PREDICTIVE GIS MODELING FOR MINEFIELD DELINEATION IN POST-CONFLICT STATES

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The Global Landmine Problem

The problem of civilians becoming unintentional victims of landmine detonation in the world today is one that cannot be underestimated in terms of its importance to global and local humanitarian efforts. The human-life and financial costs associated with landmine detonation are paramount, and are being addressed by the Global community via the United Nations Department of Peacekeeping and its associated agency UNMAS (The United Nations Mine Action Service). In terms of human-life cost, the current statistic is that every 28 seconds a person steps on a landmine, resulting in 6500 – 20,000 new casualties per year[1]. These tragic events are happening in at least 84 states, and _every_ world region is affected, as seen in figure 1.

It is the intent of this literature review to enlighten the reader in two main topic areas. The first is that of mine action and our understanding of it, with specific regard to what is generally understood to be the most affected continent: Africa. A comprehensive description and discussion of the geo-political status of mine action in Southern Africa and its relation to development will be set out.

The second topic area that will be reviewed is that of predictive GIS modeling, as it applies to mine action. The intent is to put forth the scientific (i.e.: based on peer-reviewed publications) background information that justifies and supports an experiment

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that will be conducted. The goal, in general lay terms, will be to see whether it is possible to predict with a reasonable, usable, and repeatable amount of accuracy the delineating outlines of where minefields are located in a specific geographical study area. It is hoped that the effort with predictive GIS modeling will yield a technique that is valid for use across a variety of study areas. Having said this, the study area that is the concentration of this review is the region of Southern Africa and it must be acknowledged that the results, if positive, may not be transferrable to different Geo-political regions.

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Figure 1: Landmine Affected States
(Source: The Landmine Monitor Report)

Secondary to the aforementioned human-life costs are the financial burdens that are incurred by post-war states attempting to return to or obtain a situation of peace and progression. Knezic and Mladineo state that mine contamination is one of the main obstacles to economic and other aspects of progress in Croatia[2]. At face value, this would hold true as a generalization that could be applied to other states, however we should be aware that "this approach presents the danger of over-simplification and the expectation that Mine Action solutions can be imported or transferred, with very little regard for the practical barriers that factors such as geography, lack of infrastructure, personnel and facilities for preparing equipment, represent"[3]. This statement is underscored by not only the human-life cost, but also the fact that while landmines can cost as little as $1 to deploy, they can cost up to $1000 to detect and remove[4].

The international response to the landmine crisis is referred to as "mine action". Humanitarian mine action may be thought of as all of the activities associated with humanitarian efforts in this topic area. This includes not just the act of detecting and removing landmines, but also landmine education and the destruction of stockpiles.

In terms of the detection and removal of landmines, this occurs at two interrelated scales: small and large. Small-scale mine action refers to the detection of individual landmines and their destruction. Large-scale mine action, the focus of this study, refers to the identification, prioritization and analysis of large infected areas for the purpose of small-scale mine action.

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[2] S. Knezic and N. Mladineo, "GIS-based DSS for Priority Setting in Humanitarian Mine-Action", *International Journal of Geographical Information Science,* 20(5), 2006, p. 566.
[3] N. Grobbelaar, et al., *Mine Action in Southern Africa: Instrument of Development?* (Johannesburg: South African Institute of International Affairs, 2003), p. 15.
[4] E-Mine.

The Issue of Scale As it Pertains to Mine Action

At this time, it is appropriate to offer a more detailed discussion with regard to the issue of scale as it pertains to mine action and GIS.   Regarding the usage of GIS (Geographic Information Systems) and Remote Sensing technologies both in the field and in academic research settings there are two foci in recent literature that are coincident with the two scales of mine action. First, there is small-scale mine action, and this has been delegated to the realm of remote sensing. A full scale review of remote sensing technologies as used for mine action is outside the scope of this article. Having said this, if one needs more information on the subject there is a review that is both comprehensive and recent in the International Journal of Remote Sensing written by BHP Maathuis and J.L. Van Genderin.[5]

The second focus, large-scale mine action, is where GIS technologies have been employed.   Currently, the main functionalities that have been used are MCA (Multi Criteria Analysis), and DSS (Decision Support Systems).   Some research has been effective in the use of DSS for large-scale mine action, however the current literature indicates that the employment of geo-statistical techniques have been largely unexplored in this topic area. Table 1 below, provides insight into the real-world sizes of the targets involved and the scales at which mine action occur. The key concept to be aware of is that GIS based mine action is an effort toward "area reduction".[6]

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[5] B. Maathuis, and J. Van-Genderen, "A Review of Satellite and Airborne Sensors for Remote Sensing Based Detection of Minefields and Landmines." *International Journal of Remote Sensing* 25(23), 2004, pp. 5201-5245.
[6] Ibid., p. 5205

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Table 1: The Scales of Mine Action			
Concept	Mine Action Level	Description	Entities
Macro	Strategic	Level 1 Survey	States, river basins
	Tactical	Level 2 Survey	Counties, states, watersheds
Micro	Operative	Level 3 Survey	Municipalities, parts of a river basin, parts of a watershed, particular demining projects
Sources: Maathuis and Genderen 2004, p. 5205; Knezic and Mladineo 2006, p. 570			

Our Current Understanding of Mine Action

As outlined in the introduction, the landmine crisis is one that is of great importance to the global community in terms of its economic impact and more importantly in terms of its cost of human-life. The international community's response to the landmine crisis encompasses *all* aspects related to the topic area. Within both the large and small scales, UNMAS identifies five "pillars" of mine action and it can be seen that landmine removal is only one aspect of the mine action philosophy.

The Five Pillars of Mine Action
1. Removing and destroying landmines and explosive remnants of war and marking or fencing off areas contaminated with them.
2. Mine-risk education to help people understand the risks they face, identify mines and explosive remnants of war and learn how to stay out of harm's way.
3. Medical assistance and rehabilitation services to victims, including job skills training and employment opportunities.
4. Advocating for a world free from the threat of landmines and encouraging States to participate in international treaties and conventions designed to end the production, trade, shipment or use of mines and to uphold the rights of persons with disabilities.
5. Helping countries destroy their stockpiles of mines as required by international agreements, such as the 1999 Anti-Personnel Mine-Ban Treaty. [7]

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[7] E-Mine.

The Ottawa Treaty

Eleven years after the drafting of the Ottawa Treaty, there are still questions about its efficacy on the Global stage. An international relations analysis of the treaty is beyond the scope of this literature review, however a description of it and limited discussion is most appropriate. First, it is formally referred to as the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-personnel Mines and their Destruction[8]. The convention was held in Ottawa, Canada in 1997 and there are currently 155 State parties[9], as seen in Figure 2. The treaty in addition to its full official name is also sometimes referred to as The Anti-Mine Treaty, The Mine Ban Treaty, The Mine Ban Convention, The Ottawa Treaty, or the Ottawa Convention; for the remainder of this review, it will be referred to as The Ottawa Treaty or simply 'the Treaty'.

Figure 2: State Parties to the Ottawa Treaty

Critical to the discussion that will be tendered here are two factors with regard to the Ottawa Treaty. First is the point of contention that opponents to the Ottawa Treaty

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[8] Grobbelaar, p. 5.

[9] Arms Control Association, "The Ottawa Convention: Signatories and States Parties", *Treaties*. http://www.armscontrol.org.

make, in that the chief producers and users of AP (anti-personnel) mines have not signed the Treaty. Of note in this category of states are the following: China, Russia, India, and Pakistan. Furthermore, in 2004, The United States (also a major producer and user of AP mines) explicitly stated that it would not enter the Ottawa Treaty[10].

But the Treaty is by far from 'useless' with regard to the study area of Southern Africa, and this is the second critical point must be discussed. As far as Southern Africa in particular is concerned, the Treaty has actually been quite useful in that it was the impetus for the states of the SADC (The Southern African Development Community, to cohere in becoming "the first regional organization worldwide to achieve the goal [of ratifying the treaty]"[11]. SADC member states (not all have a landmine problem) have adopted the "common approach"[12] (i.e. using the Treaty) to address the landmine problem, and Grobbelaar, Millard, et al. importantly point out that this indicates not only the SADC's realization that the landmine problem is a serious one, but also that a concerted effort is required especially because landmines are, at the end of the day, a barrier to development in the region.

GIS and Mine Action

Toward the end of realizing the pillars of mine action, GIS and remote sensing technologies have been employed in large- and small-scale operations respectively. The current large-scale understanding of mine action in terms of how it relates to GIS can be grouped into two research areas: firstly, the use of DSS to implement multi-criteria analyses, and secondly the social ramifications of using the visualization capability of GIS in terms of participatory GIS. A non-exhaustive briefing of the key

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[10] Ibid.

[11] Grobbelaar, p. 5.

[12] Ibid.

studies and projects that have used GIS for Mine Action is provided in Table 2. The information provided in Table 2 represents the pivotal studies and GI systems that are relevant to not only this review, but also to mine action and GIS as a research area.

Table 2: Key GIS and Mine Action Projects			
Year	Title	Author / Creator	Synopsis
2006	GIS-based DSS for priority setting in humanitarian mine-action.	Snjezana Knezic and Nenad Mladineo	GIS based DSS for Mine Action Priority Setting in Croatia.
2005	IMSMA: (Information Management System for Mine Action.	Geneva International Center for Humanitarian Demining (GICHD)	The latest version of the IMSMA software (V 4) has undergone a complete redesign. The system now incorporates a map driven navigation system that significantly improves both data entry and retrieval operations.
2003	GIS in Participatory Research: Assessing the Impact of Landmines on Communities in North-west Cambodia.	Craig Williams and Christine E Dunn	GIS based priority setting and the integration of non-metric data and "participatory" GIS.
2003	Integration of Different Data Bodies for Humanitarian Decision Support: An Example from Mine Action.	Aldo A. Benini, Charles E. Conley, Richard Shdeed, Kim Spurway and Mark Yarmoshuk	Examines the integration of disparate data sets for Mine Action priority setting in Lebanon.
2000	IMSMA: Information Management System for Mine Action.	Geneva International Center for Humanitarian Demining (GICHD)	IMSMA is the UN-approved standard for information systems supporting humanitarian de-mining. The intent is to collect standardised mine related data and manage it in a standardised system using powerful statistical and geographical tools.
1997	Global Landmine Survey	UNMAS	Collection of social, economic, and contaminated area data for the globe.

The function of large scale mine action is well defined by Knezic and Mladineo in that the "primary goal of humanitarian demining operations is to clear all suspected minefields and restore them so as to make them available for their previous use"[13]. This speaks to the land use theme that is prevalent in GIS, and in this regard mine action is an attempt then to employ human engineering toward the deliberate change of land use classification, in this case for a positive humanistic goal.

The research conducted by Knezic and Mladineo is key in the topic area of demining operations in that it is one of the few projects in the current literature to apply GIS technologies[14]. The limited availability of materiel in this field was confirmed by my own research, and the literature review offerings of Knezic and Mladineo.

While the Knezic and Mladineo project does not specifically address locating minefields, it does address several issues that are key in GI Studies. Namely, their research "describes the necessity of developing a methodology that [renders] the decision making process more objective"[15]. The key point in general terms is that it is necessary to convert data into information that can be used by the relevant stakeholders to make better decisions. Knezic and Mladineo attempt, successfully, to employ a GIS-based DSS in order to provide objective grounds on which to decide which contaminated areas to engage in small-scale mine action. Their goal was to determine "where humanitarian demining would pose the biggest positive effect"[16]. Their approach was to employ a hierarchic model that acknowledges the different problems that must be addressed at varying scales. Knezic and Mladineo divided the entire scope of the problem into three levels of analysis: strategic, tactical, and

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[13] Knezic, p. 566.
[14] Ibid, pp. 565-588.
[15] Ibid, p. 566.
[16] Ibid.

operational.   This adds one more level to the original two scales outlined at the beginning of this review. The reason that this was done was because there were three relevant scales at which the analysis had to take place in their particular study area. Through the use of GIS functionality, namely multi-criteria analysis and DSS, they were able to offer decision support information that was "acceptable to most stakeholders"[17] because the stakeholders had been involved in the input process and were under the impression that the process was objective.   This facilitated the acceptance of the decisions that were made, in terms of regional priority setting – an important factor in the success of the program because at the outset individual stakeholder's believe their specific regions ought to be the priority.

The social umbrella under which studies like Knezic and Mladineo's occur cannot be underestimated. Ultimately, the success or failure of a decision support program could rest in the hands of the people and organizations being affected in that if they fail to accept it, it will fail. Further, it is valid to challenge the data-driven top down approach because "lives and livelihoods are directly at stake"[18].

The human aspect of GIS in humanitarian mine action is addressed in the current literature by Williams and Dunn. Their case study was in North-west Cambodia, where GIS was used to "develop priorities for landmine clearance"[19]. Williams and Dunn's article in *Transactions in GIS* was the only other article found for review on the topic of GIS and mine-action; it was cited by Knezic and Mladineo as one of the few examples of the use of GIS in mine action[20]. This lends support to the contention that using GIS

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[17] Ibid, p. 584.
[18] C. Williams, and C. E. Dunn, "GIS in Participatory Research: Assessing the Impact of Landmines on Communities in North-west Cambodia.", *Transactions in GIS* 7(3), p. 396.
[19] Ibid, p. 393.
[20] Knezic, p. 569.

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in the topic area if mine action is thus far limited in general terms, and certainly in terms of geo-statistics. Nonetheless, Williams and Dunn give a good outline of the social and scientific implications that can be present when using GIS in less-developed states. Their intent was to make the use of GIS more democratic and less divisive by way of "integrating in a single framework (a GIS) local, indigenous, 'non-conventional' *knowledge* with official, 'expert', spatially referenced *data*. This juxtaposition of information types raises important questions about interpretations of 'accuracy' in geographical information and, in particular, how notions of spatial accuracy and precision are privileged by GIS developers and users"[21].

The actual practice of their research was successfully able to identify several factors important to mine action. One of the points Williams and Dunn make may appear to be slightly counterintuitive to the reader at first; they contend that "total clearance is not only unrealistic but also unnecessary"[22]. Their statement draws into the spotlight the importance of effective decision-making plans, and goes a long way toward explaining why DSS has been the main focus of GIS-based mine action up to this point.

Relating to the data itself and the crux of Dunn's project is the issue of so-called knowledge-based geographic information. A good half of their study focused on the integration or the production of data that could be used in a GIS that is based on interviews with villagers. The large-scale purpose behind attempting to integrate non-traditional types of GIS data relates to the current scientific understanding of mine action in that "clearing mines alone may not resurrect a village where the resources and

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[21] Willams, p. 394.
[22] Ibid, p. 395

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facilities that allowed the village to prosper are no longer available"[23]. What this means is that the participatory element in GIS data collection reveals information that might not otherwise be obvious, yet is critical to the goal of mine action. This is an especially important factor in lower income states that do not have spatially referenced datasets that are of use in GIS.

Williams and Dunn admit that their study was not really an exercise in implementing a participatory GIS, but was rather a participatory MIA (Mine Impact Assessment). Nonetheless, their study is one of two in the current literature that made use of GIS for the purpose of mine action.

The Study Area and the SADC

Since "Africa is widely acknowledged as the most mine-affected continent in the world" it is appropriate to study it for the purposes of mine action[24]. This is true mainly because of the positive impact that may be realized through mine action and a greater understanding of the processes that are occurring.

The Southern African Development Community (SADC) is a regional organization consisting of 14 Southern African states. It was created via the Southern African Development Co-ordination Conference (SADCC) in 1980.   The primary purpose of SADC was to enhance social and political development through the concept of regional cooperation. The four "principal objectives" behind the formation of SADC are:

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[23] Ibid, p. 396.
[24] Grobbelaar, p. 3.

1. To reduce Member States dependence, particularly, but not only, on apartheid South Africa.
2. To implement programmes and projects with national and regional impact.
3. To mobilize Member States' resources, in the quest for collective self-reliance.
4. To secure international understanding and support.[25]

Within SADC, there are eight states that have a landmine problem; however, all member states are party to the Ottawa Convention, as seen in Table 2. This is an important qualifier to the contention that SADC states consider mine action an important part of the development process in the region.

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[25] SADC. "SADC History Evolution and Current Status", http://www.sadc.int/about_sadc/history.php

**Figure 3: SADC States and SADC
(Grobbelaar, Millard et al. 2003; SADC 2008)**

Table 2: Southern African Development Community (SADC) States			
No.	**State**	**Landmine Affected**	**Signatory of Ottawa Treaty**
1.	Angola	√	√
2.	Botswana		√
3.	Democratic Republic of Congo	√	√
4.	Lesotho		√
5.	Malawi	√	√
6.	Mauritius		√
7.	Mozambique	√	√
8.	Namibia	√	√
9.	Seychelles		√
10.	South Africa		√
11.	Swaziland	√	√
12.	Tanzania		√
13.	Zambia	√	√
14.	Zimbabwe	√	√
Table Created from Information at The Arms Control Association (2008) and from Grobbelaar, Millard et al. 2003.			

The particular state that is the focus of this article is Mozambique. Significant mine action progress has occurred in Mozambique, and "[of] all the current programmes, Mozambique's is the most substantial"[26]. This feat is respectable, especially given that Mozambique is second only to Angola in terms of mine contamination and casualties[27]. In order to offer perspective on the issue, facts regarding the landmine situation in Mozambique are presented below, in addition to the comparative casualty information staged in Figure 4.

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[26] Grobbelaar, p. 12.
[27] Ibid.

Mozambican Landmine Facts: Impact Survey 2001

1. More than 10% (1.7 million) of the population were facing threats to their lives and livelihoods owing to the presence of mines.
3. Landmines and UXO (unexploded Ordinance)s are found in all 10 provinces (123/128 districts).
4. At least 558 km² are suspected of having some degree of contamination.
5. There have been 172 known accidents in the past two years.
6. The most frequently reported blockages of access to resources related to:
  – agricultural land (464 communities, 950,000 persons, 369 km²)
  – roads (231 communities, 369,000 persons).
  – non-agricultural land used for hunting, gathering firewood, and other economic and cultural purposes (180 communities, 291,000 persons, 137 km²).
  – sources of drinking water (less frequent affecting 55 communities, 87,000 persons)[28].
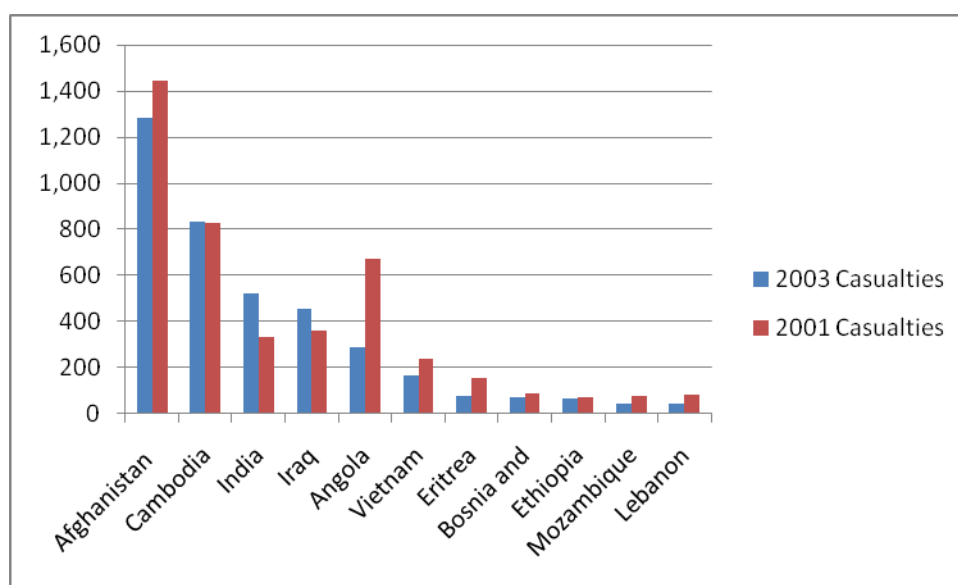
Figure 4: Selected Landmine Casualty Statistics
(Data source: Landmine Monitor Report)

Logit Analysis and Predictive GIS Modeling

Introductory Remarks

Extensive research into the possible methodologies that could be employed for the predictive GIS modeling of landmine fields indicates that as of yet there are no

[28] Ibid, p. 9.

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works that address this specific topic. Methodologies used in other fields of investigation, however, appear readily transferrable to the current application because of the similarities in the geographic nature of the phenomena being modeled.

The first similarity between current literature and the methods being employed in this experiment is that we are looking to use GIS to significantly predict entity locations with geographic data attributes as the independent variables. The second similarity is in the nature of the subject entities and the fact that we are looking to predict a dichotomous variable in terms of presence / absence. Predictive GIS modeling will be used for this experiment, and the validity of the results will be tested using methods proven in current literature. The predictive engine that will be used is logistic regression therefore a discussion of how this technique is used along with that of predictive GIS modeling will be provided.

Logit Analysis

Since logistic regression, often referred to as Logit Analysis, is the predictive driver that could be used in a GIS based demining project it will be discussed first[29]. In their review of logistic regression methodology, Dreiseitla and Ohno-Machadob correctly point out the fact that a discussion should be provided of the algorithm employed in "papers using predictive modeling, as otherwise the validity of the claims in the papers cannot be assessed by the reader"[30]. To this end, a discussion of logistic regression will now be provided.

In the case of a GIS based Mine Action project, the dependent variable will be point form landmine locations, and the independent variables will include geographic

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[29] F.C. Pampel, Logistic regression: A Primer (Thousand Oaks: Sage Publishing, 2000).
[30] S. Dreiseitla, and L. Ohno-Machadob, "Logistic Regression and Artificial Neural Network Classification Models: a Methodology Review", *Journal of Biomedical Informatics* 1(35), 2002, p. 352.

attribute data. The attribute data will range from topographical attributes (slope, aspect, distances to features), but also categorical or nominal attributes such as land use category. There are three main reasons to use logistic regression, and all three are dependent on an initial exploration of the dataset. Exploring the dataset, as described, reveals that it is prudent to proceed with the use of logit analysis for GIS based Mine Action. A discussion of these three reasons in relation to a GIS based Mine Action project will now be staged.

First and foremost, logistic regression is specifically suited to modeling a dependent variable that has a dichotomous outcome[31]. As was the case with Alexander and Waters[32], Malo[33], Lee[34], and numerous other studies that used logit analysis, when a binary (ie: presence/absence format) dependent variable is under investigation we may be confident in conducting logistic regression analysis. This is particularly true when the probability of dependent variable occurrence is under investigation[35], and here we would be investigating the probability that a given location will be landmine contaminated. With the case of landmine location we are modeling the probability of existence, and then using the logistic regression coefficients as the proportion that each predictor contributes to the probability of occurrence. While Tapia[36] and Lee[37] were studying golden eagle habitat and landslide occurrence respectively, the robustness of the logistic regression predictive technique may be seen not only in the current

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[31] Ibid.

[32] S. M. Alexander. and N. M. Waters (2000). "The effects of highway transportation corridors on wildlife: a case study of Banff National Park." *Transportation Research Part C* 1(8): pp. 307 - 320.

[33] J. E. Malo, et al. "Can We Mitigate Animal –Vehicle Accidents using Predictive Models?, *Journal of Applied Ecology* 1(41), 2004, pp. 701-710.

[34] S. Lee, "Application of Logistic Regression Model and its Validation for Landslide Susceptibility Mapping using GIS and Remote Sensing data", *International Journal of Remote Sensing* 26(7), 2005, pp. 1477-1491.

[35] Dreiseitla, p. 352.

[36] L. Tapia, J. Dominguez, et al., "Modelling Habitat Use and Distribution of Golden Eagles Aquila Chrysaetos in a Low-Density Area of the Iberian Peninsula", *Biodiversity Conservation* 1(16), 2007, pp. 3559-3574.

[37] Lee, pp. 1477-1491.

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investigation's application but also in the prevalence of use in biomedicine. A vast number of biomedical publications have been indexed that make use of logistic regression[38], and evidently the reason is because with regard to medical conditions either a patient has one or does not.

The second main reason for choosing logit analysis to predict the presence of landmines is the fact that a wide array of input variables may be used. What this means is that we are not limited when choosing our predictors. The input variables may be continuous, categorical, or both[39] [40]. This is of particular importance when investigating a phenomenon such as landmine placement. This is because placement is the result of human activity, yet is likely influenced by a combination of both physical limitations (i.e.: topography) and cultural-geographic features (i.e.: distance to international borders, or distance to military installations). This relates to GIS based Mine Action projects because independent variables that are continuous, categorical, and nominal would have to be used.

The third reason for using logistic regression again is in relation to the nature of the dataset. A distinct advantage may be obtained in that we are not assuming normality with regard to the distributions of the variables used[41].

Since logistic regression coefficients may be interpreted as a percentage odds ratio of occurrence[42], the coefficients may also, in terms of GIS be used as ratios for the GIS modeling of input predictor GIS layers in turn creating a predictive surface; the details of this specific methodology will be discussed in the following section.

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[38] Dreiseitla, pp. 352-359.

[39] G. V. Ostir and T. Uchida, "Logistic Regression: A Nontechnical review", *American Journal of Physical Medical Rehabilitation* 1(79), 2000, pp. 565-572.

[40] Lee, pp. 1477-1491.

[41] Ibid.

[42] Ostir, pp. 565-572.

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Predictive GIS Modeling

Three key studies surfaced during the research of this literature review that use the method that will be outlined below. Lee[43], Tapia, and Malo are the most current examples of this method in practice, and they successfully predict golden eagle habitat, landslide locations, and animal-vehicle accidents respectively. This gives support to the contention that the logistic regression based method of predictive GIS modeling is a transferrable one, therefore making it useful in a broad range of application areas provided that the data are of an appropriate nature.

In general terms, the process for predictive modeling used in this experiment will now be explained. This will be performed both in terms of a review, and in terms of an information extraction endeavor for the purpose of the landmine experiment at hand. Firstly, it is appropriate to mention that in recent published predictive GIS modeling papers, it is evident that for dependent variables of a presence/absence nature that one must begin with a series of statistical tests so as to determine influencing factors before the GIS work can begin. Lee[44], Tapia, and Malo all use logistic regression to determine which predictors are influencing their respective dependent variables.

Lee[45] and Malo do not specify which of the common incremental model building types he uses. The three types are forward selection, backward selection, and stepwise[46]. The concept underlying each of the approaches is to introduce variables until "the ensuing new model [is] not significantly more informative than the previous one"[47]. Tapia is the one author who does make specific mention of the logistic

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[43] See discussions in Lee;Tapia; Malo
[44] Ibid.
[45] See discussions in Lee; Malo.
[46] Dreiseitla, pp. 352-359.
[47] Malo, p. 705.

regression method employed, and it was stepwise logistic regression that was used[48].

This is the tactic in which variables are both entered and removed, but with the same

goal of creating the most parsimonious (i.e.: fewest predictors) model. The reason for

attempting to achieve a parsimonious model is to avoid inflated standard errors[49]. This

contention is cross-supported in the paper on animal-vehicle accidents in that "reduced

models may be regarded as the best statistical tools for prediction that can be produced

using the minimum number of parameters"[50].

In terms of model significance, two out of the three key studies mentioned used

the Wald test in order to determine which predictors contributed significantly to the final

model (Malo, Suarez et al. [51] and Tapia, et al.[52]). Since the Wald test is an available

output in SPSS v13 (the intended software package for the current study) it appears

appropriate to use this when selecting variables for the current study on landmines

when the point of data analysis has been reached. On the side of final model

calibration and choice, it appears as though the consensus in the literature is to create

two models, one that is 'saturated' (i.e.: all potential predictors included) and then a set

of reduced models whereby a choice is made from that group as to which has the

greatest explaining power while being the most parsimonious at the same time[53].

After significant predictor variables have been established with the previously

described logit analysis, the recent studies highlighted in this review proceeded on to

the actual mapping of the predictive surfaces. While Alexander[54] used the Idrisi raster

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[48] See discussions in Tapia.
[49] See discussions in Ostir.
[50] Malo, p. 705.
[51] Ibid., pp. 701-710.
[52] See discussions in Tapia.
[53] Ibid.
[54] See discussions in Alexander.

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based GIS, the other studies used the ArcGIS and the GRID file format type. In essence, the process at this point involves using the previously calculated logistic regression coefficients as proportions with regard to the contribution of each predictor in the final surface. Lee[55] calculates a "frequency ratio" for his final surface and this would be akin to the "odds ratio" described in the Logistic Regression review by Ostir and Uchida[56].

Validation of the surfaces produced by all of the recent studies is the key to determining the validity of the prediction surfaces. It is in this way that the prediction may be described as effective or non-effective, and quantitatively to what degree. While Tapia (2007) does not offer details on the validation process both Lee (2005) and Malo (2004) offer some discussion on this topic. The key idea is to compare known locations with the prediction map (Lee 2005), and in this way a literal percentage of correct prediction may be obtained. Malo (2004) makes specific mention that a subset of known points is to be removed before subsequent analysis in order to provide the most true and unbiased indication of prediction effectiveness. Strikingly high effectiveness levels were achieved in all three studies, ranging from 78% to 87% accuracy in their predictions. Without exception, the parsimonious models were more effective than the saturated models, and in keeping with the methodology the saturated models were only used as references to indicate the relative contribution of each of the predictors[57].

One of the key points from Lee's study is that he refers to the predictive surface as a "landslide susceptibility index" and this lends support to the proposal that the

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[55] See discussions in Lee.
[56] See discussions in Ostir.
[57] See discussions in Malo.

resultant surface in the landmine study will be called the Landmine Likelihood Index[58]. An additional key point to extract from this review is, as Lee points out for certain topic areas it is necessary to have a-priori knowledge of the main causes of the dependent variable in question. Although out of scope at this stage in the literature review, it should be mentioned that with regard to landmine placement several sources in current literature have been identified that will provide the a-priori knowledge required for the landmine predictive surface experiment

Through this review of recent studies that have made effective use of GIS modeling, it appears quite plausible and reasonable to carry on with using logistic regression based GIS modeling so as to predict landmine locations. Using this methodology will allow us to identify areas of high priority for landmine clearance efforts in an equally relevant and effective manner as, for example, Tapia "[identifies] high-priority areas for golden eagle conservation"[59].

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[58] Lee, p. 1480.
[59] See discussions in Tapia.

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