Figure 16 shows that with 95% confidence the mean of a sample of the population would fall within the region of a positive one to two percent change in stance on the issue of infrastructure. This is a good insight, as an overall positive population outlook on infrastructure is a desired effect. Here N is 65 design points x 34 zones = 2210, thus we have taken the mean for each zone over ten replications. From this point, we begin a closer look of the various regions of Figure 9. Of interest were the regions that experienced a very positive change in stance or a very negative change in stance. This is more clearly apparent in Figure 17.

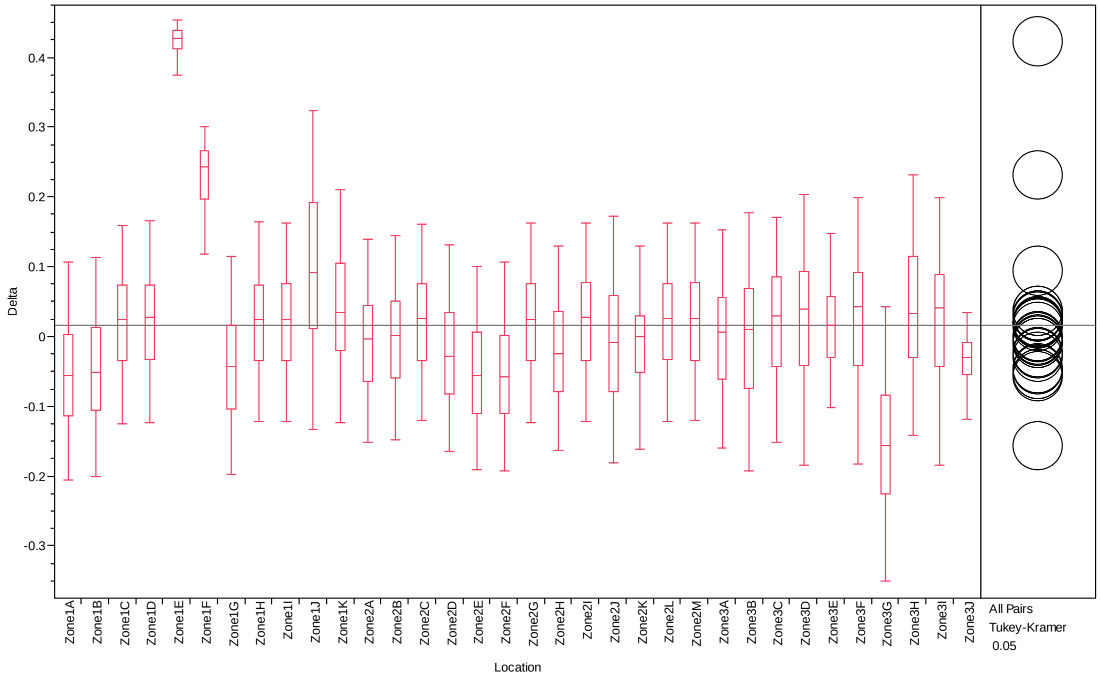


Figure 17. Proportional Change in Stance by Location

It is apparent that Zone 1E and 1F showed the greatest overall positive change in stance over all the scenarios. Zone 3G had the most negative response to infrastructure stance over all the scenarios. A more in-depth analysis of stance on infrastructure in reference to the locations of Figure 9 follows.

a. Zone 1E

Seven agents of the population were located in Zone 1E. They represented three of the 48 stereotypes under study. Four of the agents were non-military age males, and six of the agents were non-educated. Of importance is the fact that all seven agents were of the Suwaid tribe and had political affiliation with the Office of Muqtada al-Sadr (OMS). From the study of demographic segments depicted in Figure 11, it was shown that stereotypes consisting of Suwaid tribal affiliation and OMS political affiliation had the greatest positive change in stance on the issue of infrastructure.

b. Zone 1F

There were a total of five agents located in Zone 1F. Three of the agents were non-military-age males, and four of the agents were non-educated. Three of the agents were associated with the SIIC political party, and two had Dawa political affiliation. Contributing to the large positive stance on infrastructure is the fact that all of the inhabitants of Zone1F are of the Suwaid tribe. Again, this follows the analysis of demographic segments depicted in Figure 11. Also contributing to the positive stance are the three agents with SIIC political affiliation. Contributing negatively to the overall stance in this zone are the two members with Dawa political affiliation. For the analysis of stereotypes (Figure 11), it was noted that education had lesser importance and that age was not important at all (Figure 12). Our regression by stereotype (Figure 13) showed that age and education were statistically significant and important to our metamodel, but were dominated by the effects of tribe and political affiliation. Taken together, the overall improvement in stance in Zone 1F is substantial, but not as large as that achieved in Zone 1E.

c. Zone 3G

There were a total of four agents inhabiting Zone 3G. Three of the agents were military-age males, and all were educated. Again, this information is of lesser value by the analysis of stereotypes (Figure 11), but is added for the reader's information. Two members had affiliation with the Dawa political party, and all four agents were members of the Albu Durraji tribe. Since all four inhabitants were of the Albu Durraji tribe, the analysis of stereotypes (Figure 11) showed that this tribe had the most negative change in stance on the issue of infrastructure. Countering this trend is the fact that one member was affiliated with the SIIC party, while another was with the OMS party.

4. Comparison of Stereotype versus Location

We have shown that stereotype and location of the agent are important, but we wish to know which of these two has the dominant affect on the agent's change in stance on the issue of infrastructure. Figure 18 is a partition tree that provides some insights in answering this question.

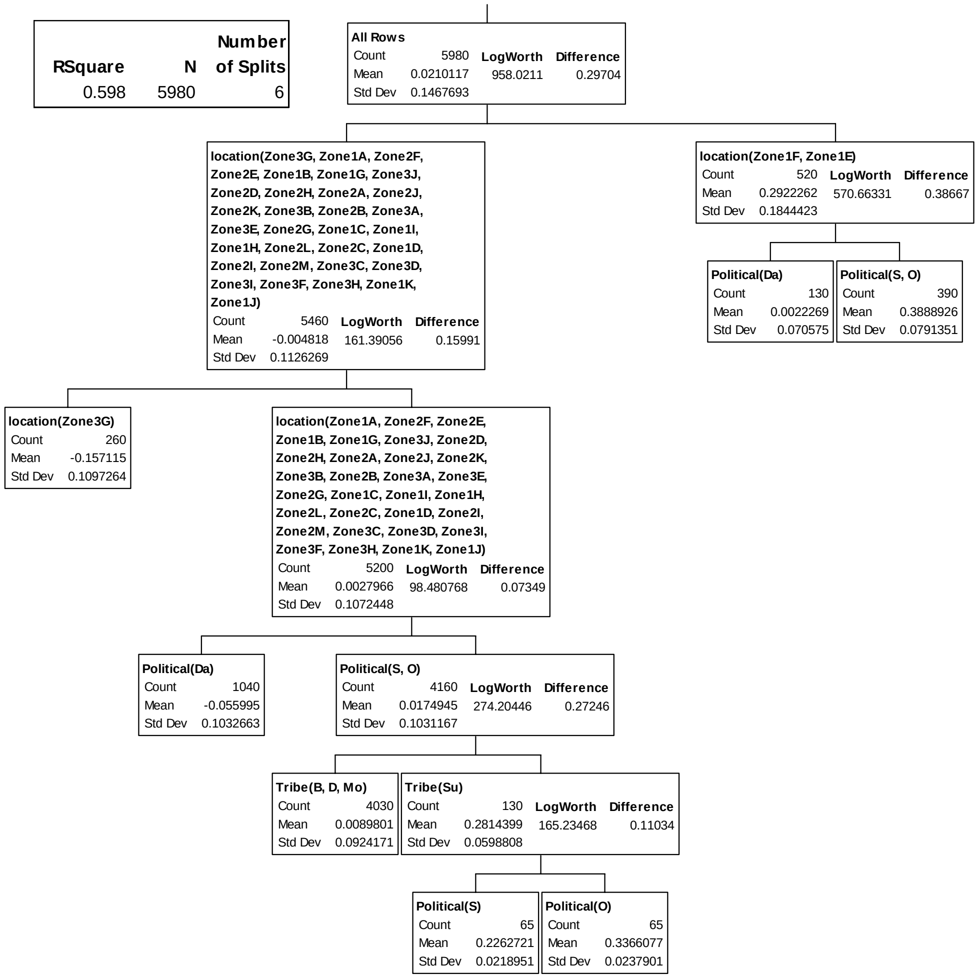


Figure 18. Partition Tree of Change in Stance by Demographic Segments and Agent Locations

The model places a higher importance on location of the agents over their demographic segments. After location, the political affiliation of the agent is the most important in determining the agent's stance on the issue of infrastructure.

Further study is required from this point to be able to determine the importance of the agent's locations in reference to the locations of infrastructure objects (Figure 19). We could reason that the cause of the agents' increasingly positive stance in Zones 1E and 1F is that there are infrastructure objects of both types located in these zones, and that they are associated with the Suwaid tribe, who are the major inhabitants of these zones. We could also hypothesize that the cause of increased discontent in Zone 3G is the lack of infrastructure objects in that location, and that the agents in those locations are penalized for using infrastructure objects associated with another tribe. Further research is required to determine the validity of these hypotheses.

name	type	location
Infra_B_1	Market	Zone2A
Infra_B_2	Structural	Zone2B
Infra_B_3	Services	Zone2C
Infra_D_1	Market	Zone3A
Infra_D_2	Structural	Zone3B
Infra_D_3	Services	Zone3C
Infra_Su_1	Market	Zone1E
Infra_Su_2	Structural	Zone1F
Infra_Su_3	Services	Zone1E
Infra_Mo_1	Market	Zone1K
Infra_Mo_2	Structural	Zone1J
Infra_Mo_3	Services	Zone1K

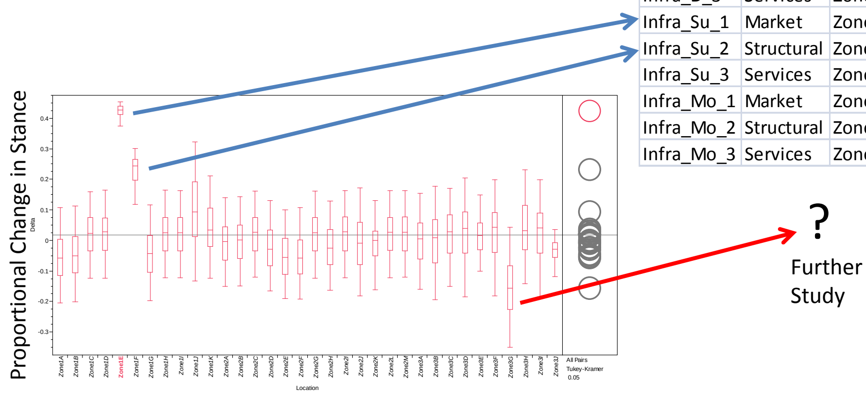


Figure 19. Relation of Positive Change in Stance on Infrastructure by Zone to Locations of Infrastructure Objects

V. CONCLUSION

A. SUMMARY

Operations in COIN and SSTR require a cultural understanding of the population in which they are conducted. The center of gravity in irregular warfare is the population, and the U.S. and its partners must be able to operate as proficiently in this environment as they once were prepared to do so conventionally during the Cold War. To do this effectively, the U.S. and its allies must implement all the tools and techniques available to aid their understanding of the cultural terrain. One approach to this very complex problem of human behavioral modeling is that posed by the modeling and simulation community.

TRAC Monterey has embarked on the development of a Cultural Geography model, intended to aid the decision maker in understanding the effects of his actions on the local population. Its development is rooted in the prevailing theories of social science, and implements the beliefs, values, and interests of the major demographic segments (age, education, tribe, and politics) in an area of operations to determine their stance with regard to these attributes on the relevant issues. We use this function of the CG model to quantify their change in stance on issues of relevance over the course of a year. This is an important first step toward using insights about the population's stance in course-of-action analysis.

B. SIGNIFICANT CONTRIBUTIONS

This research introduced a prototype analysis rooted in the proven methods of experimental design and data mining to explore one portion of the CG model. The process identified the critical demographic factors (i.e., those that the model determines to be the most relevant) in regards to the issue on infrastructure. It further proved the utility of efficient experimental design in exploring complex simulation models of this type. Additionally, the methods employed during this research were an aid in debugging the infrastructure portion of the CG model.

C. FUTURE RESEARCH

As the development of CG continues, the analysis conducted in this research will also require modification to explore added concepts and functions. TRAC Monterey has benefitted greatly through the use of efficient experimental designs in the CG model and in other models it has developed, and will continue to rely on this method as development continues. Since this research examined only one modest portion of the model's performance, further research should be aimed at conducting a more comprehensive examination of all aspects of the model. The social network employed in the model is open to several study questions regarding types of hierarchy and the strengths of relationships. Exploration of the issues of security and elections, with a comparable methodology, would aid in debugging and provide insights into these sectors of the model. Additionally, there were questions proposed through the progression of this research that TRAC Monterey would benefit from through further study. They are as follows:

- What is the impact of a network enabled force on operational effectiveness in an IW environment?
- How does coalition force structure impact "operational effectiveness?"
- What is the relationship between blue and red rates of activity within the model?
- What sequence of events lends to a change in issue stance?

Since it was not possible to employ the benefits of computing clusters to reduce the replication time and increase the number of factors for study, a more thorough examination of the model, such as that conducted by Benjamin Marlin (2009) in his analysis of the Peace Support Operations Model (PSOM), would be beneficial. His research pointed out several sensitivities in PSOM to be considered by its users and developers. Application of Marlin's methodology to CG would allow for a comprehensive examination of the complexities of the model, to identify important interactions or lack thereof. It would also better establish the depth of questioning that CG is suitable in answering.

In addition to that previously stated, further research should be conducted in "bridging the gap" between the current extent of analysis required to obtain information from CG and the field analyst who requires rapid answers and may possibly not have the educational background to interpret and report on the results. Efforts should be focused on supplying a scaled-down version of the results of comprehensive experiments and analyses, perhaps by putting metamodels into Excel worksheets that could give insights to a deployed analyst about specific questions. It would be important to identify the relevant questions posed by the planning staffs, and then reach-back support could create an appropriate metamodel from the in-depth analysis of CG. The metamodel would then be able to provide quick insights in the field, but would be limited to answering the specific question(s) for which it was created. Additionally, some type of modularity must be created in the interface to allow for the removal and application of the various metamodels.

Finally, though there may be substantial gains in data collection techniques, software development, and methods of analysis, the complexities of human behavior will present modeling challenges for the foreseeable future. The CG model is an attempt to gain insights on one small portion of the world during a small period of time with regard to a specific mission. CG's power to predict is therefore extremely limited, and it should therefore be used in the context for which it was developed.

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