Cartography for Visualizing Anthropogenic Threats:
A Semiotic Approach to Communicating Threat Information in 3-D Spatial Models

By

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For my kiddos, never stop learning.

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LIST OF ABBREVIATIONS

AoI	Area of Interest
API	Application Programming Interface
AR	Augmented Reality
DTRA	Defense Threat Reduction Agency
FBI	Federal Bureau of Investigation
GA	Geovisual Analytics
GE	Google Earth
GIS	Geographic Information System
GVIS	Geographic Visualization
LM	Landscape Modeling
POC	Point of Concern
PRA	Probability Risk Assessment
RAM	Risk Assessment Methodology
RAMCAP	Risk Analysis and Management for Critical Asset Protection
SU	SketchUp
TIMA	Target Method Inspiration Actor

ABSTRACT

Since civilization emerged in Mesopotamia, sociological conflict and sometimes-nefarious behavior, hereafter referred to as anthropogenic threats, evolved along with the societies. In modern times, the presence of people with damaging and dangerous intentions in our societies is indisputable. Societal risk induced by anthropogenic threats is seen as a growing problem by public safety and intelligence agencies as well as owners and operators of designated critical infrastructure, e.g. bridges, ports, utilities, etc.

Use of geographic information systems (GIS) has become commonplace across a range of disciplines, including natural hazards and associated risk models but is not immediately useable for modeling anthropogenic threat phenomena due to their non-recurring and inconsistent nature. GIS, however, can be a powerful tool for communicating critical aspects of anthropogenic threats, particularly if a suitable symbology is available. This research applies well-established graphical semiology to produce a visual threat assessment language. This language is embodied in widely available GIS software, Google Earth, interoperating with landscape modeling (LM) software, Trimble SketchUp, in order to 1) visualize anthropogenic threats, and 2) consider environmental mitigations for those threats. A prototypical threat modeling application connects the two software applications.

The results of this research are threefold. First, a standardized symbology is designed for visualizing anthropogenic threats. Second, this symbology is demonstrated in commonly available GIS software. Third, a framework is established for coupling LM and GIS packages that immediately increases their value in emergency management and response planning.

CHAPTER 1: INTRODUCTION

Use of geographic information systems (GIS) has become commonplace across a range of disciplines, including natural hazards and associated risk models. In many models, such as those for earthquakes and floods, GIS layers are static; in some, such as those involving extreme weather, time-dependent storm tracks are superimposed on GIS. However, for fast moving, meso-scale (University of Washington 2014) events, such as wildfire, GIS is unwieldy and seldom used directly, although the evolving risk may still be visualized geographically. At the micro-scale, where chaotic risk events play out in seconds over just a few square meters (essentially all anthropogenic risks fall in this category) GIS is the wrong tool for modeling; geographic visualization is sacrificed as well, unnecessarily.

Natural hazards such as hurricanes and tornados present recurrent, hence to some extent predictable, risks to life and property. By contrast, the risks created by anthropogenic threats, such as arson or terrorism, are essentially unpredictable because the events are unique, one-offs. Traditional risk assessment models fail to capture the dynamism associated with nefarious human activity.

Hazards are characterized by measurable factors, such as storm-track and wind-speed. Similarly, threats are characterized by various factors, which can exist in the environment independently of a fully realized or imminent threat. As an example, social unrest as an inspiration for nefarious activity exists independently from riots, which might be one manifestation of the realized threat. Defacement of public property is another possible manifestation. However, gang members, as actors in the environment, may also choose defacement of public property with the inspiration of marking turf boundaries rather than social unrest. This *complecting* of multiple, emerging, and changing threat factors make them all the more difficult to recognize.

The difficulty in recognizing threats is particularly acute when related to critical infrastructure facilities like seaports or airports. The potential shock of a realized threat can have consequences far beyond the immediate and localized effects of the threat method. A decision maker charged with the protection of a facility must be enabled to respond to emerging threats in a timely manner.

The emergence and evolution of threats faced by security professionals on an ongoing basis creates a requirement for a dynamic approach to threat evaluation and communication. For this scenario, the visual communication afforded by GIS could be powerful, if the symbology employed in such visualizations could be rendered with automated and programmatic functions to present a 'real-time' view of the threat evaluation.

Another aspect to the challenge of managing security in facilities like ports is the scarcity of resources with which to respond or mitigate threats. The decision maker must also be enabled to plan and prioritize the deployment of assets available to make the most of a finite amount of manpower and material.

The changing nature of threats and the reality of scarce resources creates a requirement for a geovisualization tool that communicates not only the presence of a threat but also acts as a decision-support tool for prioritization in planning and response. The visual language implemented in a tool built to support threat recognition must account for and communicate the aspects of the threat that will affect prioritization decisions.

The successful recognition of a potential threat at a specific location is termed a *point of concern* (POC). In many situations, multiple POCs exist and may evolve quickly. Special cartographic representations must be employed to effectively communicate complex aspects of anthropogenic risk in the GIS. The semiology of the cartographic representation of the POC must also be considered (E.J. Pratt Library - Victoria University 2015)

This research describes a tripartite application using: (1) a custom modeling script to assess threat factors; (2) Trimble SketchUp to render anthropogenic threats in spatial cartographic fashion; and (3) Google Earth to collect data and distribute the results. The three components of this research are inter-operated by scripting their APIs.

Google Earth (GE) is an inexpensive and easy to use GIS that is accessible to a wide range of stakeholders. Importantly, GE accommodates user-defined placement of cartographic symbols. Likewise, Trimble SketchUp (SU), recently purchased from Google, but still closely integrated with GE, is a 3-D modeling tool widely used by architects and designers of the built-environment, which is the focus of most anthropogenic threats. SU also facilitates user-defined symbols. A SU application-programming interface (API) allows its models to be conveniently transposed and depicted in GE.

MacEacheren (2004) makes a strong statement regarding maps and graphics relative to vision, visual cognition and three-dimensional cartography:

> The evolutionary recent development of abstract visual tools such as maps and graphics make it unlikely that special visual processes have evolved that allows us to read them. Understanding representations and processes used to grapple with the real world, then, is likely to take us farther toward understanding how vision and cognition react to stimuli that are as unnatural as maps than has trying to understand these stimuli in isolation.

Commonly available tools make it possible to create three-dimensional representation of physical objects in the visualization layer of a GIS environment. If a notional concept like ‘threat’ can be programmatically translated into such an object then it will be possible to support the visual cognition of ‘threat’.

This research shows that modeling and communicating anthropogenic threats in relation to objects in the built environment can be accomplished in GIS today using commonly available GIS tools. The chapters that follow layout fundamental concepts related to the threat factors that need to be communicated, an explanation of the proposed semiology used in the cartographic communication, a demonstration of the technological implementation and lastly conclusions about how the research should progress going forward.

CHAPTER 2: BACKGROUND

Since civilization emerged in Mesopotamia, sociological conflict and nefarious behavior, hereafter referred to as anthropogenic threats, evolved along with the societies (Baharani 2008). In modern times, the presence of humans with violent intentions in our societies is indisputable. These “bad actors” may unilaterally concoct or organize with others to attempt actions that damage, or threaten to damage, societal norms. Risk induced by anthropogenic threats is seen as a growing problem by police and intelligence agencies (Whitehead 2014).

The psychopath operating unilaterally can present an acute, virulent threat in society. Kacyznski, known as the “Unabomber”, is an example of the lone bad actor (FBI 2008). In contrast, Muhammad and Malvo, associated with a series of murders known as the “Beltway Sniper Attacks”, and Larry Phillips Jr. and Emil Mătăsăreanu, perpetrators of the 1997 North Hollywood shootout, represent pairs of actors who choose to act together briefly (FBI 2007; Wallace 2013).

At the opposite end of sophistication is the Provisional Irish Republican Army (IRA) in Northern Ireland. This organization intended through its actions to force a British withdrawal from Ireland and form a new government. This objective was political and the strategy employed was one of insurgency. The specific tactic chosen by the IRA was terrorism. IRA actions employed increasingly sophisticated operations and weaponry. This organization represents the most sophisticated type of anthropogenic risk, one whose political aim is nation-state in scope and whose capabilities threaten to evolve to match their ambition.

Authorities responsible for the security and preservation of the societal values and norms face an enormous challenge when devising plans, policies, and procedures to deal with evolutionary and fickle nature of anthropogenic threats. The potential threats are both difficult to recognize and to communicate in real-time. Also graphical symbology for representing such threats has not been established; as a consequence, they cannot be meaningfully depicted in emergency management contexts such as GIS-based “dashboards”.

With regard to recognition of threats, simple regression is often used to demonstrate a correlation between various environmental and sociological circumstances and a range of recurrent crimes (Cohn 1990). Larceny, petty theft, defacement of property, and even heinous crimes like kidnapping and rape, occur frequently enough (depending on the scale of the study) to be treated this way. So-called “heat maps” are commonly used to depict the geographical aspects of correlation (Perry, et al. 2013). This type of heat map depiction is becoming common as a decision support tool. Figure 1 is an example of this capability as a feature in a real estate website. While shopping for a place to live the user can see a visual depiction of categorized, recurring criminal activity.

Similarly, probabilistic risk assessments (PRAs) and event trees have been shown to be useful for assessing terrorist threats and creating risk baselines (Ezell et al. 2010). One such model is the Risk Analysis and Management for Critical Asset Protection (RAMCAP) system, which is based on the equation:

$$\text{Risk} = \text{Threat} \times \text{Vulnerability} \times \text{Consequence} \qquad [1]$$

Here, Threat represents a spatial target under a single method of attack. Vulnerability is an assessment of how likely such an attack is to succeed, and Consequence embeds the financial, military, and/or operational costs of a successful attack.

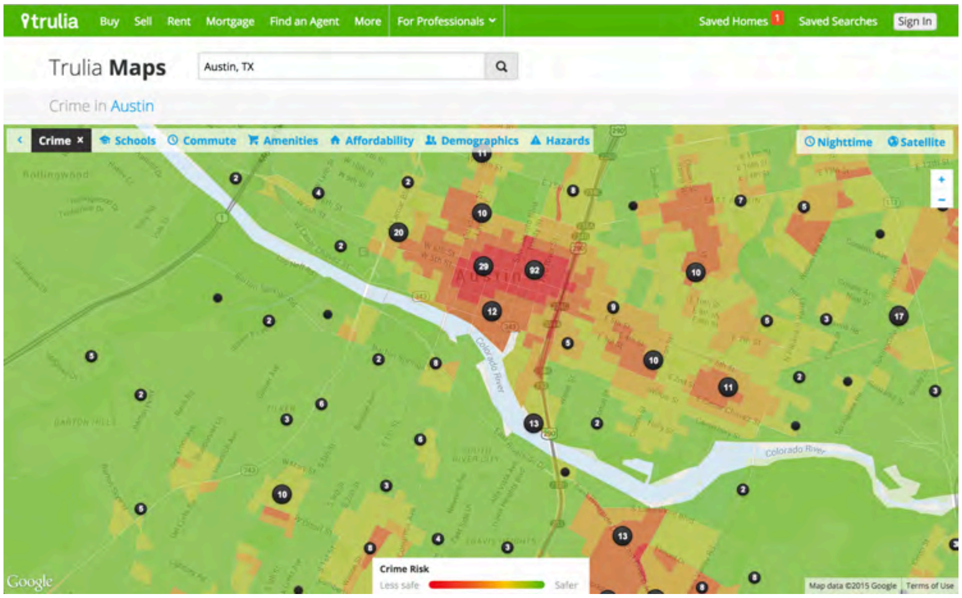


Figure 1 Crime heat map presented by Trulia.com

To determine Consequence, *effects' modeling* simulates the economic effects of a various successful attack scenarios; this generally involves engineering-heavy calculations based on simulations of damage and remediation costs, such as those developed by the Defense Threat Reduction Agency (DTRA). Thus, Risk is denominated in economic terms, at least that is the aim.

Application of the RAMCAP model by the U.S. Federal Government, among others, has been shown to produce ambiguous results for decision makers (Cox 2008). Shortcomings described by Cox are largely related to the simplicity of Equation [1], which does not take into account the powerful inspirations and dynamic methods characteristic of a terrorist adversary; rather it treats the threat and therefore the risk as static. Cox points out another shortcoming: inability to aggregate multiple, perhaps connected threat masses and their inter-related probabilities. An improved model is clearly needed for complex attacks, which are commonplace.

A modification of the RAMCAP model has been proposed by Sandia National Laboratories (Sandia) in a white paper describing its own Risk Assessment Methodology (RAM) for evaluating threats associated with violence, vandalism and terrorism against critical infrastructure (Matalucci 2008). Sandia's RAM approach adapts the traditional one by incorporating a probabilistic adversary and response-oriented approach, viz.

$$\text{Risk} = P_A \times (1 - P_E) \times \text{Threat} \times \text{Vulnerability} \times \text{Consequence} \qquad [2]$$

Here, P_A is the probability of an attack and P_E is the probability of security systems being effective against an attack. As these two probabilities can be adjusted, they help decision-makers to understand the range of risks at a facility.

The shortcoming of Equation [2] is that it again abstracts away the dynamic human factors that could impact the probability of attack; in practice, it is primarily focused on mitigation efforts at the security system level. Specifically, the RAM model ignores the inspiration, i.e. passion and determination, of the individuals involved, both in attacking and defending. As well, RAM like RAMCAP needs be extended to account for multiple threats and vulnerabilities and their temporal interactions.

Another approach used to assess risk and prioritize resource allocations is the traditional frequency/severity matrix, recast as a probability/severity matrix (Table 1). The entries in such a matrix supplant all but Consequence in Equation [2].

Table 1 Example of a Probability/Severity Matrix

		Improbable	Remote	Occasional	Probable	Frequent
		1	2	3	4	5
Catastrophic	5	5	10	15	20	25
Significant	4	4	8	12	16	20
Moderate	3	3	6	9	12	15
Low	2	2	4	6	8	10
Negligible	1	1	2	3	4	5

Dillon et al. (2009) have demonstrated the shortcomings of utilizing these types of matrices, too. Among the challenges they find is that risk-based decision-making requires preference: deciding which risks to mitigate *a priori*. However, there are not enough resources to eliminate all risks, and the large number of potential attack scenarios makes it difficult to assess and include portfolio effects of mitigation measures.

Furthermore, Ezell et al. (2010) explain that it is difficult to get meaningful probability assessments from experts. Determining likelihood of one attack scenario over another (which the probability/severity model requires) has been shown to be futile.

In fact, the circumstances antecedent to terrorism events are non-recurring and consequently do not lend themselves to traditional statistical probability models associated with many other types of risk (Foote 2005). Taking the Vulnerability and Consequence terms of Equations [1] and [2] as given, the remaining – and by far largest – challenge in assessing the risks associated with terrorism lies with simply recognizing the threats themselves.

Hoffman (2006) clearly differentiates between terrorism and "ordinary" crime. In general, he asserts, the terrorist is a violent intellectual who is ineluctably political in his aims or motives, whereas the criminal is a psychopath guilty of action or negligence in a manner injurious to the public welfare. Among other distinguishing characteristics, Hoffman (2006, p. 37) noticed motivation:

> The terrorist is fundamentally an altruist: he believes that he is serving a "good" cause designed to achieve a greater good for a wider constituency - whether real or imagined - which the terrorist and his organization purport to represent.

Thus, the terrorist is inspired in their actions, not strictly criminal. Any attempt to assess risk associated with terrorism, also to mitigate it, must take into account the inspiration calling the terrorist to action (Hoffman 2006).

As Staffel (2011) has observed, anthropogenic threats do not emerge randomly but rather from *threat masses*, precursor conditions defined by the confluence of four factors:

- Target, a person, object or place that is the aim of an attack
- Inspiration, a reason or motivation for an attack
- Method(s), a tool, tactic, technique or procedure used to carry out an attack
- Actor(s), a person, entity, or organization that carries out or facilitates an attack

These so-called *TIMA factors* (Staffel 2011) are all dynamic. Terrorist threat masses emerge and dissipate continuously and chaotically in the environment as the TIMA factors ebb and flow. For example, a group of students may begin verbally assaulting each other and discuss fighting at school the next day, perhaps in online social forums. Meanwhile a fringe member of the social network may brag about possessing a weapon. In this scenario, methods, actors, targets and inspirations all exist. However, the circumstances pointing to the confrontation may dissipate, one of the members may become sick, or the potential fighters may receive counseling or even become friends. The environments in which the TIMA factors potentially interact are forever changing. Any tool made to visualize the threats for decision makers should be architected to take into account the ephemeral nature of these factors. The rendering of threat related visualizations should be implemented as functions in order to enable communication of threat factors in real-time as they emerge.

The emergence of the threat is the indication that there exists the potential for the method to occur at or on the target and as such the concern has the attribute of location. A tool designed to support planning and response to threats should communicate, with sufficient spatial specificity, where the concern is located to assist decision makers in planning and response. This requirement generally rules out the use of heat map visualizations since the threat is considered individually, not as a population, and the concern is better treated as a point object.

When the threat composed of TIMA factors is coincident with facility components (e.g. a fuel tank in a port facility) that decision-makers are charged with protecting, decisions will have to be made about preventing or mitigating the potential threat. The threat concerns may be many and so many facility components may have threat concerns attached to them. A means of visual prioritization in response must be enabled for the decision maker. The facility components themselves have characteristics relative to the threat concern associated with it as well as to the other facility components the decision maker must consider.

The characteristics that assist with prioritization decisions are the component's *criticality* and it's *exposure*. The array of facilities to be considered in response may be viewed as having an ordinal ranking of importance called the component's criticality. In the method described by Staffel (2011) the decision maker assigns the facility components a ranked criticality score beginning with 1 for the least critical. While the criticality score describes how the components relate to each other, the exposure score describes how the component relates to potential threats. Each component is assigned to an exposure category of 1 through 5 based on the definitions given in Appendix A - i.e. a component with a score of 5 has the greatest type of exposure to potential threats.

Although anthropogenic threats are nearly always spatial, visualizing them through mapping is seldom attempted. This is unfortunate given that threats, unlike hazards always present risk. Without effective communication the benefit of risk analysis and management strategies may be lost (Ibrekk and Morgan 1987).

A counter-example to the lack of threat mapping is PortSec, a GIS-based tool that allows visualization of multiple concurrent threats at the Ports of Los Angeles and Long Beach (Figure 2). Although based on Equation [1], PortSec is sophisticated in treating the ports as complex “systems of systems” (Orosz 2009) with multiple areas of interest (AoI) that are each dynamic in their day-to-day operations. The PortSec user interface (UI) provides a convenient environment for *threat-gaming* and understanding tactical responses to multiple threats. The study area is divided into parcels that correlate to operational areas for the first responders. Threat levels are assessed subjectively. The cartographic representation of threat uses colors to denote levels of risk related to anthropogenic threats. The visualization provided by the PortSec application lacks the spatial specificity of the potential threat or information about the nature of the threat to enable decision makers to respond in a manner relevant to the underlying threat factors.

Many other organizations would benefit from the ability to visualize anthropogenic threats in GIS: power plants, fuel tank farms, water treatment sites, and military facilities generally. The ability to view threat information along with facility data in the same computerized environment will improve context for analysis and decision-making.

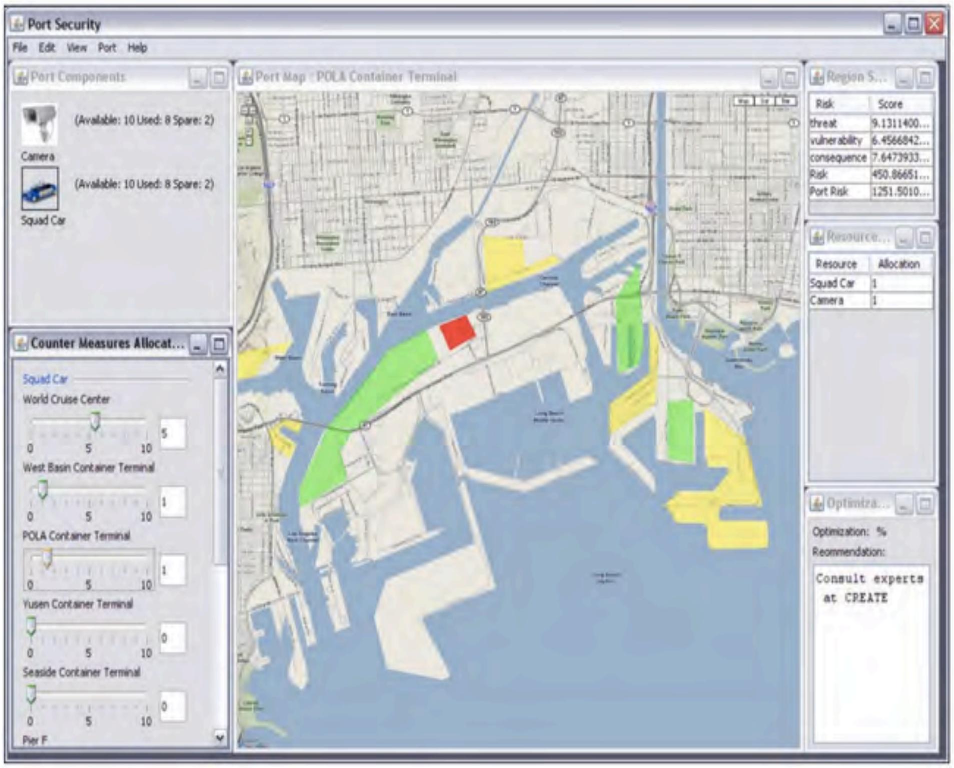


Figure 2 User interface of the PortSec tool

Operators of industrial plants are accustomed to the notion of using “information dashboard” applications to monitor process state and overall system health. An example of this type of application is IBM’s ILOG JViews Diagrammer (Figure 3), applied to the City of San Francisco, as a “system of systems”. The ILOG JViews software is composed of “data-aware” graphical objects representing individual systems components that can be depicted as a visual model of critical processes and infrastructure. This software could be a potentially useful foundation for threat modeling except that all components are pre-determined, not dynamic. It is also expensive to procure and maintain. This application is an example of the type of “real-time” dynamic view of infrastructure needed by decision makers although it does not consider anthropogenic threats, only industrial process parameters.

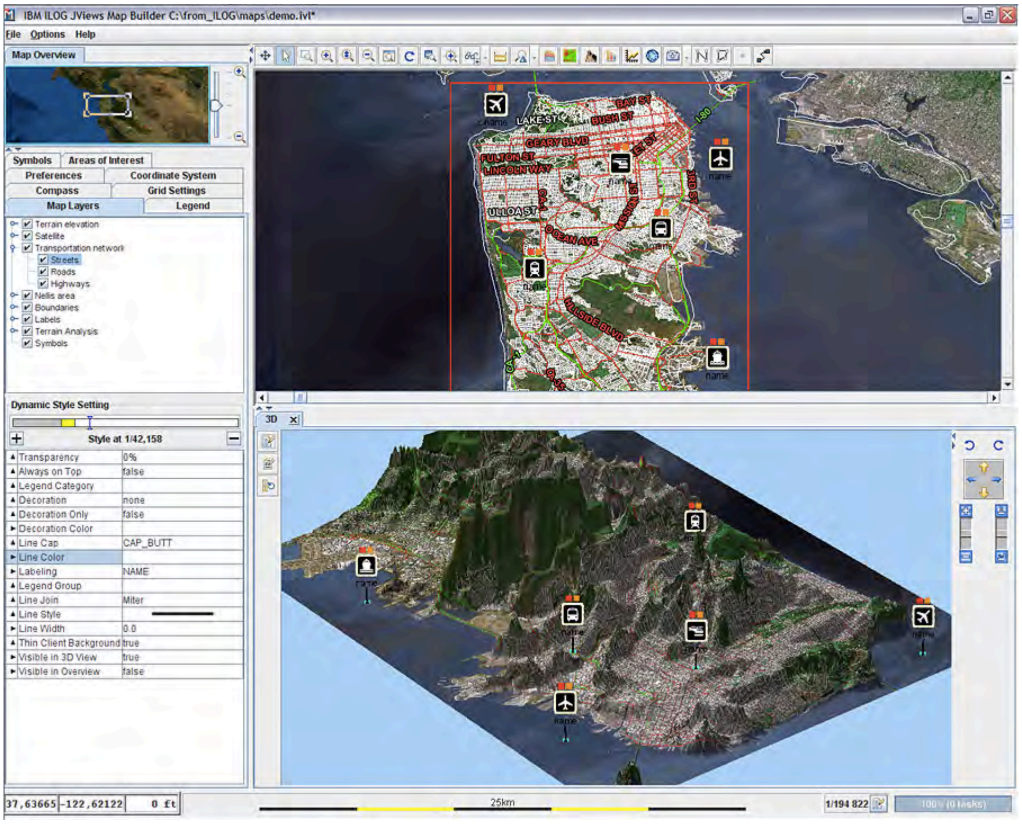


Figure 3 IBM JViews ILOG Diagrammer as an example of monitoring

For anthropogenic threats, both greater spatial precision and specific denotation of threat circumstances are essential. Geovisual analytics (GA) can improve visual communication regarding the salient factors underpinning the threat(s) within the study area (Tomaszewski, et al. 2007). Andrienko et al. (2010) state that these types of visualization tools must "reach the user" almost viscerally.

The way graphics, especially maps, communicate has been well studied (MacEacheren 2004). Bertin (2011) describes cartographic communication of information in his seminal work *Semiologie Graphique*. Here, Bertin outlines principles of qualitative and quantitative information display through the use of visual objects that possess variable attributes. He describes symbols like lines, shapes and textures as communicating quantitative and qualitative information (Bertin 2011).

Bertin’s work is foundational as a language and rule set for graphics, "identifying their visual variables and finding the rules to build graphics properly" (Dursteler 2002). Bertin identifies seven visual variables signifying information aspects: position, size, shape, orientation, color, texture, and value as seen in Figure 4.

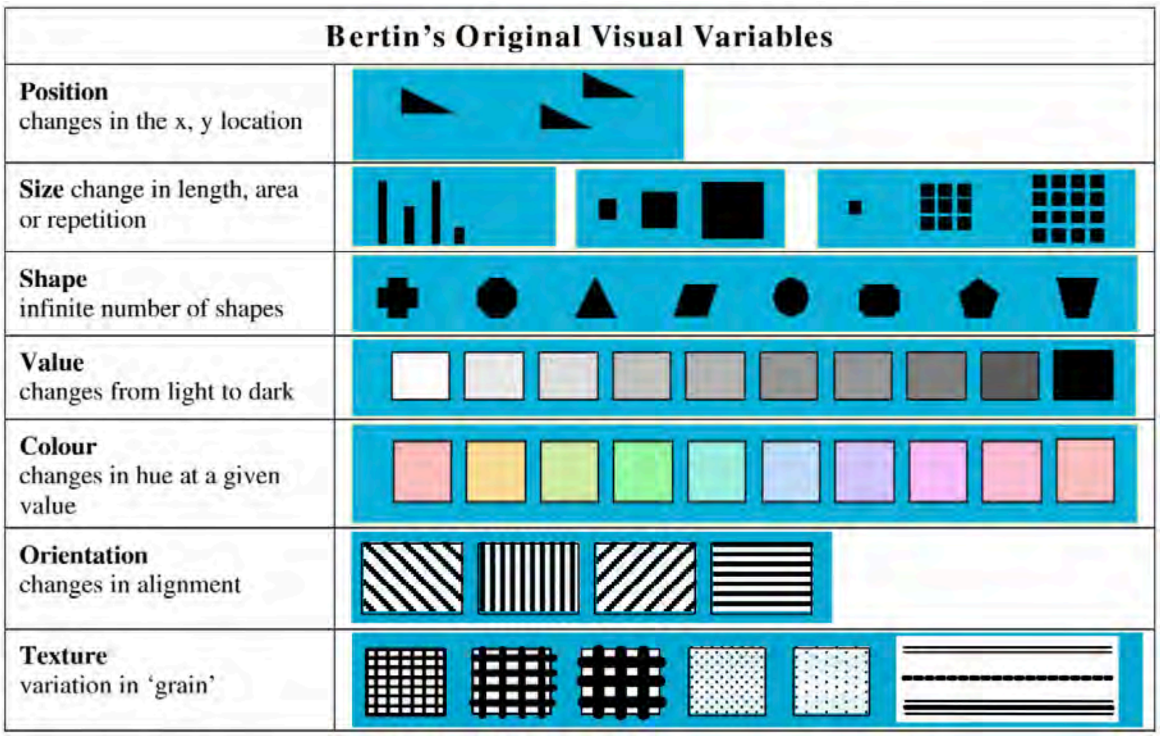


Figure 4 Bertin's Original Visual Variables as presented by Carpendale

In addition to the seven variables Bertin also states that the ‘level’ of the variable is determined by its ‘perceptual properties’; four properties are given:

Selective variables permit the perception a group of the same category

Associative variables permit the grouping of all categories

Ordered variables permit stepped classing of categories

Quantitative variables permit a ratio difference between two categories

For a visual communication to support decision makers in responding to rapidly developing threats, the cartographic symbology used will have to at once permit selective, associative and ordered perception. The viewer will need to be alerted to the presence of a potential threat. The symbology used will have to simultaneously be perceived as a glyph for relating threat information and be distinguishable from the rest of the objects in the environment. The glyph will have to communicate scoring information related to the exposure and criticality scores as well and display ordered values to support decision-making.

The work embodied in this thesis extends the notion that the variables envisioned for the 2D plane directly apply within the 3D special modeling environment. While Bertin provides the framework for a foundational cartographic grammar, the original seven visual variables are insufficient to fully guide the creation of a dynamic semiology in the 3D environment.

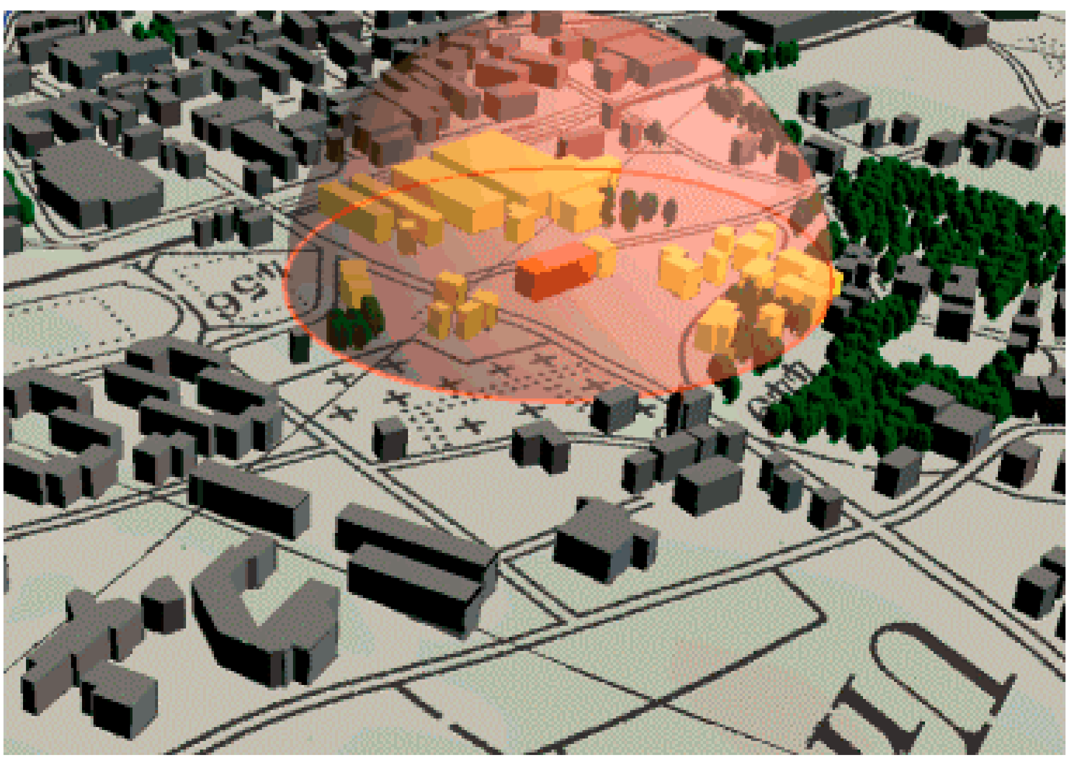


Figure 5 Haeberling's example of 'Special Aspect' Visual Variable

The 3D cartographic model produced as a result of the threat analysis can be described as a “special graphic aspect” (Haeberling 2002), “easily created with most of the modern software, although Bertin did not take them into account in his discussions.” As an example Haeberling presents a transparent bubble (an object that does not exist in reality) overlying surface elements representing real objects (Figure 5).

The “special aspect” used to depict points of concern in this research, like Haeberling’s example, draw on multiple visual variables for their creation. The glyph for communicating threat information should take into account the viewer perspective in the 3D environment and consider the communication of the values being communicated. The effectiveness (or appropriateness) of the special aspect as cartographic communication can be analyzed by looking at how the visual variables are used in rendering it. Sluter (2001) outlines the “new” approaches to cartographic research and summarizes Bertin’s visual variables relative to the level of measurement depicted in a map (Stevens 1947). The table below (Table 2) is adapted from Sluter and shows the type of measurement data appropriate for each of the variables.

Table 2 Visual Variables adapted from Sluter (2001)

Level of Measurement			
Visual Variable	Numerical	Ordinal	Nominal
Location	x	x	x
Size	x	x	
(Color) Value		x	
Texture		x	
Color (Hue)			x
Orientation		x	
Shape			x

This thesis demonstrates the use of easily available GIS and design software, Google Earth and Trimble SketchUp, respectively, to support analysis and decision-making related to anthropogenic threats. The “processes” being monitored in this instance are dynamic threat masses. Potential changes to infrastructure can also be modeled to assess mitigating effects on threats. Novel cartography is proposed to visualize anthropogenic threats and associated risks.

Andrienko (2010) challenges the makers of GA applications to make them “not only useful and useable but also accessible to users” on commonly available and inexpensive platforms.

Google Earth is a digital globe and map viewer with the capability to display 3D objects and terrain. It utilizes the Keyhole Markup Language (KML) as its native file format, which has been widely accepted throughout the GIS community. Different versions of GE are capable of rendering KML on desktop computers, in browsers, and on mobile devices.

Trimble SketchUp is a 3D landscape-modeling environment for designers, builders and engineers “to show other people what they mean”. [Emphasis added.] SU can be leveraged to model and communicate the idea of anthropogenic risk in physical space.

These tools are widely used and may be deployed to enhance visual cognition of threats. In order to exploit the tools in such a manner a semiological foundation for the aspects of the threats being considered is required. Chapter 3 describes a proposal for creating a cartographic glyph that promotes the visual cognition of threat.

CHAPTER 3: CONCEPT

The spatial context in which a threat occurs is referred to as the *scene*. The word scene has three dictionary meanings (Macmillan), all of which are applicable to threats:

1. A part of a play, book, movie etc. in which events happen in the same place or period of time
2. A view that you can see in a picture or from the place where you are
3. A place where something happens, usually bad

The traditional display of "heat maps", i.e. choropleths, depicting threat likelihood or prevalence within a scene, literally misses the point: that threats are isolated events in space and time. A heat map blurs the specific locations of threats in a scene and ignores time altogether. As argued in Chapter 2, threats can and should be treated as individuals not populations; consequently their geovisualizations cannot be generalized heat maps of a scene.

Human recognition of a threat involves a complex of sensory inputs being interpreted in the context of experience. A cognitive map (Kitchin 1994) of threat is formed that develops over time in the context of the evolving sensory inputs. The introduction of ubiquitous mobile devices and massive digital social networks has effectively created new sensory inputs. However, it is unlikely that a human will be able to build an accurate cognitive representation of threats directly from voluminous, streaming digital media. Computer processing is required to interpret an immediate meaning from the continuous stream. A simple but functional threat-modeling engine is provided in Appendix A.

Computer software is also required to portray the interpreted stream as a traditional sensory input. This project makes use of a novel, map-based cartographic representation to communicate information about an interpreted threat, because of a map’s superiority to other types of visual representations for carrying information to humans (Tufte 2001). Humans associate threats with particular objects or other individuals, generically entities. This relationship between threats and entities exists quite abstractly as a part of the evolving cognitive map. A general anxiety or apprehension, defined as *concern*, may attach to specific entities in the presence of threats. The attachment of concerns to physical entities located in the environment exactly creates *points of concern*. Rapidly evaluating points of concern and determining appropriate actions is of fundamental concern to decision makers charged with the protection of critical infrastructure – i.e. port facilities.

The focus of the research is *communicating* the threat-entity-concern relationship via geovisualization; it presupposes the existence of a computational threat-modeling engine, which broadly mimics human recognition of threats, based on the TIMA factors; the TIMA factors, without such an engine, remain abstract notions. An innocuous entity, a water tank, for example, can have significance in a scene when complected with knowledge of a threat in the area.

An entity with significance in the scene is said to be a scene *component*. The TIMA factors interaction with components in the scene are communicated via geovisualization. A scene can contain many such components, each of which may become a POC when complected by TIMA factors. The POC is a location in space where a threat is recognized to have significance with regard to some entity in the scene.

A new cartographic glyph, called a *threat glyph*, is proposed to carry information about fundamental aspects of the concern attached to a component, i.e. a POC. The size of the concern for that threat may be large or small (not zero). The glyph associated with the POC is a graphical object meant to act as the *sign vehicle* (MacEacheren 2004) for the threat-entity portrayed in the scene. Cognition of relevant threat factors stimulates and supports decision-making activities related to threat mitigation or response.

A scene component that has become a POC is said to be *targetable*. The threat glyph is specifically designed to visualize targetable POCs. The information carried by the sign vehicle relates to three specific attributes of the targetable POC as seen in Figure 6.

1. *Location*. The glyph is positioned on the POC.
2. *Criticality* score. The glyph carries this information by way of the glyph height. Each scene component is forced ranked 1 through n.
3. *Exposure* score. The glyph carries this information by way of the glyph width. Each scene component is given a score of one through five based on predefined criteria.

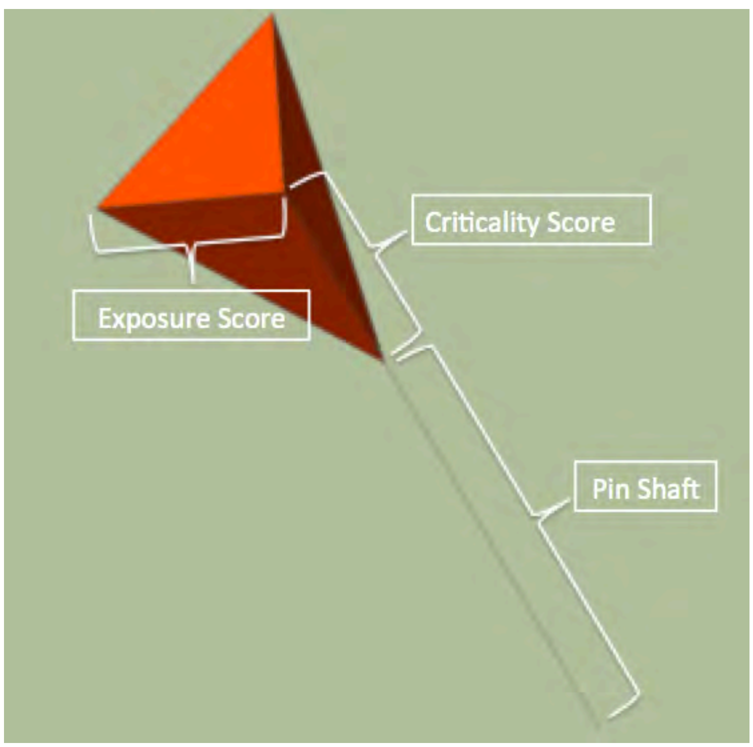


Figure 6 Dimensions of shape determined by criticality and exposure scores

Bertin (2011) uses color as an example of a selective variable. The threat glyph is rendered using the color described in SketchUp as ‘OrangeRed’. This color is often associated with warning symbols in the real world like traffic cones and barrels. It is meant to catch a viewer’s eye and draw attention to the object itself.

When more than one POC is rendered in the scene, it is the visual *size*, the product of criticality x exposure, that allows the viewer to draw conclusions about how large or small the concerns are. This comparison facilitates prioritization decisions concerning analysis or mitigation of threats.

A cartographic rendering script manipulates these values to create a 3_D object in the geovisualizations. The glyph is rendered at the map coordinates of the targetable component that has been associated with a relevant threat, via the common cartographic technique of placing a point symbol (and optionally data) via a *map pin* as shown in Figure 7.

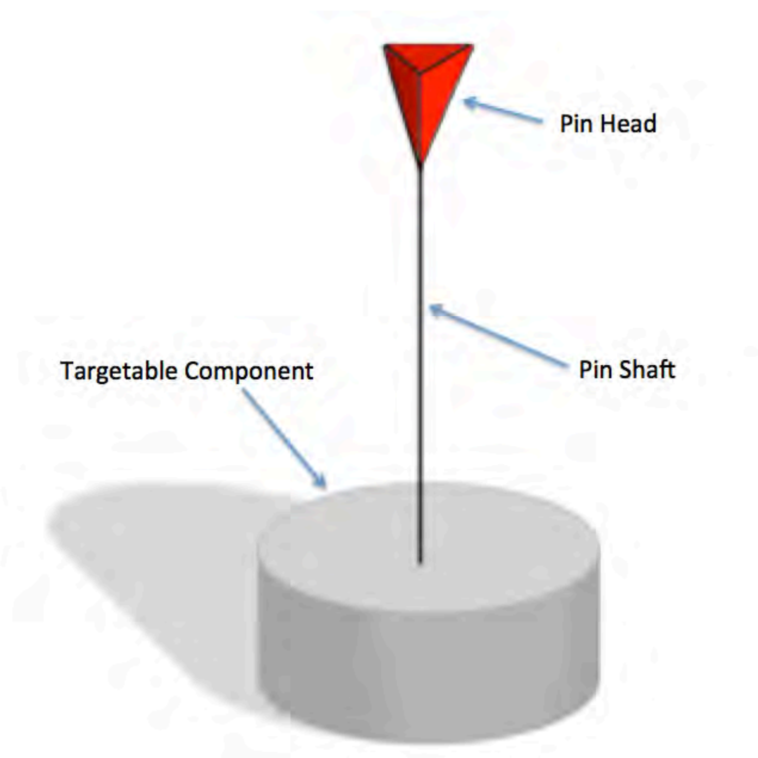


Figure 7 The POC takes the shape of a map pin

The pin shaft is extended to attach to the actual POC. The location aspect of the POC is communicated by a vertical line, which is 'pinned' to the scene object associated with the relevant threat.

The built environment generally appears as a collection of cubes, cylinders, and spheres of varying dimensions (buildings, towers holding tanks, etc.). For a POC to be easily visualized amongst the common objects in the built environment it must be distinguishable from them. Pyramids rarely appear in the modern built environment but are widely known from antiquity. However, an inverted pyramid is a completely odd object that is never seen in the day-to-day environment, but instantly recognizable (Figure 8). This distinguishable shape is associative in that it permits instant recognition of threat glyphs within the scene.

Figure 8 Inverted pyramid cartoon

Illustrated by Beatriz M Kassar

Thus, POCs portrayed by the threat glyph are differentiated from other objects in the scene by *pre-attentive selection* (Zhaoping and Dayan 2006). The threat glyph represents a POC as an object on par with but completely distinct from tangible objects in the environment. The threat information is presented the user in a way that pre-attentive selection occurs in the context of a cartographic representation of the scene.

The viewer perspective within the rendered scene must also be considered. Given the 3D viewing environment a special aspect glyph is developed to address the multiple perspectives the user will experience. A traditional 'top down view' of the scene might cause the threat glyph to obscure the POC component to which it is pinned (Figure 9). Accordingly, the pyramid base is quartered and all but one of the quarters, touching two corners is stripped away, leaving the top of the shape a right triangle.

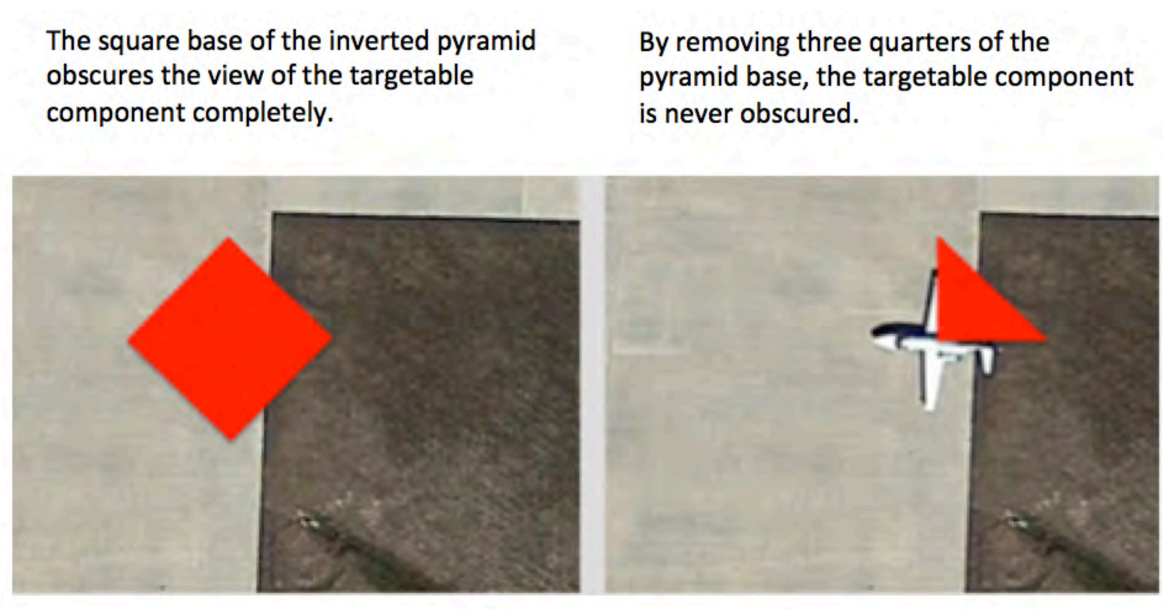


Figure 9 Modifying the pyramid glyph to avoid obscuring component

The shaft of the pin passes directly through the apex of the inverted, quartered pyramid up to the right-angled corner of the base. From the top-down view the shape now appears to be an isosceles right triangle whose right angle is centered on the targetable component.

The size of the threat glyphs symbolizing POCs in a scene still varies in two dimensions, criticality and exposure as was illustrated in Figure 6. The size of the glyph represents the ordered aspect of the glyph. The heights of the glyphs will be unique across the POCs in the scene due to the forced ranking of criticality scores to the targetable components. The widths of the glyphs, defined by the legs of the triangular base of the threat glyph have a length are determined by the exposure score. This sizing scheme forces every POC to have a unique rendering all the while maintaining a common shape in the geovisualization. This ordered sizing permits the decision maker to quickly ascertain information related to prioritization of concerns in the scene.

This geographic visualization calculates the 'Z' height of the threat glyph by adding a product of the criticality score and a constant to a line object of a set length which itself is positioned at the 'X' and 'Y' coordinate values given to the system component by the user. The inverted quarter-pyramid is then rendered with a shape and volume determined by the adjoining isosceles triangle (perpendicular to the vertical line) with a 90^{o} angle at the top of the vertical line. The acute angles of the triangle join to the end of the vertical line before the criticality derivative value was added.

The dimension values applied to the programmatic rendering of the glyph in SketchUp applied in the units of feet (the unit of measurement is set in SketchUp when creating a new project). The default set height for every 'pin shaft' is 1,500 feet above the surface elevation. The criticality height is the criticality score multiplied by a constant of 100. The length of the exposure leg of the glyph is the exposure score multiplied by a constant of 10. This parameterization is highly flexible and can be easily manipulated in the custom software built as a part of this research.

Informed by the threat glyphs, authorities may choose to make changes in the physical environment to address the threat aspects that those glyphs communicate, i.e. to intervene by environmental modifications. This intervention may be considered a form of geodesign (Dangermond 2010), or more accurately geo-redesign. Classically, the term geodesign applies to holistic development (or re-development) that balances human and pre-existing environmental objectives. Here the term is extended to a reactive planning method that tightly couples a design proposal with threat assessments informed by geographic context (Flaxman 2010).

Specifically, by rendering the threat scene in a modeling tool like SU, a geodesign process can be undertaken to address the criticality and/or exposure values of the scene components. As an example, to reduce the exposure of a POC, a barrier may be modeled around the component; to reduce the criticality of a POC, a redundant component may be modeled. Any such plans have quantifiable costs. After a design change is proposed, the threat-modeling engine is run again and the POCs are re-rendered. A change in the size (because of criticality and exposure) of the POC directly demonstrates the effects of mitigations that have been designed. This ‘test and learn’ process allows authorities to quickly evaluate strategies affecting POCs via the same geovisualization as the original threat assessment. In this way, quantifiable solutions can be developed for anthropogenic, non-recurring threats, even though the threats themselves are not subject to statistical measurement.

The glyphs are generated programmatically to take advantage of the user-friendly environments afforded by GE and SU. The iterative nature of the proposed modeling exercise requires that the POC(s) be generated automatically, only requiring the user to submit basic inputs. Chapter 4 demonstrates the implementation of custom software written to generate the symbols and make GE and SU interact to support the user's visual cognition of threats.

CHAPTER 4: DEMONSTRATION

The following example is given to illustrate the basic end-to-end process of the threat evaluation and subsequent geovisualization as described in Chapter 3. First, information about the components in the scene is collected using Google Earth (GE), which is then imported into the SketchUp (SU) environment for evaluation via the SU API. Next, the prototype threat-modeling engine, also implemented in SU, produces the geovisualization of POC threat glyphs there. Finally, these glyphs are exported back to GE via the SU API again, for dynamic geovisualization.

The location chosen for this demonstration is a private airport near Austin, Texas (Figure 10). The operator of this facility is defined as the *user* of the software system(s) demonstrated.

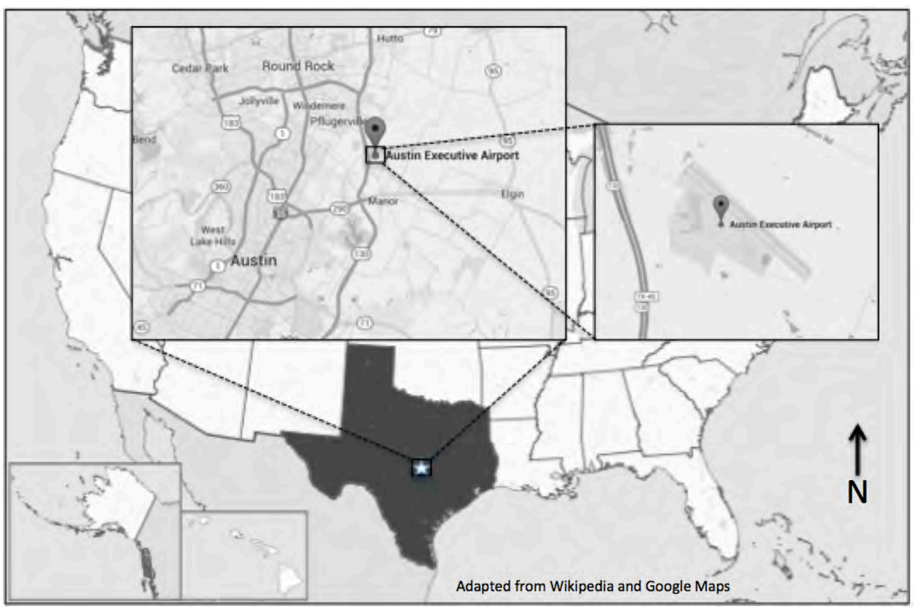


Figure 10 Study area for demonstration

The airport, "Austin Executive" (Figure 11), comprises of a number at risk components, including aircraft hangars, office space, and fuel depots. The user is concerned, to one degree or another, about possible threats to all these components.

Figure 11 Aerial imagery of study area from Google Earth

Through GE search feature, the user locates their facility, and centers on a view of it (Figure 12).

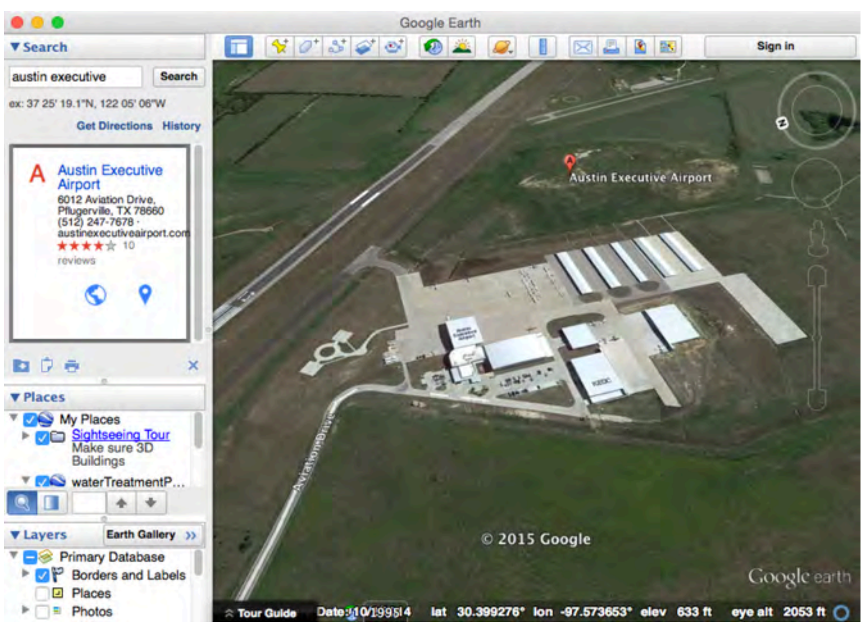


Figure 12 Google Earth Search feature

Next in GE, The user creates the information about the at-risk components that will be supplied to the threat-modeling engine and the subsequent geovisualization. For each component, the user simply positions a native GE "Placemark" (Figure 13) on the component and edits its description field to include information required by the engine as described in Appendix A.

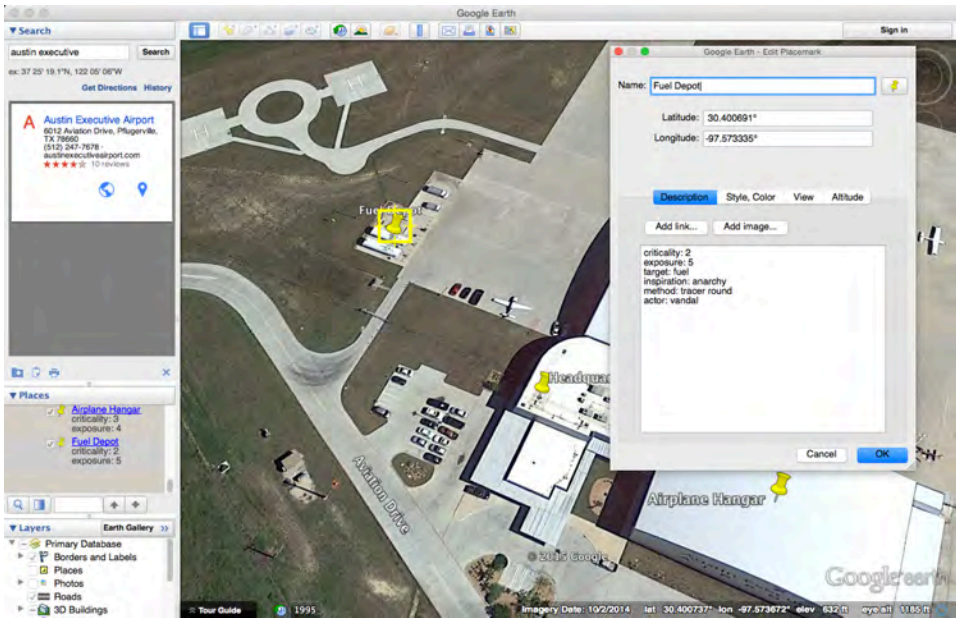


Figure 13 User edits entity attributes using 'Placemarks'

Once all of the relevant components have been identified and described, the user then saves the inputs, as a KML file for evaluation and geovisualization in SU.

SU is invoked with a custom script, which presents a graphical user interface (GUI, Figure 14) that allows the user to load the KML file previously created in Google Earth. The GUI's 'Click to Load' button coverts the KML file to a data format required by the threat-modeling engine.

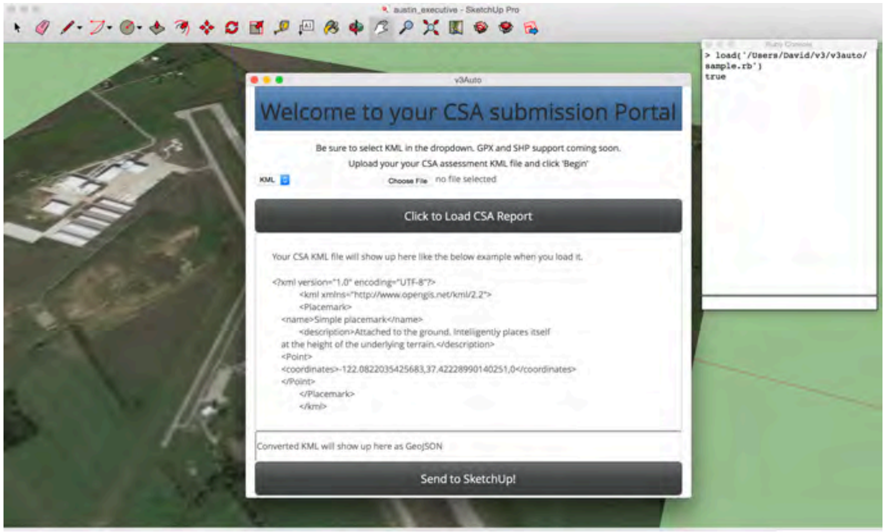


Figure 14 Program is launched from SketchUp Ruby console

The user triggers the threat-modeling process by clicking the GUI's 'Send to SketchUp!' button, which subsequently runs the geovisualization process, too. Threat glyphs appear in the scene where any of the designated components have been found to be targetable. In this demonstration, the geovisualization identifies two of the three components as targetable (Figure 15).

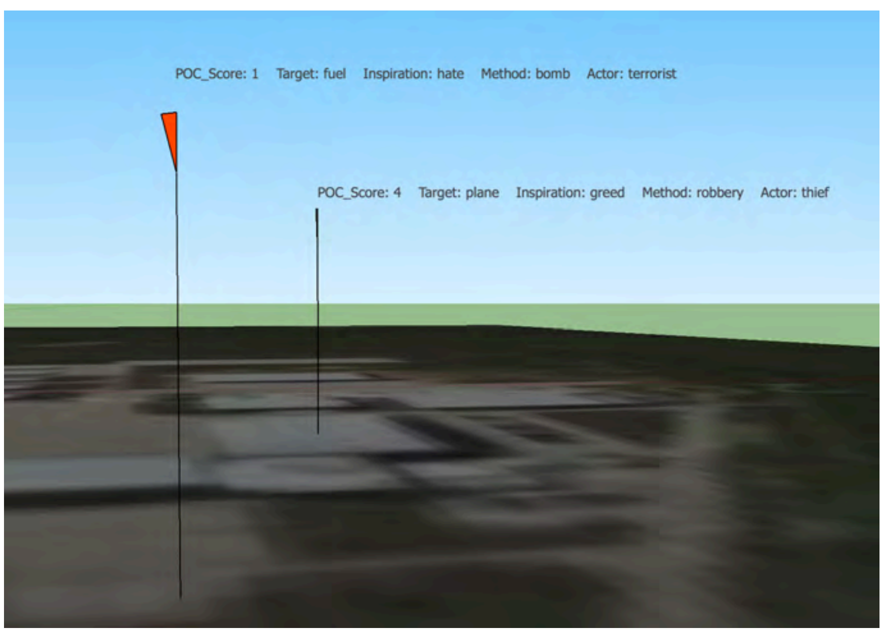


Figure 15 POC glyphs appear in SketchUp geovisualization

Figure 16 abstracts the threat glyphs from the scene. The glyph on the left is taller than the one on the right because it is associated with a targetable component deemed more critical. This glyph is also wider as this component has greater exposure than the other. A preattentive selection goes to the POC on the left even if the viewer has little or no knowledge of the components in the scene or their respective attributes.

Figure 16 POC glyph sizes differ based on criticality and exposure

The same POCs with their threat glyphs can also be visualized in GE. Clicking the GUI's 'Preview in Google Earth' option automatically re-renders the scene in GE as seen in Figure 17.

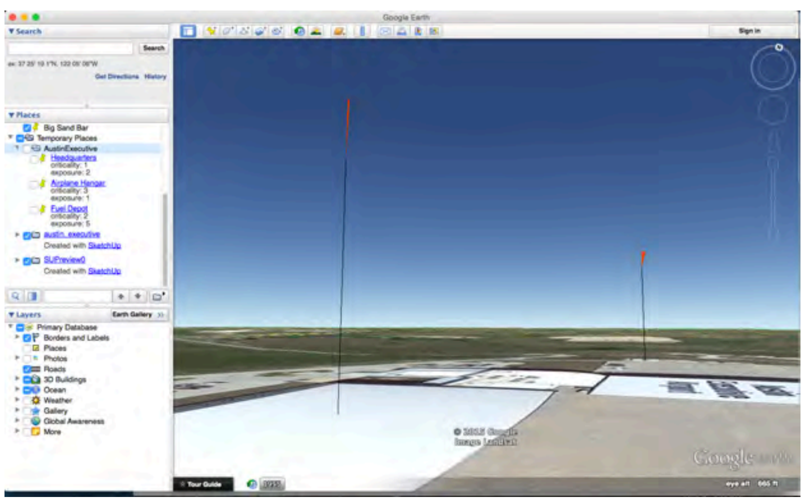


Figure 17 POC glyphs render in the Google Earth application

Facility design changes may now be proposed to address some or all the POCs that appear in the scene. This geodesign is again done in the SU environment. In this demonstration, the largest POC is associated with the fuel tanks stationed in the northwest portion of the airfield between the aircraft hangar and the helicopter pad (Figure 18).

Figure 18 Fuel tanks on the northwest portion of the airfield

The threat-modeling engine identified that the fuel tank was exposed to two threat methods; incendiary projectiles and bombs. To address this exposure, a geodesign mitigation consisting of an earthen wall, to be constructed of gabion styled barrier (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wy/technical/?cid=nrcs142p2_027275) is modeled in SU. This geodesign allows a cost estimate to be performed to evaluate the real cost of the proposed structure, which includes barrier wall of steel wire mesh lined with cloth and filled with soil, to provide ballistic and blast protection for the fuel tanks. For aesthetics and as a side benefit to wildlife, a climbing ivy vine is added to the design (Figure 19).

Figure 19 A geodesign is proposed to address a POC

This geodesign from GeoJSON converted to KML is exported back to GE, where the user conducts a new evaluation of the components, considering the geodesign part of the scene (Figure 20). With the proposed design, which clearly reduces the exposure of the fuel tanks, a new exposure score is applied to the component.

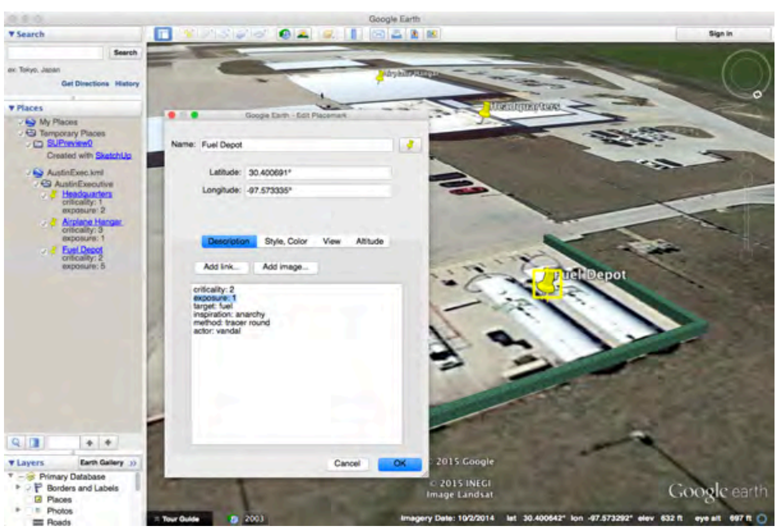


Figure 20 The geodesign rendered in GE allows a new evaluation

Re-importing the GE scene back into SU and re-running the threat model, the size of the threat associated with the fuel tanks POC has been greatly reduced (Figure 21).

Figure 21 The POC is greatly reduced after including a protective geodesign

In the full scene, the threat of robbery at the hangar is now the larger POC (Figure 22).

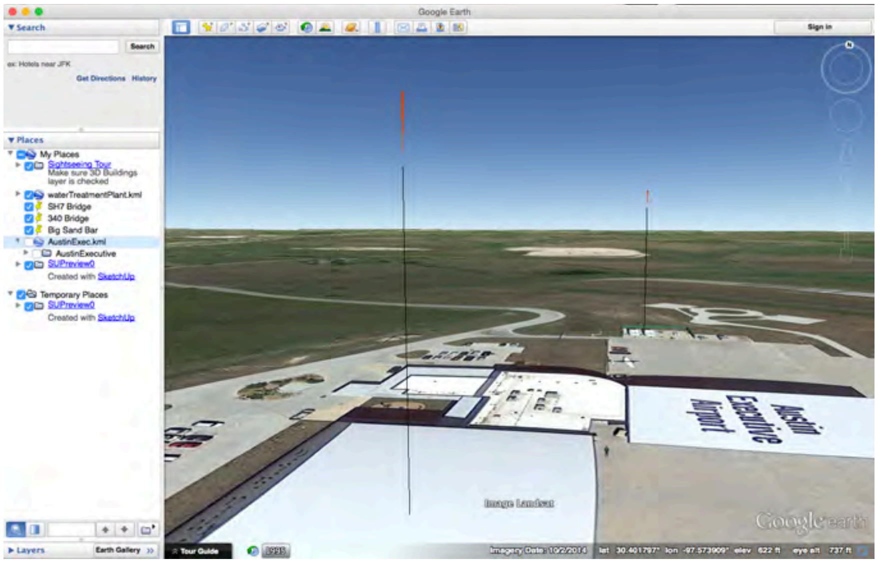


Figure 22 The POC at the hangar is larger after threat mitigation at the fuel tank

CHAPTER 5: ASSESMENT

An early evaluation of the prototypical implementation demonstrated in Chapter 4 is needed to validate the efficacy of the approach to the design of the POC glyph. As stated in Chapter 1, the purpose of the research is to objectify the notional concept of 'threat' in commonly available GIS tools. This objectification is useful only if the POC glyph, as a sign vehicle, effectively communicates information about the threats to those responsible for managing such threats. If the glyph is to be useful in a practical application it must promote pre-attentive recognition of threats as well as relative importance of the threats in the geovisualization.

The application of the capability demonstrated in Chapter 4 will most likely be useful in the management of facilities described in Chapter 1. The facilities in question will often be considered critical infrastructure as defined by the US Homeland Security Department (http://www.dhs.gov/what-critical-infrastructure). Military and law enforcement professionals will be key stakeholders responsible for assessing and managing threats against critical infrastructure.

A survey instrument regarding the threat glyph developed in this thesis was sent to 15 security professionals known to the author. The individuals selected met three criteria:

1. They each had 10 + years of field experience with threat assessments
2. They had extensive experience operationalizing threat mitigation plans
3. They had not been introduced to the POC concept outlined in Chapter 3

Eleven of the 15 professionals contacted responded to the survey and did so within 48 hours. This response rate and time was encouraging and indicates that the community of professionals involved with threat management is interested in new developments.

The survey instrument consisted of a webpage with three images and an embedded, four-question survey. The survey questions were password protected so only those invited had access. The web address (https://s3.amazonaws.com/researchdave/survey.html) was sent to the respondents with the instructions to view the three images and answer the embedded questions.

The first question read, "In image 1, which of the below components has been assessed as most critical?" Image 1 (Figure 23) is the scene after the results from custom SU software have output POCs and these have been imported to GE. The GE 'Placemark' labels are still present as they would be when a user has created and saved them in GE.

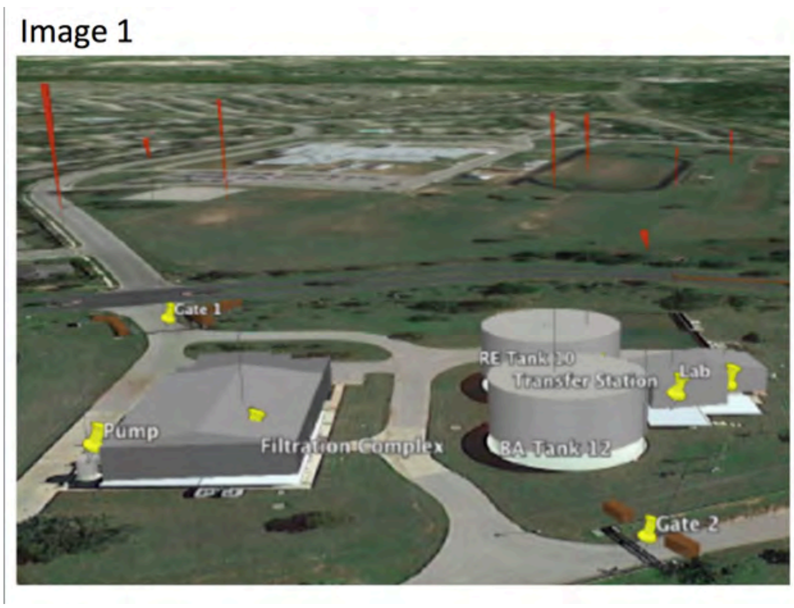
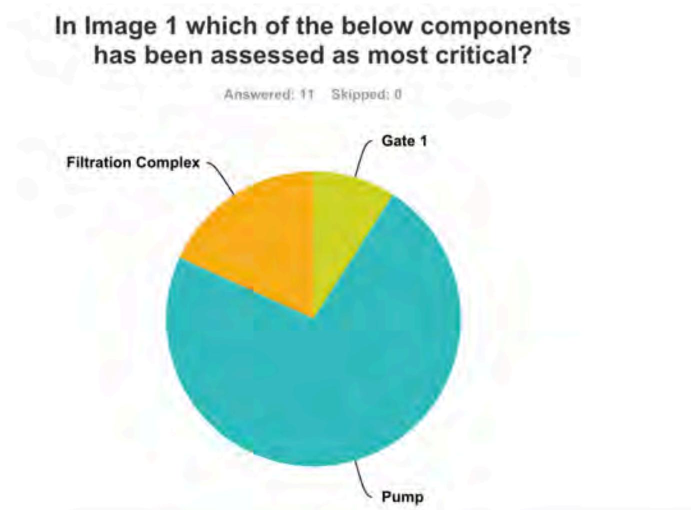


Figure 23 Image 1 from survey

The three options available for the respondent were Gate 1, Pump, and Filtration Complex. The selected options were chosen to orient the respondent to three POCs near each other.

The question did not indicate that the user should look at the POC symbol and did not provide any explanation of the symbol's meaning. It only asked the respondent to identify the component that had been deemed most critical. The respondent would have to identify the component by the “Placemark” label and was then left to determine Criticality.

The response to Question 1 is encouraging. Eight of the 11 respondents correctly identified the component deemed most critical (Figure 24).



Answer Choices	Responses	
Gate 1	9.09%	1
Pump	72.73%	8
Filtration Complex	18.18%	2
Total		11

Figure 24 Responses for Question 1

The second question addressed the exposure aspect of the POC. Like, Question 1, Question 2 did not directly reference the symbol being evaluated. Question 2 asked, “Image 2 shows the same fuel tanks at different moments in time, time A and time B. Is there more threat exposure at time A or time B?” Image 2 (Figure 25) showed the fuel tanks used in the demonstration in Chapter 4. The scene is closely cropped to avoid showing the wall that was included in the geodesign.

Image 2

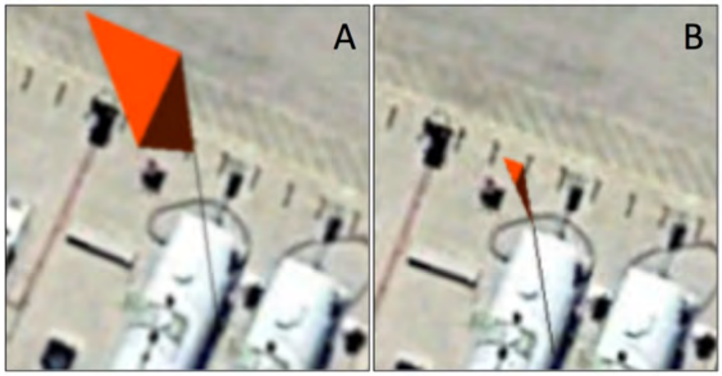


Figure 25 Image 2 from survey

Nine of the 11 respondents properly chose answer “A” (Figure 26). While 9 out of 11 is certainly a large percentage of correct answers (more than Question 1), the two incorrect answers are problematic. Image 2 is the second exposure the respondent has had to the symbol. “A” is clearly larger than “B”; the size heuristic to exposure should be obvious. The fact that it was not clear for all respondents is cause for further investigation. Perhaps the length of the symbol sides are pre-attentively reserved for a single aspect.

The third question in the survey was meant to address the apparent utility of the output from the demonstration in Chapter 4 by asking, “Assume you are leading a team to secure the facility in Image 3. Does the symbology and information presented provide you with enough information about the threats to initiate movement or make a hasty defense plan?”

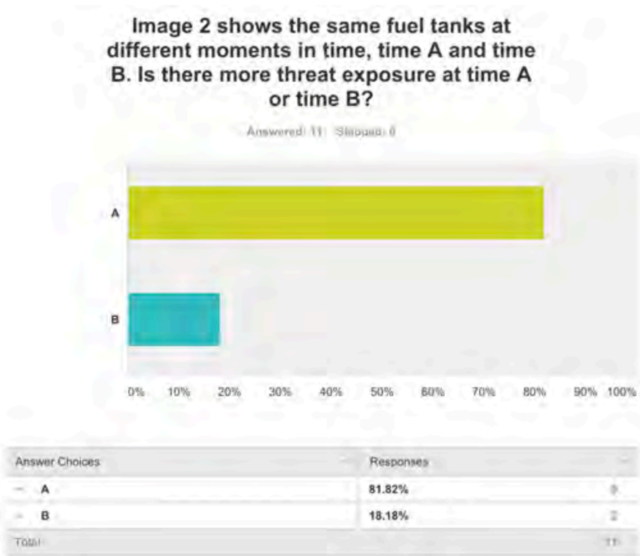


Figure 26 Responses for Question 2

Image 3 (Figure 27) shows the output of the threat evaluation and geovisualization within SU as demonstrated in Chapter 4.

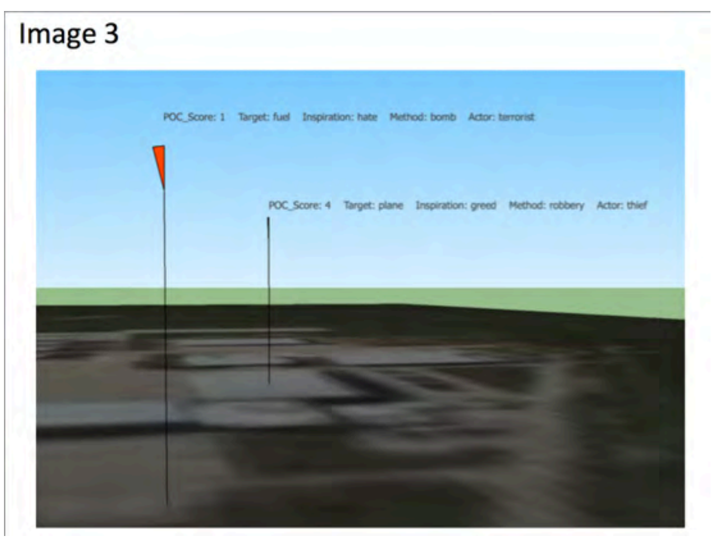


Figure 27 Image 3 from survey

The POCs are shown with labels that include the TIMA factors associated with them.

This image is the third exposure to the symbol that the respondent has had and the question specifically calls out the symbology.

Seven of the 11 respondents answered that the presented symbology and information was enough to at least begin employing assets creating a hasty defense plan. Despite the doubts raised by incorrect responses in Question 2, having 7 of 11 experts respond that the information presented in Image 3 would be enough to begin taking action is extremely encouraging. To discover that there is utility even in this very early prototype is reason enough to continue developing this capability.

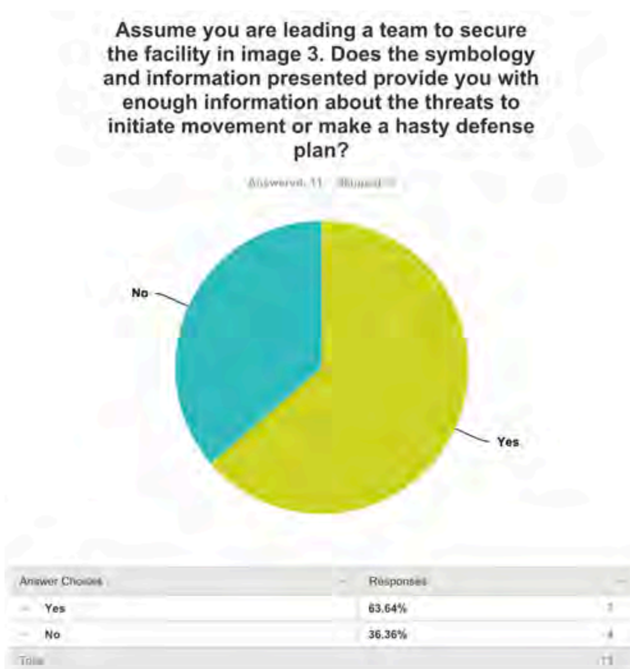


Figure 28 Responses for Question 3

The final question posed in the survey doubled down on the notion of utility by asking if the respondent had a use case in mind for what they have seen in the images.

Question 4 asked, “Would you or a team you know be interested in evaluating a tool that allowed you to drop in information about a facility and have a threat visualization, similar to those in images 1-3, output to you based on near-real-time threat-factor data?” Seven of the 11 respondents answered “yes” (Figure 29). Four of the 7 respondents indicated “not sure” while none of the respondents chose “no”. This response, like the responses to Question 3, is also encouraging. Knowing that the majority of respondents can envision a current user base and use case for the demonstrated output means that there will be opportunity for very tangible evaluations and feedback of the prototype coming out of this research. As it is developed those parties should be engaged in the process to maintain relevancy.

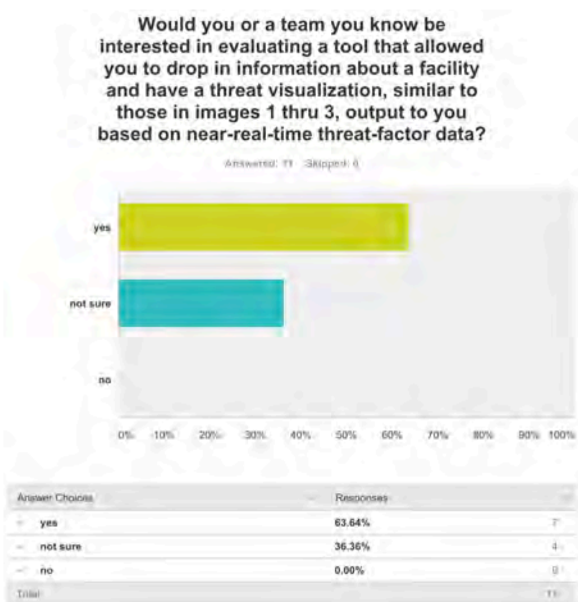


Figure 29 Responses for Question 4

While the survey responses indicate a strong interest in the potential for a tool that provides a geovisualization of threat information, some issues with the survey instrument and method cloud the results.

A major problem with the evaluation of the effectiveness of the geovisualization is that the instrument utilized 2D images to present the scene view to the respondent. A major consideration in the design of the glyph was the special aspect symbol afforded by the 3D environment. Given the 2D nature of the images presented, it is unknown if a multi-perspective view of the scene would have had an impact on the viewer’s ability to interpret the scene.

One of the major gains resulting from this research is a programmatic framework that can be used to develop scenarios and glyph parameterization for experiments related to the communication of threats to decision makers charged with protecting critical infrastructure. The prototype developed in this research seems to represents a step forward for decision makers protecting port facilities. In the next chapter, some conclusions and suggestions for future work are outlined.

CHAPTER 6: CONCLUSIONS

Societal risk posed by anthropogenic threats is a growing and persistent problem. Traditional analysis techniques do not adequately address the non-recurring nature of anthropogenic threats. While GIS tools are commonly used to model and visualize risk associated with natural hazards they are surprisingly not much used for anthropogenic threats. This research has demonstrated that with the appropriate semiology, GIS tools may be quite useful for communicating threat factors (particularly the TIMA factors described) via geovisualization.

The glyph design demonstrated in this research proposes a standardized symbology visualizing anthropogenic threat factors. This glyph carries information about the criticality and exposure aspects of a targetable scene component. This glyph is programmatically rendered in a commonly available modeling tool, SketchUp, using input values derived from user inputs in Google Earth regarding potential POCs in the environment.

Based on the responses to the evaluation described in Chapter 5, additional research into the application of the visual variables in Special Aspect symbology is warranted.

The uncertainty surfaced in Question 2 of the survey indicates a deeper look into how the visual variables are employed. There are many paths forward for future work with this research. Three immediate lines of investigation stand out however. The first is a formal, quantitative assessment of the efficacy of the threat glyph as sign vehicle (MacEachren 1997). Some informal, qualitative results are reported below. The second, informed by the first, is refinement of the threat glyph; possibly including other visual variables to more fully address attributes of the POC. Third, an evaluation of how the glyph and it’s interpretation change with modifications to the parameterization of exposure and criticality.

More communicative than heat maps, threat glyphs at discrete Points of Concern have immediate utility in emergency management and response planning. The current threat glyph, however, considers only two dimensions of a threat: criticality and exposure. Obviously there are other dimensions, such as type of threat (physical, electronic, biochemical, etc.) and its potential impacts (number of structures, number of people, monetary damages, etc.)

Other than location, only one visual variable, size, or at most two, differential size leading to shape, are employed by the threat glyph proposed here. Unused visual variables such as color (hue and value, Figure 30) and texture should be reviewed. Shading may be utilized to communicate the values assigned to a POC, for additional scoring permutations suggested in Appendix A.

Figure 30 Four shades of color represent score values

Texture is another visual variable that is not represented in this research. Texture might be utilized in a future implementation to communicate a class of threat methods or targets associated with a POC. The application of texture in traditional cartography is commonplace. A military 1:50,000 scale map makes use of texture to indicate the density of vegetation as seen in the area indicated by the red circle in Figure 31.

In the same way, texture could be applied to POC. The surface of the threat glyph might use a number of texture patterns to act as an associative variable (Bertin 2011). As an example, Figure 32 shows three texture treatments applied to a notional POC shape with a hypothetical legend gives meaning to the texture applied to the object surfaces.

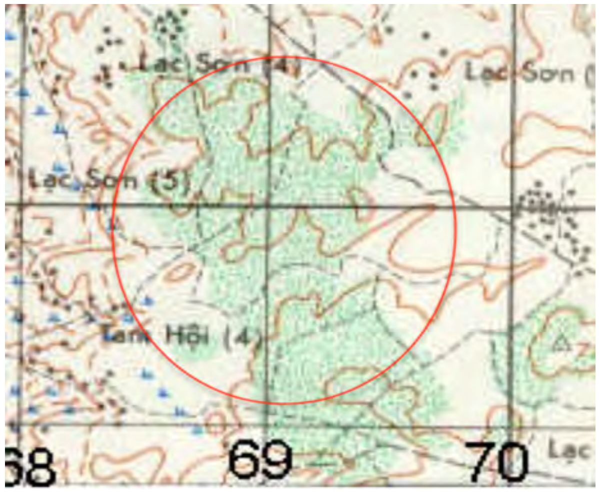


Figure 31 Mottled green texture represents a class of vegetation

Figure 32 Texture treatments applied to a POC along with a legend

Inasmuch as the informal survey already indicates the utility of the threat glyph concept, a dedicated study needs to be conducted to assess various combinations of the visual variables and their affects in pre-attentive processing of threat circumstances. This study could easily be a follow-on thesis to the present one. The parameterization of size is easily manipulated in the current prototype. One form of future work could incorporate various constant values applied to the criticality and exposure scores to determine what difference is made in the viewer's ability to interpret the sign vehicle. Additionally the use of 3D perspectives should be used when assessing the glyph's effectiveness to have better confidence in an evaluation. It would be possible to record interactions in the GIS environment of the study area with changing points of view to provide a survey respondent with a 3D perspective of the scene. These recorded videos could be provided to survey participants via YouTube.

One of the inspiring outcomes of this research is the fusion of the cognitive domain and GIS. Traditionally used to display field data, GIS can be more fully employed by the development of cartographic methods for geovisualization and mapping cognitive notions. The individual human experiences a variety of emotions, feelings and sensations that are often ignored by normal environmental sensors (i.e. rain gauges, hyperspectral images, etc.). The fact that cartographic techniques are not normally employed to display notional phenomena does not make them any less real or impactful in the environment.

This research demonstrates a method for doing so which could also be adapted to notional phenomena other than threats. Increasingly students and workers are at risk to emotional problems. Qualitative information related to healthcare is recorded in the form of adjectives. These notional phenomena are impactful at the individual level. The ability to see and act on such fleeting information is lost if treated as data points when mapping a population (i.e. heat maps).

The prospect of *cognitive GIS* seems very real if meaningful implementations of notional cartographic representation, like that demonstrated in this research, are developed.

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APPENDIX A: Threat-Modeling Engine Prototype

The threat evaluation method is referred to as "V3". A basic notion of V3 is the Threat Mass fundamental. There are four threat mass factors: Target, Inspiration, Method and Actor (TIMA). The V3 process treats the threat mass factors as disaggregated and atomic entities even when found together in the same digital artifact, document, message, paragraph, sentence or n-gram. The fact that the threat mass factor has been uncovered means that it is initially treated without prejudice and without context. The evaluation of the importance of that atomic entity is performed only after all of the conjured fundamentals are combined in every possible way to form *Threat Masses* as described by Staffel (2011). Subject matter experts perform this process during both the evaluation of streaming data from the anthropogenic environment and from a professional ongoing assessment. These evaluations are described as "Environmental Analysis" and "Scenario Development" respectively. The third process to be incorporated into the V3 process is the "Client Systems Analysis". The collection or generation of data for this process is described in this thesis in the demonstration.

Through the algorithm embodied in this research the Client Systems Analysis data is parsed for Threat Masses. The CSA Threat Masses are matched against every other Threat Mass generated from the Environmental Analysis process. As matches at the atomic level are found a score is generated for each targetable component. This score is known as a POC Score. Once the matches are complete against the Environmental Analysis outputs, a loop runs to match the CSA Threat Mass against the Scenario Development outputs. If a match is found with Scenario Development, the POC Score is given maximum value. This signifies that at the owner/operator level, at the environmental level and the expert level, a matching fundamental has been found. If no match between the Client Systems Analysis and Scenario Development is found then the POC score retains the value it was given at the end of the matching loop with Environmental Analysis. Those system components that have a POC Score greater than zero are considered “targetable”.

Targetable components are passed to a program that uses their criticality and exposure scores to create the three-dimensional glyphs used to represent their POC in the geographic visualization.

The exposure categories and definitions are:

Cat 1: Complex attack required. Must use Technical Means, Specialists and or Destructive Weapons to reach.

Cat 2: Coordinated effort required. Must use Disabling or Diversionary measures.

Cat 3: Deliberate effort required. Must bypass access of perimeter measures.

Cat 4: Can reach with some effort. Must diverge from normal behavior or routine.

Cat 5: No effort to reach. Can and is reached normally.

This geographic visualization calculates the ‘Z’ height of the threat glyph by adding a product of the criticality score and a constant to a line object of a set length which itself is positioned at the ‘X’ and ‘Y’ coordinate values given to the system component during the Client Systems Analysis process as described in the thesis. The inverted quarter-pyramid is then rendered with a shape and volume determined by the adjoining of an isosceles triangle (perpendicular to the vertical line) with a ninety-degree angle at the top of the vertical line. The acute angles of the triangle join to the end of the vertical line before the criticality derivative value was added. This creates the threat glyph as described in the thesis.

V3 may be performed as a non-computerized process with tables and charts (Figure 26). A more elaborate process would utilize computerized spreadsheets and charts to assist with the complex calculation that result from dealing with a large number of variables at once.

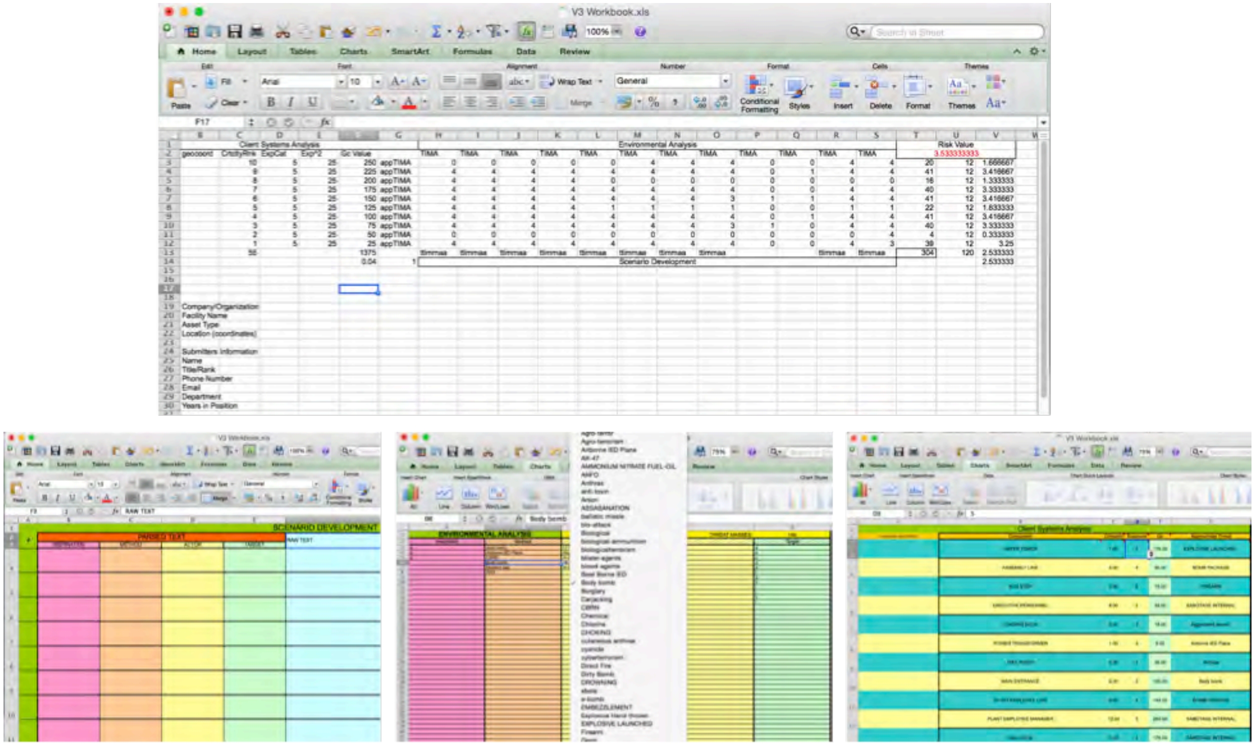

Figure 33 Spreadsheets can speed up the V3 process

The process, however enabled by spreadsheets, is still too slow to meet the needs of those who can most use the kind of threat evaluation provided by V3. The automation of method as well as the automated geographic visualization of its output is needed.

A more automated process is envisioned which combines the technology implemented in this research with a method for utilizing semantic markup of online content (Staffel, tisp.org 2013). This combination of automated analysis of online content, automated analysis threat fundamentals (Staffel, 2011) along with the automated generation of threat analysis generation provided for in this thesis is intended to enable a *streaming* data analysis of potential threats as they evolve.

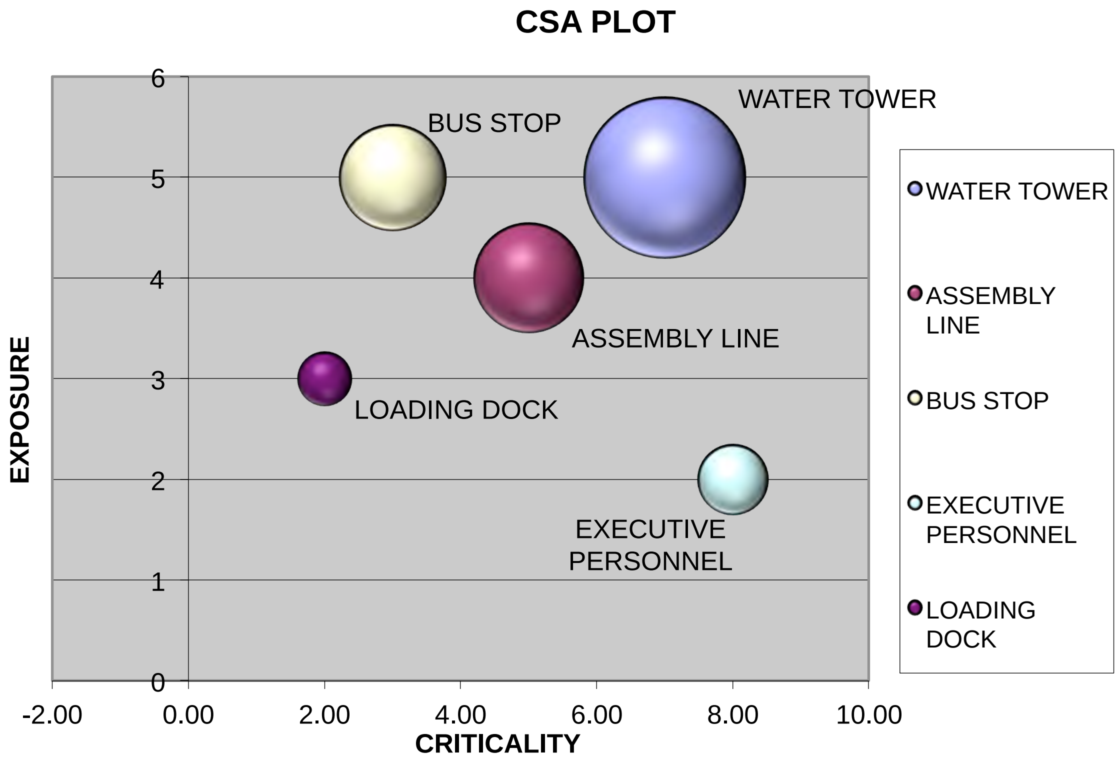

Figure 34 Example of a chart V3

To advance the V3 process to the envisioned speed required a project has been put into place, which includes the source code for the custom software created by Staffel, described in this thesis. The project is a restricted code repository on GitHub (https://github.com/davedev1977/v3auto). For access please contact the author.