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MODELING POPULATION DISPLACEMENT IN THE SYRIAN CITY OF ALEPPO

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ABSTRACT

The persistent crisis in Syria has affected millions of its citizens by forcing their displacement from native or accustomed residences. Modeling the Syrian conflict provides a computational means to better understand why, when, and where these citizens flee. Thus, an agent-based model drawn on real-world data to represent Syrian cities (the environment) and the demographic constitution of those cities (the agents) has been developed and is explained in this discussion. The outputs of the model accurately reflect population displacement as it occurred in 2013. Importantly, the purpose of this agent-based modeling and the output analysis is to develop a means to anticipate, measure, and assess future displacement in Syria as well as to model other threatened populations in crises where displacement might occur. This paper presents the methodology to crafting the environment and agents to represent the Syrian city of Aleppo and the displacement of its citizens.

1 INTRODUCTION

The Syrian Arab Republic is in the throes of a grand-scale complex dilemma in the form of the dislocation of millions of Syrians from their home regions and cities. Based on where they go and the conditions under which they leave, these individuals can fall into a number of designations determined by the United Nations High Commission for Refugees, for example Year of Global Crisis, 2012):

- stateless
- individuals in a protracted situation
- externally displaced
- internally displaced
- refugees
- asylum seekers

For purposes of this research we have taken an inclusive approach to these designations by assigning the term *population displacement* to this phenomenon. The body of literature addressing population displacement asserts that individuals within a threatened population consider all known factors then select the best option. These individuals take into consideration specific conditions and perceived risks as well as costs and benefits. Given the complexity associated with the nature of this environment and the squishy nature of human data, perceived risks-costs-benefits, we have determined agent-based modeling to be the best approach to assessing this real-world case study premised on human decision-making. The goal of this modeling is to anticipate involuntary population movement – population displacement. The model can have significant future uses such as determining why, when, and where migration will occur. Since 2010, one in three Syrian citizens has been displaced: 2.2 million have left Syria and 6.5 million are internally displaced.

This paper presents the development and validation of an agent-based model to represent Syria's population displacement during 2013.

The paper flows as follows: Part 2 provides a brief narrative of case study Syria; Part 3 discusses existent conceptual models that are expanded for use in an agent-based model for environment representation and agent characterization; Part 4 presents the resultant preliminary environment and agent matrices; Part 5 substantiates the two matrices as a valid means of modeling the environment and agents for the city of Aleppo; Part 6 discusses execution of the model and its results; Part 7 summarizes this approach and introduces suggested uses of the matrices and methodology as future iterations of the model.

2 THE SYRIAN REPUBLIC

Syria's current leader, Bashar Assad was born in 1965 in England, schooled as an ophthalmologist, and made a life in London. His return to Syria was instigated with the 1994 death of his brother, Basel, wherein Bashar shed his professional career to join the Syrian military. His father, Hafez Assad, had made new appointments in the regime to build a support base for Bashar by promoting many from the minority Alawite sector as officers. Within the government's cabinet 22 new appointments were made among the 34 members (Rabinovich 2012). Hafez Assad died on June 10, 2000; within a day Syria legislative branch, the People's Assembly, amended the constitution to lower the minimum age of the president from 40 to 34, allowing Bashar Assad age 34, to succeed his father in office. Bashar was nominated with no other nominees for president with 97.29% of the vote. Within in a month he was elected president in a referendum dated July 10.

Syrians longed for the the liberty they once had pre-Hafez Assad (pre-1970) and there existed an exceptional thirst for middle class freedom – what became known as the *Damascus Spring*.[1] But Bashar Assad proved to be an uncompromising autocrat, more unyielding than his father. Seeds for disaster were germinating in Syria and the Arab World as Bashar's character and leadership brought with it a persistent decline across the entire spectrum of Syrian life. U.N. Human Rights Watch proclaimed the first decade of his administration as 10 wasted years: unemployment was at 20%, poverty registered at 32% while at the same time Bashar's personal worth was at $122 billion (Ajami 2012). Further U.N. data highlighted the fact that the Syrian state weighed in at 165th of 175 states with free press, 152 out of 152 on the democracy index, 19 out of the 22 Arab states in economic performance. Syria also experienced the trials besetting the Arab world at-large: a youth bulge with a demography of 50% under age 19 and 57% under age 25; wiki-leaks unveiling the lifestyles of rich; widespread socio-economic problems; political corruption; and restricted political space (Lesch 2012). In January 2011 Bashar was interviewed by the *Wall Street Journal*; he boasted Syria strength lay in its links with the people. Within six weeks of that interview rebellion came to Syria.

The following is a succinct chronological review sequencing some of the escalating events, encapsulating two extremes: the deteriorating conditions in the *environment* and the ever-rising death toll and those displaced among Syrian civilians, *agents*, during three years of the crisis, 2011-2013.

2.1 January – June 2011

In February several small demonstrations occurred as Syrians sought a show of solidarity with pro-democracy protesters in Egypt, Tunisia, and Libya. Syrians wanted reform; their demonstrations, however, were repelled by Syrian security forces. Violence in southern city of Darʿā resulted in arrests of several children for writing anti-government graffiti. The families of these boys took to the streets to protest treatment of the children who were subsequently incarcerated. Matters escalated when forces raided Omari Mosque, which was a makeshift hospital. To end the unrest the government ceased basic

services to the city. No electricity, water, mobile phones; funerals were banned and quarantining went into effect.

The Syrian police were soon facing anti-government protests in several cities throughout the country. Continued discord in Darʿā resulted in Syrian security forces sealing off the city in an attempt to prevent protests from spreading. Within ten days a human activist group protested in Damascus on their behalf as well as seeking nationwide political reform as anti-government uprisings now throughout Syria. These reactions were unprecedented and unexpected; they served as justification for the regime to use force. Darʿā suffered water and food shortages and communications shut down in what became a four week siege. Even the Omari Mosque was shut down and the call to prayer banned. The violence spread to surrounding cities: Latakia, Homs, Hama, and even Damascus. However, in the capital life as normal because Sunni business classes were last to be embroiled and did not think this violence would reach them. Thus, it was those outside of the capital who suffered sniper attacks, food deprivation, and quarantining in their own homes. The Damascus elite ignored this and held hope that their riches and belongings would not come under attack. This is part of the notorious *urban - country divide* in which the Damascenes view those in the rural areas as weak or stupid for in Damascus the money, business, and elite of the Syrian state can be found. Syrians from other cities saw things differently; those who persisted in opposing the Syrian military were from two distinct sectors of the population quarters, the Alawite and the Sunni. By the end of February a major city, Homs, fell as the bastion of opposition (Brynen 2012). Both Alawite and Sunni Syrians sought safety by fleeing to mountains.

At the close of the six-month rebellion the death toll was estimated at 3000: Darʿā suffered the largest fatality per population density with 594 dead; and Homs, the third largest city with Sunni majority and substantial Alawi minority lost 761 citizens; deaths also occurred in Idlib, Damascus, and Aleppo.

Population displacement reared its head in March 2011 as a direct response to the escalating violence Syrians were now fleeing into two neighboring countries: 250 rushed north to Turkey, while others fleeing Talkalakh, a town in the governorate of Homs, spilled south into Lebanon. The military siege of Jisr al-Shughour was catalyst for thousands more to cross into Turkey. By mid-June approximately 7000 Syrians had fled to Turkey (Financial Times 2011). Still, displacement during the first six months of the conflict was relatively sparse as large groups of people only fled those cities / regions of intense targeted and/or localized violence (IDMC 2012).

2.2 July – December 2011

In August UN Human Rights Council officials estimated over 2,200 people were killed since mid-March prompting a vote to open an investigation into possible crimes against humanity. To present themselves as a legitimate group, Syrian opposition activists form the Syrian National Council (SNC) as representatives of the Syrian opposition. Within two weeks the opposition engaged in its first large-scale battle with Syrian government forces in the city of al-Rastan. Syrian troops clashed 5 days with army defectors and the Free Syrian Army. Assad's Syrian military proved superior and was able to regain control of the city.

The displacement numbers during reflected over 15,000 seeking refuge in Turkey by the end of July. Syrian refugees in Lebanon increased to approximately 2,600 by the end of August, with thousands more residing in Lebanon illegally. By September, the estimates for Syrian refugees in Lebanon rose to around 4,000 registered, with possibly as many as 6,000 in-total residing there. November reported in with the number of Syrian refugees in Turkey at 7,600. By December the number of registered Syrian refugees in Lebanon reached 5,000. Also in December Syrians were entering Jordan with 1,500 registered as refugees and thousands more unregistered. The year 2011 ended with another shelter for Syria's displaced as thousands fled to Libya (UNHRC Global Report 2011).

2.3 January – June 2012

By March the U.N. Human Rights Commission cited over 7,500 civilian deaths. Much of the killing is arbitrary and disparate: over 50 people are killed in a double suicide bombing at a military base in Damascus. The Syrian government blames opposition groups, while members of the opposition contend that the Syrian government staged the attack to discredit the opposition. A video statement purportedly released by the *Nuṣrah Front*, an Islamist militant group operating in Syria, claims responsibility for the bombings. Days later, however, spokesmen for the group denounce the video as a forgery and deny responsibility for the attack. Subsequently, more than 100 people are killed in the area known as Ḥūlah, north of Homs, with most of the victims concentrated in the village of Tall Daww. U.N. observers confirm that most of the dead were killed in house-to-house raids and that about 50 children died in the attacks. The first six months of 2012 prove the Syrian regime deadly, untrustworthy, and undiplomatic.

With the intensification of the conflict came an escalation in displacement. Assad's regime no longer practiced restraint; it had become a targeted attack against civilians. The disproportionate use of force in Zabadani, Duma, and Damascus (January) and the vicious suppression of Homs (February) left thousands of Syrians homeless. The figures tell the story as the number of refugees and internally displaced in the city Homs were estimated well over 50,000 (ICG 2013). As conflict spread into central and northern Syria, influxes of Syrians fled into Lebanon and Turkey. According to UNHCR, the number of refugees in neighboring countries had reached 40,000 by March 2012 (UN Syrian Regional Response Plan 2010). In April the UN reported that the number of Syrian refugees in Jordan, Iraq, Lebanon, and Turkey had jumped by 40 percent in the previous weeks and stood at about 55,000 registered refugees, while 200,000 or more Syrians were now displaced in their own country (Reuters 2012).

As rebel offenses acted in Damascus and Aleppo refugee numbers increased. The Damascus bomb attack that killed Assad's brother-in-law and other high-ranking security officials (on July 18) resulted in over 30,000 crossing into into Lebanon within 48 hours (BBC July 2012). Intense fighting in Aleppo resulted in approximately 200,000 fleeing the city as internally displaced, and thousands crossing into Turkey.

2.4 July – December 2012

By summer 2012 the International Committee of the Red Cross made its official declaration of the conflict in Syria as a *civil war*. The new designation means that combatants are subject to international humanitarian law and may be prosecuted for war crimes. Further violence at the capital as an explosion at the National Security Building in Damascus killed or injured senior Syrian military and security officials responsible for the crackdown against the opposition. Syrian state media claim that the attack was conducted by a suicide bomber. Senior members of the Free Syrian Army claim that the explosives were placed by a double agent within the Syrian security services and detonated remotely.

Throughout summer the now *civil war* continued. Syrian opposition leaders introduced the formation of a new Syrian opposition coalition, called the *National Coalition for Syrian Revolutionary and Opposition Forces.* By December U.N. estimates indicated 60,000 people were killed since the beginning of the conflict in 2011. Those believed to have been displaced amounted to 500,000 (UNHRC Timeline 2013).

In August the UN reported over 100,000 Syrians fled their country in that month alone; this was the highest monthly figure of displacement thus far. August proved to be a month of desperation; the numbers of displaced spiraled out of control with over 235,000 refugees in just one month (BBC September 2012). The year 2012 experienced a ten-fold increase in Syria's displaced population. According to UNHCR reports dated September 2013, approximately one million refugees left Syria during the first two years of the crisis and 1.5 million people in Syria have lost their homes and livelihoods as internally displaced people, one in every fifteen.

2.5 January – December 2013

This period saw an exponential growth in the displaced population mainly due to the escalating conflict between government troops and the rebels. The number of refugees increased from about 500,000 at the beginning of the year to nearly 2.3 million by years' end. As the rebel forces grew government troops moved to quash them at an ever increasing pace. This had the effect of both fueling the rebel response and also causing significant indiscriminate attacks on the population by the pro government forces. Citizens, fearing for their safety, began to flee in large numbers. It is this aspect of behavior that we wish to capture via our agent-based model. It offers an important dynamic interaction among government troops, rebels, and citizens that is motivating the current out flux of Syrians.

3 EXPANDING EXISTENT MODELS FOR USE IN AGENT-BASED MODELING

In reviewing the literature on refugee movement it is clear that the primary modeling approach for assessing the phenomena stems from the social scientists who employ statistical applications; these applications proved to be of little assistance in developing our agent-based model. The engineering literature on the subject yielded one game-theory treatment and one simplified modeling and simulation technique.

The game theoretical model by J. P. Azam (2002) analyzed motives of violence against civilians during internal wars. The Azam model presented two theses: 1) soldiers terrorize because they need to loot as a means to augment resources and, 2) looting is simply a function of conflict. From the state's perspective, displacement of large factions of the population reduces the fighting efficiency of the enemy as it cannot hide or obtain supplies. He executes hypotheses in a game theory format by presenting the government and the rebels sequentially deciding on the level of force engaged in violence against civilians (Stage 1) before these opposing forces decide the level of force they will engage in fighting in each other (Stage 2). The Azam model introduces counter-intuitive findings and facilitates clearly deriving the different implications to the presence of looting in civil conflicts. As a function of conspicuous atrocity, the Azam model suggests that violence against civilians is a military tactic not just a by-product of war. The outputs from this model suggest numerous factors that merit representation, many of which have not been evaluated in any of the other models. Significant to our research is Azam's findings that there will be a greater number of refugees produced if a state government gets more resources which in turn results in a type of conspicuous atrocity – a government war against civilians.

The simplified modeling and simulation approach by Bruzzone (2011) engaged a use-case to investigate the impact of migrant seasonal workers on communities. Bruzzone's model characterizes two populations, local and migrant, in an effort to measure the effects of conflict and disorder in a community and the response of local law enforcement. The model is conceptual in design and as such is not an executable model with simulation runs and outputs. Significant to our research is Bruzzone's perspective on situational population displacement due to the economic pull of another state.

There are two conceptual models put forth by social scientists that did prove very useful for researching, assessing, and measuring factors that affect population displacement. The initial model by Lance Clark (1989) and a subsequent iteration of his model by Susanne Schmeidl (1997) show a logical the progression of this conceptual modeling. Clark focused on integrating generalized structural factors. Schmeidl extends Clark's work as her model delineates among root causes, proximate causes, and intervening causes of population displacement. These factors serve to represent and/or characterize an entire situation or behavior with the idea that the assessment and model would eventually be able to predict behavior. The framework of these two models served in the development of our preliminary Environment and Agent Matrices which we crafted to broadly map factors that would be used for an at-large agent-based model of population displacement.

4 PRELIMINARY ENVIRONMENT AND AGENT MATRICES

Our initial cut at crafting an ABM Environment Matrix incorporated specific factors outlined by the United Nations Human Rights Council (UNHRC 1996). Their variables are divided as: 1) Prompting Departure - ethnic and racial tensions, social tensions, religious tensions, and others; 2) Intervening Factors – alternatives to international flight, international relief, international protection force, and others; and 3) Triggering Events – new types of people affected, spread of problems in region, increase intensity of situation, and others.

Population displacement is a complex network of relationships requiring modeling beyond conceptual (as in the case of Bruzzone, Clark, Schmeidl) and beyond linear (such as that of Azam's Game Theoretical). It is imperative that a population displacement model integrate qualitative data (historical context) and subjective data (human behavior) must be represented. As such, we drew upon our previous work of engaging multi-disciplinary, mixed-methods research to provide a means to represent both qualitative and quantitative data (Office of UNHRC 2012). The result, discussed in full detail in our previous paper, was an ABM Environment Matrix that can be individually mapped per case study to ensure adequate and correct representation of the model environment. In short, our Environment Matrix is the result of a confluence of variables: the Clark and Schmeidl models, specific factors delineated by the UNHRC, and our distinctive addition into which the outputs of the simulation will be categorized, labeled OUTCOMES (see Figure 1). The Environment Matrix should be viewed as a modifiable, extendable framework.

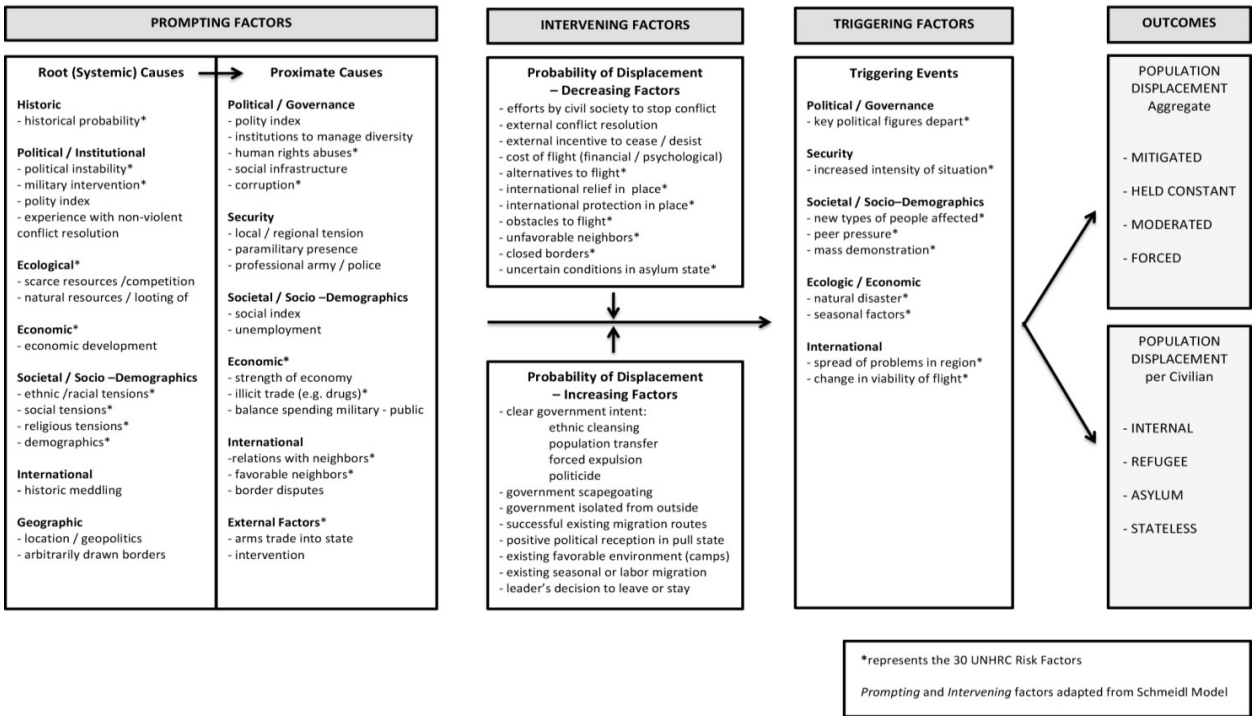

Figure 1: ABM Environment Matrix – Sokolowski / Banks Model

We next crafted an at-large, extendable Agent Matrix that included characterizing militaries, insurgents, states, and the civilian population. The initial cut for the Agent Matrix was to observe the various categories of agents and how an agent performs to achieve a goal such as survival (civilian: decision to stay or move) or to accomplish a task (regime: effort to retain political control). With the Syrian Arab

Public in mind, the agents populating this matrix reflect the current actors and segments of Syrian society – participants – involved with or affected by the current conflict. The matrix in Table 1 assigns location (state internal or external) and the actors' intent or goal (sustain power, over-throw government, or survive the conflict).

Table 1: ABM Agent Matrix – Sokolowski / Banks Model

PARTICIPANTS	LOCATION	INTENT / GOAL	FACTORS
	Internal – Syria		(see Environment Matrix)
National Defense Army (Assad Regime: Shia and Alawite) **Shabiha** (pro-government gangs)	Military Quasi-paramilitary	Political-Military	
Free Syrian Army	Rebels	Political-Military	
	External – Syria		
Iran (pro-Assad) **Russia** (antagonists – pro-Assad)	Assad Supporters	Ideological-Political	
Nusra militia – Salafists linked to al-Qaida and Taliban (protagonists – anti-Assad) **Al-Farouq Brigades** linked to Muslim Brotherhood (protagonists – anti-Assad)	Rebel Supporters	Ideological-Political	
	Internal – Syria		
Syrian Civilians 1) 75% Sunni 2) 15% Alawites 3) 10% Christian	 1) majority, anti-Assad 2) minority, pro Assad 3) minority, pro Assad	 1) survival, gain political control 2) retain political control 3) survival	

These two matrices serve as the overarching means of mapping specific data for any given case study for modeling population displacement. The discussion below details how these matrices were en-gaged and modified to model the Syrian crisis, specifically population movement during the civil war year 2013.

5 PRELIMINARY ENVIRONMENT AND AGENT MATRICES

With our general, extendable matrices in place, we are now in a position to do a focus study to develop a model that can represent the Syrian city of Aleppo to analyze it using a scale that is computationally achievable in a non-high performance computing environment. This will facilitate validating the model against the actual data well as implement our matrices as frameworks to exploring additional cities or

regions in Syria or other regions of the world. The following sections describe elements of the environment, aka *grid*, and agent characterization to include the rules for agent behavior and the logic behind each rule.

Aleppo is represented by a grid of 1089 squares. Each square represents a portion of the population living within the city (see Figure 2) The three agents linked together are the government troops patrolling the city to keep order. The troop agents are modeled using the agent construct set forth by Epstein (2013). Specifically we implement agent_ zero to represent these troops.

The agent_zero structure has three components to capture human behavior. These components are the emotional, rational, and social constructs that Epstein contends influence human decision-making. These three components interact with one another to produce the overall agent behavior. The overall behavior is called the agent's disposition. Disposition is represented by Equation 1.

$$D_i^{total}(t) = V_i(t) + P_i(t) + \sum_{j \neq i} \omega_{ji} D_j(t) \tag{1}$$

$D_i^{total}(t)$ is the agent's total disposition, $V_i(t)$ is the agent's emotional component, $P_i(t)$ is the agent's rational component, and $\sum_{j \neq i} \omega_{ji} D_j(t)$ is the influence of other agents on our agent of concern (social component). The emotional component is based on the Rescorla-Wagner model of conditioning (Rescorla and Wagner 1972). This is a conditioned response model, the response of which is learned over time. Mathematically it is represented by Equation 2.

$$v_{t+1} - v_t = \alpha\beta(\varphi - v_t) \tag{2}$$

$v_{t+1} - v_t$ is the change in emotion over time, $\alpha\beta$ are salience values that govern the rate of conditioning, and φ represents a threshold value for maximum conditioning.

As more and more rebel cells develop, the troops' emotional state increases adding to their disposition causing them to act more and more aggressively and cause indiscriminant attacks on civilians near rebel strongholds. The government agents move randomly around the city seeking out these rebel pockets and attacking them when found. Figure 3 shows pockets of rebel cells developing around the city.

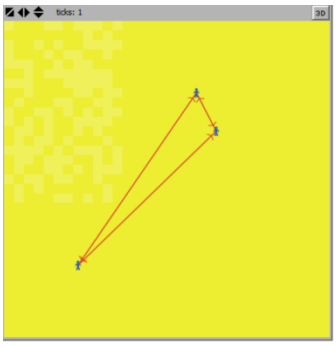

Figure 2: Sokolowski / Banks Model – Environment Matrix Aleppo

Rebels form at random locations at a base rate adjusted for the aggressiveness of the government forces. As government troops encounter rebel pockets they attack them. Rebels also are able to attack the government forces and have a probability of killing them, thus reducing the government threat. Figure 4 shows dark areas where government attacks have occurred and the civilian population has been targeted. The number of rebels in the vicinity of government troops affects the troops' rational component.

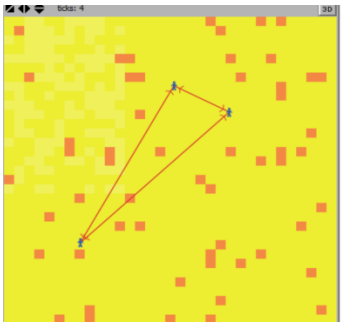

Figure 3: Rebel pockets beginning to form

The troop agents rationalize that if there are a greater number of rebels in their immediate vicinity then they are justified in attacking the location. There is a memory aspect implemented as part of the rational component. The troop agents consider the density of the rebels over a period of four days such that if the density decreased then the rationale about the threat would also decrease.

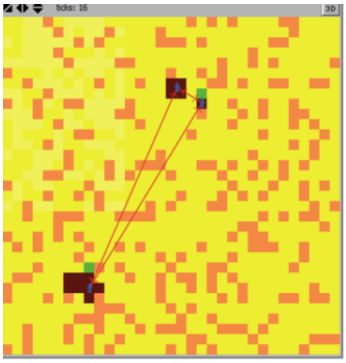

Figure 4: Pockets of government troop attacks

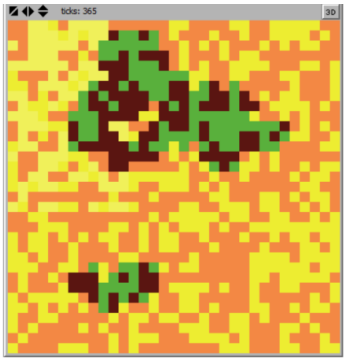

Figure 5: Refugee pockets forming around attack areas

For this simulation the social component was not included. Each of the government troops acts independently based on the condition of its local surroundings and is not influenced by what is happening in other parts of the city. As the attacks become more wide-spread civilians begin to flee the areas around the attacks based on their threshold of tolerance. This threshold is randomly assigned to each location in

the simulation. Locations can be thought of as representing neighborhoods. Refugee areas are indicated by lighter colored areas (green patches) in and among the dark attack areas. See Figure 5 for this depiction.

We executed the model for a period representing one year's worth of time to assess the percentage of the population leaving the area. One hundred replications were performed using a Monte Carlo simulation with random starting locations and movements of the government agents. Figure 6 is a graph of how that percentage is changing over time.

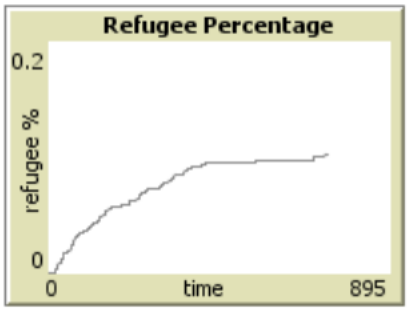

Figure 6: Percentage of population that have become refugees

The time scale of the graph is equivalent to a total of 1.5 years. The result of the Monte Carlo simulation produced a mean refugee percentage of ten percent over the years' time. Given the population of Aleppo being about 22 million our simulation should have produced about 2.2 million refugees. Data provided by MercyCorps indicated about 2.1 million refugees for this period of time (MercyCorps 2014). The de-creasing rate of refugee creation in our model is due to the rebel forces and government forces starting to neutralize one another causing a lowering rate of destruction by the government forces.

The model replicates the refugee behavior taking place within Aleppo by capturing the dynamic interaction taking place between rebels and government troops initially on an escalating basis and eventually becoming more of a standoff. Future work on this model will include representing the civilian agents using Epstein's agent_zero construct thereby giving them disposition behavior similar to that possessed by the government troop agents. For a detailed explanation of agent_zero (see Epstein 2013).

6 SUMMARY

Agent-based modeling is an important tool for investigating human and social phenomena. This type of modeling has a number of advantages over traditional statistical modeling used to investigate the phenomenon of population displacement. First, subjective data that can be represented in the model plays a role: these computer agents can mirror-image real people given the correct inputs from the research. Second, these models can closely represents how an agent (human) interacts with its surroundings and the other agents (persons) in it. Third, agent-based models can dynamically coordinate communication and activity. The authors acknowledge the strengths to this type of analysis and as such have developed the first step in agent-based modeling of population displacement to reflect an integration of previous modeling efforts. This methodology deliberately incorporates criteria set out by the UNHRC in representing specific factors to population displacement respecting the UNHRC as the authority on the subject.

The purpose of this effort was to develop a comprehensive representation of population displacement using ABM as the means to characterize accurately individuals, entities, and environment via the integration of qualitative (fuzzy or soft) data as well as quantitative values. Our methodology provides both a different approach and a different perspective to researching and understanding population displacement. As such, when populated and executed using our methodology, an agent-based model can

proffer insight on how to prevent, hold constant, or moderate escalating effects of threats to populations whose rights to citizenship, and all that it encompasses, are in jeopardy.

Our next effort will be to fully develop the model to reflect the environment with greater detail to include various neighborhoods in the city of Aleppo. Additionally, we will further characterize the population (agents) to capture the effects of the conflict between rebels and government forces and how these actions affect agent decision-making. We intend to execute and engage the model as a predictive or anticipatory tool to provide computationally sound conclusions as to where the crisis is heading over the stipulated time-steps, observing the effects of degenerating conditions and trigger points that could lead to increased population displacement, attrition, or collapse of the city.

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