A SYSTEM DYNAMIC APPROACH TO THE EMERGENCE OF REFUGEE FLOWS

Merel Smit - CSM master thesis - Universiteit Leiden

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Master Crisis and Security Management

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"As system thinkers, we must constantly strive to break down the false barriers that divide us, whether they rise up between the functional silos in a corporation, between scientific specialties, between the sciences and humanities, or between the scholar's world of ideas and the policy maker's world of action."

John David Sterman

Preface

The current refugee crisis in Europe is dominating our newspapers, TV-screens and cellphone displays since the beginning of 2015. My personal frustration regarding the response to this refugee crisis in combination with the characteristics of the method system dynamics, which I learned to use during my bachelor Technische Bestuurskunde at TU Delft, made my decision for this master thesis topic rather easy. With this thesis I hope to create more understanding for the complex issue of refugee flows and of course complete my master degree Crisis and Security Management at Universiteit Leiden.

I would like to thank my first supervisor Jelle van Buuren for all valuable feedback moments, for encouraging the use of an unfamiliar research approach and for an unlimited quantity of enthusiasm. I would also like to thank Elisa Canzani for making time to evaluate the model and Edwin Bakker for performing the role as second reader. I owe thanks to Irial Glynn and Leo Lucassen for participating in interviews and providing specific substantive information.

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Summary

The current European refugee crisis is a painful reminder of how inadequate and inconsistent policy decisions can transform a complex issue into a downright crisis. This is particularly worrisome when you consider that refugee flows in the future are inevitable (Feller, 2006). Instead of preventing refugee flows it is more useful to focus on ways to deal with the emergence of large numbers of refugees and try to avoid escalation into a crisis. This research takes part in this by studying the emergence of refugee flows and trying to gain a better insight in this complex issue.

System dynamics, a method which allows structuring complex social problems and simulating its dynamic behavior, is applied to model the emergence of refugee flows. This study has an explorative character because system dynamics is a relative new method in the field of refugee studies. The following research question is formulated: to what extend can system dynamics contribute to provide insight in the causes, underlying mechanisms, uncertainties and possible early indicators of the emergence of mass refugee flows caused by internal conflicts? Internal conflict is defined as a violent conflict within state borders in which civilians fight each other or their state authority (Weiner, 1996).

To answer this research question a general refugee model is constructed which represents the emergence of refugees caused by an unspecified internal conflict. To test the three most dominant early indicators in literature the indicators are separately added to the general model, resulting in a total of four simulation models. To explore the dynamic hypotheses regarding the general model behavior and the early indicators, the model was applied to an actual conflict: the conflict in Syria between 2011 and the beginning of 2016.

The findings are derived from the model analysis, but also from the entire course of the model process. The main push-factors for refugees in literature are identified as: human rights violations, military terror and serious disturbances of public order. Similarly free-will migrants, Internally Displaced Persons and external military intervention are identified as most important early indicators, of which only the last two show cohesion with the

emergence of refugees in the simulation model. Analysis of the generated model behavior also demonstrates an interesting point of strong increase in the number of refugees. This behavior is mainly influenced by the highly uncertain factors *problematic level of violence* and the *perception of violence*.

This point of strong increase is interesting for policy makers, as that moment can determine whether potential guest-countries should prepare for a large influx of refugees. The exact point in time is not relevant, as system dynamics is not a predictive tool, but its cohesion with the early indicators can be very valuable in the policy making process. Recommendations for future research are to apply the model to other internal conflicts in order to test the accuracy of the current findings, further refinement of the simulation model and expansion of the current model boundaries. Future research on the emergence of refugees is not only a matter of science, but also a demand from reality. Beside recommendations, transparency regarding limitations is also important to mention. Most important limitations are the difficulty to quantify subjective issues, the substantial amount of assumptions and the limited expert feedback on the simulation model.

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1. Introduction

It took the image of a lifeless body of a young Syrian boy, lying face down in the surf of a Turkish coastline, to shake up European citizens and political leaders. This boy, Aylan Kurdi, washed up near the town of Bodrum at September 2nd 2015 after a failed attempt to reach the Greek Island Kos together with his family (The Guardian, 2015). This image caused emotional reactions across all layers in European society and has become an iconic image representing the tragedies in the ongoing European refugee crisis.

In 2015 more than a million refugees and migrants entered Europe causing a crisis as European Member States are struggling to cope with the large inflow of people (BBC, 2016a). The main cause of this inflow lies in the ongoing conflict in Syria. However a substantial part of this inflow is also from other countries, like Afghanistan, Iraq, Eritrea, Kosovo and others, each with its own problems. The major part of the group of refugees is reaching Europe by sea, which often leads to life-threatening situations (BBC, 2016a). According to the International Organization for Migration [IOM] (2015) a shocking amount of 3770 people have died in 2015 in an attempt to cross the Mediterranean Sea to Europe. Other refugees entered Europe by land, mainly through Turkey and Albania. The end of this refugee crisis is definitely not in the near future. A clear indication of this is the arrival by sea of more than 200.000 refugees during the first six months of 2016 (United Nations High Commissioner for Refugees [UNHCR], 2016a).

The Syrian conflict has been escalating for some years now and the help of the international community has fallen short ever since, which logically at a certain time results in a large flow of refugees towards safe regions (Spijkerboer, 2016). However European authorities never saw it coming and were taken by surprise. Insufficient preparation has resulted in extensive problems across the entire refugee system: from the lack of immigration officers to logistical problems and from a shortage of shelter facilities to the negative impact on European citizens. The inadequate performance of the European Union (EU) nourishes the idea that the inflow of the amount of refugees is just too big to handle (Spijkerboer, 2016). This causes feelings of fear, anger and ignorance among the public which in turn results in resistance and

unrest. These negative emotions of civilians have begun to dominate the debate about the refugee inflow.

An obvious question that immediately emerges from this enumeration of problems is: why is the EU not able to adequately address the large inflow of refugees? The reason for this can be found in two causes: the complexness and suddenness of the refugee crisis. This type of issue can be referred to as a so called 'wicked problem'. Rittel and Webber (1973) defined the term wicked problem as a system with interdependent problems that contains economic, political and technical components. Another difficulty is that wicked problems are often not thoroughly understood and therefore not clearly defined (Hutchinson, English, & Mughal, 2002). In other words, a wicked problem is like a tangled ball of wool; you don't know where you have to begin to unravel the knot and when you pull a thread it is unsure what effect it will have on the knot (Lucassen, 2015).

To understand and deal with the complex issue of mass refugee flows it is necessary to first gain insight in the causes and underlying relations. There are multiple methods which are able to provide these insights and many of them are explored thoroughly. A quite new player in the research field of refugees is system dynamics. Due to its structured approach, causal based relations and the capability of generating behavior over time system dynamics is a promising method to research a wicked problem like refugee flows. This approach can possibly result in new insights into the causes, relations, uncertainties and even early indicators of the emergence of refugee flows.

Due to the rarity of this methodology in social sciences this thesis structure slightly differs from most social studies. First the concepts of early warning indicators and system dynamics are elucidated which can be useful to interpret the subsequent research question. Subsequently the scientific- and societal relevance is set out. Thereafter the link of the thesis with the master Crisis and Security Management and the common ground with Public Administration is explained. In the last paragraph the overall structure of the thesis is disclosed.

1.1 EARLY INDICATORS

In this study the emergence of refugee flows is considered a given fact.

> Mobility cannot be prevented. The odds are against this, not least because of the impossibility of policing all the world's borders and the prevalence of people smuggling and trafficking. As far as refugees concerned, prevention of flight, which denies them their basic security and safety is not only impossible, it is also not permitted under international law. (Feller, 2006, p. 1)

Added to this, the main cause for the largest refugee flows, which is violent conflict, is very unpredictable and hard to prevent. For these reasons it is more useful to focus on ways to deal with the emergence of large refugee flows by exploring different possible scenarios, identifying crucial uncertainties in the flight-process and trying to indicate the point of escalation of refugee flows. Obviously there is no glass bulb which precisely can display the future, but there are factors which can indicate the future occurrence of events, so called early warning indicators. As the name suggests a certain value or behavior of these indicators can indicate a future event and therefore can function as an early warning system. Reality is often so complex that multiple indicators are required to indicate a particular future event. This can be illustrated by the amount of indicators that is used to indicate the emergence of a violent conflict in a country, like Hagmeyer-Gaverus and Weissmann (2003) who identify 9 indicator groups which can be divided in 35 sub categories. The amount of early warning indicators can vary greatly per study due to the event type, the focus of the research and chosen level of abstraction. Early warning indicators can be divided in long-term, medium-term and short-term indicators (Walton, 2011). This study focuses on short-term and medium-term indicators, because the decision to flee is considered short-term as people are forced to flee to secure their lives. Long-term early indicators are not included, because there are little known long-term indicators and there's a lack of available data.

1.2 SYSTEM DYNAMICS

Before the research question is presented a brief introduction of system dynamics is provided as it plays an essential role in this thesis. For the reader who has limited or no

knowledge about system dynamics the information in this section can be helpful to interpret the research question and to recognize the different steps in the modeling process.

A basic principle in system dynamics is that real world problems are often too complex for people to understand. A consequence is that decision makers tend to address the symptoms instead of the underlying cause of the problem due to a lack of insight. In the absence of a method which was able to meet the complex reality, system dynamics was developed (Daalen, Pruyt, Thissen & Phaff, 2009). For this method ideas and concepts from different fields were combined, like control engineering, cybernetics and organizational theory, and applied to social systems (Richardson, 1999).

There are several definitions of system dynamics which each lay its focus on different parts of the method. A definition by Daalen et al. (2009) introduces the most basic characteristics and applicability of the method: "System dynamics is a continuous simulation model, which can be applied to physical problems, but can handle social, economic and other aspects as well". The term continuous simply means that the addressed issue predominantly consists of continuous variables instead of discrete variables. An example of a discrete issue is the optimization of the transportation process of cars, in other words issues containing whole units. In the case of refugee issues both discrete- and continuous variables are included, like the number of refugees as discrete variable and the amount of violence as continuous variable. Since this issue consists mainly of continuous factors it is useful to apply system dynamics.

The origin of a system dynamics simulation model lies in qualitative knowledge-based models. During the model process the qualitative models are transformed into data-based quantitative models. Using simulation software it is possible to simulate the quantative model over time, to look at its behavior and to study the impact of changes to the model. It really is just a small laboratory in which the simplified reality can be studied and manipulated.

The general meaning of system dynamics has now been explained which provides a basic understanding for the first part of the thesis. A more comprehensive definition and explanation will follow in chapter 3 about methodology.

1.3 RESEARCH QUESTION

The mentioned system dynamics characteristics, regarding continuous variables and the ability to handle several types of issues, make it a suitable tool to research refugee issues. However the way in which system dynamics can be applied varies widely. Because there is almost no literature about the system dynamics approach to refugee issues this study is an attempt to discover the potential contribution in this field. Therefore this thesis will have an exploratory approach. From this line of reasoning the following research question emerged: *To what extend can system dynamics contribute to provide insight in the causes, underlying mechanisms, uncertainties and possible early indicators of the emergence of mass refugee flows caused by internal conflicts?*

To answer this question first knowledge has to be obtained from literature and document analysis to determine the most important factors and structure of the refugee flow process. Thereafter an attempt is made to transform this knowledge into qualitative models by connecting known and sometimes only vaguely known relationships. The qualitative models will already provide insight in the large mechanisms. With the use of data and simple equations the qualitative models are translated into quantitative models. The last step is to simulate the models, analyze the mechanisms in the models, identify the high-impact factors and study the determined early warning indicators.

It is not evident that when more insight is gained about the mechanisms of refugee flows and useful early indicators are identified, the response to a future refugee situation can be better organized than refugee crises in the past. It can however provide a better understanding in the functioning of the refugee system and possibly offer state authorities the opportunity to be alert to countries which are indicated as very unstable. The anticipation to an imminent refugee inflow can provide state authorities with more time.

This means short- as well as a long-term vision can be elaborated, support among civilians can be preserved, relevant networks and organizations can be activated and different future scenarios designed.

Finally, a short disclaimer regarding the outcomes and future applications is appropriate. The simulation model constructed in this master thesis does in no way predict the future (Garcia, 2006). It identifies possible scenarios and is capable of producing behavior matching to these scenarios, no exact numbers. It is important to keep in mind that system dynamics models are a simplified version of reality and that there is no such thing as a perfect model (Sterman, 2002). This also means that despite the fact that refugee flows are a highly politicized issue, a hesitant attitude should be taken towards the use of system dynamics models in the political arena. System dynamics research, especially this study, is intended to provide insight, connect different research fields and foster understanding about tragic problems regarding refugee crises. Extensive attention is given to the limitations of the model to point out possible future improvements of the model and to prevent misuse (Sterman, 2000). Hopefully this research will be able to contribute to humane and lasting solutions to people in refugee situations.

1.4 SCIENTIFIC AND SOCIETAL RELEVANCE

The current refugee crisis was a permanent priority on the European Commission's agenda for the last two years (European Commission, 2016). Refugee crises are not a new phenomenon since refugees are of all times and have been found a complex topic in many periods in history (The Guardian, 2013). Among other things these facts made the Syrian refugee crisis, as well as refugees and migration in general, a popular topic for research. During online research in the catalogue of Universiteit Leiden, Scopus and Google Scholar, in which the most relevant and recent articles were selected, a great variety of articles relating to refugees were found. In some cases the written articles or proposed researches are a direct response to the current crisis, it seems scientists feel a responsibility to help to tackle this complex problem. For example, the international leading scientific journal Nature calls for living up to humanitarian values during the crisis (Nature, 2015) and a group of German

researchers have started integration studies to counter xenophobia (Schiermeier, 2015). Another finding was the great variety of perspectives for approaching the refugee problem: from research into Human Rights and European Law (Costello, 2015) to possible health challenges of the refugee crisis (Omaar & Dar, 2015) to an anthropological perspective on forced migration (University of Oxford, 2016). Also in the field of international affairs (Kirişci & Ferris, 2015) and from an organizational perspective (Morgan, 2015) research regarding the refugee crisis is conducted. However, a system dynamic approach has not been a widely elaborated research topic and would possibly give valuable new insights in refugee issues.

It is important to mention that system dynamics is not a total stranger in refugee studies and the broader field of security. In the research field of security it is for example used to gain insight in complex self-influencing systems, like the research of Ghaffarzadegan (2008) in which he argues that more security forces may lead to less security. It is also used to test the behavior of a system in different scenarios, like the study on the behavior of insiders threat in the information technology environment (Martinez-Moyano, Rich, Conrad, Andersen, & Stewart, 2008). Narrowing down the search to system dynamics studies involving refugees and border control a study performed by Pruyt, Logtens and Gijsbers (2011) is considered relevant. They conducted a study into demographic shifts from both a global and national perspective. In their system dynamics model aging and migration plays a central role. This model is a great example in terms of basic structures, but due to the focus on free-will migrants it contains totally different incentives for people leaving their home country. Quite recently Onori (2013) explored, during the Crossover Conference of Policy Making in Dublin, the applications for policy modeling in the defense sector. One of the presented cases was about the illegal border activities in Mali and how system dynamics can gain more insight in the flows of arms and drugs. Apart from the subject unit, arms and drugs instead of people, the Mali case can be helpful in the refugee crisis model in terms of basic mechanisms. More related to refugee issues is the study of Djamengo and Fanokoa (2015), who conducted research into the refugee flows from Central African Republic to Cameroon. Using system dynamics they determined the dynamics of the refugee flows and its impact on Cameroon's hosting regions. Although the above mentioned studies are more or less related to the proposed topic in this thesis, none of them they are specifically about the mechanisms- and

early indicators of the emergence of refugee flows. Despite multiple efforts in various databases, the catalogue from Universiteit Leiden, Library from TU Delft, Scopus and Google Scholar, it is concluded no similar research is yet published. It is however important to consider the possibility that scholars are working on similar studies right now but haven't yet published it. This is a probable scenario since the refugee crisis is still going and its urgency stimulates scholars to conduct research on this topic. According to the current knowledge the existence of unpublished studies regarding refugee issues is already the case in at least one on-going study. Pruyt, associated with Technical University Delft, is now working on a system dynamics model of the European problems related to the Syrian refugee crisis including separate Member States (E. Pruyt, personal communication, 20 October, 2015). The study conducted by Pruyt has no implications for this research as he focuses specifically on policy recommendations for European Member States, while this research is about the emergence of refugee flows.

In addition to the scientific relevance, this research is also important as a societal issue. Refugee crises touch the very humanitarian core values resulting in important questions like: should not every human being help another man, woman or child in distress? Next to humanitarian reasons the international community also has a legal responsibility to accept and protect people who are fleeing for war and persecution. Article 14 of the Universal Declaration of Human Rights (UDHR) states "everyone has the right to seek and to enjoy in other countries asylum from persecution" (UNHCR, 2016b). When a refugee situation is recognized and constrained there is a bigger chance that states keep acknowledging the right for asylum to refugees, instead of denying their human rights due to escalating numbers of refugees. The fact that the current refugee crisis dominated the headlines for most of 2015 (The Guardian, 2016) says enough about the magnitude of the impact on the Western world. Any new piece of knowledge is hopefully a step closer to a fitting and adequate response. These reasons make this master quite relevant, both societal and scientific.

1.5 LINK WITH CRISIS AND SECURITY MANAGEMENT AND PUBLIC ADMINISTRATION

The subject of refugee crises is in several ways connected to the field of Crisis and Security Management. The first thing that immediately stands out is the corresponding word ‘crisis’. One of the main definitions of crisis used in CSM is "serious threat to the basic structures or fundamental values and norms of a social system, which, under conditions of time pressure and very uncertain circumstances, demands the bringing of critical decisions" (Rosentahl, Michel & ‘t Hart, 1989, p. 10). The large inflow of refugees can easily destabilize national systems and become worse as time goes by. The elements of time pressure, uncertainty and critical decisions can be a disastrous combination, especially because people are the main subject in this situation. With this in mind the emergence of refugee flows is acknowledged in this study and the focus is on looking ahead; preventing the crisis instead of preventing the conflict.

Besides the clear overlaps in crisis, this master thesis topic is also strongly connected to security. When we look at the causes of the current refugee flows several security issues are identified: the ongoing conflict in Syria, violent movements both in Iraq and Afghanistan and abuses in Eritrea (BBC, 2016a). More generally speaking Weiner (1996) distinguished four causes for mass refugee flows: inter-state conflicts, ethnic conflicts, non-ethnic civil conflicts and conflicts caused by authoritarian regimes. All these types of conflict result in well-founded fear of violence among citizens, which cause them to flee. Another security aspect has to do with the changing attitude of state authorities towards refugees, which can be traced back to 11 September 2001 (Feller, 2006). When first the personal security of refugees had the main focus, now the priority has shifted to national security of the host country due to the international threat of terrorism and the polarizing political landscape. The fear of terror together with other negative aspects refugees can possibly bring along, like poverty, diseases and differences in culture, facilitate the image that refugees are a threat to the civilians way of living in host countries. This has resulted in more strict migration policies and increasing border control. So in refugee issues security exists in terms of both ‘security of refugees’ as well as ‘security from refugees’.

The link of this study to Public Administration can be found in the main aim of this research: creating insight in the mechanisms of refugee flows and find early indicators of these flows using the tool system dynamics. Together with other knowledge it can possibly play a role in the decision making process of state authorities in terms of anticipating to future refugee flows. Ghaffarzedegan, Lyneis and Richardson explain the contribution of system dynamics in the field of Public Administration as follows: "Small System Dynamics models are unique in their ability to capture important and often counterintuitive insights relating behavior to the feedback structure of the system without sacrificing the ability for policymakers to easily understand and communicate those insights" (2009, p. 3). Ghaffarzedegan et al. (2009) indicate system dynamics as a valuable tool for policy making. The system dynamics model in this thesis can possibly also function as the initial model for further research into policy making regarding refugees issues.

1.6 STRUCTURE OF THE THESIS

Now the research question and additional information is elaborated, the relevant theory is set out in chapter 2. In chapter 3 the research design of the thesis is elucidated; a more in depth explanation about system dynamics is provided. In chapter 4 the conceptualization is carried out: cohesions between all factors are illustrated in causal diagrams, the major causal mechanisms are elucidated and the dynamic hypotheses are presented. The specification phase is described in chapter 5 by presenting a real-life case, discussing the used input data and formulating the model equations. In chapter 6 the model is tested on its correctness and usability by verifying and validating the model. Thereafter the model is used to explore the behavior of the refugee flows, the mechanisms and early indicators. The results are subsequently presented in chapter 7. In chapter 8 the conclusions are drawn and the research is shortly reflected. The thesis concludes with chapter 9 in which some critical remarks on the study are discussed and recommendations for any future research on this topic are made. A short remark for easier reading: many model factors are mentioned during the different phases of this thesis and therefore indistinctness can occur. To prevent confusion the mentioned model factors are displayed in *italics*, but only when specifically is referred to a model factor.

2. Theory

In this chapter the theoretical base for the study is described. Literature is used to identify causes and causal relations which are relevant for the emergence of refugee flows. The theoretical framework is elaborated in paragraph 2.1, which explains the main theory and relevant concepts. In paragraph 2.2 a literature review is conducted into the push-factors and early indicators.

2.1 THEORETICAL FRAMEWORK

In the theoretical framework the Ravenstein model is first elucidated in sub-paragraph 2.1.1. This theory will function as the foundation for this research. Subsequently the important concept of refugees is discussed in sub-paragraph 2.1.2 and the concept of internal conflict in 2.1.3.

2.1.1 Ravenstein model

The basis of many contemporary migration theories can be traced back all the way to 1885. Ravenstein (1885) then described a model known as the push-pull model. In this model Ravenstein conceptualized migration as flows of people within and between states. The central idea of his theory is that migration occurs under the influence of repelling factors at the place of origin, known as push-factors, and attracting factors at the place of destination, known as pull-factors (Bijak, Kupiszewska, Kupiszewski, Saczuk & Kicinger, 2006). In contrast to many other migration theories, the Ravenstein model does not exclude forced migration and therefore is useful in this study. However, the focus of a forced migration model is different from a general migration model. Since refugees flee their home country to avoid violence these people are being pushed much harder than free-will migrants (Conton, 2010). Therefore the emphasis has to be on the push-factors when dealing with refugee cases. As system dynamics is about constructing a simplified version of reality it is decided that the pull-factors are not included in this study at all. This will have no serious complication for answering the central research question, because the pull-factors are initially not relevant for the mechanisms of the emergence of refugees and identifying early indicators. Another disadvantage of including the pull-factors is that it makes the construction and

communication of the system dynamics model unnecessary complex. Lee (1996) took the dominance of push-factors as a basic principle for the reformulation of Ravenstein's model and focused in his study on push-factors in the migration process. The combination of Ravenstein's and Lee's theories will provide the theoretical framework for this research by focusing on the push-side of the Ravenstein model. This will provide the basic structure for the design of the system dynamics model.

2.1.2 Refugees

The broadest view on migration, which also complements the earlier mentioned push-pull model, is that people migrate from their country of origin to seek a better life for themselves and their family. This view includes free-will migrants, who willingly leave for a country with better economic conditions, and also refugees, who leave for example because of war, persecution or abuse (McLaughlin, 2003). However, the emphasize for refugees lies almost entirely on push-factors (Conton, 2010), while the choice for free-will migrants is more a rational consideration between push and pull-factors (McLaughlin, 2003). Also the nature of push-factors differs: free-will migrants have mainly economic motives (European Commission, 2000), while refugees flee as part of a survival strategy (Conton, 2010). Because of these fundamental differences it is necessary to distinguish different types of migrants. In this study the distinction between three categories is made: free-will migrants, refugees and Internally Displaced Persons (IDPs). The term free-will migrants speaks for itself, these are people who voluntarily decide to migrate to another country based on economic motives (Massey, 1993). Refugees, however, are forced to leave their home country to secure their family and themselves from harm. The official definition of refugees formulated during the 1951 Refugee Convention is someone who:

> owing to a 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 to, or owing to such fear, is unwilling to avail himself of the protection of that country. (UNHCR, 2016c, first paragraph)

The UN refugee status provide people the legal basis to seek and obtain asylum, based on Article 14 of the Universal Declaration of Human Rights. IDPs are people who are pushed

from their home region, but do not cross the national border of their country. This type of refugees is not qualified for the refugee status as formulated by the UNHCR, because these people are not looking for asylum in another country. When these people do not cross the national border their home country remains responsible for them and therefore UN refugee rights do not apply. There is no need for explaining that IDPs often have to deal with security issues due to a unwilling or unable government (McLaughlin, 2003). The most recent estimation of the UNHCR is that there are 38.200.000 people that are internally displaced due to threat of violence (UNHCR, 2016d). It appears however that the complex reality doesn't clearly distinguish these categories as presented here. Not always clear distinctions can be made between refugees and free-will migrants; motives can be blurred and overlapping (Carling, 2015). Nevertheless an attempt is made in this study to focus solely on refugees, both in literature as in data. Free-will migrants and IDPs are not included as main subject in the model, however these two categories can be included when they appear to be added value for the refugee simulation model. In that case refugees remain the subject of the simulation model, but the addition of these categories to the model will be considered.

2.1.3 Internal conflict

There are multiple causes for people to flee their home country. As shortly mentioned earlier, Weiner (1996) divides each refugee movement into four different categories: inter-state conflicts, ethnic conflicts, non-ethnic civil conflicts and flights from repressive authoritarian and revolutionary regimes. This division can be brought back to only two categories: inter-state conflicts and internal conflicts. Inter-state conflicts are conflicts between two or more states. Internal conflicts are conflicts within state borders in which civilians fight each other or their state authority. Other states are only involved for possible external intervention. History shows that internal conflicts produces more refugees than inter-state conflicts (Weiner, 1996). This has to do with the increasing level of violence in internal conflicts. Due to the proximity of the enemies personal retribution is an easy option which often results in an escalation of the conflict. Because internal conflicts produce more refugees this study focus solely on internal conflicts.

2.2 LITERATURE REVIEW

A literature analysis is conducted regarding the push-factors and possible early indicators of mass refugee flows. In sub-paragraph 2.2.1 the review regarding push-factors is discussed and in sub-paragraph 2.2.2 the relevant literature for early indicators is elaborated.

2.2.1 Push-factors

Logically, starting with the push-factors it is evident to keep in mind that refugees relocate because they want to secure themselves and their families from severe violence. Zolberg, Suhrke and Aguayo (1986, p. 153) describe it as "persons whose presence abroad is attributable to a well-founded fear of violence". This term *well-founded fear of violence* on its own is the main push-factor for people to decide to leave and therefore can function as an umbrella factor for the varying underlying causes that contribute to the fear of violence. But how can this term be decomposed into multiple sub-causes? Literature and reality agree that fear of violence is not solely a matter of actual risk and security. People's perception of violence is also an important component (Dake & Wildavsky, 1990; Slovic, Fischhoff & Lichtenstein, 1980). A plain but comprehensive definition of perception is "the ability that individuals have to give an interpretation of the situations they see, hear or feel" (Chaowsangrat, 2011, p. 90). Multiple factors which possibly influence people's perception about fear of violence can be found in literature. However, all these factors raise one or more problems. Some factors cannot be applied to all countries dealing with internal conflicts, like assessment of crime rates, probability of victimization (DuBow, 1979) or mass media coverage (Reiner, 2007). Others are difficult to define and to determine, like threat of persecution and threat to personal safety (Conton, 2010). Furthermore there is only little data available or even nothing at all. On the other hand it is not an option to totally exclude the perception, since excluding such an important factor is similar as stating that this factor equals zero (Forrester, 1956). However it is known from literature and reality that the perception of violence is anything but zero. For this reason it is decided that the factor *perception of violence* is included in the model, but is not further specified in sub-factors.

The logical second component which influences a *well-founded fear of violence* is the effect caused by actual violence regardless of a value judgment, in short, the *effect of violence*. This factor is influenced by several push-factors that enlarge the level of violence and therefore the effect of violence on fear. The first identified push-factor is *serious disturbance of the public order* (Feller, 2006 ; Zolberg et al., 1986). The extension of the established UN definition of the term refugee, during the Convention on Refugee Problems in Africa in 1969, included not only people who are dislocated due to persecution but also the ones who are threatened by an unknown internal or external enemy. In this more comprehensive definition all persons are included who are "threatened by external aggression, occupation, foreign domination or events seriously disturbing public order" (Convention Governing the Specific Aspects of Refugee Problems in Africa, 1969). This formulation implies that an identifiable enemy is no longer necessary and that people fleeing from violence in general can also be acknowledged as refugees (Zolberg et al., 1986). In contrast to the other three factors mentioned in the extended definition of refugees, serious disturbances of the public order are taking place during internal conflicts and is therefore identified as a push-factor. The second identified push-factor is widely acknowledged in refugee literature. *Military terror* is a large cause of fear and entails the presence of military activity in an internal conflicts (Feller, 2006; Hall, 2000). This not only involves military troops representing the state, but also opposition troops and other militant groups. The presence of military troops increases the level of violence which results in increasing numbers of civilian casualties. The last identified push-factor that influences the effect of violence is the amount of *human rights violations* (Feller, 2006). Internal conflicts often involve inability of state authorities to protect their citizens and in some cases they are even the ones attacking their own citizens. When this happens the human rights of the citizens are at stake and this will result in the displacement of people. The UN recognized this effect by stating that states will have to comply with human rights or otherwise refugee movements will remain a big issue (Feller, 2006).

In figure 2.1 the total cohesion of all factors is illustrated. The top layer is the main cause for people to flee; a well-founded fear of violence. This fear consists of the public perceptive level of violence and the actual level of violence in a country, as shown in the middle layer of

the graph. The push-factors that influences the effect of violence are placed in the lowest layer. Important to mention is that another literature dominating push-factor is not included in this study. This factor is defined as political terror (Conton, 2010; Hall, 2000) by which is meant the violation of rights of citizens caused by the state or state agents. Despite the frequent mentioning of political terror as an important cause, this term has a very similar meaning as the earlier mentioned human rights violations. Reliable sources about political terror even implies that it's data is completely based on the amount of serious human rights violations (Political Terror Scale, 2016). The main difference between these factors is that political terror are human rights violations caused by state authority, while human rights can also be violated by non-state authorities. In this study the preferences is given to the factor human rights violations because state authority is not always the cause for violence in internal conflicts. The identified cohesion of fear and the push-factors can be viewed as the initial foundation for the system dynamics model.

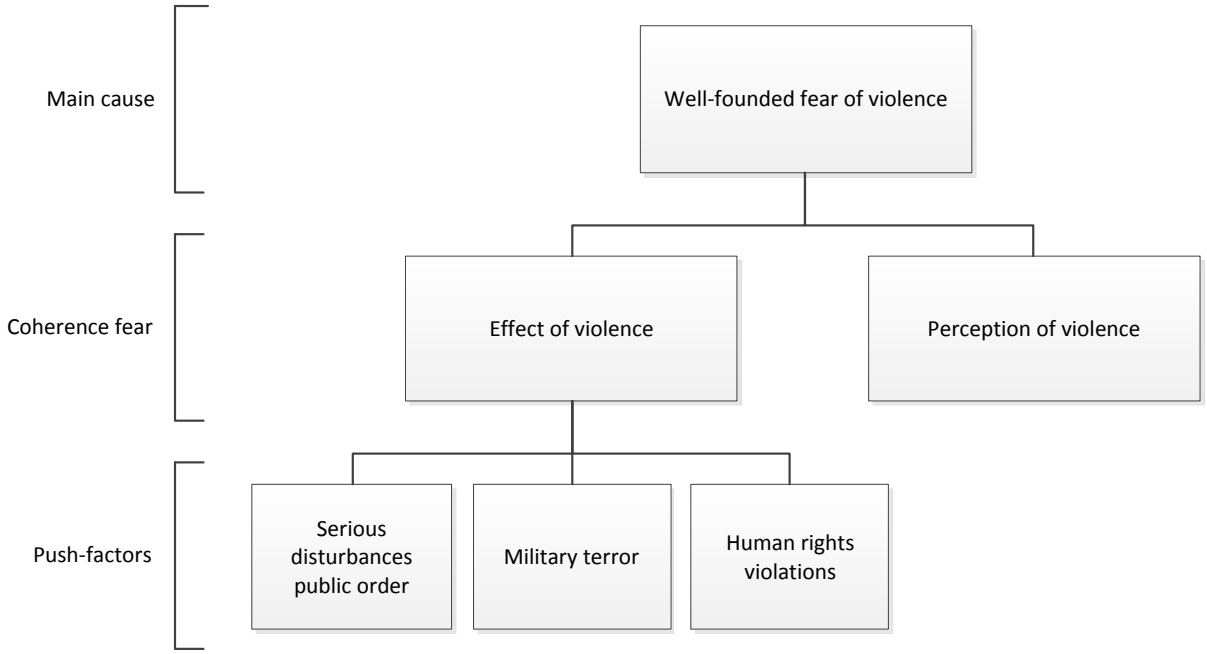


Figure 2.1 Cohesion violence and fear

2.2.2 Early indicators

As explained in the introduction, early indicators can indicate particular future events which allows them to function as an early warning system. Complex issues often require multiple early indicators to indicate an event. In this case it is the aim to identify early indicators that can function as a signal for the emergence of mass refugee flows caused by internal conflicts.

Literature mentions various types of early indicators for refugee flows. Two early indicators are mentioned earlier in this thesis in the section about the definition of refugees. As free-will migrants and IDP's are not the subject of this study, it was decided these groups were not included in the construction of the refugee models. However the emergence of free-will migrants and IDP's can contribute to the model as these groups have a relevant connection to refugees. McLaughlin (2003) illustrates the relation of *free-will migrants* and refugees by an example regarding the conflict in Bosnia-Herzegovina. During the conflict thousands of people moved to Central-Europe to seek a better life and remained to stay there. This group was defined as free-will migrants because they were able to move before the period of ethnical cleansing. The hundreds of thousands that had to flee during this period were defined as refugees. The relative small group of free-will migrants consisted of educated and skilled people who were able to find a job in another country quite easily. This is possibly a general phenomenon that occurs often during internal conflicts, as well-educated and well-earning people have more resources to leave when their home country is becoming unstable. Professor Migration History Leo Lucassen agrees with this and adds that free-will migrants are not only an indication for refugee flows in terms of time but also in terms of location (L. Lucassen, personal communication, October 14, 2016). Based on these sources the presence of *free-will migrants* is identified as the first early indicator.

The same logic is applicable to the second identified early indicator: *IDPs*. When a country is becoming unstable and people have to flee to secure their lives, displacement within a country is more common than a cross border flight, therefore the amount of IDPs worldwide is greater than the amount of refugees (McLaughlin, 2003). An internal flight to a safe region requires less resources and is simply easier than an external flight. Besides why should you

flight across borders when it is not necessary in terms of security? Naturally it is also possible that initial IDPs become refugees when safe regions are minimized. In this sense IDPs can be a first indication of a future refugee flow in case the conflict escalates. Especially during relative slowly evolving internal conflicts *free-will migrants* and *IDPs* can possibly be useful early indicators for refugee flows.

The article of Zolberg et al. (1986) shows that *external military intervention* is another important driving force behind the emergence of refugee flows. Military intervention, carried out by external actors, means basically the contribution of extra fire power for one of the combating groups in the conflict. The extra fire power results in an enlargement and intensification of the fire zone. Logically this leads to more civilian casualties and less safe areas which results in an increase in the amount of refugees.

To keep this research feasible only the above three indicators are explored further, although there are many more possible early indicators. The selected three indicators were perceived as most dominant in literature and it is expected they have the strongest causal relations with the emergence of refugee flows. Two other important indicators found in literature, namely the presence of an ethnic conflict (Feller, 2006) and bad neighborhoods (Weiner, 1996), are not included. The indicator ethnic conflict is excluded due to the study's focus on refugee flows caused by internal conflicts in general, regardless the nature of the conflict. Bad neighborhoods, a term for unstable regions of several countries, can produce a large number of refugees due to the chance the violence will spread to other countries and the minimization of neighboring countries to flee to. However, there are many examples of stable countries in unstable regions, like Iran, in which the people have no reason to flee. Therefore the indicator bad neighborhoods is not an adequate early indicator for refugee flows.

3. Research design

In this chapter, about the research design of the study, the chosen methods are elucidated. This slightly differs from traditional research in social sciences as this chapter is more comprehensive due to required explanation regarding system dynamics. Methodology paragraph 3.1 is divided in two sub-paragraphs: in 3.1.1 both qualitative as quantitative aspects of the used methods are discussed and in sub-paragraph 3.1.2 the different model phases of the modeling process are elucidated. This knowledge is not required to understand the final results, but it is hopefully convenient to understand the line of reasoning leading to the final results.

3.1 METHODOLOGY

System dynamics is increasingly applied in a wide range of studies as a tool to structure and understand the complex reality. These studies vary from research of population growth, the dispersion of diseases, fluctuations in the housing system to depletion of fossil fuels. Despite its increasing use in scientific research it is not a common method in the field of social sciences. Due to the social nature of this study it only make sense to provide the reader with global principles of system dynamics.

3.1.1 Qualitative and quantitative method

A commonly used definition of system dynamics which focusses on the different components of this method states: "method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies, which facilitates quantitative simulation modeling and analysis for the design of system structure" (Wolstenholme, 1990, p. 3). This definition puts forward an interesting characteristic of the method system dynamics, namely that is has both qualitative as quantitative components. The distinction between qualitative and quantitative components is expressed through different types of models and the modeling phase they are used in. Qualitative system dynamics models are used during the conceptualization phase. By illustrating the most important factors and by structuring these, the complex issue

is already reduced to a simple diagram, a so called causal loop diagram or simply causal diagram, which is explained later in this chapter. Therefore it functions well as a communication tool for actors with different educational- or professional backgrounds. The qualitative models are the basis for the quantitative models. Models are quantified by inserting simple mathematical equations and by implementing data. Quantitative models are constructed during the formulation phase using simulation software and are referred to as simulation models. During the final analysis phase the simulation model is used for generating behavior and testing the impact of changing factors.

In addition to system dynamics also other methods are used in this thesis. For the collection of data and the verification of the simulation model the so called triangulation of methods is applied. Triangulation is the metaphorical word for a process which uses three independent methods to verify an outcome (Miles & Huberman, 1994). Literature study is used for determining the theoretical framework, identifying push-factors and constructing the models both for substantive as technical aspects. More general knowledge about refugees, like definitions and rights, are obtained during the document analysis. Also information and data about the selected actual refugee crisis, necessary to determine the accuracy of the model, is derived from document analysis. The third method that completes the triangulation are expert interviews. Two expert interviews are conducted to complement the knowledge required for model building and verifying the simulation model and gaining. The first expert interview is conducted with dr. Irial Glynn who examined asylum policy making for his PhD and is currently researching the impact of migration on societies. This year he published a book about the diverging policies of Australia and Italy towards refugees arriving by boat since 1990. The second interviewed expert is Leo Lucassen, Professor Global Labour and Migration History and director of the International Institute of Social History. His research focuses among other things on global migration history, migration systems and migration controls. In paragraph 5.2, in the chapter about specification, the data collection process is further elaborated.

3.1.2 Model phases

The concept ‘system’ has popped up frequently in this thesis. Obviously everyone has a sense of the meaning of the word system. In system dynamics the word system means the following: "A system is a whole that cannot be divided into independent parts or subgroups of parts" (Ackoff, 1994, p. 175). In other words this means that all factors which are part of an issue including all its main mechanisms form a system. The objective of system dynamics is to identify a system without losing sight of reality, where interaction between the system and external factors are often more complicated. The borders of the system are determined by the chosen system boundaries. Important to realize is that system boundaries are selected by the scholar, based on the focus of the research, and is therefore subjective (Daalen et al., 2009).

The establishment of a working system dynamics simulation model takes place in two phases: a qualitative phase and a quantitative phase. During the qualitative phase a causal diagram of the issue is constructed. Causal structures are the first building blocks from the system dynamics toolbox. The term 'causal' is essential, as system dynamics is based on causal relations and cannot handle correlations and indirect influences (Daalen et al., 2009). Causal relations can have a positive or a negative polarity. A positive polarity between variable A and B means that when variable A changes, variable B changes in the same direction (Richardson, 1997). In other words when variable A increases it influences variable B in such a way that it also increases, see an example in figure 3.1. When a negative polarity is in place between variable A and B than the effect is different. If variable A changes in a certain direction, variable B changes in the opposite direction (Richardson, 1997). In other words, when variable A increases it influences variable B in such a way that it decreases and vice versa, see an example in figure 3.2.

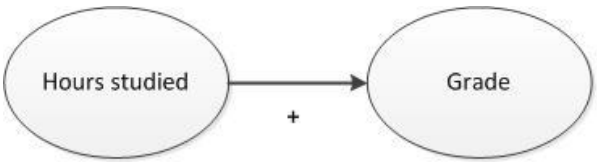


Figure 3.1 Example positive relation

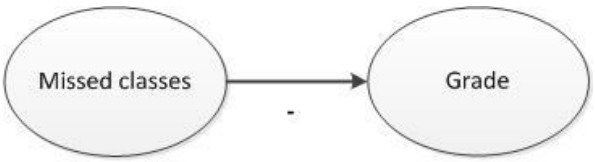


Figure 3.2 Example negative relation

Another important aspect of the causal diagram is the feedback loop. A feedback loop consists of two or more variables who influence each other creating a loop form. For example, variable A influences variable B and variable B in its turn influences variable A. This means all variables in the feedback loop are, after some time, influenced by its own past behavior. There are positive and negative feedback loops. A loop is called positive when an initial increase in variable A eventually results in an additional increase in variable A. When an initial increase in variable A after some time results in a decrease in variable A it is called a negative feedback loop. Examples of positive and negative feedback loops are respectively showed in figure 3.3 and figure 3.4.

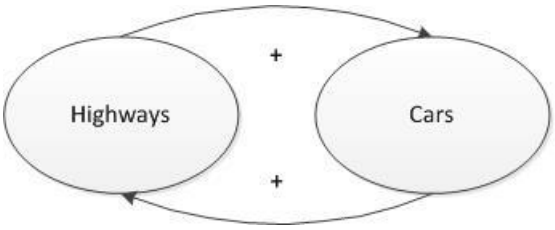


Figure 3.3 Example positive feedback loop

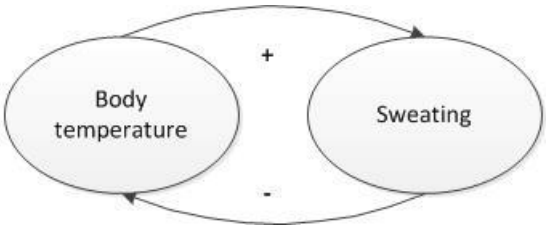


Figure 3.4 Example negative feedback loop

Now the main elements of the causal diagram are explained it is time to briefly explain the process of making a causal diagram. It starts off by having a clear idea about the real issue. When the issue is defined the most important elements can be determined. Then slightly less important elements, still essential for the model, are added. These elements are the group of factors which are used to construct the causal diagram. Next the relations between the factors and also their polarity are determined. Thereafter the feedback loops are indicated. Finally the elements that are irrelevant for the causal diagram are removed. Despite the fact that a causal diagram is a qualitative model, that only consists of factor names and causal relations, it is a valuable tool in system dynamics and other fields of research. Causal diagrams aid to gain insight in the structure and mechanisms of an issue and can therefore function as a communication tool for explaining a complex issue. Because a causal diagram is able to illustrate counterintuitive mechanisms it can sometimes be sufficient to solve complex issues.

During the second phase, the quantitative phase, the causal diagram is translated into a stock-flow diagram, which makes it possible to use in simulation software. There are multiple software programs that can simulate system dynamics models, each with its own

benefits and specific applications. For this study the software Vensim is used. Previous experience with Vensim makes this software the most efficient choice. There is no standardized way to transform the causal diagram into a stock-flow diagram, but there are some general steps which can be followed. The first step is to identify the 'stock variables'. A stock variable contains the elements that move through the system and can be increased or decreased by so called 'flows'. An inflow increases the initial stock and an outflow decreases the stock. Examples of stocks are a population, a warehouse inventory or amount of pollution. An illustration of a stock-flow element is provided in figure 3.5, which shows the course of a fish population.

Figure 3.5 Example stock-flow construction

After the identification of the flows, the remaining factors from the causal diagram are classified, such as auxiliary variable and constants. Auxiliary variables and constants are factors that help to understand the mechanisms that influence the behavior of flows. The difference between these factors is explained in next chapter. The general steps of the qualitative phase and quantitative phase are now described, but in practice these steps can also be carried out differently and alterations after these steps will almost always take place.

For additional information about system dynamics some books are recommended. The Fifth Discipline written by Peter Senge (1990) is widely valued for its approach to system thinking. An integrated way to look at system dynamics is offered by John Sterman (2000) in his book Bussiness Dynamics System Thinking and Modeling for a Complex World. A more applied approach in which the basic theory, qualitative exercises and quantitative exercises using the software Vensim are offered can be found in the case book Small System Dynamics Models for Big Issues written by Eric Pruyt (2013).

4. Conceptualization

In the previous chapter the research design of the study is set out. In this chapter that theory is applied to the central issue in this thesis: the emergence of refugee flows. First the system, the area which covers the real issue, and the systems boundaries are identified in paragraph 4.1. Subsequently in paragraph 4.2 the causal diagram is constructed, based on the earlier identified push-factors. Each identified early indicator is integrated separately in a causal diagram, creating a total of four causal diagrams. This allows to study every early indicator individually and eventually determine the impact per early indicator on the system. Finally, in paragraph 4.3 the expected behaviors of the four models are described in the dynamic hypotheses.

4.1 CAUSAL DIAGRAM

The causal diagram is the basis for the eventual simulation model. Important for a simulation model is that it should not be too complex in order to make it manageable during simulation and understandable during interpretation. Models that resembles reality but are too complicated to interpret have no added value. Only when a model is relatively simple and can therefore be communicated to others will be helpful in the issue solving process (Garcia, 2006). To determine the focus of the system first the model boundaries are defined. The first three model boundaries are already discussed during the literature review in paragraph 2.2. The first one is the choice for refugees as main subject. Free-will migrants and IDPs are excluded as model subject, but included as model early indicators. The focus on refugees is also reflected in the second model boundary through the use of solely push-factors since refugees are pushed from their home country to survive. The third model boundary is the assumption that refugee flows are caused by internal conflicts, excluding inter-state wars. Subsequently the model is suitable for mass refugee flows, which means more than ten thousand refugees, simply because it is based on knowledge regarding mass refugee flows. Another model boundary is the focus on the emergence of the refugees, in other words how fear causes people to make an external flight. The arrival in host countries or return to their home country falls beyond the scope of this study. The last model boundary is a limitation in

terms of time. The model factors and early indicators focuses on short- and medium term dynamics. This means it can be applied to internal conflicts or periods in internal conflicts which cover a period varying from months up to a few years. In table 4.1 the six model boundaries are summarized.

Model boundaries	Excluding
Refugees	Free-will migrants, IDPs
Push-factors	Pull-factors
Internal conflicts	Inter-state conflicts
Mass refugee flows	Refugee flows < 10.000
Emergence refugee flows	Arrival host country, return home country
Short-term and medium-term	Long-term dynamics

Table 4.1 Model boundaries

4.2 DIAGRAMS OF THE MAJOR MECHANISMS

For the construction of the causal diagram the mentioned model boundaries determine the so to speak playground and the identified push-factors are the main elements. The additional factors are derived from literature, international reports, expert interviews and sometimes just plain logic. Also the causal relations and their polarity are constructed in this manner. The most important mechanisms of the causal diagram are illustrated and shortly explained in this section. The causal diagrams, one general causal diagram and three including each one early indicator, are quite voluminous and therefore included in appendix A.

In paragraph 2.2 is discussed that *fear of violence* is partly the result of the *effect of violence* which in turn is influenced by the push-factors *human rights violations, disturbances of the public order* and *military terror*. Based on literature these are all correct relations, however in terms of causal relations a few factors are missing. The *effect of violence* is for example not directly affected by just the presence of military terror, but by the implication that military activities causes casualties. This also applies to the other two push-factors: *human rights violations* and *serious disturbances of public order*. The construction of these causal

relations are illustrated in figure 4.1. It can be seen that the higher the push-factors are, the higher the amount of *injured by conflict* and *deaths by conflict* become. When the amount of *injured by conflict* and *deaths by conflict* increases also *the effect of violence* increases. The positive polarity between the factors also means that when one decreases the following factor also decreases, both factors are moving in the same direction.

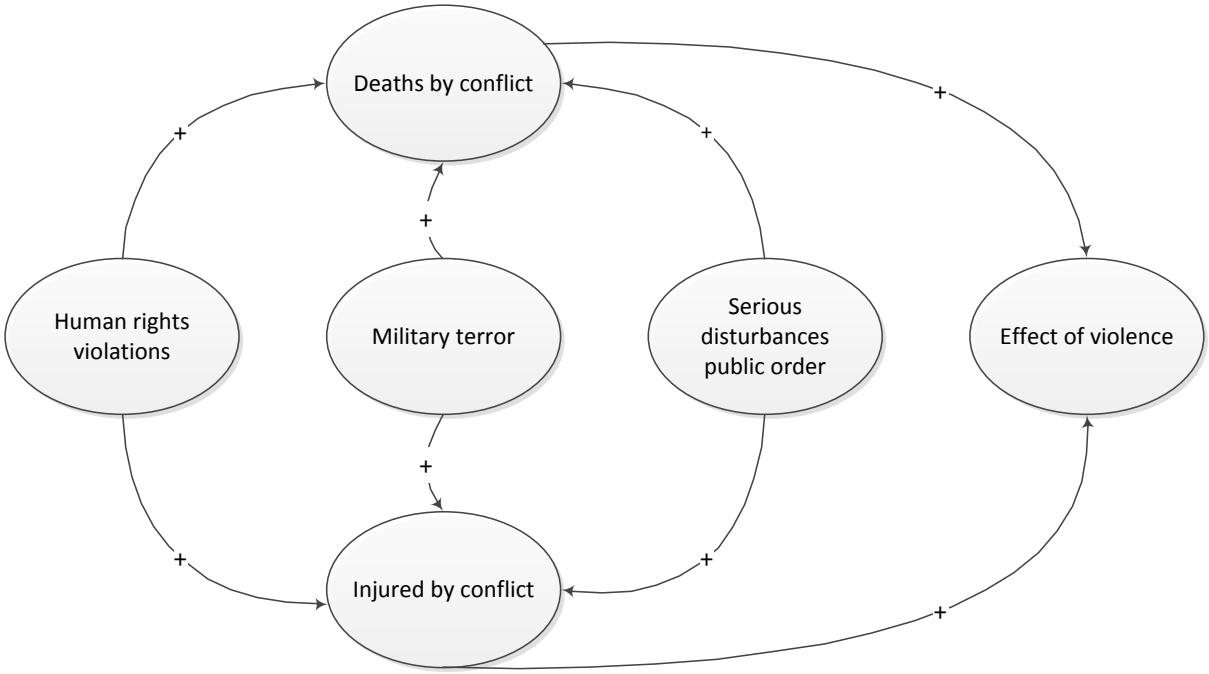


Figure 4.1 Major mechanism push-factors and violence

As shown during the literature review the construct of fear is hard to grasp. It was concluded that the *fear of violence* should be influenced by a reality based violence component and a perception of violence component. In this thesis these components are respectively mentioned as the *effect of violence* and *the perception of violence.* Figure 4.2 shows that both *effect of violence* and *perception of violence* have a positive relation with *fear of violence*. This means when the *effect of violence* or *perception of violence* increases also the *fear of violence* increases and the same applies to decrease. To design a credible approach of a fear mechanism another factor has to be added. Non-war traumatic events are generally observed as abrupt and life-threatening (Ursano, McCaughey & Fuller, 1994). During war however traumatic events occur frequently and these events can become the new standard. Also history shows that people can get used to the most horrible situations, like for example the people in concentration camps during WWII (L. Lucassen, personal communication, October 14, 2016). To include this phenomenon in the causal diagram the factor *habituation*

to violence is added and linked *to fear of violence*. This link has a negative polarity because when a person is more habituated to violence the fear of violence will decrease.

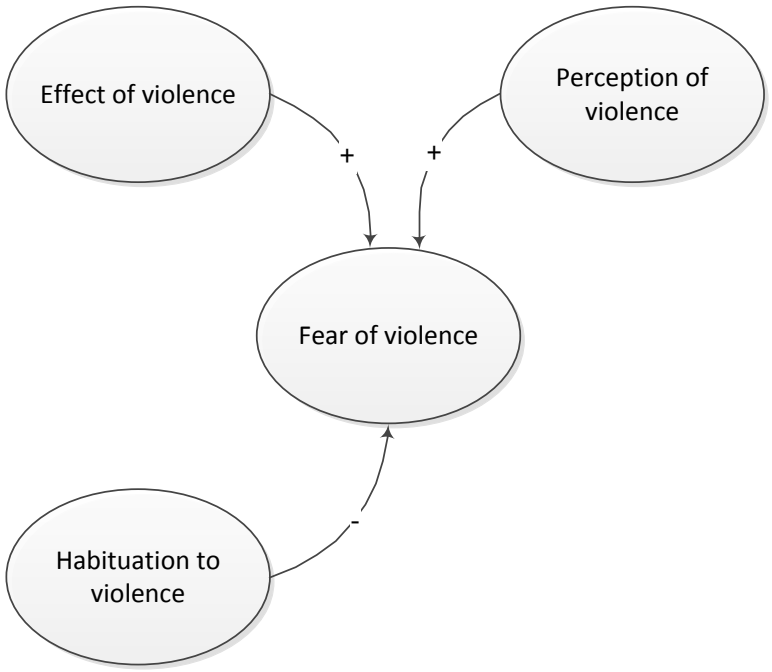


Figure 4.2 Major mechanism violence and fear

The final elaborated mechanism of the general causal diagram is about the moment residents decide to flee across national borders and become refugees. As explained earlier in paragraph 2.2 the main cause for refugees to flee is a fear of violence. When fear reaches a certain level, people make the estimation that the risk to stay is too big and they decide to flee. This behavior can be explained using the biology behind fear. When danger is getting closer an incentive is created which can reach some critical points. If the incentive passes all critical points it becomes an unconditional incentive and the flight modus is activated (Panksepp, 1990). Contextual conditions and personal conditions ensure that people react differently to danger and therefore are not fleeing all at once moment under the same level of violence (Steimer, 2002). However, during a widespread serious risk like war, there is a certain level of fear that activate the flight behavior of the mass. This level is important in this research, because it triggers the mass refugee flows which can eventually cause a refugee crisis. To incorporate this behavior the factor *problematic level fear of violence*, which represents the point where the flight behavior of the mass is activated, is included in the causal diagram. In figure 4.3 is illustrated that the more *fear of violence* there is amongst people, the more refugees emerge. The *problematic level fear of violence* has a negative

polarity with refugees, because the higher the problematic level, the more fear people tolerate before they decide to flee. The complete causal diagram is presented in appendix A.

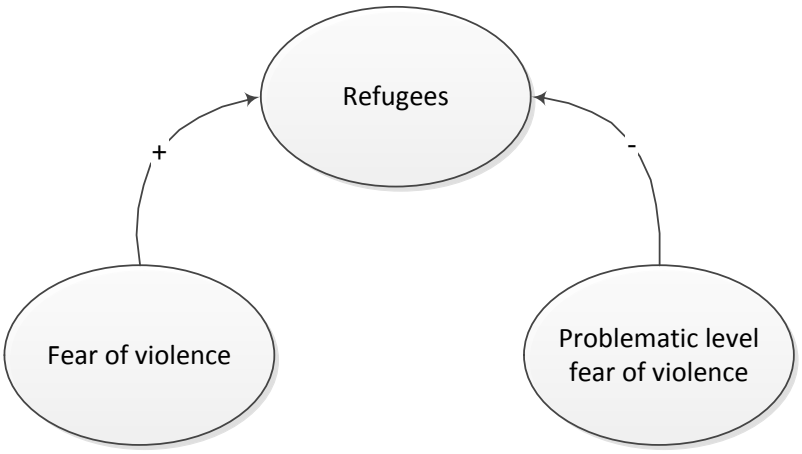


Figure 4.3 Major mechanism fear and refugees

The first early indicator *free-will migrants* is logically linked to the amount of residents in the home country, the more free-will migrants leave to other countries the less residents remain in the home country. In addition, the smaller the amount of residents, the smaller the group of leaving free-will migrants. These links are shown in figure 4.4. The cohesion between free-will migrants and refugees is based on a vaguely known relationship, which entails that an increase in free-will migrants in unstable countries is a harbinger for mass refugee flows in terms of time (L. Lucassen, personal communication, October 14, 2016; McLaughlin, 2003). The complete causal diagram including early indicator *free-will migrants* is displayed in appendix A.

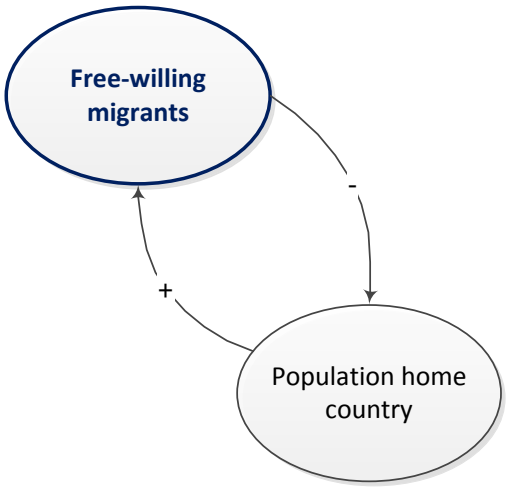


Figure 4.4 Mechanism early indicator free-will migrants

The emergence of *IDPs* is the second identified early indicator and is, just as the amount of refugees, influenced by the population. Due to the often 'slow' start of conflicts and the lack of resources most people who are directly threatened by the violence will make an internal flight to a safer region. However when a conflict escalates and the entire country is affected more and more people will decide to make an external flight. Also a part of the group who already made an internal flight will yet make the choice to flee beyond national borders. Due to the lack of information on this subject this hypothesis is based on the observations during the current conflict in Syria (Internal Displacement Monitoring Center, 2014). However it is not evident that this pattern occurs during all internal conflicts. The cohesion between IDPs, refugees and population is illustrated in figure 4.5. *Population home country* has a positive relation with factor *refugees* and early indicator *IDPs*, which means that when the population increases the amount of refugees and IDPs also increases. The positive link between *IDPs* and *refugees* represents the pattern of IDPs becoming refugees when a conflict escalates and spreads over a country. The negative link between *refugees* and *population home country* is the logical mechanism of a decreasing population due to the increasing amount of refugees. In appendix A the total causal diagram together with the early indicator *IDPs* is illustrated.

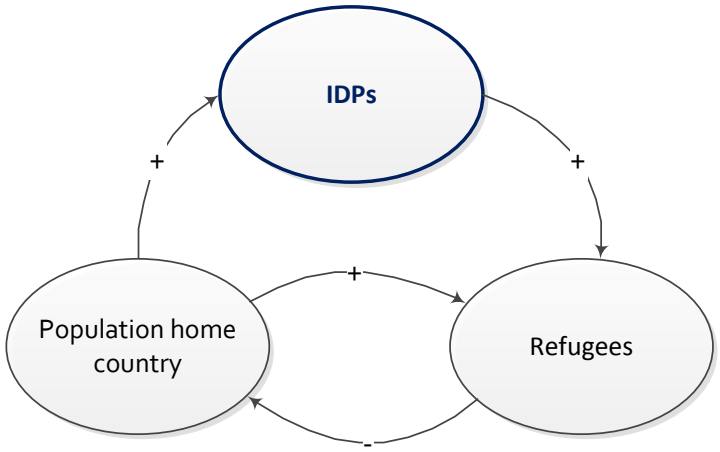


Figure 4.5 Mechanism early indicator IDPs

The third early indicator, *external military intervention*, leads to an enlargement of the conflict zone and the extension of the duration of the conflict due to the additional number of weapons (Zolberg et al., 1986). This results in more casualties which in turn leads to an increase in *fear of violence* resulting in an increase of *refugees*. As shown in figure 4.6, *external military intervention* can be seen as reinforcement of the push-factors, as it has a

similar effect on the amount of victims and creates an intensification of the existing conflict. The complete causal diagram including early indicator *external military intervention* is displayed in appendix A.

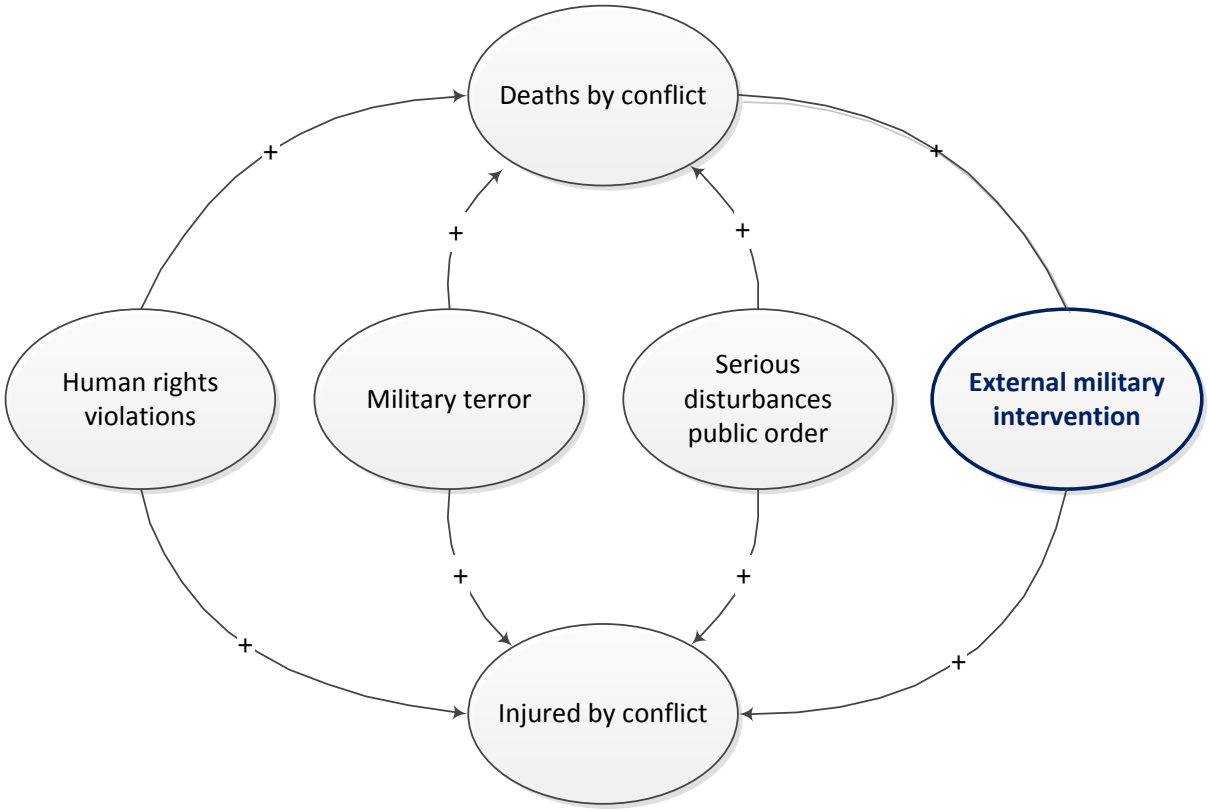


Figure 4.6 Mechanism early indicator external military intervention

4.3 DYNAMIC HYPOTHESIS

The entire system is now constructed in causal diagrams and the main mechanisms are explained. To transform these qualitative models into quantitative models the causal diagram is changed into a stock-flow diagram and imported in the software Vensim. First the factors *population home country, wounded victims* and *refugees* are identified as stock variables. Than the additional flows, which increases and decreases the stocks, are constructed. For example, *births* as the inflow and both *deaths* and *external flight* as the outflow for the stock *population home country*. Subsequently the remaining factors are identified as auxiliary variables and constants. An example of some auxiliary variables are the factors *military terror* and *fear of violence,* the values of these factors can vary. Some

identified constants are for instance the *birth rate* and the *death rate,* the values of these are constant. An image of the complete stock-flow diagrams in Vensim can be found in appendix B. It has to be mentioned that for model purposes some alterations are made in the transformation from causal diagram to the stock-flow diagram. This is manifested by adding some factors to make the modeling process easier, such as adding the variable *effect of violence on fear.* But also by including a model factor in another model factor, such as *problematic level fear of violence,* which is incorporated in the variable *flight rate*.

Using the stock-flow diagram a dynamic hypothesis is described; a hypothesis about the behavior of the model. During the simulation phase the hypotheses of the refugee system and the identified early indicators will be tested on their accuracy and usability. The constructed refugee model is a relatively simple model containing three stock variables. The increase in the amount of *refugees* starts of slowly, but when the conflict escalates it has a sharp increase. In the initial stage of the model the push-factors are quite low. This means that the amount of casualties are limited, which results in an increasing but still low level of *fear of violence*. As the level of *fear of violence* remains low, so does the amount of *refugees*. When the conflict evolves and escalates, the levels of *human right violations*, *military terror* and *serious disturbances of public order* increase. This results in an strongly increasing amount of casualties, which raise the level of *fear of violence*. The increase in the *fear of violence* magnifies the amount of *refugees*. Especially when the conflict spreads across the country and violence is wide-spread, the amount of *refugees* is subjected to a steep increase.

The dynamic hypotheses about the three stock-flow diagrams included by the different early indicators can be divided in two types of behavior. The early indicators *free-will migrants* and *IDPs* are essentially affected by the same cause refugees are affected by, namely fear. Obviously their relations to fear slightly differs as *free-will migrants* have other main motives for leaving the country and *IDP's* remain to stay in their home country. However it is evident that *free-will migrants* and *IDPs* are inherent to *refugees*, which is useful for their possible role as early indicator. The dynamic hypothesis of *free-will migrants* is not based on the early indicator itself, which is based on real world data, but on the cohesion in behavior with

refugees. The reason why the behavior of free-will migrants is not generated by the model, like *refugees*, is that it makes comparing these factors more reliable. If *free-will migrants* is also based on these same push-factors it is very logical these two have a cohesion in behavior, while maybe there is none in reality. The hypothesis of free-will migrants is that the number mainly increases directly at the beginning of the conflict and have some peaks just before or during escalation of the conflict. Most free-will migrants leave the country before refugees, both at the beginning and during the escalation of the conflict. *IDPs* is also based on real world data and the hypothesis about its behavior is quite similar to the one of refugees. In the beginning the amount of *IDPs* increases directly due to local conflicts. Depending on the level of escalation of the conflict the amount of *IDPs* are further increased. However the quantity of IDP flows will be larger and emerge faster than refugee flows due to the initial availability of safe regions in the country as well as the lack of resources. The third early indicator, *external military intervention*, belongs to the second type of hypothetical behavior. *External military intervention* is not inherent to an internal conflict and also not to the emergence of refugee flows. However the hypothesis is that when *external military intervention* occurs the amount of *refugees* significantly increases due to the extra fire power. This is different from the other hypotheses because *external military intervention* directly cause the amount of *refugees* to increase, while *free-will migrants* and *IDPs* don't directly cause *refugees*. Despite the different types of expected behavior all three early indicators are considered possibly useful for the indication of refugee flows.

5. Specification

By transforming the causal diagram into a stock-flow diagram the qualitative phase is alternated by the quantitative phase. In order to actually generate dynamic behavior simple equations, that define the relation between the model factors, are constructed. Also data is imported in the model in order to define initial values, constants and auxiliary variables. Real world data of an actual refugee crisis is applied to the general refugee model in order to determine whether it correspondents to reality and can be used for further exploration. More on this and the case selection is discussed in paragraph 5.1. Subsequently the methods of gathering the data and the made assumptions are elaborated in paragraph 5.2. The formulation of mathematical equations is described next in paragraph 5.3.

5.1 CASE SELECTION

To test the model, to gain insight in the dynamic behavior and to explore the functioning of possible early indicators data is inserted in the model. The selected data is real world data from an actual refugee crisis. Benefits of real world data is that it can be used to check whether the model is in line with reality. The selection of a particular conflict depends on the several assumptions set by the model. The relevant assumptions for this model are that the conflict produce refugees, the total amount of refugees is larger than ten thousand and that these refugee flows are caused by an internal conflict. It is also evident that there is enough data available about the conflict, which is often problematic due to the limited access and chaos during times of war. First the Bosnian War, between 1992 and 1995, is considered as an appropriate case to apply to the model. However, it appeared the available data was too limited. The current Syrian war seems to be more appropriate, enough data is available and many studies are done about this conflict. The fact that this war is still going on is no implication for this study, because the model focusses on the short- and medium term indicators of the emergence of refugee flows. By selecting the past five years, the emergence of refugee flows and the development of the conflict can be generated and analyzed. To properly introduce the conflict in Syria in this thesis, a short summary of the conflict until the end of 2015 is provided below.

In March 2011 peaceful anti-government demonstrations escalate, sparked by the arrest of some teenagers who painted revolutionary texts on a school wall. After government forces began shooting protesters more civilians joined the demonstrations demanding president Assad's resignation. Demonstrations spread nation-wide and protestors use firearms to protect themselves. During 2012 violence escalates into a civil war with on one side the government's security forces and at the other side the opposition forces (BBC, 2016b). Attacks by the opposition are increasing in 2013 due to a supply of foreign weaponry. In this year also the first convincing proof of the use of chemical gas is delivered. The war further escalates in 2014 due to more chemical attacks, the rise of terrorist group Islamic State and the start of the United States-led coalition launching air strikes. In 2015 the fighting again intensifies by the increasing use of chemical attacks, bombings and torture. The number of deadly victims increases by the interference of Russia (I AM SYRIA, 2016).

5.2 DATA COLLECTION

Data collection regarding the conflict in Syria is conducted for the factors in the stock-flow diagram. Not all factors require input data, but the stock values need initial values, constants require input values and most auxiliary variables need input data. This data is collected in three different ways: by performing a literature study, document analysis and expert interviews. To provide insight in all factors which require data, an overview is created with all used input data and all data sources in appendix C. To keep the overview comprehensible all data sources only have a short reference. The complete reference can be found in the model references list, in chapter 8. In some cases a test or some sort of analysis is necessary to retrieve input data. In that case the overview refers to another appendix in which the test or analysis is explained. Most important input data, which calls for a deeper explanation, are shortly elucidated in this section. An important remark is the attempt to only use data covering citizens, which means data regarding combatants is excluded. Unfortunately the actual context and recordings are often indistinct, especially data regarding civilian casualties. Most data makes a clear distinction between residents and combatants, but some numbers are more ambiguous and can give a false representation of reality.

Input data for two of the three push-factors as well as two of the three early indicators are based on data produced by the Fragile State Index (FSI). Every year the Fund For Peace (FFP), which is an independent non-profit research- and educational organization, publishes the FSI for 177 countries. The ranking is composed of 12 indicators which are based on thousands articles and reports (FFP, 2016a). The indicators are ranked from zero to ten and their total sum determines the country's place in the ranking. For the input data of push-factor *military terror* the FSI indicator 'security apparatus' is used. This indicator is defined as the extent to which the state owns the monopoly on violence and if this is used in a legitimate way. The values of the security apparatus are amongst others based on degree of internal conflict, military coups, militancy and rebel activity. For the second push-factor *human right violations* the FSI indicator 'human rights and rule of law' is selected. This indicator entails the amount of political prisoners, religious persecution, torture and executions. The input data for early indicator *free-will migrants* is based on the FSI indicator 'human flight and brain drain'. This indicator includes, as the name suggests, migration per capita, decrease in human capital and emigration of educated people. The last factor is the early indicator *external military intervention*. For this purpose the FSI indicator 'external intervention' is used, which includes foreign assistance, presence of UN missions and foreign military intervention (FFP, 2016b).

Clear-cut input data regarding push factor *serious disturbances of public order* is not available. In order to approach the degree of disturbances an analysis on the conflict timeline of Syria is conducted. The analysis is conducted by examining the detailed timeline of non-profit organization I AM SYRIA from the beginning of 2011 till the end of 2015 and ranking each month with a grade from one to five. One represents mild disturbances and five severe disturbances. The ranking results in a graph of the level of serious disturbances of the public order between 2011 and 2015, displayed in figure 5.1. An overview of the ranking and the values, which are used as input in the diagram, can be found in appendix D.

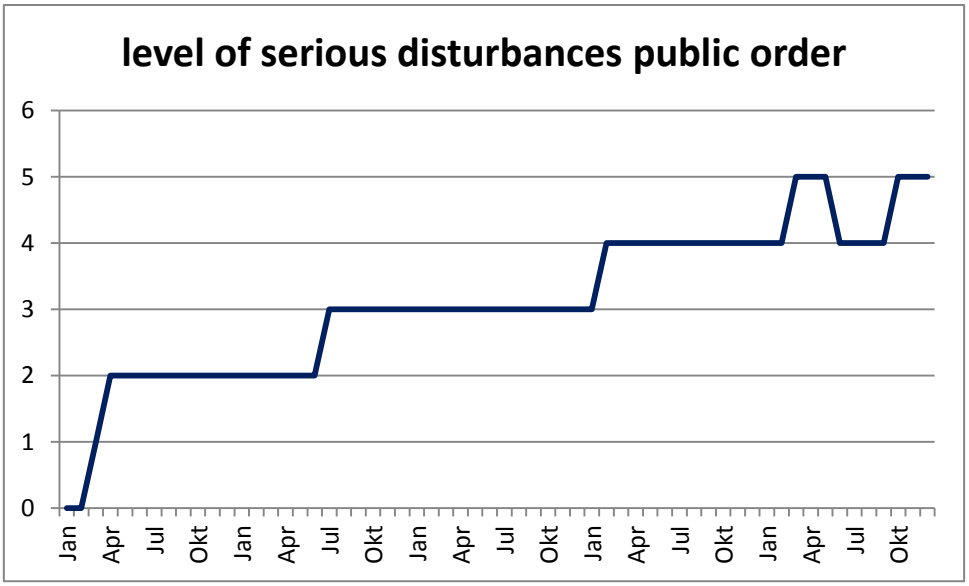


Figure 5.1 Analysis serious disturbances of public order Syria 2011-2015

It is now explained how the input data of each of the three push-factors is determined. However, it is not clear what their weight relative to one another is, in their relation to the factors *death by conflict rate* and *injured by conflict rate*. In other words, the importance of a particular push-factor compared to the other factors. In appendix E it is explained how these weights are determined.

Perception is a very subjective concept and impossible to measure. After contemplating multiple options it was decided to base the factor *perception of violence* on a combined factor called 'societal safety and security', which is an indicator of the Global Peace Index (GPI). The GPI is determined by Visions of Humanity, a community committed to global peace. The combined factor societal safety and security is composed by ten factors, of which some qualitative and some quantitative. The complete list of factors is placed in appendix F, along with the annually value of the combined factor and the assigned ratings which are used as input for variable *perception of violence*.

Unfortunately due to the nature of the model some necessary data is incomplete, not available to the public or simply unknown. For this reason a number of assumptions are made regarding the input data. When possible, these assumptions are based on some sort of

source. All assumptions regarding input data are listed in table 5.1, together with the source it's based on. The assumptions are further elucidated in appendix G.

Assumption	Source
Number of wounded is 4*number of deaths	SCPR (2015) , Coupland & Meddings (1999) Belammy (1992) , Melsom, Farrar & Volkers (1975)
Average recovery time is 2 months	No authorative source
Effect of death is 3*effect wounded	Murthy & Lakshminarayana (2006) , interview Lucassen
Values used for *effect of violence on fear*	Interviews Glynn & Lucassen
Values used for *habituation to violence*	Butler, Panzer & Goldfrank (2003), interview Lucassen
Problematic level of fear is 0.6	Pruyt (2013), Steimer (2002)
Free-will migrants is 0.1*refugees	MPC (2013)

Table 5.1 Assumptions input data

5.3 MATHEMATICAL FORMULATION

To determine the relation between two or more factors, equations are implemented in the stock-flow diagram. The way they cohere defines what kind of behavior they generate. In some cases the equations are based on known- or vaguely known relationships derived from literature, reports and indexes. However other equations are established by using the method of trial and error or setting assumptions. The construction of equations and the underlying reasons for a certain approach are difficult to communicate; it is rather abstract and several software functions are involved. Therefore it is paramount to be as transparent as possible and present it in a comprehensible way. This is attempted by providing an overview of all equations, along with a short explanation when necessary. The overview of the general stock-flow diagram equations can be found in appendix H. The equations of early indicators and their additional factors are shown in appendix I. As for the equations which

require a more comprehensive explanation the same applies as for the input data; most important equations are discussed below and the remaining are discussed in the appendix. Most assumptions are already elucidated in the previous data section, but any equation-specific assumptions are elucidated together with the discussed factor.

A function that is often used in the construction of the equations in this model is the lookup function. This function in Vensim can generate values based on the input it receives. A commonly used input variable is time, but it can actually be any variable in your model. A big advantage of a lookup function is that it is able to model a relation, which is not easily represented in an equation. A lookup ensures that a certain series of input produce a certain series of output. For example, the FSI (2016) provides annually the level of *human right violations* in Syria by means of a grade between zero and ten. Using a lookup function with the input of variable time, the model can produce level of human rights violation X in corresponding year A and level Y in corresponding year B. This way the actual dynamics, or in this case human rights violations, can be simulated in the model. The lookup function is applied to all three push-factors, using time as input and the FSI values as output. One remark for these functions is that the FSI value is an average for the entire year, so it is assumed that FSI value always corresponds to the middle of the year.

$$\frac{(human\ right\ violations * 0.63) + (military\ terror * 0.69) + \big((serious\ disturnbances\ of\ public\ order * 2) * 0.53\big)}{100000}$$

The equation of the variable *death by conflict rate*, which is displayed above, is based on the sum of all weighed push-factors. The variable *serious disturbances of public order* is multiplied by 2 to obtain the same scale as the other push-factors as these were based on a ten-point scale while *serious disturbances of public order* is based on a five-point scale. The value of 100.000, where the complete weighed sum is divided by, is called a normalization factor. This factor has no substantive meaning, but is purely used to achieve a useable output. When this normalization factor is excluded the value of the output is so large that it will induce ridiculous behavior in the rest of the model. The equation of variable *injured by conflict rate*, which is presented below, is constructed in a very similar way as *death by conflict rate*. The only difference is that the sum of weighed factors is first multiplied by 4,

before dividing by 100.000. This multiplication is based on the identified killed to wounded ratio of 1 to 4. By multiplying the weighted sum by 4, the amount of generated injured people becomes 4 times as big as the amount of deaths.

$$\frac{\Big((human\ rights\ violations * 0.63) + (military\ terror * 0.69) + \big((serious\ disturbances\ public\ order * 2) * 0.53\big)\Big) * 4}{100000}$$

The variable *effect of violence* is determined by a simple equation, the number of deadly victims and injured victims are added. The assumption is made earlier in the data section that the effect of *death by conflict* is 3 times bigger than *injured by conflict* due to the bigger effect of deaths on fear,. To reflect this in the model the variable *death by conflict* weighs 3 times more than variable *injured by conflict*, as can be seen in equation below.

$$(death\ by\ conflict * 3) + injured\ by\ conflict$$

The equation constructed for variable *fear of violence* is characterized by the implemented MIN- and MAX-function, as can be seen below. This function applies as a so to speak floor and ceiling for the output values. Because *fear of violence* is defined as a variable which varies between 0% and 100% the MIN- and MAX-function ensures there are no values generated outside this area. Another remarkable component in the equation is the function of *perception of violence* as a multiplier of *effect of violence on fear*. It is unknown how this construct of fear actually works, so it is assumed for this model the *perception of violence* can possibly reinforce the value of *effect of fear of violence*. Depending on the perception in society the *effect of violence on fear* is multiplied by 1, 1.5 or 2.

$$MAX(MIN((effect\ of\ violence\ on\ fear * perception\ of\ violence) - habituation\ to\ violence, 1), 0)$$

The *flight rate*, which influences the amount of *refugees*, is determined by a lookup function with the input variable *fear of violence*. Peculiar about this lookup function is the sudden alteration in the output values, which can be seen in figure 5.2. Up till the moment where the value of fear of violence is 0.6, the function is quite linear. However from this point on the graph is becoming exponential. The input value of 0.6 is identified as the *problematic level of fear of violence.* It represents the point that the amount of fear becomes to great

and the mass of people decides to flee across national borders. The exact values are established due to trial and error.

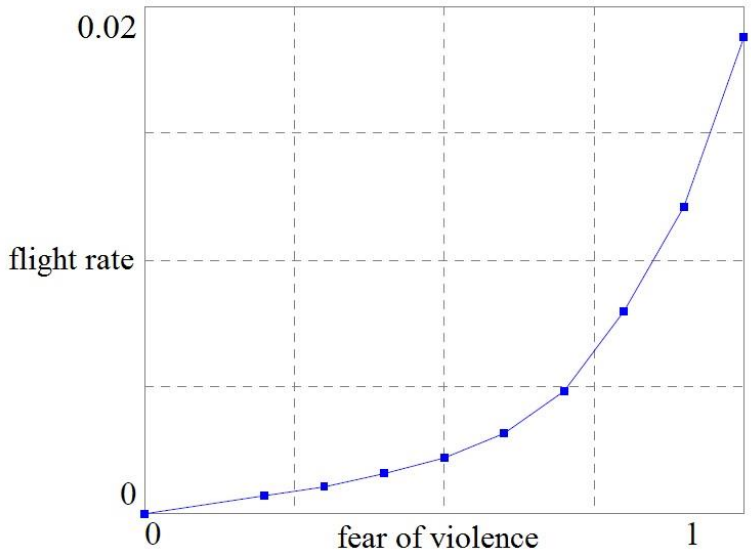


Figure 5.2 Lookup function flight rate

The equations of *habituation to violence*, *perception of violence* and *effect of violence on fear* are elucidated in appendix J. Including these three factors, all equations of the general model which require an explanation, are discussed. However, the three models containing early indicators have some additional factors, hence extra equations. As explained earlier, the inclusion of an early indicator sometimes requires the addition of more than one factor to fit the early indicator properly in the model. The number of extra factors differs per early indicator. As disclosed in the previous data section the input of the used early indicators exists of real world data. Due to the inequality of available data it was necessary to use different constructions for the implementation of the early indicators. This is reflected in the implemented equations which are described below.

The diagram including early indicator *free-will migrants* is constructed by using the variable *emigration rate*. This variable is established by the implementation of a lookup function with time as input and the annual values regarding human flight derived from the FSI (2016) as output. Also in this case the FSI values are corresponding to the middle of the year. As shown in the equation below the *emigration rate* is used to determine the amount of free-will migrant*s* by dividing it by 100.000. The value of 100.000 is once more a normalization factor.

$$(emigration\ rate/100000) * Population\ home\ country$$

The addition of the flow *free-will migrants* to the model result in an extra outflow to the stock *population home country*. Next to the existing outflows also the free-will migrant flow causes a reduction in the population.

The second stock-flow diagram contains the early indicator *IDPs*. For both *internal flight* as *external flight IDPs* real world data is directly used as output. They are constructed in the same way, by using a lookup function with the input of time. These two flows results in increases and decreases of the stock *IDPs*. The amount of produced IDPs who decide to make an external flight, and thus become refugees, are added to the existing flow *external flight*. This is represented in the constructed equation for *external flight* displayed below. *External flight IDPs* is not multiplied by *population home country* because it's already expressed in the required unit, namely person/month.

$$(flight\ rate * Population\ home\ country) + external\ flight\ IDPs$$

The stock-flow diagram including early indicator *external military intervention* is established by the addition of this one variable. As explained before, this early indicator is quite similar to the push-factors. It is also constructed by the implementation of a lookup function with input of time and the annual values derived from the FSI (2016) as output. Once more the FSI values matches the middle of the year. The variables *death by conflict rate* and *injured by conflict rate* are constructed in the same manner as can be seen in equations below only difference is the addition of the weighed variable *external military intervention* to the total sum of push-factors. The upper equation represents variable *death by conflict rate* and the lower variable *injured by conflict rate*, as can derived from the multiplication by 4 representing the killed to wounded ratio. In order to keep these equations clear and readable the push-factors and early indicator are abbreviated.

$$\frac{(hrv * 0.63) + (mt * 0.69) + \big((sdpo * 2) * 0.53\big) + (emi * 0.59)}{100000}$$

$$\frac{\Big((hrv * 0.63) + (mt * 0.69) + \big((sdpo * 2) * 0.53\big) + (emi * 0.59)\Big) * 4}{100000}$$

6. Model testing

All stock-flow diagrams, the general refugee diagram and three diagrams including early indicators, can now be simulated due to the implementation of input data and equations. As they are able to simulate system behavior, from now on the diagrams are referred to as simulation models or simply as model. Before the simulation models are used to explore the refugee dynamics, first correctness and suitability of the models are tested. This is a very important part of system dynamics as it not only determines the value of the model, but it also builds confidence in the model for the modeler and its clients. Model testing distinguish two different phases: the verification- and validation phase. During the verification phase the model's correctness and consistency is tested. The validation phase focuses on the usability of the model; does the model matches the aim of the study (Van Daalen et al., 2009). Although the main part of model testing is performed in this stage, model testing is also performed trough all phases of the model cycle due to the iterative character of system dynamics. In paragraph 6.1 the verification process is described and in paragraph 6.2 the validation process is elucidated.

6.1 VERIFICATION

During the verification phase the main goal is to find out whether the model is constructed correctly and in a consistent manner. This is determined based on several verification tests. In this section the model is tested on correct coding, a dimension analysis is conducted and numerical errors are tested. These are considered the most important but definitely not all verification tests (Van Daalen et al., 2009).

6.1.1 Correct coding of the model

The first test is checking the coding of the model. This is done by checking the equations during the model building process, which resulted in many iterations, but also during the verification phase (Van Daalen et al., 2009). A useful tool here is to have a readable model, with a clear structure and understandable formulation. To achieve a readable model the simulation model is divided in different phases, starting with a simple population model and

finishing with the entire refugee model including early indicators. Each phase the model is extended with a few factors and is made completely operable. This way the effect of the added factors can be checked directly and errors are easily identified. The different phases also helps to communicate the model to less involved persons. By the use of these different phases and many iterations there are no errors found in the individual equations, all assumptions taken into account.

Another strategy for testing the coding is isolate sections of the model and see if it generates the intended behavior (Pruyt & Van Daalen, 2009). Using this strategy it can be verified if the separate sections have the intended outcome, hence if the different groups of equations function as intended. For this test the identified phases are again addressed. First only the simple population section, which means the *population* stock with *birth* flow and *regular death* flow, is isolated and simulated. The *population* increases over time as intended, because the *death by conflict* flow and *refugee* flow are excluded.

The second isolated phase contains the push-factors together with the *death by conflict rate* and *injured by conflict rate*. The simulation of this phase produces the expected behavior; there is no change observed compared to the behavior of the complete model. This section in itself is quite isolated in the model and due to the lack of incoming links it is very logical that there is no change with respect to the behavior of the complete model.

The stock-flow combination regarding *wounded victims* is the third section which is isolated. Simulation shows there are no wounded victims generated at all. This meets the expected behavior as all push-factors, which causes the wounded victims, are excluded in this simulation.

The fourth isolated group of factors covers the section where the *effect of violence* is transformed to fear which produces eventually refugees. As expected, no refugees are generated during simulation due to the lack of fear caused by the exclusion of deaths and injured victims. Due to the absence of fear the *habituation to violence* is constant on a value of 0.2. This variable decreases the *fear of violence*, nevertheless this does not results in a

negative value of *fear of violence* due to the MAX-function in the equation. These results indicate that this isolated section contains correct equations.

The last isolated section is actually a collection of the sections of all three early indicators. First early indicator *free-will migrants* is isolated together with the basis population model. As expected the total *population* increases compared to the simulation of the whole model. This is caused by the exclusion of *deaths by conflict* and the *refugee* flow. The outflow of *free-will migrants* results in only a relatively small decrease of the *population*. The section regarding the early indicator *IDPs* is by itself an isolated section in the model and is therefore build by testing its intended behavior. In this case further investigation is not necessary. The last isolated section concerns the early indicator *external military intervention*. As explained earlier the early indicator *external military intervention* functions similar as the push-factors. So the same logics applies here; there is no difference between the isolated early indicator and the whole simulated model due to its own isolation in the model. Based on these findings it seems the model is correctly coded.

6.1.2. Dimension analysis

The second test to verify the model is a dimension analysis. On the one hand it is checked if the units of the factors resembles their meaning in the real world and on the other hand it is tested whether the units match their corresponding equations (Forrester & Senge, 1980; Richardson & Pugh, 1981). A difficulty in this model is the relative big amount of subjective factors. In this model it is impossible to assign meaningful units to these kind of factors. For this reason they are simply allocated with the term dimensionless. Dimensionless factors causes problems during a dimension analysis when this type of factor is linked to a factor owning a unit as the new equation does not match the new unit. This error occurs seven times in the general refugee model and are the only errors. The units of the dimensionless factors are not changed to units which match the equations because it adds no meaning to these factors.

In the early indicator model regarding *free-will migrants* nine unit errors are identified. Seven of these errors are the same as the ones in the general refugee model and are not modified. One error states that the equation regarding units is wrong in the flow variable *free-will migrants*. After investigating this error it appears no unit is inserted for variable *emigration rate*. This is probably overlooked during the model building process. The correct unit, 1/month, is inserted in the variable *migration rate* and the error is solved. The last error in this model also applies to the *emigration rate* variable. The error claims that the input of *emigration rate* is determined with the unit month, which refers to the time variable as input for the lookup function, while this not matches the inserted unit 1/month. It is true that the input of *emigration rate* is determined in terms of months, however content wise it can't be justified to apply unit month to this variable. After all, *emigration rate* can't be expressed in for example 6.8 months. Therefore the unit of emigration rate remains 1/months and the error is accepted.

For the early indicator model regarding *IDPs* the same kind of errors apply. Seven errors are the same errors as in the general model and two errors can be explained by the input of time in lookup functions. These particular variables are *internal flight* and *external flight IDPs*. Both have a lookup functions with time as input and person/month as inserted unit. In substantive terms person/month is the correct unit, so the two errors are again accepted.

In the *external military intervention* model eight errors are detected; seven of them are the ones detected in the general model and one is caused by the use of time in a lookup function. After investigating this error it appeared the unit month has no meaning for this variable and the unit maintains to be dimensionless.

The dimension analysis have indicated quite a number of unit errors. Some errors were useful, such as the error regarding the emigration rate. Others were less useful due to the fact that the actual meaning is not taking into account during this analysis which sometimes results in illogical suggestions.

6.1.3 Numerical errors

The last test to verify the model is testing on numerical errors. Two strategies for testing in numerical errors are investigating numerical method dependent errors and model dependent errors. The first strategy is about determining the appropriateness of the chosen integration method and step size. Model dependent errors can also depend on the integration method and step size, but are originally caused by incorrect formulation (Van Daalen et al., 2009). The integration method is determined based on the presence of discrete variables and the general nature of the model. The constructed simulation models are continuous and have a minimum of discrete variables. An applicable integration method for these characteristics is the so called method Runge-Kutta 4. For models with a discrete nature the Euler-method is more suitable. The choice for time step is a trade-off between accuracy and calculation time. The smaller the time step, the more accurate the outcome, but the longer the calculation time will be. To determine the right time step a process of trial and error is useful. As initial attempt a step size value is chosen which lies between $\frac{1}{2}$ and $\frac{1}{10}$ of the smallest time constant in the model. The smallest time constant in the models is the average recovery time of two months. The first step size thus lies in the range between 1 and 0.2, so the step time option 0.25 is selected as first attempt. When the model is simulated using 0.25 as time step the model generates the intended behavior. Because it is not always evident what is the smallest time constant in the model it is important to always test the step size sensitivity. This is done by bisecting the step size and check whether the behavior is changed. This process is repeated until there is no difference in behavior between two step sizes; this is the appropriate step size. When the step size sensitivity test is applied to the general refugee model, it appears 0.25 is the suitable step size as behavior of the model is not changing by step size 0.125. Using this strategy the occurrence of numerical model dependent errors are avoided. In addition, the model produces the expected behavior so there's no indication for model dependent errors.

Based on the three conducted verification tests it can be concluded that this model is constructed in a correct and consistent manner.

6.2 VALIDATION

The validation phase determines if the models meet the study objective and build confidence for modeler and client. Validation of a model can be investigated with a whole series of tests, but in this study only the most important and relevant tests are conducted. The conducted tests can be divided in two types of tests. The first type of tests are known as direct structure tests (Barlas, 1996; Forrester & Senge, 1978). This means the structure and relations are tested directly, without simulating the model. The second type of tests investigate the models through analysis of the simulated behavior and are mentioned as structure-oriented behavior tests.

6.2.1 Boundary adequacy of structure test

Determining the boundary adequacy of the structure is an important test which investigates if the main concepts, given the objective, are included in the model. It is a trade-off between an adequately comprehensive system and a model which is transparent enough to be communicated (Van Daalen et al., 2009). The objective of this thesis is gaining insight in the emergence of refugee flows and identify possible early indicators that indicate future refugee flows. The first attempts for constructing causal diagrams and stock-flow diagrams during this thesis contained many redundant elements, such as flows to different host countries and the asylum procedure. These elements however do not fall into the scope and are therefore excluded at an early stage. Other excluded elements are discussed in paragraph 3.2, in the section about model boundaries. More interesting are the elements which are included in the model. To meet the model objective of gaining insight in the emergence of refugees, the reason behind the decision to make an external flight has to be included. This is represented by the push-factors and the factors regarding fear. Civilian casualties are included since these factors have an impact on the level of fear. The basic population part is included to communicate the model in an easier way and to maintain the real world dynamics of a population. The stock total amount of deaths, with the inflows of regular deaths and deaths by conflict, was first part of the model but is excluded from the model after feedback from E. Canzani (E. Canzani, personal communication, November 9, 2016). E. Canzani is a researcher specialized in system dynamics and is conducting her PhD at the Universität der Bundeswehr München. She has given feedback during the verification-

and validation process from a system dynamics perspective. She questioned the additional value of the death stock and because it falls outside the model boundaries this stock was excluded from the model. Given this demarcated model system and made adjustments the model boundaries are considered adequate.

6.2.2. Face validation test

The face validation test is about the evaluation of the model by experts specialized in the model topic (Van Daalen et al., 2009). The earlier introduced I. Glynn and L. Lucassen have acted as experts on the emergence of refugee flows and have evaluated the model in the last phase of the model building process. They both agreed on the general structure of the model, but also provided some feedback on the construction of fear and early indicators (I. Glynn, personal communication, September 16, 2016; L. Lucassen, personal communication, October 14, 2016). Based on these interviews several adjustments are made. As explained earlier E. Canzani has acted as the system dynamics expert in this thesis and has given feedback when all models were completely constructed and operable. Generally, she was convinced by the models, but she also gave some specific points of feedback (E. Canzani, personal communication, November 9, 2016). This feedback was largely implemented in the model and is exemplified when the particular topic is addressed in this paragraph.

In addition, other relevant indirect-structure tests are conducted. The findings of the theoretical structure and parameter confirmation test, the direct extreme condition test, the empirical structure confirmation test and the empirical parameter confirmation test are presented in appendix K. The conclusion of these tests are that, besides one small conceptual change, no validation issues are found.

6.2.3 Extreme condition test

First the extreme condition test is conducted which, different from the direct extreme conditions test, compares the simulated model behavior to the expected behavior of the real situation (Forrester & Senge, 1980). For this test two factors in the model are inserted with extreme conditions, extremely small or extremely large values, and their generated behaviors are analyzed. The first selected factor is the *birth rate*. This constant is modified from 0.002 to 0.02, which means the amount of newborns is multiplied by factor ten. All

other factors in the model remain unchanged. It is expected that, due to the massive increase of newborns, the *population* increases. With a slight delay also the *regular deaths*, *deaths by conflict* and *refugees* increases, a natural consequence of a larger population. The increase in *refugees* is caused by a combination of a larger *population* and an increased *flight rate*, which originates from a higher amount of *deaths* and *injured people*. As figure 6.1 and figure 6.2 shows, the extreme behavior lies in the line of expectation of the real situation. The *population* is no longer decreasing. It is even strongly increasing during the first three years, after which it slowly tones down. The reason for toning down is the results of the just explained increasing amount of *regular deaths, deaths by conflict* and *refugees*. As expected are the values for the tested *flight rate* significantly higher than the regular values for *flight rate*.

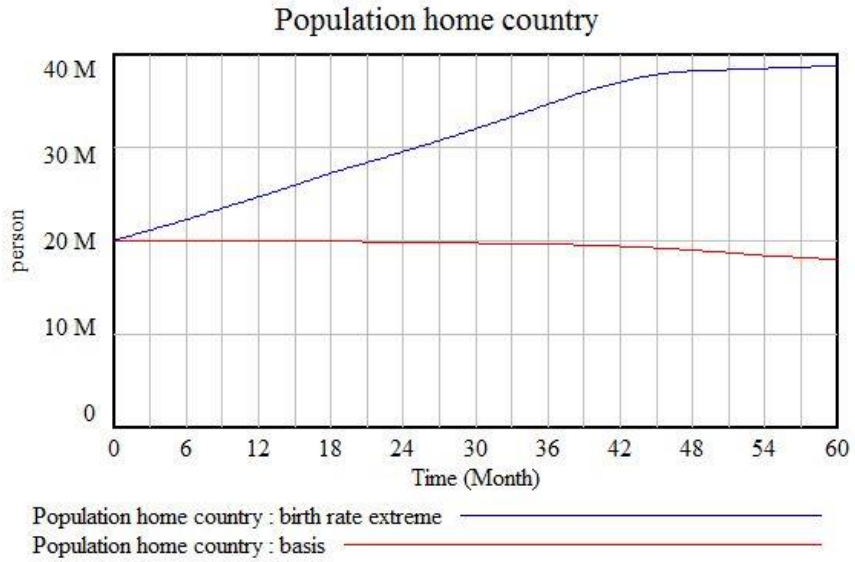


Figure 6.1 Extreme condition test birth rate for population home country

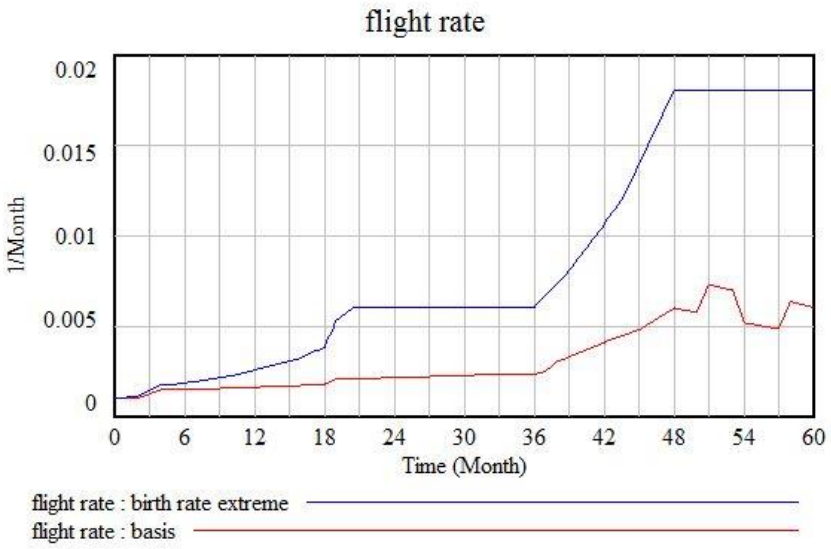


Figure 6.2 Extreme condition test birth rate for flight rate

The push-factor *human right violations* is subsequently selected for the extreme condition test. This factor is using a lookup function with input time to generate values between 8 and 10, representing the level of *human right violations*. For this test all output values are set to 1, which means a minimum level of *human right violations*. All other factors in the model remain unchanged, including the other two push-factors. It is expected that, due to the lack of *human right violations*, the amount of *deaths* and *injured people* are decreasing. This has an effect on the *level of violence*, which result in less people making an *external flight*. As figures 6.3 and figure 6.4 show the model matches this expected behavior. The *population* remains quite constant due the decrease in *deaths by conflict* and the decreased *flight rate*.

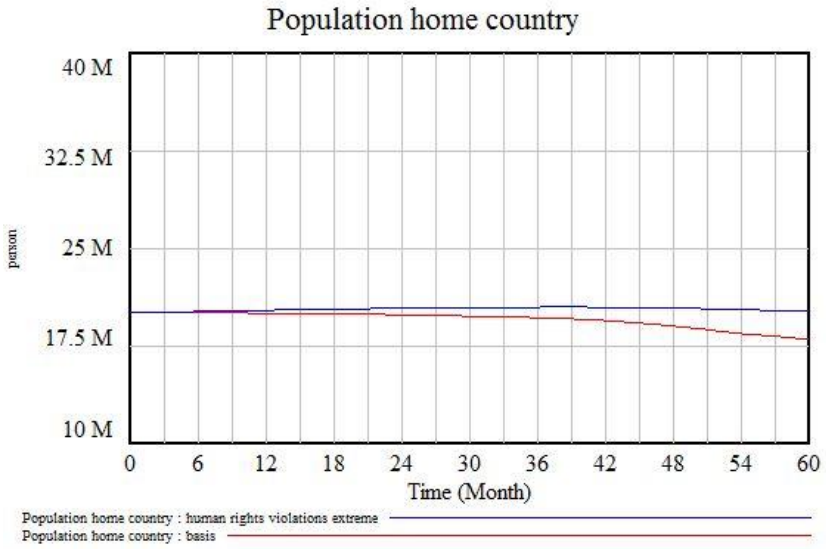


Figure 6.3 Extreme condition test human right violations for population home country

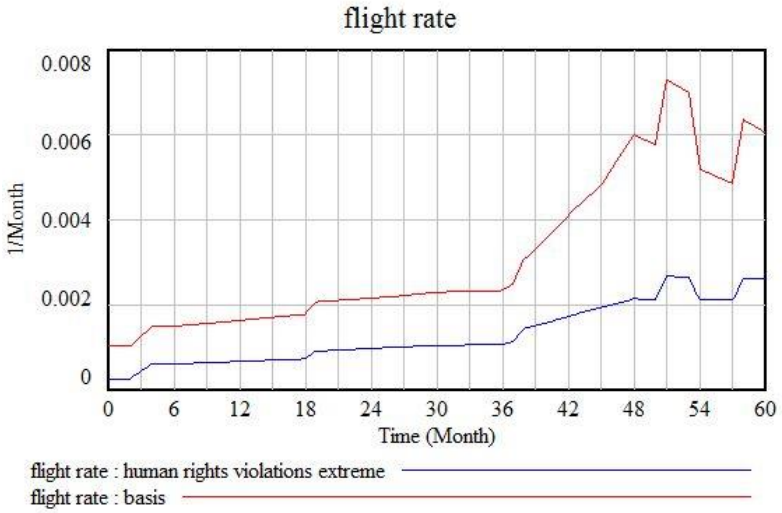


Figure 6.4 Extreme condition human right violations for flight rate

6.2.4 Sensitivity analysis

Another important validation test is the sensitivity analysis, which is often used in the validation of system dynamics (Randers, 1980). This analysis determines the sensitive elements in the model. In other words, by increasing and decreasing each model factor by approximately 10% it is determined if this change have a substantial effect on the model (Forrester & Senge, 1980). When the behavior of the model is significantly different, it is concluded that the model is sensitive for that particular factor. When a factor is identified as sensitive it is important that the input value is accurate, since a small change can have a big effect on the model. Sensitivity can also be useful for policy making. When a sensitive factor can directly be influenced it is possible to change the behavior.

As figure 6.5 shows, is the model sensitive for changes in the variable *effect of violence on fear.* The graphs of the basis simulation and the two sensitivity simulations show diverging behavior. Due to this sensitivity it is important that the input of *effect of violence on fear* is accurate. There is an accurate foundation for the construct of this variable, however the exact values are assumed. The sensitivity combined with the uncertainty of input values makes this variable an important limitation of the model.

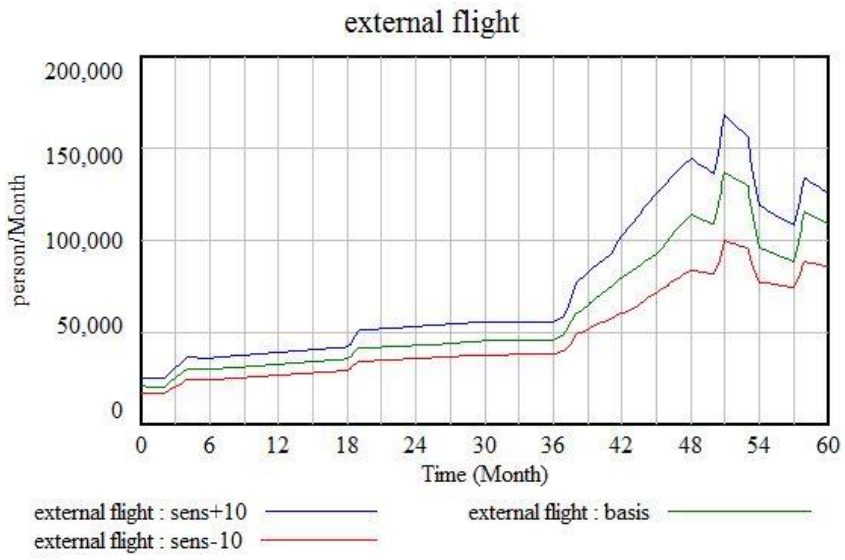


Figure 6.5 Sensitivity analysis effect of violence on fear for external flight

The sensitivity analysis in figure 6.6 shows that the model is also sensitive for *perception of violence*. It has to be noted that, due to the earlier assumed limited three values this variable can produce, the 10%-rule is not applied here. Instead of increasing or decreasing the value with 10%, the overlying or underlying value is chosen. This analysis shows therefore a somewhat distorted view compared to the other sensitivity analyses. Interesting is the dramatic change in the line of behavior in the variable *external flight,* which is displayed in 6.7. Due to the increased *perception of violence* the level of fear is much higher than during the basis simulation. The increased amount of *refugees* during the first few years results in more flattening behavior in the last years, which is caused by a decreasing *population*. The basis simulation in steeply increasing at that time and even passes the upper sensitivity simulation. This finding can be valuable for example policy regarding the perception of violence.

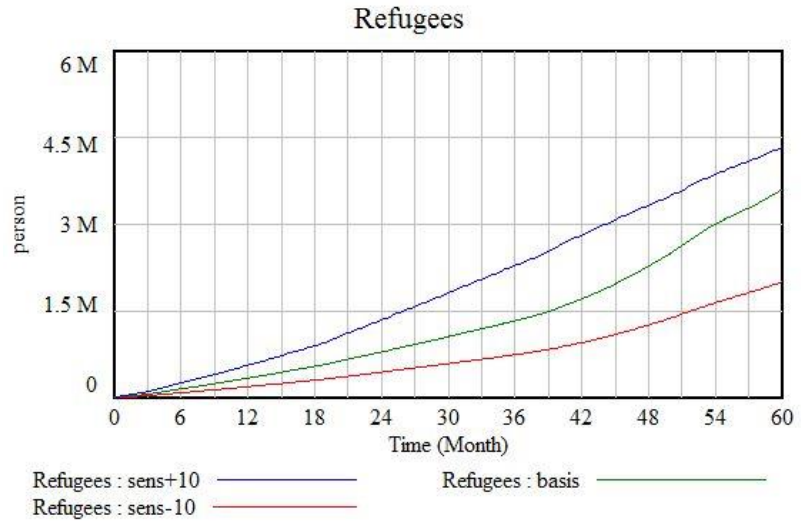


Figure 6.6 Sensitivity analysis perception of violence for refugees

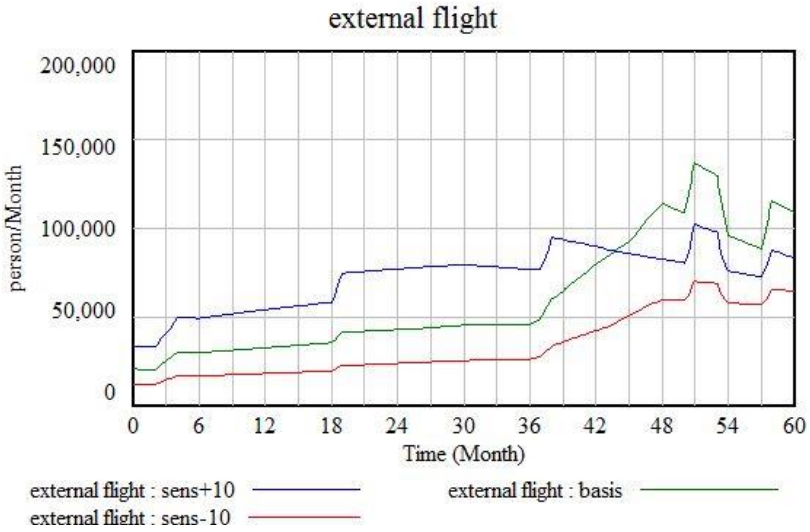


Figure 6.7 Sensitivity analysis perception of violence for external flight

The sensitivity analysis is also conducted on the other model factors. The results can be found in appendix K.

6.2.5 Qualitative characteristics

The last validation test is comparing the qualitative characteristics of the real situation to the model behavior. It is important that the behaviors roughly match as it is crucial for the analysis of the issue. To test this, the actual- and model behavior of some important factors are compared. In figure 6.8 the actual Syrian population between 2011 and 2015 is shown. When this graph is compared to the model behavior in figure 6.9, it is clear that in both cases the population decreases over time.

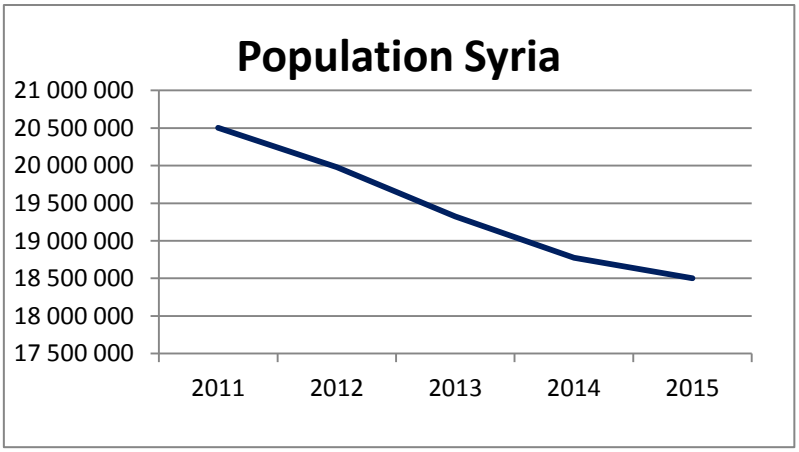


Figure 6.8 Population Syria 2011-2015

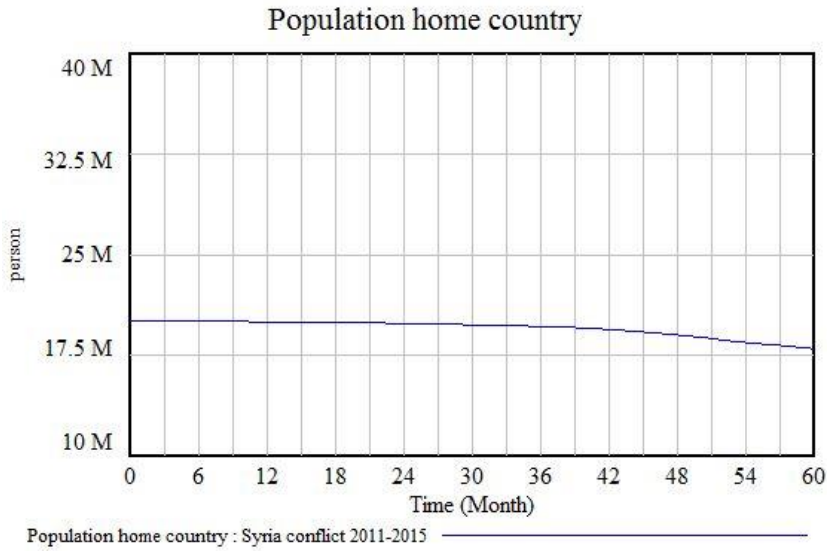


Figure 6.9 Model population Syria 2011-2015

When a closer look is given, it is determined that the actual population is first decreasing rapidly and in the last 1,5 year it flattens. While the simulated *population* acts vice versa; at first it decreases slowly followed by a stronger decline. A plausible explanation for this difference in behavior is the slower increase in the emergence of *refugees* in the model compared to reality. This is elucidated later in this section.

The next tested factor is *deaths by conflict*, of which the actual number of civilian deaths in Syria is displayed in figure 6.10. The model generated deaths by conflict are shown in figure 6.11.

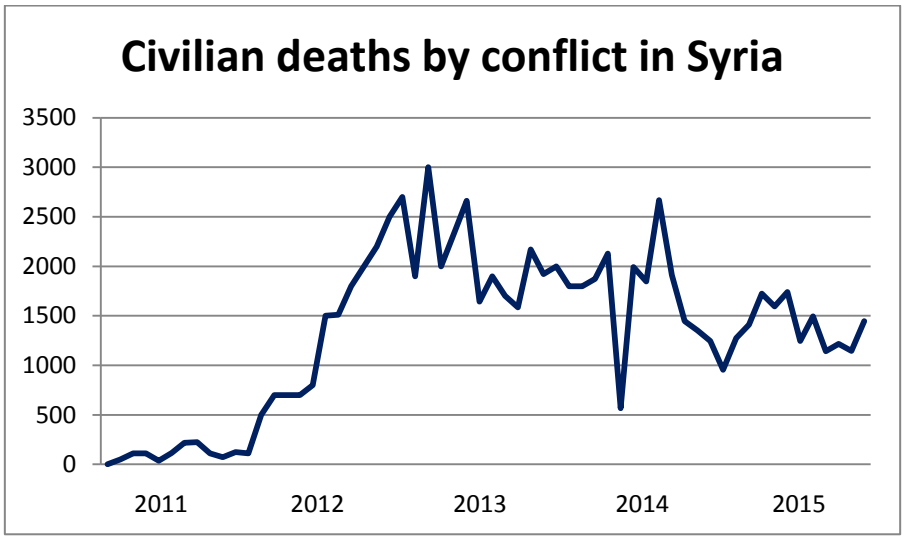


Figure 6.10 Deaths by conflict Syria 2011-2015

Figure 6.11 Model deaths by conflict Syria 2011-2015

When the behavior is analyzed it is evident that the amount of deaths in the first year in the model is way larger than the actual numbers. This is partly caused by a gap in the data regarding the actual number of deaths in the second year. This lack of data was solved by interpolating the number of deaths, which can possibly cause over- or underestimation. The

second reason is that deaths, under the influence of a relative low level of violence, are faster generated in the model than the actual number of deaths in Syria. Besides this difference, both graphs show increasing fluctuating behavior and a slight decrease in late 2015.

The last comparison is made between the generated amount of refuges in the model and the actual total registered Syrian refugees. The actual number of registered Syrian refuges is displayed in figure 6.12 and the generated amount of refugees in the model is shown in figure 6.13. When the behavior of these graphs are compared it appears the actual number of refugees strongly increases in the second part of 2012 and half-way 2014. Between these periods of strong increase the growth is flattening. The model generated behavior has a simpler graph and does not show flattening behavior in this same period. In accordance with the actual behavior, the generated behavior also shows an increase in 2014 and smoothing behavior in 2015.

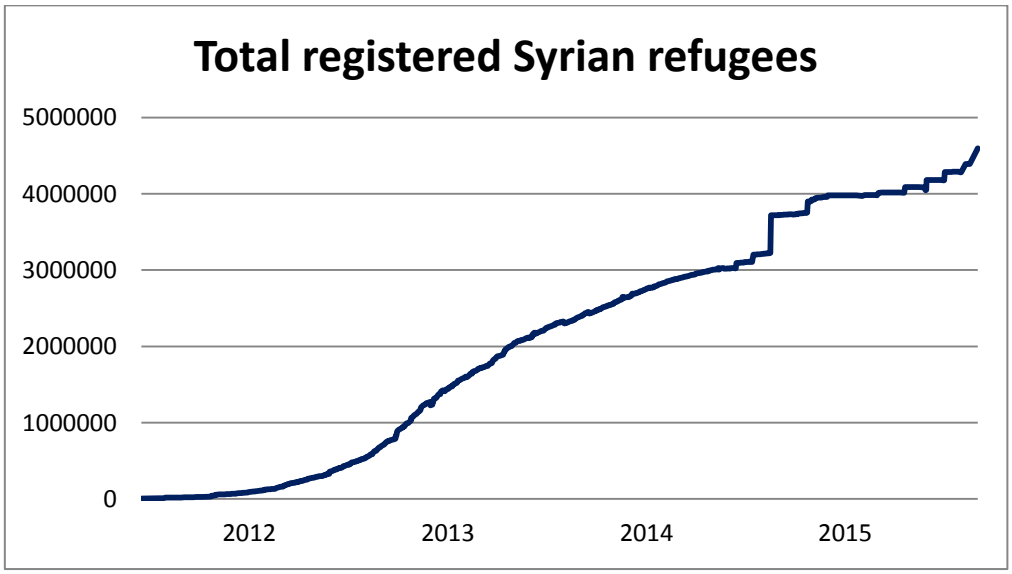


Figure 6.12 Registered Syrian refugees 2012-2015

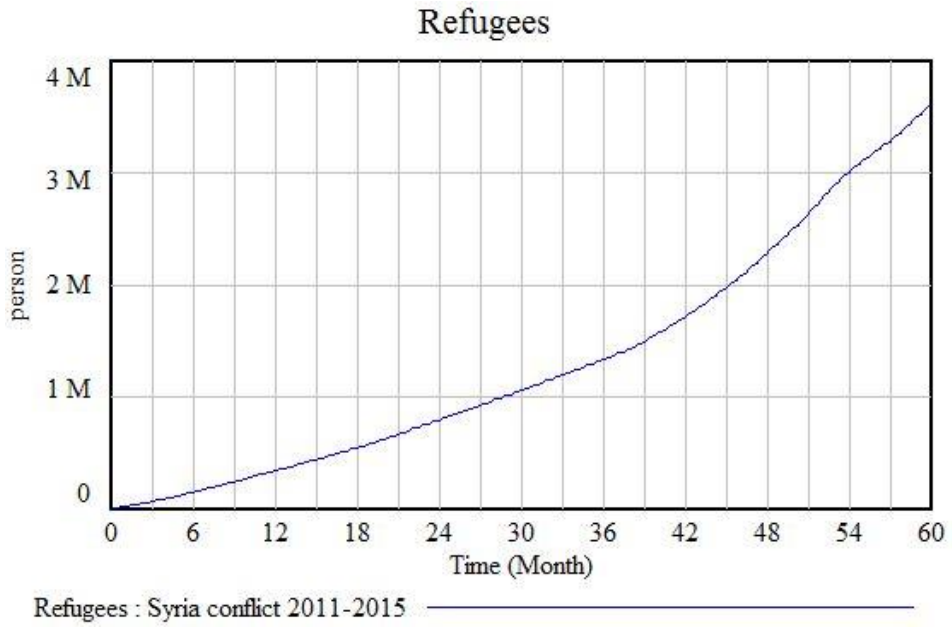


Figure 6.13 Model refugees Syria 2011-2015

Based on this qualitative characteristics test it is concluded that the model generates plausible behavior that roughly matches the actual behavior of the Syrian conflict. Differentiations are among other things caused by the simplification of the model and the lack of data.

The conducted validation tests, both direct structure- and structure-oriented behavior tests, show that the study objective is met in a satisfying way and that it can be used for model analysis.

7. Model analysis

Now the theory, conceptualization, formulation and model testing are completed, the model behavior and early indicators are analyzed. First the general refugee model is analyzed; behavior of the most important factors are observed and the underlying mechanism for this behavior is studied. Subsequently the three early indicator models are explored and their hypotheses regarding possible coherence with the emergence of refugee flows is tested. This is followed by a short discussion about the applicability of the general model on other internal conflicts. Finally, the limitations of the model are identified and discussed.

7.1 MODEL BEHAVIOR

The main causes for the emergence of refugee flows are the three identified push-factors: *human right violations, military terror* and *serious disturbances of public order.* The upper right graph and the lower graphs of figure 7.1, represents the behavior of the push-factors which are determined by real world data. The levels of these push-factors combined with their assigned weights determine the *death by conflict rate,* displayed in the upper graph on the left of figure 7.1. If a closer look is given to the *death by conflict rate* it is apparent this variable is a sort of sum of all push-factors, of which mainly the behavior *of serious disturbances of public order* defines the behavior of *death by conflict rate*.

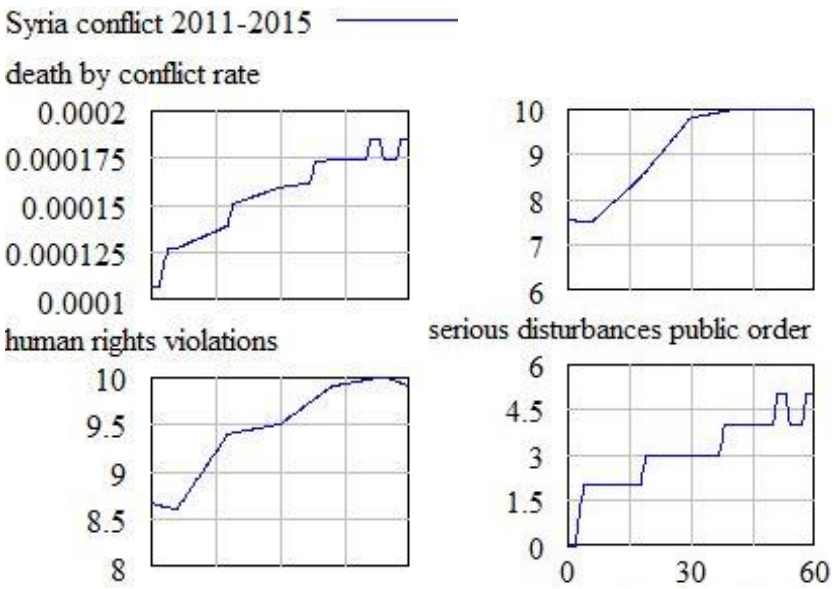


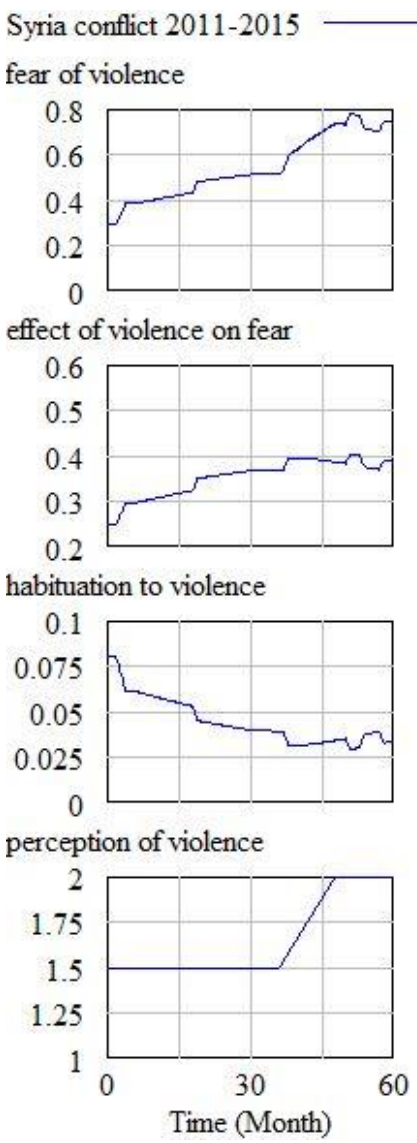
Figure 7.1 Model behavior push-factors and death by conflict rate

Corresponding to the push-factors, the *death by conflict rate* is the first few months quite low. After two months however, this is towards the end of February 2011 when the demonstrations in Syria started, the *death by conflict rate* starts to steeply increase. Thereafter it remains to increase, but less steep than before. This pattern continues under the influence of the course of *serious disturbances of public orde*r. Around month 53 the *death by conflict rate* drops for the first time to a lower value due to a temporary enervation of the fighting. After this small decrease it escalates again and *death by conflict rate* reaches its previous peak.

As explained earlier in this thesis, the *injured by conflict rate* is constructed in the same way as *death by conflict rate*, only difference is that *injured by conflict rate* is multiplied with value 4 in order to establish an accurate death to killed ratio. *Death by conflict rate* and the *injured by conflict rate* influence respectively *death by conflict* and *injured by conflict*. Figure 7.2 and figure 7.3 show the increasing amount of casualties in the first three years. From month 40 the amount of casualties start to decrease, but remains to have increasing tendencies in month 50 and 58. The decreasing amount of casualties half-way 2014 seems to be counterintuitive. At this point all push-factors indicate an escalating conflict, no stabilization or descent in fighting. However, due to the many killed people and refugees up to that point these numbers are indeed decreasing.

Figure 7.2 Model behavior death by conflict

Figure 7.3 Model behavior injured by conflict



The amount of casualties have, influenced by the *effect of violence*, a link to *effect of violence on fear*. Together with *habituation to violence* and *perception of violence*, the variable *effect of violence on fear* determines the level of *fear of violence*. The *fear of violence* can vary between 0% and 100%, but remains in this simulation about the Syrian conflict between 30% and 80% (upper graph figure 7.4). This seems plausible when the unrest before 2011 and the further escalation after 2015 are taken into account. The upper graph of figure 7.4 shows also the important role of perception. The change in perception, displayed in the lowest graph, has a clear effect on the *level of fear*. Halfway 2014 the *level of fear* becomes considerably higher due to the increase of the multiplicative effect of perception from 1.5 to 2. *Habituation to violence* is a naturalizing effect on fear of violence, but due to the relative small impact of habituation the effect remains limited.

Figure 7.4 Model behavior fear of violence, effect of violence, habituation to violence and perception to violence

Fear of violence is directly linked to *flight rate* which entails the important *problematic level of violence* set to 0.6. When the upper graph of figure 7.4 is observed again, it can be seen that approximately in month 38 the problematic level of 0.6 is crossed for the first time. As figure 7.5 clearly shows, the *flight rate* is increasing faster around month 38. The *flight rate* determines together with the *population home country* the variable *external flight*; the amount of leaving refugees per month. As figure 7.6 shows, the emergence of refugees per month slowly increases the first three years. In this three years two sudden steeper increases are observed, around month 2 and month 18. These are both results of intensification of the fighting as presented in the variable *serious disturbances of public order*. In early 2014 the perception increases and the *problematic level of fear* is crossed, resulting in a short exponential increase of the outflow of refugees. This point is crucial in this refugee model, as this is the moment that the mass of the Syrian population decide to make an external flight. Although the exponential behavior passes quickly into a more linear behavior, it still has a way steeper slope than before 2014. In 2015 the behavior of the outflow of refugees generates fluctuating behavior with an overall decreasing tendency. This is caused respectively by the changes in the intensification of fighting and the declining population due to the number of casualties.

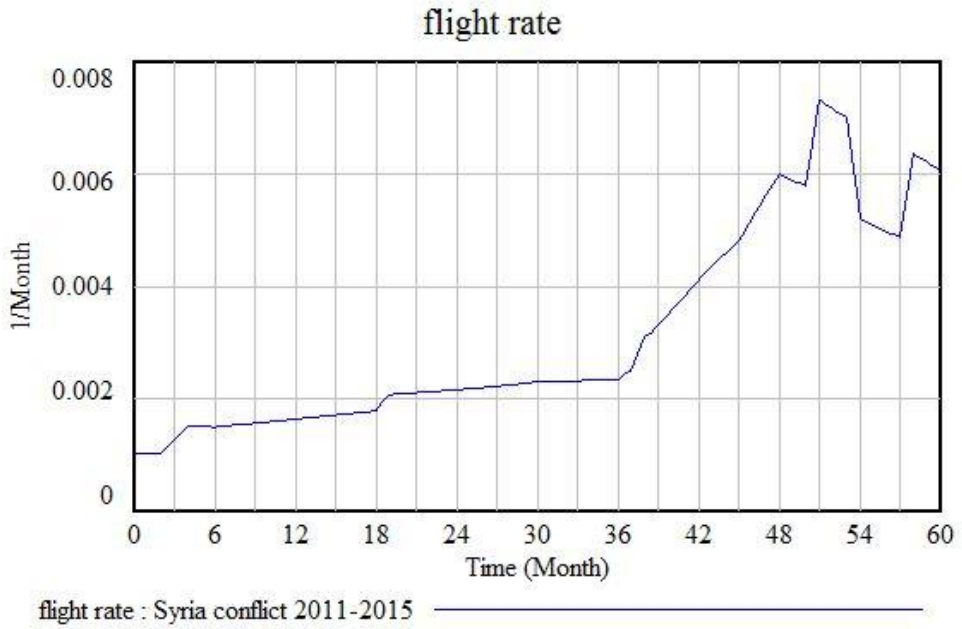


Figure 7.5 Model behavior flight rate

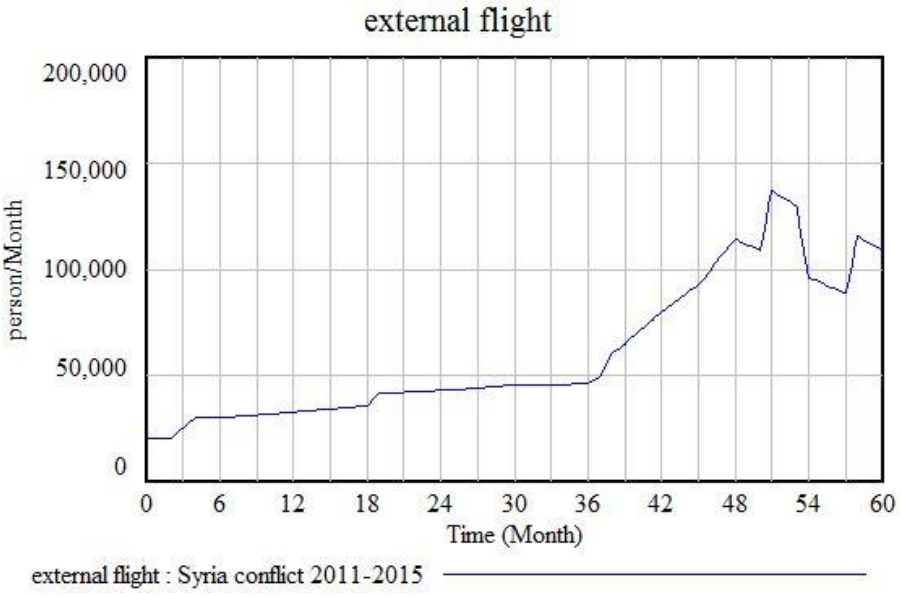


Figure 7.6 Model behavior external flight

The stock of *refugees*, displayed in figure 7.7, is a logical result of the outflow *external flight*. The first three years the amount of *refugees* increases almost linearly, after which the slope changes in a more exponential shape. The last half year the slope flattens a bit due to the decrease in monthly refugees. The large amount of *refugees* has a notable effect on the population of Syria. As figure 7.8 shows, small increases are observed in the *population* in month 10, 22 and 29. However from month 35 the *population* starts to decrease faster until the end of 2015 when it is decreased 10% of its initial population.

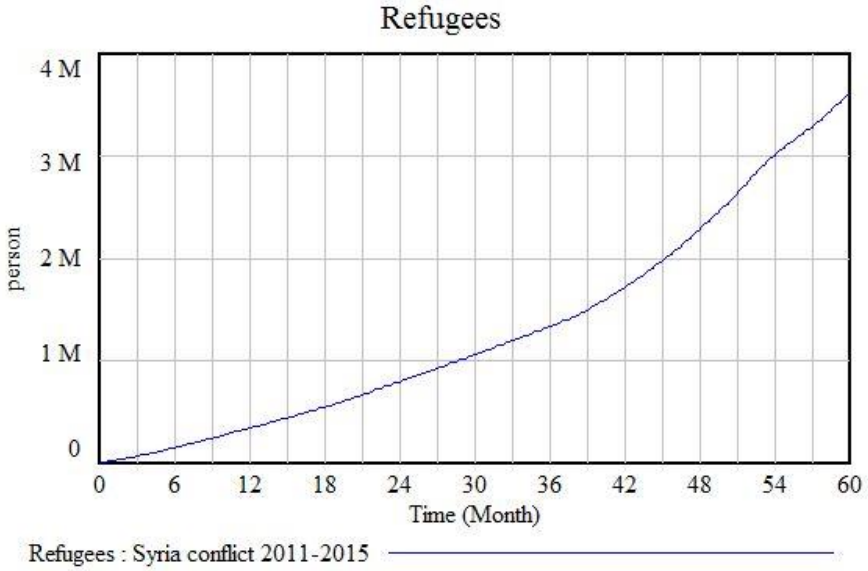


Figure 7.7 Model behavior refugees

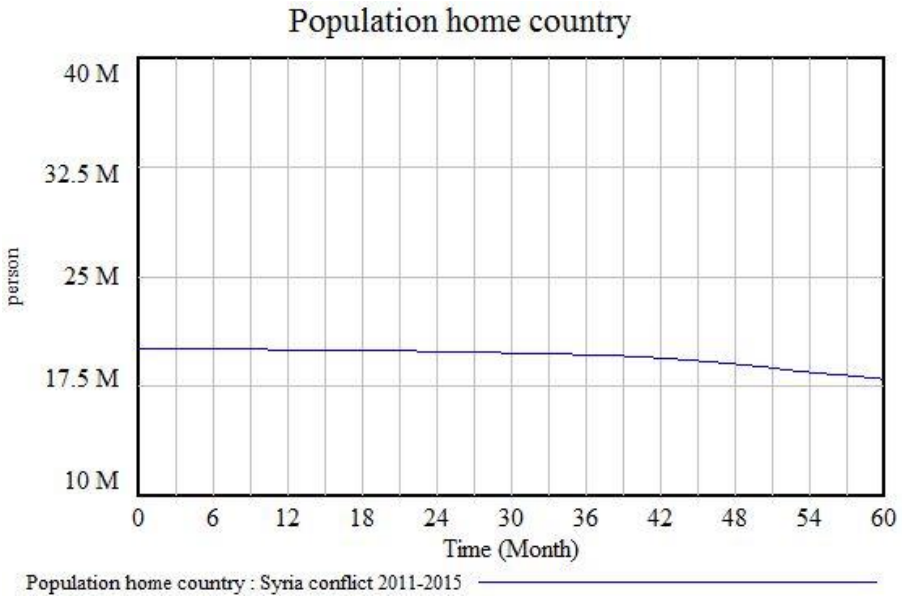


Figure 7.8 Model behavior population home country

7.2 EARLY INDICATORS

Each early indicator model is composed by the general refugee model and one of the early indicators. In this section the behavior of each early indicator is analyzed and also its possible coherence with the emergence of refugees is explored.

7.2.1 Free-will migrants

The output of *free-will migrants* is real world data, based on the registered amount of free-will migrants who left Syria between 2011 and 2015. When the behavior of *free-will migrants* is compared to variable *external flight* it is possible to determine whether these two variables have any coherence. In figure 7.9 and figure 7.10 both graphs are compared on the basis of their behavior. There is no evident peak of *free-will migrants* which takes place before the peak of external flight, as was expected in the dynamic hypothesis. The amount of *free-will migrants* is in the last two years even higher than in the first year, while it was expected most free-will migrants leave the country before- or at the beginning of a violent conflict. Based on these graphs it is concluded that the dynamic hypothesis regarding *free-will migrants* is not confirmed and there is no indication for coherence between *free-will migrants* and *external flights*. Therefore it seems to be no useful early indicator in this particular conflict. It is however possible that there is a coherence between these two variables, but that it cannot be determined using this approach. For example, when free-will

migrants indeed have a peak, but this has taken place before 2011 and is therefore not analyzed in this study. Another possibility is that this coherence exist in certain internal conflicts, but not in the studied Syrian conflict. However the aim was to construct a general refugee model and due to the lack of coherence in the Syrian case there is no indication that *free-will migrants* is a useful early indicator for the general refugee model.

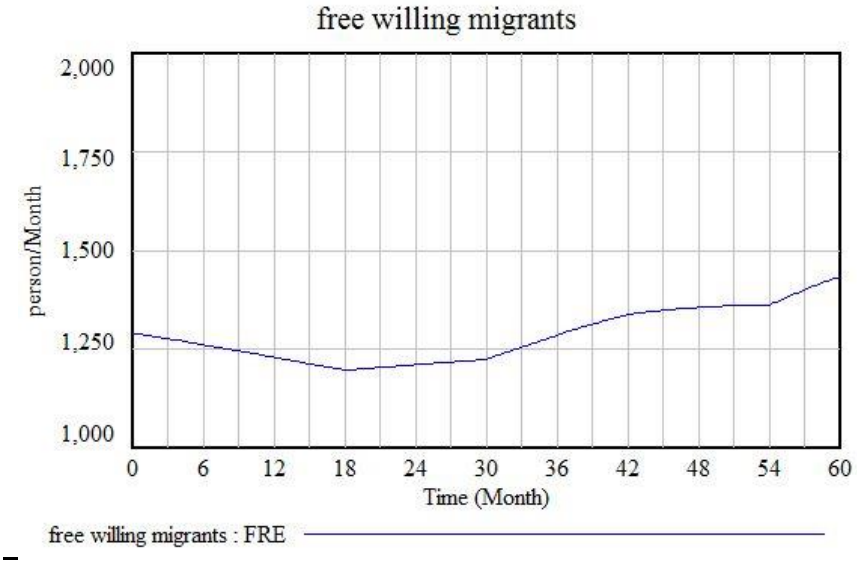


Figure 7.9 Free-will migrants Syria 2011-2015

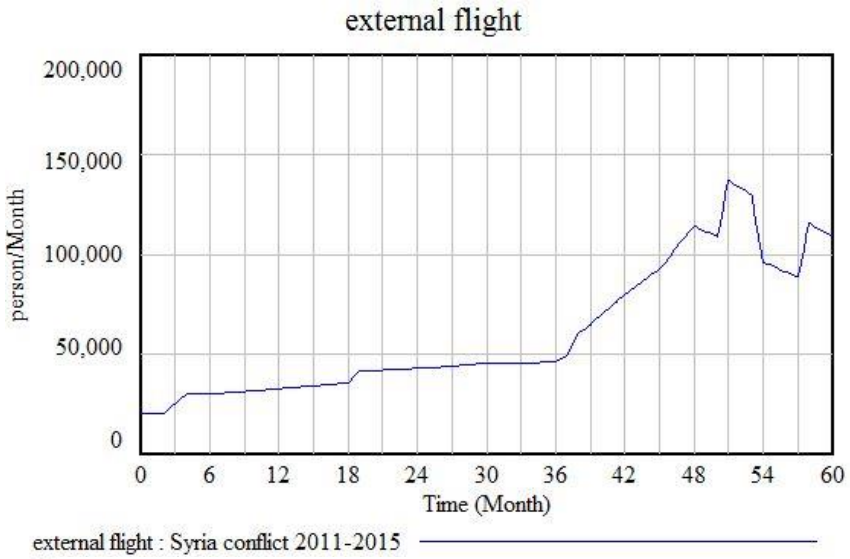


Figure 7.10 Model behavior external flight

7.2.2 IDPs

In figure 7.11 the variable *internal flight* and *external flight* are analyzed. The output data of *internal flight* is based on the registered amount of IDPs and *external flight* is generated by the model. As the graphs show, the two variables are generating totally different behavior. *Internal flight* has a dominant peak with its maximum at the end of 2013, while the slope of *external flight* slowly increases and gets steeper after three years. It is however interesting to see that when the emergence of *IDPs* is at its peak, the slope of the emergence of *refugees* starts to increase. It seems this is the moment people decide it is too dangerous to stay in Syria or the complete contrary that people decide to stay in their homes. Also figure 7.12, where the stocks *IDPs* and *refugees* are displayed, shows promising behavior. The amount of *IDPs* is increasing faster and is after five years significantly larger than the amount of *refugees*. However the last two years the slope tones down and even starts to decline. At this point, in late 2015, the amount of *refugees* is still increasing, which makes IDPs in this conflict a useful indicator. Based on this model it is concluded that the hypothesis regarding *IDPs* is confirmed and that it potentially can function as an early indicator. An important remark is that despite the conclusion the factor *IDPs* is a useful indicator in the Syrian case, it is not automatically a generic early indicator which can be used in the general refugee model and is useful in other internal conflicts. To determine whether IDPs is a generic early indicator for refugee flows more conflicts have to be studied using the general refugee model. For now IDPs is mentioned as an early indicator in the Syrian refugee model and a potential generic early indicator for the general refugee model.

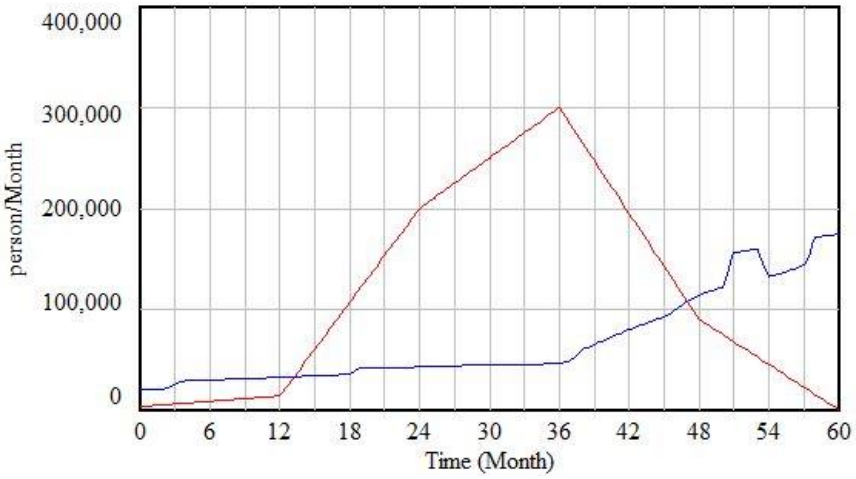


Figure 7.11 Model behavior internal flight and external flight

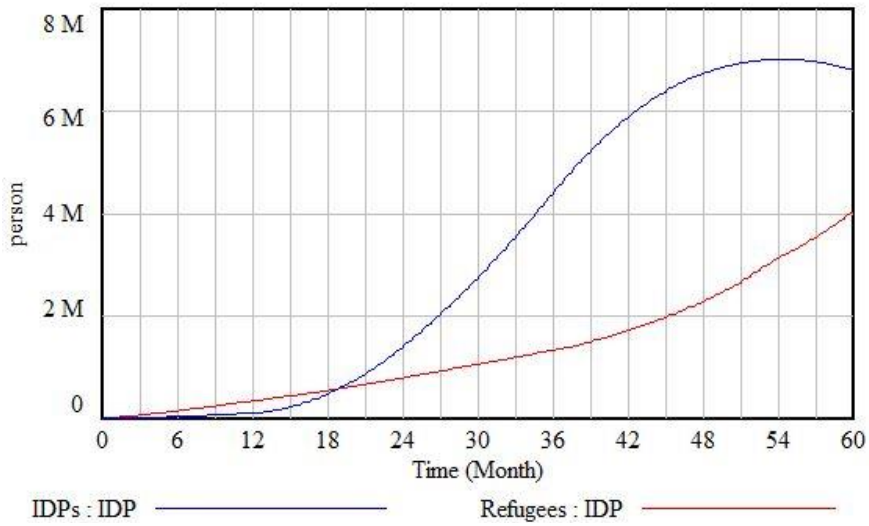


Figure 7.12 Model behavior IDPs and refugees

7.2.3 External military intervention

As explained during the section about dynamic hypotheses is the third early indicator, *external military intervention*, slightly different from the first two early indicators. Main reasons for this is that *external military intervention* is not inherent to an internal conflict and that this early indicators itself causes an increase of refugees. Therefore the use of this early indicators seems to be somewhat obvious. As figure 7.13 shows is the *death by conflict rate* significantly higher than in the absence of *external military intervention*. This increases the number of casualties, resulting in an increase in *fear of violence* (figure 7.14).

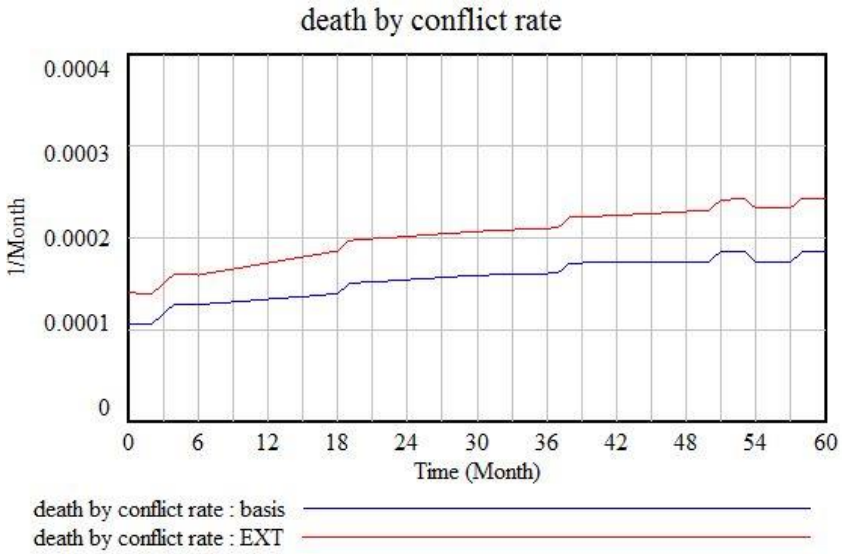


Figure 7.13 Model behavior death by conflict rate including early indicator external military intervention

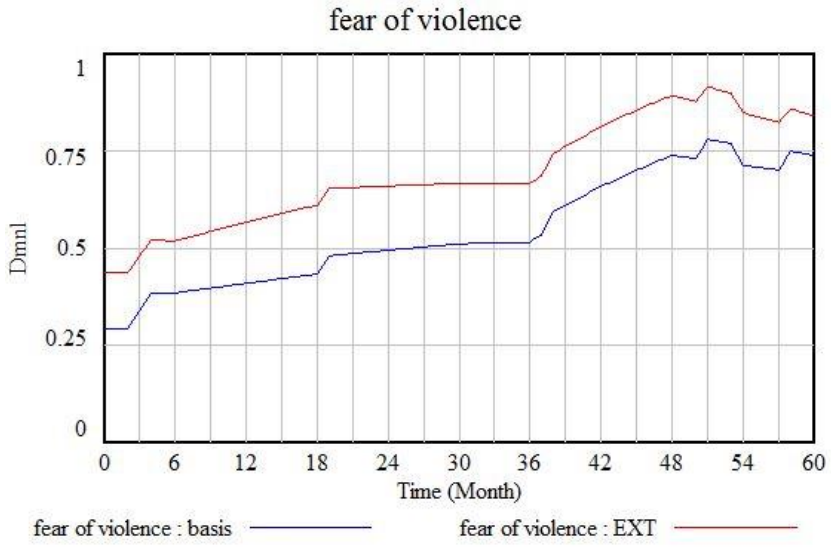


Figure 7.14 Model behavior fear of violence including early indicator external military intervention

The presence of *external military intervention* affects also the rest of the model. Figure 7.15 and figure 7.16 show that the new refugees per month and the total amount of *refugees* increase significantly under the influence of *external military intervention*. The big effect of *external military intervention* on the model is plausible when the extra fire power brought by external intervention is considered. Extra fire power facilitates not only the intensification of a conflict but it also prolongs the conflict. Based on these findings it is concluded that the hypothesis regarding *external military intervention* is confirmed and that it can function as an early indicator in the Syrian refugee model. Here too, *external military intervention* is not automatically a generic early indicator which can be used in the general refugee model. Besides the point that *external military intervention* should function as an early indicator, there is also the question whether external military intervention is present in an internal conflict anyway.

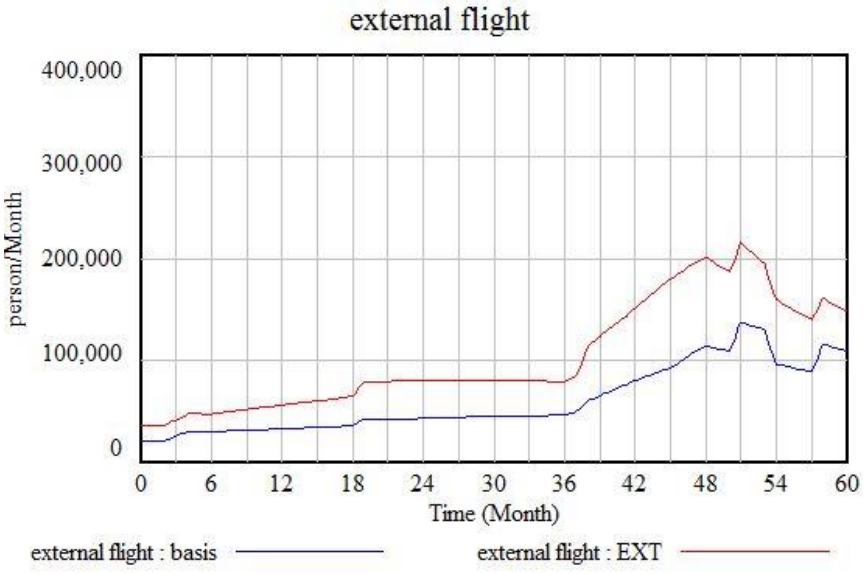


Figure 7.15 Model behavior external flight including early indicator external military intervention

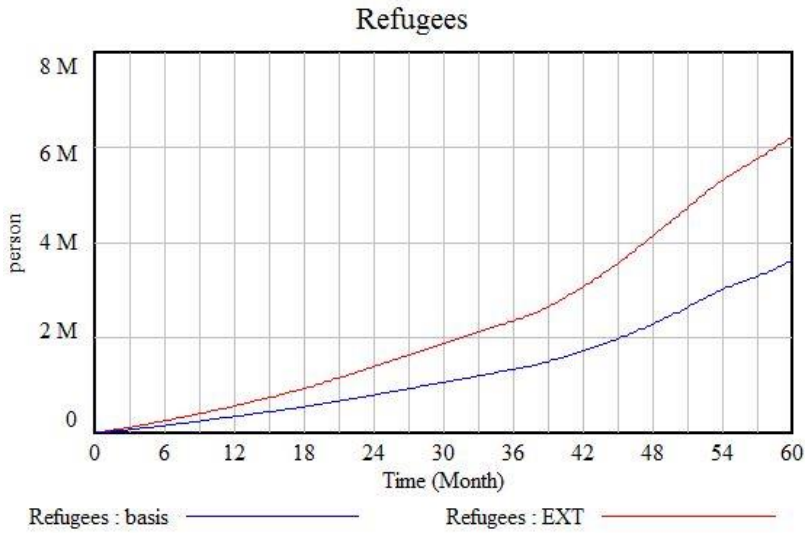


Figure 7.16 Model behavior refugees including early indicator external military intervention

7.3 APPLICABILITY OF THE MODEL TO OTHER CONFLICTS

In this thesis the constructed general refugee model is applied to the Syrian conflict and results are derived from this Syrian refugee model. The model testing and results concluded that the simulated behavior is plausible and is able to provide both new insights in the behavior as in the identified early indicators. However one successful application does not prove the universal applicability of the general refugee model to internal conflicts. In order to establish a legitimate foundation for the universal applicability of the model and to build more confidence in its use, it is necessary to apply the general refugee model to more real-

life internal conflicts. The application to other actual internal conflicts are not included in this thesis, because it would make this study way too comprehensive for a master thesis. So this is definitely an interesting recommendation for future research. Something that is included in this thesis and which is crucial for this proposed future research, is what internal conflicts are qualified for the general refugee model, what are the points of attention and what is its purpose. These issues are shortly elucidated in the section below.

Conflicts which qualify for the constructed general refugee model firstly have to agree with the predefined model boundaries. This means the conflict is an internal conflict, which produces refugees. Inherent to this model boundary is that people have the possibility to flight across borders, so are not impeded in any way. Another model boundary is that these refugees are forced to leave their home country due to push-factors threatening their lives. The model is based on knowledge regarding mass refugee flows, so is only applicable to conflicts producing more than 10.000 refugees. The general focus of the model is on the emergence of refugee flows and the time focus is short-term and medium-term. Next to meeting the model boundaries, is the availability of data crucial. In times of war it is common that data is not registered, not stored properly or not shared with the public. Data of the simulated conflict is required for input data, initial values and validation.

Since the general refugee model is a universal model for internal conflicts the application of this model to an internal conflict, other than the Syrian conflict, is basically as simply as adjusting the input data. However, it should be considered people from different countries react diverse to different conflicts. When a significant variety in reactions between conflicts appear to be present, it can be considered to slightly adjust the equations of relevant variables, such as the *effect of violence on fear* or the *habituation to violence*.

When the potential early indicators, IDPs and external military intervention, are analyzed in the simulation of other conflicts, it is possible they will be determined as useful early indicators for the general refugee model. Suppose this is true and these early indicators function well as an indication for mass refugee flows for all simulated actual conflicts. How can this general refugee model be useful when applied to current or future conflicts and

should the generated behavior of these models be interpreted? It is extremely important to keep in mind the constructed system dynamics model is not a tool to predict the future. It is a tool to create insight in behavior and explore multiple futures under changing conditions. In this case it can be used in the future to explore possible developments in unstable countries, whereby the early indicators can function as an indication for the country's stability. This topic is more extensively discussed in the next section about the limitations of the model.

7.4 LIMITATIONS OF THE MODEL

This chapter has discussed new insights provided by the simulated models and their potency when applied to other conflicts. However, an important part of system dynamics is identifying the model's weaknesses and the limits of its potential. In other words, the limitations of the model. Limitations of the study are normally discussed in the discussion section. However, since there are quite a number of model limitations, these specific limitations are discussed in this section. The most important model limitations together with the general limitations of this study are subsequently discussed in the discussion section. First limitations regarding the simplification of reality are described in section 4.2.1 and limitations regarding subjectivity of the studied topic in section 4.2.2.

7.4.1 Simplification

The main model limitations are caused by the transformation from vaguely known relations into a specified quantitative model and the custom that system dynamics structures complex issues by using the simplified version of reality. Due to these model characteristics some caution has to be taken into account when interpreting the results. As connections between factors are based on both known- and vaguely known relations, it is important to realize the results should not be interpreted on a micro-level. System dynamics is useful in identifying mechanisms and interpreting behavior, not producing exact numbers. A second important limitation, which is also inherent to the system dynamics method, is that the model cannot function as a predictor. This is a common mistake when people, who are not involved in system dynamics, learn the first things about the simulating- and solution abilities of this method. It is essential not to create false expectations in order to avoid inappropriate use of

results. As explained earlier in this thesis, system dynamics is useful in gaining insight in complex problems and testing the impact of changes in the system.

The simplification of reality also results in a certain degree of information loss. The consideration about what is included and what is excluded is defined by the determined model boundaries and the level of abstraction. For example, the set model boundaries of the constructed model only include push-factors, while established networks in guest countries is a known pull-factor for refugees. Subsequently there are more factors which are not identified as most important in the system, but which still play a significant role in reality. An example of this regarding push-factors is the feeling of hopelessness and the falling living standards (I. Glynn, personal communication, September 16, 2016). Also the generalization of internal conflicts is considered as a limitation, since ethnic or religious conflicts have their own specific characteristics. The level of abstraction is for example reflected in the decision not to make a distinction in living areas, which can help to get a more detailed insight in the internal flows and external flows. All these decisions are made to make and operable and manageable model, but are at the same time limitations for this study.

7.4.2 Subjectivity

Objectivity is something that science pursues and on which its authority is based. Public opinions, personal interests and value judgments are like viruses that can contaminate the objective results of scientific research. How to accept this pursuit of objectivity when simulating real life issues? Reality is full of feelings and opinions which, despite of their subjective character, can have a big impact and therefore have to be respected in simulation models. Yet most modelers are trying to stay away from topics concerning human behavior and political issues. A logical decision when the difficulties with operationalization and data are considered. However Sterman (2000) thinks models are most valuable when they are used to contest existing perspectives. Especially in issues regarding human behavior and political issues substantial research is already conducted. However, only few from a system dynamics perspective, while these issues are often most pressing. For example, issues like radicalization, criminality and of course refugees. This principle by Sterman is exactly what this thesis has attempted to do; providing a new perspective on the emergence of refugee

flows, that has been researched by a multitude of other fields. The main subjective difficulty in this study is obviously expressed in the construct of fear, which cause people to flee. Fear is an elusive phenomenon, which cannot be constructed based on pre-defined knowledge. However by roughly approximating the construction of fear, based on the little knowledge that is known, it can be useful as a way to provide more inside in the overall issue. A second, more general remark regarding subjectivity is about country specific response to conflicts. Despite the construction of a general refugee model, it should be taken into account that people in different countries can have diverging reactions towards conflicts due to nature of the people and history of the country. So the build-up of fear and moment of mass flight possibly differs slightly per country.

Subjectivity is however not solely a point of concern regarding the thesis topic, but also about the entire modeling process. During the operationalization phase, especially when constructing the causal diagram, subjectivity can play a role in determining the connections between factors (Garcia, 2006). However when quantifying the factors, selecting data, using data and interpreting the results, subjectivity can also occur. It is attempted to be aware of subjectivity trough all phases of the research process. A remark regarding the negative value that surrounds subjectivity which is important to mention is the following: "The intrinsic subjectivity of the modeling process isn’t really a negative factor, since it is impossible to study a social system totally objectively" (Garcia, 2006, p. 54). With these considerations in mind this study has been conducted. Due to the explorative nature of this study it can be concluded that the limits of model simulation have been searched and may even be stretched, especially in terms of subjectivity.

8. Conclusion

In this thesis the emergence of mass refugee flows caused by internal conflicts is studied. The method system dynamics is applied to shed new light on this topic with the aim of creating new insights in the causes, underlying mechanisms, uncertainties and possible early indicators. By determining the extent of new insights the initial research question can be answered.

Based on a performed literature analysis three main causes for the emergence of refugee flows are identified: human right violations, military terror and serious disturbances of public order. In accordance with the selected theoretical framework the three main causes are regarded as the three most important push-factors. Possible early indicators, factors that function as early warning indication for future events, are identified accordingly. The following early indicators were identified in literature as most dominant: free-will migrants, Internally Displaced Persons (IDPs) and external military intervention.

Together with other relevant factors several qualitative causal diagrams are constructed, which provide insight in the cohesion and mechanism in the refugee system. With the use of causal diagrams the cohesion between the push-factors and the factor *effect of violence* is determined. Also the mechanism of fear and mechanism regarding the decision to flee are established. The causal diagrams revealed a notable difference in model cohesion between early indicator external military intervention and the other two early indicators. Despite the mapped relations with other model factors, *free-will migrants* and *IDPs* are relatively independent from the general model, while *external military intervention* is actively influencing the model by increasing the level of violence. In addition, it is also important to realize that external military intervention is not inherent to an internal conflict, while free-will migrants and IDPs are.

After transforming the qualitative causal diagrams into quantitative stock-flow diagrams and implementing it in the specialized software Vensim, the simulated model behavior and identified early indicators are studied. From the simulated model behavior it appears that there is a certain point in time where the amount of Syrian refugees per month extremely

increases. Mainly responsible for this behavior are the factors *problematic level of violence*, which is incorporated in the *flight rate*, and the factor *perception of violence*. These factors are not only extremely important due to their big impact on the behavior of refugees, but also because both factors are relatively uncertain. Subsequently it is determined that two out of the three identified early indicators indicate some degree of coherence with the emergence of Syrian refugee flows. It seems that the peak in the number of *IDPs* per month mark the moment in time where the amount of refugees per month starts to increase rapidly. The early indicator *external military intervention* seems to be a valid early warning for the emergence of Syrian refugees since the indicator itself leads to intensification- and lengthening of the conflict. Despite the findings that IDPs and external military intervention appear to be useful early indicators in the Syrian conflict, further research is needed to determine whether they can function as an early warning system in other internal conflicts as well. For this reason they are considered potential early indicators for the general refugee model.

When the study is evaluated in a more general way, it can be concluded that the selected push-component of the Ravenstein model is largely the appropriate theory for this research. Mainly because this study focuses on refugees who are fleeing as survival strategy, which means push-factors dominate. On the other hand, it would be interesting to include pull-factors, as established networks in guest-countries have a big influence on the emergence of subsequent flows.

The research itself, a system dynamic approach to the emergence of refugee flows, contributes to the very limited system dynamics studies on refugees as well as on highly subjective issues. The substantial contribution is a variety of insights obtained over the course of this study; both qualitative as quantitative and both static- as dynamic insights. Obviously these insights need to be interpreted while acknowledging that some relations are based on only vague connections, the model is based on multiple assumptions, at times incomplete data is used and only one conflict is applied to the general refugee model. Altogether it is concluded that the use of system dynamics has resulted in a substantial amount of new insights regarding the emergence of refugee flows, especially the system dynamics perspective in general is considered to be valuable.

9. Discussion

This explorative study is in general terms an extension of existing theories; a relative new method in social sciences, system dynamics, is applied to the frequently researched subject of refugees. Existing theories and literature are used as the foundation for simulating identified factors and relations over time, whereby new insights are obtained regarding their dynamic behavior. Some findings on the other hand seem to challenge existing theories, like the use of factor *free-will migrants* as an early indicator for refugee flows.

The findings of this research also have some weaknesses, both the simulation model as the study in general has multiple limitations. In the model analysis section the model limitations are already elucidated, of which subjectivity throughout the modeling process and the effects of simplification are the most important limitations.

In addition to the model limitations, also some limitations are determined regarding the design of the study and execution of the research. The explorative nature of the study results in, besides the positive outcome of a new perspective, the consequence of staying relatively close to the surface in terms of content and making many assumptions. Another limitation is determined during the modeling process, when no large feedback loops were identified in de delimited refugee system. System dynamics thrives on issues with feedback loops since it provides insight in often counterintuitive behavior. The lack of large feedback loops does not mean system dynamics is not an appropriate method, as the method fits well on many other components of the selected issue. This is supported by the new insights gained. The next limitation elaborates on the earlier discussed subjectivity issues. As soft social variables are hard to quantify, it is attempted to determine their constructs and behavior in accordance with reality. However, it is obvious that the approach of these soft variables is way less accurate and substantiated than hard variables. In addition, the expert feedback received on the simulation model is limited. Only during the validation phase general feedback was given on the model. More attention was paid to feedback regarding model analysis and processing of this feedback if time and availability of system dynamics experts had allowed it. Most important limitation is already mentioned several times. The results derived from model behavior are only used for gaining insight in the refugee system

and the determined early indicators function as an indication for refugees, not as a predictor for refugees.

With this message in mind some recommendations are made based on the main findings of this research. From a practical view several types of research recommendations are made. As the constructed general refugee model is designed for internal conflicts in general, it is recommended to apply several qualified conflicts to the model in order to determine its accuracy and usefulness. Another option is to first refine the model by, for example, evaluating the constructed mechanism of fear and including important pull-factors, like established networks with guest-countries. A third option is to expand the model by broadening the model boundaries or change the level of abstractness. Opportunities for model expansion which are briefly explored during this study are the inclusion of the self-enforcing violence loop, division in population by gender or age and the mapping of both source- and guest-countries. More generally, it seems there is a need of scientific research about early indicators of refugee flows. Not only to determine whether the early indicators mentioned in literature can indeed function as an early warning, but mostly because there is a strong demand from real-life in which countries struggle to deal with refugee issues.

To resume with the figurative thread of the tangled ball of wool, presented in the introduction as a metaphor for a wicked problem, this research is definitely not the solution to unwire the knot. It is however a way of pulling apart the threads and see how the threads are put together. In other words, how the emergence of refugee is structured and what components have a high impact.

When the wild assumption is made that the two potential generic early indicators, IDPs and external military intervention, are indeed properly functioning generic early indicators, an interesting future approach can be explored. Assume that that these two indicators together with a cluster of proven early indicators are put together in a simple overview. They will be weighed on their past indication strength and each indicator receives a current rating for each country from 'cold' to 'hot'. For example, The Netherlands is currently rated 'cold' for early indicator IDPs and Syria is rated 'hot'. When the average of the total sum of a country is rated as 'hot' this is an indication for extra monitoring towards the situation in this country

and its neighboring countries. In extreme cases it is even advisable to take precautions as a potential guest-country and mobilize goods, activate asylum processes and arrange shelter. This is just one of many mind-experiments which show possible future opportunities for policy makers.

Personally I learnt a lot in the process of constructing the model and writing this thesis. In first instance I gained new knowledge and skills in a professional manner. I perceive the gained knowledge regarding refugees as a valuable learning opportunity and the high degree of self-dependency as my main challenge. Another challenge was the attempt to combine two entirely different research fields, namely social science and system thinking. Substantially and practically it proved to be more difficult than expected; subjectivity is hard to capture in a quantified model and system dynamics experts appear to be scarce. Subsequently it was also an unexpected experience on an emotional level; the moment you realize the numbers in your Excel-file are real people who lost their lives due to a terrible war says it all. I hope this research somehow can contribute to today's challenges regarding refugees and that it can provide a greater understanding for the tragic issue of refugees.

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12. Appendices

APPENDIX A. – CAUSAL DIAGRAMS

General refugee causal diagram

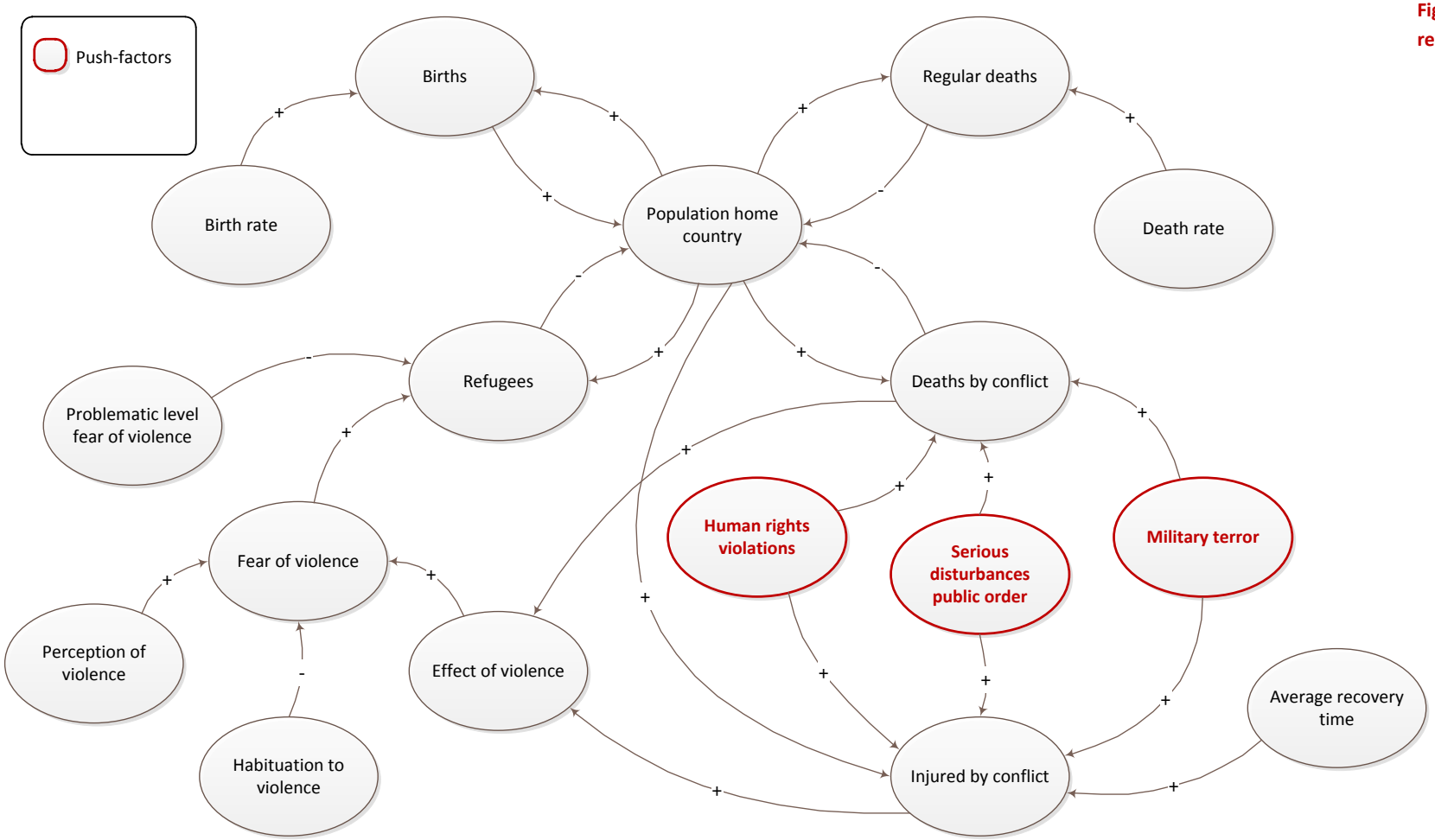

Figure A.1 General refugee causal diagram

Causal diagram, early indicator 'free-will migrants'

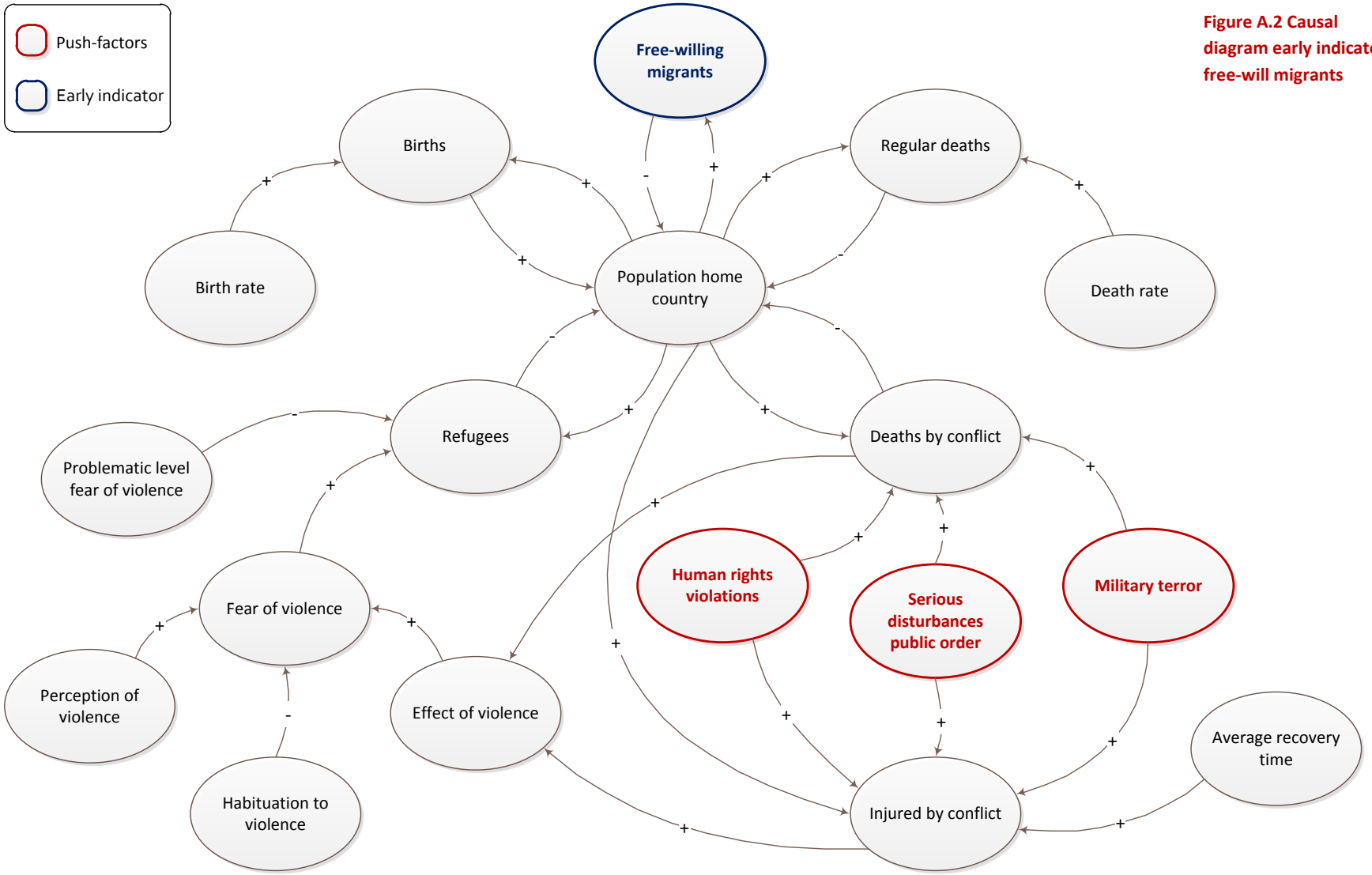

Figure A.2 Causal diagram early indicator free-will migrants

Causal diagram, early indicator 'IDPs'

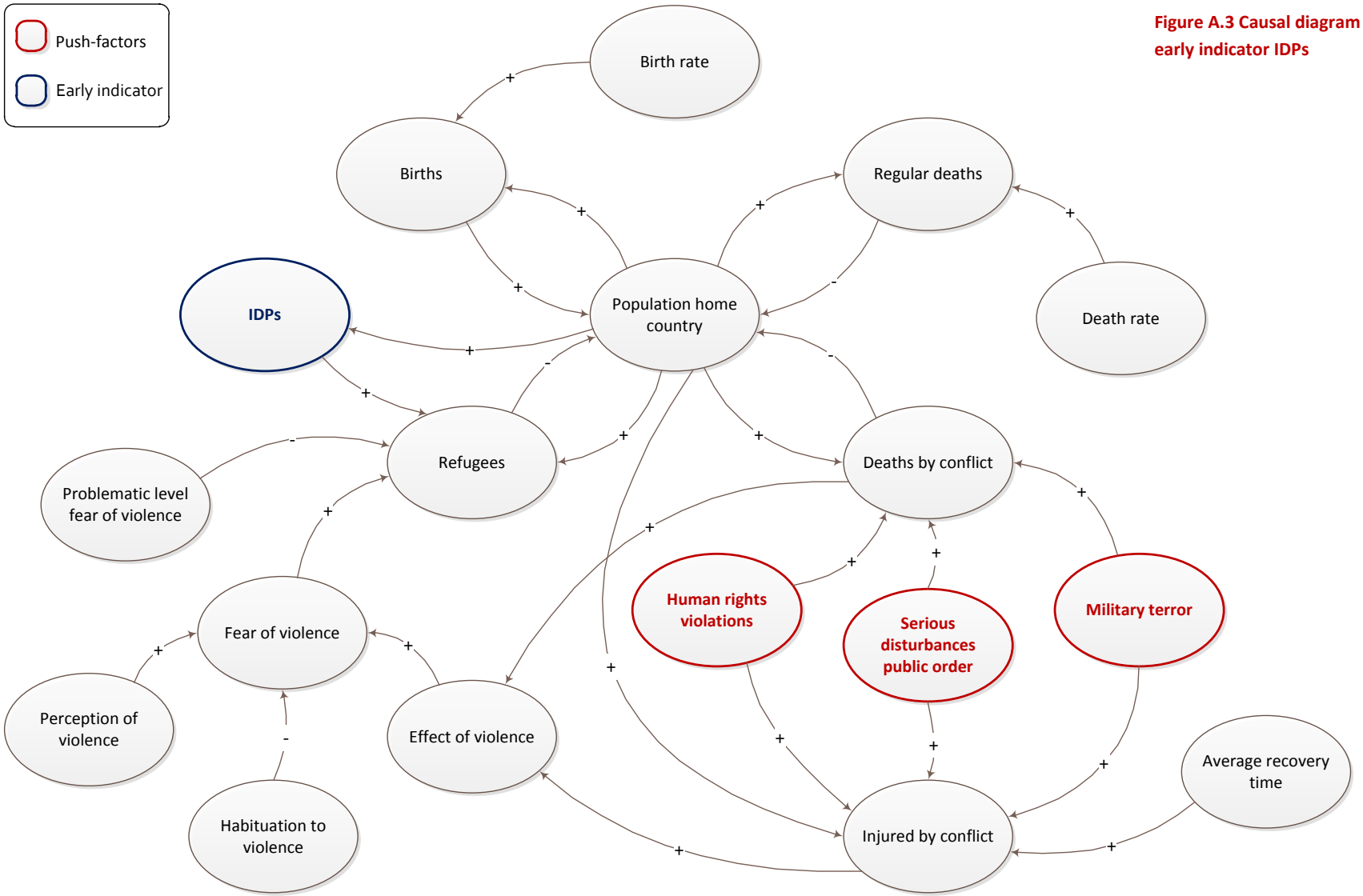

Figure A.3 Causal diagram early indicator IDPs

Causal diagram, early indicator 'external military intervention'

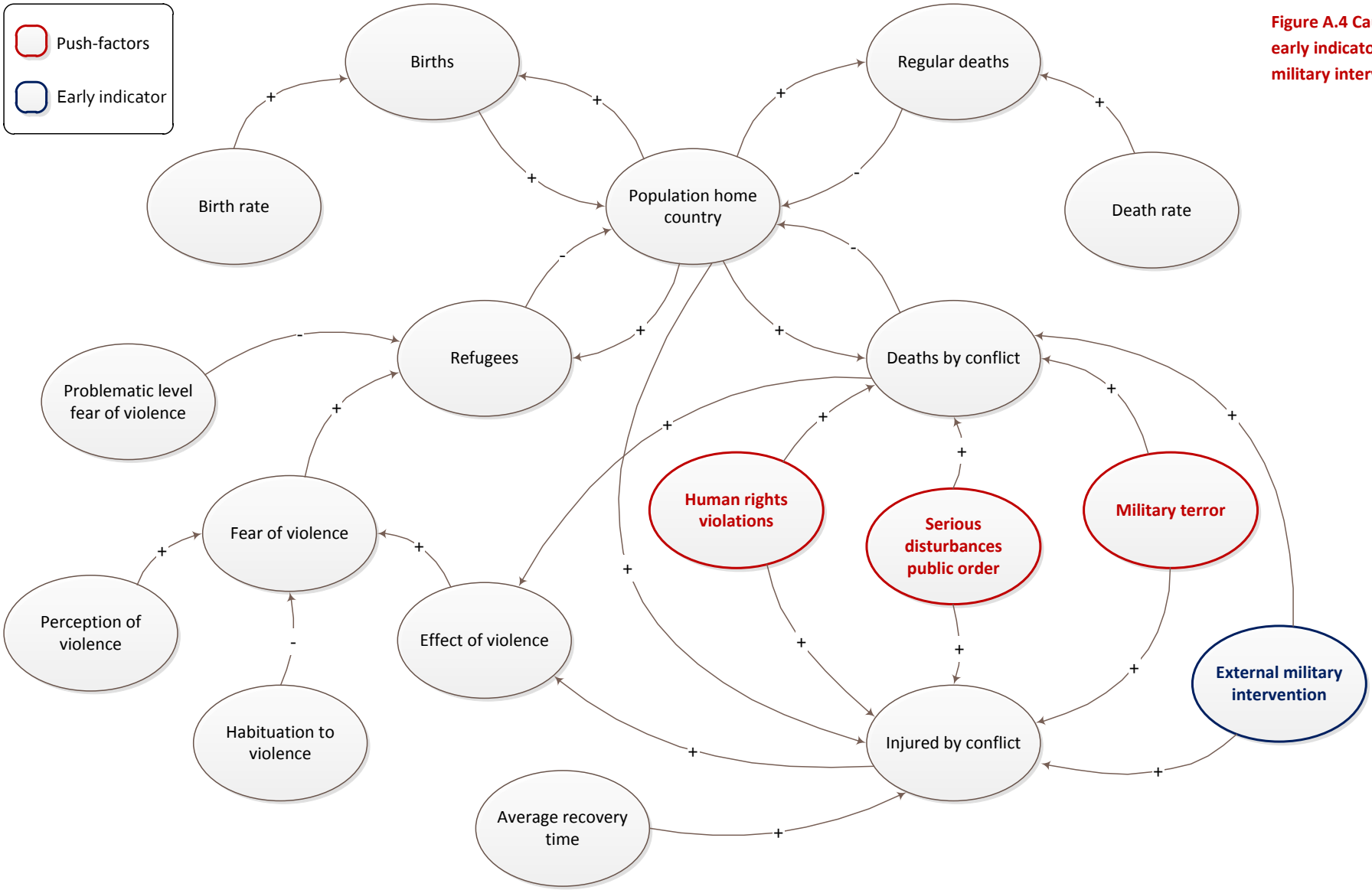

Figure A.4 Causal diagram early indicator external military intervention

APPENDIX B. – STOCK-FLOW DIAGRAMS IN VENSIM

General refugee stock-flow diagram

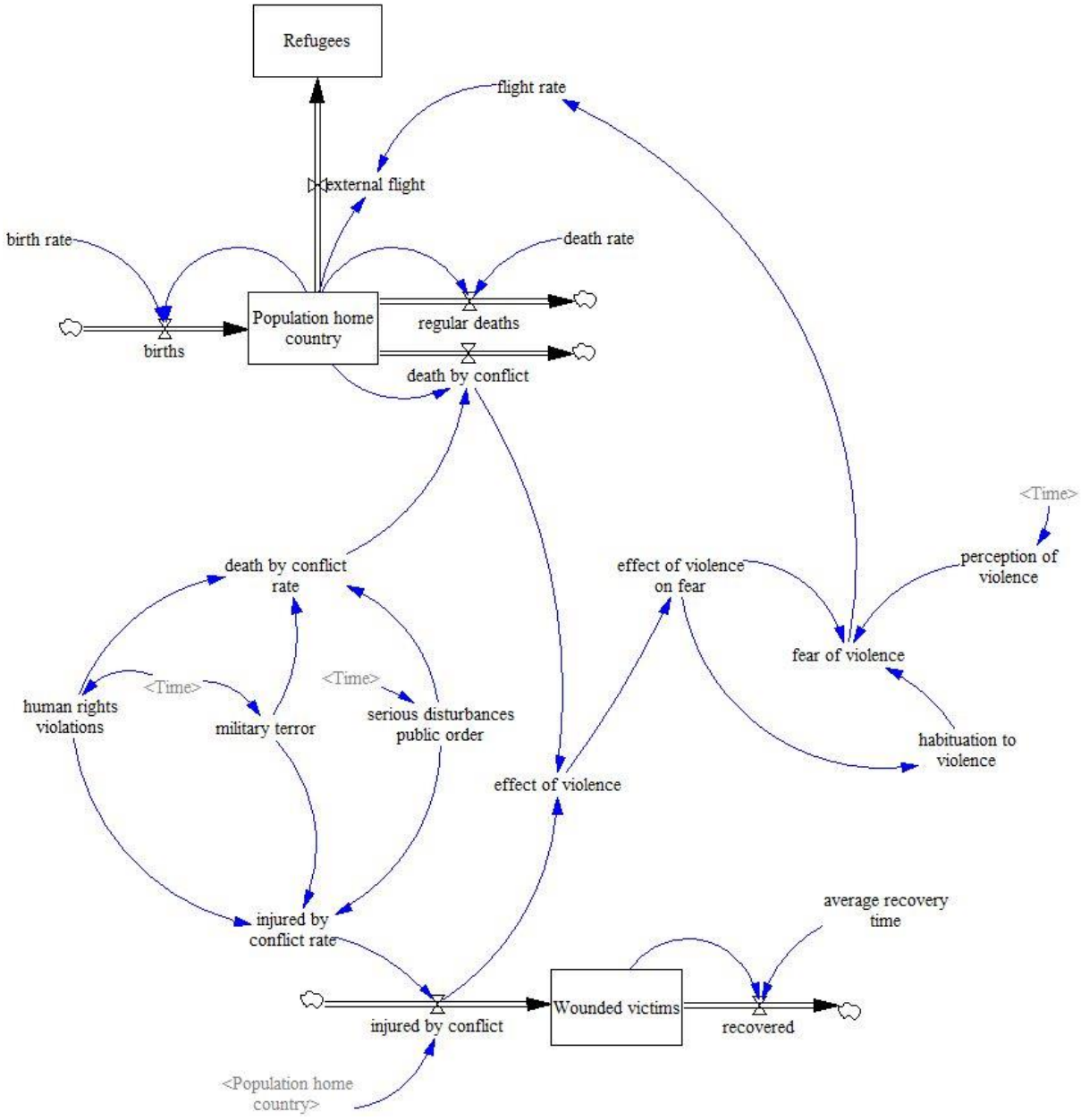

Figure B.1 General refugee stock-flow diagram

Stock-flow diagram, early indicator 'free-will migrants'

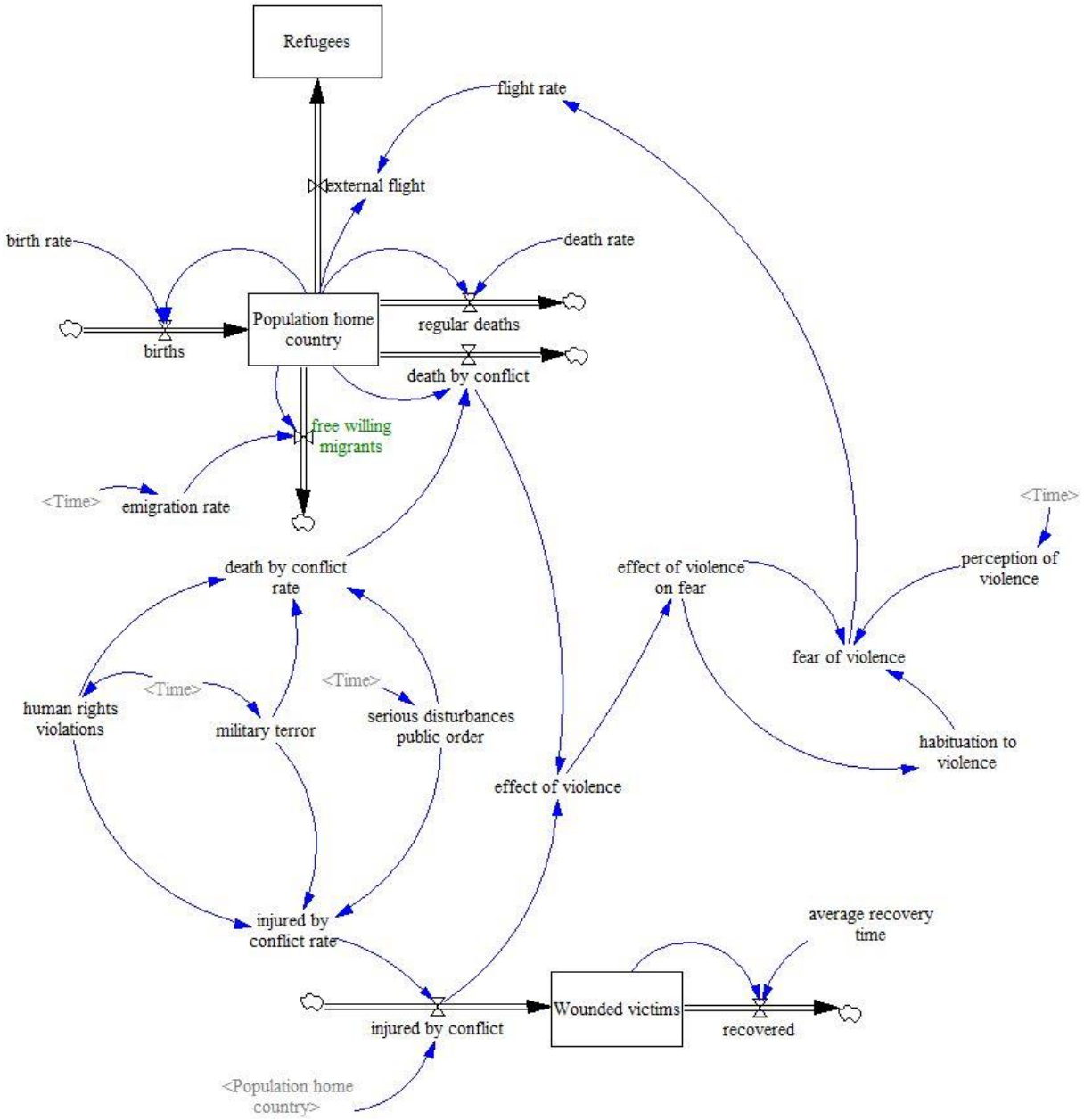

Figure B.2 Stock-flow diagram early indicator free-will migrants

Stock-flow diagram, early indicator 'IDPs'

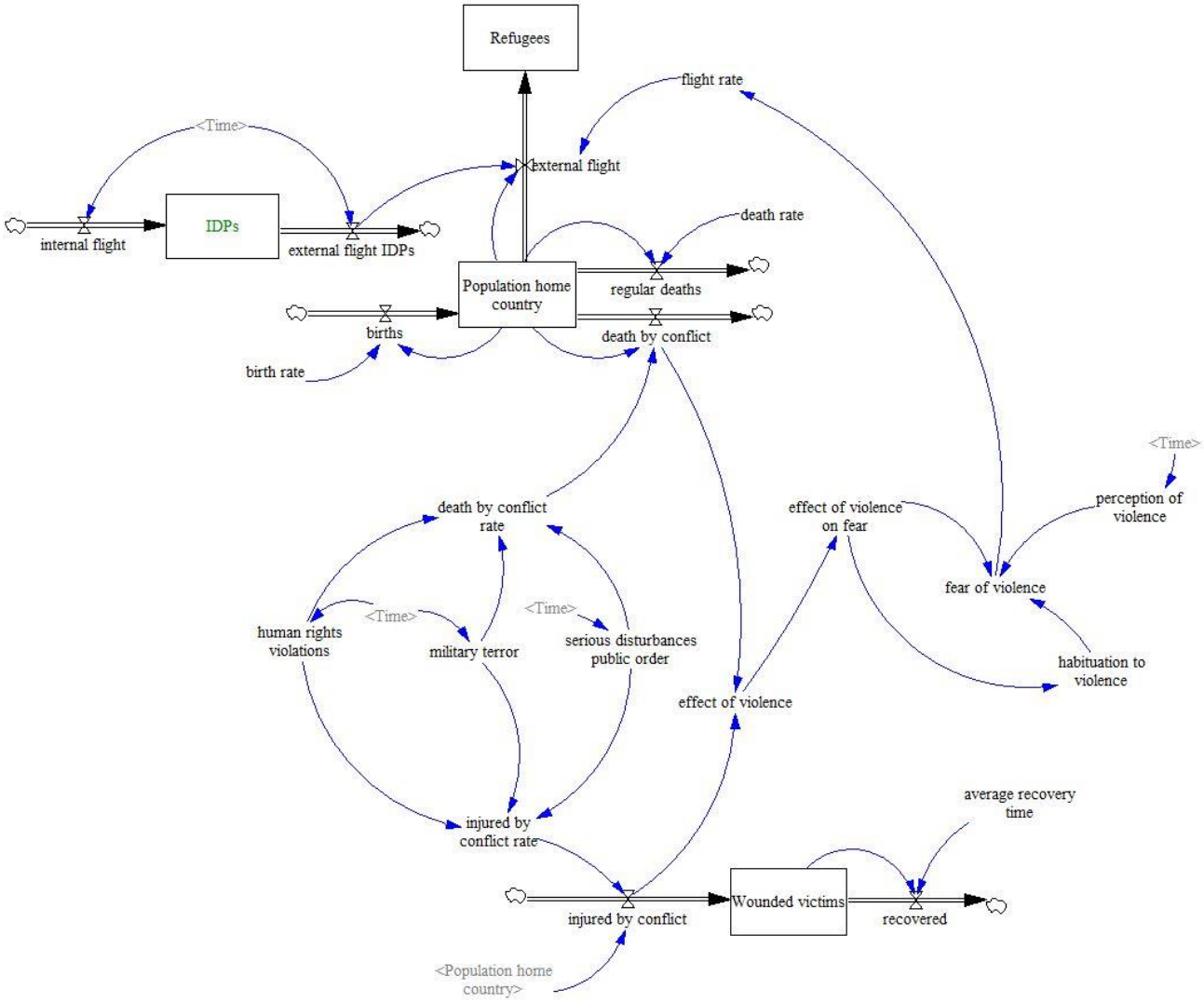

Figure B.3 Stock-flow diagram IDPs migrants

Stock-flow diagram, early indicator 'external military intervention'

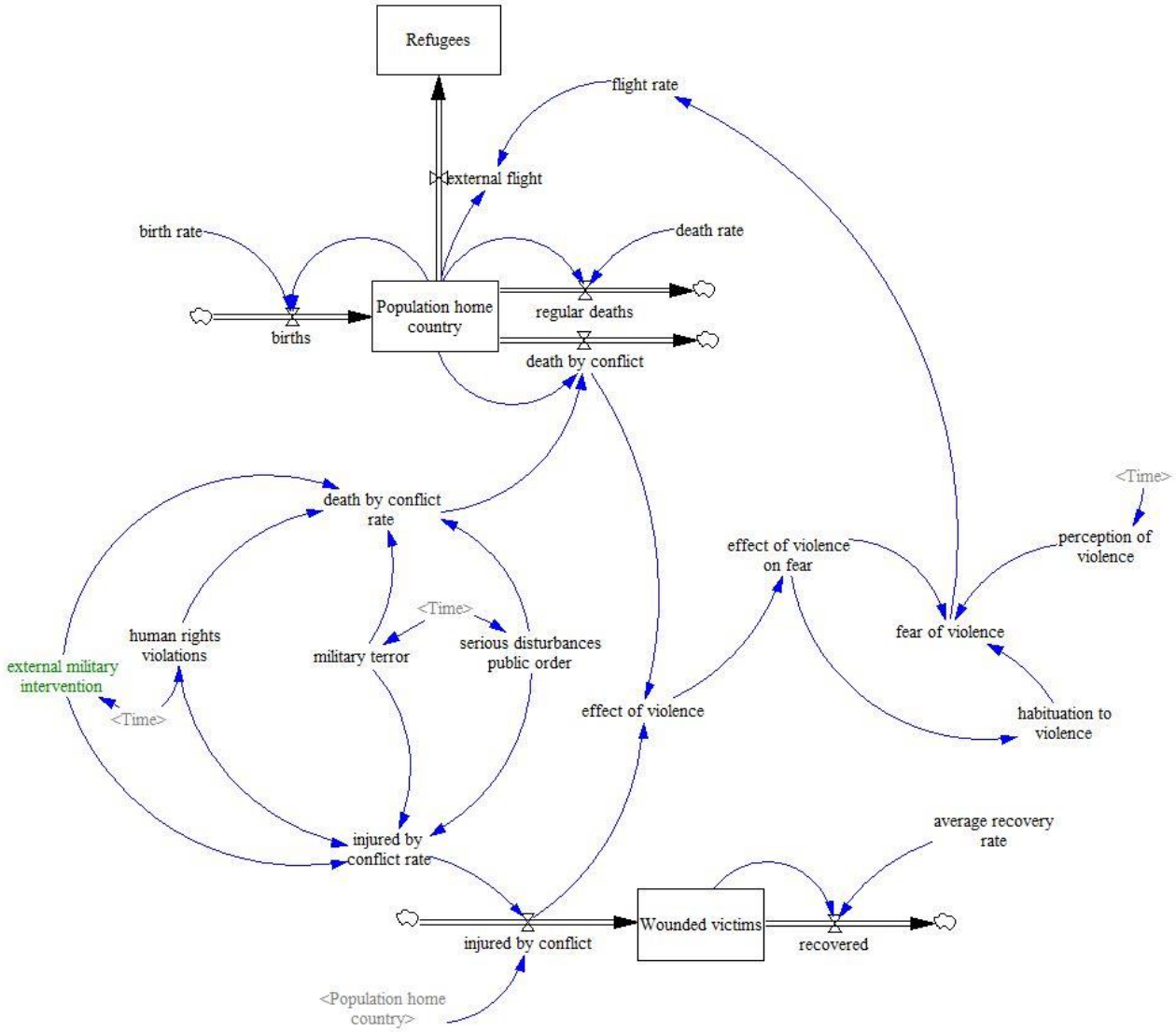

Figure B.4 Stock-flow diagram early indicator external military intervention

APPENDIX C. – *OVERVIEW INPUT DATA*

Data Syria sorted by model phase								
Green values are used as input in model								
model settings	*initial time*	*final time*	*time step*	*units time*	*integration type*			
time bounds	0 (01-01-2011)	60 (31-12-2015)	0.125	month	RK 4 auto			
phase 1	*(start) value*							*source*
population home country	20000000							(UN, 2015)
birth rate	24.1/1000 residents/year → 0.002/person/month							(UN, 2015)
death rate	5.6/1000 residents/year → 0.0005/person/month							(UN, 2015)
phase 2	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*source*
human rights violations	8.8/10	8.6/10	9.4/10	9.5/10	9.9/10	10.0/10	9.8/10	(FSI, 2016)
military terror	7.6/10	7.5/10	8.5/10	9.8/10	10.0/10	10.0/10	10.0/10	(FSI, 2016)
serious disturbances public order	analysis of conflict timeline → see appendix D							(I AM SYRIA, 2015)
phase 3								*source*
death by conflict rate	correlation push-factors and deaths → see appendix E							(FSI, 2016)
								(SN4HR, 2015)
injured by conflict rate	correlation push-factors and deaths → see appendix E							(FSI, 2016)
								(SN4HR, 2015)
	no data available wounded, aproximately 4 times deaths							(Coupland & Meddings, 1999; SCPR, 2015)
								(Belammy, 1992; Melsom, Farrar& Volkers, 1975)
average recovery time	no data available, aproximately average 2 months							No authorative data
phase 4	*value*	*explanation*						*source*
effect of violence	death has 3 times bigger impact on people than injured	sources indicate: the higer degree of trauma, the bigger the impact						(Interview Lucassen; Murthy & Lakshminarayana, 2006)
effect of violence on fear	every 6000 units dead/injured --> +0.1 fear	sources indicate: the greater the impact of violence, the more fear						(interviews Glynn & Lucassen)
perception of violence	ranking societal safety and security → see appendix F	this factor is used as multiplyer for impact of violence on fear						(GPI, 2016)
habituation to violence	the higher level of violence, the slower fear will decrease	people get used to violence, this depends on level of violence						(Butler, Panzer & Goldfrank, 2003; interview Lucassen)
	0→0.2, 0.1→0.15, 0.2→0.1, 0.3→0.06, 0.4→0.03, 0.5→0.01							
fear of violence	between 0% and 100%	increase by impact on fear*perception, decreases by habituation						(ex.14.16, Pruyt, 2013; Steimer, 2002)
flight rate	level is set to 0.6	one certain level of fear activates flight behavior for the mass						(ex.14.16, Pruyt, 2013; Steimer, 2002)
phase 5 - early indicators	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*source*
free-willing migrants	6.6/10	6.3/10	6.0/10	6.2/10	6.9/10	7.4/10	8.6/10	(FSI, 2016)
	aproximately 10 times smaller than refugee flow							(MPC, 2013)
IDPs	433000	600000	3000000	6500000	7600000	6600000	6E+06	(IDMC, 2016)
external military intervention	5.8/10	5.5/10	7.9/10	8.1/10	8.6/10	9.9/10	10.0/10	(FSI, 2016)
	correlation early indicator and deaths → see appendix E							(FSI, 2016)
								(SN4HR, 2015)

Table C.1 Overview input data

APPENDIX D. – *ANALYSIS OF CONFLICT TIMELINE*

Since data regarding the level of serious disturbances of public order is not available a conflict timeline analysis of Syria is conducted. A timeline, published by a local Syrian non-profit organization, is analyzed and ranked per month. This is done by grading each month with a grade from one to five, in which one represents mild disturbances and five severe disturbances. In table D.1 all black displayed values are determined by ranking the events that happened that month. The green displayed values are the ranked values times two in order to establish a similar scale as the other push-factors. These values are directly used as input data in the model.

Jan	0	0	Jul	3	6
Feb	0	0	Aug	3	6
Mar	1	2	Sep	3	6
Apr	2	4	Okt	3	6
May	2	4	Nov	3	6
Jun	2	4	Dec	3	6
Jul	2	4	Jan	3	6
Aug	2	4	Feb	4	8
Sep	2	4	Mar	4	8
Okt	2	4	Apr	4	8
Nov	2	4	May	4	8
Dec	2	4	Jun	4	8
Jan	2	4	Jul	4	8
Feb	2	4	Aug	4	8
Mar	2	4	Sep	4	8
Apr	2	4	Okt	4	8
May	2	4	Nov	4	8
Jun	2	4	Dec	4	8
Jul	3	6	Jan	4	8
Aug	3	6	Feb	4	8
Sep	3	6	Mar	5	10
Okt	3	6	Apr	5	10
Nov	3	6	May	5	10
Dec	3	6	Jun	4	8
Jan	3	6	Jul	4	8
Feb	3	6	Aug	4	8
Mar	3	6	Sep	4	8
Apr	3	6	Okt	5	10
May	3	6	Nov	5	10
Jun	3	6	Dec	5	10

Table D.1 Ranked events and transformed input data serious disturbances of public order

APPENDIX E. – *CORRELATION PUSH-FACTORS AND EI EXTERNAL MILITARY TERROR*

The strength of the relations between push-factors and amount of deaths are obviously not numbers you can find in an article or report. In an attempt to make an estimation about the strengths of these relations the correlation between the amount of deaths and the three push-factors is determined. The amount of injured people during the conflict in Syria is unknown and therefore not included in the correlation test. The amount of deaths, due to the conflict, is derived from the monthly reports of the Syrian Network for Human Rights. As the correlation results show in tables E.1 to E.4, all F-values are smaller than the p-value of 0.05, which means all correlations are significant. The multiple R displays the strength of the relation. All multiple R-values are different, so the strength of the relation with the amount of deaths differs per push-factors. The rounded values displayed in green are used for the weighing of push-factors for their relation to the injured and death rate. This same method is applied to the early indicator external military intervention, which has the same relations as the push-factors.

Human Rights Violations -Deaths

Regression Statistics		
Multiple R	0,633222	0.63
R Square	0,40097	
Adjusted R Square	0,390642	
Standard Error	0,390122	
Observations	60	

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*		
Regression	1	5,908697	5,908697	38,82323	5,65681E-08	<0.05	SIG positive relation
Residual	58	8,827303	0,152195				
Total	59	14,736					

Military Terror - Deaths

Regression Statistics		
Multiple R	0,687538	0.69
R Square	0,472709	
Adjusted R Square	0,463618	
Standard	0,739448	

Error	
Observations	60

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*		
Regression	1	28,4306	28,4306	51,99615	1,29652E-09	<0.05	SIG positive relation
Residual	58	31,7134	0,546783				
Total	59	60,144					

Serious Disturbances Public Order - Deaths

Regression Statistics		
Multiple R	0,534321	0.53
R Square	0,285499	
Adjusted R Square	0,27318	
Standard Error	1,952935	
Observations	60	

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*		
Regression	1	88,39058	88,39058	23,17556	1,09661E-05	<0.05	SIG positive relation
Residual	58	221,2094	3,813956				
Total	59	309,6					

External Military Intervention - Deaths

Regression Statistics		
Multiple R	0,594088	0.59
R Square	0,352941	
Adjusted R Square	0,341785	
Standard Error	658,2222	
Observations	60	

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*		
Regression	1	13706652	13706652	31,63635	5,61647E-07	<0.05	SIG positive relation
Residual	58	25128872	433256,4				
Total	59	38835524					

Table E.1 - E.4 Correlation test push-factors and EI external military intervention

APPENDIX F. – *RANKING FACTOR SOCIETAL SAFETY AND SECURITY*

Major factor 'societal safety and security' is based on:
Level of perceived criminality in society
Number of refugees and IDPs as percentage of population
Political instability
Political terror scale
Impact of terrorism
Number of homicides per 100000 people
Level of violent crime
Likelihood of violent demonstrations
Number of jailed population per 100000 people
Number of internal security officers and police per 100000 people

Table F.1 Factors used for major factor 'societal safety and security'

Input for variable *perception of violence* is based on the combined major factor 'societal safety and security' derived from the Global Peace Index (GPI). In table F.1 the list of quantitative and qualitative factors is displayed, on which the major combined factor is based. The initial values of the major factor published by GPI are showed in table F.2, in the GPI column. Based on the GPI's classification regarding stability the initial values are transformed to a useful model rate. The exact conditions for transformation are described in the bottom half of table F.2. As shown, the initial values can only transform to three values: 1, 1.5 and 2. The green displayed values are directly used as multiplier in the model.

Year	GPI	Rates
2010	2,6	1,5
2011	2,7	1,5
2012	3,2	1,5
2013	3,8	1,5
2014	4,2	2
2015	4,2	2
2016	4,2	2

0 - 2 is stable → rate = 1
2 - 4 is unstable → rate = 1,5
> 4 is chaos → rate = 2

Table F.2 GPI classification and transformation to input data

APPENDIX G. – *ASSUMPTIONS INPUT DATA*

The assumptions regarding input data are shortly listed in the main text. As most assumptions require an explanation, this appendix pays attention to the reasons for making assumptions and the substantiating of the made assumptions.

As often the case with violent conflicts, the number of wounded people over the course of the Syrian conflict is unknown. This information is not required as input data, as the model itself generates the number of wounded people, but is important to determine the ratio between the amount of deaths and injured. They both are triggered by the same push-factors, but probably not to the same degree. In the search for the ration between the amount of deaths and injured one article is found stating that the ratio ranges between 1.9 and 27.8 (Coupland & Meddings, 1999). In this article also other articles are mentioned speaking of a wounded to killed ratio of 2.8 (Bellamy, 1992; Melsom, Farrar & Volkers, 1975). The Syrian Center for Policy Research (2015) made in February 2016 an estimation about the total deaths and injured caused by the Syrian conflict, which would come down to a wounded to killed ratio of 4. Because the ratio is derived from numbers of the actual conflict, lies in the mentioned margin and is so close to the cited value of 2.8, the ratio of 4 is assumed as wounded to killed ratio.

The second assumption is about the recovery time for wounded victims of the conflict. By this is meant the period someone is treated in the hospital, aftercare and psychological damage are excluded. No authoritative sources regarding this matter are found and therefore, based on some grey sources and logic, it is assumed the average recovery time is two months.

The next assumption has to do with the effect of violence on fear. In the model this effect is caused by the amount of casualties. Due to the degree of trauma and its irreversibility it seems logical that deadly victims have a bigger effect than injured victims. Murthy and Lakshminarayana (2006) state that several studies have proven that there's a direct link between the degree of trauma and the amount of psychological problems. When fear and anxiety can be regarded as the mildest form of psychological problems this statement supports the presumption about difference in effect. In addition, Lucassen conjectures a link

between the severity of the trauma and the level of fear (L. Lucassen, personal communication, October 14, 2016). Based on these information it is assumed that deadly victims have three times more effect on fear than wounded victims.

In the model this relation directly followed by the relation between the factor *effect of violence on fear* and the factor *fear of violence*. This relation may look redundant but is very useful for model purposes. The relation basically means the greater the effect of violence, the more fear people feel (I. Glynn, personal communication, September 16, 2016; L. Lucassen, personal communication, October 14, 2016). Obviously there are no known values for this relation, therefore it is assumed when the factor *effect of violence on fear* increases with 6000 units, the factor *fear of violence* increases with 0.1 units. These exact values are established by simulation tests using the principle of trial and error.

The next assumption is about the factor *habituation to violence*. People have the capability to get used to a high level of violence (L. Lucassen, personal communication, October 14, 2016) or even develop their resilience for future events (Butler, Panzer & Goldfrank, 2003). To include this in the model it is assumed, again based on trial and error, that in the absence of violence the level of fear decreases with 0.2 units and when the level of violence is at its highest it only decreases with 0.01 units. In other words in the absence of violence the level of fear increases rapidly and during extreme violence people will get used to it, but quite slowly. Between these extremes the values of the habituation of violence are decreasing exponentially; the more violence the less rapidly get used to it. Exact input data of habituation to violence can be found in the overview in appendix C.

The construction of *Problematic level fear of violence*, which is incorporated in factor *flight rate,* is based on an exercise in a casebook about system dynamics (Pruyt, 2013). The underlying idea of this factor is that there's a certain level of fear which activates the flight system (Steimer, 2002) for the mass of the people. The value for this problematic level is assumed to be 0.6. This is determined by experimenting with different values in the model.

The last assumption is created to allow the early indicator *free-will migrants* to generate a credible amount of migrants. For this early indicator only a FSI indicator between zero and

ten is available as input data, so by using a multiplier of 0.1 the initial large value is transformed in a much smaller useful value.

APPENDIX H – *OVERVIEW EQUATIONS SYRIA PER MODEL PHASE*

Equations Syria sorted by model phase		
phase 1	*equation*	*comment*
population home country	births-death by conflict-external flight-regular deaths	innitial value is 0
births	birth rate*Population home country	
birth rate	constant	
regular deaths	death rate*Population home country	
death rate	constant	
death by conflict	Population home country*death by conflict rate	
death by conflict rate	((hrv*0.63)+(mt*0.69)+((sdpo*2)*0.53))/100000	100.000 is a normalization rate
phase 2	*equation*	*comment*
human rights violations	lookup function - input: time, output: value hrv	annually input data is implemented half-way each year
military terror	lookup function - input: time, output: value mt	annually input data is implemented half-way each year
serious disturbances public order	lookup function - input: time, output: value sdpo	annually input data is implemented half-way each year
phase 3	*equation*	*comment*
injured by conflict rate	(((hrv*0.63)+(mt*0.69)+((sdpo*2)*0.53))*4)/100000	100.000 is a normalization rate
		multiplication by 4 for death to killed ratio 1:4
injured by conflict	Population home country*injured by conflict rate	
wounded victims	injured by conflict-recovered	innitial value is 0
average recovery time	constant	
recovered	Wounded victims/average recovery time	
phase 4	*equation*	*comment*
effect of violence	(death by conflict*3)+injured by conflict	multiplication by 3 due to assumption
effect of violence on fear	lookup function - input: effect of violence, output: value effect of violence on fear	exact lookup function established by trial and error
perception of violence	lookup function - input: time, output: perception of violence	output can only produce three values (1/1.5/2)
habituation to violence	lookup function - input: effect of violence on fear, output: habituation to violence	exact lookup function established by trial and error
		function gradually decreases
fear of violence	MAX(MIN((effect of violence on fear*perception of violence)-habituation to violence, 1), 0)	MAX/MIN-function limits values between 0-100%
		perception of violence functions as a multiplyer
flight rate	lookup function - input: fear of violence, output: flight rate	function increases lineairly untill 0.6, thereafter exponetially
external flight	flight rate*Population home country	
refugees	external flight	innitial value is 0

Table H.1 Overview equations Syria per model phase

APPENDIX I – *OVERVIEW EQUATIONS SYRIA PER EARLY INDICATOR*

Equations Syria sorted by early indicator		
free-willing migrants	*equation*	*comment*
emigration rate	lookup function - input: time, output: emigration rate	annually input data is implemented half-way each year
free-willing migrants	(emigration rate/100000)*Population home country	100.000 is a normalization rate
population home country	births-death by conflict-external flight-free willing migrants-regular deaths	free-willing migrants is additional outflow
IDPs	*equation*	*comment*
internal flight	lookup function - input: time, output: internal flight	real world data is used for inflow of IDPs
IDPs	internal flight-external flight IDPs	innitial value is 0
external flight IDPs	lookup function - input: time, output: external flight IDPs	real world data is used for outflow of IDPs
external flight	(flight rate*Population home country)+external flight IDPs	external flight IDPs is added to external flight flow
external military intervention	*equation*	*comment*
external military intervention	lookup function - input: time, output: external military intervention	annually input data is implemented half-way each year
death by conflict rate	((hrv*0.63)+(mt*0.69)+((sdpo*2)*0.53)+(emi*0.59))/100000	100.000 is a normalization rate
injured by conflict rate	(((hrv*0.63)+(mt*0.69)+((sdpo*2)*0.53)+(emi*0.59))*4)/100000	100.000 is a normalization rate
		multiplication by 4 for death to killed ratio 1:4

Table I.1 Overview equations Syria per early indicator

APPENDIX J – *EXPLANATION EQUATIONS*

To complete the explanation of the constructed equations in the main text, three additional equations are elucidated. Successively the equations of *effect of violence on fear*, the *perception of violence* and *habituation to violence* are discussed.

The variable *effect of violence on fear* is used to transform the effect caused by the number of casualties into a certain level of fear. This is established by using a lookup function with the input of variable *effect of violence*. By trial and error the exact values for *effect of violence* and its corresponding values for *effect of violence on fear* are determined. In other words, by what level of violence the level of fear increases. Results of the trial and error-process is that with each 6000 units increase of effect of violence, the effect of violence on fear is increasing with 10%. The use of these values produces a credible behavior and is therefore implemented in this lookup function.

As discussed earlier it is known that perception plays a big role in mechanisms of fear. The exact effect is however unknown and therefore assumed in this model. *Perception of violence* can generate three different values, depending on societies perception of violence. The value of an annually published major factor is used as input for the lookup function. The input values are divided into three groups: stable, unstable and chaos. Each group has its own matching output value, respectively 1, 1.5 and 2. For example, when the input is 3.2 it means people perceive that their country is unstable. The variable *perception of violence* subsequently produces the matching value 1.5.

Habituation to violence is a variable which reduces the fear of violence because people get used to violence when it is the new norm in society. The lookup function uses therefore the *effect of violence on fear* as input variable. Depending on the level of violence, the level of habituation is established. It is assumed earlier that the higher the level of violence is the slower the fear will decrease, so the smaller the value of habituation. In figure J.1 this is represented by a gradually decreasing function. The exact values are established by trial and error and can also be found in this graph.

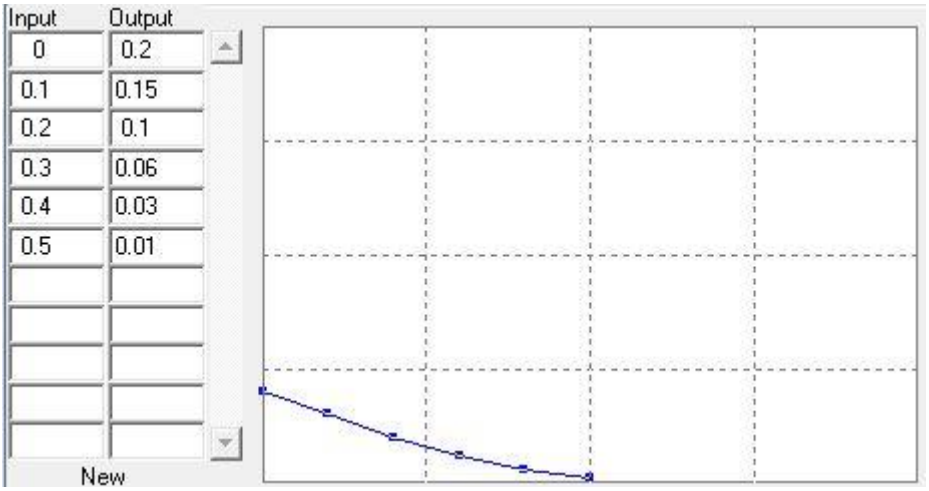

Figure J.1 Lookup function habituation to violence

APPENDIX K. – *VALIDATION TESTS*

Additional to the validation test in the main text, some relevant tests are conducted in this appendix. The first three tests belong to the sub-group of indirect-structure tests. The last test is a direct-structure test and complements the partly conducted sensitivity analysis in the main text.

Theoretical structure and parameter confirmation test

The first conducted direct structure test is the theoretical structure and parameter confirmation test. This test checks if the structure and model factors are consistent with the qualitative and quantitative knowledge regarding the real world (Forrester & Senge, 1980; Richardson & Pugh, 1981). As all factors and input data is based on literature, reports and expert interviews it can be concluded that the constructed model correspondents to refugee flows, especially to the refugee flow caused by the conflict in Syria. The justification for the model structure is described paragraph 4.2 regarding operationalization, the used input data and made assumptions can be found in appendix C and constructed equations are explained in appendix H.

Direct extreme condition test

As the name suggests, the direct extreme condition test investigates if the model equations produces credible output under extreme input values (Forrester & Senge, 1980; Richardson & Pugh, 1981). The model is not simulated for this test; every equation is just analyzed separately. During the analysis no aberrant output was detected. This is no surprising result since the principle of extreme values was always kept in mind during the model building process.

Empirical structure confirmation test

The empirical structure confirmation test checks whether the model structure and equations corresponds to the real world (Forrester & Senge, 1980; Richardson & Pugh, 1981). This test is actually already conducted through the steps of theory, conceptualization and formulation. Naturally some elements in the model do not exactly match reality, like the

amount of push-factors and the construct of fear. However this is related to the simplified nature of system dynamics and all substantiated earlier in this thesis.

Empirical parameter confirmation test

Parameters, the determined values for the model factors, are compared to the real system during the empirical parameter confirmation test. This test is checking both the conceptual and numerical conformity with the real system (Forrester & Senge, 1980; Richardson & Pugh, 1981). The numerical values are accurate since most values are directly derived from reality and the remaining values are assumptions which are as much as possible based on literature or other sources. An overview of the numerical values and assumptions can be found in appendix C. Conceptual wise the model has still room for improvement. As indicated by E. Canzani the names of the variables *impact of violence* and *impact of violence on fear* are not correct formulated for their function in the model. In system dynamics the word 'impact' commonly refers to an area, so this can lead to misunderstandings. To prevent confusion the word 'impact' is substituted by the word 'effect' (E. Canzani, personal communication, November 9, 2016). This is now corrected through all phases of the thesis.

Sensitivity analysis

The sensitivity analysis is conducted on all model factors. The results of the analysis are classified in three groups: little or no sensitivity, slightly sensitive and sensitive. Next to the variables *effect of violence on fear* and *perception of violence*, which are described in validation section, there's a third variable causing sensitive behavior. The model is sensitive to small changes in stock variable population home country, as is shown for *death by conflict* in figure K.1 and for *refugees* in figure K.2. This means it is important that the input data of this stock is accurate. There are multiple trustworthy sources consulted for the population in Syria in the beginning of 2011, therefore the initial value is considered accurate.

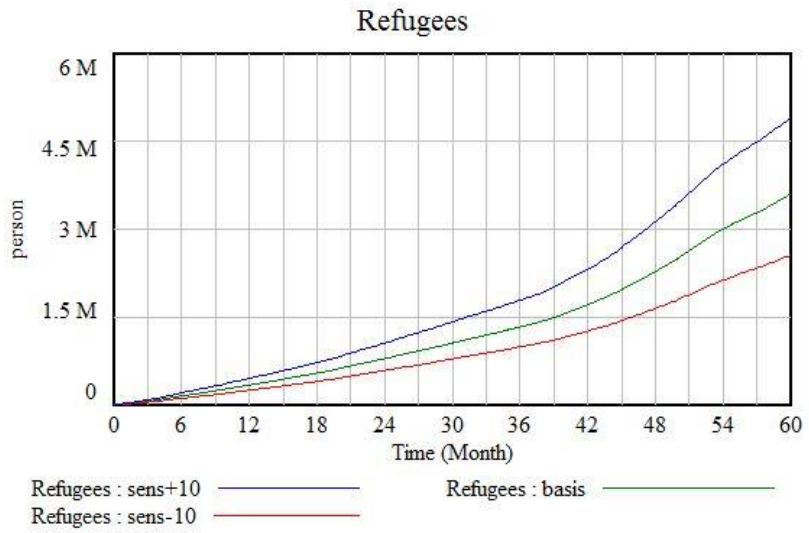

Figure K.1 Sensitivity analysis refugees for population home country

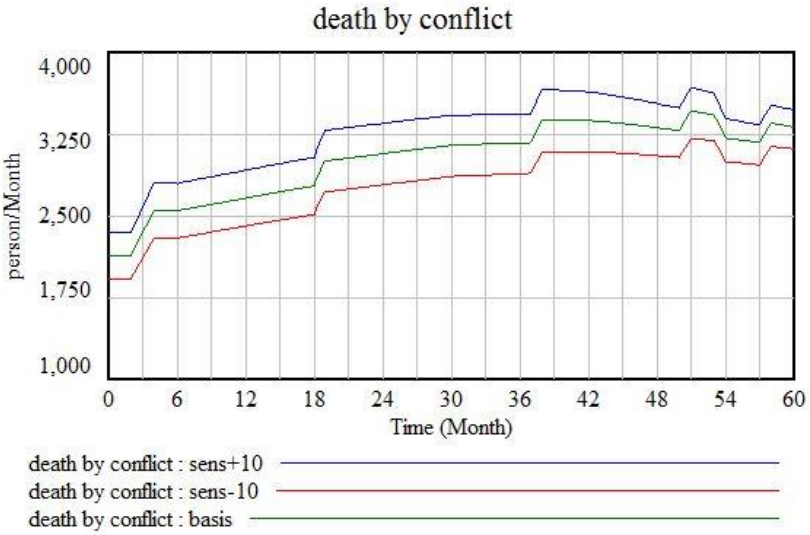

Figure K.2 Sensitivity analysis death by conflict for population home

Factors which generated small but no drastic changes are classified as slightly sensitive. This concerns the factors: human rights violations, military terror, serious disturbances public order, injured by conflict rate, effect of violence, flight rate and external military intervention. It has to be noted that the last two of these factors are very limited sensitive. Factors for which the model has little or no sensitivity are: birth rate, death rate, average recovery time, habituation to violence, emigration rate, internal flight and external flight IDPs.