Chapter

USING SYSTEM DYNAMICS TO EXAMINE ALTERNATIVE FUTURES FOR THE SYRIAN REFUGEE CRISIS

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ABSTRACT

The refugee migration from Syria has been called the humanitarian crisis of our time. After examining other System Dynamics models that relate to the refugee crisis, we built a model to incorporate a sub-model of the Syrian civil war along with a sub-model of the movement of refugees and their eventual immigration. We found parameters of the model that provided a good fit to the time-series available for the period 2010 to 2018. Then we used this model with these parameters to project the crisis into the future. We found that if nothing is done, the countries accepting immigrants will be overwhelmed. Then we considered two alternative futures by modifying the structure of our model. First, we examined the impact of compassion fatigue in which immigration is limited after a certain number of refugees have been accommodated. The results from this modification demonstrate that immigration cannot be controlled without creating unsustainable growth in the refugee camps. So, as a final

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modification, we considered repatriation of the refugees which might be possible if the violence in Syria can be resolved (i.e., ceasefires established and peacekeepers deployed). This approach might resolve the crisis in the long-term; however, this would require substantial funding for incentives to encourage refugees to voluntarily repatriate and the large and rapid increase in the population of Syria could not be accommodated without significant economic development aid. Future work should model the impact of the civil war on Syria's infrastructure to determine the economic development aid that would be required.

Keywords: system dynamics, computer simulation, Syria, refugees

INTRODUCTION

For many aid workers, the refugee migration from Syria is considered the humanitarian crisis of our time [1]. Millions of people have been displaced by the violence [2] and hundreds of thousands have died both in Syria and in transit to refugee camps [3]. These camps are crowded and conditions are desperate [4]. Immigration services have been overwhelmed and there has been backlash caused by the large number of immigrants coming into accepting countries [5].

System Dynamics uses a perspective of Stocks and Flows. Stocks represent collections of real-life objects that accumulate over time. Flows are the way Stocks increase or decrease. A good way to think about Stocks is as containers and a good way to think of Flows is as pipes with taps that control the flow in and out of the containers. One System Dynamics expert describes the process of building a model as getting "the plumbing figured out" [6].

At any point in time, the people affected by the Syrian civil war are in one of three places: in Syria, in refugee camps, or having immigrated. Large numbers of refugees are flowing over international borders trying to find a safe haven; therefore, System Dynamics, with its perspective of physical objects in containers connected by flows, is ideally suited to examine the refugee crisis and how it might develop over time.

The driving factor of the crisis in Syria is violence. We collected time-series data on the Syrian civil war and the refugee crisis it is causing. Then, we built a model of the crisis and found parameters for the model that

provide a good fit to the data. We use it to examine possible courses of action the United Nations High Commission for Refugees (UNHCR) could take to resolve the crisis in the long-term.

In the next section, we provide a brief literature review. In the following section, we describe a baseline model with the important interactions highlighted. Then we show how we found the parameters for the model that provide a good fit to the data from the start of the Syrian civil war from 2010 to 2018. This is followed by a discussion of the baseline model projections into the future. Then we modify the model to consider actions that might alleviate the unsustainable situations we found in the baseline projections. In the conclusion, we summarize our findings and discuss further work.

LITERATURE REVIEW

Forrester's Urban Dynamics [7] was the first example of a push-pull System Dynamics model of migration as the creation of jobs and housing drew workers to a city or the deterioration of businesses and housing encouraged them to leave. In the refugee crisis, the Syrian civil war is causing large numbers of people to flee the country seeking a safe haven and possibly a new life somewhere else.

There have been several attempts to model the dynamics of insurgency and terrorism that are relevant to the Syrian civil war. Wils et al. [8] examined the sustainability of nations in the face of international and domestic conflict. Choucri et al. [9] built a proof of concept model of state stability reacting to terrorism. Anderson [10] looked at insurgency and counter-insurgency operations based on the US Department of Defense Field Manual 3-24. Saeed et al. [11] built a simple model of the economic and psychological agendas of national policy-makers seeking internal peace. Pruyt and Kwakkel [12] explored extremism and terrorism. Enos [13] built a conceptual model which included the impact of the web presence of the Islamic State of Iraq and Syria (ISIS) on recruiting. These models include the impact of violence but do not attempt to quantify the refugees it creates.

Djamengo and Fanokoa [14] modeled the resettlement in Cameroon of people fleeing the Central African Republic civil war. Armenia and Volpetti [15] built a qualitative model of the impact of border control on the flow of refugees across the Mediterranean to Europe. Struik et al. [16] considered the impact of the influx of refugees on the workload of Dutch police processing asylum papers and handling illegal immigrants. Hattle et al. [17] studied the impact of media attention on the willingness of countries to accept immigrants. Vernon-Bido et al. [18] looked at the resettlement of Syrian refugees in Turkey. Clancy [19, 20] explored the rise and fall of ISIS and included its impact on refugees.

None of these models take a long-term perspective. In this paper, we model the impact of protests by Syrian citizens, the regime response to these protests, and the battles between rebels and the regime on the flow of refugees to neighboring countries. Then we examine possible scenarios that might arise as the number of protests and battles decrease over the long-term.

METHODS

The Baseline Model

In Figure 1, we show the baseline model of refugee movement with people flowing out of Syria becoming refugees and eventually immigrants. The initial population in Syria is from 2010 before the civil war started.

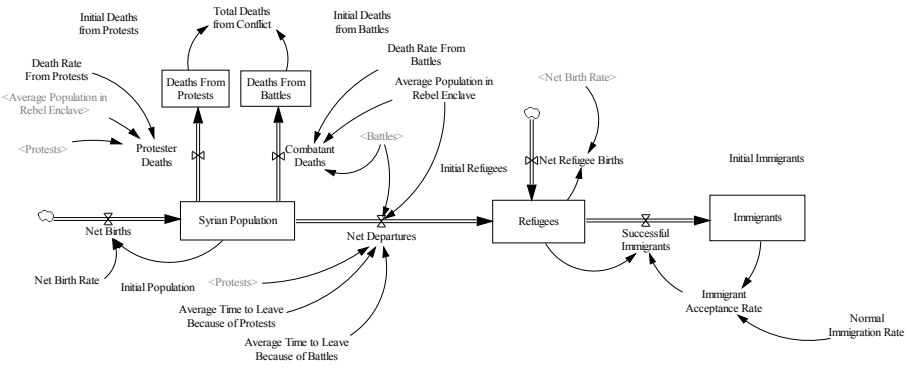

Figure 1. The Baseline Model of Refugee Movement.

On the far left of Figure 1 is net births which is the difference between the births per year and the deaths from natural causes per year. A small number of deaths occur during protests and a larger number of deaths occur during battles. The number of protests and battles at any point in time is calculated in the violence sub-model (see Figure 2). These are used along with a death rate from protests, a death rate from battles, and the average population in a rebel enclave to determine the deaths from protests and the deaths from battles. The net departures from Syria is based on the number of protests and battles, the average time to leave because of protests and battles, and the average population in a rebel enclave. In the baseline model, the net departures is assumed to decrease the Syrian population and increase the number of refugees.

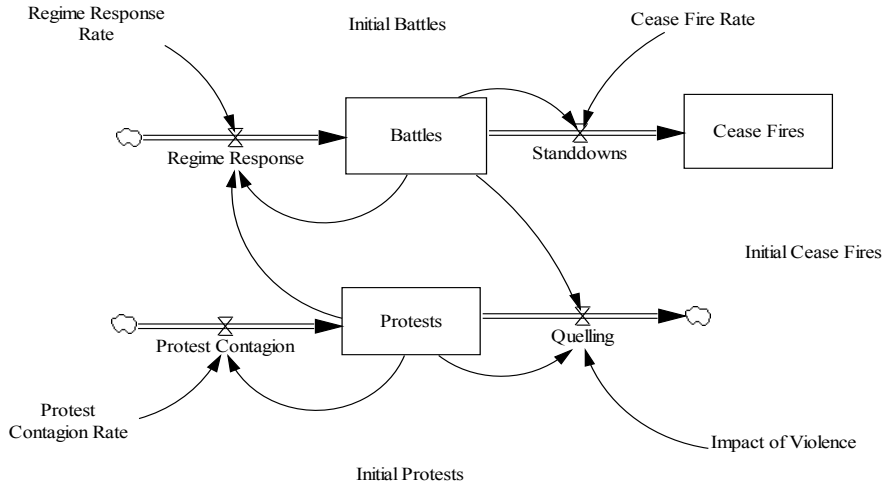

Figure 2. The Violence Model.

The refugees will also have positive net births. Some people are able to immigrate and thereby escape the refugee camps. The number of successful immigrants is based on the number of refugees and the immigrant acceptance rate.

The sub-model of violence in Syria, shown in Figure 2, is based on a predator-prey relationship [21]. We assume there is an interaction between the anti-government protests and battles between the regime and rebel forces. There is an initial number of protests and a contagion rate with protests in one location encouraging protests in other locations. There is a regime response to the protests in which the protests are quelled by violence but this causes rebels to organize and battles with the regime to begin. Finally, there are ceasefires. Therefore, protests will increase first, peak, and then decline as battles increase. Battles will have a delayed response to protests. They will increase as protests increase, peak, and decline after protests decline.

Finding the Parameters of the Baseline Model

Among the best practices in System Dynamics is the validation of the model against available time-series [22, 23, 24, 25, 26, 27]. We found time-series on the UN website [28, 29] and elsewhere [30, 31] and estimated the parameters in the baseline model by minimizing the sum of squared error between the data points and the model projections.

Table 1. Parameter Values Found during the Data Fitting Process

Number	Parameter	Value	Units
1	Initial Number of Protests	50	Protests
2	Protest Contagion Rate	1.37	Protests/Protest/Year
3	Regime Response Rate	0.00481	Battles/(Battles*Protests)/Year
4	Impact of Violence	0.0794	Protests/(Protests*Battles)/Year
5	Cease Fire Rate	0.201	Battles/Battle/Year
6	Net Birth Rate	0.0241	People/Person/Year
7	Death Rate in Protests	0.00161	People/Person/Protest/Year

8	Death Rate in Battles	0.0133	People/Person/Battle/Year
9	Average Time to Leave the Country because of Protests	35.8	Protest-Years
10	Average Time to Leave the Country because of Battles	3.28	Battle-Years
11	Average-Sized Enclave	65,000	People
12	Immigrant Acceptance Rate	0.0713	People/Person/Year

The first parameters we wanted to estimate were for the violence sub-model. We examined data on all of the cities in Syria to determine when the fighting started and ended in each, and thereby found a time-series for the number of battles [31].

The parameters 1 through 5 in Table 1 were found to provide a good fit to the data for the period 2010 to 2018 (see Figure 3).

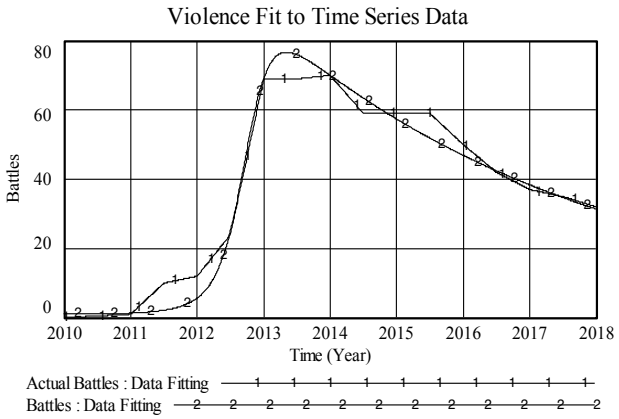

Figure 3. The Violence Model Fit to Data.

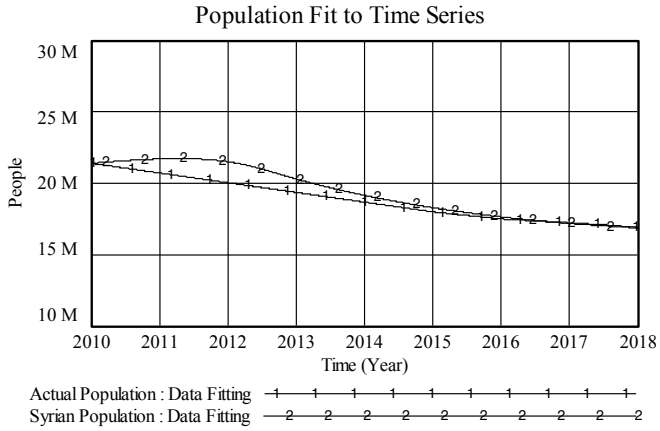

Figure 4. The Population Model Fit to Data.

For the Syrian population, we found data for 2010, 2015, 2016, 2017, and 2018 [29]. Parameters 6 through 11 in Table 1 provided an interesting fit to the data (see Figure 4). Notice that the population in the baseline model is increasing over the period 2010 to 2012. This is because the deaths from violence and the net departures is relatively low since the protests and battles are just starting and the net births is quite high. Since we do not have data for the period 2011 to 2014, we simply drew a straight line in the time-series between 2010 and 2015. The baseline model fits the data well for the period 2015 to 2018.

Figure 5. The Deaths in Conflict Model Fit to Data.

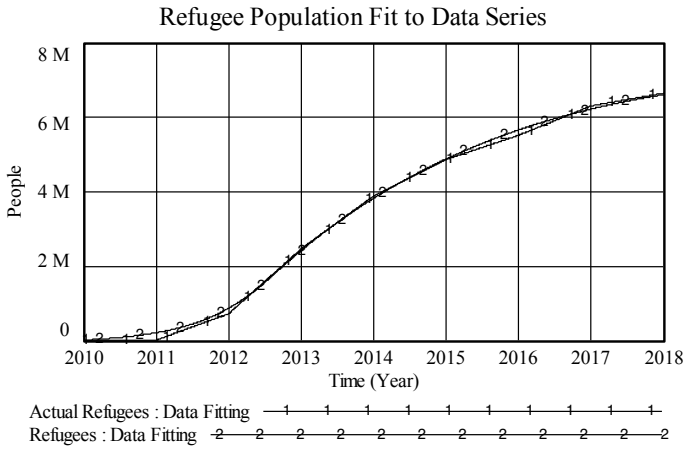

Figure 6. The Refugee Movement Model Fit to Data.

We obtained a time-series for the deaths from violence [30]. Then we found the parameters 7 and 8 in Table 1 that provide a good fit of the time-series (see Figure 5). We found a time-series for the refugees [28] and obtained values 9 through 12 in Table 1 that provided a good fit to the data (see Figure 6).

Projections of the Baseline Model

Now that we have confidence in the baseline model, we can make some projections into the future. We assumed there were no drastic changes needed to the model structure or its parameters. For example, we assumed the involvement of Russia and the United States does not change in the future.

The first projection is the future violence. The number of battles is projected to decrease gradually and drop to near zero by 2040, as shown in Figure 7.

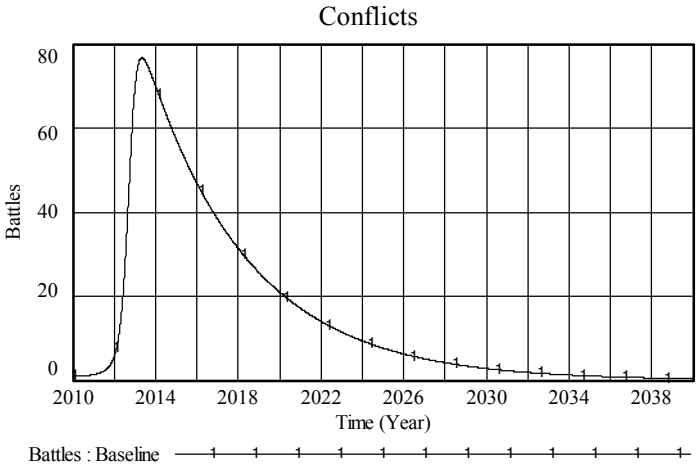

Figure 7. Baseline Violence Projections.

The projected Syrian population and the number of refugees are shown in Figure 8. The Syrian population is projected to start to recover after 2020 as the violence decreases and the net births begin to exceed the deaths in the conflict and the departure of refugees. The number of refugees is projected to start to decline after 2020 as immigration begins to exceed the refugees arriving and the net births in the refugee camps. However, the projected number of refugees remains at several million people in 2040.

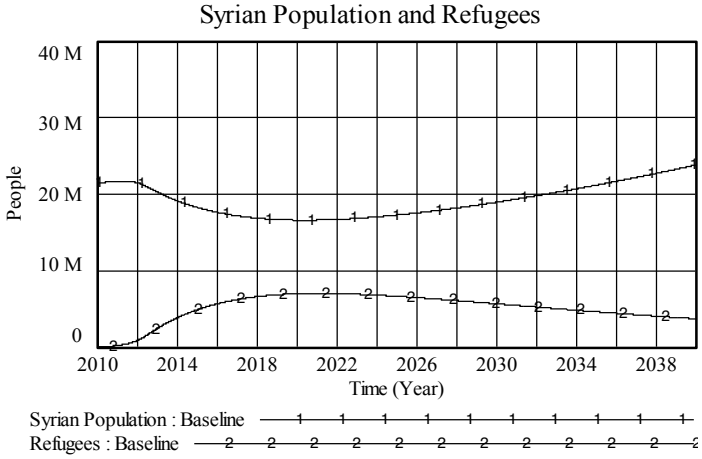

Figure 8. Baseline Population Movement Projections.

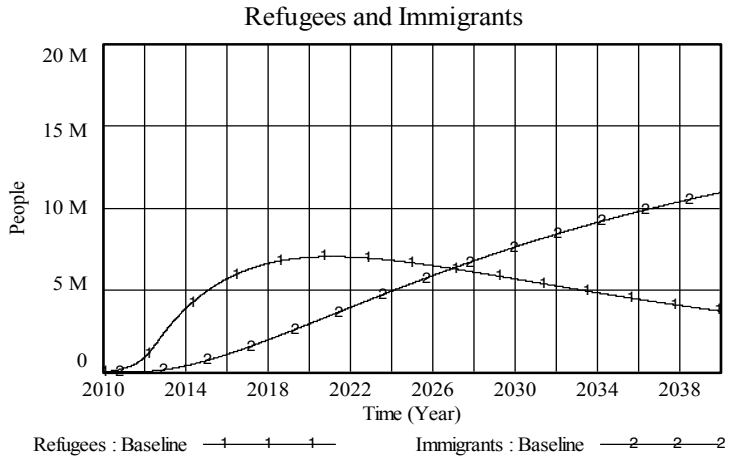

Figure 9. Baseline Refugee and Immigration Projections.

Immigration is projected to continue to increase up to 2040 with no end in sight (see Figure 9). This huge number of immigrants may not be sustainable, so we will consider two alternative futures to limit immigration.

Alternative Futures for the Refugee Crisis

The first alternative future is based on compassion fatigue[1]. The idea is there is a limit on the number of refugees who will be allowed to immigrate.

The changes to the model are shown in the immigrant acceptance rate on the right-hand side of Figure 10. The compassion fatigue effect is a multiplier that is less than or equal to 1.0. The normal immigration rate is multiplied by the compassion fatigue effect to obtain the immigrant acceptance rate. The input to the compassion fatigue effect function is the ratio of the immigrants divided by the compassion fatigue threshold. The output is the compassion fatigue multiplier. In Figure 11, input comes into the function on the x-axis and the associated output is shown on the y-axis.

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[1] The first mention of compassion fatigue with regards to refugees might have been the boat people escaping Vietnam in the late 1980s [32]. Also see [33] for a detailed description of the situation from the perspective of the UNHCR.

When the input is less than or equal to 1.0, the multiplier (i.e., the output) is equal to 1.0. That is, before compassion fatigue sets in, the immigrant acceptance rate is equal to the normal immigration rate. When the input is greater than 1.0, the multiplier is less than 1.0. That is, once compassion fatigue sets in, the immigrant acceptance rate begins to fall.

We have limited knowledge about the compassion fatigue effect, so as recommended by modeling best practices [26, 25], we conducted a sensitivity analysis on the values in this function. We tried the values shown in Table 2. We changed the variables one at a time holding the others at their nominal values.

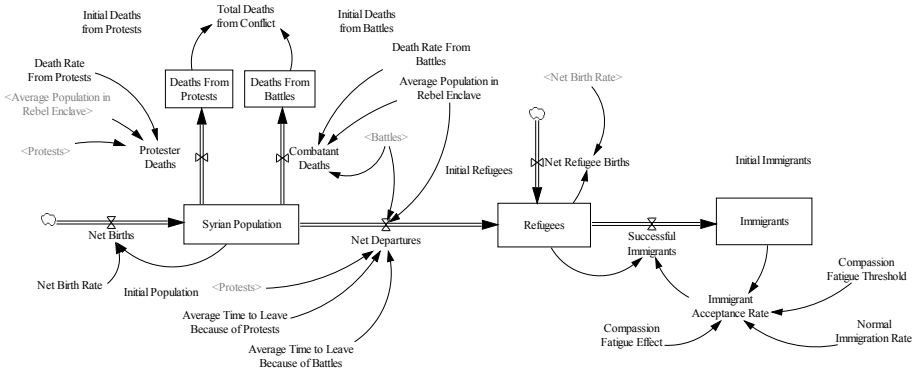

Figure 10. The Revised Model with Compassion Fatigue.

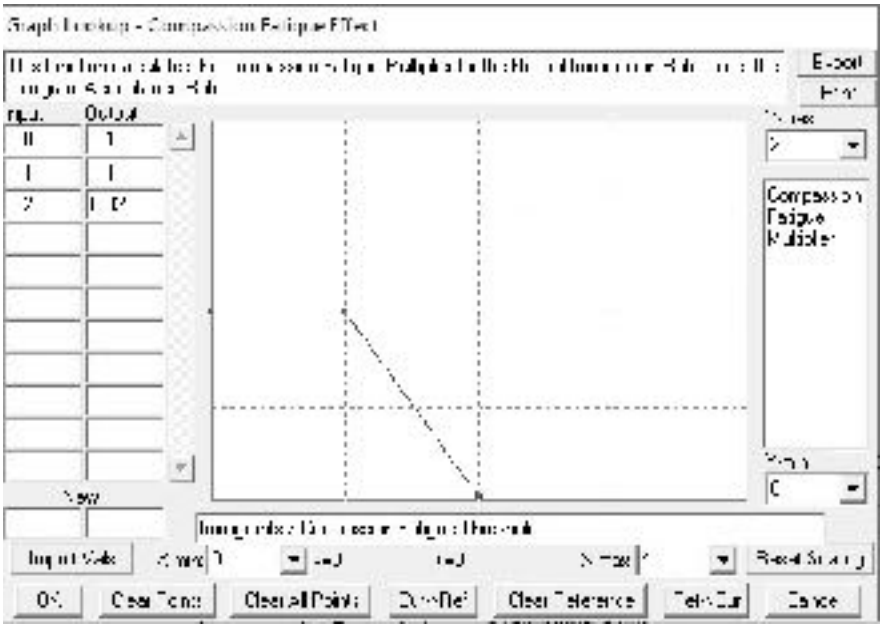

Figure 11. Implementation of the Compassion Fatigue Effect.

Table 2. Sensitivity Analysis Values for Compassion Fatigue

Parameter	Units	Lower Value	Nominal Value	Upper Value
Compassion Fatigue Threshold (CFT)	Millions of Immigrants	1	2	3
Lower Limit Threshold (LLT)	Immigrants/ Compassion Fatigue Threshold	1.5	2	3
Lower Limit Multiplier (LLM)	Multiplier for Normal Immigration Rate	0.01	0.02	0.05

First, we varied the compassion fatigue threshold. From Figure 12, we can see when the compassion fatigue threshold varied, the number of immigrants stabilized at different levels. From Figure 13, it appears the number of refugees continues to grow. This shows that changes in the compassion fatigue threshold can avoid overwhelming countries accepting immigrants but will create unsustainable refugee camps.

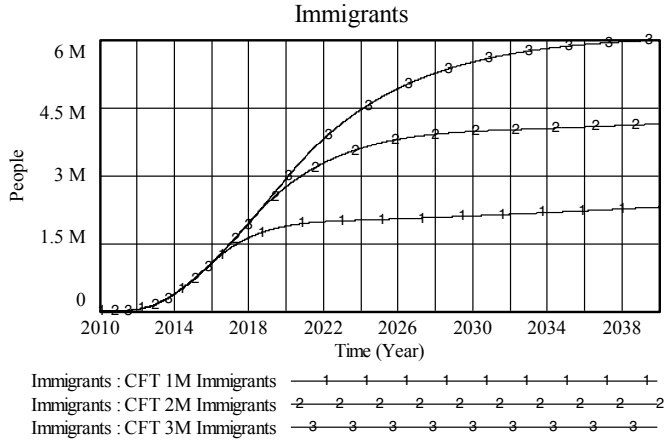

Figure 12. Immigrants Varying the Compassion Fatigue Threshold.

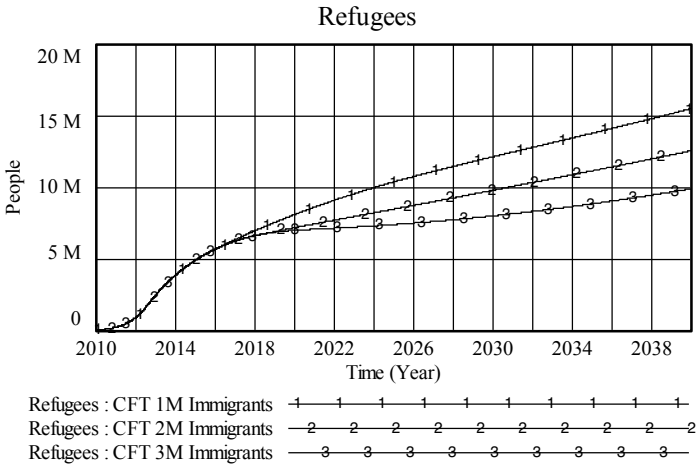

Figure 13. Refugees Varying the Compassion Fatigue Threshold.

Next, we examined the results when the lower limit threshold varied. As shown in Figure 14, when the threshold at which the multiplier reached its lower limit varied, immigration stabilized at different levels. In Figure 15, we can see that the number of refugees continued to grow in all three cases; therefore, we have a similar result that controlling the number of immigrants will create a crisis of unsustainable refugee camps.

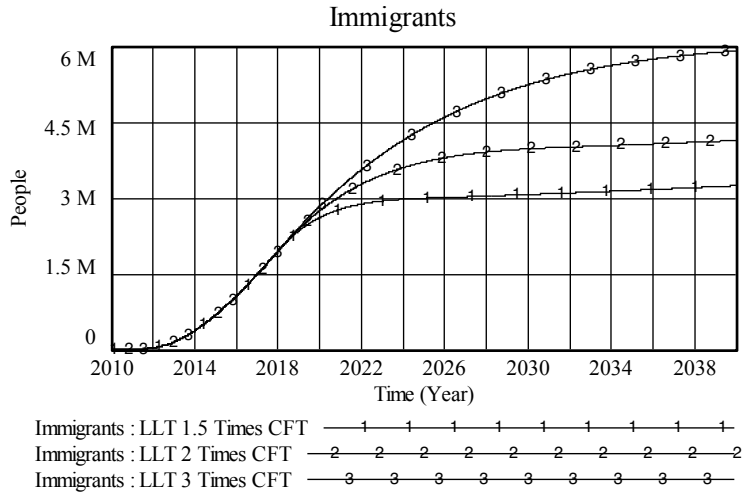

Figure 14. Immigrants Varying the Lower Limit Threshold.

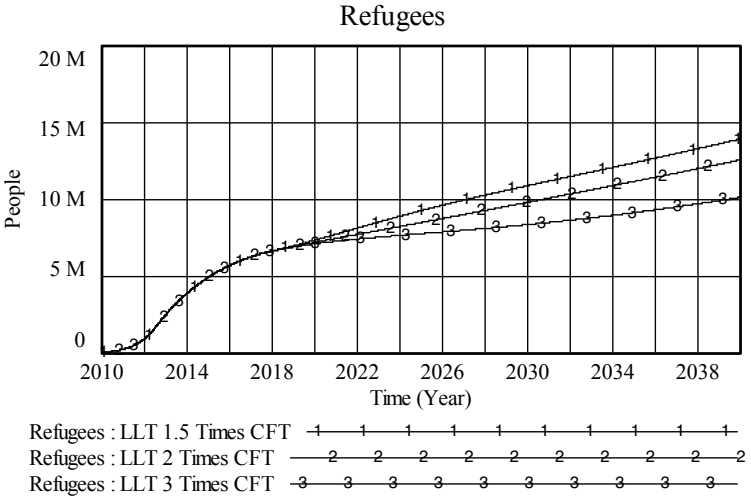

Figure 15. Refugees Varying the Lower Limit Threshold.

When we varied the lower limit multipliers, we found the model was not sensitive to these values (see Figures 16 and 17). The values would need to be much larger to affect the results and in that case, there would be limited compassion fatigue.

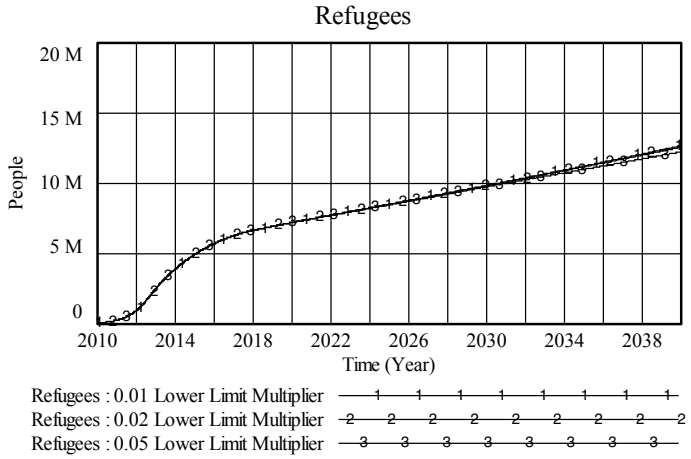

Figure 16. Immigrants Varying the Lower Limit Multiplier.

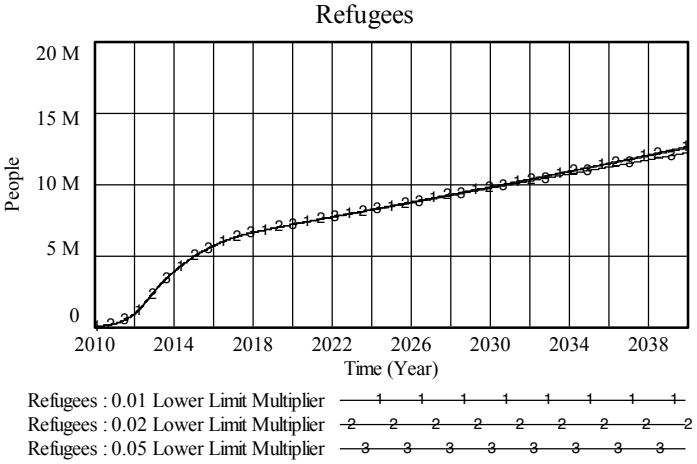

Figure 17. Refugees Varying the Lower Limit Multiplier.

There is one more modification to the model we felt could resolve the problems created by the refugee crisis when compassion fatigue sets in, namely repatriation[2]. Assuming the refugees fled Syria to escape the violence, once the violence has reduced, it may be possible to repatriate them.

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[2] Again, the first example of repatriating refugees may have occurred when the Vietnamese boat people were screened and those considered economic migrants returned to Vietnam [33].

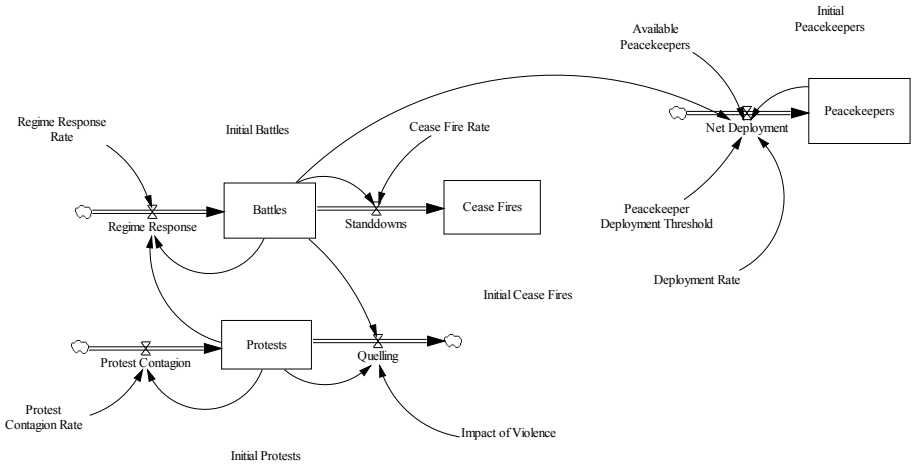

Figure 18. The Revised Violence Model with Peacekeepers.

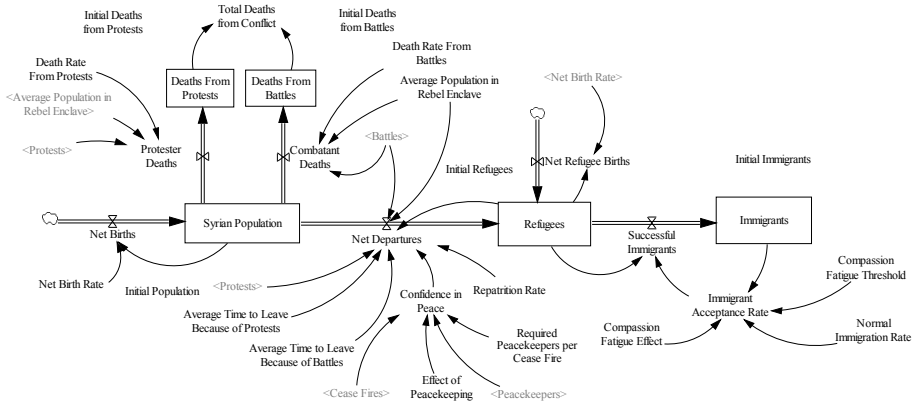

Figure 19. The Revised Refugee Movement Model with Repatriation.

Some refugees would not be repatriated because their lives would be at risk if they were sent back[3]. We assumed this is a small percentage that is represented in the lower limit on the compassion fatigue effect multiplier. The vast majority of refugees could be repatriated if their safety could be guaranteed. The violence would need to be reduced to where ceasefires could be put in place and UN peacekeepers were deployed to enforce them[4].

A peacekeeper deployment model is shown on the right-hand side of the revised violence sub-model in Figure 18. Once the violence is below a certain level, the peacekeepers can begin to deploy based on a deployment rate until all the available peacekeepers are deployed. This model is based on the capacity-constrained population growth [34].

We modified the net departures in the refugee movement model to employ a repatriation rate and a confidence in peace multiplier (see the net departures flow in Figure 19). The net departures start positive when the violence level is high and refugees flee Syria. As the violence decreases, we assume ceasefires can be reached and peacekeepers can be deployed to enforce them. The more peacekeepers per cease-fire, the greater the refugees' confidence that the peace will be enforced. Then the refugees would be more likely to be willing to repatriate. So eventually, the net departures would become negative as more people return to Syria than flee.

The confidence in peace is based on a peacekeeper effect. The effect function is shown in Figure 20. We assume the ceasefires are agreed to battle-by-battle. The number of ceasefires is calculated in the revised violence model (see Figure 18). We also assume there is a required number of peacekeepers to completely enforce a ceasefire. If the number of peacekeepers deployed divided by the number of ceasefires is small compared to the required number, the refugees will have little confidence the peace will be adequately enforced. So, the multiplier will be less than 1.0 and the repatriation will be lower than its potential. Once the number of peacekeepers deployed divided by the ceasefires reaches the required level,

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[3] This decision for the boat people from Vietnam was done during the screening process [33].

[4] This situation may have first occurred in the 1990s when a cease-fire was arranged in Cambodia and UN peacekeepers were deployed before repatriating 360,000 refugees from Thailand who had fled the violent Khmer Rouge regime [33].

the confidence in peace multiplier will be 1.0 and the repatriation will reach its full potential.

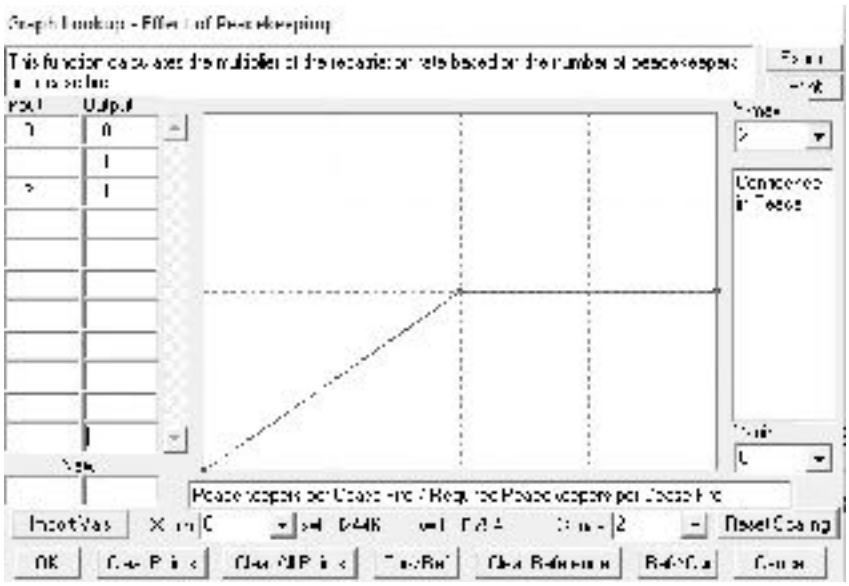

Figure 20. Implementation of the Effect of Peacekeeping.

Again, we conducted a sensitivity analysis on the parameters of the repatriation model and changed the variables one at a time while holding the others at their nominal values (see Table 3).

Table 3. Sensitivity Analysis Values for Repatriation

Parameter	Units	Lower Value	Nominal Value	Upper Value
Peacekeeper Deployment Threshold (PDT)	Battles	2	5	10
Available Peacekeepers (APK)	Soldiers	10,000	15,000	30,000
Deployment Rate	Soldiers/Soldier/Year	2	4	8
Repatriation Rate	People/Person/Year	0.2	0.5	1.0

Peacekeepers Required per Cease-Fire (PK Required per CF)	Soldiers/Cease-Fire	100	200	500

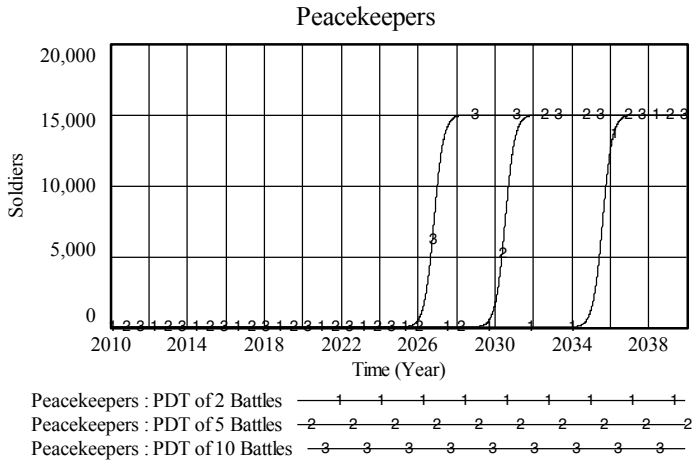

Figure 21. Peacekeeper Deployment Varying the Deployment Threshold.

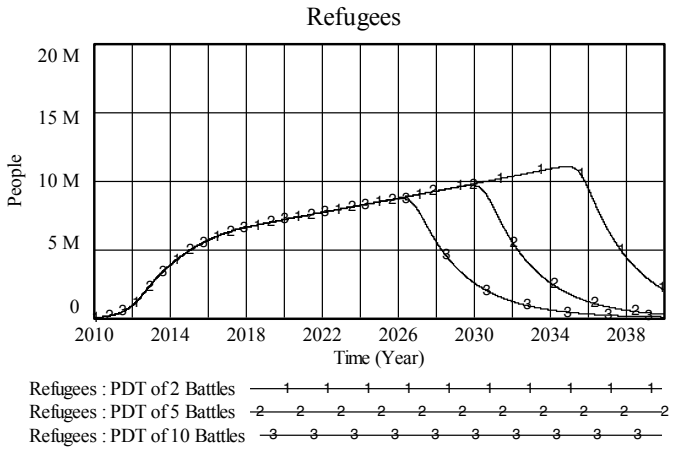

Figure 22. Refugees Varying the Deployment Threshold.

First, we varied the peacekeeper deployment threshold. In Figure 21, we see that when the threshold is lower, the peacekeepers will be deployed later. That is, it will take longer to reach the lower number of active battles. Therefore, the repatriation will be delayed and more refugees will be

involved (see Figure 22). Also, when the threshold is lower, the increase in the Syrian population will occur later (see Figure 23).

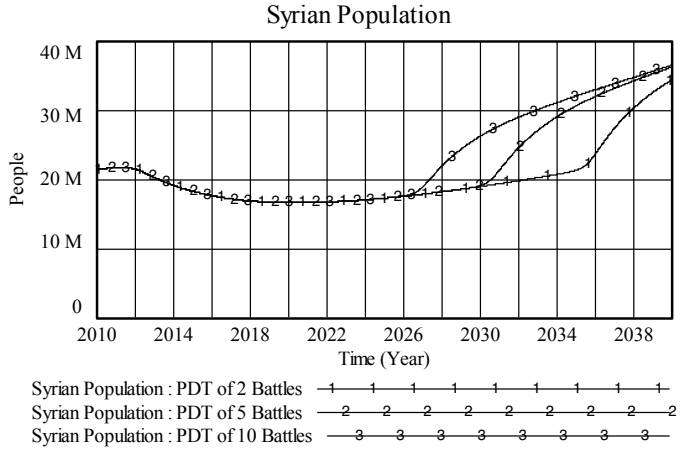

Figure 23. Syrian Population Varying the Deployment Threshold.

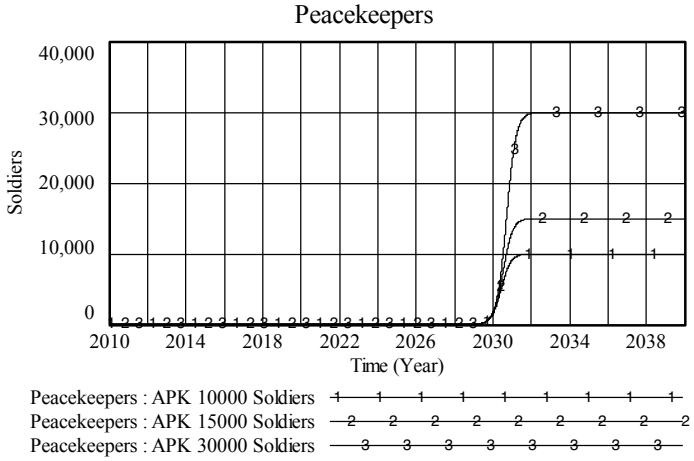

Figure 24. Peacekeeper Deployment when the Available Peacekeepers Varies.

Next, we varied the peacekeepers available. Since the deployment threshold is held constant the peacekeepers will be deployed at the same time no matter the number available (see Figure 24). We found that our model is not very sensitive to changes in the number of peacekeepers (see Figures 25 and 26). More peacekeepers will facilitate the repatriation but there appears to be diminishing returns on their impact. This may be a

shortcoming of the model. More peacekeepers should have a much larger impact.

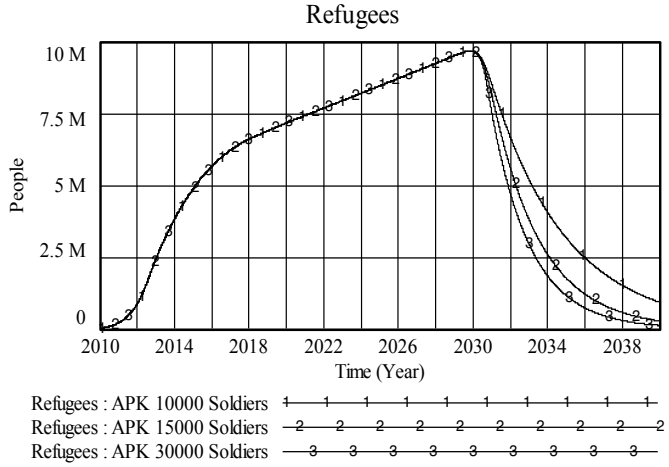

Figure 25. Refugees Varying the Available Peacekeepers.

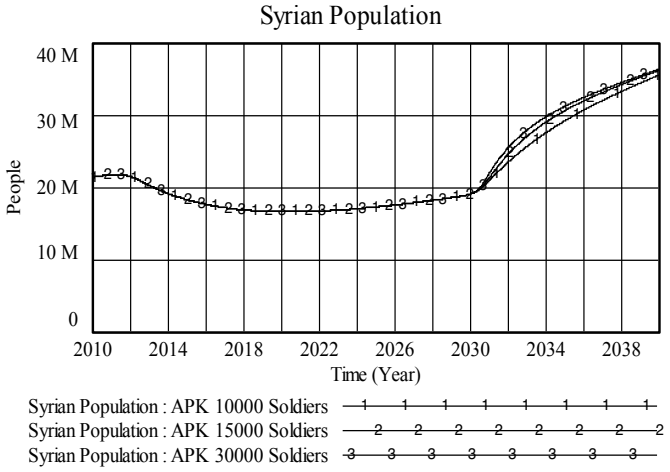

Figure 26. Syrian Population Varying the Available Peacekeepers.

We varied the deployment rate. When the deployment rate is smaller, the deployment will start later and take longer, the repatriation will be delayed, more refugees will be involved, and the increase in the Syrian population will occur later (see Figures 27, 28 and 29). These results are very similar to those found when the deployment threshold was varied.

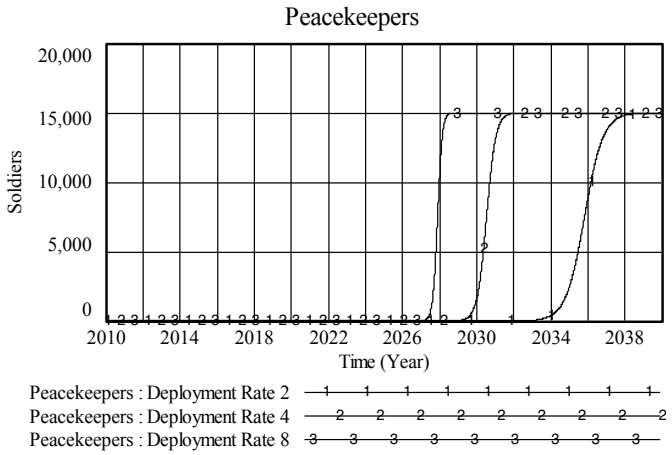

Figure 27. Peacekeeper Deployment Varying the Deployment Rate.

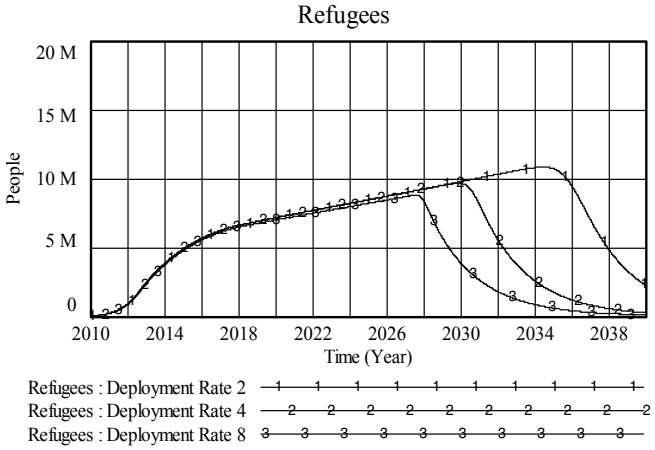

Figure 28. Refugees Varying the Deployment Rate.

In Figure 30, we can see the impact of the repatriation rate on refugees. It is projected to take many more years to repatriate the refugees if the rate is small. When the rate is large, a large and rapid increase in the Syrian population is projected (see Figure 31). This would probably be unsustainable without significant economic development aid from Western countries.

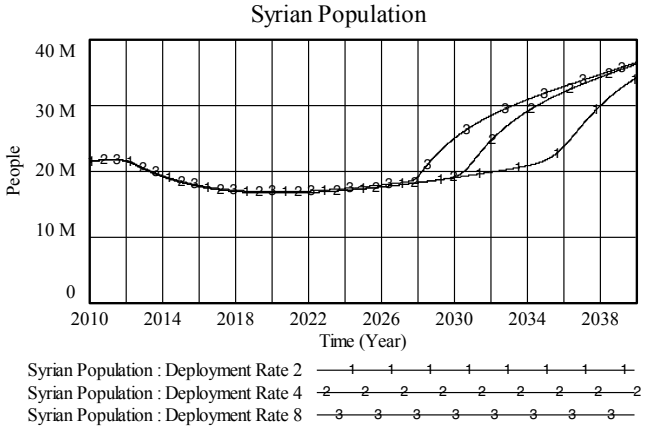

Figure 29. Syrian Population Varying the Deployment Rate.

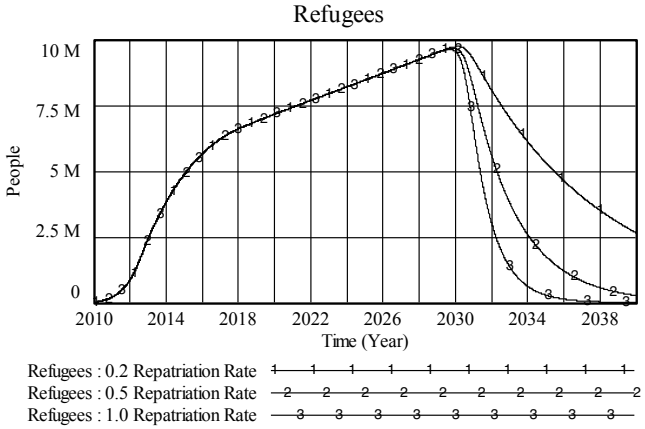

Figure 30. Refugees Varying the Repatriation Rate.

Finally, we varied the required peacekeepers per ceasefire. It is projected to take many more years to repatriate the refugees if the required number of peacekeepers is large (see Figure 32). That is, it would be more difficult to enforce the ceasefires and more peacekeepers would be required to get the same confidence in peace. When the required number of peacekeepers per ceasefire is small, a large and rapid increase in the Syrian population is projected (see Figure 33). Again, this would probably be unsustainable without significant economic development aid from Western countries.

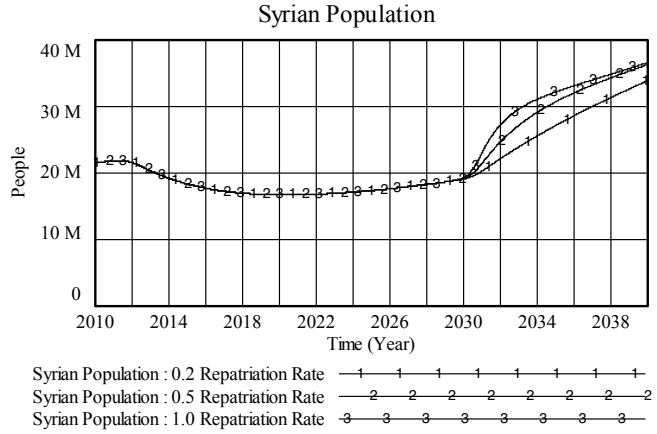

Figure 31. Syrian Population Varying the Repatriation Rate

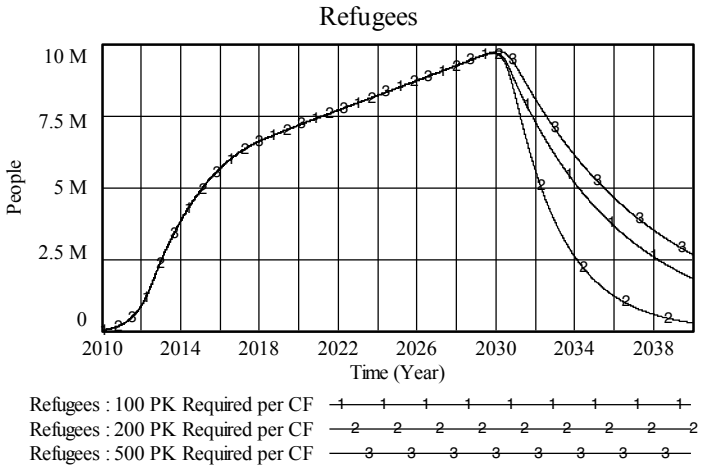

Figure 32. Refugees Varying the Required Peacekeepers/Cease-Fire.

In all cases, complete repatriation is projected to take many years and involve millions of people. This huge repatriation may not be realistic, but it would resolve the refugee crisis in the long-term if it could be implemented.

The UNHCR has a policy of only repatriating refugees who volunteer. In the past, financial incentives have been offered to encourage refugees to repatriate [33] which could require a significant amount of extra funding.

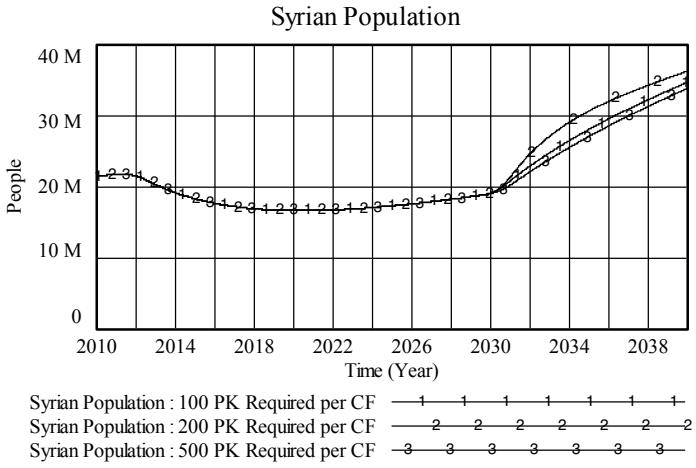

Figure 33. Syrian Population Varying the Required Peacekeepers/Cease-Fire.

CONCLUSION

In this study, we developed a small but realistic model of the Syrian civil war and its impact on the country's citizens. We found that many citizens have died in protests and many thousands of rebels and soldiers have died in battles. Also, millions of citizens have fled the country seeking a safe haven and ended up in refugee camps in neighboring countries. The civil war has caused a huge humanitarian crisis that likely will not be resolved in the short-term.

Our model shows that the immigration of refugees will likely overwhelm the receiving countries. If it slows down because of compassion fatigue, this would result in an unsustainable situation in the refugee camps.

Our data collection found evidence that the violence in Syria is showing signs of being resolved. If this continues and if their safety can be guaranteed, it may be possible to repatriate many refugees. We considered the situation in which ceasefires are agreed to and UN peacekeepers are deployed to enforce them. Then we took a preliminary look at the scope of the problem of repatriating a large number of refugees.

We recognize that voluntary repatriation may require financial incentives. The amount of the incentive would be based on the quality of life in the refugee camps compared to the quality of life in Syria. Future work should examine this trade-off.

Additional future work includes: examining the relationship between the increase in peacekeepers on the confidence of peace in the peacekeeping model; modeling damage to Syria's infrastructure to determine the required economic development aid to be able to repatriate refugees; validating the compassion fatigue model and determine if compassion fatigue for the Syrian refugee crisis has already set in; and validation of the repatriation model as it has been reported that Turkey may already be considering involuntary repatriation of Syrian refugees without considering their safety [35].

Additional data collection is also recommended, including the continuation of data collection as the civil war and the refugee crisis develops to determine if the trends continue and collecting data on other conflicts to determine if this model can be generalized.

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