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THESIS

**THE PEACE GAME: A DATA-DRIVEN EVALUATION
OF A SOFTWARE-BASED MODEL OF THE EFFECTS
OF MODERN CONFLICT ON POPULATIONS**

by

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September 2015

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BASED MODEL OF THE EFFECTS OF MODERN CONFLICT ON
POPULATIONS**

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ABSTRACT

Over the years, wargames have been used by decision makers and operational experts to gain insight into not only how an operation could expect to unfold, but also in unveiling gaps in capabilities of a plan or concept of operation. While most of these games focus on “war,” the Peace Game focuses on helping planners gain insight as to how Security Force Assistance (SFA) and Security Cooperation (SC) operations may unfold.

The Peace Game attempts to model population behavior in a specific region. In the past, movement of the masses has been used as an indicator of regional stability. This thesis concentrates on assessing the migration algorithm within the Peace Game. While the current algorithm does a satisfactory job of simulating migration, it can be made better.

The suggested improvements in the Peace Game focus on three models. There are two regression models; one that models population deaths over time and another that models displaced persons over time. The third model is roughly based on a compounding interest model. This model is known as the Population Attrition Model (PAM) and is applied to both deaths and displaced persons. All of the models are grounded in an analysis of historical data from more than 40 conflicts. All of the models are an improvement in simulating the reality of population migration in regions of conflict.

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LIST OF ACRONYMS AND ABBREVIATIONS

CJCS	Commander Joint Chief of Staff
CPA	Comprehensive Peace Agreement
DCMP	Data Collection Management Plan
DOD	Department of Defense
DSTL	Defence Science & Technology Lab
FPS	First-Person Shooter
HADR	Humanitarian Assistance/Disaster Relief
HSBA	Human Security Baseline Assessment
IDMC	Internal Displacement Monitoring Centre
IDP	Internally Displaced Person
JEM	Justice and Equality Movement
JPME	Joint Professional Military Education
MCMSMO	Marine Corps Modeling & Simulation Management Office
MCCDC	Marine Corps Combat Development Command
NAS	Naval Air Station
NFO	Naval Flight Officer
NGO	Non-Governmental Organization
NPS	Naval Postgraduate School
NTC	National Training Center
OCHA	Office for the Coordination of Humanitarian Affairs
PAM	Population Attrition Model
PSOM	Peace Support Operations Model
SC	Security Cooperation
SFA	Security Force Assistance
SPLA	Sudan People's Liberation Army
SPLM	Sudan People's Liberation Movement
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNISFA	United Nations Interim Security Force for Abyei
UNMISS	United Nations Mission to the Republic of South Sudan

WFP

World Food Program

EXECUTIVE SUMMARY

“Shall we play a game?”

— *WarGames*, 1983

“Games about warfare have probably existed nearly as long as war itself” (Perla, 1990, p. 1). Wargames are an excellent tool to gain insight into the “what ifs?” of a military operation. Wargames “simulate,” but are not simulations in the modern sense of the definition. The big reason is that most modern simulations are lacking one crucial component—the human thought process. Simulations can take a set of parameters and expected results, run that data through some simulation program and create a list of results with some predetermined degree of confidence. These types of simulations may create some unexpected results, but eventually, they can be explained by analyzing the results and reanalyzing the inputs. However, with a human in the loop, a completely unexpected result is usually accompanied with a question like, “Why did they do that?!” or “That makes no sense!” This is where wargames prove their worth. This is not to say wargames are better than computer simulations but that wargaming is a complementary tool in the larger kit of operational analysis.

Wargames have come to the forefront of innovation within the DOD. So much so that both the Secretary of Defense and Assistant Secretary of Defense have directed dedicated research within the field (Hagel, 2014; Work, 2015). Their thinking is that well-constructed wargames will yield better analysis for future operational planning and program management. The overall benefit will be better-prepared forces at reduced costs. This type of high-level focus gave rise to such games as the Peace Game:

The Peace Game is a software-based model of peace and stability operations that are underway in regions such as South Sudan and Afghanistan with the potential to revolutionize campaign planning. The Peace Game is an immersive environment requiring no special installation that is designed to expose decision-makers to the complexities and non-linear qualities of modern conflict. (Powers, Appleget, & Heerlein, 2013, p. 1)

In this fashion, the Peace Game stands apart from a great number of professional military games. Most are wargames designed to simulate “war.” This one focuses on Security Force Assistance (SFA) and Security Cooperation (SC) operations. What also sets the Peace Game apart is the algorithm that drives the non-player element of the game. This is the algorithm that drives the local population of the regions. Like any wargame, the Peace Game has human players that will represent different factions or forces. What is not represented by the human players is the local population. Given historical events in places like Central Africa and very recent events in Northern Iraq, Turkey, and Hungary, it is essential for decision makers to understand how a populace will react to regional conflict (Smale, 2015). The Peace Game endeavors to capture this critical metric in SFA planning.

Currently, the Peace Game uses the basic concept of the Malthusian Trap in its modeling of the migration algorithm (Malthus, 1798). This justifies the use of an exponential curve to model the growth in migration. That is to say that the more people move, the *more* people move. In a simpler sense, rate of migration is compounded. While this was a reasonable assumption, it was not based in a myriad of research. The Peace Game designers had a short timeline to create the game and had to incorporate a host of other attributes into the game program. At the time, this was an algorithm that fit the overall game construct and time constraints.

This is where this thesis continues the story. The current algorithm in the Peace Game is good, but it can be better. The focus was to get the Peace Game to better represent reality. The research is focused on gathering data on past conflicts involving mass migrations. We constructed three new models for incorporation into the construct of the Peace Game that represent data collected by the United Nations High Commissioner for Refugees (UNHCR) and other Non-Government Organizations (NGOs).

The first two models are essentially one model broken up into two parts. These models are based on regression analysis. Because the Peace Game accounts for deaths and displaced persons, a regression model was created to address each category. The third model was a single model applied separately to the data. This model was based on a compounding interest model. It is named the Population Attrition Model or PAM. While

these models are relatively simple in nature, keep in mind that there currently exist very few analytical models on the topic.

The models were tested and compared to the current model that exists in the Peace Game. Overall, the new models outperformed the original model in all except one case. That particular case was the Sudan conflict. Considering that this was the original scenario for which the Peace Game was built, this was not a surprise. Excluding that one instance, either of the new models display that they elevate the use of the Peace Game to a wider range of scenarios. The PAM model performs better when using a comparative historical model to create a new scenario. The regression models are better used in the case of a not-seen-before conflict.

Incorporating either (or both) of the new models into the Peace Game will improve the game in the sense that it will better mimic real-world effects of conflict on human migration and displacement. Once these models are incorporated into the Peace Game, further work can begin. A function that closes adjoining country borders would display a realistic constraint that is a real planning factor in SFA operations. An additional function not currently available in the Peace Game is in regards to population demographics. Currently there is demographic functionality attached to the various regions within the game (religion, social norms, reliance on a resource). However, that is not attached to the population. If that population moves to another region, the demographic does not go with them. Applying this demographic to individuals instead of the region could show a region's demographic change compared to the current static nature of regional demographics.

The Peace Game is a great tool for SFA operational planning. It can be made better by incorporating the PAM and regression models. Like most great wargames, the expansion of the game is limited only by the player's imagination. Wargames will continue to be part of the bigger picture of operational analysis. The Peace Game will be part of that process as it expands and improves.

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Professor Jeff Appleget and Professor Tom Lucas proved to be the best sounding boards. Thanks for keeping me on track and focused. I quickly realized that in a thesis, motivation could be a double-edged sword. Both professors made sure I did not bite off more than I could chew. I think when a student sets out to write a research thesis, they think, “I’m going to build a house.” I know that is what I did. However, as things progress, you realize that you cannot build a house. It is too big, and there is never enough time. Eventually, I realized that I was not building a house; I was not even building a wall for a house. I was building a brick for a really big house. However, it is a really nice brick and should fit nicely in the big house. So, thanks to Professor Appleget and Professor Lucas for helping me to build this brick.

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I am not ashamed to admit that this curriculum was a shock to my system and a significant kick to my rear. I consider myself a struggling analyst, at best. I will take what

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I. INTRODUCTION

A. BACKGROUND

Upon defining what a wargame is *not*, Peter Perla, the modern-day father of wargaming explains what a wargame *is*. He says:

a more restricted and more useful definition is that a wargame is a warfare model or simulation whose operation does not involve the activities of actual military forces, and whose sequence of events affects and is, in turn, affected by the decisions made by players representing opposing sides. In the end, a wargame is an exercise in human interaction and the interplay of human decisions, and the simulated outcomes of those decisions make it impossible for two games to be the same. As a result of all those factors, wargaming is not a panacea for learning about or solving the problems of warfare. Its forte is the exploration of the role of potential effects of human decisions; other tools are better suited to the investigation of other more technical aspects of reality (Perla, 1990, p. 164).

In November 2014, Secretary of Defense Chuck Hagel released a memorandum to the leadership of the U.S. Department of Defense (DOD) under the subject “The Defense Innovation Initiative.” In the memo, Secretary Hagel lays out a broad framework to establish a “Department-wide initiative to pursue innovative ways to sustain and advance our military for the 21st Century and improve business operations throughout the Department.” One of the bullet items that Secretary Hagel outlines is wargaming: “A reinvigorated wargaming effort will develop and test alternative ways of achieving our strategic objectives and help us think more clearly about the future security environment.” Recognizing the uncertainty of future wars and expected future fiscal restraints Hagel directed Deputy Secretary of Defense Bob Work to supervise the coordinated effort of this initiative (Hagel, 2014, p. 2).

Undertaking this task, Deputy Secretary Work released a memo in February 2015 with the subject line of “Wargaming and Innovation.” In the memo, he describes “atrophied” DOD efforts within the wargaming discipline. He lays out a detailed plan on how to bring the ideas of wargaming to the forefront of the overall long term military strategy. Specifically, he attributes good wargaming as a way to curb the effects of current and future fiscal constraints. “When done right, wargames spur innovation and

provide a mechanism for addressing emerging challenges, exploiting new technologies, and shaping the future security environment. They can potentially make the difference between wise and unwise investment trajectories and make our forces more successful in future conflicts.” (Work, 2015, p. 1). In other words, the use of wargames can highlight potential strengths or weaknesses in strategic planning and the capabilities of both friend and foe. This helps to minimize exposure to costly programs that may not yield the results desired. Perhaps, that billion dollar widget is not the right fit for our future war plans and the program should be cut for either a better fit or a better cost. Spending resources on a wargame to determine the viability of a program is cheaper than buying the program at the cost of millions or even billions of dollars and finding out that the system does not fit the overall strategic goals.

B. WHAT IS WARGAMING?



Screenshot from the film *WarGames*. From Goldberg, L., Hashimoto, R., Schneider, H., McNall, B. (Producers), Lasker, L., Parkes, W. F., Green, W. (Writers), & Badham, J. (Director). (1983). *WarGames* [Motion Picture]. MGM/UA Entertainment.

“Games about warfare have probably existed nearly as long as war itself” (Perla, 1990, p. 1). Wargames can be as basic as checkers, chess, and tic-tac-toe. Complex wargames involve multiple interactions of multiple players using multiple computers for input, execution, data collection, and analysis. Wargaming can be as simple as a playing a board style game at the staff planning level to a complex training scenario involving multiple units at a place like Naval Air Station Fallon in Nevada or National Training Center (NTC) in Fort Irwin, California. In Perla’s book, *“The Art of Wargaming,”* he refers to wargames as simulations; however, they are not simulations in the more recognized sense within modern operations analysis. Of course, wargames can simulate,

but they are not a simulation in the way that one puts in a set of parameters and has a computer crank out some data after 10,000 runs of a program. Wargames provide insight through the “interplay of human decisions and game events” (Perla, 1990, p. 8). Simulations provide analysis through running a model multiple times (usually through a computer) to get an expected (statistical) output. The main difference between the two is the human interface. Modeling human behavior is difficult, at best and impossible, at worse. How often has a decision been questioned, “Why did he/she do that?” Perla sees wargames as a tool within a greater toolkit that is part of the overall process of learning about warfare. Wargames should be used as a tool to start or help with the investigation of processes (Perla, 1990).

So what makes a wargame? As stated earlier, wargames can range from a simple board and a few pieces to a complex integrated scenario involving millions of dollars of hardware and personnel. For the purposes of this thesis, wargames consist of two media: a traditional board game and a software based game. Traditional board-style games, like Risk, generally lend themselves to a useable basic construct for professional wargames. When developing wargames for a professional audience, time is usually the biggest factor, (although money often is a driving factor, we will ignore this limitation for now). Development and play time (duration) are also factors. Development time is a factor in the sense that the wargame sponsor often wants it “*right now!*” Playtime is especially a factor, among high-level decision makers playing the game, as they never have enough time and are usually getting ready to move on to the next thing. For these reasons, board games can be a good option, as they tend to be simpler to develop and easier to implement. In a time-constrained environment, this is a driving factor: simplicity of development. Most of the drawback in board games tends to be in the adjudication of events and the data collection management plan (DCMP). The DCMP is done through a manual entry process (either by the players or the administrators of the game). This is usually labor intensive, time consuming and subject to transcription errors. As stated earlier, simplicity of development can be a positive driving factor in board-style wargames. This same fact can also be a limitation. In a simple wargame, fidelity is such that some of the detailed factors that greatly affect the outcome of a wargame are

overlooked or omitted. As is often seen in real-world human decision making, the answers are not always black and white. There are potentially second and third order effects of all decisions. Consider the ageless game of chess. For all of its known complexities, by modern combat standards, it is quite simple. There are two players, six categories of pieces divided among sixteen pieces for each player (only 32 pieces total). Each piece-type has its own attributes of movement and attack. The game does mimic some of the basic war constraints (freedom of movement, ability and strength of attack, etc.), but it does not completely cover all of the issues encountered in modern campaign warfare. As seen in recent years, there are almost always more than two players in a campaign. Chess does not capture the complex problem of logistics, resupply, and reinforcements; or the geopolitical atmosphere of modern warfare. So how does one incorporate these extra factors into a wargame to best mimic the real world, while not overloading the players or the developers? This is where modern software based computer wargaming changes the conversation.

The U.S. military has been using computers to aid in wargaming since World War II. Most of these early computer games were just digital depictions of a board game. The computers were generally used as a giant calculator that helped to adjudicate a simulated dice role to speed up the process of the gameplay (Smith, 2009). As technology marched on, so did the commercial gaming industry. The computer game industry was outpacing the military wargame enterprise. Eventually, the gaming industry had advanced so far, that military leaders took notice. The old saying “necessity is the mother of all invention” was never more obvious than in this respect with the U.S. Marine Corps. In the mid-1990s, the U.S. Marine Corps did what they usually do: find a ten-cent solution to a million-dollar problem. Training funding and training range availability were in short supply. A couple of Marines at the Marine Corps Modeling and Simulation Management Office (MCMSMO) purchased (for \$49.95) the popular First-Person Shooter (FPS) game *Doom II* (by id Software). Id Software released *Doom II* so that commercial gamers could modify the playing environment. The Marines did the same; instead of demonic aliens, they used enemy soldiers; instead of fictional future weapons, they used M-16s and M-

249s. This was one of the first applications of taking existing commercial software and truly adapting it for a specifically military purpose (Riddell, 1997).

Figure 1. Screen Shot of Marine Doom



Serious Game Classification. 2015. [Screenshot]. Retrieved from <http://serious.gameclassification.com/EN/games/5141-Marine-Doom/index.html>

So where is the benefit? From a sole DCMP viewpoint, the possibilities are limitless. Digital output of “what happened” allows game players and decision makers to collect and analyze every part of the game without transcription errors or time wasted in collecting the data during the post-game process. Every move can be cataloged into a usable file format (such as .csv); those data can then be pulled into an analytical program (Python, R, JMP, etc.) for a detailed review. Computer wargames also allow the players to review each game in a detailed hot wash not available with board games. Flexibility is a key component of a good computer wargame. If the basic code and construct of the game is solid, it will provide a good base from which to create game excursions and expansions. Expanding on a board game (i.e., creating a bigger world within the game), can be difficult and time consuming. How big is the board going to get? In a computer game, designers can use the computer terminal as a window into the game construct. From here, the possibilities are endless! The downside is that this kind of flexibility takes

a significant amount of time to code and incorporate into the game program. Another limitation is the technical experience. Designing games like this requires at least two individual skill sets: programming and game designing. A good programmer can make a technologically sound game, but will be missing the required practical and historical fidelity needed. A good designer will envision a realistic, usable game but not have the expertise to get it into a usable computer program. Working together, these two types of individuals can create a valuable game that can provide training and insight (Dunnigan, 2000). Incidentally, this is how the Peace Game became so successful.

C. WHAT IS THE PEACE GAME?

In 2012, a group of Operations Research students at Naval Postgraduate School (NPS) was tasked to develop a new wargame in order to better understand Security Force Assistance (SFA) operations. The result of this effort is known as “The Peace Game.” Matthew Powers writes, “The Peace Game is a software-based model of peace and stability operations that are underway in regions such as South Sudan and Afghanistan with the potential to revolutionize campaign planning. The Peace Game is an immersive environment requiring no special installation that is designed to expose decision-makers to the complexities and non-linear qualities of modern conflict.” (Powers, Appleget, & Heerlein, *The Peace Game*, 2013, p. 1). The Peace Game is a different take on wargaming in the sense that there is no single enemy or force that players are fighting. The game endeavors to expose players to the complexities of modern peace support missions. In the game, you can have myriad entities all working in unison (but not necessarily together). Some of these entities may include an international security force, internal (or local) police force, civilian populace, internal criminal force, external criminal force, local civilian leadership, and national civilian leadership. All of these entities will be working to their *own* end, but not necessarily the *same* end. Seeing how all of these forces work within the construct of the game, allows decision makers and planners to better prepare for real world SFA missions. The main target audiences of the Peace Game are senior decision makers, students (JPME and service War College), SFA operators, and concept developers.

1. How Did “The Peace Game” Get Its Name?

Peace Game co-developers, Matt Powers, Lieutenant Commander, U.S. Navy and Major Danny Heerlein, German Army, attended the 2012 International Association of Peacekeeping Training and Education Centers (IAPTC) conference in Helsinki, Finland to present their unnamed prototype game. At the conference social, Lieutenant Commander Powers used his innate social skills (and some tactically placed libations) to solicit security professionals, dignitaries, and academic professionals to play the game the following day. While discussing the as-of-then unnamed game as a type of wargame, one professional pointed out to him that he should be wary of using the term “wargame” at a peacekeeping conference. To which Lieutenant Commander Powers replied, “I’m sorry did I say wargame? I meant PEACE game.” The now named “Peace Game” was never scheduled to be presented at the conference. The following day, Lieutenant Commander Powers and Major Heerlein found an empty room, in which to play the game during the lunch break. By the end of lunch, the participants were impressed by the simplicity, usability, and insight of the game. It was the gameplay specifically that caught the attention of a German Army officer and a NATO representative. From here, The Peace Game was born into the professional realm (M. Powers, 2015).

What to infer from this little anecdote? The Peace Game is not a single purpose game for SFA planning and knowledge. It is a configurable program that can be modified to an infinite number of scenarios and mission sets. It can be used for SFA, Humanitarian Aid/Disaster Relief (HADR) operations or even a full out “force on force” scenario. Once a basic understanding of the construct of the program is grasped, the design of the game is really up to the players; what they want to mimic and gain insight into can be designed through their eyes.

2. Are There Other Types of Programs Similar to the Peace Game?

The Peace Support Operations Model (PSOM) is similar to the Peace Game. “PSOM is a campaign-level, simulation-based, human-in-the-loop wargame which portrays the civilian populace as agents within the model. The model’s metrics are both quantitative and qualitative in nature, providing results that are analogous with irregular

warfare. Many of the Measures of Effectiveness offered by PSOM, such as attrition, are easily understood. However, much of the output is a cultural representation of the uncertain effects military and political actions have on the population.” (Marlin, 2009). How does this differ from the Peace Game? Up front, the Peace Game is a much simpler program than PSOM. PSOM is built in Visual Basic, whereas the Peace Game is a Java Script program. PSOM incorporates 300 algorithms. The Peace Game currently has 5 algorithms.

How are they the same? They both contain a migration function for the civilian population. In the case of PSOM, it is currently deactivated. The migration algorithm in the Peace Game is currently in use. The designers feel that this is absolutely necessary to properly evaluate the effectiveness of game outcome. As stated earlier, this algorithm is the primary focus of this thesis.

D. HUMAN MIGRATION

Where there has been extensive research on international human migration, there is precious little research on modeling human migration. These reports, often authored by sociologists, describe reasons behind migrations in general terms. In the most used general terms of the factors effecting human migration are “push-pull” factors (Johr, 2015). The push factors are those factors that would force a populace out of an area. They are usually defined as negative characteristics (e.g., famine, economic downturn, war, religious/cultural persecution, etc.). The pull factors are those that will attract a populace into an area. As one would expect, these are counter to the push factors and are generally considered positive (e.g., security of property, employment opportunities, higher quality of life.). These are the basic characteristics of migration and have been applied to many international migration studies (United Nations Department of Economic and Social Affairs, 2012). While these factors have been discussed in a sociological sense, with few exceptions, they have not been modeled in an analytical sense. The studies that do analyze migration in a mathematical construct only do so in what can be considered a normal socio-economic sense of migration (Ishtiaque & Ullah, 2013).

Even if there did exist an abundance of analytical studies on human migration, most of them would not apply to what this thesis explores. Specifically, we will be exploring human migration of populations in conflict. However, from the basic knowledge of human migration, we can deduce an assumption. The assumption is in regards to the “push-pull” factors. It is reasonable to assume that the “push” will far exceed the “pull.” In war zones, like Darfur or Afghanistan, one can assume that the local population will be driven by the mindset that *“anywhere is better than here.”* This assumption is incorporated into the basic migration algorithm in the Peace Game and is discussed later. From this, the Peace game tracks persons that have left one area for another. The metric from what we base our analysis will not be *where* they go, rather that they have reacted to conditions within an area. Persons whose “decision” is to move to a different region are simply considered “displaced” from their home region. This is due to two limitations. First, the Peace Game currently does not “tag” people. What this means is that at the start, the regions within the game are populated with a representative number of persons. Once those people move, they simply get absorbed into the receiving region’s population. The point of origin is currently not attached to that person. The game will track the increase and decrease of people, but not their place of origin. Second, there is little data available about population composition within the UN’s refugee camps. From the perspective of the United Nations High Commissioner for Refugees (UNHCR), they mostly care about the population size within a camp, not necessarily where they came from. It may sound crass, but the “who” and “why” part of a refugee is less important to the UNHCR. The UNHCR simply cares that you are a person in need of help at the gate of their camp. That person’s reason for being there is an issue for another department or organization.

When considering the amount of regional and international strife in the world over the past three decades, one would think that there would be more analysis in campaign planning for SFA type operations. From relatively small SFA operations like Grenada and Somalia, to large nation-building campaigns like Iraq and Afghanistan, the United States, NATO, and the United Nations have conducted many types of these

operations; yet most of these campaigns get bogged down or even shut down because of failing to understand the basic needs and goals of the interested parties.

The overall goal is to determine if the Peace Game can be modified to reasonably mimic and represent human migration so that it can give decision makers insight and strategy when planning for an SFA or Humanitarian Assistance operation. This game is part of a larger movement to better merge the mathematical analysis that goes with campaign modeling with the social science that is grounded in less mathematical terms. This will not be a data-based simulation that gives emphatic conclusions from thousands of model runs. Rather, the Peace Game uses real human game players, making reasonable decisions from a historical and tactical perspective towards their specific force goal (e.g., Peacekeeping troops, criminal/terrorist factions and local government troops). At a minimum, players of the Peace Game should get new ideas and ask new questions.

II. BACKGROUND AND LITERATURE REVIEW

A. SCENARIO

The beginnings of the current conflict in Sudan (and, as of 2011, South Sudan) can be traced back to the beginning of the Second Sudanese Civil War (1983-2005). The Comprehensive Peace Agreement (CPA), signed in 2005, brought an end to hostilities and established South Sudan as an autonomous state within the country of Sudan. In July 2011, South Sudan became its own independent and recognized country. However, regional fighting continued along the border regions between the two countries, specifically within the Abyei region. Abyei is still a contested region as its sovereignty status has yet to be determined (CIA World Fact Book, 2013).

The history of Sudan and the Sudanese conflict is well documented. As one of the major trouble spots in the world regarding internal strife, human rights violations, and displaced persons, it is a major focus of the United Nations; specifically the UNHCR. The UNHCR was established in 1950 by the General Assembly with its mission “to lead and co-ordinate international action to protect refugees and resolve refugee problems worldwide” (United Nations High Commissioner for Refugees, 2001). In practice, the UNHCR monitors the movement of refugees and manages the administration of refugee camps. As of July 2015, there are over 1,000,000 total refugees/internally displaced persons (IDPs) from South Sudan (United Nations High Commissioner for Refugees, 2001). Broken down, there are approximately 266,000 IDPs and 746,000 refugees. The difference between refugees and IDPs may seem insignificant, but it is worth a brief mention. When talking about IDPs and refugees, it is all about place of origin. The following is the UN’s definition of IDP:

IDPs have not crossed an international border to find sanctuary but have remained inside their home countries. Even if they have fled for similar reasons as refugees (armed conflict, generalized violence, human rights violations), IDPs legally remain under the protection of their own government – even though that government might be the cause of their flight. As citizens, they retain all of their rights and protection under both human rights and international humanitarian law.” (United Nations High Commissioner for Refugees, 2001)

The UNs definition of refugee is defined as such:

Owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country; or who, not having a nationality and being outside the country of his former habitual residence as a result of such events, is unable or, owing to such fear, is unwilling to return to it. (Convention and Protocol Relating to the Status of Refugees, 1951, p. 14)

It is important to make the distinction between refugees and IDPs as they play into how international organizations like the UN will address the issue. It explains what kind of assets and forces will go into operational planning. It may also drive the international response. As refugees start spilling out of their country of origin, the international community tends to have a bigger response, because now it becomes not just the origin country's problem, but everyone's problem.

In the case of Sudan and South Sudan, the UN has responded by sending troops into the region in order to maintain peace. As of March 2015, the UN has 11,734 uniformed personnel (including police forces) in South Sudan, as well as an additional 2,600 civilian support personnel. This mission is known as the United Nations Mission in the Republic of South Sudan (UNMISS) (United Nations Peacekeeping Web Page, 2015).

B. SUDAN AND SOUTH SUDAN CONFLICT 2010–2011

The years 2010 and 2011 were particularly bad years for the conflict. The CPA from 2005 put an end to the fighting and set a timetable for a referendum on the South Sudan's independence. In January 2011, the citizens of South Sudan voted to secede from Sudan. South Sudan gained full independence status that July. However, many of the details of the CPA were still in debate. The biggest issues were regarding the status of the demarcation for the border between the two countries, as well as the status of the Abyei region and Abyei town.

1. The Abyei Region

The Abyei region is centrally located along the border region of Sudan and South Sudan (Figure 2).

Figure 2. Map of Abyei Region



The Abyei region is depicted by the yellow in the left frame. In both frames one can see that the region is literally split by the borders of Sudan and South Sudan. From Pike, J. (2014). Abyei Area. Retrieved from <http://www.globalsecurity.org/military/world/war/abyei.htm>.

The Abyei region is approximately 10,000 square-kilometers. It is rich in oil reserves and fertile land. According to the original CPA Abyei was to remain part of Sudan until a referendum could take place (Pike, 2014). “In 2009, the Permanent Court of Arbitration ruled that the biggest oil fields in Abyei would remain a part of Sudan, while its other areas join South Sudan.”(Insight On Conflict, 2015). However, the lines of demarcation had still not been established by the time South Sudan became its own country. With tensions and violence rising in the region, the UN established a mission to deal with the Abyei situation. A separate mission from the UNMISS, the United Nations Interim Security Force for Abyei (UNISFA) initially comprised 4,200 armed personnel and 50 police and civilian support personnel. Although the authorized strength has been

increased to just over 5,300 armed personnel, the number of personnel in the region has remained mostly static. Currently, there are just over 4,000 armed personnel in the region (United Nations Peacekeeping Web Page, 2015).

A referendum was supposed to take place in 2011 in that the citizens of the Abyei region were to vote on whether to become part of Sudan or South Sudan. The vote never took place because there was a dispute over voter eligibility. Missiriya nomads, who are loyal to Sudan, spend several months of the year in Abyei grazing their cattle. Sudan claims that they have a right to participate in the vote. South Sudan claims that only the historical local inhabitants (the Dinka Ngok) are eligible to vote. Not surprisingly, these people are more loyal to South Sudan (Pike, 2014). Bottom line, the Abyei region has been at or near the center of this Sudan situation for a long time and there does not seem to be a peaceful solution in sight.

2. The Exodus

As stated earlier, 2011 was a turbulent time for the whole region. However, Abyei was hit particularly hard. In May 2011, Fatoumata Lejeune-Kaba posted an article on the UNHCR website. In the article, Fatoumata discussed the numbers of residents evacuating the area of Abyei and Abyei town.

The security situation remains precarious after fighting erupted over a week ago in Abyei, which is claimed by both the northern and southern authorities.

UNHCR staff reported that Abyei was nearly emptied of its normal population of 50,000 to 55,000 people. Over a third of the tukuls (traditional huts) had been burnt down. Many others were looted or destroyed, and were missing roofs, doors or windows. Trucks were seen carrying looted goods out of Abyei. There were large numbers of fighters on the streets, and sounds of sporadic shooting could be heard on Monday evening.

So far, 31,256 displaced people have been registered in Warrap state and 27,961 in Agok itself. Smaller numbers have been reported in neighbouring states south of Abyei. Some families were separated in the fighting. (Lejeune-Kaba, 2011)

These are the types of numbers that will play into evaluating the Peace Game's migration algorithm.

C. BASELINE SCENARIO PLAYERS

The following section discusses the original players that were included in the first versions of the Peace Game. Each one of the forces or factions was represented by a human player. These players were not necessarily Subject Matter Experts (SMEs) on their particular force. They did all have some basic understanding of military operations as well as general understanding of history regarding SFA operations.

1. Sudan

It all starts with Sudan. For the sake of the game play, the timeline starts in 2011. In May of 2011, Sudan sent 5,000 troops into Abyei. Sudan claims that the move was in response to an ambush by South Sudan forces that left 22 Sudanese soldiers dead (Copnall, 2011). While it is not stated by the Sudanese government as to why the troops are in the region, it becomes plain to see that this was part of an attempt to take control of the region, using the ambush as an excuse. To that end, the Sudanese forces, within the construct of the game, will be there to assume control of the Abyei region. The Sudanese forces stay within the region for about one year, withdrawing most of its forces from Abyei in May 2012. However, the Sudan government kept some troops in the region and in the general area just outside Abyei town. Two platoons of troops were left in Abyei town, dressed in police uniforms and two battalions of regular troops about 40 miles away in the village of Diffra (Ferrie, 2012).

2. South Sudan

The forces acting within Abyei on behalf of the South Sudan government are a little bit more, nebulous. These forces originated from the Sudan People's Liberation Movement (SPLM), and were officially named the Sudan People's Liberation Army (SPLA). Since South Sudan's 2011 independence, the SPLA have been the regular troops of the South Sudan Government (Pike, 2014). However, total troop strength seems to be in doubt. To quote John Pike at globalsecurity.org, "The exact numbers of troops in the

SPLA are a mystery wrapped in an enigma” (Pike, 2014). There has been a practice of creating “Ghost Soldiers” in that troop numbers are exaggerated and falsified so that senior officers can then pocket the pay of the non-existent troops. At times, the SPLA has been “reported” to have total troop strength of 200,000-320,000 total troops, the number in 2010 seems to be closer to around 140,000 regular and irregular troops. The irregulars are more akin to citizens with rifles (Pike, 2014). “Militia” is too formal of a term for these troops. From this number, there are 10 divisions separated further into brigades and battalions. Specifically, the 3rd Division is located with the North Bahr-al Ghazal and Warrap states of South Sudan. These would be the most likely units to respond to events within Abyei. Even though a division in the SPLA is estimated to be 10,000-14,000 troops, one can expect only about 80% of that number being actual combat troops (Pike, 2014). It is also reasonable to believe that the entire division would not be deployed to the area. Because of these reasons, the total number of SPLA troops the game will employ will be 6,000 troops or about two brigades total.

3. The United Nations Peacekeeping Force

When the clashes in Abyei started in 2011, the UN established two missions in South Sudan and the border region with Sudan. The UNMISS mission, started in July 2011, was to stabilize security in the newly formed country as it saw instability as a “threat to international peace and security in the region” (United Nations Peacekeeping Web Page, 2015). The UNISFA mission, started in June 2011, was a separate mission with a more specific purpose. To quote the UNISFA’s web page, “The operation has been tasked with monitoring the flashpoint border between north and south and facilitating the delivery of humanitarian aid, and is authorized to use force in protecting civilians and humanitarian workers in Abyei” (United Nations Peacekeeping Web Page, 2015). As stated earlier, the initial troop authorization was at 4,200 troops. It was later increased to 5,300 troops. However, these troops were not all available at the onset. There was a build up over the coming months. According to UN Security Council reports, the initial wave of 453 troops arrived in late July (Report of the Secretary-General on the situation in Abyei, 2011). That number had increased to 3,800 troops by March 2012 (Report of the Secretary-General on the situation in Abyei, 2012). The game will reflect the buildup of

troops over time in that the UN player will be able to see his troops but not be able to move or unitize certain elements until a determined time.

4. Non-Governmental Organizations (NGOs)

Not surprisingly, there have been a number of both large and small NGOs working within South Sudan and, specifically, Abyei. Equally unsurprising, the UN has an organization dedicated to corraling the efforts of these different humanitarian entities. The UN's Office for the Coordination of Humanitarian Affairs (OCHA) defines its mission as, "OCHA is responsible for bringing together humanitarian actors to ensure a coherent response to emergencies. The aim is to assist people when they most need relief or protection. A key pillar of the OCHA mandate is to 'coordinate effective and principled humanitarian action in partnership with national and international actors.'" (United Nations Office for the Organization of Humanitarian Affairs, 2015).

OCHA's webpage reports that as the fighting started in 2011, three of the UN's own organizations (UNHCR, WFP & UNICEF) were in the area (United Nations Office for the Organization of Humanitarian Affairs, 2015). From this, the game will include three or four small units of NGOs working in the area of Abyei. Within the construct of the game, NGOs will be defined as any organization whose mission is directly involved with humanitarian aid and assistance. These elements will not have any ability to fight or assume control of a region.

5. United States Military Forces

History does not show that the United States sent a dedicated force to Sudan separate from any of the UN missions within Sudan and South Sudan. However, the Peace Game was developed specifically to determine a course of action if the United States did decide to send its own SFA force. As such, there is a player and a force to fill this role. The total force strength of this player was about 50% of the combined strength of the Sudan and South Sudan fighting forces at about 5,500 troops.

6. Criminal Factions

In the mix of all of these forces lies a myriad of other factions and organizations that do not appear to have well defined lines of alliance. Some of their motivations are religious, social, economic, or a combination of all. There are a few factions that bear mentioning, but within the construct of the game will be lumped into one organization known as “thugs.” One such force is the Justice and Equality Movement (JEM). JEM does not support South Sudan as so much as it is more anti-Sudan. While JEM has recently started to align itself with SPLA, this was not the case in 2011–2012. JEM’s main area of influence was the Darfur region in Sudan. However, they have travelled out of that region to disrupt Sudanese forces. Although they are looking for their own version of justice against atrocities in Darfur, their actions have not done much to create stability in the region. For the most part, they have just created more chaos and confusion (Justice and Equality Movement, 2012). For this, they are being categorized as a criminal faction.

Another group is the Missiriya tribes. The Missiriya is an Arabic nomadic tribe that spends some of the year in Sudan and the other part of the year in the Abyei region. As stated earlier, they tend to side with the Sudanese government, but are essentially their own people. Their primary livelihood is based in livestock. During grazing season, they come down from the north into the Abyei region to feed and graze their cattle. For this reason, they have claimed land rights to the Abyei region. They also have their own militia, of course, that they use to protect their cattle and their land, but have also been used as enforcers to intimidate anyone who challenges their land claims (Abandoning Abyei, 2008).

These factions will be blended together into one criminal faction that will contribute to the destabilization of the region. The Human Security Baseline Assessment (HSBA) for Sudan and South Sudan is a research project commissioned by the Small Arms Research organization to analyze the movement of small arms in Central Africa. Their website has been keeping a running commentary of events in the entire region. The following is a quote from the HSBA website (July 2013), talking about a recent pipeline explosion within Abyei.

On 12 June, there was an explosion near Ajaja, at a fuel station 62 km east of Diffra, after an oil pipeline was cut and set on fire. The station is not on the main north-south pipeline, but on a line running from east to west, connecting Diffra to Hejlj. The Sudanese government said it carried 18,000 barrels per day. Local sources said a truck moved south towards Ajaja from the region of Domboloya just before the blast was heard. On 15 June, the Sudanese government said the pipeline had been repaired and was fully operational.

It is unclear who set fire to the pipeline. On 15 June, Sudan's oil minister, Awad al Jaz, blamed the Justice and Equality Movement (JEM). JEM deny the charge. In Abyei, groups close to the Sudan People's Liberation Movement said Missiriya carried out the attack. Both scenarios are plausible. (The Crisis in Abyei, 2013)

As stated, "Both scenarios are plausible." This is just one example of how a myriad of groups are contributing to the instability and forced migration of the local populous within the region.

D. THE ALGORITHMS

Before discussing the migration algorithm, some of the other algorithms within the Peace Game should be addressed. This will help to frame how the game, as a whole, is played and analysed. In the next chapter, the actual game setup and game play will be introduced and discussed. Discussing the algorithms and what is going on "under the hood" will provide better understanding when game design and set up is discussed.

1. The Combat Model

This is the most basic algorithm. The original developers decided to use a tried and true model, "Lanchester's Square (Aimed Fire) Law" (Lucas & Dinges., 2004).

$$dy/dx = (\alpha/\beta)(x/y) \quad (1.1)$$

In Equation 1.1, x and y are the size of the forces, while α and β are the attrition coefficients of the forces (x and y respectively). These define the change in the size of the forces as a function of x and y (dy/dx) (Powers, Appleget, & Heerlein, 2013). This assumes that the two opposing forces know the location of the other. Within the game, the laws are embellished if a force is given the ability to ambush an opposing force. The attrition coefficients (α and β) are representative of the capability of the force and are

randomly generated variables along a (truncated) Gaussian curve. The mean-value of the generated curve for each force reflects the actual fighting capability of that force. Even though this is being called the Peace Game, violence and war will still need to be included. What will be discussed later is how these battles have 2nd and 3rd order effects that influence the outcome of the game (Powers, Appleget, & Heerlein, 2013). As one could expect, violence of any kind within a region will affect the overall stability and security of a region.

2. The Trainer Algorithm

A game like the Peace Game lends itself to modelling unconventional forces such as military advisors or trainers. Forces similar to the Army's Green Berets or other types of forces have been used in a trainer/fighter role in the past. The original creators of the game decided that this would be a useful tool to include in the game play. The trainer's capability is based on Wright's Learning Curve (Powers & Heerlein, 2013). T.P. Wright first introduced his learning curve in the February 1936 edition of *The Journal of the Aeronautical Science*. The article was titled "Factors Affecting the Cost of Airplanes." What Wright was saying in this article is that the overall cost of an item (planes, in his case) goes down as the number manufactured goes up. This plays into the point that the more someone does something, the more efficient they will be in that task. However, there is a point where that curve levels out and no more efficiency can be gained (Wright, 1936). This curve is applied to the trainer/advisor in that the more experience the trainer gets, the better he will be at teaching and advising the local populace. This takes into account an acclimation period with the local people and culture. However, much like Wright's curve, it does reach a maximum capability (Powers & Heerlein, 2013).

Figure 3. Trainer Capability based on Wright's Learning Curve



The learning curve used by the designer in the original game (normalized advising capability on the y-axis and number of consecutive rounds gaining advising experience on the x-axis). This curve has not been changed, although the operability has. Now, it can be easily modified within the Peace Game program to fit the user's needs. From M. Powers, personal communication, August 2013.

3. Human Migration and the Malthusian Trap

Political economist Thomas R. Malthus first described his theory in 1798. The most basic definition of his Malthusian Trap is “that the power of population is indefinitely greater than the power in the earth to produce subsistence for man” (Malthus, 1798, p. 4). Once the industrial revolution gained significant momentum, other scholars would take it a step further, saying “The ‘Malthusian trap’ is often used to describe the dynamics of pre-industrial societies in which economic growth does not lead to an improvement of living conditions, because populations tend to grow faster than economic output.” (Korotayev, et al., 2011, p. 1). What all of these scholars are saying is that there is a tipping point in society where the demands of the population exceed the carrying capacity of the system (or region). Carrying capacity is defined as, “the level of human activity (including population dynamics and economic activity) which a region can sustain (including consideration of import and export of resources and waste residuals) at acceptable ‘quality of life’ levels in perpetuity.” (Bishop, 1974, p. 32). What this says is that there is a tipping point of sustainability within a system. At this tipping point, the good becomes the bad. Think about the following scenario; as a population migrates to a region seeking a resource for which it is starved, the resource is in sufficient supply and

the region is stable. As more people flock for the “goodness,” the supply of the resource is consumed at a faster rate. At some point, the demand exceeds the supply and people become less happy about the region, given the fact that there is now limited “goodness.” The region goes into a downturn because of a perceived lack of “goodness.” This can potentially cause instability and strife in the region, thereby causing a breakdown and eventual failure of the system that made the region desirable in the first place. To quote the great former baseball player Yogi Berra, “Nobody goes there anymore because it’s too crowded” (Berra, 2000).

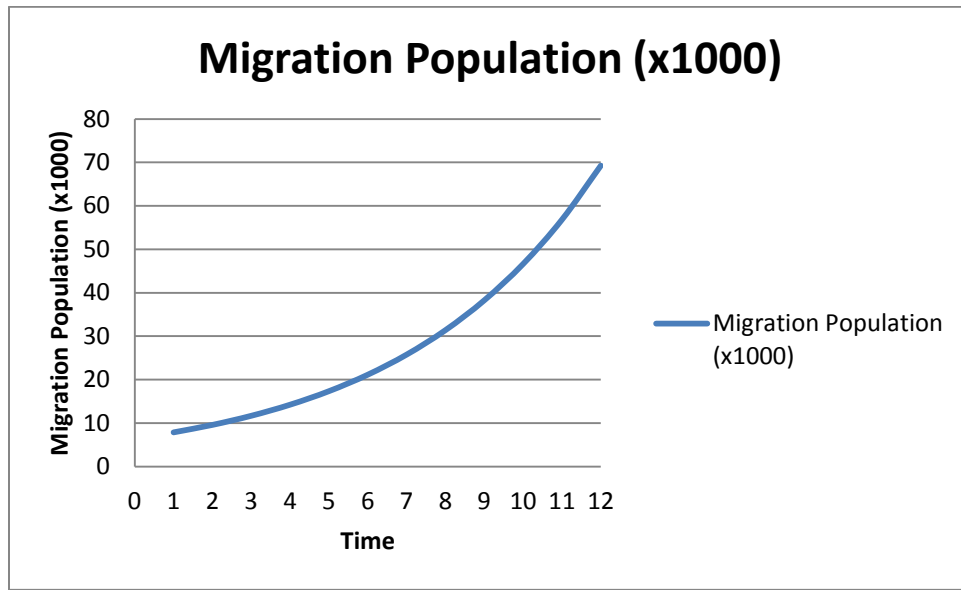
So, why explain the Malthusian Trap in such detail? The Peace Game uses this basic concept of the Malthusian Trap in its modeling of the migration algorithm. In an interview with Lieutenant Commander Powers, he had the following to say about the original thought process behind building the migration model using Thomas Malthus’ concept.

I am using the theory of the Malthusian trap to justify our exponential growth in migrating population. Since we did not model effects like birth-rate and emigration, I am arguing that the movement of individuals throughout the regions results in exponential growth within “desirable” places.

I connect the dots by beginning with the idea that the scarcity of resources in South Sudan particularly reflects what Malthus wrote in his essay. I then explain my simple simulation/optimization experiment using estimated UN data for displaced persons within South Sudan (350k) in order to estimate the parameters of our assumed exponential behavior. (We need to take a look at the parameters used in the Abyei model). I will then draw attention to the fact that a (much more complex) model, also Malthusian-based, predicted the type of instability that exists in Sudan today. (M. Powers, personal communication, August 2013)

As was the way for the other algorithms, the curve for the migration algorithm was originally hard coded into the game assuming an exponential curve for the Malthusian Trap.

Figure 4. The Malthusian Trap



This shows the exponential curve on how many people will migrate based on the lack or abundance of resources within a region (in 1000s of people). The vertical axis represents total number of people, while the horizontal axis represents the time segments. In this case, the time segment is arbitrary. In the game this can be set to any time interval desired (week, month, season, year, etc.). From M. Powers, personal communication, August 2013.

So what does this tell us? What it is saying is that if there is a scarcity of a need or desire, a number of the population will react or decide to do something. Keep in mind that not every person will react, but only a percentage. What they will decide to do will be discussed in the next segment. For now, just know that at time 'x' a number of the population will decide to make a decision. As time goes on, more of the population will make a decision, if that particular need is not addressed in some way. These needs are portrayed in the game based on a 1–5 rating (1 = less important, 5 = very important). The needs can be modified as well. In the case of the Sudan scenario, the needs are water, food, oil (economy), medicine, and religion (Muslim and Christian). A need can be added or renamed. For instance, when modeling a scenario in Boston 1775, users used “Tea” as a desired resource. The naming convention is for realism and game play aesthetics. The underlying goal here is to call out a need that will cause the population to react, if a shortfall in supply to that need is not met.

Figure 5. Resources Population Tab from The Peace Game

Resource	Add/ Drop	Order	Name	Population's Need	Importance	Wildcard
	x	↑ ↓	Oil	☐	0	☒
	x	↑ ↓	Water	☒	5	☐
	x	↑ ↓	Food	☒	4	☒
	x	↑ ↓	Medicine	☒	4	☐
	x	↑ ↓	Christian	☒	3	☐
	x	↑ ↓	Islam	☒	4	☐

+
Redefine people's default behaviour regarding resources (Advanced)

Here is where the resources are set in type and priority. Notice that there can be multiple high priority (3-5) and resources that have a priority of zero. This will apply to groups. In that sense, another group may have a high priority for oil, but much lower for Islam. From The Peace Game Scenario Generator.

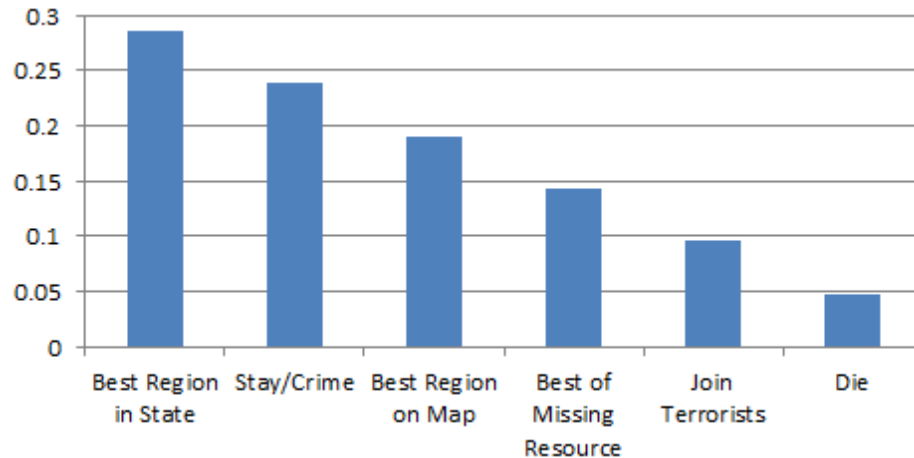
4. Population Behavior Algorithm

The other algorithm that feeds the migration behavior is the Population Behavior Algorithm. The designers wanted to create realistic reactions without making the process overly complex. Remember that not everyone within a population will decide to react. This algorithm applies only to those members of the population that have decided to do something, based on a perceived lack of a resource. As it is, the population that decides to do “something” within a given region will react to events in one of six ways.

- Go to the best region in their state (best case).
- Stay in their current region, but turn to crime.
- Go to the best region on the map (regardless of country borders).
- Go to the region that has the most of the resource that the population needs most.
- Join a criminal/terrorist faction.
- Stay in current region and perish (worst case).

The percentages of probabilities of these actions are in Figure 6.

Figure 6. Probabilities of the Behavior Algorithm



This shows the probability that a person will do one of these actions. The x-axis is the categorical decision and the y-axis is the probability of making that decision. This is a weighted “dice roll” where the dice is rolled on every individual that decides to “do something.” From M. Powers, personal communication, August 2013.

Reading Figure 6, one can see that the probability of a person going/staying in the best region within their state is approximately 0.286, where the probability of dying is approximately 0.047. This is a step-down model decreasing equally by, approximately, 0.05 for each decision from left to right. Similar to the Trainer Capability, this was originally hard coded into the game program. Now, this can be easily manipulated by the users or game developers to fit the particular game being created or played.

It is important to keep in mind that this is just simply a “dice roll” for each individual person (who decides to act) within a region. This does not say that 28.6 percent of all people will stay in the region. What the algorithm says is that for each deciding individual within the region, on a weighted dice roll, that there is a 28.6 percent chance that the dice will show that individual will stay within the region. Again, this happens for each person within the region. If a region is populated with 1,000 people and 200 decide to act, this dice roll will occur 200 times. This is why this process ends up being stochastic vice deterministic (Lucas, 2000). Looking closely at the decisions, it could also mean that some people, who decide to do something, will “decide” to do

nothing but remain in their current state and perish. Realistically, no one would *decide* to die, but for the construct of the game, this decision will best mimic what occurs in reality. People with inability to leave or turn to crime essentially have only one course to take: that is to perish.

This randomness means that the game played the same way, with the same decisions made, can still yield different results. Commercial game makers strive to have this characteristic in their games. For them it is all about the “enjoy-ability” of the game, and just as important, the “re-playability” of the game. This part of the program is the part that can best mimic the uncertainty of human decision making. Because it would be unwieldy to use 1000 people as game players to play the local population, this method works well for the actual human players and/or decision makers. It also represents real world SFA operations. In most operations, at least in the early stages, leaders on the ground need to make decisions with limited input and interaction with the local populace. It can take weeks, months and even years to get the civilian population to become part of the coordinated decision making process.

5. The Criminal Element

The final algorithm is the factor of crime and stability in a region. The study of this algorithm is not part of this thesis. However, it is worth mentioning as it demonstrates that there are a significant number of factors working to influence the population within the game. The original developers used a basic concept that bears mentioning, as it affects game play and contributes to the overall movement of populations around the regions. The basic understanding is that as crime rises in a region, the stability will go down. As stated earlier, one of the options of the “dice roll” in the Human Behavior Algorithm was “stay in their current region, but turn to crime.” Using this concept, the designers thought this curve would look more logarithmic in shape. That is, as more people turn to crime, the stability in the region will be reduced, but at some point the rate of the reduced stability will taper off.

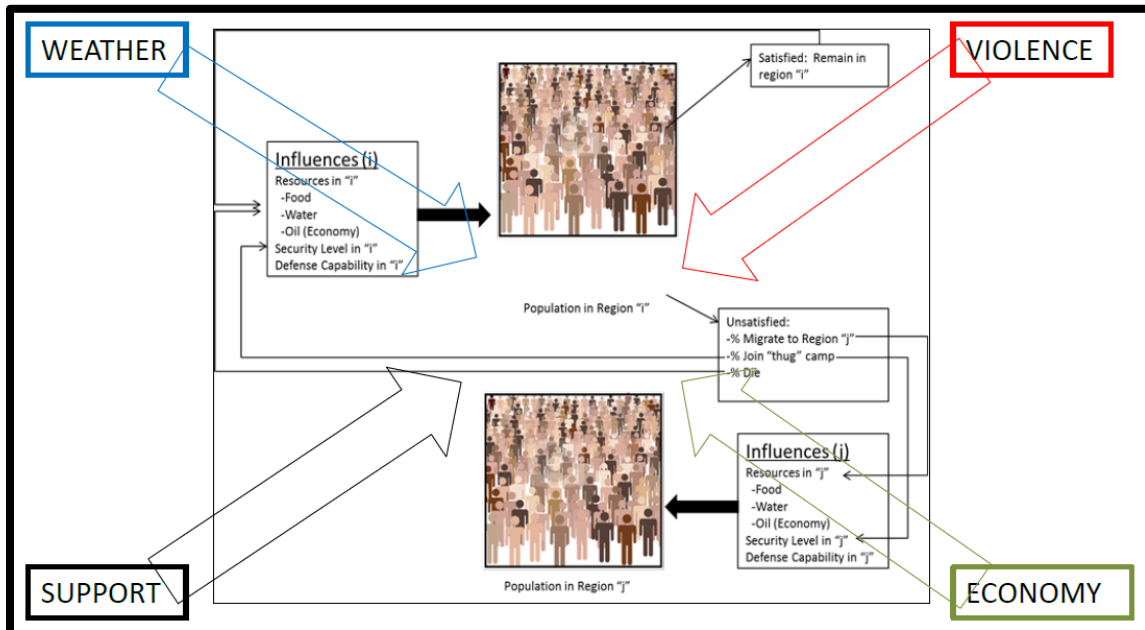
There are two paths to choose from when it comes to the criminal element, turn to crime or join a terrorist organization. Within the game, when a person turns to crime, it

does not force migration as a first order effect, but as a second order effect. Turning to crime will reduce overall security within a region, which unchecked will eventually make people migrate. However, joining a terrorist organization will have a direct effect on migration. When a person joins a terrorist organization, they leave the region and become part of the closest terrorist force. That force may be within the region, but for accounting purposes, they no longer belong to the regional population, rather they become part of the fighting force for the terrorist player.

6. Bringing It All Together

Now that the individual algorithms have been explained, how does it all factor in? Within the game program, players can include even more factors than previously described. For instance, weather can be a factor. Just as in the real world, weather plays into the social, economic, and stability characteristics of a region. This is especially true in regions like Sudan. Weather has already been discussed as a factor with the migration of the Missiriya tribes with their livestock. This can be accounted for within the game. Figure 7 shows in simpler terms how the population is affected and how they react within the game.

Figure 7. Algorithm diagram of population behavior



From Powers, M., Appleget, J., & Heerlein, D. (2013). *The Peace Game: A software-based model for understanding the complexities of modern conflict at the strategic level*. Ft. Leavenworth, KS: Joint Center for International Security Force Assistance.

Figure 7 encompasses all of the factors that create the push and pull of the various regional populations within the Peace Game. The big items on the periphery, weather, violence, support, and economy, all interact with factors that influence the overall satisfaction of the population. Support measures the local perception of other-than-local actions within population borders, thereby affecting overall stability of a region when a player's units are in a region. Economy is broken down into an item (or items) that provide financial stability. In the case of the Sudan scenario, it is oil. The oil supply in Sudan is not enough to sway the global market, but its economic value to the citizens of Sudan and South Sudan has great potential. This factor can be augmented to a myriad of other economic resources, like livestock or crops, if the scenario requires.

Violence affects security level and the impact of violence on a population is a function of defense capability. Security level mimics internal security of a region (crime and internal tribal rivalries), where defense capability mimics the ability for local populations to withstand external threats to security (external rival tribes, external

terrorist organizations, and any other raiding factions). As discussed earlier, weather can influence economy, security, and support. Weather can also be turned off as a specific function within the game. Weather need not be defined as four seasons. Players can model any number of seasons with any length. For instance, in a desert environment there may only be two seasons (dry and rainy), but in another environment there may be a need for more fidelity (micro-seasons that last only a few weeks or a month).

All of these factors determine the population's satisfaction with a region and their likelihood of moving to another region. Once a move happens, the same process is instantaneously repeated in the next region, and so on. This starts to play into 2nd and 3rd order effects. As one might expect, this eventually has the ability to affect all the other regions on the map. As an example, let us say a population is unsatisfied with its current plight in Region "A." A portion of that population moves to Region "B." The population of region "B" was satisfied and the region was stable. However, the influx of people from Region "A," exceeded the capacity for support in Region "B" (2nd order effect), which in turn reduced the satisfaction level of Region "B" and reduced security (3rd order effect) (Powers, Appleget, & Heerlein, 2013). The potential effect on the overall board can be huge. One might say: it's a game changer.

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III. METHODOLOGY

A. RECAP THE PROBLEM

Before discussing the technical aspects of the game in the next chapter, we will restate the problem at hand. This thesis evaluates the Peace Game migration algorithm to assess whether it replicates real world scenarios. This will enhance the ability to plan and execute SFA operations. As stated earlier, there is precious little material in the form of mathematical models that can predict and evaluate human migration in conflict. Most studies have revolved around the sociology aspect and not the analytical aspect of migration. Where there is data on the topic, it is often incomplete and sometimes inaccurate. While trying to gather data that would be relevant in assessing the migration algorithm, one finds a myriad of sources (OCHA, UNHCR and various NGO websites), but no single one that brings a comprehensive data set together. When considering the migration algorithm, we must look at the decision points for first reference into where to look for data. The six decisions mentioned in the previous chapter is the base. Again, the decisions are:

1. Go to the best region in their state (IDP status).
2. Stay in their current region, but turn to crime.
3. Go to the best region on the map (Refugee status).
4. Go to the region that has the most of the resource that the population needs most (Either IDP or refugee status).
5. Join a criminal/terrorist faction.
6. Stay in current region and perish (worst case).

B. THE MIGRATION DATA

Migration data is needed to assess the probabilities of decisions 1, 3, and 4, while casualty data would be needed to assess decision 6. Gathering data relating to decisions 2 and 5 can get a bit fuzzier. In the regions and missions that The Peace Game would most be used for, it can be difficult collecting both census data and definitional data of criminal organizations and terrorist groups. Similarly, it can be difficult to collect data on who

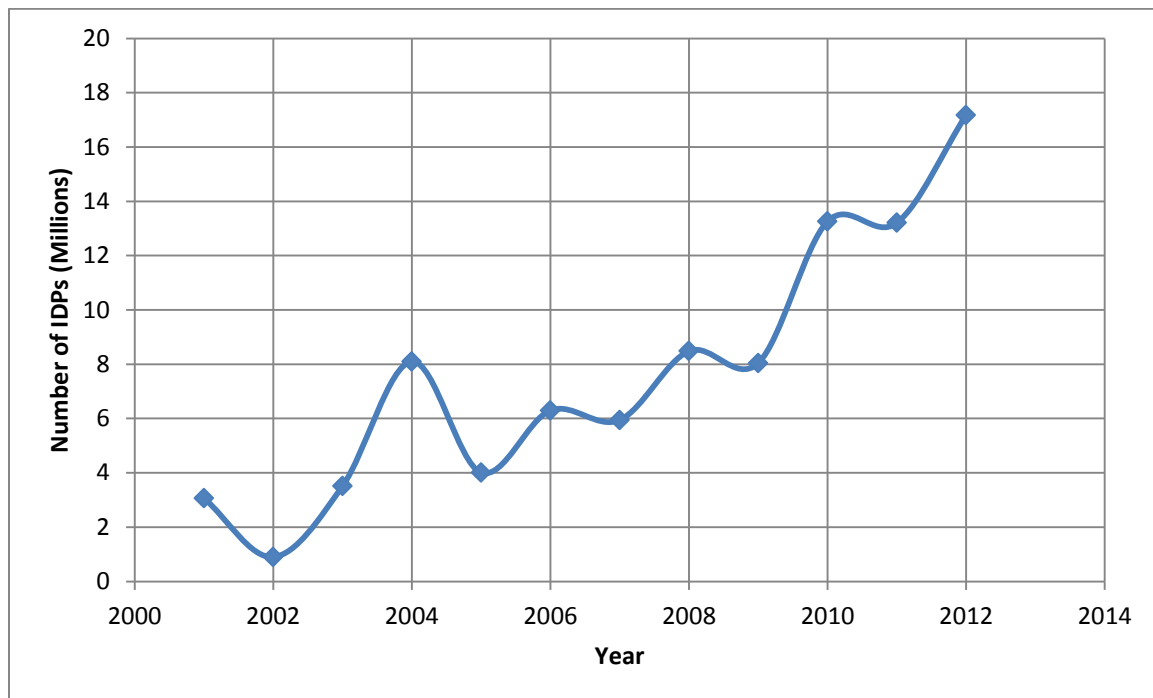
migrates and to where. Chapter I defined the difference between an IDP and a refugee. Those definitions are essential and are part of the problem. This is especially true in the case of Sudan and South Sudan. IDPs are displaced individuals who have not crossed an international border. In the case of Sudan and South Sudan, when South Sudan became a recognized country in 2011, the Sudanese IDPs in the south officially became refugees. As it turns out, that data becomes redefined and lost in the noise of accounting. A similar thing happened in 2005 when South Sudan became an autonomous state within the country of Sudan. Somewhere along the line the data were redefined. For this reason, a lot of the data used is collected from multiple resources. Where data between years is missing, interpolation (linear) is used.

1. Internal Displacement Monitoring Centre (IDMC) Data

The initial data set comes from Internal Displacement Monitoring Centre, located in Geneva, Switzerland (Internal Displacement Monitoring Centre, 2013). They collected data over a myriad of conflicts and years. The data is good based upon sampling the data from other resources (UNHCR specifically), but it is incomplete. For instance they have zero data entries for the years 1998 through 2000. To fill in those years as well as other missing data points, the UNHCR website data is used (United Nations High Commissioner for Refugees, 2001). They have yearly reports on IDPs and refugees within the areas of concern.

After taking an initial look at the data set, it becomes apparent that some of the data is not necessary. First, some conflicts are not long enough. Taking 2 data points for a short conflict does not provide enough of a trend to do analysis. Second, the total data set covers the years 1997 through 2012 (minus the data mentioned previously). Within that time, some conflicts have begun and ended, so the overall number from this time potentially fluctuates. Figure 8 shows this.

Figure 8. Number of IDPs (Millions) Over Years 2001–2012

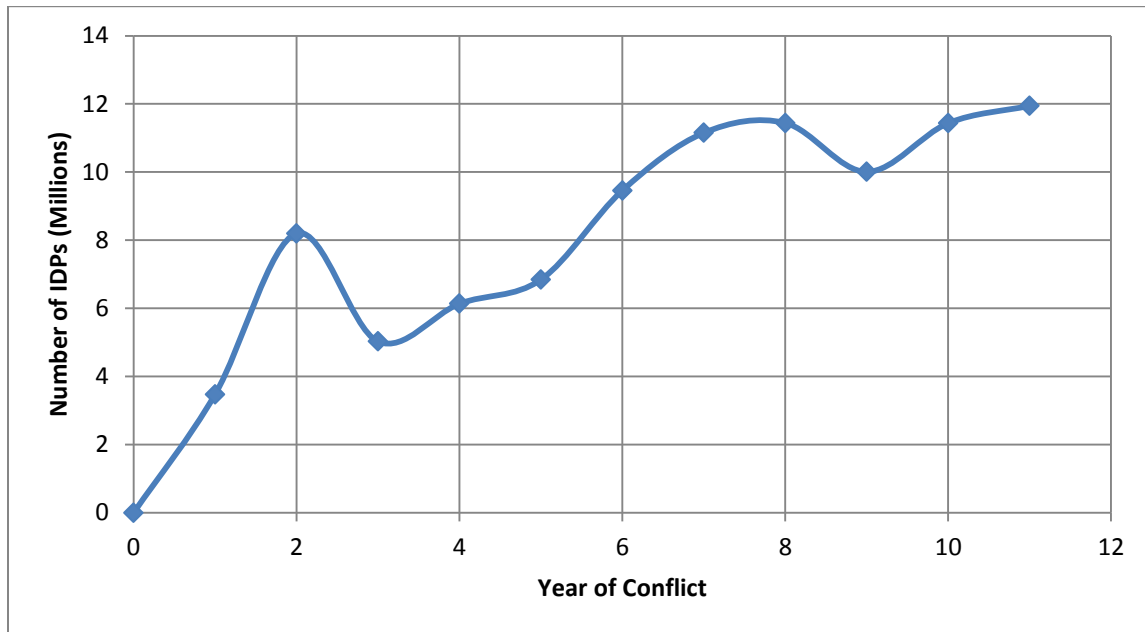


The above graph shows the amount of IDPs globally from the years 2001–2012. The data from 1997 is omitted because the intervening years (1998–2000) are missing. The graph still shows an overall rise in global IDPs, but the trends fluctuate due to conflicts ending or the population being redefined (refugee, political asylum seeker and legal immigrant). From the IDMC Metadata Excel CSV file.

This is a good start, but the data needs to be normalized. As stated earlier, within the total dataset, there are some conflicts that only lasted a year or less. In order to make the data set usable from an analytical standpoint, the data is baselined from a year by year standpoint. Seeing as the purpose is to track the amount of migration as a conflict goes on, calendar years (1997, 1998, 1999, etc.) are not a usable time slice. Rather, the baseline is from an elapsed time from the start of a conflict (Year 1, Year 2, Year 3, etc.). From that, data is compiled from some of the longer conflicts. Incidentally, the longer conflicts also accounted for a great percentage of the total IDPs globally. The conflict regions selected are Columbia, Sudan (north and south combined), Iraq, Turkey, Afghanistan, Lebanon, and The West Bank and Gaza region. These conflicts are selected for two reasons. First, each of these conflicts contains 11 annual data points; so they have the duration desired to analyze an annual rate of migration. Second, these conflicts account for over 80% of all IDPs over that time. To further normalize the data, the total

population of the region/country is added the data set. After normalizing the data, the overall look of the number of IDPs over time can be seen in Figure 9.

Figure 9. Number of IDPs over Time within Conflict.



This graph depicts the number of IDPs over an elapsed time of a conflict, starting at year zero with zero IDPs. This is compiled data from the previously mentioned seven conflicts. From the IDMC Metadata Excel CSV file.

This is interesting to see (and initially looks promising), but it is going to be tough to justify using this particular data set for a few reasons. Foremost, the data only tracks IDPs. It makes no mention of refugees. From that perspective, this is only showing a partial picture. Recall that within the Peace Game, there are three categories of migration (go to best region in the state, go to the best on the map, go to the region that has the most of a resource). Because of the nature of the data, grouping all three of these categories into one category will make for a usable analysis. This will become evident in the initial data analysis. So, where to find useable data that will fit the current construct of the Peace Game?

2. Defence Science & Technology Lab (DSTL) Data

The developers of the PSOM worked together with the British Ministry of Defence in creating their migration algorithm. In 2008, the Defence Science & Technology Lab (DSTL) in Porton Down, England published a report on an Excel-based program to predict how populations are displaced from their countries during conflict. It measured the number of people that are internally displaced as well as refugees. The program was also designed to predict how many people will become a fatality of a conflict. Some of the factors that went into the analysis were distance of a country from a conflict and the length of a shared border between those two countries. The model is simple, but it does incorporate more factors than the Peace Game's migration algorithm. Adding to the complexity, it is incorporated into PSOM, which, as stated earlier, is a far more complex program than the Peace Game. Due to the way it is incorporated into PSOM, the model is not useful for the Peace Game. However, the report is insightful and it does have some value here, specifically, the data that populates the model (Stevens & Thomas, 2008).

DSTL went through the painstaking process of collecting data on 61 different conflicts that involved massive amounts of population displacement. The data is initially split into two different categories, coercive displacement and non-coercive displacement. There are 14 cases of coercive displacement in where, "the purposeful policy held by an actor in a conflict was to relocate populations en masse" (Stevens & Thomas, 2008, p. 3). For the purposes of the Peace Game, these data are removed as there is currently no functionality within the game for a player to forcibly move a population. This left 47 non-coercive conflicts. Within these data lies some valuable information. The main points of data that are useful to this analysis are "years until max displacement," "target population (millions)," "estimated number of killed (thousands)," and "actual number of displaced (millions)." These categories consist of singular data points for each named conflict. This was due to limitations that DSTL had with gathering the data.

Many of the conflicts in the sample lasted for several years with periods of localised violence and periods of relative peace. As a result, the number of people displaced did not always rise monotonically to a single peak rather there were peaks and troughs as displaced people returned to their homes

even as others were being displaced or people were displaced, returned home and were displaced again. Consequently, the total number of people displaced over the conflict was frequently higher than the maximum at any single time. Unfortunately, it was not generally possible from the available data to identify the total number of people displaced or to identify the number of people displaced as a result of a particular phase in the conflict. For consistency therefore, given the limitations of the data available, the analysis considered the maximum number of people displaced at any one time and compared it to the total number of people killed up to this time. (Stevens & Thomas, 2008, p. 3)

This echoes the graphs seen earlier in Figures 8 and 9. It also illustrates the complexity of identifying people as a conflict comes to an end, maps are redrawn, and the people (as data points) are redefined (e.g., immigrant vice refugee, returnee vice IDP, etcetera). However, from this simple dataset, some usable analysis for the Peace Game can be conducted.

Another important fact to note is that this data set only defines displaced persons. It makes no distinction between IDPs and refugees. The data only captures the fact that there are persons that are no longer living in the place from which they originated. This actually works well for the Peace Game. As stated earlier, the Peace Game does not “track” individuals. The game only takes a census of an area for each turn. Where those persons came from and where they went is not specifically cataloged. What a player can see is that an area can be defined as “good” or “bad” by the amount of people within that area over time. This happens to coincide with the data set, which should make for a good representation when comparing the results of actual data with what the Peace Game results produce. This also helps to compare the new models in comparison with the Peace Game and the historical data.

C. MODELING THE DATA

As is the case with most data sets, the DSTL data cannot be taken at face value and ready for analysis at the onset. First, the data needs to be rescaled. From that end, it makes sense to take percentages of the target population that is displaced or killed. This will prevent extremely large or small numbers from skewing the results and analysis.

This now the data will contain the above mentioned categories as well as “Percent Displaced” and “Percent Killed.”

Looking at the key findings of the DSTL report, one sentence sticks out.

Extensive work has been carried out to identify the factors which influence refugees to choose one neighbouring country over another however it has not been possible to produce a reliable statistical model. The most influential indicators here are the total number displaced, the distance of the neighbouring country from the conflict and that length of the shared border. (Stevens & Thomas, 2008, p. 2)

While trying to include in the model the length of a shared border and the distance of a neighboring country would be difficult, it is also not necessary due to the fact that this type of functionality is not yet in the Peace Game. With that said, perhaps the overall size of a country can have an influence on migration. With this in mind, a final category is added to the data set. Using the CIA World Fact Book, country size (in square kilometers) is added to the data set (CIA World Fact Book, 2013). To recap, the categories of the data set are as follows:

1. Year until max displacement
2. Country size
3. Target population (millions)
4. Estimated number of killed (thousands)
5. Actual number of displaced (millions)
6. Percent of population killed
7. Percent of population displaced

D. CREATING THE MODEL

1. Regression Model

Again, using the DSTL data set, it would only be prudent to look at some regression analysis to see how well a model fits the data. The main software used is JMP (JMP Software, 2014). The initial plan is to look at all the data as a function of time. Again, the end result will model two dependent variables: the expected number of deaths

of a population, and the expected number of displaced persons. The main independent variables to be included from the data set are:

- Year until max displacement
- Country size
- Target population (millions)

As stated earlier, the DSTL data does not include the size of a country or its surrounding borders. The DSTL report does incorporate land mass and length of border, but it is unclear as to what data is used (Stevens & Thomas, 2008). Given the relative simple nature of the Peace Game, using simply the land mass of a country provided by the CIA World Fact Book, might provide some insight into improving the overall realism in the game.

2. Compounding Interest Model

After an initial look at the data, it becomes apparent that modeling migration and death as a function of time is the correct approach to take. This also happens to be intuitive. Something that also becomes obvious is the fact that as time goes on; the population size changes (due to death and migration). As such, overall numbers and percentages might also change. The problem is starting to present itself as a typical financial problem. Specifically, it is looking like a compounding interest problem. The primary motivation for this is that the Peace Game time slice can be of any duration (day, week, month or year). Therefore, when a projected game might be expected to last a matter of months, getting fractions of a yearly interest rate gives better fidelity to the overall results of the game. With this in mind a compounding interest formula is used as the basis of this model (Gerver & Sgroi, 2011).

$$A = P(1 + r / n)^{nt} \quad (1.2)$$

where:

- A = Ending balance
- P = Principal
- r = Annual rate of return

- n = Number of times the interest is compounded per year
- t = Number of years money has been invested

We adapt this equation to model the change in population due to migration, and separately, due to deaths.

$$R = S(1 - r / n)^{ny} \quad (1.3)$$

where:

- R = Remaining population
- S = Starting population
- r = Rate of migration *or* Rate of deaths
- n = Number of times the change in population is compounded per year
- y = Number of years until maximum displacement

Note that this assumes a constant rate of attrition due to either migration or death. While we know this is not the case, current data is so inconsistent that no trend can be identified that supports modeling a supportable non-constant attrition rate. In addition, our starting population is shrinking due to attrition, so the remaining population is less than the starting population; therefore we subtract the compounding rate, rather than add it.

$$R = S(1 - r / n)^{ny} \quad (1.4)$$

When we solve for the annual attrition rate, the equation looks like this:

$$r / n = 1 - (R / S)^{1/ny} \quad (1.5)$$

This equation will be useful for the Peace Game, that allows the user to input the length of turn. For example, if a turn length is three months (or four turns per year) then the n above will be four. For our remaining discussion, we assume one turn per year. This will simplify the final equation.

$$r = 1 - (R / S)^{1/y} \quad (1.6)$$

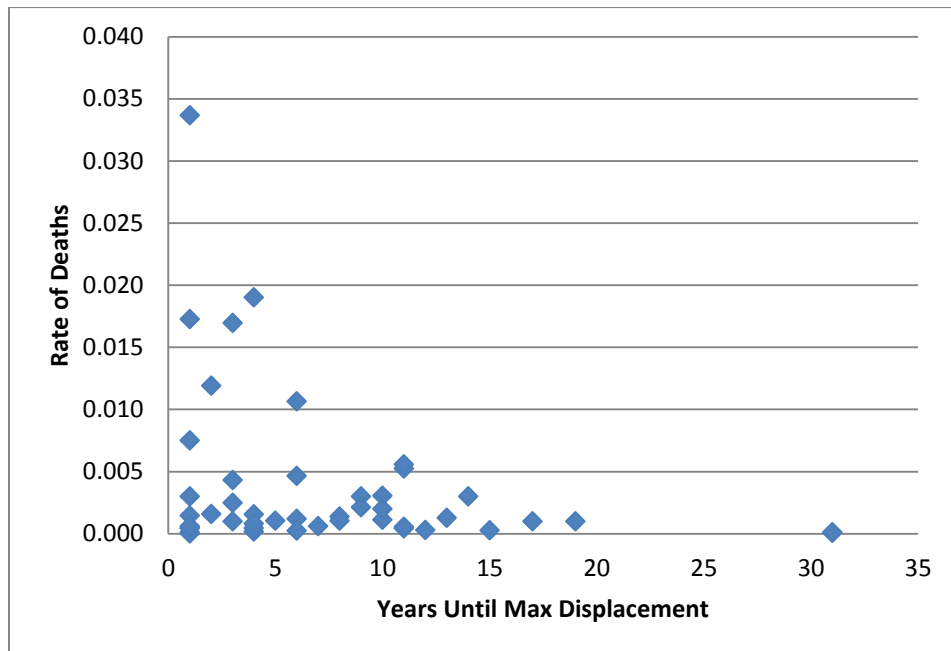
where:

- R = Remaining population
- S = Starting population

- r = Rate of migration *or* Rate of deaths
- y = Number of years until maximum displacement

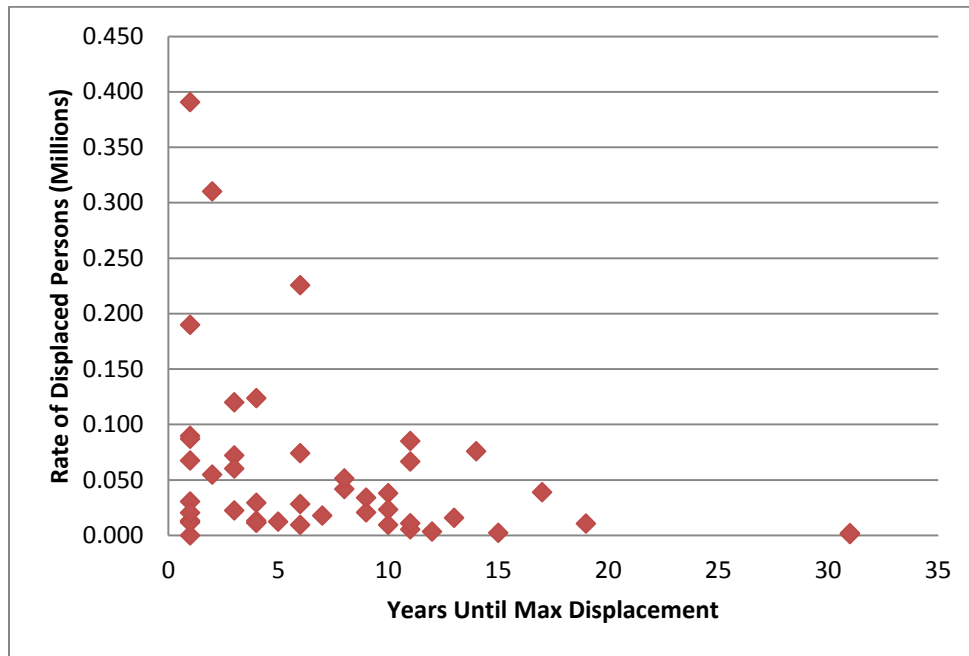
From this point forward, we will refer to this as the Population Attrition Model (PAM). This formula is applied to calculate both the rate of migration and rate of death in all 46 conflicts. Figure 10 is the graphical depiction of those results. Figure 11 shows a similar depiction for displaced persons over time.

Figure 10. Annual Rate of Deaths over Time Until Max. Displacement



This shows the rate of death over time in years using the estimated number of deaths in thousands. From the DSTL data set.

Figure 11. Rate of Displaced Persons Over Time



This shows the rate of displacement over time in years using the actual number of displaced persons in millions.

While this does not show an exact linear relationship, due to the fact that these samples are not all by a linear year, it does show a trend. It shows that as time goes on the overall rate of displacement goes down. From here, the 46 samples are placed in “bins” based on a yearly categorical convention for years until maximum displacement (1 year, 2–5 years, 6–9 years, 10–15 years, >15 years). This convention makes sense as a way to easily categorize the conflicts and remove some of the noise.

This looks like something that can be used to figure out if the model is representative of what will happen in a conflict. To emphasize one of the first points made in Chapter I, there is precious little research available when it comes to modeling human migration in conflict. This is most likely due to the volatile nature of the data. It seems that no one conflict is like any other. With this in mind, the hope is not to make a perfect model, but rather improve upon the model that is already resident within the Peace Game. The final analysis will be discussed in Chapter IV.

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IV. RESULTS AND ANALYSIS

A. BUILDING THE MODELS

In this chapter we develop and evaluate the models. PAM was discussed in detail in the previous chapter, so we will not go into great detail about it in this chapter. Later both of these models are compared to the current Peace Game algorithm. The comparison is in the form of comparing the results of all of the models against the actual historical numbers from a few selected conflicts. We calculate rates of attrition (deaths and displacements) by taking all of the conflicts and “binning” them into groups. We use the mean rates from the bins. This is described in greater detail later. The sample conflicts are chosen based on their proximity of their particular migration and death rates to the bin’s calculated averages of the collective death/migration rates.

1. Regression Models

When constructing a regression model, generally there are four things to analyze; summary output, Analysis of Variance (ANOVA), parameter estimates, and residuals. The summary output generates the R^2 and Adjusted R^2 . This is the measure of the proportion of the total amount of variation explained by the linear model; higher is better, with an R^2 of one meaning the models explains all of the variability. Also, within the model, the F-test is a measure of significance. This tests the null hypothesis that all coefficients $\beta_i = 0$, versus the alternative that at least one coefficient is non-zero. A significant *p-value* indicates that the model is better than just taking the mean of the response variable; a highly significant F-test will show *p-value* $<.001$. Similarly, the t-test values indicate the significance of parameter estimates; again, lower is more significant (an associated *p-value* $\leq .10$ is a good rule-of-thumb for including the term in the model). The residual plots are used in validating the model. When plotting the residuals versus predicted, you are looking for constant variance. This displays itself as a “shotgun blast” of points on the graph. Another residual plot to look at is the residuals versus row plot. This indicates autocorrelation; i.e., does the previous data point influence the next data point (e.g., low value followed by low value, etc.)? Finally, the distribution plot of the

residuals is a final check on model validation. Does the spread of residuals approximately follow a normal distribution (Seagren, 2015)?

Not all these tests for validating a model fall along the lines of textbook answers for a model. As has been the main theme, there is little research on modeling human behavior. This is due to the volatile nature regarding human decision making and behavior. So what would be considered a terrible text book model might actually be usable for the Peace Game, given the realm in which the model was created. It is important to recall that the primary goal of a wargame is to stimulate the human players. With that in mind, the initial attempt at creating a regression model that fit the data is based on the three independent variables previously stated.

- Year until max displacement
- Country size
- Target population (millions)

a. Regression Model for “Actual Displaced”

Taking the data set into the statistical analysis software JMP (<http://www.jmp.com/>) and creating a model using the above variables creates a poor initial model for calculating the expected amount of people that will be displaced.

Table 1. Parameter Estimates for Model with “Actual Displaced” as Response

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	629146.53	397764.7	1.58	0.1212
Year Until Max Displacement	67918.01	35290.7	1.92	0.0611
Country Size (sq. km.)	0.0971	0.3583	0.27	0.7876
Target Pop (Millions)	23003.85	19862	1.16	0.2533

This model has an R^2 of 0.142 and an Adjusted R^2 of 0.081.

This model fails due to the low R^2 and Adjusted R^2 values, as well as some of the t-test (“Prob>|t|”) values that are too high (> 0.10). So, the thought process now is that maybe the model needs to be simplified. Because of the nature of the Peace Game, these parameters need to be something that is measured within the game. As stated earlier, the

Peace Game construct is simple. A simple construct deserves a simple model. “Country Size” appears to have no real significance in this model. As a result, it is removed for the next model (Table 2).

Table 2. Parameter Estimates for Model with “Actual Displaced” as Response

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	659045.28	378037	1.74	0.0884
Year Until Max Displacement	70953.32	33105.85	2.14	0.0378*
Target Pop (Millions)	23894.16	19376.56	1.23	0.2242

This model has an R^2 of 0.141 and an Adjusted R^2 of 0.101.

This model performs similarly to the original. The only good thing about this model was that it shows that “Year Until Max Displacement” is a significant factor. This shows that we might be onto something with regards to how the population is attrited as a function of time. With that in mind the thought process moves to question the y-intercept. Ordinarily, this is not something that is usually done in regression models. In order to keep this model simple and within the construct of the Peace Game this seems the best way to go. To think of it logically, at year zero of a conflict, there should be zero displaced persons. This also makes sense from a data collection standpoint as most of the international organizations and NGOs do not start collecting data until the conflict starts. While this might not be the actual case, it is one of the assumptions that we need to make. Populations “in the know” will migrate before things get really bad and before they come to the attention of the international community. But for our assumptions, we set the intercept at time zero and displaced persons at zero (Table 3). Fortunately, the JMP functionality allows the simple removal of the y-intercept.

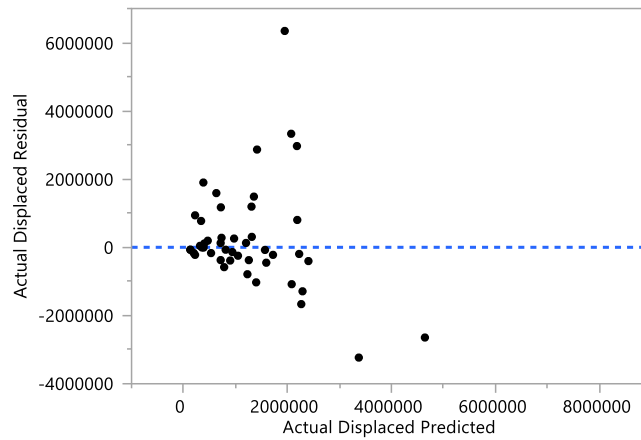
Because we are locking the intercept at zero, JMP generates no R^2 or Adjusted values. We do get a parameter estimate report that shows us whether our factors are significant (Prob>|t| value < 0.10). In conjunction with the parameter estimates there are the Residual versus Predicted plots to show that there is fairly constant variance (Figure 12). The row plots however, do not show this (Figure 13). There is definitely a type of “cone” effect going on there. This is not completely unexpected as the model is fairly

simple and the data is volatile within the parameters. This will be looked at in the comparison of the models later. The key thing to remember here is that we are not shooting for a perfect model, but rather a better model than what currently exists within the Peace Game.

Table 3. Parameter Estimates for Model with “*Actual Displaced*” as Response (No Y-Intercept)

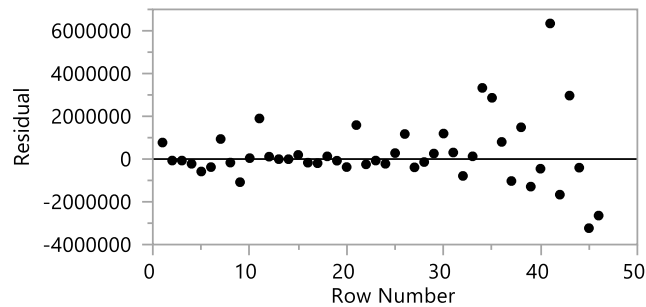
Term	Estimate	Std Error	t Ratio	Prob> t
Year Until Max Displacement	103638.64	27910.33	3.71	0.0006*
Target Pop (Millions)	40034.22	17411.65	2.30	0.0263*

Figure 12. Residual by Predicted Plot



Residual plot for “*Actual Displaced*” Model

Figure 13. Residual by Row Plot



Residual by Row Plot for “*Actual Displaced*” Model

This model looks like it might work. Note that “*Target Pop (Millions)*” in Table 2 shows a higher “*Prob>|t|*” value than ideally desired, but given that it fits really well in the model in Table 3, we decide to leave it in. With that, we have the following model that we will test out.

$$\text{ActualDisplaced} = 103638.64 * \text{YearUntilMaxDisplacement} + 40034.22 * \text{TargetPop(Millions)} \quad (1.7)$$

b. Regression Model for “Estimated Killed”

Using a similar process to the “*Actual Displaced*” model we create the “*Estimated Killed*” model. Again, taking the data set into JMP and creating a model using the same original variables (“*Year Until Max Displacement*,” “*Country Size*,” “*Target Population*”) we create an initial model. As is the case with the other model, this creates a poor initial model for calculating the expected amount of people that will be killed.

Table 4. Parameter Estimates for Model with “*Estimated Killed*” as Response

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	46217.14	32088.39	1.44	0.1572
Year Until Max Displacement	3662.37	2846.96	1.29	0.2053
Country Size (sq. km.)	0.0452	0.0289	1.57	0.1246
Target Pop (Millions)	387.59	1602.30	0.24	0.8100

This model has an R^2 of 0.136 and an Adjusted R^2 of 0.075.

Again, this model fails due to the low R^2 and Adjusted R^2 values as well as some of the t-test (“*Prob>|t|*”) values were too high (> 0.10). The same thought process from the other model is carried forward into this model. The initial thought is to use the same parameters as the displaced model. However, “*Country Size*” appears to have greater significance than the other parameters. Jumping right into removing the y-intercept, we create the following model.

Table 5. Parameter Estimates for Original Model with “*Estimated Killed*” as Response (No Y-Intercept)

Term	Estimate	Std Error	t Ratio	Prob> t
Year Until Max Displacement	-2642.867	2604.826	-1.01	0.3160
Country Size (sq. km.)	0.0568239	0.028113	2.02	0.0495*
Target Pop (Millions)	-949.0955	1481.808	-0.64	0.5252

No R^2 or Adjusted R^2 .

This model shows that country size is the only significant factor in determining the amount of persons killed. However, we discard this model because using this single factor while eliminating the factors of time and population size due to significance is counterintuitive. The basic assumption is that population attrition is a factor of time. At this point we backtrack and apply the same logic where we put the y-intercept back in, but remove “*Country Size*.” Recall that this is the same method we used in building the “*Displaced Persons*” model. Table 6 shows the result.

Table 6. Parameter Estimates for Model with “*Estimated Killed*” as Response

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	60154.84	31348.21	1.92	0.0616
Year Until Max Displacement	5077.32	2745.26	1.85	0.0713
Target Pop (Millions)	802.63	1606.78	0.50	0.6200

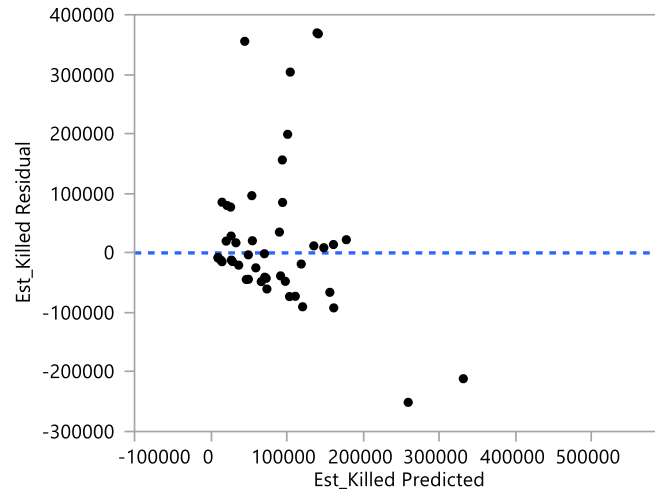
This model has an R^2 of 0.085 and an Adjusted R^2 of 0.043.

This model performs even worse than the original! However, just like the “*Displaced Persons*” model, this model shows that “*Year Until Max Displacement*” is a significant factor. Again, this shows that there is something significant about how the population is attrited as a function of time. From here, we remove the y-intercept in the same fashion as the “*Displaced Persons*” model.

Table 7. Parameter Estimates for Model with “*Estimated Killed*” as Response (No Y-Intercept)

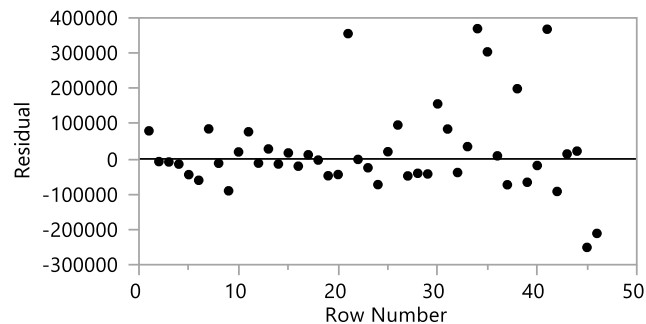
Term	Estimate	Std Error	t Ratio	Prob> t
Year Until Max Displacement	8060.70	2330.53	3.46	0.0012*
Target Pop (Millions)	2275.82	1453.89	1.57	0.1247

Figure 14. Residual by Predicted Plot



Residual plot for “*Estimated Killed*” Model

Figure 15. Residual by Row Plot



Residual by Row Plot for “*Estimated Killed*” Model

Once again, it looks as though we have a model that might work. Note that, once again, “*Target Pop (Millions)*” in Table 6 shows a higher “*Prob>|t|*” value than ideally

desired, but given that it fits really well in the model in Table 7, we decided, yet again, to leave it in the model.

In all of the cases, the different iterations of the “*Actual Displaced*” regression model perform better than the “*Estimated Killed*” regression model. When this is compared to the actual historical data, we should expect this trend to continue. This is simply due to the fact that the number of persons killed in the data set is an estimated number. With that, the model that we will test for “*Estimated Killed*” is below.

$$\text{EstimatedKilled} = 8060.7 * \text{YearUntilMaxDisplacement} + 2275.82 * \text{TargetPop(Millions)} \\ (1.8)$$

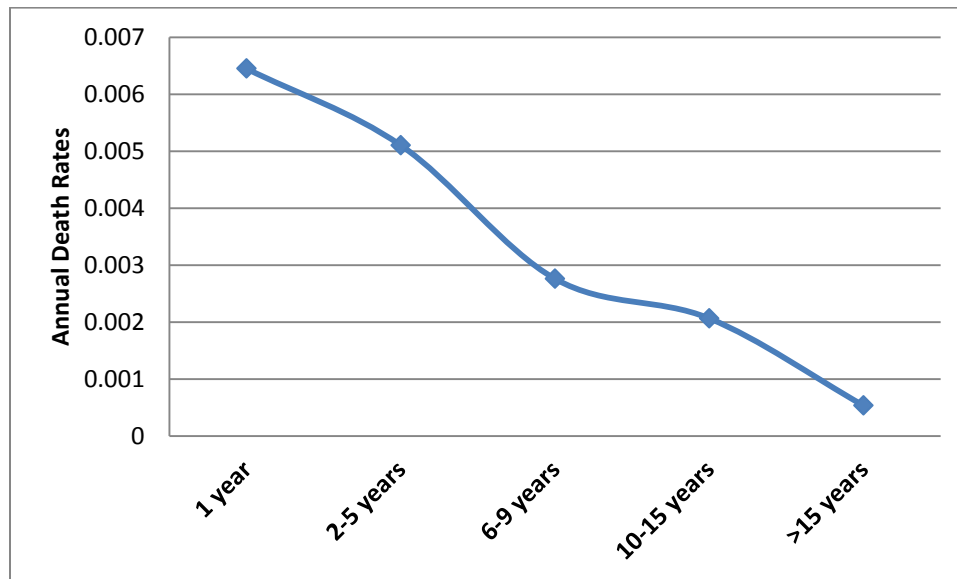
2. Population Attrition Model (PAM)

As stated in Chapter 3, PAM is based upon the calculated rates of annual deaths and calculated rates of annual displaced persons. The individual data points are highly variable, so we place the individual data points into “bins” that make sense from a “duration of conflict” standpoint and take the overall average from each bin. The bins are separated into the following categorical variables (with sample size).

- 1 year (10 samples)
- 2-5 years (12 samples)
- 6-9 years (9 samples)
- 10-15 years (11 samples)
- >15 years (4 samples)

When looking at the data this convention makes sense from the perspective that conflicts within each bin have a similar feel and look while still incorporating the full spectrum of types of conflicts. Once the data is binned in this fashion, the mean of both the death rate and displacement rate is calculated. Figure 16 and Figure 17 show the simple trend over the five data points.

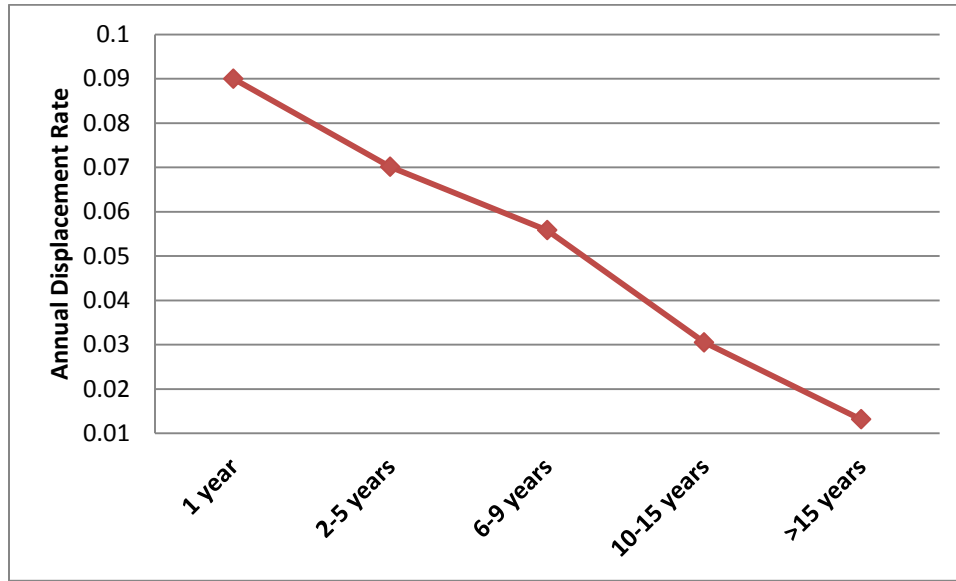
Figure 16. Rate of deaths over time (Binned)



When the conflicts are placed into the categorical bins, there is a distinct trend showing a decrease in the annual death rates as the length of the conflicts increase.

Figure 16 definitely shows a steady decreasing trend where the rate of deaths decreases over time. As stated earlier, this same convention is applied to the displacement data again using “Years until maximum displacement” as the filter. The results are similar. Figure 17 shows this trend.

Figure 17. Rate of displaced persons over time (Binned)



When the conflicts are placed into the categorical bins, there is a distinct trend showing a decrease in the displacement rates as the length of the conflicts increase.

Using the calculated rates from each bin in PAM, an expected number of deaths and displaced persons can now be calculated. In the next section, those numbers are compared to the actual historical data as well as the tabulated results produced from the Sudan scenario during Peace Game play.

B. COMPARING THE MODELS

Now that the data is compiled and the two models (PAM and the regression model) are established, it is time to look at the results of the models and how they compare to each other as well as the resident algorithm in the Peace Game. All of these models are compared to a sample of actual historical results from the original DSTL data set. For the PAM model, we use the bin averages for rates of death and migration. The linear model uses the actual number of years from the exact sample we will be comparing. Both models utilize the actual target population of the sample. The “>15 Years” bin was not used. There are only four samples from that bin and they are of such a length that they can all be considered outliers due to their length of conflict. We assume conflicts of over 15 years in length are so rare that they do not fit into any model.

Table 8. Input Data Table

Bin	Avg. Target Population	Avg. Estimated Deaths	Avg. Actual Displaced	Avg. Death Rate	Avg. Migration Rate	Sample	Actual Sample Year
Year 1	11,591,000	29,000	486,000	0.00644715	0.08998888	Burundi	1
Year 2–5	10,759,000	80,800	1,022,000	0.005101518	0.070098613	Eritrea	3
Year 6–9	7,432,000	89,300	1,311,000	0.002759288	0.05577949	Algeria	9
Year 10–15	12,915,000	213,600	2,607,000	0.002064705	0.030508654	Sierra Leone	10
Sudan (Darfur)	5,410,000	400,000	2,220,000	0.019020086	0.123708994	N/A	4

This is the main input table for calculating the amount of displaced persons and deaths. The linear model uses the last column for inputs. The average rates from each bin are used by the PAM. These particular conflicts are chosen due to the fact that their specific migration and death rates are close to the bin averages of those categories.

Using the data from Table 8 in the new models, we tabulate the results and compare the different models. The Peace Game inputs come from the results of actual gameplay of the Sudan scenario. Recall that the Peace Game has an arbitrary time slice. As such, the calendar duration of a round can be anywhere from a day to a year and anywhere in between. The example data from the Sudan scenario has the time per round as being three months (or one season), where four rounds equals one year. The PAM model is applied to the Peace Game results and calculates a result of the number of displaced persons and deaths. All of these models are compared to the historical results of the individual samples (See Table 8). The percent difference between the model and the historical results is the measure of success. The model that produces results closest to the historical results is depicted in green.

Table 9. Burundi Scenario Results

Population				
5,850,000	Deaths	Migrated	% Difference (Death)	% Difference (Migrate)
Actual	101,000	1,110,000	N/A	N/A
Peace Game	226,609	470,650	124.37%	57.60%
Linear Model	21,374	337,839	78.84%	69.56%
PAM	37,716	526,435	62.66%	52.57%

The Burundi conflict began in 1993. It was 1 year until maximum displacement. In this sample, PAM outperforms the other models, but they are all relatively close. This can be attributed to the fact that after only one year/round of play there should not be much difference as they are all starting from the same place. As time goes on, the results should be further apart.

Table 10. Eritrea Scenario Results

Population				
3,880,000	Deaths	Migrated	% Difference (Death)	% Difference (Migrate)
Actual	50,000	660,000	N/A	N/A
Peace Game	384,392	913,118	668.78%	38.35%
Linear Model	33,012	466,249	33.98%	29.36%
PAM	59,079	760,088	18.16%	15.16%

The Eritrea conflict began in 1998. It was 3 years until maximum displacement. In this sample, PAM performs better than the other two models. As expected, as time goes on, the results are showing a greater spread.

Table 11. Algeria Scenario Results

Population				
9,370,000	Deaths	Migrated	% Difference (Death)	% Difference (Migrate)
Actual	250,000	2,500,000	N/A	N/A
Peace Game	1,887,546	5,020,695	655.02%	100.83%
Linear Model	93,871	1,307,868	62.45%	47.69%
PAM	230,139	3,780,146	7.94%	51.21%

The Algeria conflict began in 1954. It was 9 years until maximum displacement. In this sample, the Linear Model is the better performer in the migration category but PAM was the performed better in the death category.

Table 12. Sierra Leone Scenario Results

Population				
4,150,000	Deaths	Migrated	% Difference (Death)	% Difference (Migrate)
Actual	125,000	1,330,000	N/A	N/A
Peace Game	881,492	2,359,739	605.19%	77.42%
Linear Model	90,052	1,202,528	27.96%	9.58%
PAM	84,894	1,105,700	32.09%	16.86%

The Sierra Leone conflict began in 1991. It was 10 years until maximum displacement. In this sample, the Linear Model is the best performing model. However, PAM is relatively close.

At this point it appears that, in any case, the PAM or linear model is an improvement over the current model that is incorporated into the Peace Game. However, there is one more comparison to make. How would the new models compare in against the actual Sudan scenario? The results are in Table 12.

Table 13. Sudan (Darfur) Scenario Results

Population				
5,410,000	Deaths	Migrated	% Difference (Death)	% Difference (Migrate)
Actual	400,000	2,220,000	N/A	N/A
Peace Game	669,271	1,656,426	67.32%	25.39%
Linear Model	44,555	631,140	88.86%	71.57%
PAM	82,376	1,059,813	79.41%	52.26%

The Sudan conflict in Darfur began in 2003. It was 4 years until maximum displacement. In this sample, Peace Game performs better in both death and migration counts.

A scenario where the Peace Game outperforms both of the new models is disconcerting to see at first. After a bit of thought it occurs to us that this is not an anomaly but rather a factual truth. The Peace Game was created to model the Sudan/South Sudan conflict region for the U.S. MCCDC. Thus, the algorithms within the Peace Game are most likely tuned to be biased towards representing that region of the world. It stands to reason that the Peace Game would perform better in the scenario for which it was originally created. This assumes the fact that the original creators did their due diligence in researching the Sudan conflict and creating a scenario that would best represent the view of the ground situation in Sudan at the time of the original prototype development.

C. ANALYSIS

After looking at the different samples, as well as a few others not specifically depicted here, the conclusion is that the Peace Game is finely suited to represent the Sudan conflict as it is currently constructed. The new models (PAM and the linear regression model) expand the usability of the Peace Game. The current user interface is already set to create any type of scenario that the user can think up. Incorporating the new modeling into the construct of the Peace Game will eliminate the game's Sudan bias and allow the game to better represent any conflict that is similar to the regions represented by the modeled data. The Peace Game will be better suited to represent the outcome of nearly any SFA operation involving regional conflict.

How to employ the new models? Which one is better? Which one to use? The short answer is...both. It is a situation dependent answer. Part of the answer lies within the original data set from DSTL. Looking at the data, it becomes apparent that there is a great preponderance of conflicts within the Central African continent. A lot of those conflicts have a similar flavor. However, there are some of those other conflicts that are smaller in sample size and general make up. The Baltic and Eastern Europe conflict of the late 1990s have a different construct all together (the current Crimean conflict, as well). What makes sense, based on the results, is that if there is a scenario that looks similar to a historical conflict, use the PAM model. The PAM is taking its guidance directly from the rates created from the DSTL data. If the scenario looks like it is something not seen before, endeavor to use the linear regression model. The caveat to using the linear model is that there needs to be consideration for length of conflict. Part of the game building needs to include the expected length of the conflict. This can be a tough point to lock down, but the linear model relies on this information to determine its results.

The main takeaway from all of this is that neither of these models is perfect. There is not enough data to create a finer model. However, these models do perform better than the current model within the Peace Game. These will make the Peace Game better represent human migration within areas of conflict. As the Peace Game grows, so shall these baseline models. If more functionality and metrics are added to the Peace

Game, these models should be reevaluated for efficacy. Bottom line, the Peace Game is equipped to grow and these models will provide the foundation for future growth.

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V. CONCLUSIONS

A. THE PEACE GAME TODAY

In its current form, the Peace Game is an excellent tool for decision makers at all levels to use in order to better shape SFA and SC operational planning. It has the most important characteristic required for a successful wargame: it provides excellent insight to the decision maker. The initial prototype from 2012 was a great start. As Lieutenant Commander Powers and Major Heerlein continued their development of the game, the program's player interface and usability only improved. The construct of the Peace Game is such that the game board is a blank slate that can be modified and adjusted to fit the players' needs. The game can be modeled as a campaign game or as a tactical game. The limitation is only bound by the players' imagination. As with all good wargames, the space for expansion and improvement of the Peace Game has no limit.

Using the new models developed in this thesis in the manner described in Chapter IV will improve the performance of the Peace Game dramatically and create a more realistic environment for game players. However, because these models are simple, they can be generally applied to other similar programs and projects. As the global migration crisis grows, so will the research and development of games like the Peace Game grow. These new migration models can provide a basis for that expansion of research.

B. FUTURE WORK

The main subject of this thesis has been on improving the migration algorithm within the Peace Game. Along that same line of thought, there are a few other items that can help to improve the overall realism of the Peace Game. Among these items to look at for future work include another analysis of the new proposed migration models, the addition of population demographics, and a more realistic representation of country borders.

1. Another Look at the Migration Algorithm

The current migration algorithm is good and provides enough "movement" of the population to trigger decisions by players in a timely manner. The initial thought process

of the developers was to get things moving quickly in the game. What they did not want was players going through the initial few rounds doing seemingly nothing, waiting for something to happen. To that end, the algorithm is successful. However, the analysis and comparison of the existing algorithm and the proposed new models shows that both PAM and the regression models better mimic events of the real world.

Can these models be improved? The short and obvious answer is, yes. This will first need to include more research of data. While it is unfortunate that migration due to conflict seems to be on the rise (United Nations High Commissioner for Refugees, 2015), it means that there will be more data on migration. From this incoming data a new cycle of analysis should be conducted. As stated earlier, the new models are not perfect, but they do perform better, by a good margin, than the current algorithm. With more data, these new models can be expanded and improved upon as well.

The models could be broken down by a few other factors. Some of these factors to look at are continent or development of region. One of the theories that arose during this research was whether there was a difference in how migration was affected by the development of a country or region (second or third world development). For instance, is there a difference in migration within a region like Iraq or Ukraine verses migration in Afghanistan or Central Africa? In countries like Iraq or Ukraine, there is generally an established national infrastructure of roads and public transportation. A good theory to test would be if this infrastructure helps or hinders migration. If the government shuts down such a system does the population stay in place, as they know no other way to get out of an area? In a third world country, where there is a far less developed national infrastructure, does any of this matter? Does the population use the natural landscape to move as so many previous generations have done? These questions lend themselves to further research in the subjects of country development and infrastructure systems. Of course, when incorporating these types of factors two things will happen. First, the models will become more complex. This can sometimes be a bad thing. Second, this would have to be something that would be incorporated into the construct of the Peace Game. There is currently no functionality that specifically addresses this factor.

If there could be a difference determined between the categories of development, a model for each category of development could be created. These models could be

incorporated into the Peace Game. Scenario development for game players could be “modularized” within the Peace Game interface. The functionality could be as simple as selecting a second or third world option within the user interface to set the model to be used for that particular game.

2. Population Categories

As the Peace Game currently stands, the population is “monochromatic.” That is to say there is no distinction between the populations from different regions. From turn to turn, the Peace Game measures the size of the population within each region. It does track the amount of people that have left or arrived within a region, but not what region they have gone to or come from. The game is also memoryless in this function. As the rounds continue, a person is now identified only by the region he/she is currently in, not where he/she originated from at the onset of a game. In reality, a population could migrate across the entire board without players being able to see or track that progression. By being able to “tag” persons, players will be able to get better fidelity on what drives a population and how region demographics change. Such change could affect (and often does) regional security. For instance, if a player is just concerned about the census of a region, and sees that it has fluctuated over time, but remains relatively stable, he could get a false sense of stability. If the population was “tagged,” a player could track how the demographic of the census changes. Using a basic color convention (red, blue, green) could assist in visualizing this for game players. Say the region in question started out with a “blue” population majority, but by the end of the game the “blue” population was gone and replaced by a “green” population. From this, a player could gain insight as to what happened and whether that was good or bad. Because the Peace Game is so easy (user friendly) to modify, this convention could apply to religion, social or economic characteristics.

3. Country Border Characteristics

The Peace Game currently has the functionality to create multiple countries with multiple regions. In fact, this convention is part of the decision making process for the population within the migration algorithm (go to best region within their state versus go

to best region on the map). What the Peace Game does not currently have is a “closed border” function. In reality, there are countries in the world that share a border, but it is nearly impossible for populations to cross those borders. The most obvious of these examples is the border between North Korea and South Korea. If there was a functionality that could “close” or “partially close” a border, this would do two things. First, it would better mimic real world political scenarios; second, it would create a “herding” effect on the population. This would show potential 2nd and 3rd order effects on other neighboring countries. Part of this was included in the DSTL study when they used border length as a factor in their modeling (Stevens & Thomas, 2008, p. 12). The thought being that an open border of large size would have a significant bandwidth when it comes to cross-border migration. Closing a border would close off options to the population and one could see the effects of that (i.e., greater casualty count, degradation in security, more of a population turning to crime or terrorism).

C. FINAL THOUGHTS

The Peace Game is a great tool for decision makers (at various levels) to play out a potential future SFA operation. Incorporating the proposed models will make it even better. However, these models do not only fit within the Peace Game. These models, and the research involved, can be included into other models and similar games that may be developed in the future. As the research and analysis of the topic of human migration in conflict expands, so should the models. I look forward to seeing how these changes will better enhance the Peace Game and see if this propels the game to yet another level of insight and analysis. The Peace Game’s relatively simple user interface and blank slate construct mean that the game player’s imagination is the only limit to the game. Small improvements like the ones proposed will create a more realistic planning environment to minimize the operational surprises that always come when campaign planning collides with campaign execution.

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