12-2008

Spatial Event Analysis Tool: An Application for Mapping Terrorists' Events

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An application for mapping terrorists' events

A Major Individual Project presented in partial satisfaction of the requirements for the degree of Master of Science in Geographic Information Systems

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December, 2008

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ACKNOWLEDGEMENTS

There are a number of people I would like to acknowledge and thank for their assistance over the last year:

First, I would like to thank my wife and family. The past year would not have been possible without their love, support and understanding. To of my wife, spending the last year away from home has been the hardest thing I have ever done…and I will not do it again. I appreciate you always being there for me, and kicking me in the pants when I needed it. To my daughter, I dedicate this study, a year away from her was extremely difficult, but she has acted like a "trooper" and I am extremely proud of her.

To the faculty of the University of Redlands department of Geographic Information Systems, and particularly my faculty advisor, Dr. Fang Ren, you all have a thankless job, and I could not have done this project without you. To Dr. Ren, I am convinced I have the best advisor. Who else could take someone with the limited GIS understanding as I did, and develop a GIS professional? To the entire faculty, I would not like your job, but I could not think of a finer set of academic professionals.

To my classmates, this project would not have been possible without your wit, assistance and knowledge. In particular, I would like to thank Chris Brown, my constant confident; Nathan Frantz and Michael Ziyambi, probably the smartest GIS professionals I have ever met. I would also like to thank Russ Johnson, another true professional, and someone I could always talk to concerning domain knowledge.

ABSTRACT

Spatial Event Analysis Tool
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The Spatial Event Analysis Tool is an application to assist United States Army scenario developers who are charged with creating realistic and accurate settings, or story lines, for Army experimentation events. The application focuses on terrorist events reported in newspaper articles and are readily available on the internet. In the past, these reports have been overlooked because their locations are difficult to geocode in a GIS. However, when this information is structured, categorized, with even a general location, tremendous value will be derived through spatial analysis of terrorist events. In Army experiments, this allows for a temporal understanding of how and where terrorist organizations operate. It also aids in identifying trends in terrorist activities.

For participants in Army experiments, the application can serve as a decision support tool that will aid in developing alternative methods to confront terrorist organizations. Most importantly it will allow experiment participants to study nontraditional problem sets with which the Army's leadership is increasingly confronted.

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List of Acronyms

SEAT	Spatial Event Analysis Tool
TRADOC	Training and Doctrine Command
DCSINT	Deputy Chief of Staff for Intelligence
DPS	Defense Planning Scenario
NPA	New People's Army
ASG	Abu Sayyaf Group
MILF	Moro Islamic Liberation Front
MNLF	Moro National Liberation Front
ARMM	Autonomous Region of Muslim Mindanao
CPP	Communist Party of the Philippines
MIPT	Memorial Institute for the Prevention of Terrorism
NCTC	National Counter Terrorism Center
WITS	Worldwide Incident Tracking System
CASE	Crime Analysis Spatial Extension
SEDAC	Socioeconomic Data and Application Center
NGA	National Geospatial-Intelligence Agency
GNS	GeoNet Name Server

1. Introduction

The advent of terrorism in the modern age has had an intense and far-reaching impact on the United States. This is especially evident in the U.S. Army, which has found itself in unique confrontations and in different roles because of the attacks on Washington D.C. and New York City, the resulting military actions in Afghanistan and Iraq as a part of the global war on terrorism. U.S. national policy regarding terrorism is clear in its mandate to take both proactive and reactive measures to ensure the safety of Americans both; overseas and within the United States. The United States Army has translated this mandate into changes in force structure, organization, equipment, training, and doctrine. Many of these changes have come about and will continue to come about because of experiments the United States Army has conducted.

The goal of this project is to provide a realistic and accurate visualization of terrorist groups and the many events they conduct. The objective of the project is to spatially depict the activities of different terrorist organizations by means of generalized locations, like those locations one might find in a newspaper. The terrorist data must be rich in attribute information and be derived from newspaper or internet sources. Using GIS tools, the ultimate aim of this project is to demonstrate the identification of patterns and changes in the patterns of terrorist events. More specifically, this project intends to depict terrorist areas of operations, areas of terrorist influence, modus operandi (or how terrorist operate), and whether an organization's area is growing over time.

As alluded to before, United States Army has for many years conducted war games, simulations, and field exercises to evaluate emerging Army concepts, improve military capabilities and readiness, and lessen misgivings regarding potential threats it will face. Military experiments have gained renewed emphasis as the U.S. Army attempts to understand the modern terrorist threat. The results of such experiments aid in lessening surprise and allow the Army to develop doctrine, refine military training, and evaluate material solutions. Experiments require scenarios that allow for assessments and evaluations. Subsequently, "Military experimentation is a source of great competitive advantage…" (Krepinevich, 2000).

Experimentation scenarios, whether contemporary or futuristic, display changing situations over time. When developing a scenario it is most important that it results in a realistic portrayal of the operational environment, and that the scenario depict credible events (TRADOC, 2005).

As the need for military experimentation increases, demand for detailed background for experimentation scenarios has reached an unprecedented level. The amount of information needed to adequately support an experiment is further complicated by the diversity of missions that the armed forces face. No longer is the military only concerned with conventional military tasks. There is a need to understand the makeup of social networks of different organizations and the forms they will take, particularly those of terrorist groups. Just as important as the relationships among networked organizations are the identification of specific areas of operation and influence, ways of working, temporal, and spatial relationships of events credited to different organizations (Reed, 2007).

1.1. Problem Statement

The United States Army's Training and Doctrine Command's (TRADOC's) (2007) problem is "how to depict terrorist events for Army experiments." Presently, terrorist events are quantified in charts and graphs, clusters on a map board, or on Microsoft Power Point slides. TRADOC needs an approach to depict trends and allow analysis of terrorist events. Power Point presentations place a tremendous load on the scenario writers and lack the depth and realism or allow for the analysis that experiments need.

TRADOC also needs to be able to replicate intelligence reports in their scenarios. Because such experiments include participants from academia, business, and allied militaries, intelligence reporting in scenarios is often precluded. That is because of the classified nature of military reporting. Newspaper articles and internet sources can be used to depict terrorist events, however, event analysis derived from newspaper reporting and other internet sources has been overlooked since these sources lack specific coordinates or locations. Much can, in fact be inferred from events, even if specific locations are not known. TRADOC recognizes the benefits of using newspaper and internet sources to add realism to their scenarios. Despite the wealth of information available from newspapers and the internet, TRADOC is unsure how to use these reports spatially.

1.2. Client

TRADOC's Deputy Chief of Staff for Intelligence (DCSINT) is the executive agent for the creation of scenarios for all Army experiments and training events. In order to develop realistic scenarios for TRADOC, the DCSINT requires a geographic information system (GIS) application that visually portrays actual events based on newspaper articles or data sources available on the internet. TRADOC also requires application that will permit the analysis of these events to determine where and how terrorist organizations are operating.

1.3. Client Expectations

The client requires an application for use primarily by scenario developers and experiment participants. While initially focused on terrorist events in the Philippines, this application must be readily expandable to accommodate terrorist groups from other countries. The application also requires a database that combines geographic and terrorist event information. Finally, the application will be used to assist in answering information requests from event participants within a specified time frame.

A wealth of geographic and detailed terrorist event information is required to ensure an accurate and realistic scenario. This data must be entirely unclassified while remaining relevant to challenges that the U.S. Army will face now and in the future (Wilson, 2006). Geographic features should include, but are not limited to, the items shown in Table 1.

Table 1. **Feature Type Examples**

Feature Type	Example
Transportation Infrastructure	Roads, Highways, Waterways, Railways
Geographic Information	Elevation, Contours, Island Boundaries
Geographic Names	Administrative Codes, Place Names
Administrative and Political Boundaries	National, Province, Municipalities
Populated Places	Cities, Towns, Refugee Camps
Energy Infrastructure	Power Plants, Power Sub-Stations, Refineries, Pipelines, Power Distribution Networks
Communications Infrastructure	Radio Stations, Television Stations, Newspaper Publishers, Cellular Towers
Transportation Choke Points	Tunnels, Bridges, Dams

In order to achieve their expectations, the client recommends terrorist event point data that is detailed and includes: who was responsible for the event, the ideology of the group; a targeted facility or victim; attack type; casualties of the event; and a city name for the location of the event.

The terrorist data combined with the geographic information must answer some of the following spatial questions for exercise participants in response to a scenario information requirement. Examples of scenario information requirements include:

- Determine the culpability of an unattributed terrorist event.
- Is there an increase or decrease in terrorist events over a period of time?
- Determine the modus operandi of a terrorist organization.
- Determine the greatest threat of an assortment of terrorist organizations.
- What is the likely target of a terrorist organization: victim type, facility, or location?
- Is there an increase or decrease in a terrorist's area of operations (AO) over time based on terrorist events?
- Is there a relationship between activities of a terrorist organization and the organization's ideology?
- Which terrorist group is the deadliest? What group conducts the most attacks?
- Is there a correlation between a terrorist group and its attack type, target, or tactic?

These scenario information requirements directly relate to one of the nine generic spatial and temporal questions:

- "Where is?"
- "What is at location?"
- "What is the spatial relation to?"
- "What is in a particular spatial relationship to?"
- "What is similar to?"
- "Where has occurred?"
- "What has changed since?"
- "What will change if?"
- "What spatial pattern(s) exist(s) and where are anomalies?" (Egenhofer & Kuhn, 1999).

1.4. Proposed Solution

A geographic information system that allows for analysis of spatially referenced data is required to meet TRADOC's needs. The GIS will allow for spatial analysis, and rely on a database that is derived from open source data, such as information that comes from newspapers or the internet. A tool that can geolocate generalized locations, such as those found in open sources, also needs to be explored. If required, modifications can be made to the GIS to facilitate ease of use. The application, designated the Spatial Event Analysis Tool (SEAT), will depict terrorist events and add realism to military scenarios. The tool can analyze events conducted by different terrorist organizations and in different locations. By portraying events over time, the tool will demonstrate increasing or decreasing activity of a terrorist organization. It can also show whether a terrorist group's area is expanding over time and whether there is a relationship between different terrorist organizations operating in the same area.

The data and locations used by the SEAT will be derived from open source reporting sources. The generalized location of the event will then be cross referenced with a gazetteer in order to geolocate the event and make it usable within the tool. Once these events are geolocated, a subsequent analysis of event clusters will allow for a determination of where and how a terrorist organization operates.

Other approaches were evaluated as part of this solution to determine if they were applicable to terrorist events analysis. Most notably, techniques used by the law enforcement community were explored in order to determine their usability in analyzing terrorist events.

The result of these efforts will be a SEAT which will provide the military client with a dimension of military experiment scenarios that has been sorely missing.

2. **Background and Literature Review**

There have been attempts to integrate terrorist events into TRADOC scenarios under the guidance of TRADOC regulations. However, while these regulations are relatively general and descriptive as they pertain to what an experiment and supporting scenario are meant to accomplish. They are not clear as far as scenario mediums and specific problem sets or locations that scenarios should replicate because they do not reflect a thorough understanding of terrorism by the U.S Army (Betts, 1982).

Until recently, the Army has relied on outdated manuals for an explanation of how terrorist operate. These manuals also tend to concentrate on the similarities of terrorist groups, and not on the uniqueness of different groups. U.S. Army manuals also tend to highlight how to counter terrorist groups and not how these groups operate. Until recently, these counterterrorism efforts were based on the U.S. Army's experience in the Vietnam War in the 1960s (Aylwin-Foster & Army, 2005).

The recent integration of terrorist events in scenarios has been done mostly by foreign militaries that face the threat of terrorism. One example is a model developed by the British during their intervention in Northern Ireland in the late 1970's (Campbell & Connolly, 2003). While this model is applicable, it too is dated. Even recent publications tend to highlight dated organizations, rather than modern day terrorist organizations. The recent Spanish study, *The Production of Terrorist Violence: Analyzing Target Selection Within the IRA and ETA* (de la Calle, Sánchez-Cuenca, & Instituto Juan March de Estudios e, 2006) highlights the tactics of European terrorist organizations from the 1970s. The only country that appears to have had constant and recent experience with terrorism is Israel. While insights can also be gleaned from their experience, each terrorist group has different goals and operates differently (Aylwin-Foster & Army, 2005).

Terrorism is a renewed, but unique problem set that the United States Army has struggled with for some time. The military has been stuck in conventional wisdom. Conventional wisdom in the Army is that the U.S. Army is meant to conquer and defend against other armies. Terrorist organizations are different from national armies as they and their organizations do not represent recognized governments, as do conventional armies and their governments. Because of this, terrorist organizations and more specifically the events they conduct have been limited in integration of U.S. Army scenarios and experiments.

2.1. Terrorism Background

Terrorism is a form of unconventional and psychological warfare. The word is politically and emotionally charged, especially since September 11th, 2001 in the United States. The

Figure 1. **French Reign of Terror** (O'Kane, 1991).

word "terrorism" was first used in reference to the Reign of Terror during the French Revolution (see Figure 1). While the history of terrorism goes back centuries it is often overlooked because terrorist events have not appeared with equal intensity and there have been frequent periods of time relatively free of terrorism. As a result, when terrorism reappeared after a period of relative calm, there was a tendency to regard it as a new phenomenon, without precedent (W. Laqueur, 2001).

Supporting Laqueur's assertion, modern terrorism is identified from the end of the Second World War to the beginning of the twenty-first century. The modern history of terrorism is subsequently divided into three types of terrorist conflict: terrorism in the service of national liberation and ethnic separatism; left-wing terrorism; and Islamist terrorism.

These three types of terrorist conflict are important to the U.S. Army because the Army's involvement in conflicts since 1975 has been limited to small-scale wars. These types of terrorist conflict were seen, but not necessarily experienced by the Army. Left wing terrorism was prominent in the 1970s, primarily in Europe and South America, but the US. Army was not used against these threats. An example of terrorism in the service of national liberation and ethnic separatism was the conflict in the Balkans in the 1990s, but this type of terrorism was targeted at different ethnicities in Bosnia, and not against the U.S. Army. The Irish and British conflict in Northern Ireland is also an example of terrorism in the service of national liberation and ethnic separation. Islamist terrorism has been active in the Middle East since the 1980s, and at times the U.S. military has been the target of this type of terrorism, but it wasn't until September 11, 2001 and the subsequent invasion of Afghanistan and Iraq that the U.S. military has been used in a large scale, against terrorism. On the other hand, the Israeli Army, has significant experience with Islamist terrorism, even before that country's birth in 1948, as Israel has been the target of most Islamists (Shughart, 2006).

Because of lack of recent experience combating terrorism, the confrontation with terrorism poses a significant challenge to the Army. The U.S. military has struggled to adapt to combating terrorism, which is seen as protracted, insurgent-type warfare. America's affinity for high-tech conventional conflict and quick, kinetic, unilateral solutions that avoid direct contact with the local populace has slowed its response to this complex form of conflict (Wilson, 2006).

2.1.1. Key Characteristics of a Terrorist Event

Official definitions of what constitutes terrorism are used by nations to determine counterterrorism policy. Unfortunately, definitions are often developed to serve policy. Most government definitions outline the following key criteria or characteristics when determining whether an event constitutes simple crime or is a terrorist attack: target, objective, motive, perpetrator, and legitimacy or legality of the act. Terrorism is also often recognizable by a claim of responsibility from the perpetrators (ADL, 2004). Nevertheless, a number of characteristics are indicative of terrorist events.

Violence – According to Walter Laqueur of the Center for Strategic and International Studies, "the only general characteristic of terrorism generally agreed upon is that terrorism involves violence and the threat of violence." However, the criteria of violence alone do not produce a useful definition, as it includes many acts not usually considered terrorism: war, riot, organized crime, or even a simple assault. Property destruction that does not endanger life is not usually considered a violent crime (Walter Laqueur, 2003).

Psychological impact and fear – The terrorist attack or event is carried out in such a way as to maximize the severity and length of the psychological impact. Each act of terrorism is a performance devised to have an impact on a large audience. Terrorists also attack symbolic targets to show their power and to shake the foundation of the country or society to which they are opposed. This may negatively affect a government's legitimacy, while increasing the legitimacy of the given terrorist organization and/or ideology behind a terrorist act (Juergensmeyer, 2000).

Perpetrated for a political goal – Something all terrorist attacks have in common is their political purpose. Unlike letter writing or protesting, terrorism is a political tactic used by activists when they believe no other means will effect the kind of change they desire. The change is desired so badly that failure is seen as a worse outcome than the death of civilians. This is often where the interrelationship between terrorism and religion occurs. For example, when a political struggle is integrated into the framework of a religious or cosmic (Juergensmeyer, 2000) struggle, such as the control of an ancestral homeland or holy sites like Israel and Jerusalem. Additionally, failing in a political goal (nationalism) becomes equated with spiritual failure. For the highly committed, it is worse than their own death or the deaths of innocent civilians (Walter Laqueur, 2005).

Deliberate targeting of non-combatants – It is commonly held that the distinctive nature of terrorism lies in its intentional and specific selection of civilians as direct targets. The criminal intent is shown when babies, children, mothers, and the elderly are murdered or injured, and put in harm's way. The victims of terrorism are often targeted not because they are threats but because they are specific "symbols, tools, animals or corrupt beings" that tie into the terrorists specific view of the world. The victim suffering accomplishes the terrorists' goals of instilling fear, getting a message out to an audience, or otherwise accomplishing their often radical religious and political ends (Juergensmeyer, 2000).

Disguise – Terrorists almost invariably pretend to be noncombatants, hide among noncombatants, fight from in the midst of noncombatants, and when they can, strive to mislead and provoke the government soldiers into attacking the wrong people. When an enemy is identifiable as a combatant, the word terrorism is rarely used (FBI, 1999).

Unlawfulness or illegitimacy – Some official definitions of terrorism, notably government, add a criterion of illegitimacy or unlawfulness (FBI, 1999) to distinguish between actions authorized by a legitimate government (and thus lawful), and those of other actors, including individuals and small groups. Using these criterion, actions that would otherwise qualify as terrorism would not be considered terrorism if they were government-sanctioned. For example, firebombing a city, which is designed to affect civilian support for a cause, would not be considered terrorism if it were authorized by a legitimate government. These criterions are inherently problematic and are not universally accepted, because: it denies the existence of state terrorism. The same act may or may not be classed as terrorism depending on whether its sponsorship is traced to a legitimate government; "legitimacy" and "lawfulness" are subjective, depending on the perspective of one government or another, and they diverge from the historically accepted meaning and origin of the term. For these reasons these criterion are not universally accepted. Most dictionary definitions of the term do not include these criterion (Walter Laqueur, 2003).

2.1.2. Terrorism Defined

An internationally accepted definition of terrorism has remained elusive. The United Nations has attempted to gain consensus for a definition since the organization’s inception. The lack of consensus actually predates the United Nations and was also a major challenge to the League of Nations as far back as the 1930s (U.N., 2008).

A 1988 study by the US Army found that over 100 definitions of the word "terrorism" have been used (Record, 2003). In many countries acts of terrorism are legally distinguished from criminal acts done for other purposes, and "terrorism" is defined by statute (Hoffman, 1998). This greatly compounds the difficulty of providing a precise definition. The United Nations, and United States, definitions of terrorism are indicated as following:

United Nations Definition of Terrorism:

“…We affirm that the targeting and deliberate killing of civilians and non-combatants cannot be justified or legitimized by any cause or grievance, and we declare that any action intended to cause death or serious bodily harm to civilians or non-combatants, when the purpose of such an act, by its nature or context, is to intimidate a population or to compel a government or an international organization to carry out or to abstain from any act cannot be justified on any grounds and constitutes an act of terrorism…” (United Nations Proposal on Terrorism, 2005)

United States Definition of Terrorism:

“...the unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives.” (United States Federal Code and the United States Federal Bureau of Investigations, 2001)

2.2. Military Experimentation & Scenario Background

TRADOC is responsible for conducting experiments and war games to evaluate military fighting concepts, new weapon systems, military organization designs, operational plans, and how to improve soldier effectiveness on the battlefield. Experiments are normally conducted under specific scenarios, which provide a framework that allows for the assessment of capabilities of U.S. forces and equipment under specified situations. They also identify strengths and weakness, as well as potential improvements and changes to the Army (TRADOC, 2005). An experiment should also explore the potential possibilities of what the future may hold for the environment and the military. See Table 2 for examples of concepts that have proven their value through experiments (Krepinevich, 2000).

Table 2. **Unbelievables** (Cerf & Navasky, 1984)**.**

Notable Quote	Source
"This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us."	Western Union internal memo, 1876.
"The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?"	David Sarnoff''s associates in response to his urgings for investment in the radio in the 1920s.
"Heavier-than-air flying machines are impossible."	Lord Kelvin, president, Royal Society, 1895.
"Airplanes are interesting toys but of no military value."	Marechal Ferdinand Foch, Professor of Strategy, Ecole Superieure de Guerre
"Has there ever been danger of war between Germany and ourselves, members of the same Teutonic race? Never has it even been imagined".	Andrew Carnegie, 1913
"This so-called war is nothing but about twenty-five people and propaganda"	Arthur Vandenberg, U.S. Senator from Michigan, 1939
"If God had wanted a Panama Canal, he would have put one here"	King Philip II of Spain, c. 1552
"Defeat of Germany means defeat of Japan, probably without firing a shot or losing a life."	Franklin D. Roosevelt, 1942

2.2.1. Scenario Characteristics

A good scenario must be realistic and portray appropriate forces on real terrain within an expected operational environment (USJFCOM, 2007). A scenario derived from a defense planning scenario (DPS) is inherently considered realistic. Military forces and equipment that are portrayed in future scenarios are derived from defense budget projections. All aspects of the experiment must be reasonable. As DPS derived scenarios are thoroughly vetted by the defense community, the scenario is treated as reasonable and logical (TRADOC, 2005).

The scenario must be robust and reusable. The scenario should stress the concept that is being evaluated. A "measurement space" allows for the assessment of the capabilities of doctrinal concepts, tactics, forces and weapons systems. It also allows for comparisons of different approaches or alternatives. Scenarios should be usable for many studies. This requires that the scenario be well documented, adequately staffed and it should garner the appropriate approval for its use (TRADOC, 2005).

2.2.2. Scenario Types

Depending on what is to be evaluated, TRADOC has many different types of scenarios to choose from. Besides the concept that is to be evaluated, different scenarios may require different levels of coordination, validation and approval. The different types of scenarios include: operational scenario, which can be either standard or non standard, a study scenario; a dynamic scenario; and a vignette (TRADOC, 2005).

Operational scenario - An operational scenario is a graphic and narrative portrayal of a future hypothetical conflict. It is thorough and includes all aspects that influence an experiment. An operational scenario describes all aspects of a conflict; before, during, and after. It does not include military forces alone, but also the social, political, economic, and geographic considerations of a region or area. All aspects of the environment are considered, including threat, friendly and non aligned forces, and people or cultures (TRADOC, 2005).

Standard operational scenario – TRADOC's standardized operational scenarios are derived from defense planning scenarios (DPS). DPS are developed at the Department of Defense level and are considered the most standard of operational scenarios. These scenarios are rigorously developed, exhaustively coordinated among the defense industry and different military service; Air Force, Navy and Marines. Standard operational scenarios validated among all Army agencies and their senior leaders (TRADOC, 2005).

Nonstandard operational scenario – Nonstandard scenarios are not derived from DPS scenarios but developed to test a concept that is outside of a time period where a current policy or concept exists. Nonstandard scenarios are developed to meet the unique needs of the Army alone (TRADOC, 2005).

Study scenario – A study scenario is developed for modeling, simulation, or gaming purposes. A study scenario is usually derived from a DPS scenario and is not significantly different from an operational scenario other than it is applied to an electronic medium. A study scenario may not be as comprehensive as an operational scenario, but meets the needs of the tested or challenged concept (TRADOC, 2005).

Dynamic scenario – A dynamic scenario is open-ended. It is derived from either an operational or study scenario, but free play is anticipated. The purpose of the scenario is not to arrive at a predetermined outcome and game play is expected to arrive at an unforeseen result. A dynamic scenario provides the greatest challenge to scenario developers as the developer must be prepared for any potential event or direction that free play may take the experiment (TRADOC, 2005).

Vignette – A vignette is a study or operational scenario focused on a specific period or location. Vignettes are very focused and do not include all of the considerations that a full operational scenario may include. Vignettes are scenarios developed for a limited scope, time, or location. Vignettes are usually very restrictive and constrained (TRADOC, 2005).

2.3. Literature Review

While there are few academic dissertations addressing the spatial aspects and analysis of terrorist events, there are some similar concepts that may be adopted. Most notably this section intends to address the similarities between terrorist and criminal events and how law enforcement addresses crime analysis. Because the data used in this study is derivational, a critical review of the consequences of using data from newspaper reporting and from internet will also be discussed. The final portion of this literature review will provide a brief review of spatial statistics and their potential applications in terrorist event analysis.

2.3.1. Terrorist Event Analysis and Similarities to Crime Event Analysis

While little work has been published concerning the spatial aspect of terrorist events, criminal event analysis suggests that much can be gained through the spatial visualization of terrorist events. By visualizing spatial density, the changes of events over space and time, as well as activities of terrorist organizations, decision makers will be informed as to how best to allocate counter terrorism resources, define a defense posture for counter terrorism forces, and identify measures for protecting civil infrastructures and populations (Memon & Larsen, 2006).

While, the study of terrorist events has fallen under the domain of criminal analysis there are many differences in the motivations of terrorists versus criminals. According to Xu & Chen, the analysis of criminal events can result in predictions. Terrorist events can also lead to predictions of further violent activity, but these preparatory events usually go unreported in the press. Therefore, the value of terrorist event analysis will lie in quantifying trends instead of predicting subsequent events. Xu & Chen also point out that event analysis is by nature an after the fact approach to analyzing terrorist organizations. Unlike petty criminal events, criminal network analysis such as that of organized crime groups and gangs requires the ability to integrate information from multiple crime incidents and different sources in order to realize trends and patterns about the structure, organization, and its operations. Xu & Chen also address the challenges of the veracity of reporting used as data in criminal event analysis. The accuracy of data is a significant challenge for identifying trends of criminal events and interdicting social networks, such as a criminal organization. These challenges may not be important to understanding where and how an organization operates, but challenges may affect the fidelity of predictions, especially if exact location information such as an address or grid coordinates are not provided.

While understanding social networks and conducting event analysis has been practiced by law enforcement for many years, it has not been formally acknowledged by the U.S. military. The main inhibitor to military acceptance of this approach lies in the different restrictions that affect law enforcement and military forces. Law enforcement approaches information in terms of evidence that will stand up in a U.S court. The military looks at information in terms of trends and intelligence where a degree of conjecture may be required. As an example of this, Krebs (2002) states "*analyzing networks after an event is fairly easy for prosecution purposes. Mapping covert networks to prevent criminal* *activity (events) is much more difficult…"* There is much to be realized by the military by doing exactly what Krebs states. Doing it spatially and temporally with modern automated tools, however, adds dimensions that will inform in a way that has not been previously considered. Approaching terrorist events in the same way that law enforcement approaches criminal events will allow for the identification of where and how terrorist organizations operate, much in the same law enforcement determines how and where organized criminal groups and street gangs operate, based on the activity (events) they conduct.

As the military prepares for a period of persistent conflict in which there is a greater potential for terrorist threats (Casey, 2007), greater emphasis is being placed on the Army to understand social networks like terrorist groups. Specifically, emphasis is being placed on where, how, and why terrorist groups operate. The answers to these questions can be derived from the event a terrorist group conducts. While Reed recognizes that old approaches are no longer applicable to modern terrorist threats, existing methods and tools from other domains may provide tremendous value (Reed, 2007). For example the National Law Enforcement and Corrections Technology Center's Crime Mapping and Analysis Program's, Crime Analysis Spatial Extension (CASE), provides the ability to analyze criminal events with a nearest neighbor, a standard deviation and sequencing function for spatial information of criminal events (CMAP, 2008). Integrating event analysis as part of understanding social networks during Army experiments, and subsequently during operations, will certainly inform the where and how of social networks such as terrorist organizations.

While few approaches to terrorist event analysis have been explored, many approaches are readily available within the law enforcement domain. Other methods, such as CASE and non-military approaches like those in this study have application and are relevant outside of their traditional domain needs recognition. Although the completeness of information is particularly stringent for law enforcement, it is not always the case for the military. The fact that an event occurred may be enough, as long as it can be classified and a location established. As a result of this literature review many similarities have been identified between terrorist organizations and organized crime groups and gangs; examples of covert networks that share common traits and conduct

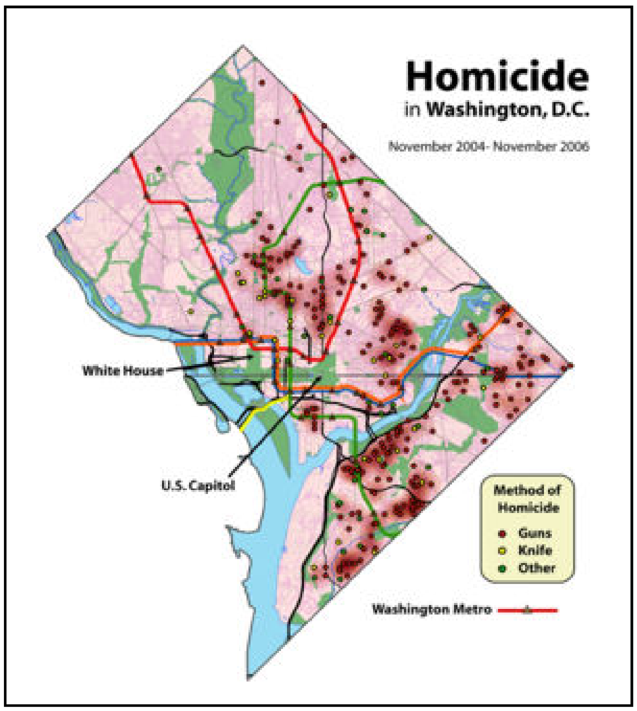


***Figure 2*. Criminal Event Analysis** (Grubesic, 2001)

similar activities. Events conducted by terrorist groups may cluster in a similar way that crime events cluster. This allows approaches to terrorist events in a similar manner that law enforcement uses for criminal events (see Figure 2). A set of classifications can be developed to assist in grouping the different aspects of an event in order to arrive at a conclusion regarding the significance of a group of events. As an example, one would be able to determine if a terrorist area of operation is growing or condensing. Recognizing that events reported in newspapers do not have the same degree of specificity required by law enforcement purposes, press reporting does have a factual aspect to it. From a law enforcement perspective, visualization of events from newspaper reporting can be informative, and while but it will not allow for predictions in the same way that Grubesic (2001) envisions it, it can predict some aspects of terrorist events. Alternative approachs such as those used by law enforcement to cluster events may prove useful.

2.3.2. Open Source Data

Since the data used in this application is derived from open sources, such as the internet and newspaper reports, the data will require a critical review. Factual accuracy of an event requires where an event occurred, what the event was, and who carried the event out. Because much of this information is derived from newspapers, an objective evaluation of the details of an event must be determined. “Journalists rarely have the resources or access to penetrate their sources' informational worlds to establish facts independently” (Ericson, 1998, p. 83).

However, by relying on multiple reporting sources one can come to realize that an event occurred, a spatial proximity of where that event occurred, what that event was, and possibly, who claimed responsibility for the event. This information can be derived from civilian press reporting and responsibility for the event can be determined by the reporting source, i.e. a police or government official.

David Noble recognizes that there is much value from the use of open source information “However, because the accuracy of this open source information varies widely, the

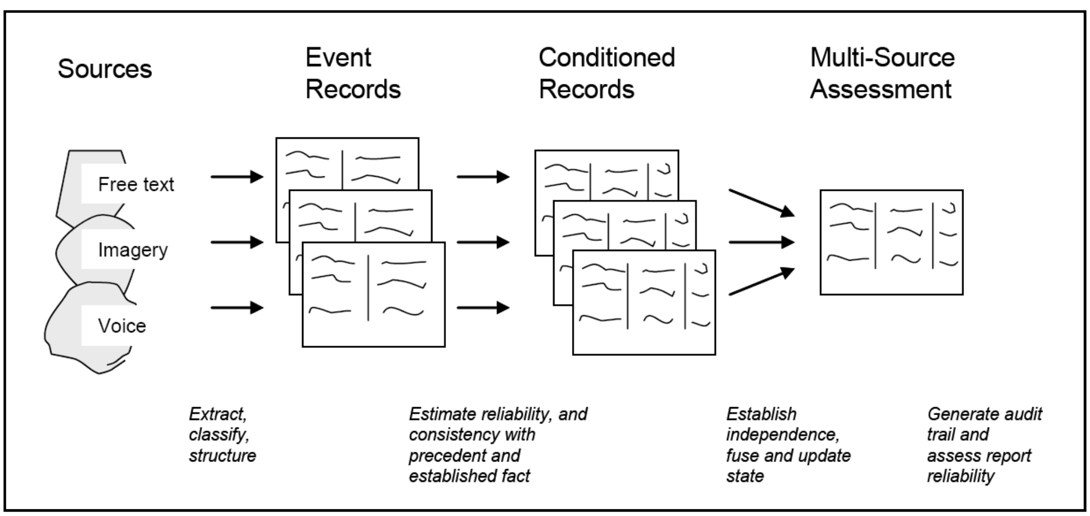


***Figure 3.* The Fusion Process** (Noble, 2004)

correctness of the information needs to be assessed before it can be used reliably" (2004). Historically, this correctness of information was analyzed objectively by experts who could then determine the validity of the information based on their long-standing study of the information. Noble suggests in this age of technology and advanced information systems, much of this evaluation can now be done by computers. This approach however, is outside of the scope of this study. As an alternative, Noble does suggest the reliance of data that has already been validated by an institution, and is subsequently cross-referenced with other information in order to increase the data's reliability. Noble's fusion process is highlighted in Figure 3 (Noble, 2004).

2.3.2 Spatial Analysis and Statistics

Spatial analysis or spatial statistics contain many of the formal techniques which study entities using their topological, geometric, or geographic properties. It is the use of location to identify trends and potential prediction of terrorist events. Different methods are used for point pattern analysis and polygon data. According to O'Sullivan & Unwin (2002), point pattern analysis can describe patterns of locations of point events and test whether there is a significant occurrence of clustering of points in a particular area. In order to conduct point pattern analysis, data must meet five important criteria:

- The pattern must be mapped on a plane, meaning that it will need both latitude and longitude coordinates.
- A study area must be selected and determined prior to the analysis.
- The Point Data should not be a selected sample, but rather the entire set of sought for analysis.
- There should be a one-to-one correspondence between objects in the study area and events in the pattern.
- Points must be true incidents with real spatial coordinates. For example, using the centroids of a census tract would not be a useful process.

Once the point data meet these five criteria, there are various methods that we can use to analyze the point pattern, including quadrant count method, kernel density estimation, and distance-based approaches. Among these techniques, quadrant count and kernel density estimation can help detect the spatial first-order effect (the intensity of the event distribution in the study area), while other distance-based methods, such as nearest neighbor distance and L function are often used to identify spatial second-order effects (the interdependence of the events or the spatial autocorrelation of the events).

Spatial autocorrelation is also often present in the attributes of lattice data. For example, median household income across counties in California could be correlated. This reflects a fundamental concept in geography that nearby things are often more similar than things which are far apart (Tobler, 1976). To quantify the spatial autocorrelation of areal data, there are various measures developed which includes Moran's *I*, Geary's *C*, and, local indicators of spatial association (LISA) have been extensively discussed in the literature (Getis and Ord, 1992; Bailey & Gatrell, 1995; Anselin, 1995). Although these measures work directly on the attributes of area objects, it is also feasible to apply this measure to point data by aggregating it to certain areal units. However, modifiable area unit problem (MAUP) may present when aggregating events to lattice unit.

Although spatial statistical analysis has been well discussed in literature, the application to terrorist events is rare. Aldenderfer & Blashfield (1984) suggest that clustering events is useful in developing a scheme for grouping entities. The authors propose that clusters of objects or events are a viable method for creating multiple classifications for a single event. The clustering of terrorist events by target, method, time and location will assist in classifying events, and will subsequently allow the determination of a terrorist organization's characteristic patterns and style of attack.

Aldenderfer & Blashfield (1984) caution that this approach to classification is relatively simple, but it will not evaluate why something happens, and is not as statistically supported as factor analysis might be. Cluster analysis is a relatively simple method for classifications and has historically been used by the law enforcement community to understand organized crime networks and gangs. Because of similarities among networked organizations such as crime groups and gangs, terrorist organization should not be much different.

In summary, this project intends to demonstrate that through the use of spatial analysis and clustering techniques, patterns and trends of terrorist events can be realized. That this can be done with information derived from newspapers and internet sources will not only meet the client's requirements. The study will also demonstrate that precise locations of terrorist events are not necessary in order to visualize how terrorist groups operate and better inform decision makers.

3. Study Area and Data

This section describes the study area for this project, the Philippines, as well as some of the unique considerations of the data that were used to recreate the terrorist events there. All data used for this study was derived from open sources and is readily available on the available on the internet. The following section presents a brief overview of the geography of the Philippines. Additionally, based on the definitions defined in the previous section a description of the major and some minor terrorist organizations that operate in the Philippines is discussed.

3.1. Background of Study Area

The Philippine Islands are located in the western Pacific Ocean, and consist of over 7107 separate islands. The islands are commonly divided into three groups, as depicted in Figure 4; the Luzon Islands are in the north, and the central Visayas Islands and Mindanao Islands are in the south. The total land area of the country is 116, 000 square miles and it shares maritime boundaries with Malaysia, Indonesia, China, Taiwan and Vietnam. The capital is the port city Manila and the country is administratively divided into 80 provincial areas. The population of the country is 76.5 million people (GOP, 2008).

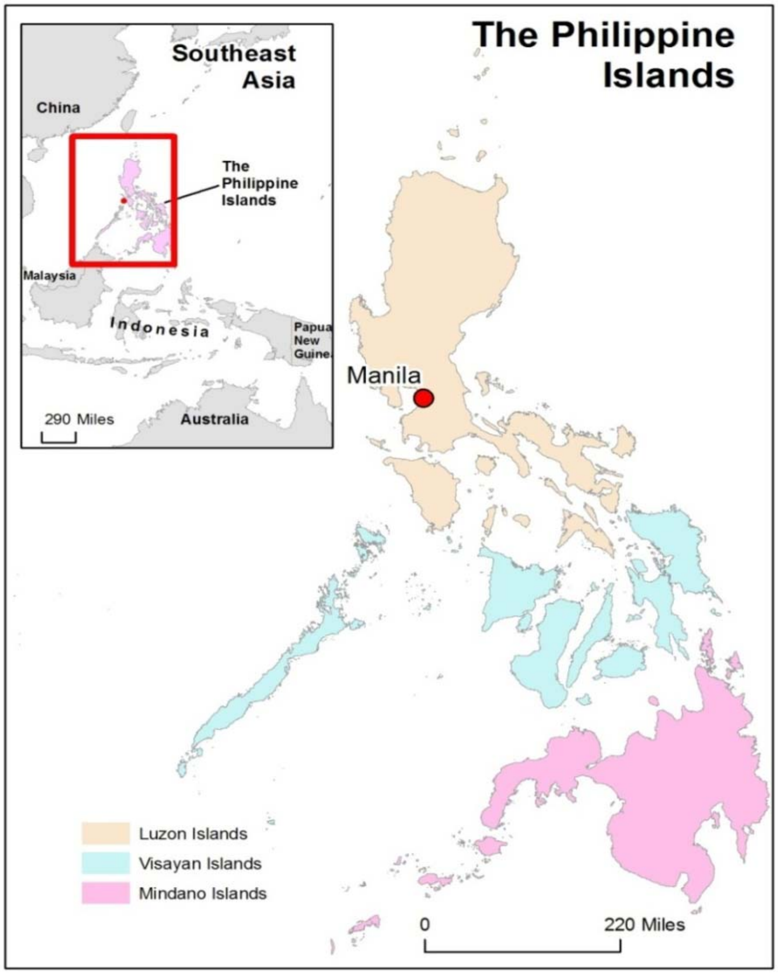


Figure 4. **The Philippine Islands**

The Philippine Islands were ceded to the United States in 1898 as a result of the Spanish American war and the nation remained under American control until the Japanese invaded the island chain in 1941. The United States subsequently liberated the Philippines from the Japanese at the end of World War II. The Philippines were granted independence in 1946. Since then the Philippine nation has had a continual history of insurrection, as well as Muslim resistance to the country's non-Muslim, Catholic majority rule. The most severe revolt occurred in the 1970s when a massive Islamic rebellion broke out, and while the major Islamic groups have since brokered truces with the Philippine government, conflict continues (Niksch, 2003).

The Philippines is one of the many fronts in the United States' global war on terrorism. The Philippines is a strong political, economic and, military ally of the United States. The Philippines is considered a major non-North Atlantic Treaty Organization ally, and annually conducts military exercises with the United States military, even though the military relationship has been controversial to the people of the Philippines (ADL, 2004).

Today, there are four major terrorist groups active in the Philippines: the Moro National Liberation Front, the Moro Islamic Liberation Front, the Abu Sayyaf, and the New

People's Army. The first three are Islamic groups that operate primarily in the southern islands where most of the country's Muslim minority live. The Communist New People's Army operates in the northern Philippines and is considered an anarchist group. There are at least four other terrorist groups operating in the Philippines, but these are considered splinter or break away groups from the major four groups indicated above. At least one transnational terrorist group is also active in the Philippines; The Indonesian Jemaah Islamiyah, which operates throughout Southeast Asia (ADL, 2004).

3.1.1. Moro National Liberation Front (MNLF)

Emerging in the early 1970s, the MNLF sought an independent Islamic nation of all Filipino islands where a sizeable Muslim population was present. In 1996, the MNLF signed a peace agreement with Manila that created the Autonomous Region of Muslim Mindanao (ARMM), an area composed of two mainland provinces and three island

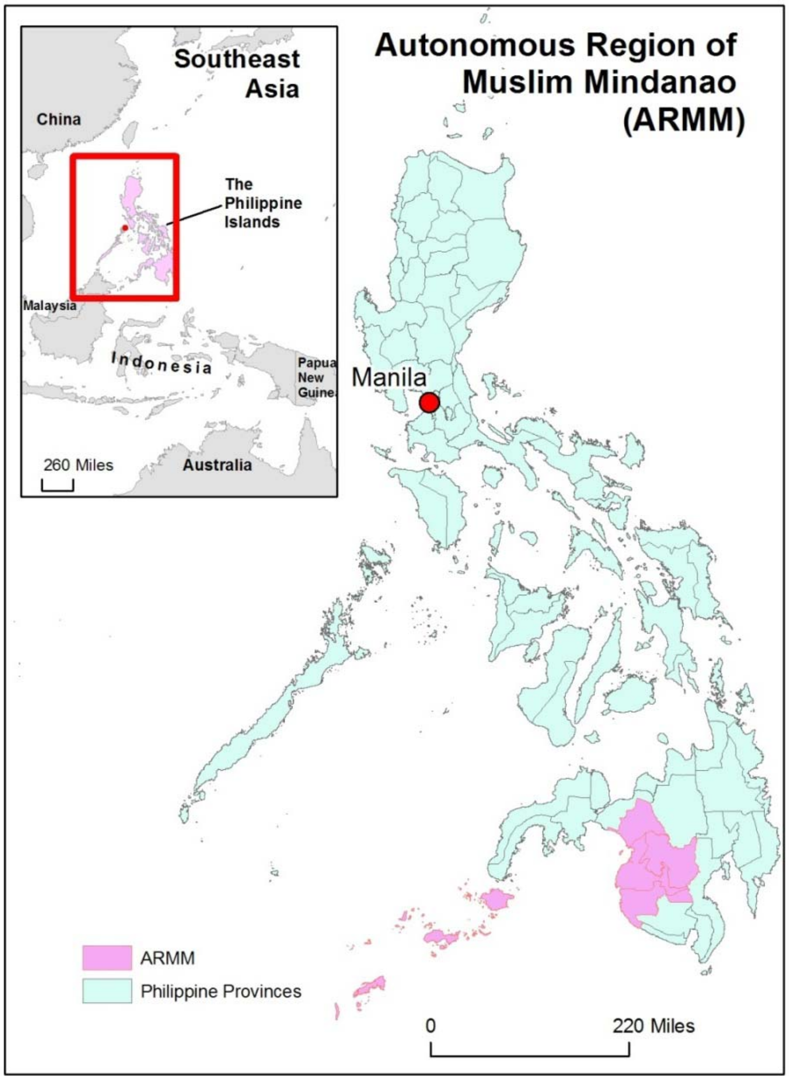


***Figure 5*. Autonomous Region of Muslim Mindanao (ARMM)**

provinces, in which the predominantly Muslim population enjoys a degree of self-rule. The area controlled by the ARMM is depicted in Figure 5.

MNLF chairman and founder Nur Misuari was installed as the region's governor, but his rule ended in violence when he led a failed uprising against the Philippine government in November of 2001. He is currently in jail and MNLF leader Parouk Hussin took over as ARMM governor in 2002. Nur Misuari reportedly still has a small band of followers who remain actively opposed to the current arrangement (ADL, 2004).

3.1.2. Moro Islamic Liberation Front (MILF)

***Figure 6.* Salamat Hashim, Leader of the MILF** (BBC, 2006).

As the largest Islamic extremist group in the Philippines, the MILF split from the MNLF in 1977 and continues to wage war against Manila. Headed by Islamic cleric Salamat Hashim, the MILF seeks a separate Islamic state in the southern Philippines. Hashim is depicted in Figure 6. Although the MILF signed a peace agreement with Manila in 2001, MILF-sponsored violence has continued. Manila accuses the MILF of responsibility for the March 2003 Davao City airport bombing that killed 21 people, and for harboring members of the small militant Pentagon gang accused of kidnapping foreigners in recent years (ADL, 2004). The MILF has an estimated 12,000 members.

3.1.3. Abu Sayyaf Group (ASG)

The smallest, most active and most violent Islamic separatist group in the southern Philippines is Abu Sayyaf (Bearer of the Sword). The group emerged in 1991 as a splinter group of the MNLF. Its founder, Abdurajik Abubakar Janjalani, was a veteran of the Islamic mujahideen movement in Afghanistan and was killed in a clash with Philippine police in 1998. ASG's current head is thought to be Janjalani's younger brother Khadafi Janjalani. The flag of ASG is depicted in Figure 7 (ADL, 2004).

***Figure 7*. Flag of the Abu Sayyaf Group (ASG)** (Rogers, 2004).

Abu Sayyaf engages in kidnappings, bombings, assassinations, and extortion from businesses and wealthy businessmen. Most of its activities are centered in the southern island of Mindanao, but in recent years the group has broadened its reach. In April of 2000, ASG kidnapped 21 people, including 10 foreign tourists, from a resort in Malaysia and in a separate incident, abducted several foreign journalists and an American citizen. In May of 2001 Abu Sayyaf kidnapped 20 people from a resort island in the Philippines and murdered several of the hostages, including American citizen Guillermo Sobero. In June of 2002 U.S.-trained Philippine commandos tried to rescue three hostages being held by Abu Sayyaf on Basilan Island. Two of the hostages, including American citizen Martin Burnham, were killed in the resulting shootout. Philippine authorities believe that the ASG had a role in the October 2002 bombing near a Philippine military base in Zamboanga that killed three Filipinos and a U.S. service member. In February of 2004 Abu Sayyaf claimed responsibility for a Philippine ferry fire, but at this writing, Philippine authorities doubted the claim (ADL, 2004).

The group finances its operations primarily through robbery, piracy, and ransom kidnappings. Both the MNLF and MILF condemn Abu Sayyaf's activities. Philippine forces have apprehended a number of Abu Sayyaf terrorists. Most recently, in December of 2003, Philippine soldiers captured senior Abu Sayyaf commander Ghalib Andang, a.k.a. Commander Robot. Andang is suspected of involvement in the April 2000 kidnapping of Western tourists in Malaysia (ADL, 2004).

Today, Abu Sayyaf is composed of several semiautonomous factions with an estimated cadre of several hundred active fighters and about 1,000 supporters.

3.1.4. New People's Army (NPA)

The NPA is the military wing of the Communist People's Party of the Philippines (CPP). Founded in 1969 with the aim of overthrowing the Philippines government through guerrilla warfare, the NPA strongly opposes the U.S. military presence in the Philippines and publicly expressed its intent to target U.S. personnel in the Philippines in January 2002, warning that any American troops who enter their stronghold areas will be considered legitimate targets. The flag for NPA is depicted in Figure 8. The NPA primarily targets Philippine security forces, politicians, judges, government informers, and former NPA rebels. The NPA's founder, Jose Maria Sison, lives in self-imposed exile in the Netherlands and reportedly directs operations from there (ADL, 2004).

***Figure 8*. Flag of the New People's Army** (Jones, 1989)

Manila is committed to a negotiated peace settlement with the NPA but peace talks between the Communist Peoples Party (CPP), the political arm of the NPA, and the Philippine government stalled in June of 2001 after the NPA admitted killing a Filipino congressional representative. In September of 2002, the NPA claimed responsibility for assassinating a mayor, attacking a police station, and killing the police chief, and blowing up a mobile telecommunications transmission station (ADL, 2004).

The NPA derives most of its funding from supporters in the Philippines and Europe and from so-called revolutionary taxes extorted from local businesses. Together, the CPP/NPA has an estimated strength of over 10,000 members.

3.1.5. Other Terrorist Groups

Other terrorists groups are occasionally active; however these groups are considered to be splinter groups derived from one of the main terrorist groups. The strength of these other terrorist organizations is considered small and is exemplified by the small number of events that these groups have conducted. These smaller, splinter groups are depicted in Table 3.

***Table 3.* Terrorist Splinter Groups**

Philippines Splinter Groups	
Original Group	**Splinter Organization**
NPA	Alex Boncayao Brigade (ABB)
ASG	Rajah Solaiman Movement (RSM)
MILF	The Pentagon Group
NPA	Peoples liberation army (HMB)
Philippine Military	Bungkatol Liberation Front

3.1.6. International Support to Terrorism

All the Islamic groups reportedly have links with international terrorism, particularly with Jemaah Islamiyah (JI) and Al Qaeda. The MILF is suspected of training JI members at MILF training camps in the southern Philippines.

***Figure 9*. Fathur Rohman Al-Ghozi** (Rogers, 2004).

It is suspected that early funding and organizational support of Abu Sayyaf was provided by Osama Bin Laden associate and brother-in- law Muhammad Jamal Khalifa. In 1997, the U.S. State Department designated Abu Sayyaf a foreign terrorist organization (ADL, 2004).

In January 2002, Filipino police arrested Indonesian Islamic extremist Fathur Rohman Al-Ghozi, depicted in Figure 9. Al-Ghozi is a self-confessed member of Jemaah Islamiyah and an Al Qaeda explosives expert.

Following his arrest, Ghozi led Filipino authorities to a large cache of arms and explosives in Mindanao and told a Filipino court that he planned to use the explosives for jihad attacks in Asia. He was sentenced to 17 years in prison. In July 2003, Al-Ghozi escaped from prison and in October

2003, Philippine forces tracked him down and killed him. In November 2003, the Philippines arrested Taufik Rifki, who reportedly admitted he was the financier for a Jemaah Islamiyah training camp in the southern Philippines (ADL, 2004).

Most recently, in February 2004, Filipino Jaybe Ofrasio, was arrested in Belfast, Northern Ireland, and charged with funneling money to JI.

The U.S. designated the CPP/NPA a foreign terrorist organization in August 2002, and listed NPA founder Jose Maria Sison as a Specially Designated Global Terrorist (SDGT). Authorities in the Netherlands froze assets in his bank accounts there and cut off his social benefits (ADL, 2004).

3.2. Data Source and Quality

As a prerequisite all data used for this study was derived from open source information; data that is available to the public and attainable without charge on the internet. For this study, the point data for the terrorist events, Philippine geographic data, and reference data that would allow the correlation of a generalized city name to a coordinate system are required. Because an objective analysis of data is beyond the scope of this study, the data was acquired from reputable organizations that have pre evaluated the data.

All data first had to be converted into tabular form. In most cases this was accomplished by importing the data into Microsoft Excel data sheets. The exception was the Place Names data, because Microsoft Excel 2003 is not capable of accepting more than 64,000 rows of data, however, Microsoft Excel 2007 is able to read this amount of data. Unfortunately, ArcMap 9.2 is not compatible with it. This ESRI incompatibility was resolved with the release of ArcMap 9.3, but to facilitate data preparation, Place Name data was simply imported as a Microsoft Access 2003 table.

3.2.1. Terrorist Event Data

Originally, the terrorist event data used for this study was to be derived from the Memorial Institute for the Prevention of Terrorism (MIPT). Their data for the Philippines included 329 different terrorist events that occurred in the Philippines from 1991 to 2007. An example of the MIPT data sheet is depicted in Appendix 2.

The information that MIPT used and included in their database was provided by the Rand Corporation. The data provided by MIPT was primarily considered because it was the same information used for a previous TRADOC spatial project conducted by Mark Covey on social networks of terrorist groups (Covey, 2007). Unfortunately, MIPT lost

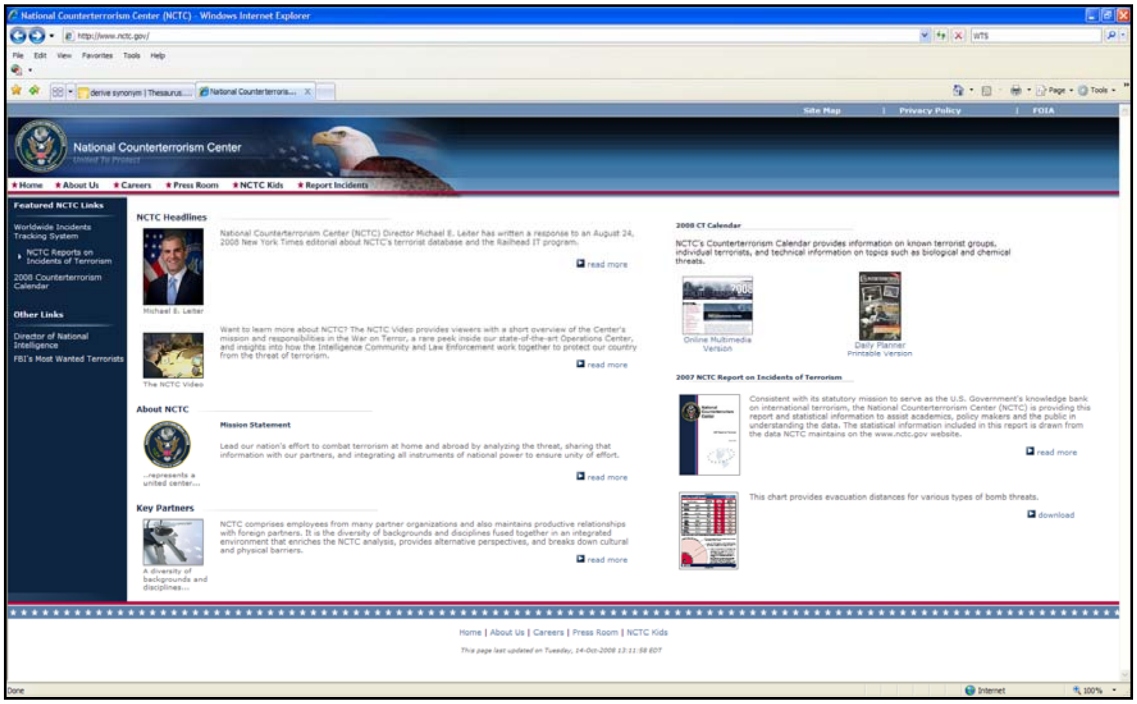


Figure 10. **NCTC Web Site** (NCTC, 2008)

their contract to publish and maintain terrorist data on the internet, so an alternative data source had to be found.

An alternate data source was identified at the National Counter Terrorism Center’s (NCTC) web site (see Figure 10) (NCTC, 2008). The NCTC’s World Wide Incident Tracking System (WITS) maintains a comprehensive global terrorist event database. Six hundred and seventy four terrorist events were recorded in the Philippines between 2004 and 2007. The data from NCTC’s WITS database was actually more detailed than the data that was considered from MIPT.

Figure 11 depicts the WITS web interface. To be included in the database, terrorists

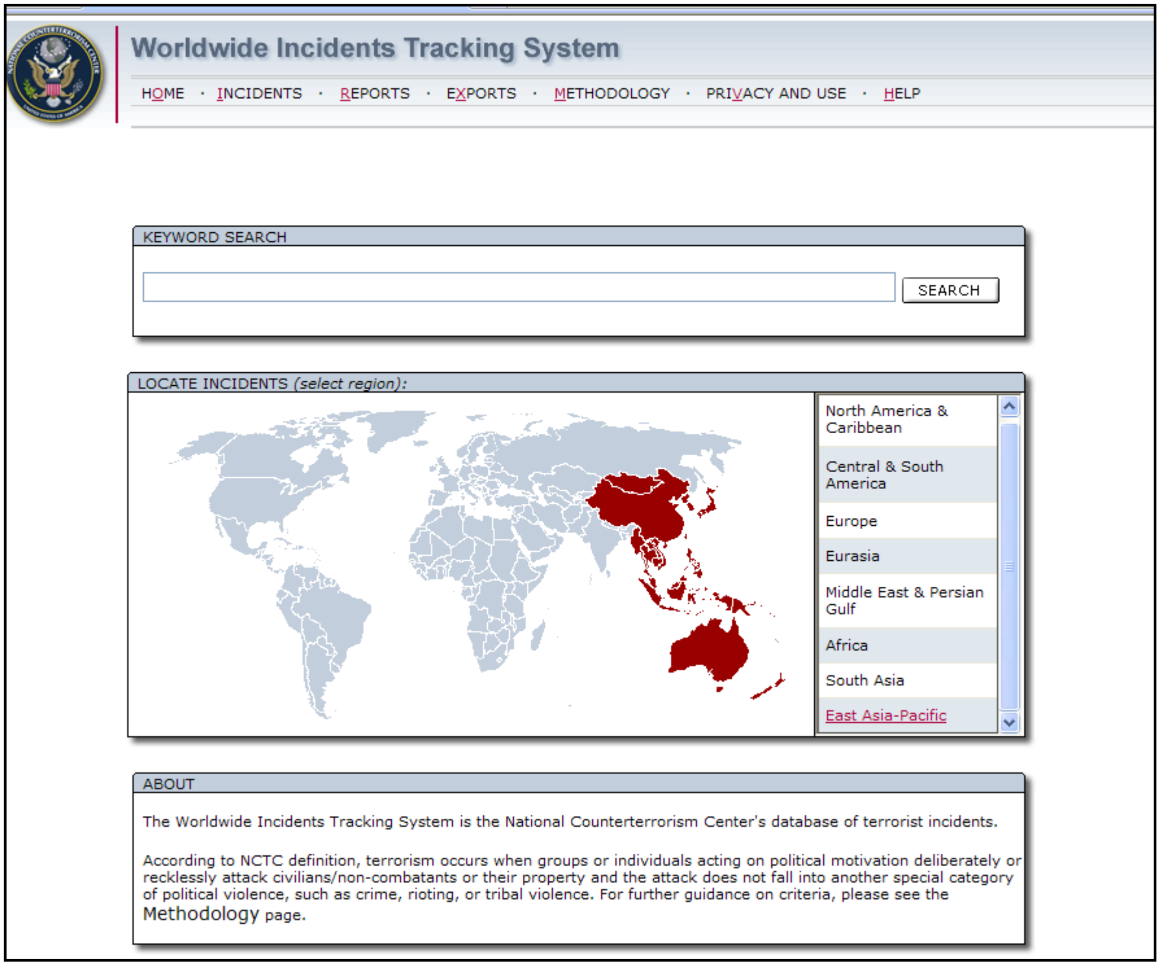


***Figure 11*. WITS Web Interface** (NCTC, 2008)**.**

groups must have initiated and executed an event such as failed or foiled attacks, as well as hoaxes, are not included in the database. Spontaneous hate crimes without intent to cause mass casualties were excluded to the greatest extent practicable. While genocidal events can be interpreted as the most extreme form of politically motivated violence against civilians, attacks in this category were excluded, in part because of the inherent difficulty in counting such events and because the inevitable undercount does not do justice to the scope and depth of such atrocities. A cause and effect of the event cannot be determined strictly by the data that is kept by WITS (NCTC, 2008).

3.2.1. Philippines Geographic Data

Geographic data for the Philippines was acquired from Geo Community, (GeoCommunity, 2008) and the features included in the data are listed in Table 4.

Table 4. **Philippines Data**

Feature Type	Example
Transportation Infrastructure	Roads, Highways, Waterways, Railways
Geographic Information	Elevation, Contours, Island Boundaries
Geographic Names	Administrative Codes, Place Names
Administrative and Political Boundaries	National, Province, Municipalities

Although the data from Geo Community contains useful information, it was not originally projected and did not have a datum. The common geographic datum for the Philippines is the Luzon 1911 datum. However, because this project would eventually be part of a global project encompassing many other countries besides the Philippines, it was decided to use the Worldwide Geodetic System (WGS) of 1984. Additionally, the Universe Transverse Mercator (UTM) was chosen as a global projection, instead of the Philippines Transverse Mercator (PTM). The Philippines falls in UTM Zones, 50, 51, and 52 north. The difference between PTM and UTM is depicted in Figure 12.

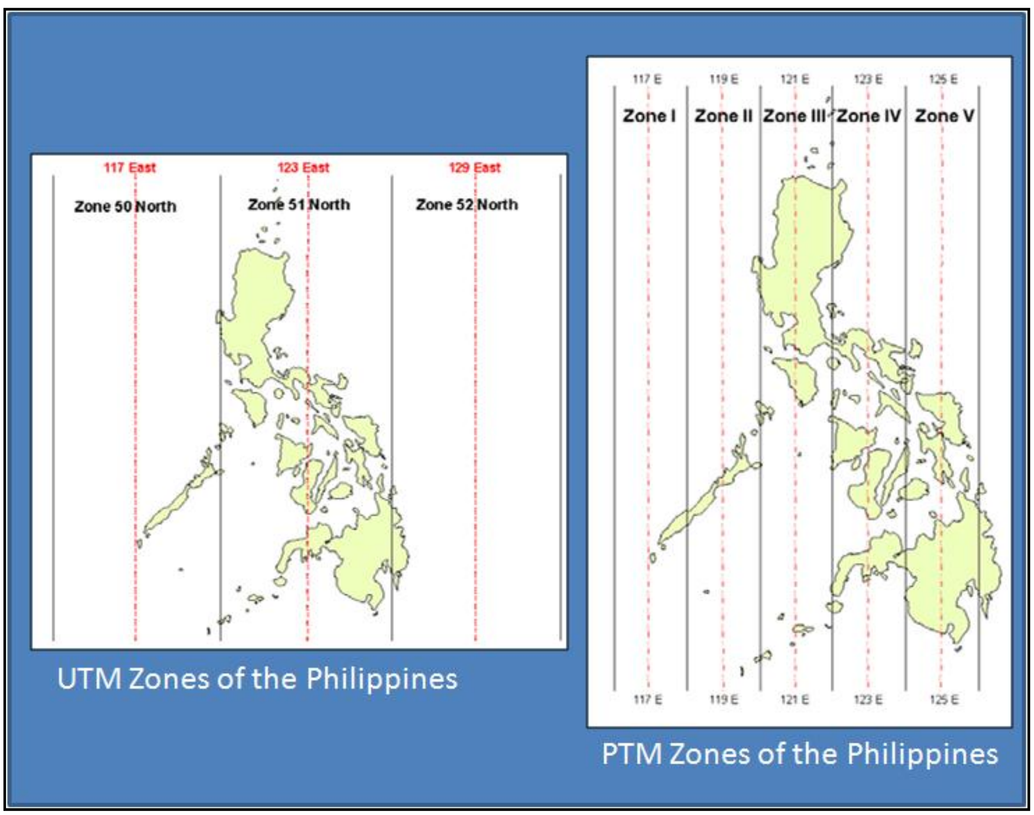


Figure 12**. Comparison of UTM and PTM Zones (SANREM, 2004).**

3.2.2. Place Name Data

One of the central tasks involved in this project is to geocode the terrorist events locations, and therefore a data set that contains place names and their coordinates is required. There were three sources evaluated for place name data. The first is the Geo Community (GeoCommunity, 2008), which provides data for the GIS industry. The second data is from Socioeconomic Data and Applications Center (SEDAC), which provides gridded population and urban areas data (SEDAC, 2008). The third choice was the GEOnet Names Server (GNS) (NGA, 2008) which provides access to the National Geospatial-Intelligence Agency's (NGA) and the U.S. Board on Geographic Names database of foreign geographic feature names.

The first two options, from Geo Community and SEDAC, were not as comprehensive as the data available from GNS. The veracity of the GNS data is considered more complete as the information is developed by NGA and vetted by the U.S. Board on Geographic Names database of foreign geographic feature names.

The data from GNS for the Philippines includes over 73,000 city and place names for the country. The GNS data includes Universal Transverse Mercator (UTM), Longitude/Latitude, and Philippine local coordinates for all place names in their database. The GNS data also provides an update date. An example of the GNS data is provided in Figure 13.

Figure 13. **GNS Web Page (NGA, 2008).**

4. Methods

This section focuses on the major methods that were applied in the project for data manipulation and spatial analysis. The most significant efforts explored include the approaches for geocoding, or the ability for mapping data based solely on a city name, aggregation of point data into polygons, and the development of a geodatabase. In addition, relevant spatial statistical methods for identifying spatial patterns in the data will also be introduced in this section.

O'Sullivan & Unwin (2002) recognized that using geographic information analysis and spatial statistics to support a study might be challenging as "geographic information analysis is not yet an established discipline." They identified through their own research that the literature in the community has at least four different contexts for the term "geographic information analysis." The context that the term "geographic information analysis" is used is different for geographers, the statistic community, technicians and the modeling community.

For the purpose of this study, an array of the terms will be used including spatial data manipulation, which is the process to make data useful, spatial data analysis, that will describe an exploratory approach to the data, and spatial statistical analysis, which is used to interrogate the data, and assist in arriving at finding. For this study, the term, spatial modeling, which involves constructing models to arrive at outcomes, will not be used as it is outside the scope of this project (O'Sullivan & Unwin, 2002).

4.1. Geocoding Approaches

Geocoding is the process of finding associated geographic coordinates often expressed as latitude and longitude, from geographic text data, such as street addresses, zip codes or, in the case of this project, city names. The features can be mapped with geographic coordinates and entered into a geographic information system. Of the utmost importance in geocoding is the standardization of names, variants and, associated data (NGA, 2008).

This section will discuss some of the exploratory methods that were used in attempting to geocode information for the Philippines. Three distinct geocoding methods were explored: conducting a spatial relate (from relates and joins); the usage of MetaCarta tools; and geocoding with ArcView's Address Locator. The spatial relate was quickly discounted as there were too many place names from the terrorist event data and too great a potential for spelling differences.

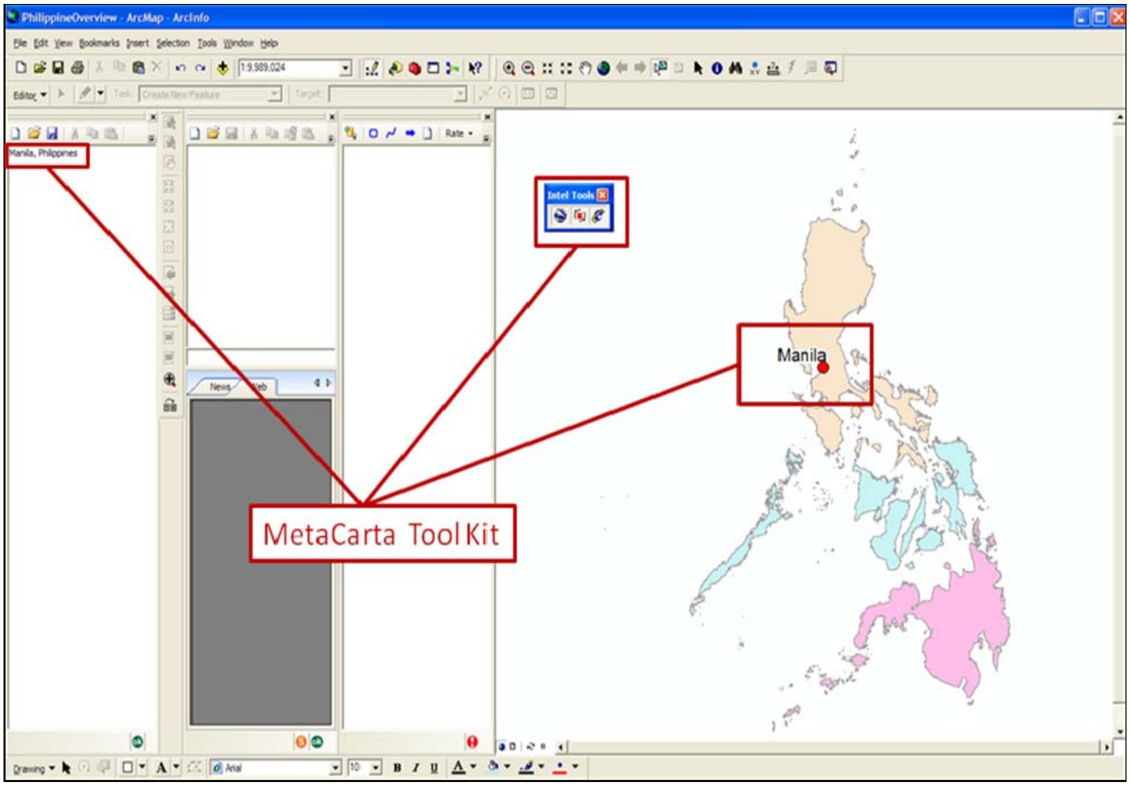


Figure 14. **MetaCarta Tool Kit (MetaCarta, 2008).**

An exploratory effort was made with a MetaCarta-derived tool kit. The tool kit was procured from the government and is very similar to the commercial version of the MetaCarta application. MetaCarta's products make data and unstructured content "location-aware" (MetaCarta, 2008). The tools are quite easy to use, very accurate, and not prone to the spelling issues that a spatial relate has. MetaCarta relies on an internet connection and the tool will subsequently search for a place name from an online gazetteer. The place name is then returned and graphically plotted in ArcMap. However, extracting the information from the tool in ArcMap and using the data in a geodatabase was not possible with the version of the tool that was provided. An example of the Meta Carta tool kit is depicted in Figure 14.

The final method explored, and subsequently used for the project, was ArcCatalog's address locator. An address locator is a dataset in ArcGIS that stores the address attributes, associated indexes, and rules that define the process for translating nonspatial descriptions of places, such as city names, into spatial data that can be displayed as features on a map. An address locator contains a snapshot of the reference data used for geocoding, and parameters for standardizing addresses, searching for match locations, and creating output (Kennedy, 2001).

Unfortunately, a Philippine address locator does not exist. What was subsequently required was the tailoring of the standard address locator that is included in ArcCatalog from its set City/State data requirement to the Philippines City/Province data set. The address locator tool easily accepted this translation once it was structured in the place name data. The only problem encountered was that the GNS data did not include a province code for its province field. The issue with province codes was overcome by adding an ADM code from GNS's lookup table. The ADM code was subsequently appended to the place name data and a 95% parse rate (640 records) was achieved with the address locator and modified GNS place name data. The remaining 5% of the 674 terrorist events were then manually parsed. An example of the modified address locator tool is depicted in Figure 15.

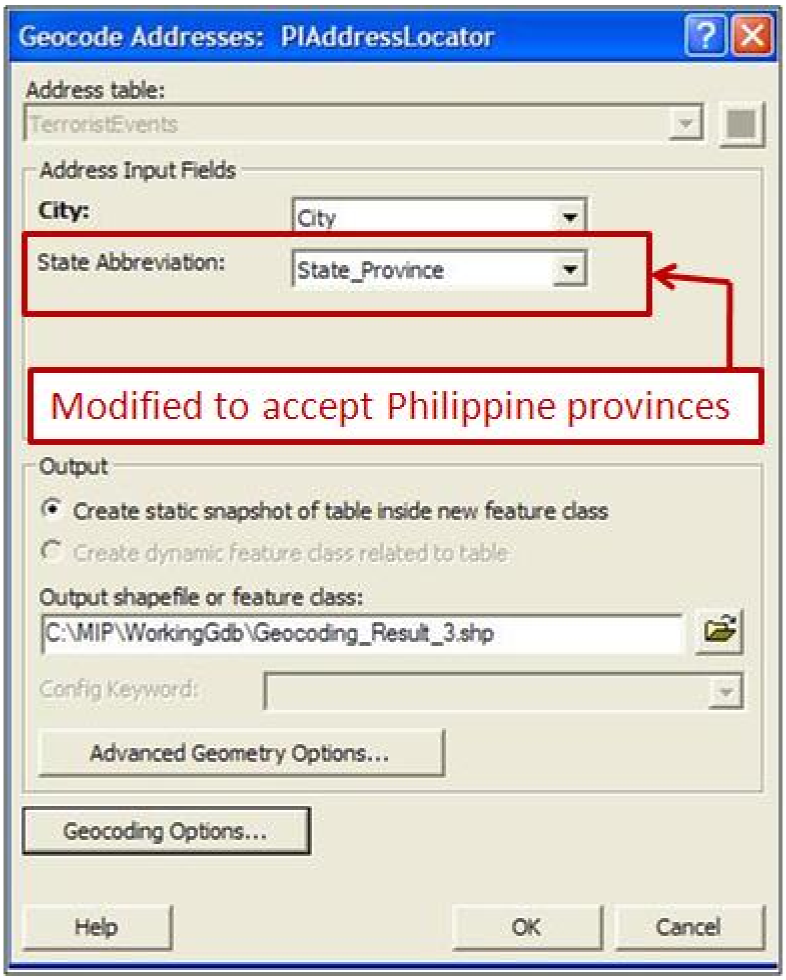


***Figure 15*. Address Locator**

4.2. Point Data Aggregation

While point data was acquired, some of the statistical analysis required the aggregation of point data to achieve polygons. Aggregation of data further enhanced visualization since

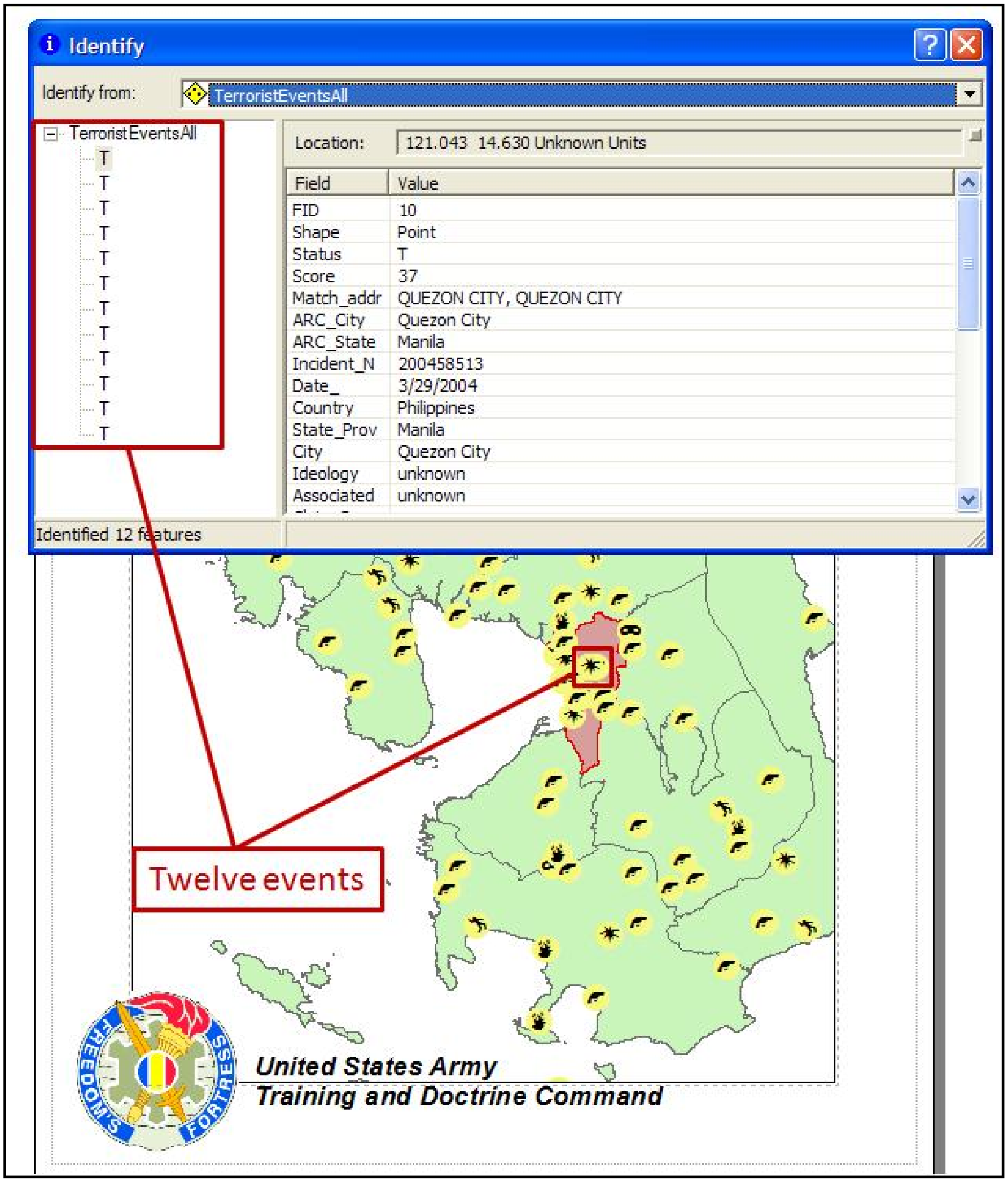


Figure 16. **Point Data Example**

the smallest reporting area for a terrorist event is at the city level and with point data many times events overlapped each other. For example, from the point data view, only one event is depicted in Quezon City, Manila, but the single symbol actually hides eleven other events, for a total of twelve events (see Figure 16).

Subsequently, aggregation of point data was achieved by conducting a spatial join in ArcMap. The spatial join tool that was used to aggregate the terrorist event points within provincial boundaries as depicted in Figure 17. Aggregation of events was conducted against provincial boundaries of the Philippines in order to gain a join count, or how many terrorist events occur within a province. By doing this, further analysis could be conducted at the provincial level.

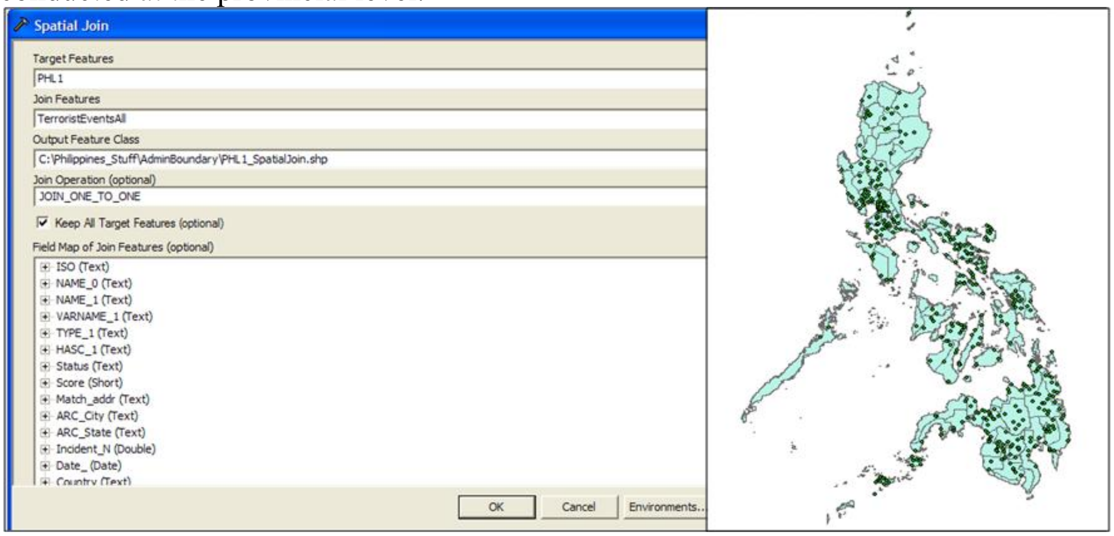


Figure 17. **Spatial Join Example**

Figure 18 depicts the results of the spatial join. The result of this join provides polygons with multiple attributes from the original point data.

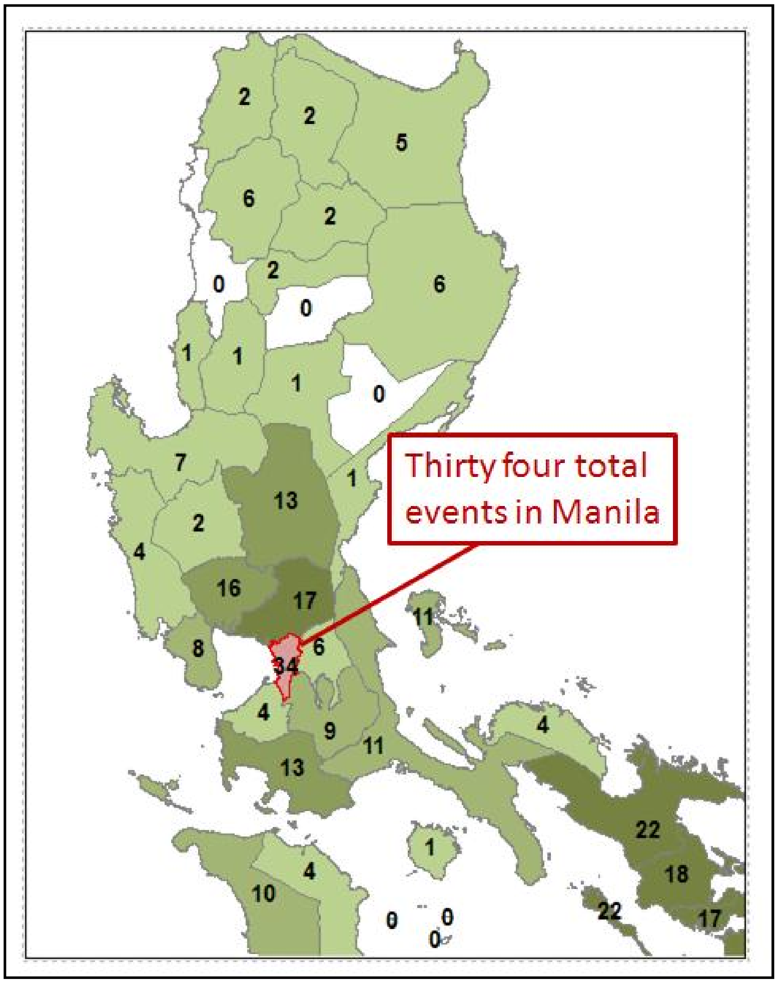


Figure 18. Point Data Aggregation

4.3. Geodatabase Design

A geodatabase is designed to store, query, and manipulate geographic information and spatial data and is also known as a spatial database. Within a spatial database, spatial data is treated as any other data type. Vector data can be stored as point, line or polygon data types and may have an associated spatial reference system. A geodatabase record can use a geometry data type to represent the location of an object in the physical world and other standard database data types to store the object's associated attributes (Arctur & Zeiler, 2004).

The conceptual design behind the geodatabase for the Spatial Event Analysis Tool emanates from the actions that a terrorist takes to conduct an attack or event. Replicating the different fields of an action, in this case a terrorist event is a challenging undertaking. However, replication of an event is the sole intention of the geodatabase that supports the Spatial Event Analysis Tool. The conceptual design for the geodatabase is depicted in Figure 19.

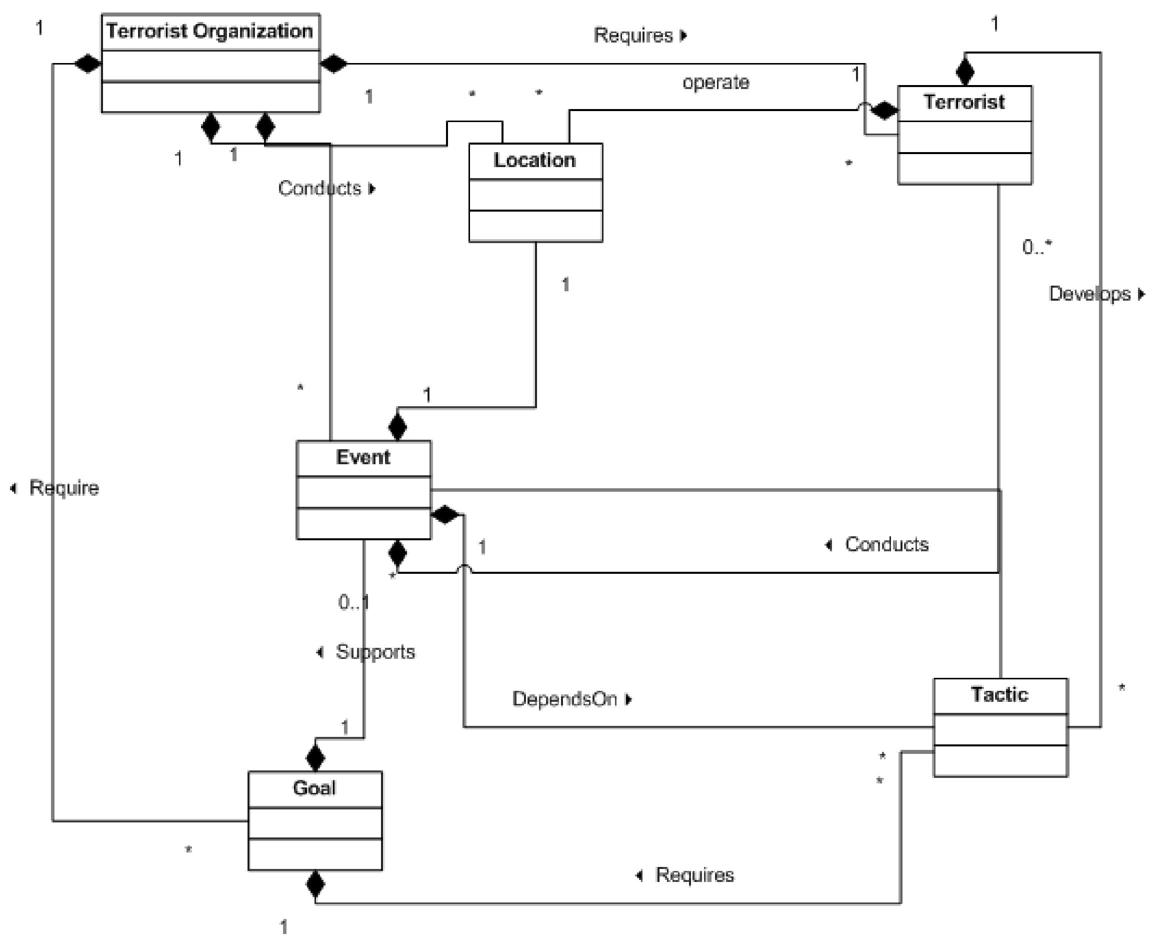


Figure 19. **Conceptual Database Design**

The intent of the conceptual design is to consider the relationships among the many aspects of a terrorist event. In the abstract, all relationships emanate from the event itself.

An event occurs somewhere, and subsequently has a locational position. Normally, the location is defined as a street address or grid coordinate. For this project, the location is a city name.

A terrorist organization carries out an event. The terrorist organization has a goal in mind when carrying out a terrorist event and the actions of the attack. For example, an Islamic terrorist organization may have a goal of demonstrating Islamic justice for a social discrimination, slight, or perceived injustice. One commonality of all terrorist events, regardless of the goal is that the event must be spectacular and garner attention. A terrorist event is not successful if it does not intimidate or terrorize, and that will not occur if the event doe not garner attention.

The terrorist attack can be carried out by one or more terrorist organizations but those organizations must share a common goal. Terrorist organizations may form alliances of convenience, but ultimately any slight differences in goals will cause friction amongst terrorist organizations that cooperate. Additionally, it is not uncommon for terrorist organizations to combat each other. This is because like a terrorist group may have a disagreement with the government, a terrorist organization can also have a disagreement with other terrorist organizations. Usually, this is because of conflicting goals among terrorist organizations. For example Islamic groups, which are religious, generally conflict with communist organizations, which are political. That is because communist organizations generally do not recognize religion, while religious organizations do not recognize modern politics. Conflict can also occur between different sects of a religion, such as what occurred in Iraq between the Sunni and Shia sects of Islam.

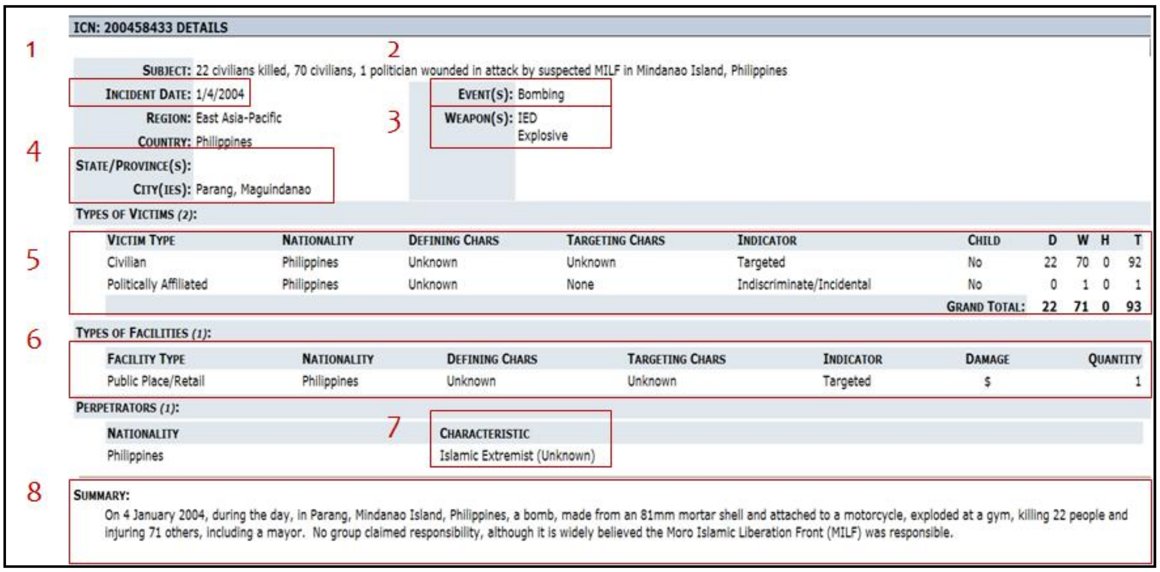
A terrorist organization has members, or individual terrorists. The individual terrorist is bonded to the organization by the goal of the organization. The terrorist organization requires multiple individual terrorist. The individual terrorists carry out different roles and functions for the terrorist organization. Roles that individual terrorist may have are bomb maker, a security specialist, a trainer, supporter or even a spokesperson. While it is possible that one terrorist maybe a member of multiple terrorist organizations, this is becoming increasingly rare.

The last aspect of the conceptual database is the tactic. Terrorists and their organization carry out an attack with different tactics. A tactic used during a terrorist attack can be unique and be the signature of a particular terrorist organization. For example, Islamic terrorist organizations tend to rely on suicide bombing tactics. The tactic also supports the goal of the terrorist organization. Extending the example of the suicide bombing, a tactic that is reinforced by the religious concept of martyrdom, figures prominently in religion and subsequently the religious goals of terrorist organizations.

In an attempt to model these many facets of a terrorist event an analysis of past events was conducted and modeled in a Unified Modeling Language (UML) diagram, depicted in Figure 19. The UML that was developed was used for the Terrorist Event database conceptual design and subsequently as the basis for the Spatial Event Analysis Tool's geo database.

The main database for the Spatial Event Analysis Tool, the Terrorist Event Database, is derived from the National Counter Terrorism Center's (NCTC) World Wide Incident Tracking System (WITS), for terrorist events in the Philippines. The NCTC leads the U.S. efforts to chronicle and combat terrorism at home and abroad by analyzing the terrorist threat, sharing that information with partners, and integrating all instruments of national power to ensure unity of effort.

From the individual WITS event data sheets many fields were used to populate a file geodatabase for spatial analysis. An example of the WITS data sheet is depicted in Figure 20.


ICN: 200458433 DETAILS

1 2

SUBJECT: 22 civilians killed, 70 civilians, 1 politician wounded in attack by suspected MILF in Mindanao Island, Philippines

INCIDENT DATE: 1/4/2004

EVENT(S): Bombing

REGION: East Asia-Pacific

3 WEAPON(S): IED Explosive

COUNTRY: Philippines

4 STATE/PROVINCE(S):

CITY(IES): Parang, Maguindanao

TYPES OF VICTIMS (2):

5

VICTIM TYPE	NATIONALITY	DEFINING CHARS	TARGETING CHARS	INDICATOR	CHILD	D	W	H	T
Civilian	Philippines	Unknown	Unknown	Targeted	No	22	70	0	92
Politically Affiliated	Philippines	Unknown	None	Indiscriminate/Incidental	No	0	1	0	1
					GRAND TOTAL:	22	71	0	93

TYPES OF FACILITIES (1):

6

FACILITY TYPE	NATIONALITY	DEFINING CHARS	TARGETING CHARS	INDICATOR	DAMAGE	QUANTITY
Public Place/Retail	Philippines	Unknown	Unknown	Targeted	$	1

PERPETRATORS (1):

7

NATIONALITY	CHARACTERISTIC
Philippines	Islamic Extremist (Unknown)

8 SUMMARY:

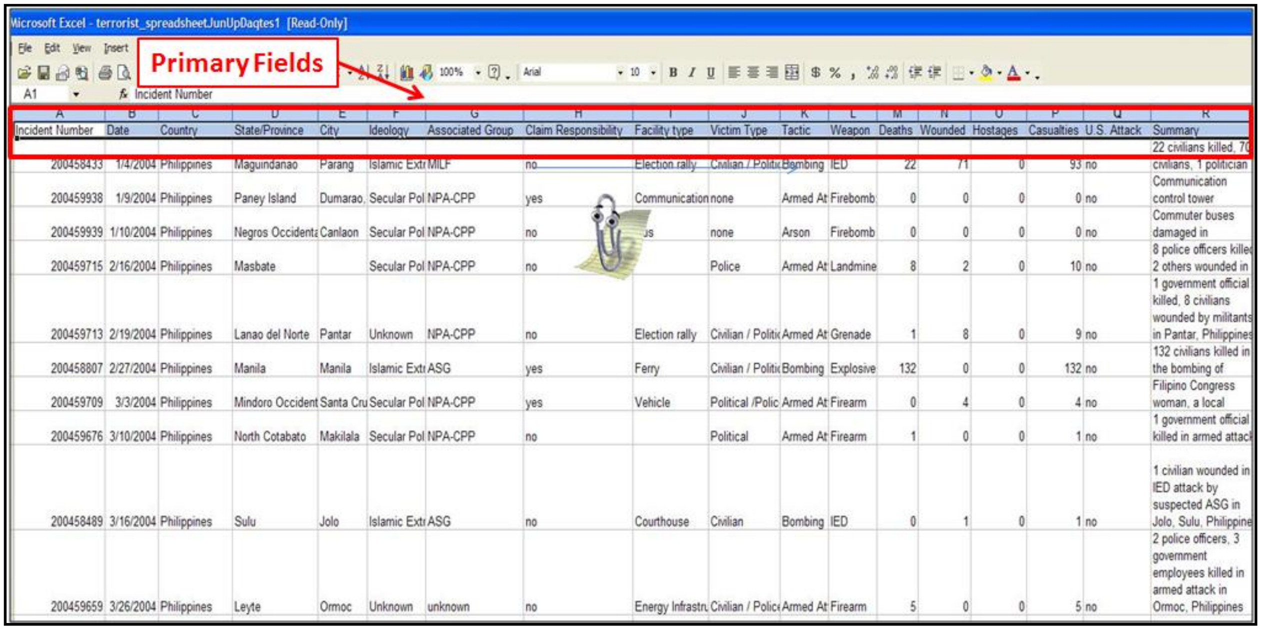
On 4 January 2004, during the day, in Parang, Mindanao Island, Philippines, a bomb, made from an 81mm mortar shell and attached to a motorcycle, exploded at a gym, killing 22 people and injuring 71 others, including a mayor. No group claimed responsibility, although it is widely believed the Moro Islamic Liberation Front (MILF) was responsible.

Figure 20. **WITS Data Event Datasheet (NCTC, 2008)**

The terrorist event table is one of the main components of the SEAT geodatabse. The tabular data is part of the file database that is used for spatial analysis. While not limited to only the following, terrorist event table includes the minimum fields:

- Incident date
- Event Type
- Weapon Used
- City and State of the Event
- Victim Information
- Facility Information
- Characteristic
- An Event Summary

A subsequent spreadsheet was developed from these eight minimum fields of the 674 terrorist events that have occurred in the Philippines between 2004 and 2007. This terrorist event spreadsheet allows for the creation of over 18 other fields that describe the characteristics of a terrorist event. An example of the Terrorist Event Spreadsheet is depicted in Figure 21.



Incident Number	Date	Country	State/Province	City	Ideology	Associated Group	Claim Responsibility	Facility type	Victim Type	Tactic	Weapon	Deaths	Wounded	Hostages	Casualties	U.S. Attack	Summary
200458433	1/4/2004	Philippines	Maguindanao	Parang	Islamic Extr	MILF	no	Election rally	Civilian / Politic	Bombing	IED	22	71	0	93	no	22 civilians killed, 70 civilians, 1 politician
200459938	1/9/2004	Philippines	Paney Island	Dumarao,	Secular Pol	NPA-CPP	yes	Communication	none	Armed At	Firebomb	0	0	0	0	no	Communication control tower
200459939	1/10/2004	Philippines	Negros Occidenta	Canlaon	Secular Pol	NPA-CPP	no	[illegible]us	none	Arson	Firebomb	0	0	0	0	no	Commuter buses damaged in
200459715	2/16/2004	Philippines	Masbate		Secular Pol	NPA-CPP	no		Police	Armed At	Landmine	8	2	0	10	no	8 police officers killed 2 others wounded in
200459713	2/19/2004	Philippines	Lanao del Norte	Pantar	Unknown	NPA-CPP	no	Election rally	Civilian / Politic	Armed At	Grenade	1	8	0	9	no	1 government official killed, 8 civilians wounded by militants in Pantar, Philippines
200458807	2/27/2004	Philippines	Manila	Manila	Islamic Extr	ASG	yes	Ferry	Civilian / Politic	Bombing	Explosive	132	0	0	132	no	132 civilians killed in the bombing of
200459709	3/3/2004	Philippines	Mindoro Occident	Santa Cru	Secular Pol	NPA-CPP	yes	Vehicle	Political /Polic	Armed At	Firearm	0	4	0	4	no	Filipino Congress woman, a local
200459676	3/10/2004	Philippines	North Cotabato	Makilala	Secular Pol	NPA-CPP	no		Political	Armed At	Firearm	1	0	0	1	no	1 government official killed in armed attack
200458489	3/16/2004	Philippines	Sulu	Jolo	Islamic Extr	ASG	no	Courthouse	Civilian	Bombing	IED	0	1	0	1	no	1 civilian wounded in IED attack by suspected ASG in Jolo, Sulu, Philippine
200459659	3/26/2004	Philippines	Leyte	Ormoc	Unknown	unknown	no	Energy Infrastru	Civilian / Police	Armed At	Firearm	5	0	0	5	no	2 police officers, 3 government employees killed in armed attack in Ormoc, Philippines

Figure 21. **Terrorist Event Spreadsheet**

The spreadsheet provided point data, down to the city level of terrorist events in the Philippines. The spreadsheet was subsequently imported into a Microsoft Access where a *.dbf table was created that could be imported into a file geodatabase. Besides the imported data, the table and geodatabase will allow for the further population of events that occur after 2007. Additionally, relationships will be established within the database in order to allow for complex queries. These queries will be developed based on the client’s requirements for spatial, temporal, and predictive analysis.

Additional reference data is included in the file geodatabase, and including administrative boundaries such as cities, municipalities, provinces, country borders, and islands. Point and line feature classes are included in order to depict transportation nodes for reference purposes. This information is exclusively in vector format. The resulting products from the analysis, as well as the geocoding tools, are all stored within the geodatabase.

After these considerations for data sources, as well as the conceptual design for the terrorist events database, the subsequent logical database design was implemented and is depicted in Figure 22.

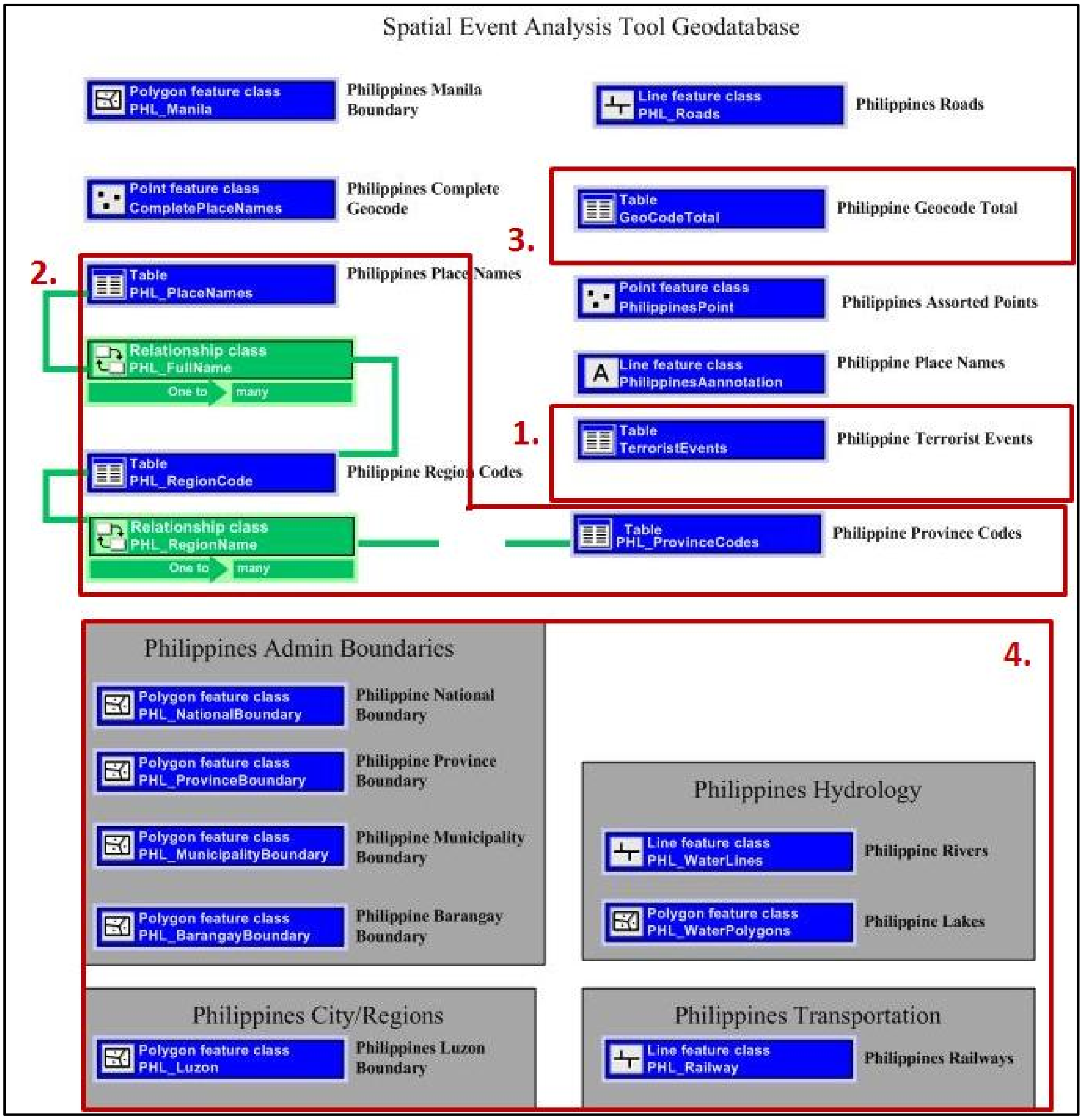


Figure 22. **Spatial Event Analysis Geodatabase**

The logical database design is a furtherance of the initial conceptual design. However, from the initial concept a technical solution was created, in this case a set of tables as well as other data sets.

The first consideration was given to the terrorist events, annotated as number 1 in Figure 22. The table that was developed was extracted from the NCTC data that was previously mentioned. That data was structured and placed into multiple rows and columns of a table in order to meet the objectives of the conceptual design, those columns and rows were previously discussed in Figure 21. All aspects of the concept were included within the terrorist event table.

The next solution was developed for location information. As previously discussed location data was derived from NGA. However, the challenge arose because of the hierarchal nature of locations. For example a city is a location, a city is within a province, a province is within region or zone, and regions or zones are part of a country. Because of this hierarchal nature of locations, multiple related tables were required, and they are depicted by the number 2, in Figure 22. Number two of the logical design, directly relates to the Location class of the conceptual design (Figure 19).

The third aspect of the location information that had to be related was the geocoding of a grid location and a city name. This was accomplished using ArcMap's geocoding tool and was ubsequently exported to a table, depicted by number three of Figure 22. The table contained over 74,000 city names and locations for all of the Philippines. The table also includes multiple grid coordinates for each location based on different projections that may be encountered in the Philippines.

The last aspect for consideration was reference data. Reference data was assembled into four major Feature datasets and is depicted by number four, in Figure 22. Those Philippine datasets included Administrative Boundaries, Hydrology Features, City/Regions, and Transportation Features. All feature classes within the datasets were either line or polygon features. Reference data was already pre structured and and no table were specially constructed for the data.

Location data, instrumental for geocoding, was almost exclusively derived from tabular data. These three tables were developed and paired with relationship classes in order to establish the hierarchal nature of a location. The hierarchal nature of administrative boundaries for the Philippines is depicted in Figure 23.

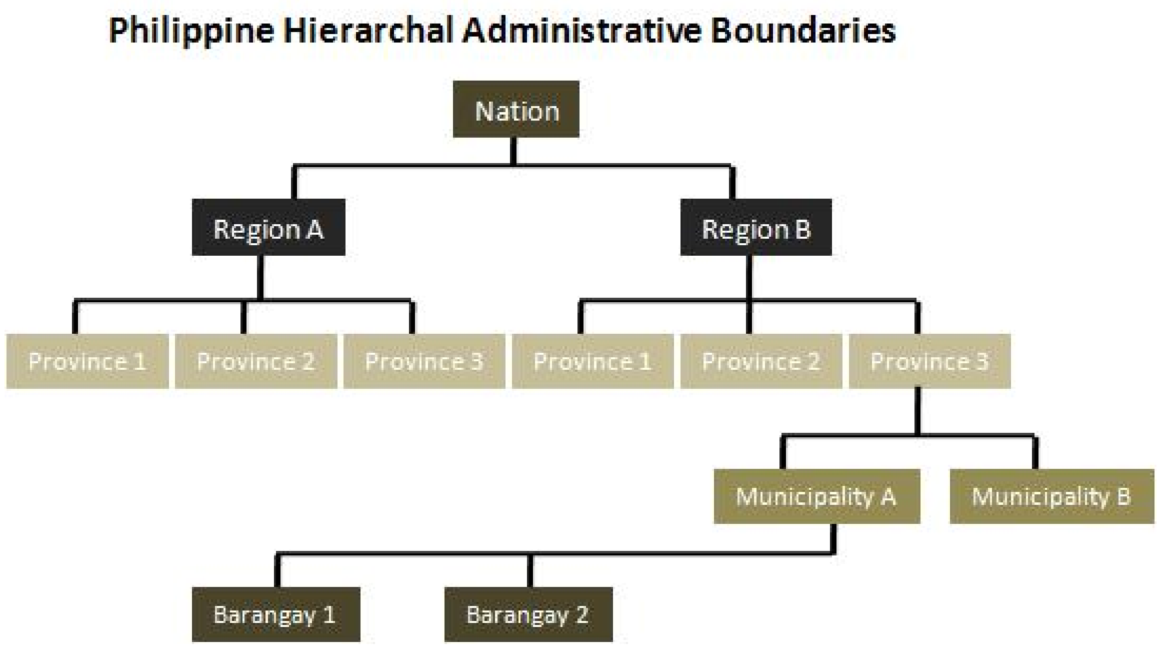


Figure 23. **Admin Boundaries Hierarchy**

For the Philippines, the barangay is similar to a United States city, a municipality is similar to a U.S. county, province is similar to a state, and region is similar to a U.S. region, such as the southwestern United States. Because of this hierarchy nature of administrative boundaries, relationship classes were developed within the geodatabase. It also constituted three tables to construct administrative boundaries.

The Terrorist Event data, as well as the final geocoding information, was also derived from tabular data. Two additional sets of point features and one annotation feature for labeling were also included in the geodatabase.

Tabular data used in the Spatial Event Analysis Tool is exclusively for location information and to depict terrorist events. Fields in the TerroristEvent table define the characteristics of a terrorist event, while fields for GeoCodeTotal provide the coordinates for locational data. PHL_RegionCode identifies the different geographic features of the Philippines, as well as the features name and where it is located. A description of the tabular data can be found in Table 5.

***Table 5.* Tabular data**

Table Name	Field Name	Field Data Description
TerroristEvents	Associated Group	The terrorist group believed to be responsible for the attack
TerroristEvents	Facility_type	The facility that was attacked
TerroristEvents	Victim_type	The victim that was attacked
TerroristEvents	Tactic	How the terrorist attacked
TerroristEvents	Weapon	What weapon the terrorist used
TerroristEvents	Casualties	Compilation of deaths and wounded as a result of the attack
GeoCodeTotal	Lat/Long	Common Latitude and longitude
GeoCodeTotal	MGRS	Military UTM coordinate
GeoCodeTotal	ADM	Province code
GeoCodeTotal	JOG	The map sheet for the point
PHL_RegionCode	F_DESIG	Geographic feature type

The database for the SEAT is kept in the first normal form (1NF) as relations are established in the database and there are no duplicate rows. 1NF is used primarily because the SEAT is a prototype effort, and data requirements are not too extensive. The purpose of normalization is to restrict the possibility of update, insertion, and update anomalies. However, in the future, when the SEAT is expanded and includes multiple countries and many different terrorist organizations normalization will be critical (Kent, 1983).

The database can easily be placed in second normal form (2NF). 2NF requires that the data first be placed in 1NF, and one of the non-prime attributes of the table are functionally dependent on a part (proper subset) of a candidate key. For example, within the terrorist group table, there may be dependencies based on the ideology table (Kent, 1983).

To place the data in third normal form (3NF) requiresThe table must be in 2NF and every non-key attribute must be non-transitively dependent on the primary key. All attributes must rely only on the primary key. So, if a database has a table with columns Terrorist, Terrorist Organization, Country, and Province, it is not in 3NF. This is because the terrorist relies on a terrorist organization. Therefore, for it to be in 3NF, there must be a second table with terrorist organization and terrorist member columns; the country column would be removed (Kent, 1983).

Placing the data in fourth normal form (4NF) occurs only if, for every one of its non-trivial multivalued dependencies is a superkey. For example, if you can have two phone numbers values and two email address values of a terrorist, then you should not have them in the same table (Kent, 1983).

The preferred normalization is fifth normalization (5NF). To be in 5NF the table must be in 4NF and there must be no non-trivial join dependencies that do not follow from the key constraints. A 4NF table is said to be in the 5NF, if and only if, every join dependency in it is implied by the candidate key (Kent, 1983).

4.4. Spatial Statistical Analyses

Various spatial statistical techniques have been well developed to identify spatial patterns of the geographic data and investigate the relationships among geographic variables. Some of the common spatial statistical methods have been implemented in current GIS software including, ArcGIS, which greatly facilitates spatial manipulation and analysis in one platform. In this project, the analysis focus was on the spatial and temporal patterns of terrorist events. Pattern identification in geographical analysis can be performed on both point data and polygon data. In the former situation, the interests lies in the presence of spatial randomness of location of events, while the interest focuses on the presence of the spatial randomness of attributes of the polygons in the latter case. For instance, cluster analysis may be conducted in order to better understand locations of crimes, or the outbreak of certain diseases to better see whether there is a pattern. In both of these cases, point pattern analysis can be of great help to institutions and policymakers in their decisions on how to best allocate their scarce resources to different areas. Corresponding to these two examples, hotspot analysis may be conducted to examine the spatial autocorrelation of crime rates and disease rate if they are aggregated to polygon level, such as census tracts, cities, or in this case provinces. A number of methods were used in this project, to analyze terrorist events including nearest neighbor, global and local spatial auto correlation, and kernel density exploration. All of these analytical methods were conducted using ArcMap's Spatial Analysis tool set.

4.4.1. Nearest Neighbor Distance

The nearest neighbor distance is one method of determining the point pattern based on the average nearest neighbor distance (NND) among events. The nearest neighbor distance for an event in a point is the distance from that event to the nearest event also in the point pattern. A clustered point pattern is expected to have a shorter NND, while a dispersed pattern will have greater NND. (O'Sullivan & Unwin, 2002).

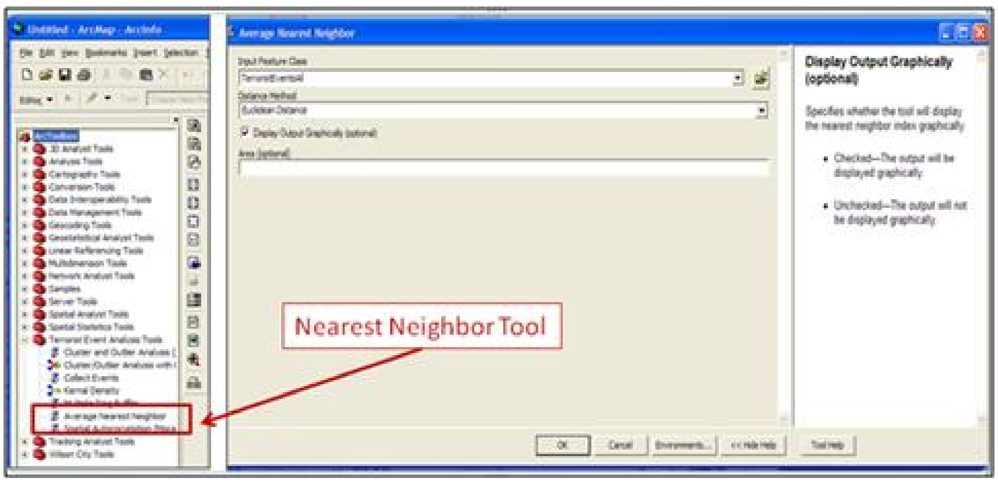


Figure 24. Nearest Neighbor Tool

ArcMap also includes the ability to conduct an average of nearest neighbor analysis. This ability is included in the Terrorist Event Analysis toolbar of the Spatial Event Analysis Tool. The NND toolbar is depicted in Figure 24. Further NND methods that can be used include the G, F, and K functions.

4.4.2. Global and Local Spatial Autocorrelation

Spatial autocorrelation indicates that data from locations near one another in space are more likely to be similar than data from locations remote from one another. This is indicative of the first law of geography, or Tobler's First Law. According to O'Sullivan & Unwin (2002), if spatial autocorrelation were not commonplace, geographic analysis would be of little interest and if geography is worth studying at all, it must be because phenomena, such as terrorist events, do not vary randomly through space.

Based on the conduct of spatial autocorrelation, there are three general outcomes; positive autocorrelation, negative autocorrelation, and noncorrelation. With spatial autocorrelation, it is then possible conduct diagnostic measures to determine the degree of autocorrelation. Methods that can be used to determine the degree of spatial autocorrelation include Moran's I, join count statistic, and Geary's C.

The most common method of spatial autocorrelation is Moran's I which possesses a unique ability to conduct both global and local analysis. Global spatial analysis or global spatial autocorrelation analysis yields only one statistic to summarize the whole study area. In other words, global analysis assumes homogeneity. If that assumption does not hold, then having only one statistic does not make sense as the statistic should differ over space (Anselin, 1995).

However, if there is no global autocorrelation or no clustering, we can still find clusters at a local level using local spatial autocorrelation. The fact that Moran's I is a summation of individual cross products is exploited by the local indicators of spatial auto correlation (LISA) to evaluate the clustering in those individual units by calculating Local Moran's I for each spatial unit and evaluating the statistical significance for each I (Anselin, 1995)

Spatial autocorrelation is conducted in ArcMap's ArcToolbox with either the Spatial Autocorrelation (Moran's I) or the Cluster and Outlier Analysis tools (Anselin Local Moran's I). Both of these tools are depicted in Figure 25.

***Figure 25*. Spatial Autocorrelation (Moran's I)**

4.4.3. Kernel Density

The kernel density method counts the incidents in an area (a kernel), centered at the location where the estimate is made. This analysis is a partitioning technique, meaning that incidents are partitioned into a number of different clusters. The user is often able to specify the number of clusters. In some forms of this analysis, all incidents, even the outliers, are assigned to one and only one group. However, other techniques allow for a form of clumping analysis, where there are groups that have overlapping membership (Burden, 2003).

The kernel density method is very good for analyzing the point patterns to discover potential hot spots. Kernel density is extensively used by criminal event analysts to determine high crime areas. This method provides a useful link to geographical data because it is able to transform data into a density surface.The choice of the kernel bandwidth, strongly affects the density surface. Additionally, kernel density can weight these patterns with other data, such as density of populations and or unemployment rates. In ArcMap, kernel density surface is created with the kernel density tool bar as depicted in Figure 26.

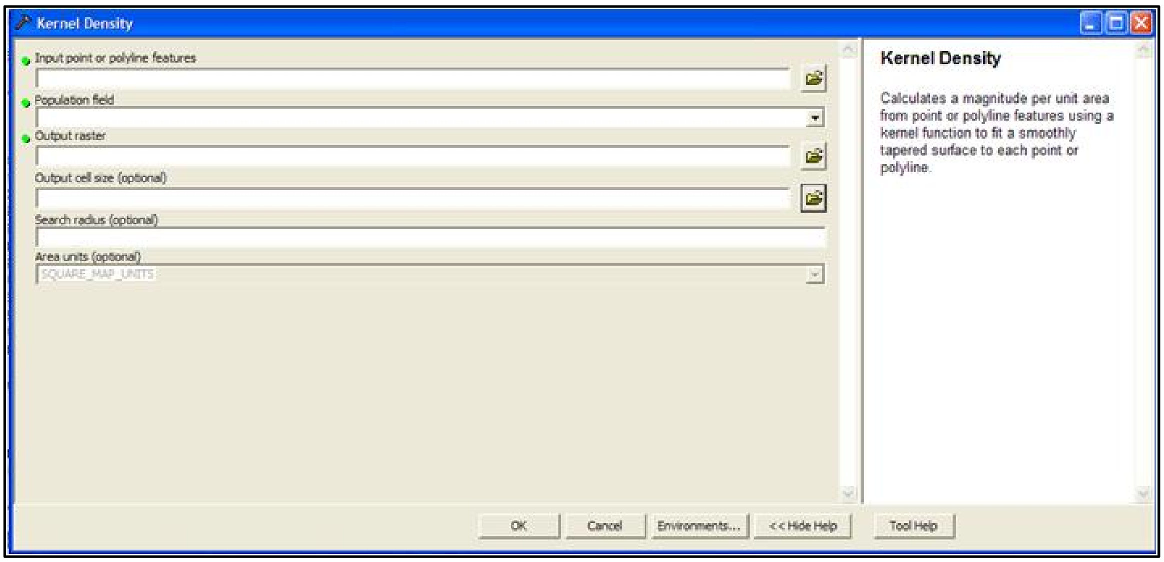


Figure 26. **Kernel Density Toolbar**

5. System Development

Based on the data and methods that are described in Sections 3 and 4, this section illustrates how the Spatial Event Analysis Tool was implemented as a GIS application. Subsequently, discussion is given to system functional and non-functional requirements, the hardware and software design, and customization of interface that was required in order to meet the client's requirements.

5.1. System Requirements

The establishment of system requirements was a critical part of this project's design, especially because of the exploratory nature of the endeavor. While the author has extensive knowledge of the domain (terrorist analysis), the author was not as knowledgeable regarding GIS. Constant coordination between the client and author was required in order to bridge this gap.

The system requirements below are divided into functional requirements that relate to specific functions that the SEAT must perform and non-functional requirements that include features, characteristics, and constraints that either define a satisfactory system or set forth criteria that could be used to judge the operation of the SEAT.

5.1.1. Functional Requirements

After discussions with TRADOC, some basic functional requirements of the tool were identified. Coordination with the client continued throughout the life cycle of the project in order to quickly identify or refine any of the client's functional requirements. Based on discussions with the client, the below listed functional requirements were considered during the design of the Spatial Event Analysis Tool.

- The application's main interface should be that of a commercial-off-the-shelf program
- Based on events, the application must display the most recent terrorist area of operations.
- The application must be easy to use and include specific toolbar and/or a toolbox.
- The application must contain data on Philippine indigenous terrorist groups.
- The data used in this application must be derived from open sources.
- The application will attempt to provide for predictive analysis of terrorist events, such as what is a terrorist group's likely target, victim type, facility, or location.
- Based on operating location and unique methods of an organization, the application must allow for the determination of culpability of an unattributed terrorist event.
- The application can be used for the determination of a modus operandi of a terrorist organization.

- The application will demonstrate spatial increase or decrease in a terrorist's Area of Operations (AO) over time, based on terrorist events.
- The system will assist in determining the ideology of an organization, based on where they operate.
- The application must provide a means for querying the data by time, event type, location.
- A means for adding additional events to the database, from newspapers or other sources must be included.
- The application shall allow users to geocode events.
- The application will depict symbols based on terrorist events that are derived from military standards.
- The application will include a gazetteer.

Additionally, a Functional Requirements identifier and tracking number were developed and are included in Appendix B

5.1.2. Nonfunctional Requirements

Only a few specific nonfunctional requirements have been identified. Overall, the application will be a professional looking system, and perform effortlessly. These nonfunctional requirements were discussed and agreed upon with TRADOC. Below, the following nonfunctional requirements are worth mentioning:

- The application must be based on Microsoft XP Operating System.
- The application must be easy to use.
- The application will operate in an unsecure environment.
- The application should require minimal training in order to operate.
- The application should be easy to maintain with software updates and patches.
- The database that supports this system must be able to be expanded to include data for other countries in the future.
- The system must allow for portability.
- The system must be reusable.

The system requires minimal effort in order to place it into operation.

5.2. System Description

Based on the requirements articulated in the previous sections, the resulting system can best be described as a system that integrates hardware, software, and open source data for capturing, managing, analyzing, and displaying all forms of geographically referenced information; primarily that information; primarily that information which pertains to terrorist events.

The purpose of the architecture of the Spatial Event Analysis Tool is to simplify any infrastructure requirements for the client. The system relies heavily on commercial-off-the shelf-software (COTS) and operates as a standalone computer. The simple architecture developed for this application will allow for easy familiarity, minimal training, portability, and minimum maintenance.

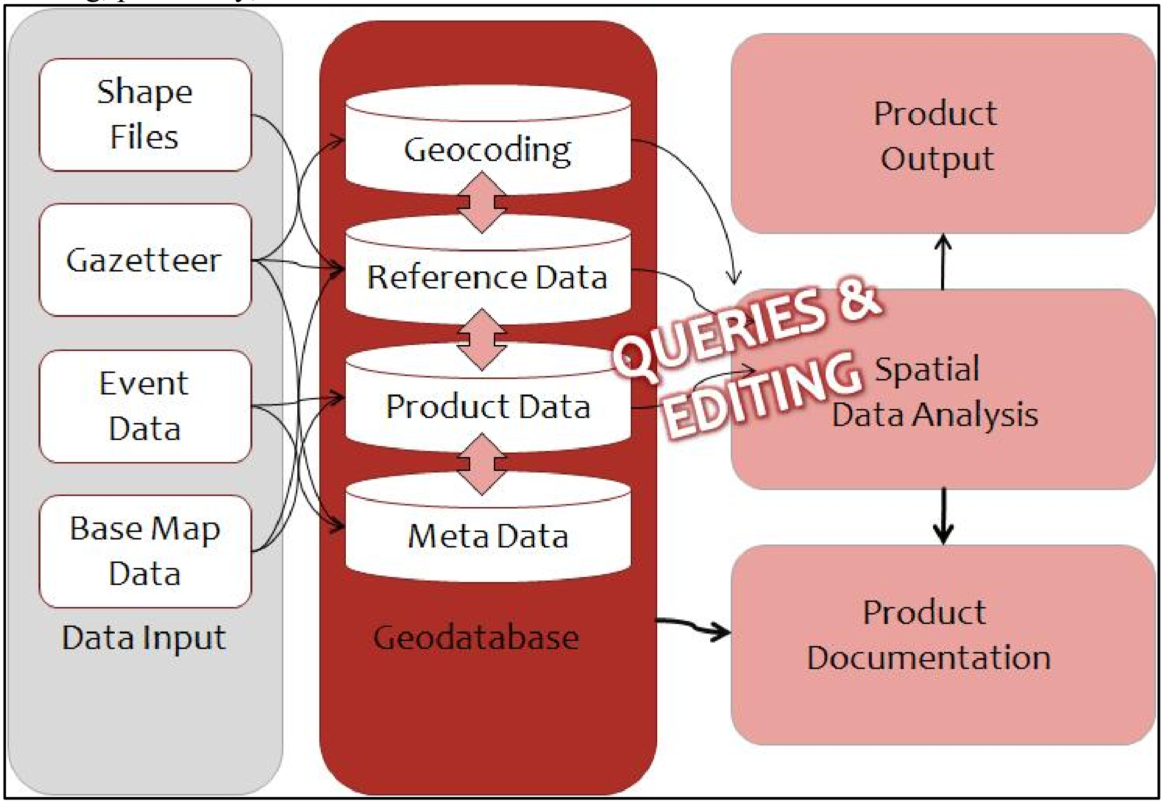


Figure 27. **System Archetecture**

The architecture of the Spatial Event Analysis Tool is depicted in Figure 27. The system resides within the Environmental Systems Research Institute (ESRI'S) geographic information system (GIS), ArcMap. The system allows for the input of multiple types of data as shown in the left column in Figure 27. The data is subsequently organized within the geodatabase as described in Section 4.3 to provide for editing, queries, manipulation, geolocating, and analysis of the data. Spatial analysis is performed with a number of modified tools that are built in ArcMap. The subsequent analysis using these tools will result in either hard copy map output or multimedia projection. Additionally, all of this information will be simultaneously documented.

5.2.1. Hardware Design

Hardware requirements supporting the system are fairly standard for today's personal computers. Since the system relies on a modified version of ArcMap 9.3, those recommended system requirements include: Intel Pentium 4, 1.6 MHz or better processor; 2.4 gigabits of disk space; 2 gigabits of ram; a video card with 256 or better color and a resolution of 1024 x 768 or better, with a 24-bit capable graphics accelerator. The system needs to run in the Window XP operating system, which is print capable.

5.2.2. Software Design

As mentioned above, the Spatial Event Analysis Tool resides within ESRI's ArcMap 9.3. The geodatabase will also rely on other ESRI products, most notably ArcCatalog. A toolbox for spatial analysis was developed within ArcMap. These tools allow for the graphical depiction of terrorist events, as well as some of the trend analyze. Some of these tools, such as buffers, are simple and will allow for visualization and the identification of terrorist areas of operation. Others are more complex and attempt to address some of the predictive analysis requirements of the application. The tool box will be built using ArcMap's customizable interface.

5.2.3. Interface Customization

In an effort to meet the client's requirement for ease of use, the normal ArcMap interface will be modified in an effort to facilitate ease of use. This will include removal of all of ArcMap's tool boxes and extraneous options. With the exception of designed tools, ArcMap's interface will be sterile and include only minimal buttons and functions necessary for the conduct of terrorist event analysis.

Table 6. **Terrorist Event Tools**

Terrorist Event Tools	
Tool	**Function**
Find	Find Features, Find Place, Find City, Find Province
Zoom In	Zoom into Location
Zoom Out	Zoom out of Location
Pan	Move Map Area
Data View	View All Layers, and Data
Layout View	Print View
Print	Print

Since minimal buttons and functions are displayed on the ArcMap interface, it is necessary to include two specialized tool bars. One is Terrorist Analysis Tools and the other is the Terrorist Event Tools. The Terrorist Event Toolbar includes the ability find features, places, and route locations. Functions of the Terrorist Event Toolbar are depicted in Table 6.

The other toolbar, the Terrorist Analysis Tools, serves as a query tool bar and also allows for temporal analysis. The Terrorist Analysis Tool is built specifically for the Philippines and allows queries by terrorist group or Philippine province. The toolbar also allows for queries by year and the ability to

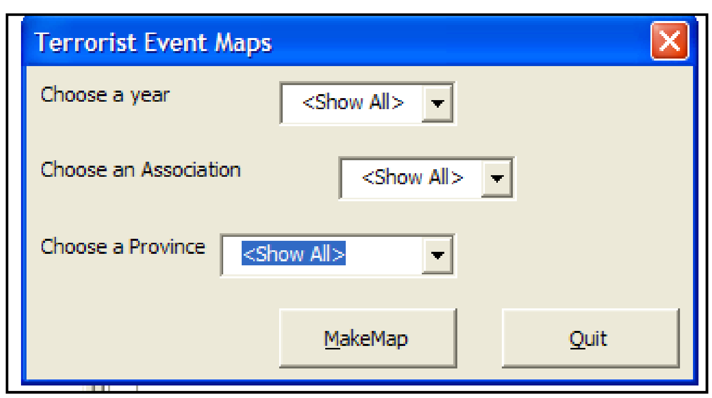


Figure 28. **Terrorist Analysis Tool**

select or unselect by attribute. The Terrorist Analysis Tool also allows for the construction of maps. The Terrorist Analysis Tool is depicted in Figure 28.

The subsequent layout, with Make Map example and the Terrorist Analysis and Terrorist Event toolbars, are depicted in Figure 29.

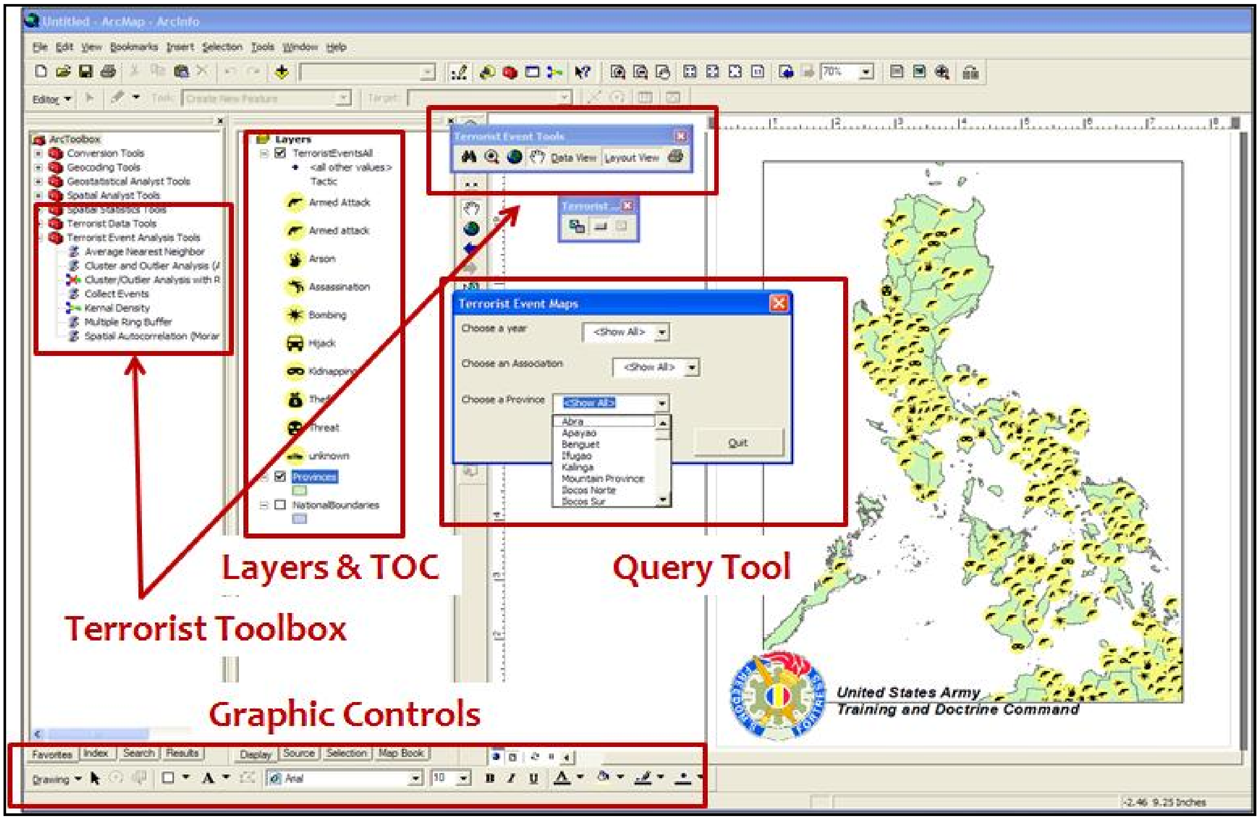


Figure 29. **"Make Map" Example**

6. **Analysis Results**

This section will focus on the outcome of the many approaches that were used for visualization and identification of patterns of the terrorist event data. All of the tools that were used for the pattern analysis were resident in the off-the-shelf ArcMap program and were described in Sections four and five. Because the dataset contains very rich attribute information on terrorist events, various types of analyses can be performed to address different issues or questions. To demonstrate the usefulness of the spatial analytical tools that were included in the system, this section will use examples to show how to apply them and what substantive findings can be obtained through the analysis. Exploratory and statistical analyses were conducted with both point data and polygon data. As mentioned earlier, the polygon data was derived from the original point data, because most of available tools work for the attributes of polygon data. Therefore, the original terrorist events were aggregated to the Philippine province level.

6.1. Mapping Terrorist Events across Provinces

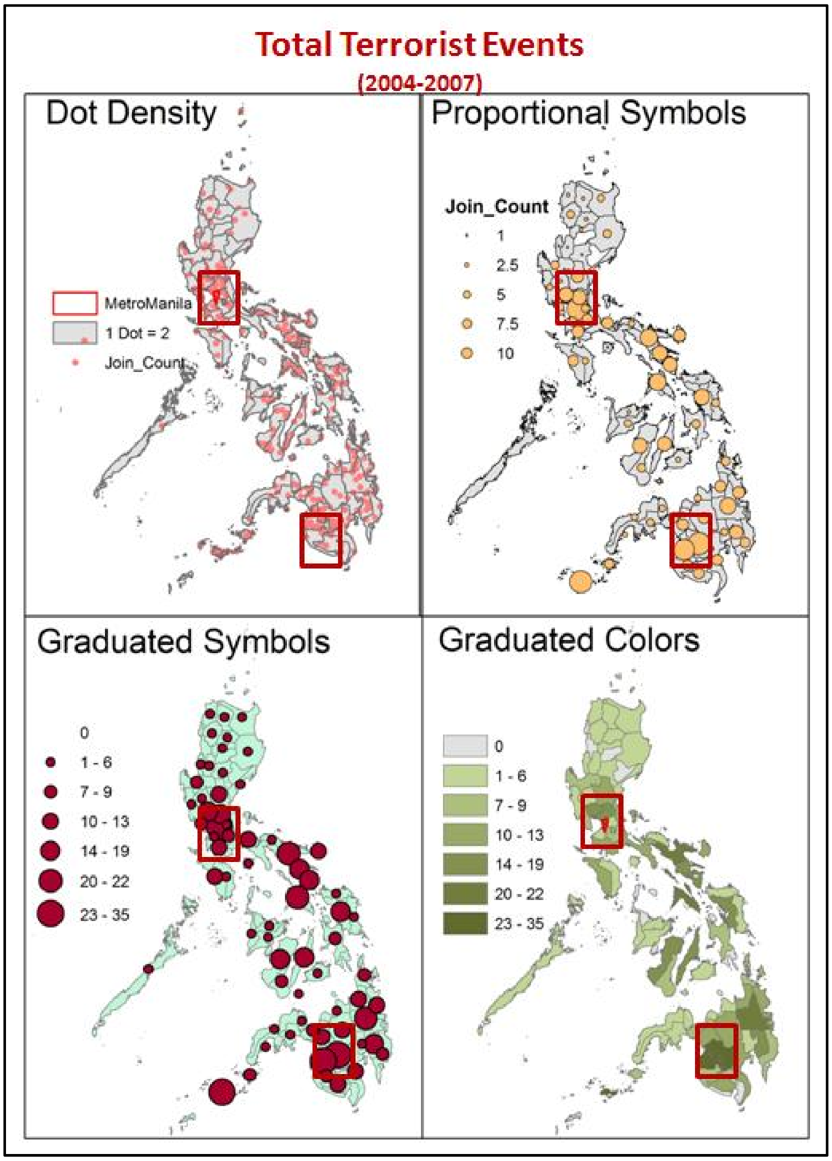


Figure 30. **Visualization Methods**

Mapping the terrorist events in an exploratory way was first conducted to identify and visualize terrorist events patterns. For the Spatial Event Analysis Tool and its ArcMap backbone, the aggregated individual terrorist events allowed visualization of the terrorist data in graduated symbols, graduated colors, dot density and proportional symbols. These visualization methods are simple to use in ArcMap and can portray any field or variable that holds numerical data. Examples portrayed include casualty comparisons, increase and decrease in events, and portrayal of events by victim, target or tactic type. Figure 30 depicts four different data visualization methods for total terrorist events in each province, between 2004 and 2007. In each of the four methods the capital city of Manila is highlighted in the center of the country by a red box. The red box in the south of each map is the area surrounding the Autonomous Region of Muslim Mindanao. Both of these areas have a high concentration of terrorist attacks: Manila because it is the national capital, and Autonomous Region of Muslim Mindanao because it is rife with conflict as the Muslim population vies for autonomy.

In viewing the four different methods of vizualization, they all protray the same amont of information and are based on the same data, but it would appear that the graduated symbols method depicts the concentration of terrorist events more prominately. However, if the comparison has been depicted at a different resolution or focused on a smaller area, than the whole country, a different visualization method may yield more significant result.

6.2. Point Pattern Analysis of Annual Events

Although the majority of the analysis occurred with polygon data, one analytical effort was attempted with the original point data. In this context, I chose to look into the annual events across different periods. The descriptive statistics shows an increase in total number of terrorist events from 2002 until 2006 and a slight decline in 2007. There were 57 events in 2004, 104 terrorist events in 2005, 258 terrorist events in 2006, and 219 terrorist events in 2007. However, the depiction in Figure 31 goes further in demonstrating where the change occurred by portraying all the terrorist events occurring in the Philippines for that year. The figure also demonstrates a high terrorist concentration around the capital city of Manila (depicted by the red box) and gradual increase in events along the eastern and southern portions of the nation.

Since the patterns shown in Figure 31 suggest a clustering pattern for 2005 and 2006, a statistical approach was used to study if the patterns were significantly clustered in those years.

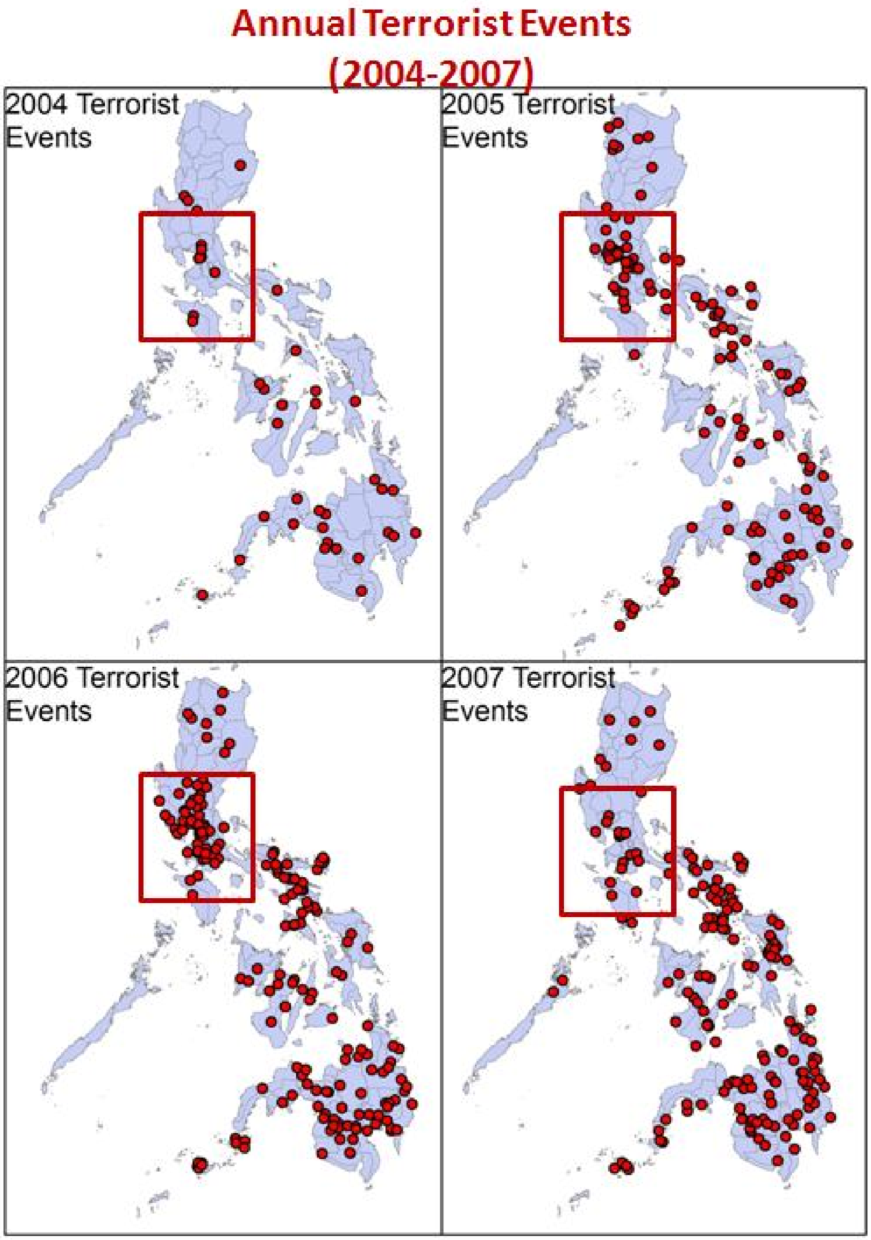


Figure 31. **Annual Terrorist Events**

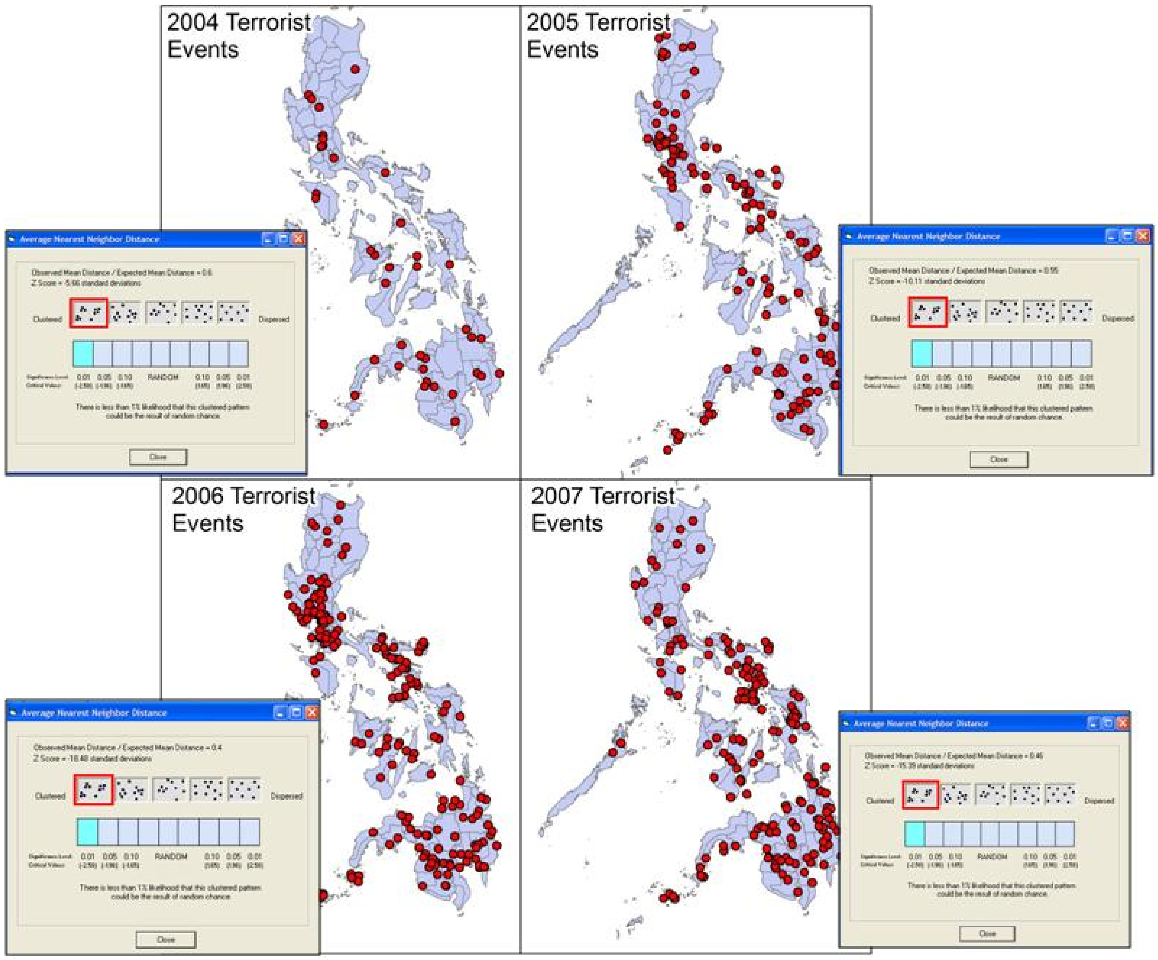


Figure 32. **Nearest Neighbor Results**

Besides the visual recognition of point patterns, an average nearest neighbor function was also conducted separately for each year, in order to statistically quantify any patterns. By conducting nearest neighbor function against each year's point data the following observed mean distance / expected mean distance was identified and depicted in Figure 32 and Table 7:

Table 7. **Nearest Neighbor Results**

Year	**Observed Mean Distance / Expected Mean Distance**	***Z Score***
2004	0.6	- 5.66
2005	0.55	- 10.11
2006	0.4	- 18.48
2007	0.46	- 15.39

In each of the observations, the expected mean is greater than the observed mean (the ratio is less than 1) and the Z score is a negative number, indicating that the annual events are clustered. Further, the Z score for 2006's observation is the smallest, which suggest that the event pattern of 2006 departed away from the random pattern the most; the terrorist event distribution of 2004 was least significantly different from the random patterns among the four years. Put differently, the terrorist events of 2004 were more dispersed than the events occurred in another three years. However, it should be noted that the limitation of this approach applied in this case study may influence the analysis result. The nearest neighbor distance is subject to edge effect and the study area itself. Therefore, the practical way to correct these effects is to conduct simulation to compare the observed pattern to the simulated random pattern. However, the implementation of nearest neighbor distance in ArcGIS does not include a simulation approach and therefore it may skew the analysis result by ignoring the true shape and size of Philippine Islands.

Besides the nearest neighbor method of mapping terrorist events, the kernel density surface is another good exploratory method to visually detect clusters. Figure 33 shows

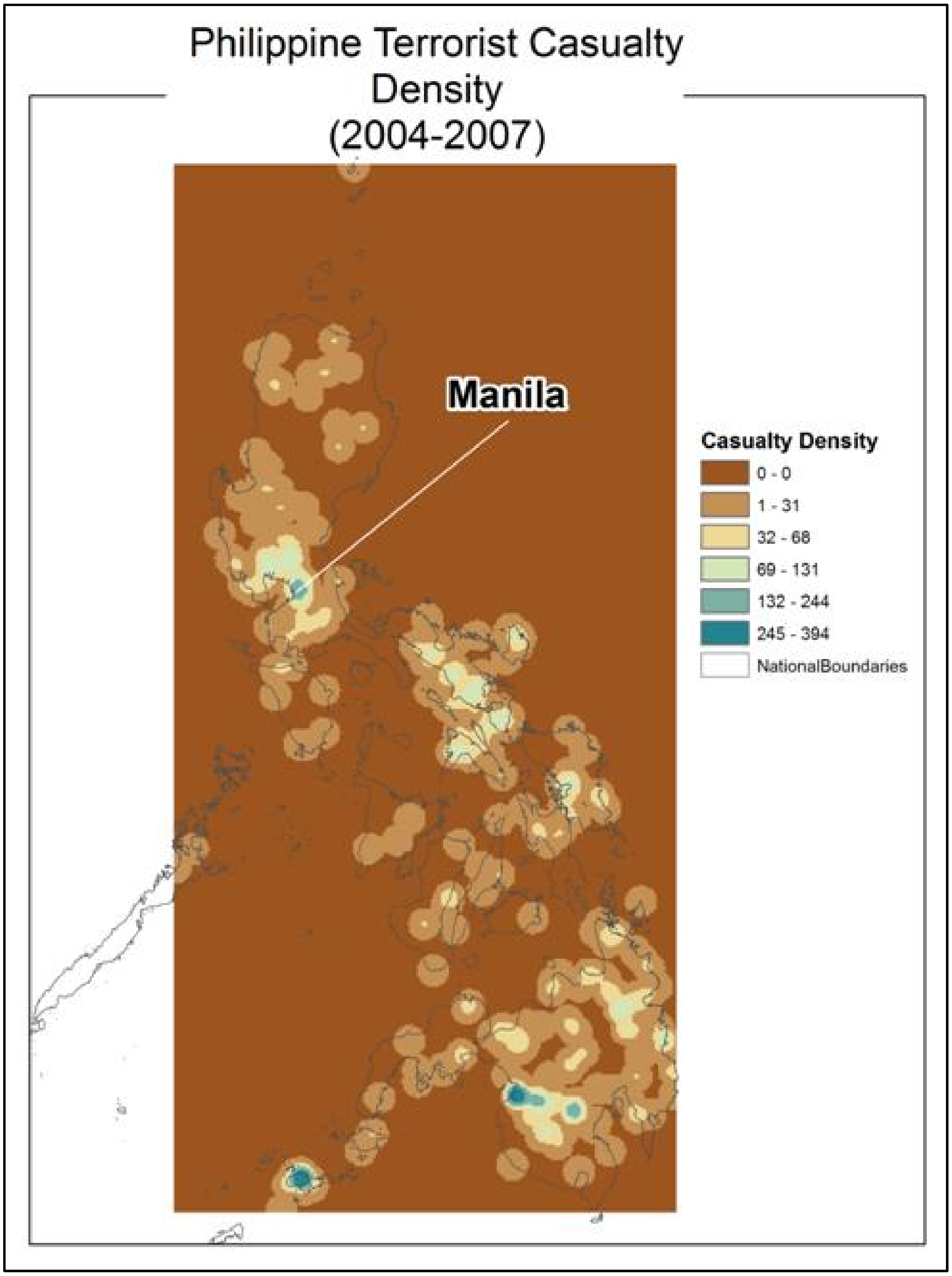


Figure 33. **Kernel Density of Casualties**

an example of a kernel density analysis of casualties in the Philippines because of terrorist attacks. The goal of kernel smoothing is to estimate how the density of events varies across a study area based on a point pattern. "Kernel estimation was originally developed to obtain a smooth estimate of a univariate or multivariate probability density from an observed sample of observations..." (Bailey & Gatrell, 1995). In the spatial case, kernel smoothing creates a smooth map of density values in which the density at each location reflects the concentration of points in the surrounding area.

As in previous examples depicting the concentration of terrorists attack, figure 33 demonstartes that the largest number of casualities occurs where the highest number of terrorist attack occurs. In figure 33, the green colors highlight the areas where the greatest number of casualities has occurs. Again, most notabale is the capital city of Manila, where based on previous analysis, the most attacks had occurred.

6.3. Spatial Autocorrelation

In conducting spatial autocorrelation to identify patterns, some unique problems were encountered with the Philippines. The first problem is the island nature of the country, which subsequently separates groups of quadrants (provinces) by the oceans that separate the islands. The other problem encountered is the Modifiable Area Unit Problem (MAUP) where depending on the size and combination of quadrants may result in different clustering aspects. For example, Figure 34 depicts the global Moran’s I for the whole of the Philippines based on the province aggregation scheme. In this example, the global Moran’s I index was 0.05, leaning towards a clustered pattern as shown in Figure 34. However, when the area is refined, the global Moran’s I value may change for the entire nation.

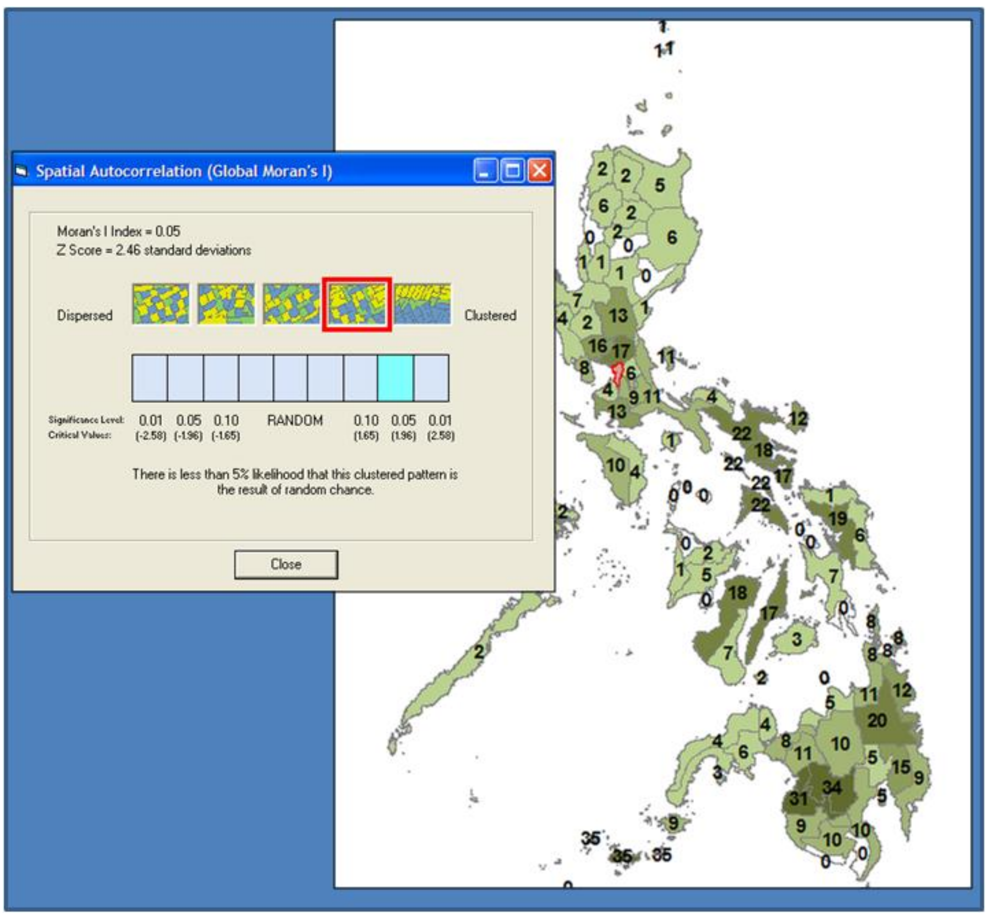


Figure 34. **Philippines Moran's I**

Further, to compare the regional pattern of terrorist events to the national pattern, the Moran's I can be calculated for a singular island. For example, when the study area includes just the islands of Luzon and only those terrorist events conducted by the New People Army is taken into account, a different Moran's I value was generated . As shown in Figure 35, the global Moran's I becomes 0.42 and the Z score indicates a significant clustering pattern at p = 0.01. Therefore, compared to the entire nation, the provinces of the Luzon islands have an increased clustering pattern of terrorist events.

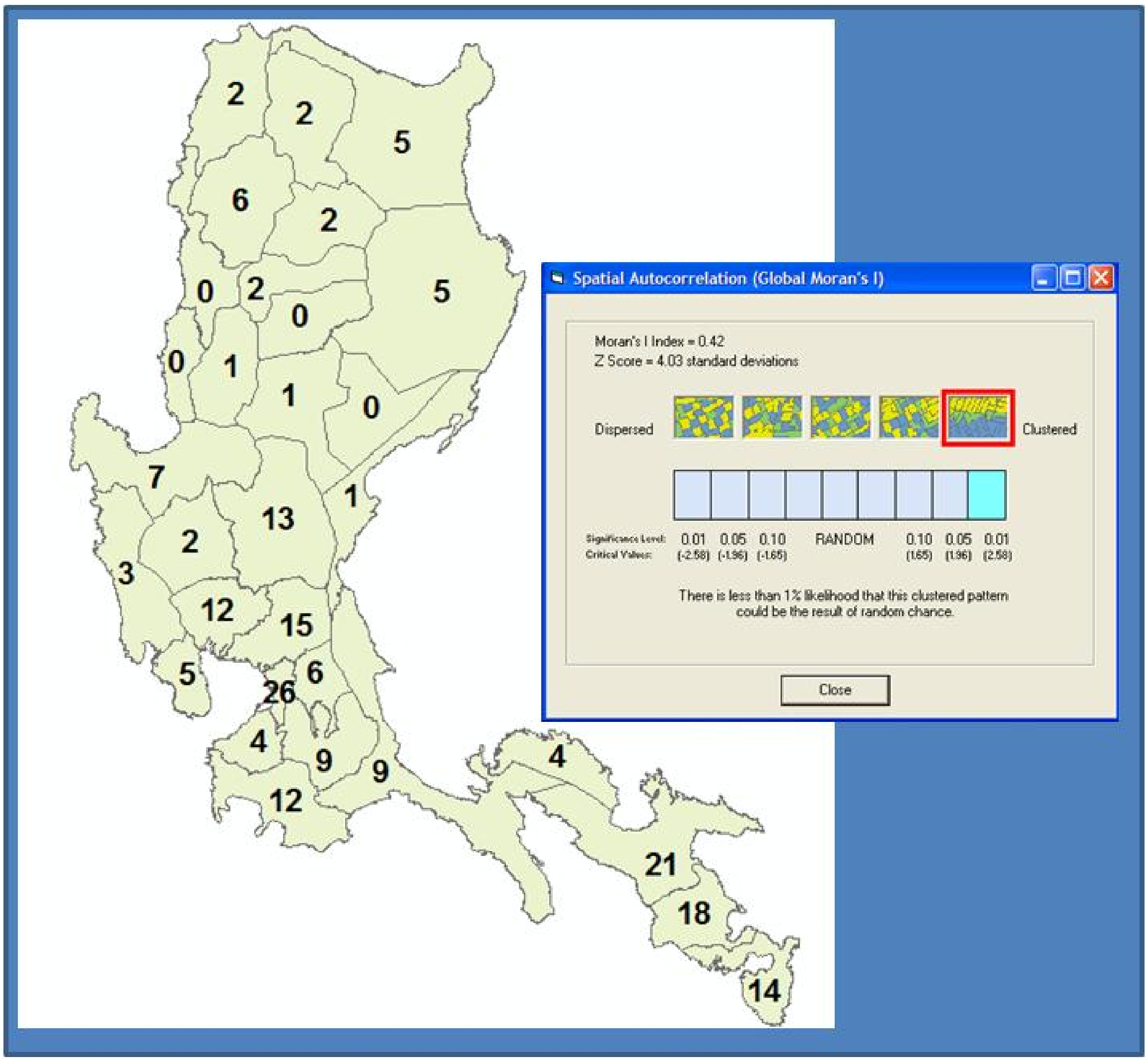


Figure 35. **Luzon Moran's I**

While these examples of identifying patterns used global measures for spatial autocorrelation and resulted in the identification of overall clustering patterns, an additional approach was used in an effort to identify local patterns. For this approach, an analysis of local Moran's I (or LISA maps) was conducted with the same data that was used to conduct the global Moran's I. That data was all terrorist events that occurred in the Philippines between 2004 and 2007, or all 674 events. The local approach output is shown in Figure 36.

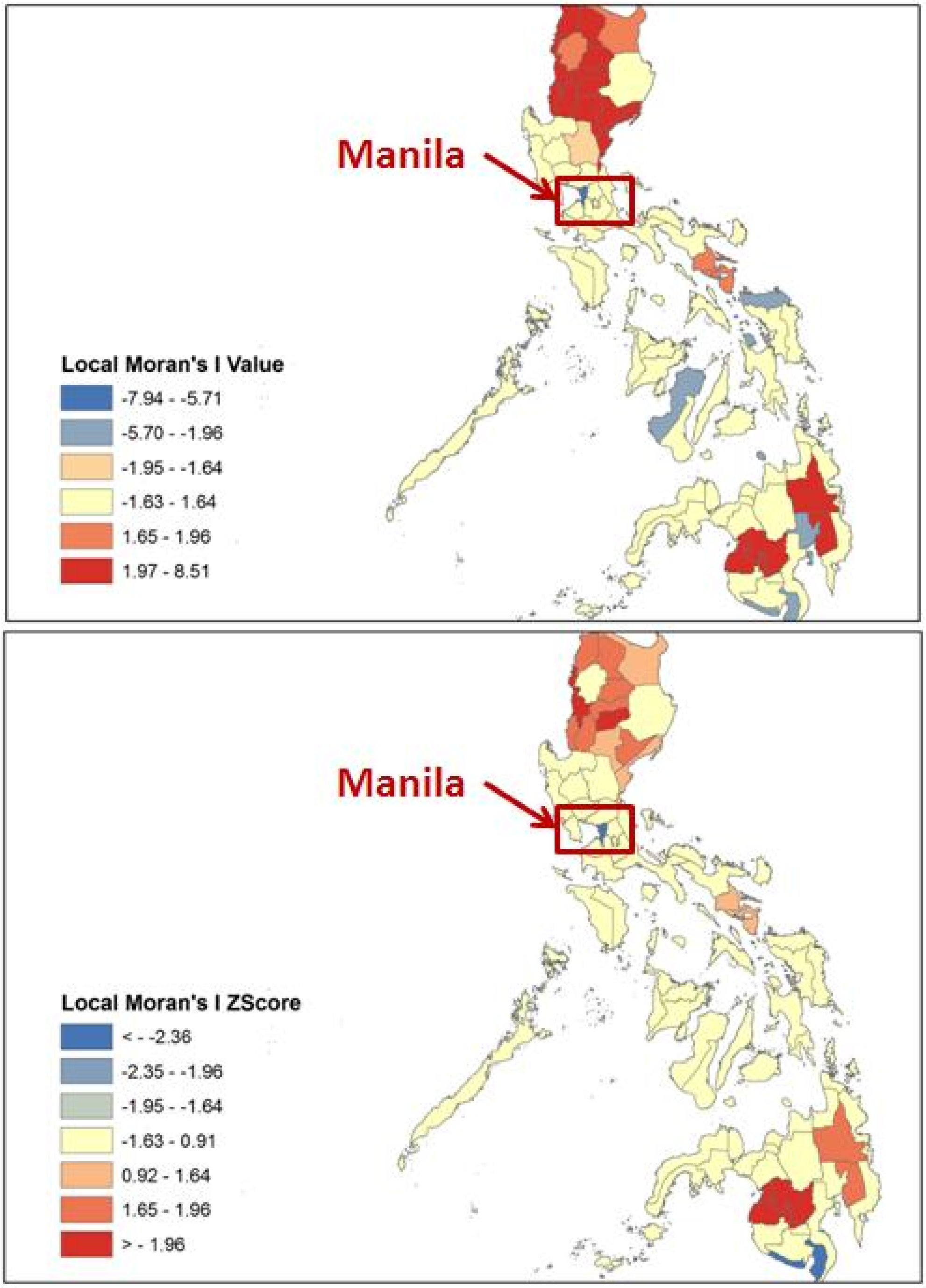


Figure 36. **Local Moran's I**

Figure 36 depicts the Local Moran’s I for the Philippines. In Figure 36, both the I values and the Z-scores are used in determining the patterns for the Philippines. Mapping the I values shows the similarity of neighboring provinces in terms of their experience in terrorist events and mapping the Z-score shows where local patterns are significant. For example, a local significant negative autocorrelation is found in the capital city Manila, suggesting Manila experience much more terrorist events than its neighboring provinces (dissimilar to its neighbors).

To make the interpretation straight forward, it is normal to classify the neighboring feature into four categories: HH, HL, LH, or LL. HH represents positive autocorrelation of high values in neighboring features; LL also represents autocorrelation of nearby features, but it refers to the concentration of low values. Both HL and LH suggest negative autocorrelation of neighboring features (dissimilar to each other). Figure 37 depicts these four types of neighborhood with a significance level at p=0.05. Looking into the figure, we find that Manila is a spatial outlier as it significantly differs from its neighbors. This spatial outlier was also found in earlier LISA maps (see Figure 36). Further, there are two spatial clusters in the map. One is the high concentration of terrorist events in the southern part of the country as indicated by the dark red in the map (HH neighborhood). This can be explained by the surge in ASG activity and the breakdown in government talks with the MILF that occurred during the period of this analysis. The other clusters are located in the northern part of the country, but this area experienced low terrorist attacks as indicated by the light red (LL neighborhood). It is unclear why this low concentration occurred. Another spatial outlier is located along the southern edge of the country. However, due to the edge effect and the study area disruption by water bodies (and subsequent lack of activity), this spatial outlier may not be true. It is also worth emphasizing that further study is necessary in order to be able to correctly explain these local patterns, especially those subject to edge effect as they cannot be solved with ArcGIS.

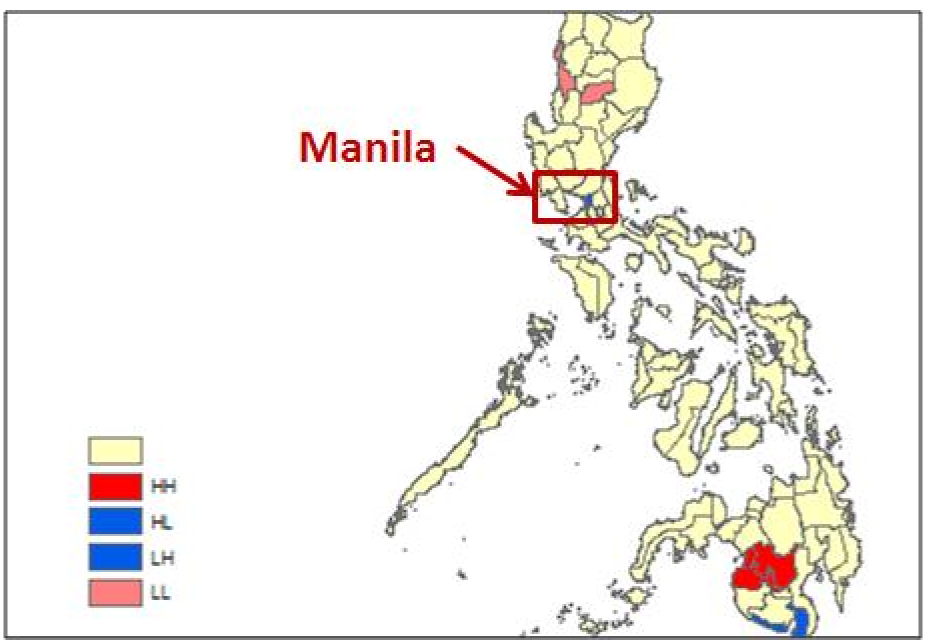


Figure 37. **Statistically Significant Areas**

6.4. Temporal Analysis

Temporal statistical analysis is difficult to conduct within a GIS. However, some exploratory efforts were made. The first thing that was segregated was yearly samples of data for a particular terrorist group. In this case, that was the New People's Army, and a geographic region of Luzon was defined for each year. Four separate Shapefiles were produced, for 2004, 2005, 2006 and 2007 respectively. Subsequently, directional distribution was produced for each year. The annual layering and subsequent output is depicted in Figure 38.

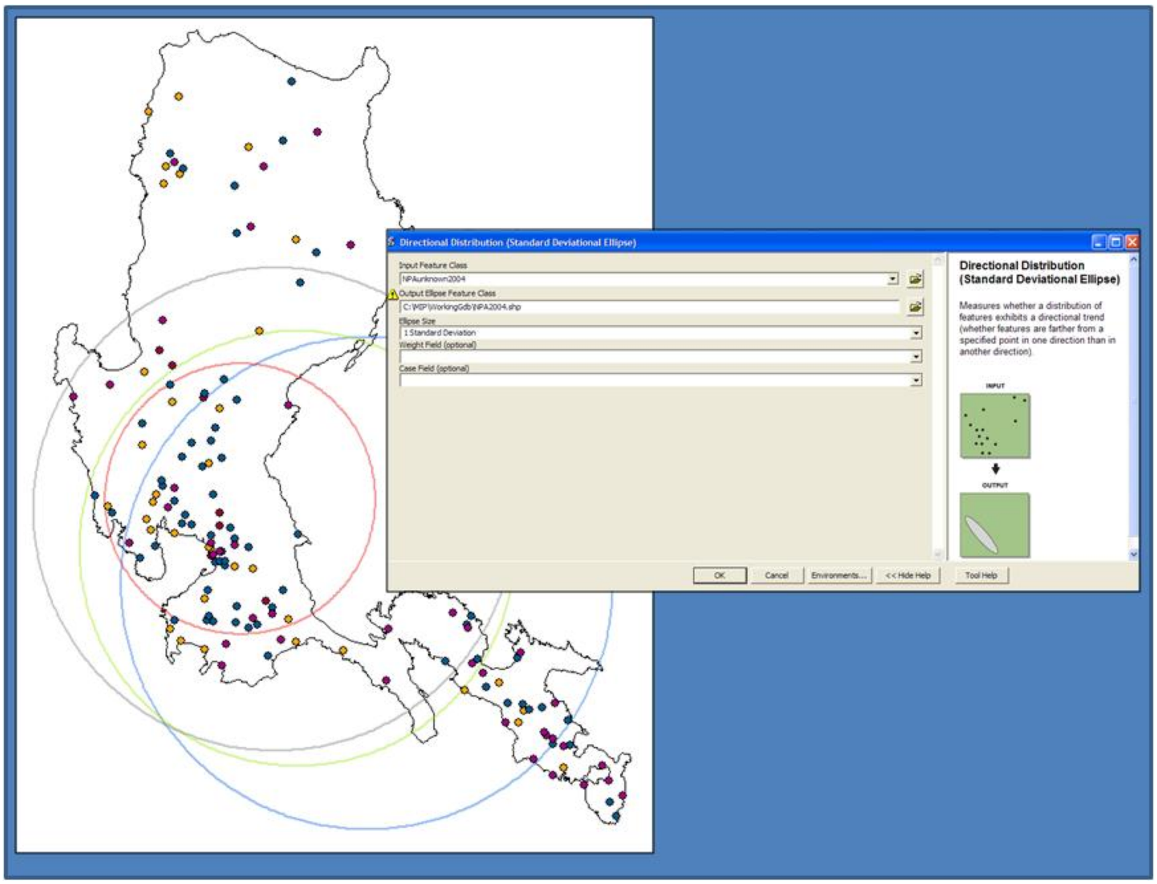


Figure 38. **Temporal Analysis**

Using the standard deviation tool for each year and evaluating the subsequent ellipse, a directional deviation of the annual events was identified. The annual deviation is portrayed as the locations and directions of the ellipse change. Evaluating the first year standard deviation (2004), portrayed in red; a standard ellipse in the center of the island chain was identified. The 2005 ellipse is portrayed in gray, and demonstrates northern distribution of terrorist events. 2006, portrayed in green and 2007, which is portrayed in blue, demonstrate a southeastern distribution of terrorist event along the island. These patterns indicate a change in pattern of the New People Army. Specifically, the analysis shows a change in the area of operation, but also the directional shift in influence over the four years of the sample.

7. Conclusion and Future Work

For Army an experiment, a GIS, using open sources and complimented by a set of analytical tools, such as those in the SEAT, assists in understanding contemporary adversaries. The SEAT proved useful in analysis of terrorist events and will benefit U.S. Army experiments. Because the data used by the SEAT is derived from open sources, scenario participants will have some familiarity with the terrorist organizations and the events they conduct. This provides a high degree of realism for experiment participants. Additionally, because open source is used, greater participation in war games can occur because the data is not derived from classified sources.

The overall goal of the project to provide a realistic and accurate visualization of terrorist groups and the many events they conduct was achieved. Additionally, the objective to spatially depict the activities of different terrorist organizations by means of generalized locations, like those found in a newspaper, was also successfully fulfilled. Using spatial analytical tools in ArcGIS, the Spatial Event Analysis Tool is able to identify spatial patterns and changes in the patterns of terrorist activities. For example, terrorist areas of operations, areas of terrorist influence, how terrorists operate, and whether an organization's area is growing can be examined with the SEAT.

There are considerations and challenges to the SEAT. Expandability of the project is possible and the NCTC maintains data for many countries that are affected by terrorism. Unfortunately, gaining an appreciation of terrorist activity over time is challenged by this data, as NCTC only focuses on the years 2004 to 2007. Additionally, as other countries data are added to the SEAT's database, a more thorough database design must be considered. The addition of other information, such as demographic, social, and financial data, should also be considered in an expanded database design.

The spatial and statistical tools of the SEAT were quite informative, but their output is also not without consideration. Primarily, the pattern identification used in the project could not tell why a pattern had occurred. Additional data (demographic, social, and financial) can assist in resolving this issue by applying regression analysis to find out relationships between the terrorist activity and other factors. In doing so, more insight of terrorist events can be obtained. Further, edge effects, as previously mentioned, were a concern for the Philippines and will be a concern for other archipelago nations, as well as those nations that share land borders.

The SEAT is expected to be integrated into U.S. Army experiments. The most significant of these is TRADOC's capstone annual experiment, which is conducted at the behest of the Chief of Staff of the Army. The experiment involves thousands of people from many industrial, foreign, academic, and government agencies and addresses whether or not the U.S. Army and the United States have the potential to contend with evolving threats over the next three to fifteen years. Terrorism is sure to figure prominently, today and in the future.

Future work worthy of consideration includes expansion of the SEAT to include regional information. Using the framework of the SEAT to address terrorist activity at the regional level, such as the Middle East, Southeast Asia, or Central Asia, is the next logical step in the evolution of the SEAT. Expanding the project would also challenge some of the considerations brought forth in this paper, such as database design, additional statistical methods, and interpretation of results.

Additionally, integration of the SEAT with Covey's Social Network Analysis Application would also add significant depth to Army experiments. The ability to link multiple terrorist organizations and their subsequent relationship to a terrorist event is seen as extremely beneficial to Army experiments, as well as Army decision makers. For example, if a terrorist event is conducted by the Aby Sayyef Group, and the group's subsequent relationship to Jemaah Islamiyah, and subsequent relationship to Al Qaeda can be visualized, tremendous value for interdiction of the groups can be realized by the Army, in both Army experiments and during actual operations.

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Appendix A: Coding Scheme for Terrorist Events

File Name of the Data File: terrorist_spreadsheet.xls

Field Name	Field Type	Width	Dec	Index	Variable Label
Event	Integer	7		Y	Event ID number
Country	String	5		N	Country of event
State/Province	String			N	Secondary location of Event
City	String			N	Primary location of event
Location	Lat/Long			N	Geocode location of event
Tactic	Integer	1		Y	Type of tactic

Code	Tactic
1	Armed Attack
2	Arson
3	Assassination
4	Bombing
5	Kidnapping
6	Theft
7	Unknown

Field Name	Field Type	Width	Dec	Index	Variable Label
Weapon	Integer	1		Y	Weapon used in event

Code	Weapon
1	Explosive
2	Firearm
3	Grenade
4	IED
5	Landmine
6	other
7	RPG
8	unknown

Field Name	Field Type	Width	Dec	Index	Variable Label
Victim Type	Integer	1		Y	Victim of event

Code	Victim
1	Business
2	Civilian
3	Civilian / Police
4	Police
5	Politian

6	none
7	Military
8	NGO
9	none

Casualties	Integer	5	Y	Casualties of event
Death	Integer	5	Y	Deaths caused by event
Wounded	Integer	5	Y	Wounded caused by event
Hostage	Integer	4	Y	Hostages taken
Associated Group	String	>1	Y	Group conducting event

Code	Associated Group
MILF	Moro Islamic Liberation Front
ASG	Abu Sayyef Group
NPA-CPP	New People's Army – Communist Party of the Philippines
Pentagon	Pentagon Group
ABB	Alex Boncayao Brigade
JI	Jemaah Islamiyah
HMB	Hukbong Magpapalaya ng Bayan
Unknown	

Claim Responsibility	Binary	1	Y	Claim of responsibility for event
U.S. Attack	Binary	1	Y	Was victim U.S. affiliated
Summary	String	>1	N	Summary of Event

Appendix B: Functional Requirements Identifier

Requirement Number	Functional Requirement
1.0	The application must be based on Microsoft XP Operating System.
2.0	The application's main interface should be either ArcMap or a form based database interface
3.0	Based on events, the application must display the most recent terrorist area of operations.
4.0	ArcMap must have a specific toolbar and/or toolbox.
5.0	The application must contain data on Philippine indigenous terrorist groups.
6.0	The data used in this application must be derived from open sources.
7.0	The application must allow for predictive analysis of terrorist events.
8.0	The application must allow for the determination of culpability of an unattributed terrorist event.
9.0	The application will allow for the determination of a modus operandi of a terrorist organization.
10.0	The application must allow for the determination of likely targets of a terrorist organization; victim type, facility, or location.
11.0	The application will demonstrate spatial increase or decrease in a terrorist's Area of Operations (AO), over time based on terrorist events.
12.0	The system will demonstrate whether there is a spatial relationship between activities of a terrorist organization and the organizations ideology.
13.0	The system shall allow the user to sort query results by attribute in the query result table. For example:
13.1	The application must provide a means for querying the data by location.
13.2	The application must provide a means for querying the data by terrorist organization.
13.3	The application must provide a means for querying the data by time.
13.4	The application must provide a means for querying the data by event type.
14.0	A means for adding additional events to the database, from newspaper reporting must be included.
15.0	The application shall allow the user to geo-reference events
16.0	The application will depict symbols based on terrorist events and provide graphic tools.
17.0	The application will include a gazetteer