SOUTH AFRICAN NATIONAL
DEPARTMENT OF DEFENCE

MILITARY DEPLOYMENT STRATEGY BASED ON RISK OF INCURSION BY LAND AND ECONOMIC VALUE

Analysis of Key Economic and High Risk Stations and the Allocation of Relevant Ground Protection to Available Military Bases in the Republic of South Africa

WBK BOSHOFF
U29274592
14 OCTOBER 2012

EXECUTIVE SUMMARY

The main objective of the military force of any country is to protect its citizens, resources and leadership. As long as the well-being and survival of the nation is at stake, this may be performed at any cost. Fundamentally, there is a strategy behind the decisions made by the military to station their troops at certain positions to protect the nation. This strategy is of great interest and will be explored in this study. Once this strategy is understood, military stationing decisions can be made under the guidance of a data model, showing mathematically the best place to station troops.

The mathematical model inherently draws input from the risk data and economic value data of each location in South Africa. The risk of a location sheds light on the likeliness of an enemy invasion at that position based on proximity, access, and capability, while the economic value portrays the reward an enemy might receive for invasion based on Gross Domestic Product delivered and population density in the area.

As the inputs are combined, a deployment need begins to unfurl across the country depicted by dark red spots on color graded maps. Taking into account the position of available military bases, their capacities and strike ranges, troops can be allocated to cover the rising risk patterns. The coverage of this deployment priority is the objective of the linear programming model in MS Excel. The model finds the best possible configuration of troops to bases to best cover the priority maps.

The results from this study are the recommended deployment strategies to be followed when analyzing risk and economic value as defined by the scope. It may not directly save money as the amount of troops remain unchanged between scenarios, but will certainly prepare military strategists for informed risk related decisions when the time comes. This study may be broadened in the future for more comprehensive deployment results that includes risk by sea and air strikes.

TABLE OF CONTENT

1. INTRODUCTION 6

1.1 Background 6

1.2 Incursion Risk 6

1.3 Economic Value 6

2. PROJECT AIM 7

3. PROJECT SCOPE 7

3.1 General 7

3.2 Incursion Risk 7

3.3 Economic Value Data 8

4. MODEL PARAMETER REVIEW 8

4.1.1 Background on Conventional Warfare 9

4.1.2 Economic Impact of War 9

4.1.3 Motivation for War 10

4.1.4 Introduction to Incursion Risk Analysis 10

4.1.5 Introduction to Economic Value Analysis 10

4.1.6 Risk-Value Relationship 11

4.2 LAND ASSAULT RISK ANALYSIS 11

4.2.1 Ground Accessibility Map 12

4.2.1.1 Terrain Types Map 13

4.2.1.2 Soil Types Map 14

4.2.1.3 Slope Map 16

4.2.1.4 Construction of the Ground Accessibility Map 17

4.2.2 Proximity to Enemy Map 18

4.2.3 Enemy Capability analysis 19

4.2.4 Construction of the Land Assault Risk Map 21

4.3 ECONOMIC CENTRES OF GRAVITY 23

4.3.1 Impact on GDP 23

4.3.2 Population Density 24

4.3.3 Criticality of industry to Nation's Survival (For Future Modelling) 25

4.3.4 Recovery Time of industry in Case of Disaster (For Future Modelling) 25

4.3.5 Construction of the Economic Value Map *25*

4.4 POSSIBLE METHODS TO OPTIMAL MILITARY DEPLOYMENT 26

4.4.1 Linear Programming Method – Preferred Method *26*

4.4.2 Simulation *27*

4.4.3 Centre of Gravity (COG) Study *27*

4. 5 THE RESOURCE – SANDF 28

4.5.1 History of Sandf *28*

4.5.2 Capability of SANDF *28*

4.5.3 Military Capacities of Bases *28*

5. OPTIMIZATION MODEL 30

5.1 Strategy *30*

5.1.1 Military Base Ranges *32*

5.2 Inputs *33*

5.3 Objective Function *37*

5.4 Results *40*

6. SUMMARY AND RECOMMENDATIONS 43

6.1 Summary *43*

6.2 Recommendations *43*

8. REFERENCES 45

7. APPENDICES 47

LIST OF TABLES

Table 1 - Weighted Elements of the Ground Accessibility Map 12

Table 2 - Terrain Type Rating Table 13

Table 3 – Soil Types Rating Table 16

Table 4 - Slope Rating Table 17

Table 5 - Proximity to Enemy Table 18

Table 6 - Initial Enemy Capability Table 20

Table 7 - Combined Enemy Capability Table 21

Table 8 - Weighted Elements of Ground Accessibility Map 22
Table 9 - Military Capacities of Cities 29
Table 10 - Weighted Elements of Ground Accessibility Map 34
Table 11 - Summed Risk-Value of the 14 Military Bases 38
Table 12 - Model Constraints 39
Table 13 - Model Results 40

LIST OF FIGURES

Figure 1 - Hierarchy of Land Assault Risk Map(LARM) 12
Figure 2 - Terrain Morphology Map 14
Figure 3 - Soil Types of South Africa 15
Figure 4 - Slopes in South Africa by Dept. of Water Affairs 17
Figure 5 – Enemy Proximity Map 19
Figure 6 - Enemy Capability Map 20
Figure 7 - Ground Accessibility Map - Output of Formula C 22
Figure 8 - Gross Domestic Product Density Map 24
Figure 9 - Population Density Map of South Africa 24
Figure 10 - Economic Value Map Output 26
Figure 11 - Image Data Processing 30
Figure 12 - Zoomed out appearance of the GAM data matrix input of the linear program 30
Figure 13 - Google Map showing Distribution of the 14 Military Bases 31
Figure 14 - Military Bases plotted in the Final Deployment Priority Map 31
Figure 15 - Ranges of Military Bases in South Africa 32
Figure 16 - Hierarchy of Model Inputs 33
Figure 17 – 3D Representations of the Sub-Elements of GAM 34
Figure 18 - 3D Representation of the Combined Elements form GAM 35
Figure 19 - Final Deployment Priority Map 36
Figure 20 - Thaba Tswane Military base range 37
Figure 21 - Results Map of Number of Soldiers allocated to each Range 41
Figure 22 - Afghan Troop Map: US and NATO Deployments 42
Figure 23 - Results from the Deployment Model 44

1. INTRODUCTION

1.1 BACKGROUND

Resting on the shoulders of the military sector of any country is the defense and well-being of its citizens, resources, and leadership. Even though South Africa has not been involved in an open confrontation with an enemy in many years, this does not keep the strategists of South Africa from suspecting and anticipating such an outcome. These strategists should keep asking themselves questions, such as, "What will be the course of action when a country, neighboring or distant, decides to build up its forces and invade our country?"

Traditionally when planning an attack, an enemy will make his decisions based the military risk he runs with invasion, and the economic advantage he gains by the move. The economic advantage can be seen as the reward for the risk venture of the military entity. When defending a location, a force will consider:

1. The risk an area runs of being invaded
2. The economic loss that can be realized from losing that position.

This defense approach will be the basis of the logic followed in this study.

1.2 INCURSION RISK

In analyzing a national security scenario, all possible invasion threats must be considered. Possible infiltration can occur by means of air, land, or sea. These borders contain countless points of entry, which calls for the elimination of the least likely landing zones. Areas with high risk of infiltration can be identified across the country and these locations and their risks can be mapped for use by optimization software.

1.3 ECONOMIC VALUE

The offensive force will try to capture economic strongholds, to not only cripple their enemy, but also improve their supply position. Locations of high economic value include but are not limited to large production industries, refineries, government, and financial sector companies. Economic value of a location is largely connected to the GDP and population density of that location and quantifies the importance of a location to the relevant nation.

2. PROJECT AIM

The aim of this project is to identify high incursion risk points, to identify points of high value to the economy of South Africa, and to develop a military power allocation strategy to be followed in the event of such incursions.

The analysis will weigh up the economic value against incursion risk at locations across South Africa, and recommend which proportion of available power capacity is to be assigned to each region or military base range, keeping a relevant basic military protection retainer (base defense force) at all military bases. The best allocation will be based on the maximum possible coverage of the risk-value matrix values.

3. PROJECT SCOPE

3.1 GENERAL

The reach of this study is limited by the availability of unclassified information. It is however in the interest of national security that no sensitive information be included in the study. For this reason, public or unclassified information was used to compile the inputs and formulate results.

According to Col. Janssen of the South African National Department of Defense (SANDOD), incursion can happen in many styles, and with different methods. Conventional warfare, as opposed to terrorism, is considered an open confrontation. It also excludes the use of biological, nuclear and chemical weapons (Garth and Hart, 2009). The style of warfare to be considered in this project is strictly conventional ground incursion. The model will exclude scenarios concerning terrorism and enemy stealth infiltration.

3.2 INCURSION RISK

The incursion risk in this project will be limited to land incursion threats by:

1. Botswana
2. Zimbabwe
3. Namibia
4. Mozambique
5. Swaziland

Full-scale land incursion is limited to several channels in the vast countryside between concentrations of high value points in South Africa and the bordering nations. It would be safe to demarcate these channels and identify them as higher risk areas.

Since referred risk is the second degree of invasion risk, only direct risk will be taken into account. This means the model takes into account only the first strike of the enemy force. In further simple terms, the model cannot account for risk that an area gains because of enemy movement/strike nearby (change in enemy proximity). For example this excludes the effect of Angola on the risk model, since it would have to move through one of South Africa's directly adjacent neighbors before performing its second strike.

3.3 ECONOMIC VALUE DATA

The economic value of a location represents the amount of usefulness of an area in an immediate (short-term) timeframe. Industries have high economic values, since these facilities can be utilized by the enemy for similar gain as deemed for the constructor. The value of a location South Africa will depend on its impact on GDP, population density, criticality of the type of industry, and the recovery time of the industry type. Cities inadvertently have high economic values, since they contribute the Gross Domestic Product, have a high population density and are critical to the economy of a nation. Sadly, low levels of data are available concerning the criticality of individual industries and their recovery time in case of usurpation or destruction. This excludes them from participating in the model, but will still be researched in the literature review.

4. MODEL PARAMETER REVIEW

Due to the sensitive nature of some of the analyses done in this field so far, it is very hard to come by proper academic material regarding the analysis and programming of war strategies. It is quite possible that the data manipulation and processing of "public data" in this project may generate an output which is considered sensitive. The material regarding defence modelling is either non-existent to the public eye or it has a price-tag which only individuals with access to a small country's turnover can afford, so it has been done with what is available. The utmost best has been done to comprehensively state the problem of military deployment as concisely and accurately as possible.

4.1.1 BACKGROUND ON CONVENTIONAL WARFARE

Wars have been waged between peoples, tribes and nations since the very beginning of time. The art of war has evolved from very primitive taking of life to complicated and calculated way of doing the same. In the words of the scriptwriter of the film Bunraku (2010), "[there are] more ways of killing a man than making bread, or making love."

Conventional warfare is the art of war that is the most common idea of structured warfare to the general mindset. It is traditionally the confrontation of two opposing forces in a structured fashion and in a designated location. Even though conventional warfare has been around for centuries, Master Sun Tzu, expert in the Art of War (translated John Minford 2002), comments that, "…just as water retains no constant shape, so in warfare there are no constant conditions." In a conventional war situation, anything can happen at any time, within the limits of this warfare genre. Conventional warfare, however, excludes acts of terrorism and guerilla warfare.

It should also be noted that in the view of some, a study of conventional warfare is outdated and focus should rather be placed on terrorism and unconventional forms of warfare. Hebrew University scholar Martin van Creveld (2006) states, "Since 1945, particularly in view of the vast increase in the number of independent polities, conventional wars, here defined as armed conflicts openly waged by one state against another by means of their regular armies, have become the exception rather than rule." However, a conventional threat should not be ruled out as a threat to national security, and an analysis in this field can only be beneficial to national security measures.

4.1.2 ECONOMIC IMPACT OF WAR

When a nation is at war, the entire country will feel the severe economic strain to keep the military supported. It is important to consider this, since mismanagement of the economic support can cause internal collapse a country. This view is supported by Kapstein (1992) in his statement: "War costs can disrupt national strategy no less than enemy forces." Braudel (1979) also supports this view when he states, "The expense of war cripples states..." For this reason, every nation has the responsibility to manage military spending carefully. Military overspending may in part be the reason of the collapse of the Greek economy recently. The spending of Greece on its defence topped countries such as that of the United Kingdom and France between years 1990 and 2009 (World Bank, 2011). Ineffective use of military funding is a national loss, and may be part of Greece's economic downfall.

4.1.3 MOTIVATION FOR WAR

To justify one country's invasion of another, the Greek term *casus belli* often comes to the fore. It is literally translated as the "reasons for war" in Greek law terminology. Even in modern war situations there have always been the identified *casus belli,* to convince the rest of the world that war is indeed unavoidable. For example, the United States referred to the attack on the World Trade Centre as their *casus belli* for the invasion of Afghanistan, and shortly afterwards used Iraq's alleged possession of weapons of mass destruction as the *casus belli* for the Iraq War (Second Gulf War).

Some common relevant Casus Belli of modern nations are mentioned below as quoted by Jackson and Morelli (2009):

1. Inaccurate intelligence regarding the pros and cons of war
2. Inability to reach an agreement or to respect or keep a previously formed truce or alliance
3. Beliefs

4.1.4 INTRODUCTION TO INCURSION RISK ANALYSIS

For any nation to attack South Africa, some *casus belli* must be prevalent. Be it in the gain and benefits of war, the analysis of this project will be relevant. The economic value of a region may be a logical *casus bellum* in the case of a South African invasion. Locations with high susceptibility and vulnerability must be marked on a map, to identify areas running a high risk of enemy invasion.

4.1.5 INTRODUCTION TO ECONOMIC VALUE ANALYSIS

The economic value of a location will be a deciding factor in its attractiveness to the enemy. When an enemy decides which locations to invade, they should consider the locations value to them as well as the value to the defending nation, as taking it would cripple the defender. The economic value of a location will depend on its:

1. Impact on GDP
2. Population Density
3. Criticality of Industry to nations economy (outside of scope)
4. Recovery Time in case of destruction (outside of scope)

Some industries will contribute handsomely to the Gross Domestic Product factor, but might be considered a luxury and will not be considered critical to the survival of the economy. Thus, losing such a luxury industry to the enemy will not have the same impact on the economy as dealing with a destroyed refinery, coal mine, railway station or armaments factory. The recovery time for a critical industry will ultimately also affect the urgency of protection needed. Some industries will take years to rebuild once destroyed, while others may have emergency stations that can be erected in a matter of months.

The concentration of a nation's citizens should also play a large role in the need for military protection. This may not affect the economy severely, but it is considered an imperative and honourable allocation of security forces. Human life is the most valuable resource any country has, and each citizen is considered an emblem of that country's pride and honour. Many a war has been waged over citizens suffering in foreign countries.

4.1.6 RISK-VALUE RELATIONSHIP

It is necessary to combine these elements of incursion risk and economic value in order to obtain the priority of security for locations around the country. Similar in idea to former United Nations Secretary General Ray Cline's (Bemidjisstate, 2006) attempt to quantify the perceived power of a nation, an equation has been formulated to give meaning to the incursion risk – economic value relationship.

The formula is to determine the Deployment Priority for each location is as follows:

Formula A: $DP = LARM * EVR$

LARM is the Land Assault Risk Map and EVR is the Economic Value Relationship (see section 5.2 INPUTS for details on Cline's model and Formula A)

As stated by Cline regarding his formula, Formula A is not suited for very accurate measurements but is to be used as guidelines for making strategic decisions.

4.2 LAND ASSAULT RISK ANALYSIS

When analysing terrain out of a military viewpoint, it is important to note certain geographical factors. To be able to move any amount of military personnel, the terrain and its advantages and disadvantages must be considered. In the case of conventional warfare, large numbers of troops and mechanized infantry will be moving together in some general direction. The numbers of materiel to move in such an operation ranges well into the tens of thousands. Note: Materiel in the traditional sense refers to military supplies and soldiers collectively.

Now, to localize the problem, channels of movement must be identified along the South African border, to anticipate the movement of any enemy troopers. These areas of high risk will be marked on a map called the Land Assault Risk Map (LARM). The main factors to be considered when choosing military operation routes to be drawn into this map are as follows:

1. Ground Accessibility
2. Proximity to the Enemy
3. Enemy Capability

The further hierarchy of the data maps may be explained visually in Figure 1.

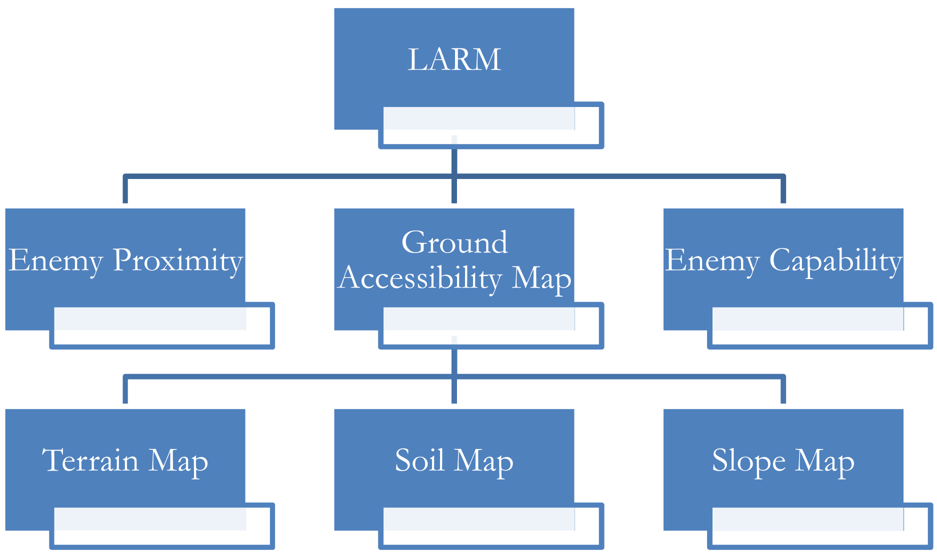


Figure 1 - Hierarchy of Land Assault Risk Map(LARM)

4.2.1 GROUND ACCESSIBILITY MAP

The Ground Accessibility Map is dependent on these elements with these weights:

Table 1 - Weighted Elements of the Ground Accessibility Map

Element	**Weighted Application***
Terrain Type	30%
Soil Type	30%
Slope	40%

**Data gathered from questionnaire in Appendix C*

These factors can be combined in to one resource map, the Ground Accessibility Map. Each factor receives a rating as to the importance of contribution toward the final accessibility of the map. The weights for the elements and sub elements have been chosen under the expert supervision of Colonel Bob Janssen and other staff of the SANDOD. The data was gathered through personal correspondence with Col. Janssen and through the use of a questionnaire collecting informed opinions from the high-level staff of the strategic planning department of SANDOD. The questionnaire can be found in Appendix C. The results from the questionnaire are presented as the relevant data maps are discussed.

4.2.1.1 TERRAIN TYPES MAP

According to Kleynhans and Moolman (from the South African Department of Water Affairs and Forestry) (2005) the terrain in South Africa has been divided into 6 categories:

Table 2 - Terrain Type Rating Table

#	Description	Accessibility Rating*
1	Plains, Low relief	1
2	Plains, Moderate relief	0.95
3	Lowlands: moderate to high relief	0.85
4	Open Hills: moderate to high relief	0.75
5	Closed Hills, mountains: moderate to high relief	0.65
6	Tablelands, moderate to high relief	0.75

**Data gathered from questionnaire in Appendix C*

The accessibility ratings are estimates made under supervision with regard to ground force access, transport ease and speed. Areas with a rating of 1 are considered easily travelled and therefore present a higher risk of sudden or unwarned incursion. Mountainous and high relief areas are still accessible by an enemy force, but a retardation factor has been implemented to show slowed transport speed and other mountain travel related problems.

There is however a concern that once the enemy has moved into a location of low accessibility, it will be harder to form a counter attack to flush the enemy from its new position. A compromise must therefore be reached between the views. Since the model however calculates risk of enemy incursion, the travel ease of the enemy will be considered, and not the travel ease of the counter attack.

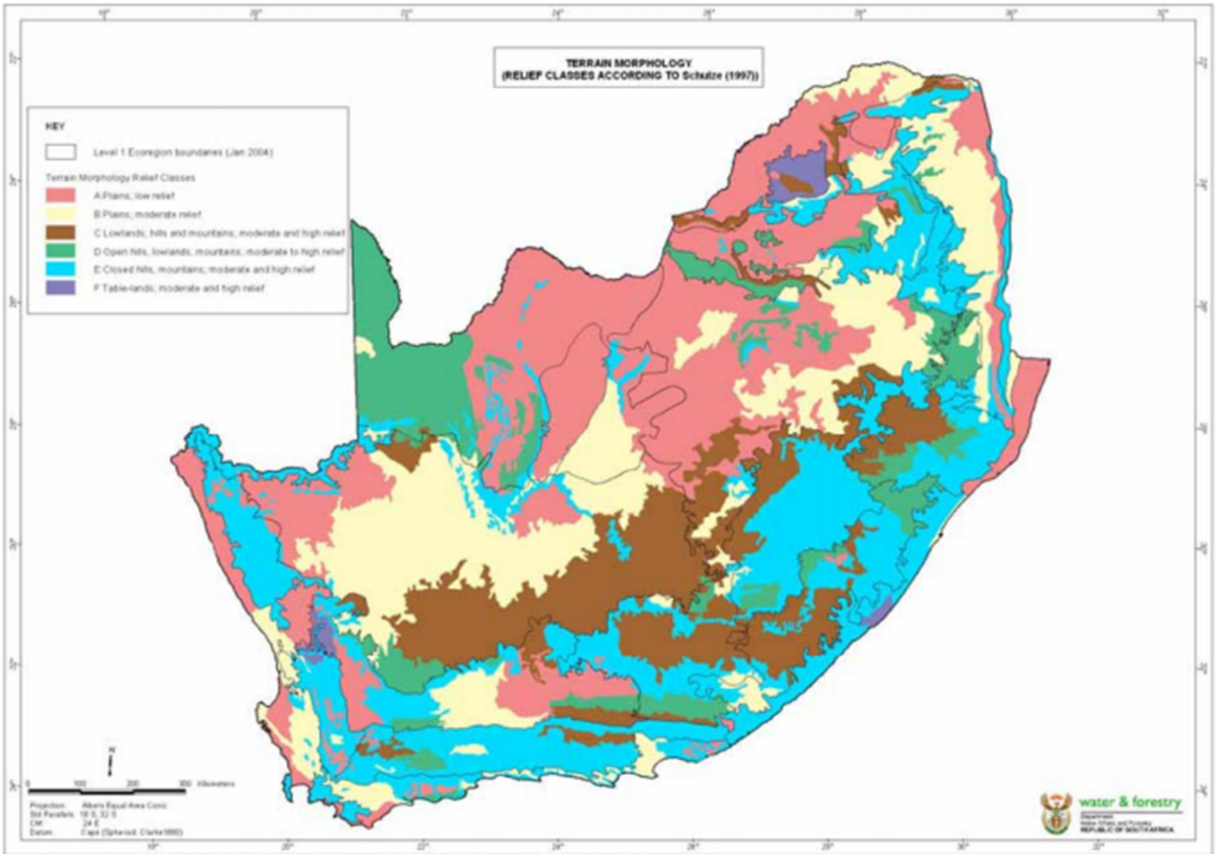


Figure 2 - Terrain Morphology Map

Source: Kruger G P (1983) Terrain Morphology Map of Southern African Soil and Irrigation Institute Dept. of Agriculture, Pretoria

The ratings have been chosen to correspond with the relief of the location. Relief is can be defined as the amount of difference between points in that area. If the elevations of points differ from each other dramatically, it is said to be of high relief. Clearly, areas of high relief will be less accessible than areas of low relief.

According to the ratings, it should be considerably (53%) more difficult to navigate through a mountainous area than through low plains.

4.2.1.2 SOIL TYPES MAP

According to the Food and Agriculture Organization of the United Nations (2012), the soil types in South Africa have been divided into 15 broad categories listed in Table 2:

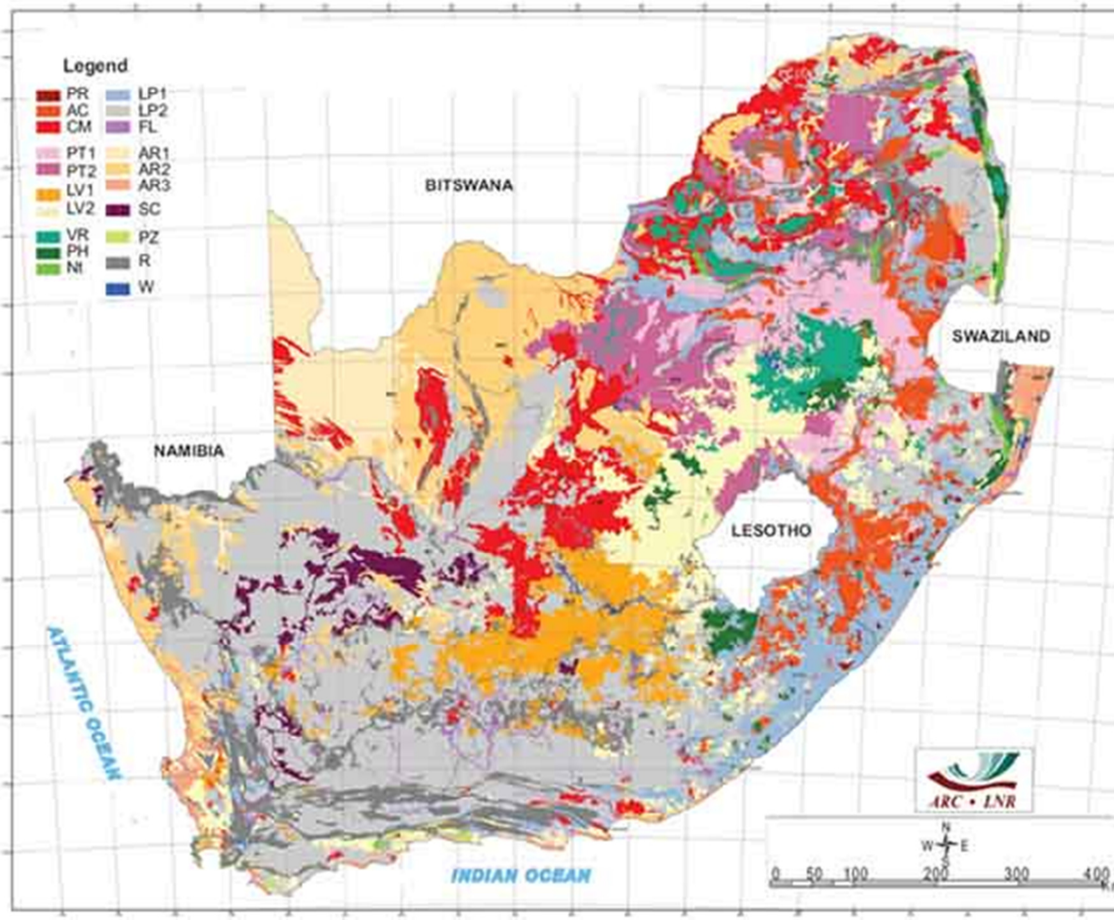


Figure 3 - Soil Types of South Africa

Source: FAO Food and Agriculture Organization of the United Nations Map of Soil Types
http://www.fao.org/docrep/008/y5998e/y5998e06.htm

The soil map is important to ground accessibility since it provides data on the types of soil an enemy force will have to travel through when advancing in South Africa. These soil types have each received an accessibility rating based on its base structure, clay content, and gravel/rock presence. When a vehicle moves over any soil, it may initially prove to be a good surface. This is not always the case when heavy vehicle upon heavy vehicle pass by the same route. Many a time the ground becomes inaccessible due to large clay pits or sand dumps forming.

Any deviation from a rating of 1 will signal a reduced accessibility in this area. Each pixel in this map will represent a location in South Africa, and a matrix of dimensions 100 x 89 pixels has been constructed containing the information on this map, each position holding a rating for its soil type.

Table 3 – Soil Types Rating Table

Soil	Characteristics	Military Accessibility Score*
Acrisols (AC) Cambisols (CM)	Weakly structured, low to medium base status Weakly structured, high base status	0.9 0.95
Plinthosols1 (PT1)	Low to medium base status	0.9
Plinthosols2 (PT2)	High base status	1
Luvisols1 (LV1)	clay accumulation, strongly structured	0.95
Luvisols2 (LV2)	clay accumulation, strongly structured	0.95
Vertisols (VR)	strongly structured, cracking and swelling clays	0.95
Leptosols1 (LP1)	Gravelly and rocky	1
Leptosols2 (LP2)	Gravelly and rocky	1
Arenosols1 (AR1)	Dunes are present	0.9
Arenosols2 (AR2) Arenosols3 (AR3)	High base status Excessively drained soils	0.95
Solonchaks (SC)	Saline marsh	0.9
Regosols (R)	Excessively Rocky	0.9

**Data gathered from questionnaire in Appendix C*

Source: Food and Agriculture Organization of the United Nations (2005)

4.2.1.3 SLOPE MAP

According to Kleynhans and Moolman (from the South African Department of Water Affairs and Forestry) (2005) the slopes in South Africa have been divided into 4 categories:

Table 4 - Slope Rating Table

#	Description	Accessibility Rating*
1	< 20 % Area with slope less than 50%	0.7
2	20 - 50 % Area with slope less than 50%	0.8
3	50 - 80 % Area with slope less than 50%	0.9
4	> 80 % Area with slope less than 50%	1

**Data gathered from questionnaire in Appendix C*

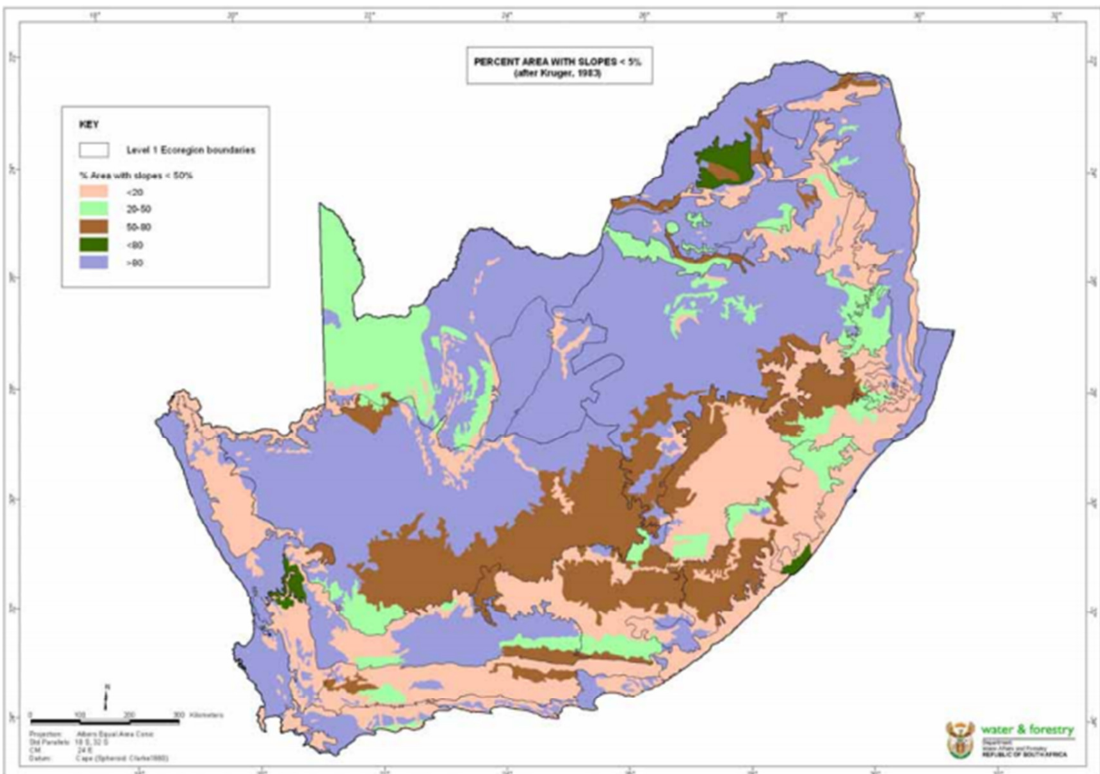


Figure 4 - Slopes in South Africa by Dept. of Water Affairs

Source: Kruger GP(1983) Terrain Morphology Map of Southern African Soil and Irrigation Institute Dept. of Agriculture, Pretoria

4.2.1.4 CONSTRUCTION OF THE GROUND ACCESSIBILITY MAP

Each map matrix constructed under the Ground Accessibility Map has the dimensions of 100 x 89 pixels or data points. For the data from these separate accessibility maps to be of use for the project, it is necessary to convert them to one map containing the data of all three maps. Each data point of the new Ground Accessibility Map (GAM) will be converted by the following formula.

Formula B: $(GAM)ij = (0.3 *TM)ij * (0.3* STM)ij * (0.4*SM)ij$ *for all i and j in 100 x 89 matrix*

TM = Terrain Map Dataset

STM = Soil Type Map Dataset

SM = Slope Map

Effectively, the landscape of South Africa has been divided into 8,900 zones, each of which has a rating for ground accessibility calculated using terrain, soil and geographical data.

The lowest score any location can receive would be when a location contains the lowest of each of the component maps. If an area has < 20 % Area with slope less than 50% (0.5), Regosols soil type (0.9), and Closed Hills, mountains: moderate to high relief (0.65), the appropriate rating will be 0.5 x 0.65 x 0.9 = 0.2925. This will indicate an inaccessible zone.

4.2.2 PROXIMITY TO ENEMY MAP

Areas that lie on the borders of the nation will naturally be more susceptible to the initial strike of an opposing force. They will serve as some sort of alert system to the rest of the nation, to warn of the progress of enemy forces as they move toward economic strongholds. It would be irresponsible to rule out the occurrence of a strike anywhere in South Africa, as they may be of aerial, naval, or insurgent land assault nature as well. For this reason, the default value of the map will be given as 0.5 rating. This means anywhere in South Africa there should be 50% urgency as compared to the areas adjacent to enemy territory.

Table 5 - Proximity to Enemy Table

#	Area Description	Safety Rating*
1	Directly Adjacent to Enemy Territory	0.5
2	Close to Enemy Territory	0.7
3	Within initial strike range of Enemy	0.8
4	Within Prolonged Siege Range of Enemy	1

**Data gathered from Col. Bob Janssen*

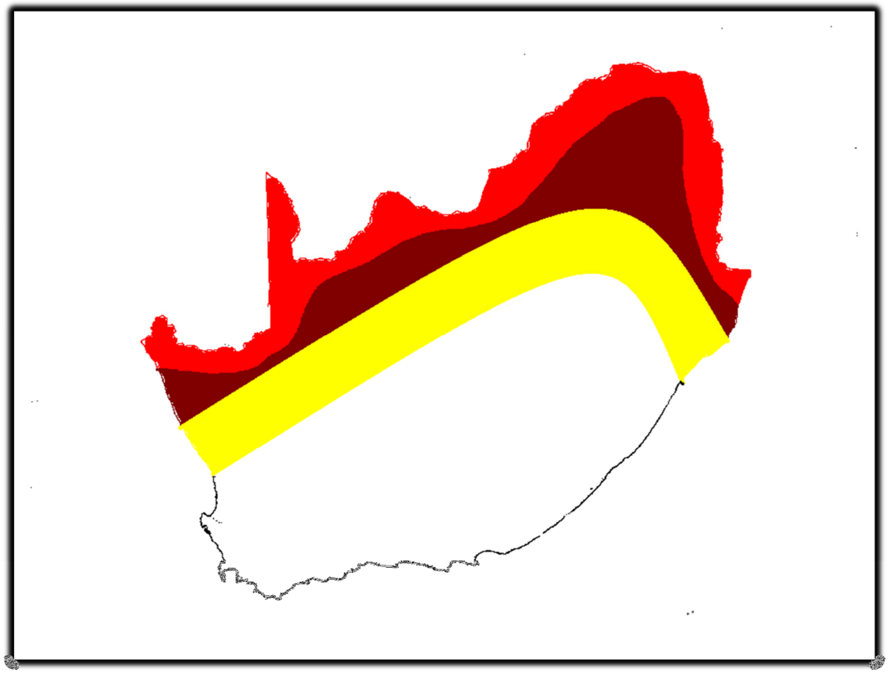


Figure 5 – Enemy Proximity Map

4.2.3 ENEMY CAPABILITY ANALYSIS

The hypothetical enemies of South Africa will be limited to the directly adjacent nations. These include:

1. Mozambique
2. Zimbabwe
3. Botswana
4. Namibia
5. Swaziland

Angola has been suggested by the supervising Colonel as a very real and prominent threat addition. However, since Angola has a referred risk on South Africa, and will have to move through one of the directly adjacent nation already taken into account, Angola will not be included in the model.

Each of these nations has a capability of attack. According to the Military Balance (2011):

Table 6 - Initial Enemy Capability Table

#	Description	Active Military Personnel	Percentage of Military Force in Southern Africa
1	Mozambique	11200	18.2410423
2	Zimbabwe	29000	47.2312704
3	Botswana	9000	14.6579805
4	Swaziland	3000	4.8859935
5	Namibia	9200	14.9837134
	Total	61400	100

The direction of these attacks can only be estimated, but it becomes clear that some areas are in danger of more than a single threat. The area surrounding Polokwane/Pietersburg can be reached from 3 of the adjacent nations, exposing it to (18.24 + 47.23 +14.65) = 80.1 % of the military force in Southern Africa (excluding South Africa and Angola).

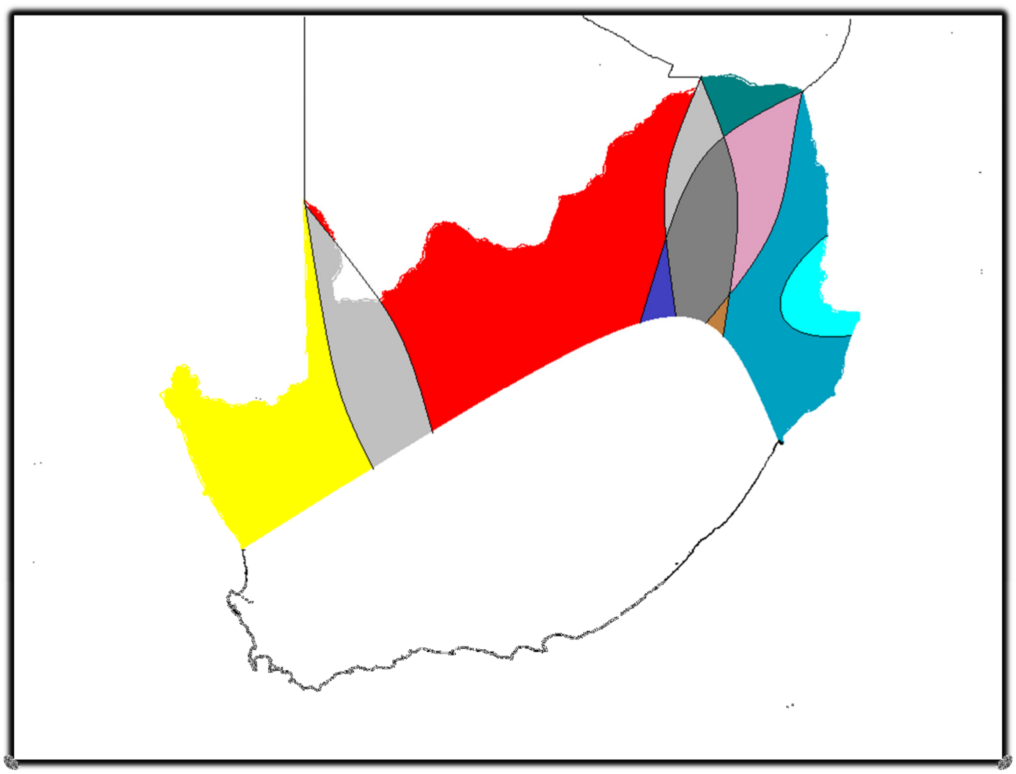


Figure 6 - Enemy Capability Map

It is now possible to assign the weighted rating to the enemy capability map. The weighted rating will be based on the maximum percentage of military force in South Africa. Even though Zimbabwe has the largest individual military force, the weighted ratings will depend on the area with the most enemy troops within range. The Polokwane area has 80.1% and therefore the weighted ratings will be a ratio of Polokwane's 80.1 % reach.

Table 7 - Combined Enemy Capability Table

#	Description	% Military Force	Weighted Rating*
1	Mozambique (Light Blue)	18.2410423	0.227642276
2	Zimbabwe (Blue Green)	47.2312704	0.589430895
3	Botswana (Red)	14.6579805	0.18292683
4	Swaziland	4.8859935	0.06097561
5	Namibia (Yellow)	14.9837134	0.18699187
6	Mozambique + Swaziland (Cyan)	23.1270358	0.288617886
7	Mozambique + Zimbabwe (Green)	65.4723127	0.81707317
8	Mozambique + Botswana (Blue and Brown)	32.8990228	0.410569105
9	Mozambique + Botswana + Zimbabwe (Dark Gray)	80.1302932	1
10	Botswana + Zimbabwe (Light Gray)	61.8892509	0.772357724
11	Botswana + Namibia (Gray)	29.6416939	0.3699187

**Calculated as a ratio relative to the maximum (grey)*

The weighted ratings of the areas are based on the maximum possible % enemy military power coverage. All areas will be shown as a ratio of the percentage coverage of the area threatened Mozambique, Botswana and Zimbabwe.

4.2.4 CONSTRUCTION OF THE LAND ASSAULT RISK MAP

Now that all of the requirement maps have been completed, the construction of the final risk map (LARM) can be commenced. It is based on the idea that each of the element maps play a weighted role the construction of the map. The elements are:

Table 8 - Weighted Elements of Ground Accessibility Map

Element	**Weighted Application***
Ground Accessibility Map	20%
Enemy Proximity Map	30%
Enemy Capability Map	50%

**Data gathered from questionnaire in Appendix C*

The weights have been selected by the supervising Colonel, to depict the relationships of priorities of each of the element with regard to the final risk map. The capability of an enemy plays the most considerable role in the consideration of risk. This is based on the decision of the Colonel as well returns of a questionnaire sent out to some members of the Strategy Advisors of the SANDOD team. The questionnaire can be found in Appendix C.

For this reason the construction of the Land Assault Risk Map will follow this formula:

Formula C: $(LARM)ij = (0.2*GAM)ij+(0.3* EPM)ij+(0.5*ECM)ij$ *for all i and j*

Since the data is generally listed between 0 and 1 for all the sub-maps of the LARM, adding the terms in Formula C will ensure that the data is not uncontrollably diminished by the continual multiplication of factors smaller than 1.

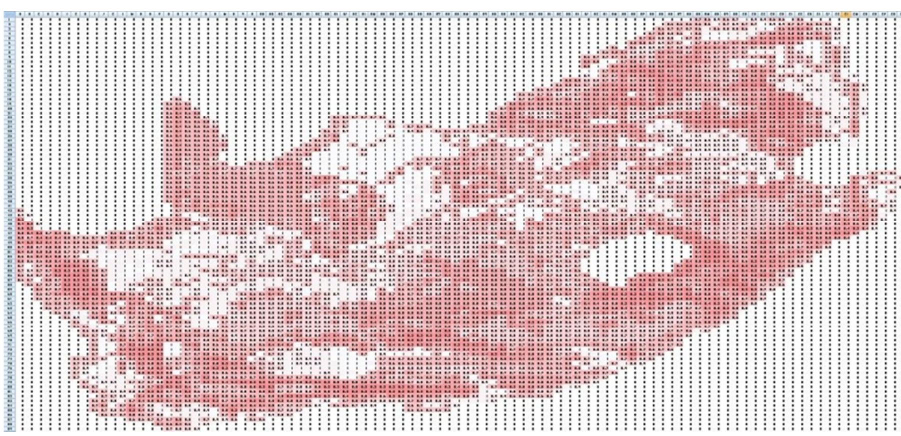


Figure 7 - Ground Accessibility Map - Output of Formula C

This output map forms part of the input of the linear program. Red indicates the least accessible and white indicates the most accessible. The economic value of a location is the remaining piece of input for the linear program to allocate soldiers in this study.

4.3 ECONOMIC CENTRES OF GRAVITY

In his work, *On War (Clausewitz, 1976)*, Carl von Clausewitz relates to strategic centres of gravity as "the hub of all power and movement, on which everything depends. That is the point against which all energies should be directed." This was written with an offensive plan in mind. According to the model in this paper, it will be interpreted in a defensive context to mean "…all energies should be directed [to protect]."

It would be good to note the general resemblance this early 1800's opinion has to the modern view on strategic economic centres of gravity. For example, Army FM 3-24 *Counterinsurgency* (2009) refers to COG as "the source of power that provides moral or physical strength, freedom of action, or will to act."

South Africa has widespread industry points which are crucial to the running of the country's financial end economic sectors. These points are to an extent the economic equivalent of Clausewitz's strategic centres of gravity. They represent the country's economic "…hub of all power and movement, on which everything depends." Should some of these locations be compromised, dire effects will follow on the rest of the nation.

To analyse the economic value of a location, these factors have to be taken into account:

1. Impact on GDP
2. Population Density
3. Criticality of Industry to Nation's Survival (outside of scope)
4. Recovery Time in case of destruction (outside of scope)

4.3.1 IMPACT ON GDP

The impact an industry has on the economy can to an extent be measured by the GDP drawn from the industry. The Gross Domestic Product is the calculated amount of revenue received by all goods and services sold or rendered. The distribution of GDP is as expected, with concentrations around the major cities and harbours. It is considered a 'soft power' of a nation, as opposed to 'hard power' being militant force (Yan Xuetong 2006).

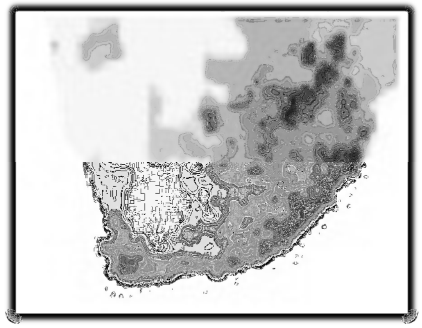


Figure 8 - Gross Domestic Product Density Map

Source: GDP Density map of South Africa, Geocurrents(2009)

4.3.2 POPULATION DENSITY

It is interesting to note the resemblance between the GDP Density map and the Population Density map shown below. It would be in the best interest of this project if the data shown was in fact the real GDP per km^2. Sadly, in most cases the GDP Density is calculated simply by multiplying the GDP per Capita figure by the population density of a certain area. For this reason, the maps are identical.

The value of the residents of a nation is very important to military leadership, and for this reason, the density of population will play a role in the economic value of a location in the form of the GDP map. This is because they are simply factors of one another.

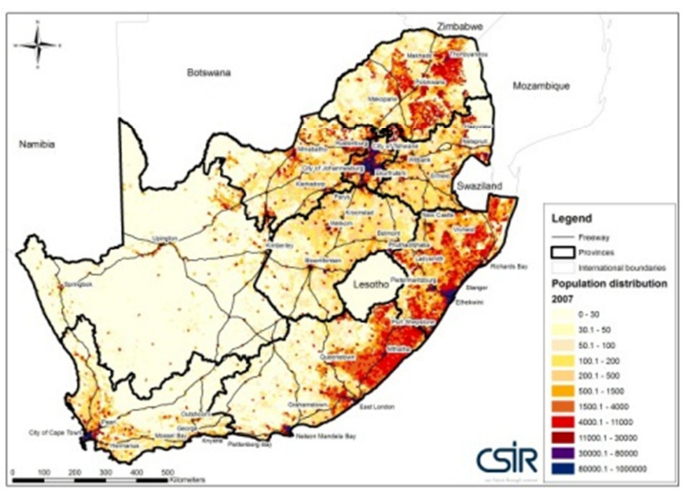


Figure 9 - Population Density Map of South Africa

Source: Population Density Map, SARVA (2007)

4.3.3 CRITICALITY OF INDUSTRY TO NATION'S SURVIVAL (FOR FUTURE MODELLING)

When analysing the GDP distribution in South Africa, one will notice that many of the industries which generate the most revenue are not critically essential to the survival of the nature. Industries such as real estate and luxuries will not crumble the nation's existence in the event of their failure. However, industries such as agriculture, electricity and transport will have a much direr effect on the nation's survival. Sadly, not enough public usable map data could be gathered to construct a comprehensive map of industries and their importance to nation's economy. Future studies can report on locational data of each industry and incorporate the data in the model.

4.3.4 RECOVERY TIME OF INDUSTRY IN CASE OF DISASTER (FOR FUTURE MODELLING)

In the same way, some industries will take longer than others to repair and return to its initial production capacity in the event of destruction or damage. A nuclear power plant or oil refinery may take years to recover to its former glory, while a simple manufacturing plant may be back in business within months. This analysis, however, is admittedly unpractical since comprehensive data is not available, and the possibility that an enemy will take the industry instead of destroying it is prevalent. This analysis would again become relevant in the event that a retaliation strike will win back the industry and then recover it to its previous state.

4.3.5 CONSTRUCTION OF THE ECONOMIC VALUE MAP

Ultimately, the economic value map is the result of the combination of the following maps:

1. Population Density Map
2. GDP Density Map

The Population Density and GDP Density Maps have been combined since they are merely factors of one another as explained earlier. The calculation of a data point in the Economic Value Map is simply the Population Density of the location. The output is displayed in figure 10.

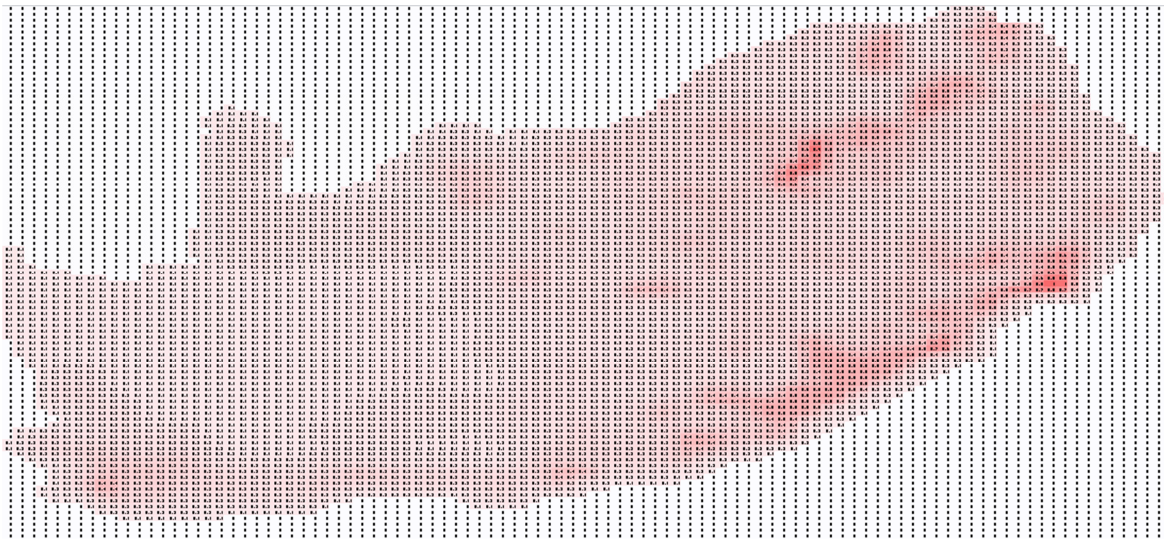


Figure 10 - Economic Value Map Output

4.4 POSSIBLE METHODS TO OPTIMAL MILITARY DEPLOYMENT

Before any decision on method of analysis can be made, the problem must first be completely understood, and all limitations and required functionality taken into account. This particular military problem has large amounts of data, and large amounts of variables. Since in a 100 x 89 matrix map, 8900 unique data points exist, and a total of 8 maps exist, indicating that the total amount of data points considered exceed 50000 data points. The optimization method should be able to handle these amounts of data points and be able to satisfy an objective function which allocates resources to 14 military bases across South Africa.

4.4.1 LINEAR PROGRAMMING METHOD – PREFERRED METHOD

A linear programming approach will maximize the objective function of summed risk-of-range times number of soldiers allocated to range, with the number of soldiers allocated set as the variable for each available military base range. The constraints will be the capacity and minimum allocation of a security for each military base, also known as base defence force, and the total amount of SANDF soldiers available for deployment in South Africa.

Map images loaded into octave can be converted to 3D matrices using the `imread` command. This generates the 3D Red Green Blue (RGB) matrix from which grey-scale layers can be isolated. A RGB photo is 3 photos each printed in one of the primary colours. A photo will be printed in red ink, after which an image will be printed in blue, and lastly printed in green. These three picture matrices can be interpreted by the Octave `rgb2gray` command to form a gray-scale image matrix. This black and white map is in turn turned into a matrix ranging from 0 (black) to 255 (white). Once converted to the gray scale range, the data is imported into MS Excel from which conditional formatting highlights the change in matrix values.

Once all the maps have been converted to matrices, the maps are considered layers in the final input of the linear program. The layers are combined in weighted ratios, to accurately relate the importance of each layer. Each military base has an effective range or area, which is its jurisdiction. The linear program will read the risk of each range (jurisdiction) and multiply it by the amount of soldiers allotted to the area, producing a value for the covered risk. This coverage of risk value is the maximized function of the linear program

4.4.2 SIMULATION

Excessively large numbers of parameters tend to clog up a simulation; it becomes "computationally challenging" in the words of Marko Hofmann (2005) in his research on parameter sensitivity in simulation. Simulation for the entire country of South Africa would indeed prove to be a task for the books. The data inputs would overwhelm any student edition simulation software available at the University of Pretoria, and would consume the time of an entire team of engineers.

The output from such a simulation may, however, be more valuable than first anticipated, since the results would be able to expose sensitive variables. For the use of this project, simulation would not be a practical answer to the processing of data intensive maps, due to the large amount of variables and data points.

4.4.3 CENTRE OF GRAVITY (COG) STUDY

COG analysis is very helpful in the selection of central locations due to the gravity of the factors. It would however give only one centre of gravity for the entire area under consideration, whilst the real locations (bases) are already in place. Furthermore, it would not be able allocate troops in the specific areas of risk, but will rather place them in a central position, with the risk evenly distributed around them. In future applications, it should be helpful to do such an analysis as well, to get a better picture of where any central unallocated forces should be stationed.

4. 5 THE RESOURCE – SANDF

The South African National Defence force has been called the most prepared and most capable military force in Africa (IISS, 2011). However, it has also been said that they lack some of the battle efficiency as portrayed by some of the other African nations (IISS, 2011). This may raise some eyebrows with regards to protection of the African economic giant.

4.5.1 HISTORY OF SANDF

The SANDF was formed in 1994 when the apartheid era came to its final halt. It was formed from the original South African Defence Force (SADF) which was considered by many as a world class fighting force (Noel Stott, 2002). The subsequent SANDF is still considered a formidable force in the continent of Africa.

4.5.2 CAPABILITY OF SANDF

According to the South Africa's Minister of Defence, the military have been underfunded and underequipped. He is convinced that the SANDF can once again become the leading African power (IISS, 2011), but remains non-resilient on his plea for added funding for national security. This having been said, the current SANDF numbers are as follows:

Active – 62082 personnel
Civilian – 12382 personnel
Reserve – 15071 personnel
Total – 89535 personnel

4.5.3 MILITARY CAPACITIES OF BASES

SANDF makes use of major bases at Bloemfontein, Johannesburg, Durban, Kimberley, Ladysmith, Lothala, Nelspruit, Kroonstad, Oudtshoorn, Pietersburg, Port Elizabeth, Potchefstroom and Youngsfield (Global Security, 2008). Because of the sensitive nature of military capacities, these capacities were fabricated under the guidance of the supervising Colonel Bob Janssen, to protect the interest of national security

Table 9 - Military Capacities of Cities

#	City	Estimated Capacity	Percentage of Total SANDF Power*
1	Bloemfontein	21000	13
2	Johannesburg	13500	8
3	Durban	16500	10
4	Kimberley	6000	4
5	Ladysmith	9000	5
6	Lothala	12000	7
7	Nelspruit	10500	6
8	Kroonstad	1500	1
9	Oudtshoorn	9000	5
10	Pietersburg	13500	8
11	Port Elizabeth	10500	6
12	Potchefstroom	13500	8
13	Youngsfield	13500	8
14	Thaba Tswane	14000	9
	Total	164000	100

**Data fabricated under supervision*

These will act as the deployment points within the model, since military personnel cannot be deployed in the bush for undisclosed amount of time. The capacity of each military deployment site will act as the maximum number of troops to be allocated to that area.

Military bases will need a number of troops to form the basic security of the facility. According to the US Department of Defence Military Dictionary (2001), the term 'base defence forces' refer to the 'troops attached to the base for the primary purpose of base defence and security…' For this reason, some of the troops stationed at a military base may not be removed. Thus, a minimum number of soldiers at base are required at every base listed above.

5. OPTIMIZATION MODEL

5.1 STRATEGY

From the constructed maps, data can be gleaned. Each color can be converted into a respective color number using the GNU Octave application. Map images loaded into Octave can be converted to 3D matrices using Octave's built in image editor commands, and further to CSV Excel files using `rgb2gray` and `dlmwrite` commands. The output is matrix of values ranging from 0 (black) to 255 (white), depicting the rating relevant to that colour.

Figure 11 - Image Data Processing

1. Full color – 2. Gray scale – 3. Integer matrix – 4. Ratio matrix with Conditional Formatting

The ratio matrix of each map is unique and has different rendered 'picture' when zoomed out in the Excel spread sheet. The ratios however follow the guidance of the cadre of SANDOD by means of Appendix C. A zoomed out render of one of the matrices is given below. Each of the pixels represents a data point, and has a value (ratio) and a tint of the conditional formatting.

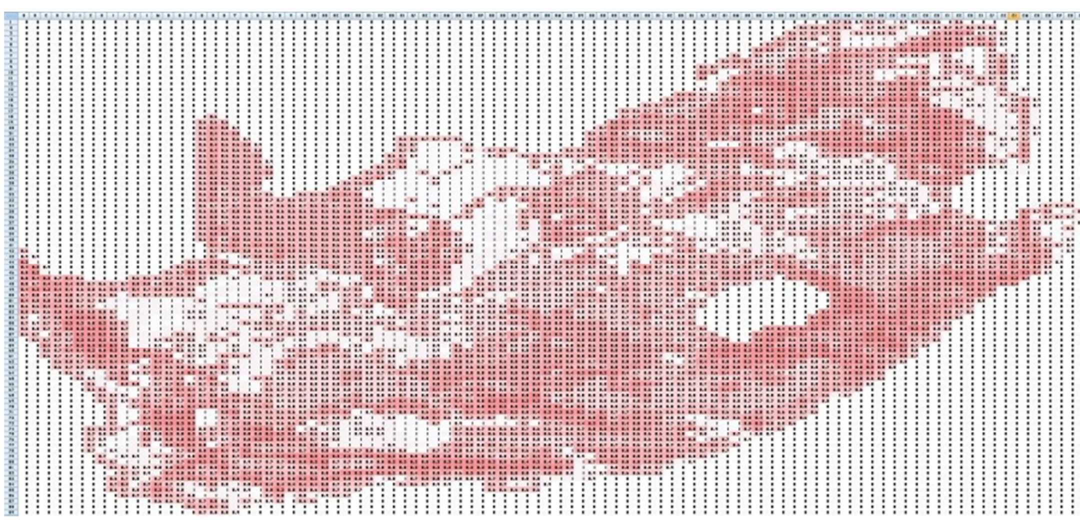


Figure 12 - Zoomed out appearance of the GAM data matrix input of the linear program

Figure 12 is a map of 8900 data points which represents the Ground Accessibility Map. Note the ease of travel close to the Botswana border, and the dark red spots surrounding Lesotho and in parts of the Mpumalanga area. Be aware that the Ground Accessibility takes into account more than the % slope of a location. It also takes terrain type and soil types into consideration.

Once the inputs are ready, the locations of the military bases are plotted on the input map. From the public data obtained through Global Security (2008), the locations of the military bases listed in Table 9 have been plotted to a map in Google Maps. These are the locations accepting soldiers.

Figure 13 - Google Map showing Distribution of the 14 Military Bases

Source: Google Maps – Military Base Map

These maps clearly show the concentration of military facilities in the Gauteng area.

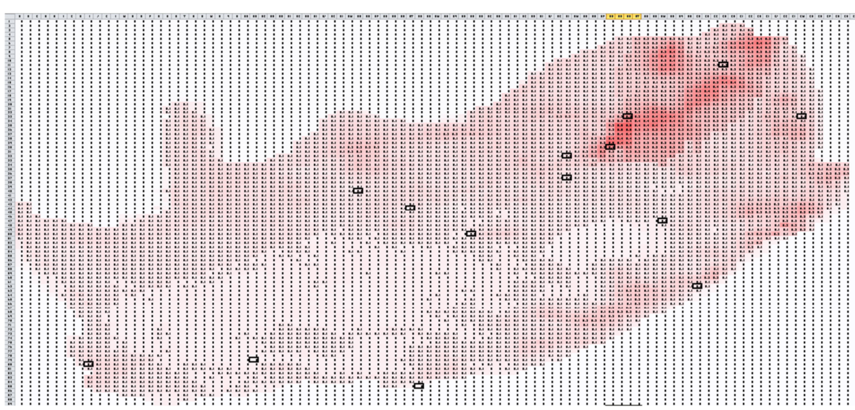


Figure 14 - Military Bases plotted in the Final Deployment Priority Map

5.1.1 MILITARY BASE RANGES

Each of listed military bases has an effective range. A dynamic range for each base was considered, but proved to put the model into a non-linear category. In simple terms, a dynamic range means as the number of soldiers stationed at a base increases, so does the range of deployment of the base itself. Since the dynamic base ranges change with every minute change in number of stationed soldiers, the model would be plummeted into a computational abyss and would require software with non-linear model capabilities.

Alternatively, fixed ranges can be chosen for each base, and would remain constant regardless of the amount of soldiers stationed to their barracks. This method has proven to be better suited for the practicality of the report, and reduces the complexity of the model. This method however puts the relevance of the output data at risk since it requires the ranges to be chosen as fixed areas. This method requires insight into the capacities and capabilities of each military base. Military bases in the Karoo area will have to cover greater areas (Oudtshoorn, Lohathla), while bases close to each other, such as in the Gauteng area, cover less ground area but greater proportion of the population.

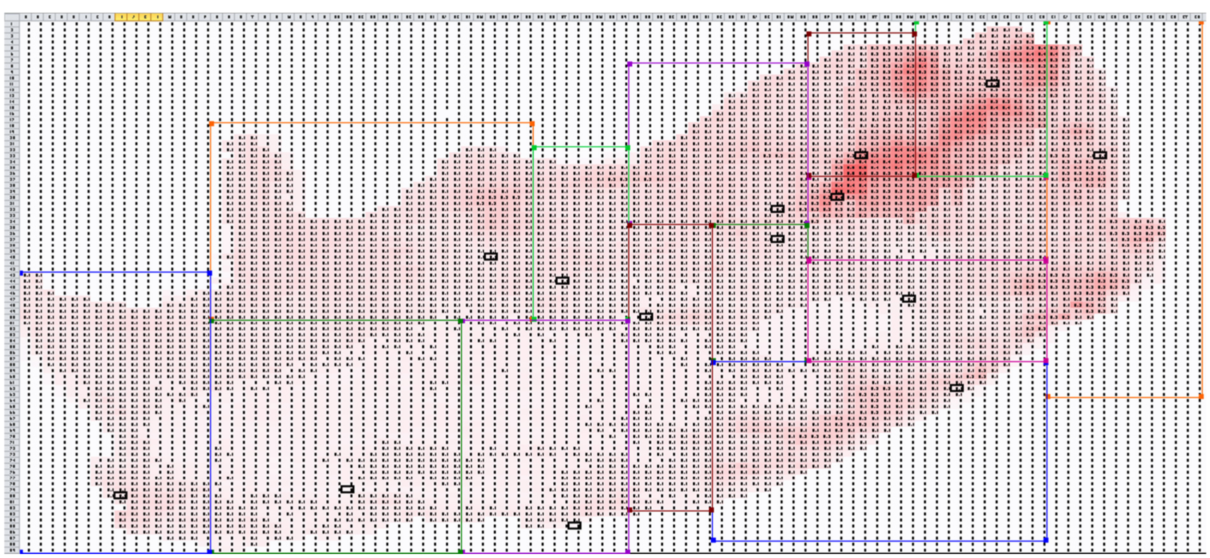


Figure 15 - Ranges of Military Bases in South Africa

It has proved an arduous task to select the most factors affecting the range of a base. Guidance from the Colonel was broad, and assumptions were required. The assumption was made that the base ranges are subject to the following criteria:

1. Location and Population Density
2. Proximity of other bases
3. Capacity of respective base

It was thought best to not have the ranges of the military bases overlap, since the risk in this area would then be covered twice or more, depending on the amount of bases within range. This would mean the model could find the solution to a high risk area by deploying a large number of soldiers to each of 2 or more overlapping bases, each returning high values for the objective function. This would result in an inaccurate output.

5.2 INPUTS

The input of the model has 2 main parts, which in turn have a total of 12 sub-factors affecting them. These factors are proportionally combined to produce their parent part. The methods of combination have been discussed in each relevant map section. Here is the breakdown of the factors affecting the linear model.

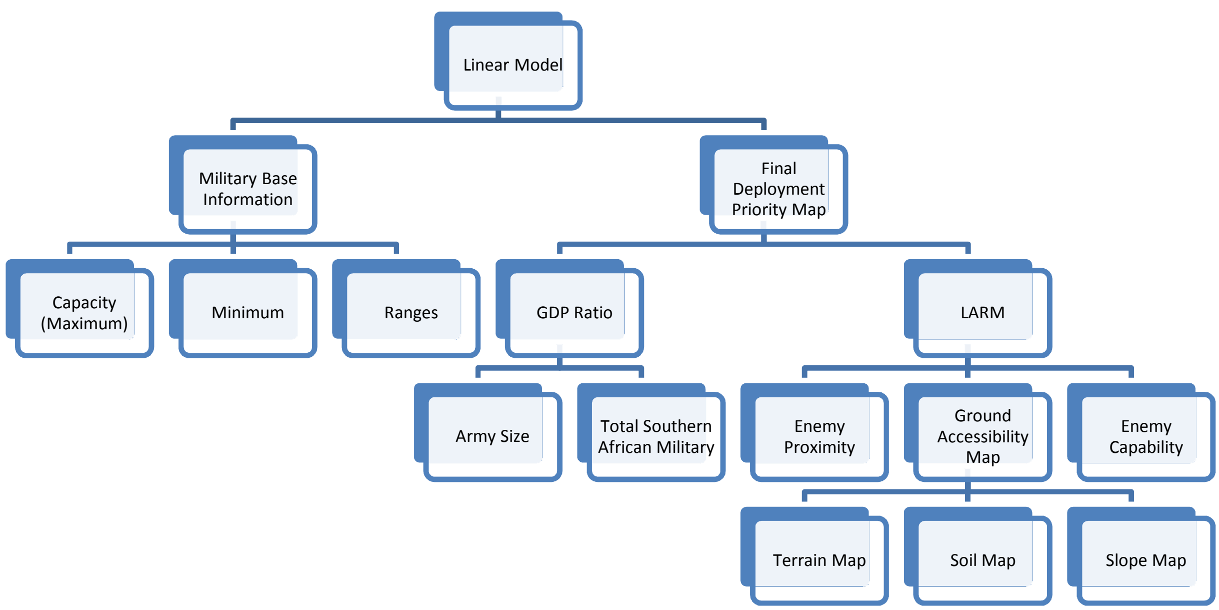


Figure 16 - Hierarchy of Model Inputs

The maps are combined with a unique strategy each time. As explained before, the construction of these maps follows a process, to ensure realistic data output from the combined map. Take the Ground Accessibility Map as an example. The 3 elements thereof are combined with these weights:

Table 10 - Weighted Elements of Ground Accessibility Map

Element	Weighted Application*
Terrain Type	30%
Soil Type	30%
Slope	40%

**Data gathered from questionnaire in Appendix C*

These maps are combined in the proportions or weights mentioned above to form their parent, the Ground Accessibility Map (GAM). The three input maps of GAM are stacked on top of each other in the proportions provided by the questionnaire in Appendix C. Now, the data of the GAM from MS Excel is given by these 3D surfaces for illustration:

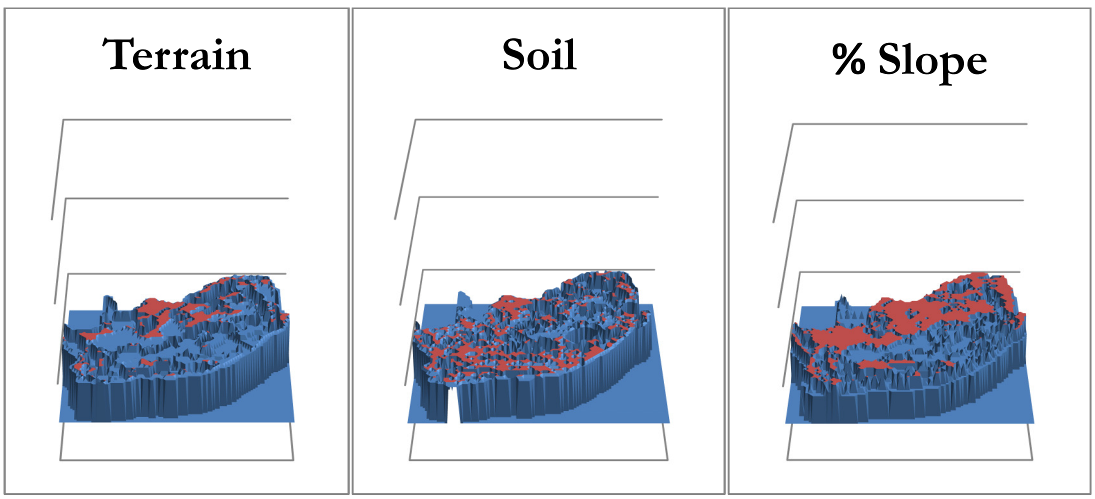


Figure 17 – 3D Representations of the Sub-Elements of GAM: Terrain Type, Soil Type and % Slope Maps respectively

Note how all three maps have red peaks in different places. When these are combined in the fashion advised by Colonel Bob Janssen, they will accentuate some areas, and some areas will lose its sub-elemental urgency. The maps are combined to form the GAM by using Formula B mentioned earlier. Fig. 10 is the two dimensional representation of this 3D GAM.

Formula B: $(GAM)ij = (0.3 *TM)ij * (0.3* STM)ij * (0.4*SM)ij$ *for all i and j in 100 x 89 matrix*

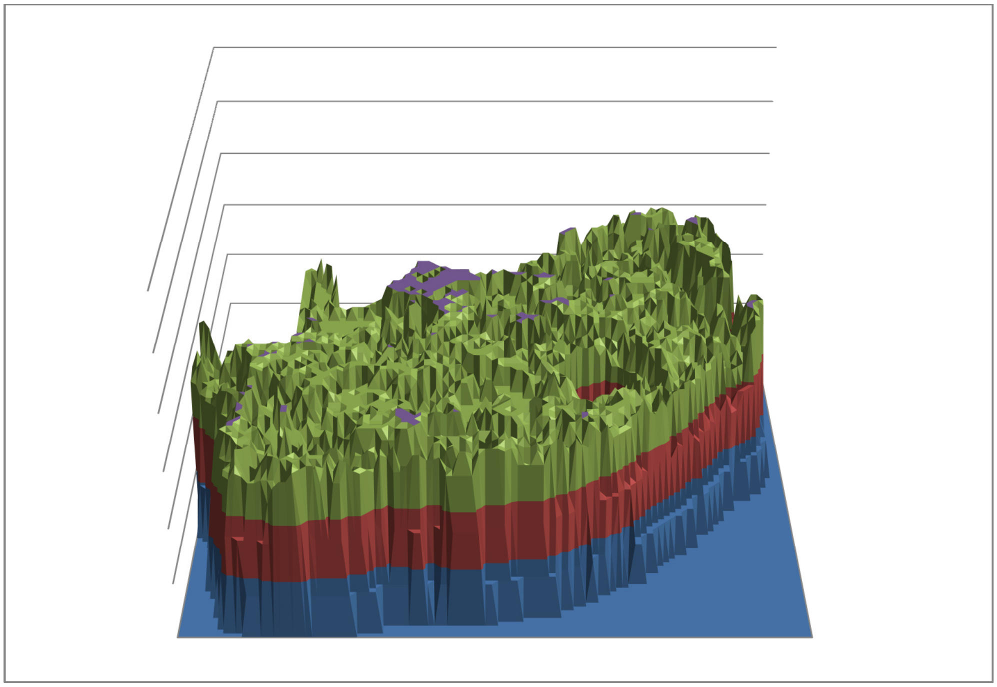


Figure 18 - 3D Representation of the Combined Elements form Ground Accessibility Map (GAM)

Similarly, data for the Enemy Proximity, Enemy Capability and Ground Accessibility maps are combined into the Land Assault Risk Map (LARM) using the proportions provided by Colonel Bob Janssen in Section 4.2.4 using formula C.

Formula C: $(LARM)ij = (0.2*GAM)ij+(0.3*EPM)ij+(0.5*ECM)ij$ *for all i and j*

This is then combined with the economic data to produce our final conglomerate input. This final process employs the Formula A.

Formula A: $(DP)ij = (LARM)ij * (EVP)ij$ *for all i and j*

Since deploying soldiers to an area of high risk but low value is illogical, a way has been found to prioritize the exiting risk by taking the economic value of a location into consideration. An area with low risk, but high economic value, should have higher priority than an area of high risk but of low or no value. For example, some areas bordering Botswana and Namibia have high risk in terms of the LARM composition (Enemy Capability, Enemy Proximity, and Ground Accessibility) but lack any type of economic value. Soldiers stationed here would be protecting nothing from a large probability of attack. All the while, there are areas within cities in Limpopo with a fraction of the risk, but with high economic value, thus demanding more protection than the areas bordering Namibia and Botswana.

Yan Xuetong (2006), regarding Ray Cline's power equation sheds light on the equality of military capability and economic value. From the section he explains 'soft' power to be economy, territory, and population related, and 'hard' power to be military might or capability related. "The concept that comprehensive national power is a product rather than a sum of 'soft' and 'hard' powers introduced by Cline makes us realize that 'soft' power is as equally important as 'hard' power in political reality. As both 'soft' and 'hard' powers stand as factors, if one of them is zero, no matter how large the value of the other is, the total value of the comprehensive power will be zero." On grounds of Cline's statements regarding the equality of 'soft' and 'hard' powers, the assumption to multiply LARM to EVP is justified. Areas with zero economic value will nullify any risk in that area. It will also exponentially prioritize the protection of high-value areas. The final risk-value map is given in the Final Deployment Priority Map in Fig. 18

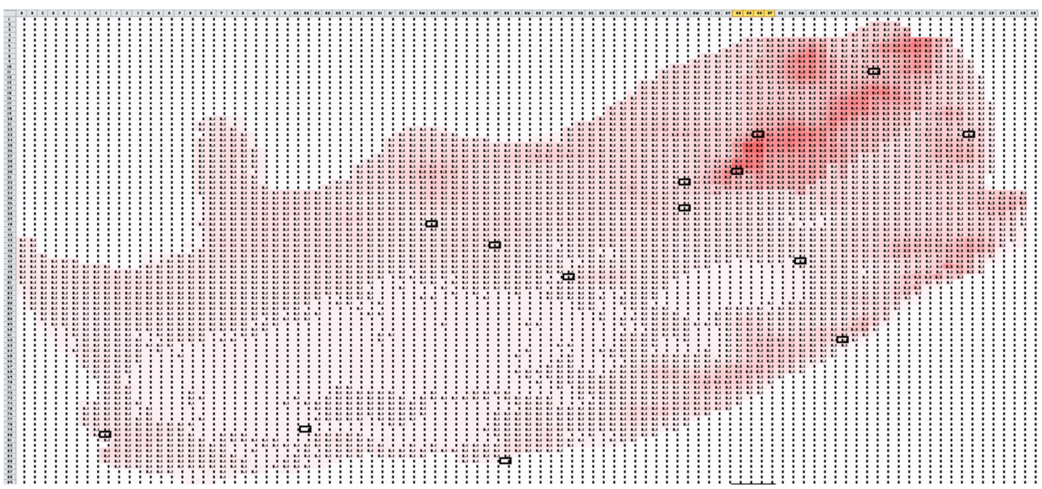


Figure 19 - Final Deployment Priority Map

Note the high risk-value in the Gauteng/Polokwane region as opposed to the lower risk-value of the economically valuable Richard's Bay area. The GDP Ratio map alone would have highlighted areas such as Durban, Bloemfontein, and Cape Town, but the presence of the Enemy Proximity and Enemy Capability maps' influence in the Final Deployment Priority Map accentuate the high risk-value areas dictated above.

5.3 OBJECTIVE FUNCTION

The high risk-value areas on the map are targeted by the objective function. Soldiers are allocated to high risk-value areas and satisfy them. So every soldier placed in a high risk-value area is of more value than one placed in a lower risk-value area. It is this value, the coverage value that we wish to maximize in our model.

Since we have 14 bases to supply soldiers to, and each base has a coverage area (range), we can calculate the risk-value of each area by summing the risk-value data points within its range. For example, Fig. 18 shows the risk-value points of Thaba Tswane military base. Summing all of its point will give a risk-value for the entire area covered by Thaba Tswane military base.

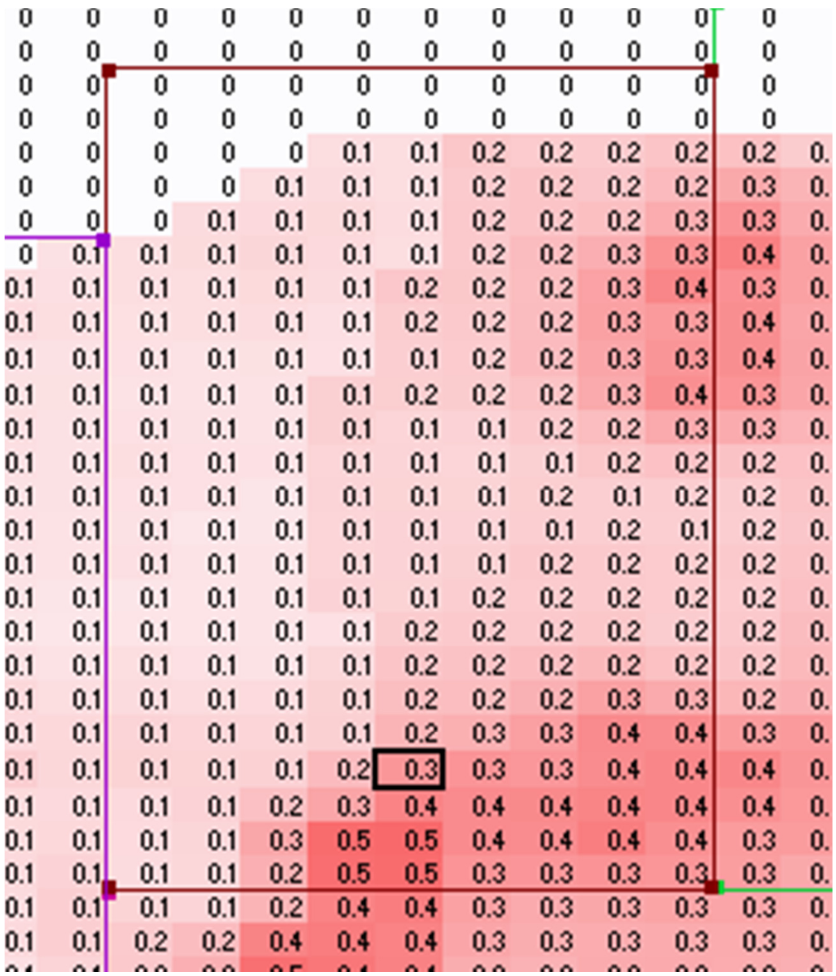


Figure 20 - Thaba Tswane Military base range

Listed below are the summed risk-value values for the 14 military bases under consideration.

Table 11 - Summed Risk-Value of the 14 Military Bases

#	Military Base	Summed Risk-Value	Percentage Total Risk-Value
1	Youngsfield CT	29.04877	6.475347
2	Oudtshoorn	36.6259	8.164388
3	Port Elizabeth	22.66472	5.05226
4	Durban	30.8368	6.873924
5	Ladysmith	23.74299	5.292621
6	Bloemfontein	20.122	4.485455
7	Kimberley	17.28625	3.85333
8	Lohathla	53.49649	11.92506
9	Kroonstadt	11.89789	2.652194
10	Potchefstroom	30.95079	6.899332
11	Johannesburg	37.77859	8.421339
12	Polokwane	56.09465	12.50422
13	Nelspruit	43.3325	9.659376
14	Thaba Tswane	34.72721	7.741146
	Total	448.6056	100

The data from Table 11 provides the objective function with a coefficient for each of the variables associated with a base. It can now compute the coverage value for each are by starting to change the values of the variables (Xi). At a quick glance at the table reveals that a soldier stationed to Polokwane or Lohathla will be twice as valuable in terms of coverage value as a soldier in Port Elizabeth or Kimberley.

The objective function is given by Formula D below.

Formula D:

Objective Function: $Maximize\ z\ ;\ z = sum(SRVi * Xi)$ *for all i*

SRVi is the Summed Risk Value for area I from Table 11

Xi is the amount of allocated soldiers to area I (variable)

Constraints:

Xi must be smaller than the maximum capacity of military base i

Xi must be larger than the minimum 'base defence force' of military base i.

The sum of all Xi must be smaller than the total amount of soldiers currently employed by the SANDF.

Table 12 - Model Constraints

#	City	Estimated Maximum	Minimum – Base Defense Force
1	Bloemfontein	21000	4000
2	Johannesburg	13500	3000
3	Durban	16500	3000
4	Kimberley	6000	1000
5	Ladysmith	9000	2000
6	Lothala	12000	2000
7	Nelspruit	10500	2000
8	Kroonstad	2500	1000
9	Oudtshoorn	9000	2000
10	Polokwane	13500	3000
11	Port Elizabeth	10500	1000
12	Potchefstroom	13500	1000
13	Youngsfield	13500	5000
14	Thaba Tswane	14000	2000
	Total	62082*	32000**

* This is the total number of available soldiers from SANDF records, not the sum of individual maximums.

** This value is the sum of all the minimum values, giving the minimum total number of soldiers to be allocated.

5.4 RESULTS

MS Excel's built in Solver proved to be a simple yet effective tool for a simple solution. Since the problem at hand is strictly linear in nature, the Simplex LP engine is selected. The solver ran for only a few seconds before returning the following results.

Table 13 - Model Results

X	**Base**	**Base Defense**	**Total Allocated**	**Base Defense only?**
x1	Youngsfield CT	5000	5000	yes
x2	Oudtshoorn	2000	2000	yes
x3	Port Elizabeth	1000	1000	yes
x4	Durban	3000	3000	yes
x5	Ladysmith	2000	2000	yes
x6	Bloemfontein	4000	4000	yes
x7	Kimberley	1000	1000	yes
x8	Lohathla	2000	12000	no – 10000 more
x9	Kroonstadt	1000	1000	yes
x10	Potchefstroom	1000	1000	yes
x11	Johannesburg	3000	4082	no – 1082 more
x12	Polokwane	3000	13500	no – 10500 more
x13	Nelspruit	2000	10500	no – 8500 more
x14	Thaba Tswane	2000	2000	yes
	Total	32000	62082	

The results of the model are to be expected after taking a closer look at the Final Deployment Priority Map listed earlier (Fig. 18). The 5 main areas where risk-value has driven the objective function can be found in:

1. Lohathla
2. Polokwane
3. Nelspruit
4. Johannesburg
5. Youngsfield

These areas all have some common characteristics. They include:

1. Being close to an enemy territory
2. Being in range of a capable enemy
3. Being reasonably accessible by land (very accessible in the case of Lohathla)
4. Being situated in areas of reasonable to high economic value (excepting Lohathla which has to support a very large area)

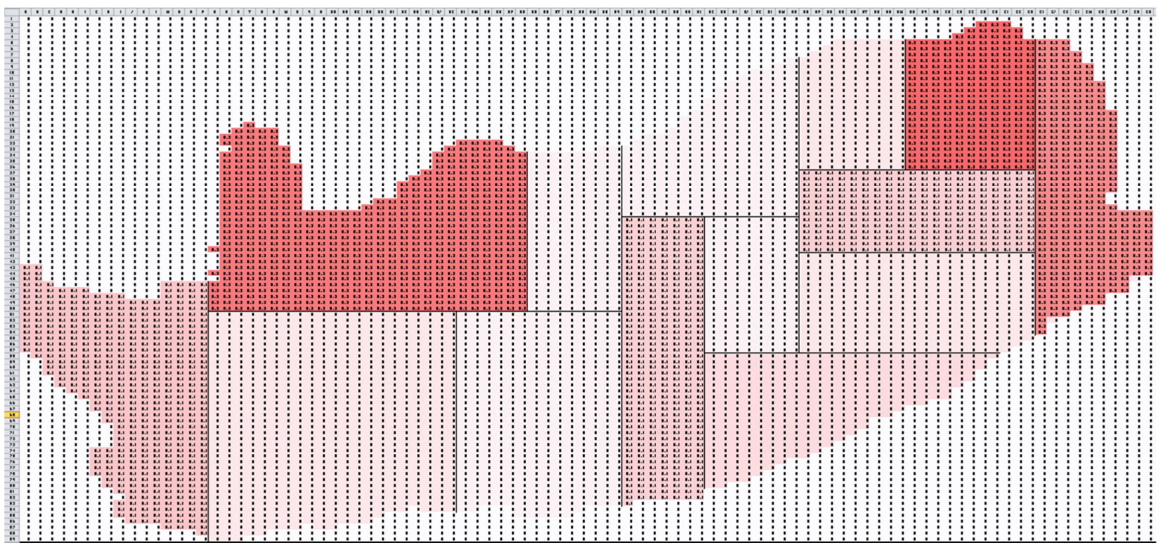


Figure 21 - Results Map of Number of Soldiers allocated to each Range

Polokwane, Lohathla and Nelspruit receive large allocations due to the overlap of enemy capability in the areas. In Lohathla, the area is under risk of invasion by both Namibia and Botswana. The area surrounding Polokwane shares the capabilities of three forces, namely, Botswana, Zimbabwe, and Mozambique, while Nelspruit shares risks of Mozambique, Swaziland, and Zimbabwe. It is interesting to note that the allocation to Johannesburg and Cape Town are very similar. Johannesburg has a larger impact on GDP than does Cape Town, but the Youngsfield base in Cape Town has a much larger area to cover.

If the optimal deployment program for land invasion is to be followed, Polokwane, Lohathla, and Nelspruit must receive priority, after which troops will be allocated to Johannesburg, Youngsfield and the rest of the bases.

The results of modern world attack strategies follow the same trend in decision making. According to the Institute for Defense Studies and Analyses (IDSA) in India (2009), the large risk involved in the US army staying on in Afghanistan whilst overspending on their military budget and economic capacity drove the US to decision regarding the Afghanistan withdrawal. Below are the offensive approach model results from a study done on risk of deployed US and NATO troops in Afghanistan. There is no information available on the methods or inputs involved, but the results and decisions made make for an interesting real life comparison.

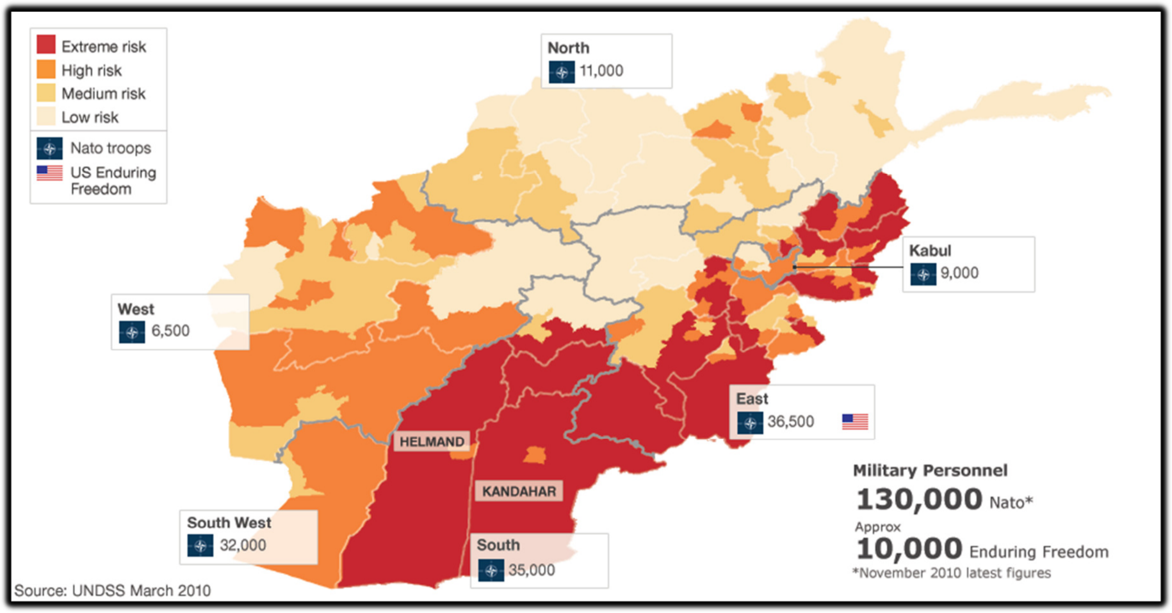


Figure 22 - Afghan Troop Map: US and NATO Deployments

6. SUMMARY AND RECOMMENDATIONS

6.1 SUMMARY

Looking back, the optimal allocation of troops between South African military bases to cover land invasion risk followed these waypoints:

1. Risk analysis of the country – based on Enemy Proximity, Enemy Capability and Ground Accessibility which included Terrain, Soil and Percentage Slope maps.
2. Economic Value analysis – indicated a locations value to the economy based primarily on the GDP and Population Densities
3. Combination of Inputs – presented Risk-Value relationships and constructing parent data maps from sub elements by stacking maps using predetermined relationships
4. Summary of Military Bases – included gathering information on location, capacity, base defense forces and range
5. Development of Linear Program – set up Excel Solver to maximize the objective function which was defined as the coverage value based on the risk-value relationship and number of soldiers deployed
6. Linear Program deploys troops – satisfied constraints of capacity, maximized objective function
7. Results generated and interpreted – geographically present LP's optimal strategy, explain why the model would have chosen these areas.
8. Next step – incorporate results with further studies regarding naval and aerial risks and setting up an implementation strategy

Future Applications: This model and its methods may in a modified state be applicable to other military operation and base risk analyses including offensive risk analysis and in-field troop defense analysis.

6.2 RECOMMENDATIONS

Since the model output clearly shows the optimal deployment strategy based on land invasion risks and economic value, a preliminary deployment decision based on land invasion risk can be made. Figure 23 visually guides the distribution process by highlighting the military bases to be given deployment priority with quantities provided by Table 13.

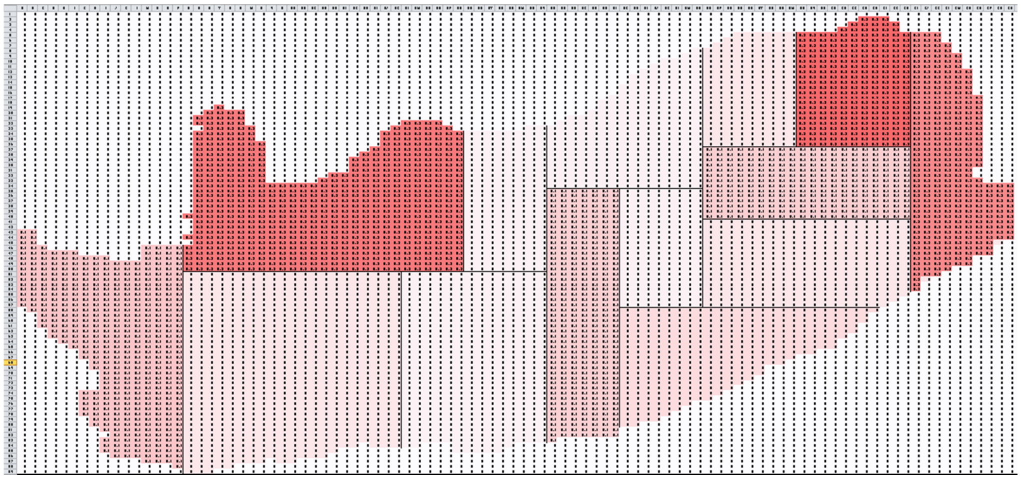


Figure 23 - Results from the Deployment Model

These results do not require the dismissal of any current soldiers in the SANDF, but rather allocate them differently across the country to best cover the risk areas. Therefore, no amount of money was saved as a result of the project. The quantifiable benefits of the analysis will only come to the fore in the event of a neighboring military unrest, when the coverage of the high-risk high-value areas will become increasingly important.

The results of this study must however be combined with further risk study results before implementation can begin. The scope of the study however limits the deployment by taking only risk of land incursion of neighboring countries into account, whilst the naval and aerial strike risks are left out. These excluded factors can accentuate different areas of risk and thus have a drastic effect on the ultimate deployment plan. It is recommended that the studies in the following areas be performed before an informed and accurate deployment strategy can be formulated.

1. Naval assault risk
2. Aerial Strike risk
3. Terrorist infiltration risk
4. Non-conventional warfare risks

8. REFERENCES

1. IISS (2011), *The Military Balance 2011*, pp.441, London: Routledge

2. World Bank (2011), The Little Data Book 2011, London: World

3. Collins, 2004, Collins English Dictionary, Glasgow: HarperCollins Publishers

4. B. C. Garth and J. Hart 2009, The A to Z of Nuclear, Biological and Chemical Warfare, Lanham: Scarecrow Press

5. Rove.To."457 Shuttle Images of Kuwait." Images from NASA. 1998. < http://rove.to/kuwait/ >(January 4, 2003)

6. Hofmann M. (2005), On the Complexity of Parameter Calibration in Simulation Models, *JDMS,* Volume 2, Issue 4, October 2005 Pages 217–226 © 2005 The Society for Modelling and Simulation International,http://www.scs.org/pubs/jdms/vol2num4/Hofmann-pp217-226.pdf [06 May 2012]

7. Stott N. (2002), From the SADF to the SANDF,*CSRV,* Volume 7, 2002 Pages 1 http://www.csvr.org.za/wits/papers/papvtp7.htm [06 May 2012]

8. IISS (2011), *The Military Balance 2011*, pp.452, London: Routledge

9. Bunraku, 2010, Motion Picture, Guy Moshe, distributed by Arc Entertainment,Toronto.

10. Van Creveld M, Modern Conventional Warfare: An Overview, 2006 , Hebrew University, Jerusalem, <http://www.dni.gov/nic/PDF_GIF_2020_Support/2004_05_25_papers/modern_warfare.pdf> [06 May 2012]

11. Kapstein, Ethan B. (1992). The Political Economy of National Security: A Global Perspective, South Carolina: University of South Carolina Press

12. Braudel F. (1979), National Civilisation, Economy and Capitalism, 3 Vol, Armand Colin, Paris.

13. Jackson M.O, Morelli M. (2009), The Reasons for War – an Updated Survey, Chris Coyne, Elgar Publishing, Stanford
14. Kleynhans, CJ, Thirion, C and Moolman, J (2005). *A Level I River Ecoregion classification System for South Africa, Lesotho and Swaziland.* Report No. N/0000/00/REQ0104.Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

15. Food and Agriculture Organization of the United Nations, 2005. Fertilizer Sue by crop in South Africa [online]. Available at: <http://www.fao.org/docrep/008/y5998e/y5998e06.htm#TopOfPage> [Accessed 05 May 2012].

16. Clausewitz C, *On War*, 1976, Howard/Paret translation eds./trans. Michael Howard and Peter Paret Princeton: Princeton University Press, 1976, revised 1984

17. Department of US Army, *Counterinsurgency,* FM 3-24.2 i. Field Manual. No. 3-24.2. Headquarters Washington, DC, 21 April 2009, <http://usacac.army.mil/cac2/coin/repository/fm3242.pdf> [Accessed 25 April 2012]

18. Global Security, (2008), *South African Defense, Army Bases,* [online] Available at: <http://www.globalsecurity.org/military/world/rsa/army-base.htm> [Accessed 05 May 2012]
19. Sun Tzu translation by John Minford (2002). *The Art of War*. Viking Press, New York
20. Statistics SA (2010), *GDP 3rd Quarter 2010*, [online], Available at: < http://www.statssa.gov.za/publications/P0441/P04413rdQuarter2010.pdf> [Accessed 04 May 2012]
21. Geocurrents(2009), *GDP Density map of South Africa,* [online], Available at: <http://geocurrents.info/economic-geography/non-state-based-atlas-preface-part-ii> [Accessed 01 May 2012]

22. US Department of Defence (2001), *Dictionary of Military and Associated Terms* , [online], Available at: <http://www.fas.org/irp/doddir/dod/jp1_02-april2010.pdf > [Accessed 01 Sept 2012]

23. SA Risk and Vulnerability Atlas (2007), *Population Density Map* [online], Available at: <http://www.sarva.org.za/enews/issues/03/images/47_large.jpg> [Accessed 01 Sept 2012]

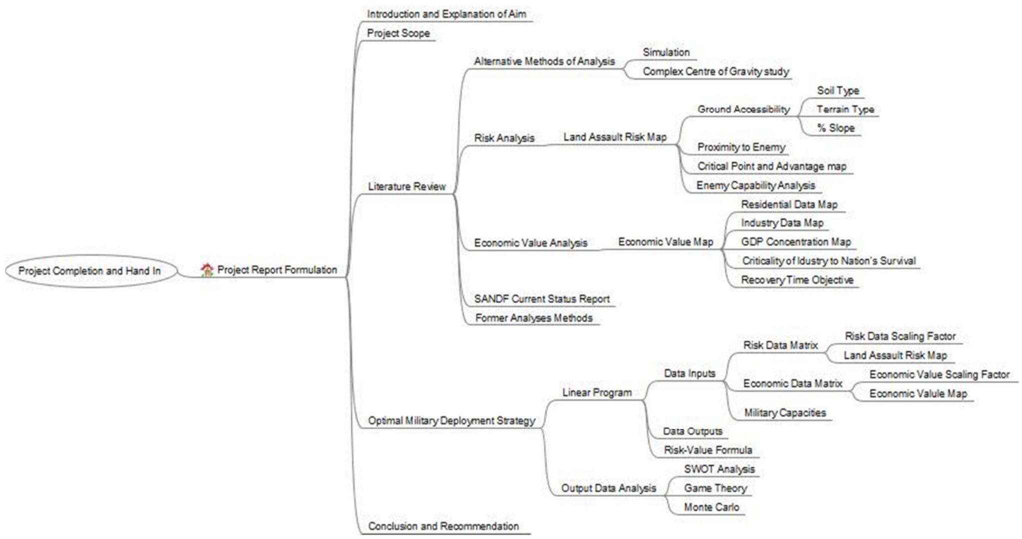
24. Institute for Defense Studies and Analyses (IDSA) (2009), *Afghan Troop Map* [online], Available at: <http://www.idsa.in/idsacomments/AneconomicallyexhaustedAmericaiswithdrawingfromAfghanistan_agupta_081209> [Accessed 01 Sept 2012]

25. Yan Xuetong (2006), *The Rise of China and its Power Status*, [online], Available at: <http://cjip.oxfordjournals.org/content/1/1/5.full.pdf [Accessed 01 Sept 2012]

26. Bemidjisstate (2006), *Political Science 1300 Power*, [online], Available at: <http://www.bemidjistate.edu/academics/departments/political_science/faculty/beech_notes/introir/POWER.htm> [Accessed 01 Sept 2012]

7. APPENDICES

Appendix A: Mind Map and Work Breakdown Structure for Project



Appendix B: Budget for Optimal Military Deployment System Project

	Optimal Military Deployment System Project Budget		
		Subtotal	**Price (R)**
	Budget:		
.1	Travelling Expenses +- 1000km	R 1,000.00	
.2	IISS Military Balance (Statistics) -Book	R 2,907.00	
.3	Stationary	R 400.00	
.4	Internet	R 400.00	
			R 4,707.00
	Total Project Budget		**R 4,707.00**

Appendix C: Questionnaire completed by staff of SANDOD

STRATEGY FACTOR SURVEY QUESTIONNAIRE

BY WBK BOSHOFF - 0725567255

This is survey wishes to gather informed opinions regarding risk and economic factors in South Africa from a military strategy point of view. The information collected herein will be used be a student (WBK Boshoff) in his final year project at the University of Pretoria in his degree for Industrial Engineering. His work will be freely available to anyone who wishes to read it, so please do not include classified information. Please mark the correct box or fill in percentages:

1. In time of war, which is the most important factor to consider when surveying a location (provide percentages if possible. Eg. 40 % Risk of Attack and 60% Economic Value):

Risk of Attack	Economic Value

2. In time of war, the risk of a location being attacked depends on which factors most (provide percentages if possible. Eg. 40 % Risk of Attack and 60% Economic Value):

Accessibility by Enemy	Distance to Enemy	Capability of Enemy

3. From military wartime perspective, the economic value of a location depends on which factors most (provide percentages if possible. Eg. 40 % Risk of Attack and 60% Economic Value):

Revenue Generation by location	Population Density of location	Criticality of location to nation's economy	Recovery Time in case of destruction

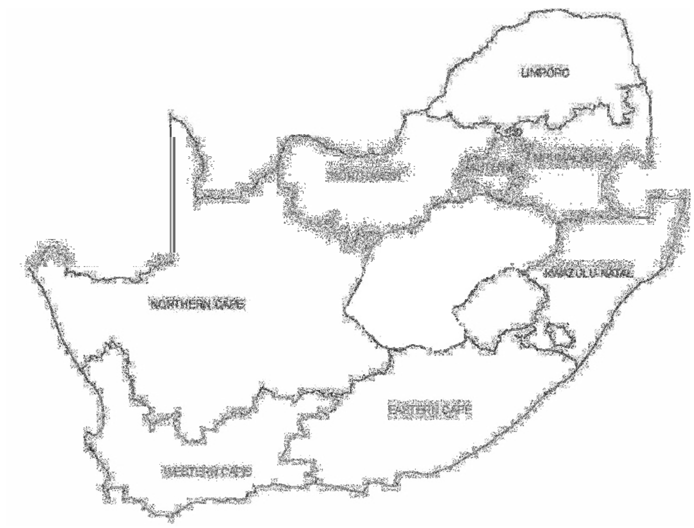
4. With regard to movement of enemy **by land**, which factors affect movement most: (provide percentages if possible. Eg. 40 % Risk of Attack and 60% Economic Value)

Terrain Type	Soil Type	Degree Slope of Area

5. Of the 5 neighbouring countries to South Africa, which is the most dangerous? Please rank. (Eg. 1 – Botswana. Most dangerous)

Namibia	Botswana	Zimbabwe	Mozambique	Swaziland

6. On the map, please mark the 5 sub-areas that have the most risk of being attacked by land.



Thank you for your time.

Please feel free to contact me regarding this project:

WBK Boshoff – wbkboshoff@gmail.com, 0725567255