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Reducing Terrorism Casualties: Analyzing Policies Effectiveness under a Systems Perspective

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Abstract: The present paper seeks to analyze and understand terrorism as a comprehensive process that, through various stages, transforms a "normal" individual with some grievances into a radicalized agent ready and available to be recruited and trained to perform terror attacks that produce casualties. The goal of this analysis is to produce recommendations regarding the leverage points in which policy interventions may be used to reduce the number of casualties that terror attacks in the west, and specifically in Europe, produce. To this end, the analysis is divided into two main sections. The first section will focus on a careful study of key literature regarding terrorism. A deep analysis is conducted in order to construct a qualitative understanding of radicalization and terrorism, finding common points among what is analyzed and developing a strong overview and understanding of the topic. The second section—the core of the paper—focuses on creating a novel System Dynamics model and on identifying leverage points. In this section, the System Dynamics model is used to construct a simulation model based on the findings from the first section. This model is then simulated on Silico.app® through various scenarios in order to identify leverage points in which policies would be best able to reach the stated goal of reducing casualties. Following these simulations, a few leverage points were evidenced, and some effective policies were also identified. The last section recaps the main findings of the analysis, its limitations and future extensions of the model (so to allow for deeper and more precise policy insight), and it is argued that System Dynamics can constitute a very powerful modeling approach in the context of counter terrorism policy making.

Keywords: terrorism; radicalization; ISIS; Al Qaeda; system dynamics; policy modeling

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1. Introduction

This paper seeks to analyze and understand terrorism as a comprehensive process that, through various stages, transform a "normal" individual with some grievances into a radicalized agent ready and available to be recruited and trained to perform terror attacks that produce casualties. "Terrorism" in the present paper is to be understood through the lens of the academic consensus on its definition [1], specifically in its second form as "*[. . .] a conspiratorial practice of calculated, demonstrative, direct violent action without legal or moral restraints, targeting mainly civilians and non-combatants [. . .]*". The goal of this analysis is to identify leverage points in which policies may be used to reduce the number of casualties that terror attacks in the west produce.

"Casualties" in the present paper are defined as a sum of both deaths and injuries, as both are a measure of the damage that a terror group is able to produce. We will use the System Dynamics computer modeling and simulation methodology [2,3] to construct a model based on our findings from a careful analysis of select studies regarding terror attacks and radicalization. We will use this model as a tool to simulate various scenarios and produce policy recommendations that are best able to reach our stated goal of reducing

casualties. After our policy recommendations, we will move on to our conclusions, in which we will use all we have learned in order to argue the importance of utilizing System Dynamics in counter terrorism studies and policy modelling.

2. Context and Previous Research

In this first section we will consider two contributions to the study of terror attacks. The first is that of Mitchel Silber, from his book "The Al Qaeda Factor" [4], in which he analyzes 16 attacks carried out in the west and measures the degree of involvement Al Qaeda had in said attacks. The second input we shall consider is that of Alessandro Orsini [5], who, once again, analyzes attacks in the west; Orsini's focus, however, is on creating a classification of attacks based upon ISIS involvement and number of terrorists. After analyzing both models we will compare and contrast them in order to draw out the "points of interest" of the present paper, using them as a springboard to continue our analysis.

2.1. The Al Qaeda Factor

The model developed by Silber differentiates terror attacks based on what kind of contact the attackers had with Al Qaeda, thus identifying three kinds of attacks:

1. Command and Control
2. Suggested/Endorsed
3. Inspired

Command and Control plots are, as the name implies, attacks that are characterized by the direct involvement of Al Qaeda. This means that the "Muscle" of the attack is not the "Brain"; Al Qaeda higher ups and leaders make use of radicalized individuals and give them specific directions for the attack at all stages, starting from the selection of the target. The next type of attacks identified by Silber are Al Qaeda "Suggested/Endorsed" plots. In such attacks, would be terrorists receive, as the name implies, either a suggestion or an endorsement to carry out an attack in the west from members of Al Qaeda. However, unlike in command and control plots, the attackers are left large or total discretion regarding methods and targets, as well receiving minimal to no training. In short, Al Qaeda is far less involved than in the first type of attack. The final category of Plots that Silber identifies are the so called Al Qaeda "Inspired" Plots. In these plots, Al Qaeda has no involvement in the attack itself, meaning no guidance is provided as to the targets or methods. However, this does not necessarily mean that the terrorists never came into contact with Al Qaeda, nor does it mean they never received training; it simply means that the attack itself has no connection to Al Qaeda.

2.2. Orsini's Model

The model developed by Orsini once again envisions three (and a half) categories of attacks, based on the type of "cells" that carry out the attack; in other words, the differentiation stems from the specific characteristics of the attackers. As such, the three types of attackers are: cells directly commanded by ISIS leaders, autonomous cells and lone wolves (trained or untrained). As we shall see, depending on who carries out the attack, the effects will be very different.

ISIS controlled cells are the first of the three types of possible attackers that Orsini envisions. As can be inferred from the name, these are cells that are under the direct guidance of ISIS and are, Orsini argues, the cells with the potential for the deadliest attacks. There are five reasons that ISIS-led cells are so deadly [6], these being that the cells receive: money; training; weapons; contact with other terrorists; a strong motivation born from the perception of having the respect of ISIS leaders and the burden of carrying out an important mission.

The second type of attackers are "autonomous cells", distinct from ISIS controlled cells, as can be inferred, due to the lack of a connection with ISIS. Orsini argues that these types of attacks are far less deadly than those led by ISIS controlled cells, using as an

example a comparison between the November 2015 Paris attacks and the 2017 Barcelona and Cambrils attacks [7]. It is pointed out how both attacks involved nine terrorists, however the Barcelona attacks only caused 14 deaths, against Paris' 130 [8]. Orsini notes how the vast difference in offensive capability of the two cells can be seen in two shortfalls of the Barcelona cell, namely in knowledge/training and tactics.

The final type of possible attackers are "lone wolves", further differentiated into trained and untrained. Lone wolves, while being the most unpredictable attackers, are also typically the least lethal as long as they are untrained. Trained lone wolves on the other hand, can be far more dangerous, as we shall see. Untrained lone wolves that have no involvement with ISIS usually commit a terror attack as a result of a life that is "unsatisfying", becoming what Orsini calls "vocational terrorists" [9,10]. As stated above, untrained lone wolves will carry out attacks that are, usually, not very lethal; this is due to their lack of training and resources, forcing them to use whatever they have at their disposal as a weapon and to select targets that they can feasibly reach alone. trained lone wolves, however, are another story entirely, as they have the potential to cause far more victims, due to them having access to knowledge and/or materials that untrained lone wolves do not.

2.3. Comparison and Conclusions

As can be seen from the analysis of Orsini's model, the main indicator of the lethality of a terror attack is whether or not ISIS played a role. Indeed, the types of attacks can be split into two categories:

1. Attacks with ISIS involvement (ISIS-led cells and trained lone wolves)
2. Attacks without ISIS involvement (autonomous cells and untrained lone wolves)

With the first category typically causing more damage than the second. We can thus find a parallel between Silber's model, analyzed before, and Orsini's: while the two models focus on different terrorist organizations, with Silber's looking at Al Qaeda and Orsini at ISIS, both differentiate attacks based on the involvement the organization has in them. However, an extra step that is taken by Orsini is that to attach a different level of "lethality" to the types of attacks, with ISIS involvement typically causing more victims and damage.

The question that arises is whether or not this same consideration can be applied to the analysis carried out by Silber; do attacks with Al Qaeda involvement cause more victims and damage than those without? Answering this question is not easy, as many, if not most, of the attacks analyzed were stopped by authorities before they could be carried out. If, however, we look at the attacks that succeeded in each category identified by Silber we may be able to draw a conclusion. In terms of Command and Control Plots, the lethality of the 9/11 attacks, the most famous Command and Control plot, is well known, with 2996 deaths (including the Terrorists) [11]. As regards Suggested/Endorsed plots, the only one to succeed was the 2005 London bombings, causing a death toll of 56, including the four terrorists [12]. In terms of Inspired attacks, two plots succeeded with widely different results: the Tradebom plot of 1993 which caused six deaths [13], and the attack on the Madrid Train System of 2004, causing 191 [14]. Looking at the attacks, the first three show decreasing lethality as Al Qaeda involvement decreases, however the final attack is very lethal and as such breaks this pattern. However, even Orsini's model had such an exception, the 2016 Nice Truck attack, with 86 victims [15], far above the average for Untrained Lone Wolves; what is important is that the general pattern holds. In the case of Silber's analysis, it is difficult to ascertain whether the general pattern holds even in light of this exception, given that most of the attacks analyzed did not succeed. However, reviewing the complexity of the plans, and the materials used, it can be reasonably held that a higher Al Qaeda involvement corresponds to more complicated plans and deadlier weapons. As such, it seems reasonable to conclude that, similarly to Orsini's model, a higher involvement of a larger terrorist group results in more lethal attacks. However, the importance of contact with a terrorist group is not only important in terror attacks, but also in the process of radicalization that individuals may undergo.

As we have seen through the review of two models for analyzing terror attacks in the previous chapter, a major descriptor of the lethality (amount of damage/number of victims) of a terror attack is the level of involvement a major terror group has in said attack. Silber considered the so called "Al Qaeda factor" in evaluating the involvement said terror group had in a large number of plots between the 1990s and the early 2000s, concluding that Al Qaeda's role is on the decline and urging policy makers to focus on local counterterrorism, as most of the plots came from terrorist that radicalized in the west. Our analysis further reveals that a higher level of Al Qaeda involvement also creates more lethal attacks. Orsini, on the other hand, categorizes terror attacks based on whether ISIS was involved and whether it is a single attacker or a cell. He concludes that ISIS involvement significantly raises the lethality of an attack, even if the attacker is a single terrorist.

However, the involvement of a terror group is not relevant only in a terror attack, but, as will be argued in the present chapter, it has a significant effect on radicalization as well. This will be argued by analyzing various different radicalization models and pointing to recurring concepts among them, before utilizing concepts from System Dynamics in order to tie what we have discovered thus far together.

2.4. Silber and Bhatt Model

The model developed by Mitchel Silber and Arvin Bhatt [16] is a radicalization model in which ideology plays a large role in the radicalization process, similarly to other radicalization models. In this model, Silber and Bhatt focus on radicalization that takes place in western cities (thus the title of the paper "the homegrown threat"). This is in continuity with the conclusions reached in Silber's book "The Al Qaeda Factor"; as has been explained, Silber notes that Al Qaeda involvement in terror attacks has been declining and urges policy makers to focus on local counterterrorism efforts. A radicalization model that focuses on the specific "type" of radicalization that the main perpetrators of terror attacks underwent in the attacks Silber studied is a logical contribution to this "invitation". The model envisions four steps in the radicalization process, that we will now look at one by one.

- Pre-radicalization: this is the starting point, when individuals come into contact with the jihadi or other terrorist ideology. There is no initial condition of relative deprivation that would spur radicalization. It is the terrorist ideology itself and a "cognitive opening" [17] (that will be explained in the next step) that would push otherwise "normal" people to begin the radicalization process.
- Self-Identification: after a cognitive opening, individuals begin approaching the terrorist ideology, meeting with like-minded people and begin the process of changing their identity. The concept of "cognitive opening" refers to a catalyst that opens individuals to great change and is a crucial element. In this model, the cognitive opening will take the form of a great trauma to the individual in question, be it Economic, Political, Social or Personal. An example of an Economic trauma could be the loss of a job; a Political trauma could be the start of an international conflict; a Social trauma may be an inability to integrate into a new community following migration; finally, a personal trauma may be the death of a friend or family member. Whatever specific form it takes, this trauma will make the individual question their previously held beliefs, and begin looking for a "solution": something that will help them reorient themselves. At this stage the terrorist ideology can become a "beacon of salvation", offering a new way of life; as such it is clear that ideology plays a key role in this model, as without it the radicalization process may not even begin.
- Indoctrination: in this phase the individual will, as the name implies, be indoctrinated, usually with the assistance of a person well integrated into the terrorist organization. This "contact point" is important and has been mentioned before by Silber in "The Al Qaeda Factor". This person is the so called "Link man", who puts the radicalizing individual in contact with a terrorist group and will eventually facilitate his joining of said group. As the indoctrination continues (in a far more intense manner if a terrorist group is joined) the individual will become gradually more radical, and they will

begin to believe that it is time for action. As such, in this phase the mental preparation to commit a terror attack begins.

- Jihadization: at this stage the radicalization process is complete, and the individual will accept that a terror attack is necessary. As such he will begin to plan a terror attack, alone or with others, by selecting a target, obtaining materials, creating a plan, etc. This phase is much faster than the others and may in some cases last only a few days.

In this model there are three key points in the process that should be noted: first, in the "Self-Identification" phase we introduce the concept of a "cognitive opening", an element alluded to in the introduction of the chapter and that we will see again in the models to come. Second, it should be noted that "ideology" plays an important role in the radicalization process, as it is the main factor that will start radicalization after a cognitive opening. The final element is the "Link Man", found in the indoctrination phase; this is the contact point with a terrorist group that allows a radicalizing individual to access said group, furthering radicalization and gaining access to the group's resources. For now, we should bear these three points in mind, as we will return to them after we have analyzed all the radicalization models of interest to us.

2.5. DRIA Model

The "Deconstruction, Reconstruction, Integration, Alienation" (DRIA) model [18] developed by Alessandro Orsini is a sequential model, meaning that envisions radicalization as a process that follows a predetermined sequence of "steps". Similarly to that of Silber and Bhatt, it is focused, and does not attempt to explain all types of radicalization with a single model, but instead focuses on a specific type. In this case, the focus is on the radicalization of terrorists by vocation, or "Vocational Terrorists", introduced in the previous chapter. These are terrorists that make the terror ideology the most important aspect of their identity and dedicate all of their efforts to reinforcing it. This is performed in order to respond to a perceived "need" of the terrorists; an interior, spiritual, need to give meaning to their lives and reduce "Existential Anxiety". As such, once again it can be seen that ideology plays a central role in the radicalization process, as we will see in more detail briefly. The name of the model (DRIA) is an acronym, with each letter representing a step in the radicalization process; we will now go through each step one by one.

- D—Disintegration of Social Identity: this is the starting point of the radicalization process, where an individual through some great event or trauma has his previous identity destroyed. This trauma leads to the "Cognitive Opening" that was explored in Silber and Bhatt's model. In the present model, the cognitive opening represents a turning point for the individual in question; given the destruction of what they believed to be "real" they seek new answers and a new way of life. At this stage there are many paths forward, and radicalization is but one of them. Indeed, individuals may choose to remain passive and not enact any change, or they may reinvent themselves in a "healthy" manner; embracing a radical ideology is just one of the many paths one may take at the crossroads of the first step [19,20]. As such, once again ideology is at the forefront of the radicalization process, as it is the key in determining whether the process will even begin: indeed, if there is no terrorist ideology, or if the ideology is not "convincing" then radicalization under the DRIA model will not even begin.
- R—Reconstruction of Social Identity: at this step, individuals that come into contact with the Jihadi ideology may choose to use it as the basis for rebuilding themselves, as was said before. The Jihadi ideology is excellent at providing "lost souls" with a new purpose. Indeed, it is an ideology that gives a clear "mission" that is filled with meaning; the perfect remedy for people who have lost their sense of orientation and truth as a result of the first stage of the model, the Disintegration of Social Identity. During the process of reconstruction under a Jihadi ideology, individuals will create a new "radical mental universe" for themselves, inspired by the radical ideology, that mutates their worldview into a categorical "us-versus-them" mentality.

- I—Integration in a Revolutionary Sect: at this stage the now cognitively-radicalized individuals will seek out likeminded people. Some will succeed in establishing contact with other radicalized individuals or with terrorist organizations and some will not. In the case of those that do not, they may still believe themselves to be a part of the organization through an imagined community, meaning they identify with the organization despite not having ever had contact. From this step we can see the groundwork for Orsini's model for terror attacks, based on what type of contact cognitively radicalized individuals will make. If they make contact with other radicalized individuals, but not a terror group they may evolve into an autonomous cell; if they contact a terror group they may evolve into either a trained lone wolf or a terror group (ISIS) led cell; if they are unable to establish any form of contact they may become untrained lone wolves.
- A—Alienation from the Surrounding World: the final stage in radicalization is crucial in enabling individuals to actually kill another human being. Alienation from the outside world is as simple as the name implies; the group into which an individual has integrated will forbid contact with the western world, which allows time for "traditional" morals to phase out and the radical ideology to fully mature. However, alienation may also be manifested on an individual basis, given that, as was seen in the previous step, it is not assured that a cognitively-radicalized individual will succeed in establishing contact with others, be they radicals or a terror group. After sufficient alienation, individuals will now be able to kill others, and as such the radicalization process is complete.

The DRIA model is once again a more specific model, looking only at a certain type of radicalization; in this case that of terrorists by vocation. As with Silber and Bhatt, ideology plays a central role, as it is the key to beginning the radicalization process after the initial "disintegration". Furthermore, the cognitive opening is once again the necessary precondition to allow the ideology to be accepted and the radicalization to progress. Finally, contact with a terror group is another common variable, however it is more elaborated in the case of the DRIA model, allowing for various outcomes depending on the type of contact established. Once again, we should keep these elements in mind as we move forward in our analysis.

2.6. Quintan Wiktorowicz's Model

The model developed by Quintan Wiktorowicz [21] is based on the participant observation of a specific radical group, al-Muhajiroun, in order to understand how it may turn "normal" people into radicals. Participant Observation, the research method used by Wiktorowicz, is a type of data collection in which the researcher fully immerses him or herself into the reality to be studied [22]. This is performed for various reasons, but in Wiktorowicz's case the objective was to view radicalization from the point of view of the individual that radicalizes so as to understand the reasoning behind joining a radical Islamic movement. As a result of his analysis, Wiktorowicz concludes that individuals become radicalized and join terror groups as a result of an intense resocialization that said groups enforce; through this process individuals come to orient all their judgments based on the values the terror group imposes upon them through resocialization and isolation from other systems of judgment (the western world). The question is thus why individuals would approach these groups in the first place; the answer, according to Wiktorowicz, is to be found, once again, in a cognitive opening. There is not much new to say about the opening itself: individuals that have had their previous worldview destroyed will seek new truths, at which point the ideology of a terrorist group may come into play and begin the radicalization process. Wiktorowicz notes however, that in the case of al-Muhajiroun, the group attempts to initiate a cognitive opening through the showcasing of "shocking" material, designed to make individuals begin to question what they believe; this is an interesting insight to keep in mind, as we shall see.

It is worth mentioning that the three models presented here represent only a portion of the studies on radicalization dynamics, with many other valid theories and models

existing. The reasoning behind our selection is due to the fact that they constitute good "sequential/phase" representation models. In other words, they break radicalization down into a "step by step" process, providing an interpretation that is more schematic than other theories. Said interpretation lends itself to a translation into simulation models, as shall be seen in the next section. In particular, the existence of mutual relationships among various aspects at stake and the circular interdependencies that we have found call for the adoption of a systemic view through an inherently systemic modeling and simulation methodology, which is System Dynamics. However, this does not mean that the models chosen are the only ones suited to the task; future research may revisit the model presented in this paper in order to improve and/or enrich it through the adaptation and implementation of additional theories and phenomena, allowing for a more complete view of the issue studied. A non-exhaustive list of valid literature which may merit investigation and possible implementation in future developments includes: Moghaddam's "Staircase" model of terrorism [23] which involves a metaphorical staircase, where each step is influenced by a specific psychological process; the "Motivational imbalance theory" [24] which argues that radicalization is founded upon the three pillars of needs, narratives and networks; "Identity fusion" [25] which involves the union of the personal and social selves; McCauley and Moskalenko's book "Friction" [26], which divides radicalization into individual, group or mass radicalization. However, at present, the literature reviewed above is sufficient to construct a very first model that will serve the purpose of starting to investigate terrorism through a System Dynamics approach.

3. Methodological Approach

Thus far we have looked at two models for interpreting and clarifying terror attacks, and three for mapping out the radicalization process. The analysis of the first two models revealed that the degree of involvement a larger terror group such as Al Qaeda or ISIS has in a terror attack will have a significant effect on the lethality of said attack, with higher involvement causing far more damage. Then, through consideration of the three radicalization models, we have noted three common elements: "Cognitive Openings", "Radical Ideology", and "contact with other radicals or terror groups". Stemming from the capacity of System Dynamics to highlight within complex systems a variety of elements useful to policy modeling [27–29]. We will rely on such invaluable ability, aimed at creating policies that support curbing terrorism damages [30], so to identify the systemic relationships among several elements in the overall system.

In order to construct our model, we will carry out a "Systemic-fication" and intertwined combination of the five models presented in the first section. Firstly, the "Al Qaeda Factor" has shown that an attack will be more deadly and/or complex if there is the involvement of an experienced terrorist group; the more involvement there is the more deadly the attack. In this sense, the model can be seen (in system dynamics terms) as a "flow" of casualties over time which feeds into a "stock" of casualties, with a variable called "terror group involvement in attacks" acting upon the flow in a positive manner; as the involvement increases, so does the flow of casualties. This small model may be seen in Figure 1.

Next, Orsini's model argues that terror attacks may be broken down into three and a half types: ISIS controlled, autonomous cells and trained and untrained lone wolves. It is again argued that the scale of damage which will be produced is related to the involvement a terror group (in this case ISIS) had in the attack. This model may as such be envisioned as four stocks, one for each type of terrorist, with one flow each, measuring the rate at which they carry out attacks. These for flows thus influence a flow of casualties, which will flow into a stock of casualties, as may be seen in Figure 2.

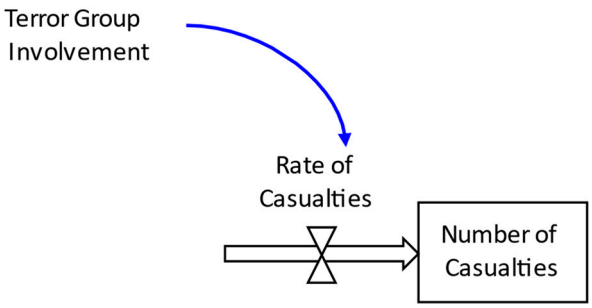

Figure 1. Silber's model in System form, source: author's own elaboration, based on "The Al Qaeda Factor".

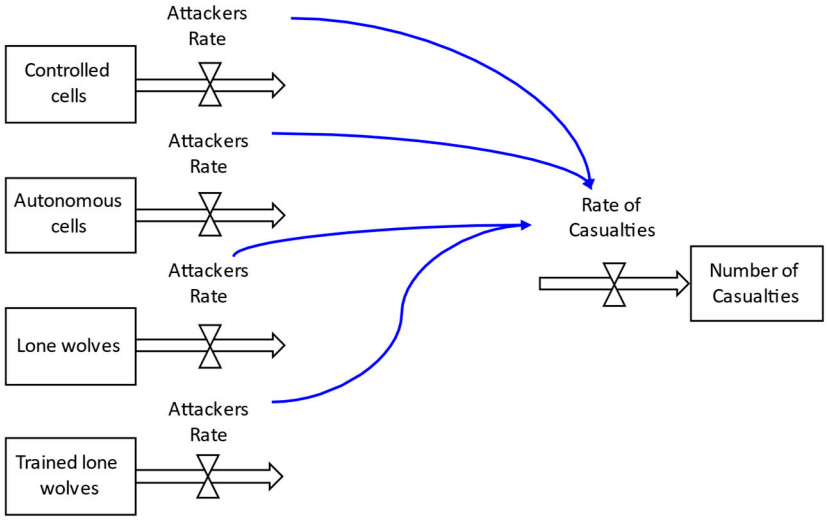

Figure 2. Orsini's model in System form, source: author's own elaboration, based on Orsini's work.

Turning to the radicalization models considered, that of Silber and Bhatt can be viewed as a stock and flow model, in which individuals start as "normal people" then gradually transform into radicalized and trained terrorists. The key element which kickstarts this model is the "cognitive opening", with further importance placed upon the necessity of contact with a terror group to nurture the radicalizing individual into a terrorist. This model may be seen in Figure 3.

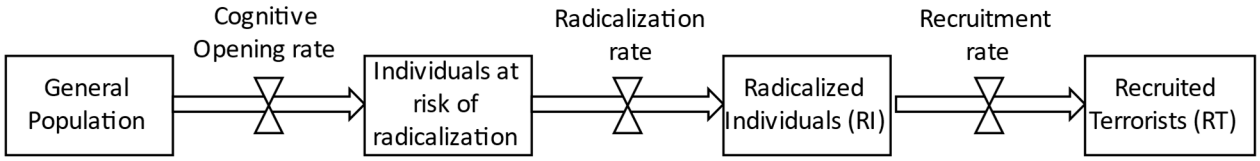

Figure 3. Silber's radicalization model in System form, source: author's own elaboration, based on Silber's work.

Much the same may be said of Orsini's DRIA model, however some additions are made: first, the possibility for cognitively opened individuals to "recover" rather than progress down the radicalization path is allowed, creating a loop inside of the system; second the possibility for individuals to become terrorists without extended contact with a terror group is envisioned, creating a split in the model depending on the degree of contact that is had, as may be seen in Figure 4.

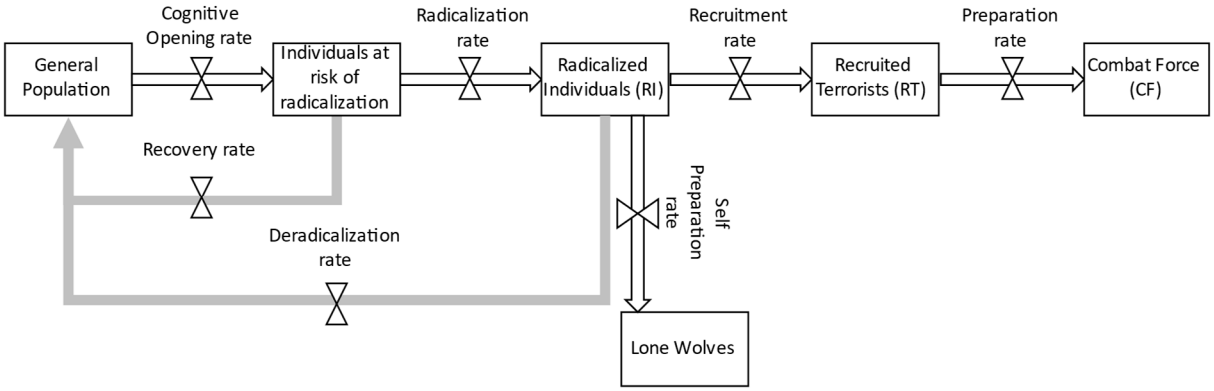

Figure 4. Orsini's DRIA model in System form, source: author's own elaboration, based on Orsini's work.

Finally, Wiktorowicz's model does not make any changes to the structures seen in the other two, but highlights, once again, the importance of cognitive openings and terror group contact in determining the "success rate" of a radicalization process. Furthermore, Wiktorowicz points out how terror groups may "induce" radicalization through the use of propaganda constructed with violent material, oftentimes born from the group's own activities; we may as such envision variable called *Number of Casualties* (given that these models only cover radicalization and not attacks we do not yet have a stock value for casualties), which influences the radicalization rate, as may be seen in Figure 5.

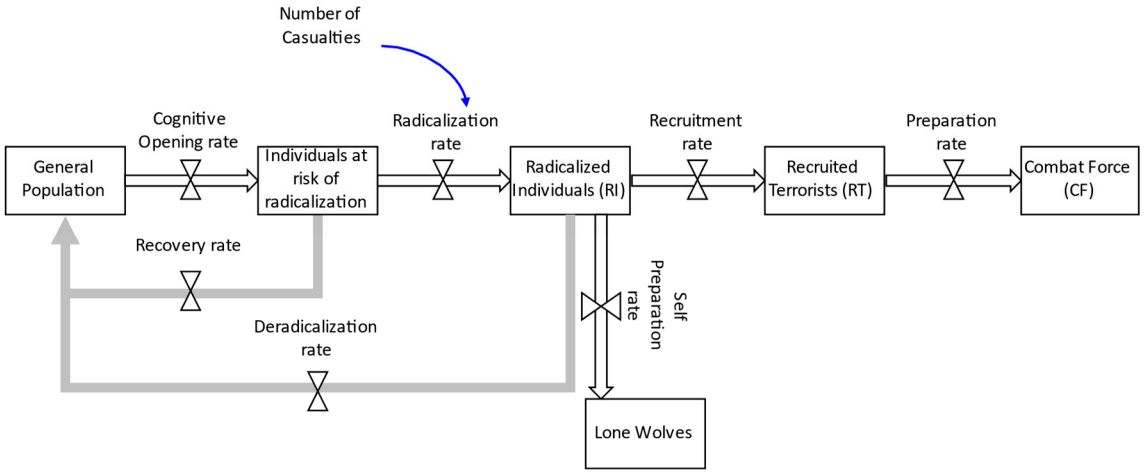

Figure 5. Previous model enriched with Wiktorowicz's insights, source: author's own elaboration, based on Orsini and Wiktorowicz's work.

By combining the five models, we are able to construct the model in Figure 6, which includes enrichments born from extra sources that will be detailed shortly.

The model breaks terror attacks into a process that begins with radicalization and ends with a number of casualties. In this specific scenario, the territorial focus of the model is Europe, however it could be expanded or focused as needed or desired. The smaller territorial focus selected in the present paper stems from the "newborn" status of the model; a smaller focus allows for better validation and initial testing, with improvements and expansion left to later work. The model functions as follows: due to cognitive openings, a portion of a population will become at risk of radicalization; of this portion some will radicalize and others will "recover", meaning they will find a different way to deal with the trauma. Those that are radicalized then have three paths ahead of them: they will either be recruited into a terror organization, become lone wolf terrorists or deradicalize and return to the "starting point". Lone wolves will immediately conduct an attack, while

recruited terrorists will be trained, some failing and some succeeding. Those that succeed will become a highly lethal combat force and conduct terror attacks. The quantity of attacks, both trained and lone wolves, will then pool into a rate of casualties, which over time will increase the total number of casualties accumulated. As these casualties accumulate, terror groups increase their "propaganda material" allowing them to increase their efforts to induce radicalization in western populations, thus creating a feedback loop in the system. Before explaining the model in more detail, a small aside must be made as regards the terminology used. Specifically, the choice has been made to utilize the term "lone wolf" to indicate those terrorists that receive no training and are not formally recruited by a terror group. This has been performed in order to maintain consistency with the main literature that has been used in the construction of the model, which has utilized this term to express the same concept. However, it is acknowledged that this term in recent years has come under scrutiny due to its misuse in mainstream discourse and its misinterpretation of how terrorists which conduct attacks alone operate in actuality [31]. Indeed, it has been pointed out that other terms would be more pertinent, such as the term "lone actor". While the authors agree that use of the term "lone actor" would be preferable from a technical point of view, priority has been given to maintaining consistency with the literature selected.

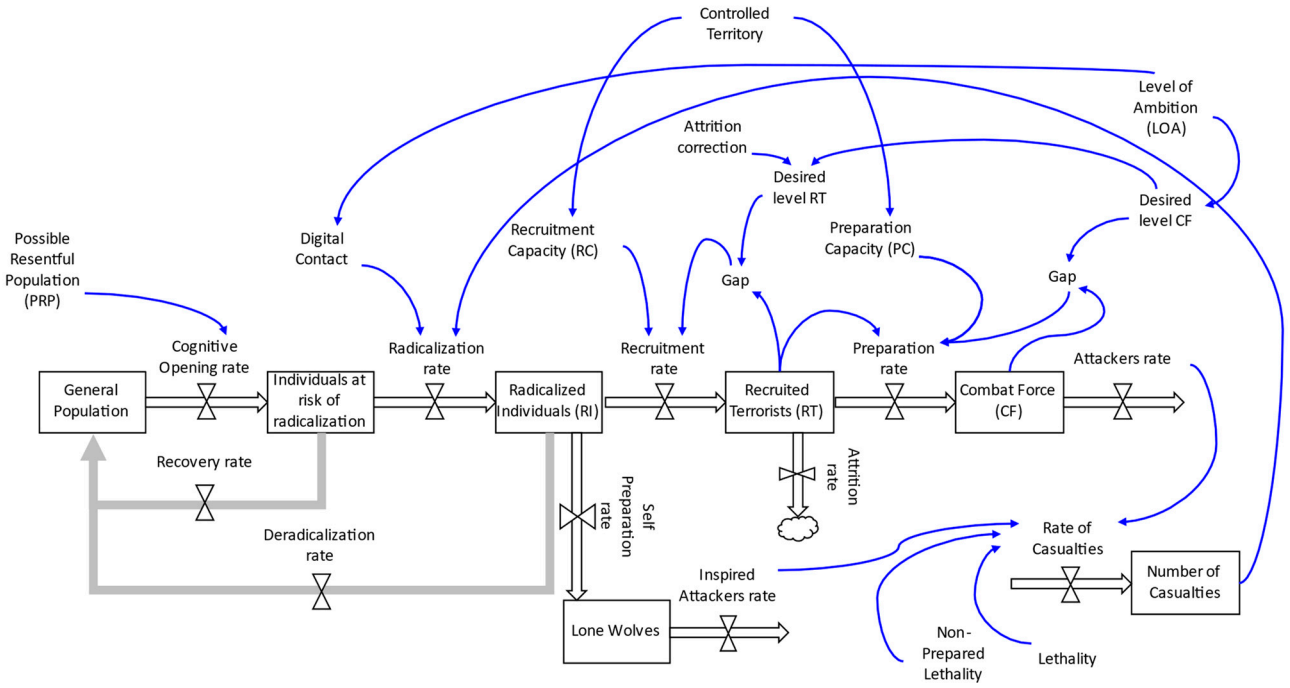

Figure 6. Final Stock and Flow model. Source: authors' own elaboration.

Returning to the presentation and explanation of the model, other sources have been used in order to compliment the main literature used in the construction of the model, primarily as regards the variables which influence the process. As such, we will look at these variables more in depth, pointing out the reasoning behind their inclusion (whether it comes from already seen literature or additional research) as well as the sources used. Starting with the cognitive opening rate, the first variable we will use is the number of people in poverty in Europe [32]; the next variable we will include is the quantity of first and second-generation immigrants living in the EU [33]; the final variable we can identify in the creation of our measure is related to education [34]. Indeed, as has been seen in the radicalization models studied, cognitive openings are born from traumas that make individuals more receptive to drastic life changes; however, given that measuring a precise rate for this phenomenon is impossible, we will combine these three variables into the *Possible Resentful Population (PRP)* as a measure of those that are most at risk of cognitive openings. Note that we are not arguing that the selected variables are the only factors

which determine a propension to cognitive openness, however given the nature of cognitive openings other variables are difficult to include. Indeed, as has been seen in the literature, cognitive openings are a deeply personal phenomena; the traumas which cause them often times are personal, such as the death of a loved one, the loss of a job, contracting a serious illness, etc. Inclusion of variables that take into account these "personal" factors, while ideal in theory, in practice is difficult due to the lack of data. Indeed, measuring how many people in Europe lose a loved one each year or become ill is difficult due to the lack of specific data; even setting arbitrary values is difficult for the same reason. As such, the variables which have been selected focus on measuring the aggravating factors toward traumas born from marginalization, given that marginalized individuals are more at risk of cognitive openings born from more socio-economic traumas. In this sense, our selected variables measure only a portion of the influences on the cognitive opening rate, with other factors being too difficult to feasibly include. This is unfortunately a limit of the model. Next is the radicalization rate; the first variable we will consider comes from the activities of the "Al Hayat Media Center" [35], which is a media wing of ISIS focused on creating publications that target a Western audience. We will also consider the share of the population that has used specific software to access the dark web [36]. Exiting the deep web, but remaining online, we have the amount of pro ISIS twitter accounts that exist and the amount of terrorist propaganda that has been removed from Facebook [37,38]. Having considered the influences on radicalization that are in the digital sphere (grouped into the *digital contact* variable), we consider those in the physical one, these being the *number of mosques* in the area of study [39] and the *number of prisoners* [40]. All these digital and non-digital variables help measure the likelihood of contact with a terror ideology. Indeed, as was seen in the literature, contact with a terror group is a key factor in determining whether radicalization will occur following a cognitive opening. While the contact envisioned was mainly intended to be physical, new technologies have enabled terror groups to contact individuals remotely, as may be seen in the sources cited regarding the relevant variables. As such, the inclusion of said variables in the model is useful. Next, the *recruitment rate* is constrained by the *recruitment capacity* which measures the ability of a terror group to recruit new members. The other variables that would influence the recruitment rate are the same factors that affected the radicalization rate, given that, as was seen in the literature, the key factor in determining recruitment into a terror group is whether or not contact with said group has occurred, and this has already been measured inside of the model. As such, the influence on the recruitment rate is already "internalized" in the system by the effect on the radicalization rate. The preparation rate follows the same logic, being constrained by the preparation capacity, which measures the capacity of a terror group to train and arm terrorists. The next variables are *lethality* which measures, on average, how many casualties one trained terrorist can produce, and *non-prepared lethality* which measures the casualties that lone wolves are able to produce. These variables are included based on the observations made in the models which analyze terror attacks, according to which there is a significant change in capacity to due damage depending on whether the perpetrator/s had assistance from a terror group or not. The terrorist's *Level of Ambition (LoA)* is defined as the amount of casualties a given terror group would like to reach in a given time period, and is set arbitrarily. From it, two variables called "desired level" variables are born. These two variables are then compared against the value observed in the relevant stocks, creating two "gap" variables which will combine with the two "capacity" variables defined earlier; together these will help determine the recruitment and preparation rates. In the case of the *desired level of RT*, a further variable is included, namely *attrition correction* which serves to offset the attrition rate, a measure of the quantity of those recruited that, for whatever reason, fail to receive training. "Controlled territory" measures the amount of territory a terror group controls [41], and will determine its capacities (recruitment and preparation). The inclusion of this variable is due to the fact that it is able to act as a good explanatory variable of the capacities of a terror group. Indeed, in order to recruit and train new terrorists there is a need for money, supplies, infrastructure, etc., all of these factors

require the terrorist group to have territory under their control. Consider, for example, that in order to obtain finances exploitable territory is needed: territory could, for example, contain oil reserves to allow for the sale of oil or populace to extort for money through illegal taxation [42]. As such, using controlled territory as a variable allows for the model to avoid unnecessary culturing while still explaining terror groups capacities. Finally, the relationships between variables, stocks and flows have all been defined by analyzing European data on demographics [43] and terror attacks [44], specifically ISIS [45], in order to set the correct relationships between the data. The reasoning behind the selection of ISIS as a model terror group is twofold: first it is a pragmatic choice, given that in terms of data availability there is more relevant information regarding ISIS than any other group; second, given that the geographical area of study is Europe and the type of terrorism studied is Jihadist, choosing the Jihadi terror group which has been the most active in conducting attacks against Europe is a logical conclusion. Of course, future research may apply the model to different terrorist groups and may change the territorial focus; all that is needed is to adjust the model to suit the desired context of study.

Table 1 summarizes the base values that have been used for the variables of the model:

Table 1. Base case variable values. Source: authors' own elaboration.

VARIABLE	BASE CASE VALUE
Immigrants (Number of People)	23,700,000
Poverty (Number of People)	96,500,000
Low Education (Number of People)	102,812,300
Dark Web Users (Number of People)	22,000
Twitter Accounts (Number of Accounts)	1000
Facebook Radical Content Views (Number of Views)	10,000
Level of Ambition (Number of People)	1000
Non-Prepared Lethality (Number of People)	6
Lethality (Number of People)	66
Deradicalization over time (% of People)	0
Territory Controlled (Km^2)	100,000

The variables Immigrants, Poverty, and Low Education, are pooled together with an overlap correction in order to form the possible resentful population. Similarly, the variables Dark Web Users, Twitter Accounts and Facebook Radical Content Views are grouped into the Digital Contact variable. The last four variables were not set through the use of a direct source, but were input in the following manner:

- The *Level of Ambition* is an arbitrary value that measures the number of casualties a terror group would like to reach per year. It drives other variables in the system, such as the *desired level of CF*, by calculating what inputs are required to reach the desired output.
- The *non-prepared lethality* and *lethality* variables have been calculated by looking at terror attacks conducted over the past 15 years, dividing the attacks into either "lone wolf" or "terror group controlled" with reference to the literature reviewed above, counting the number of casualties for each attack and thus calculating how many casualties one terrorist is able to produce on average. As such it was found that a trained and terror group supported terrorist can produce, on average, 66 casualties while a lone wolf can produce six.
- The territory controlled was arbitrarily set in order to match a "large terror group", using ISIS's maximum expansion as a reference.

As regards the stocks of the model, as may be seen in Table 2, arbitrary initial values have been assumed for all in order to "imagine" that the process described is not starting from scratch but ongoing. The only exceptions are the general population, which has been set in order to mirror the current EU population and fixed, so as to assume full refilling of the stock as it is drained by the mode, and the number of casualties, which has no initial value.

Table 2. Initial stock values. Source: authors' own elaboration.

STOCK	BASE CASE VALUE
General Population *(Number of People)*	447,010,000
At Risk Individuals *(Number of People)*	200,000
Radicalized Individuals *(Number of People)*	100,000
Lone Wolves *(Number of People)*	9
Recruited Terrorists *(Number of People)*	16
Combat Force *(Number of People)*	16
Number of Casualties *(Number of People)*	0

4. Model Simulation and Result Analysis

The program we used to simulate our model is the Silico® app, a web-based program available online at the "Silico.app" [46] url. Before simulating the model, we will clarify what assumptions and conditions we will use. First, while the model was constructed using data from ISIS and Al Qaeda, it has been designed in such a way as to be independent from these groups; as such simulations may be made considering different terror groups, real or hypothetical. Next, we will assume our general population stock to remain constant, given that we are not analyzing the possible inflows it may have. While this is not reflective of reality, we are not interested in understanding the demographic factors that contribute to a given population size: as such, we will assume the stock will remain constant and not decrease as it is drained. The second clarification regards the time measurement we will use: we will run simulations over a period of 20 years, with each "tick" of our system representing one year. Next, we will assume the level of ambition of the terrorists to remain constant, at 1000 casualties per year. This means that the "goal" of the system is to output a total of 20,000 casualties over its simulation period, however it is not a given that it will reach this number. Another assumption we will make is that all the attacks carried out by terrorists will succeed. As such, we are effectively creating a "worst case scenario" in all our simulations, as we are not considering the capacity of different security bodies to halt attacks once they have been planned.

4.1. "Real-World" Scenario

Before this baseline simulation, however, we must validate the model, that is verifying whether or not our model is descriptive of reality; in other words, we need to check that the simulated behavior (our outcome) is reflective of the actual past observed behavior over time, that is time-series of data that has been observed in the past. Our "real world" data will come from Europol's yearly terrorism reports, which cover data starting from 2014. According to these reports, Islamic terror attacks produced roughly 3218 casualties from 2014 to 2021; given that the final output of our model is casualties, a time series comparison of the real-world data and the model prediction will serve well in checking whether the model is accurate. Said comparison may be found in Figure 7:

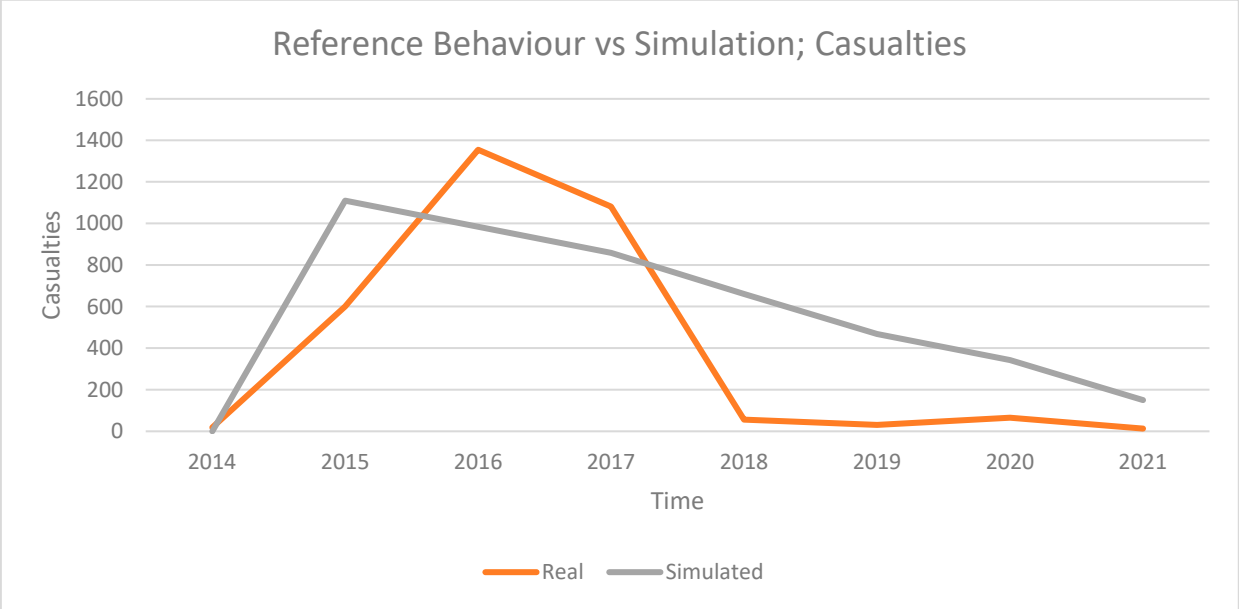

Figure 7. Reference behavior vs. simulation results. Source: Europol; authors own elaboration.

Running the simulation yields a total of 4572 casualties over eight years, with a trend over the timespan analyzed following that observed in the real-world data. The key element in this first simulation has been the *controlled territory* variable. Indeed, while Europol provides data regarding the casualties produced, other sources document that ISIS, the main perpetrator of the attacks which occurred in the studied timeframe, went from having 100,000 km^2 of territory in 2014, to just 4000 km^2 in 2019 [47]. As such, setting our model to mimic this behavior, as may be seen in Table 3, has allowed us to verify that a change in a variable in reality, when transposed into the model, will cause the outcomes to mirror each other, meaning we can assert with sufficient confidence that our model is descriptive of reality. Furthermore, the identification of the link between casualties and territory would have been interesting in of itself, however the model allows us to formalize and quantify this relationship, clarifying that it is not a direct linear link between the two, but rather the effect that territory has on terror group's capacity to recruit and train terrorists that will then determine their capacity to cause damage. The identification, quantification, and verification of this link (and as a consequence, the model itself) allows us to proceed in using the model as a tool to search for leverage points in which policy intervention would be ideal.

Table 3. "Real world" variable adjustment. Source: authors' own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	22,000	22,000
Twitter Accounts (Number of Accounts)	1000	1000
Facebook Radical Content Views (Number of Views)	10,000	10,000
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	66	66
Deradicalization over time (% of People)	0	0
Territory Controlled (Km^2)	**100,000**	**100,000–19,200 *per tick (min* 4000)**

4.2. Baseline Simulations & Simulation Analysis

It is now time to set our baseline simulation, the values of which may be found in Table 1. This simulation will be the one that we will use as a basis to compare all our planned policy interventions. The results obtained in this first run of the model will be what we will compare our future simulations (that will have policies integrated into them) against. In this first simulation we will assume our terror organization to have 100,000 square kilometers of territory under their control for the duration of the simulation; in other words, the terror organization will be at their peak performance. Our baseline simulation yields the following results:

Over the course of the simulation a total of 20,850 cumulative casualties are observed, with the rate of casualties remaining largely constant throughout the simulation. This makes sense, as in this scenario we are imagining that no action is taken against the terrorist group and they are free to conduct as many attacks as they are able; this means that they will constantly be operating at "maximum capacity", the rate of casualties will remain constant and the number of casualties will as such grow in a constant and linear manner, as seen in Figure 8. It should be noted that this trend of a constant yearly growth is not indicative of reality; in a real-world scenario some years may have no casualties while others have far more; the model is predicting a trend, not the specific pattern. However, while the specific pattern is not fully accurate, the general trend is, and as such we can begin drawing some conclusions. First, it can be noted that our large terror group has reached its set goal, even obtaining an extra 850 casualties. This is not so surprising as we have simulated them having a large amount of territory for the duration of the simulation. As such, we have assumed that no action has been taken against them and they have had ample land (and therefore resources) available to them in order to prepare their attacks. A second observation may be made if we compare the recruitment rate against our stock of radicalized individuals:

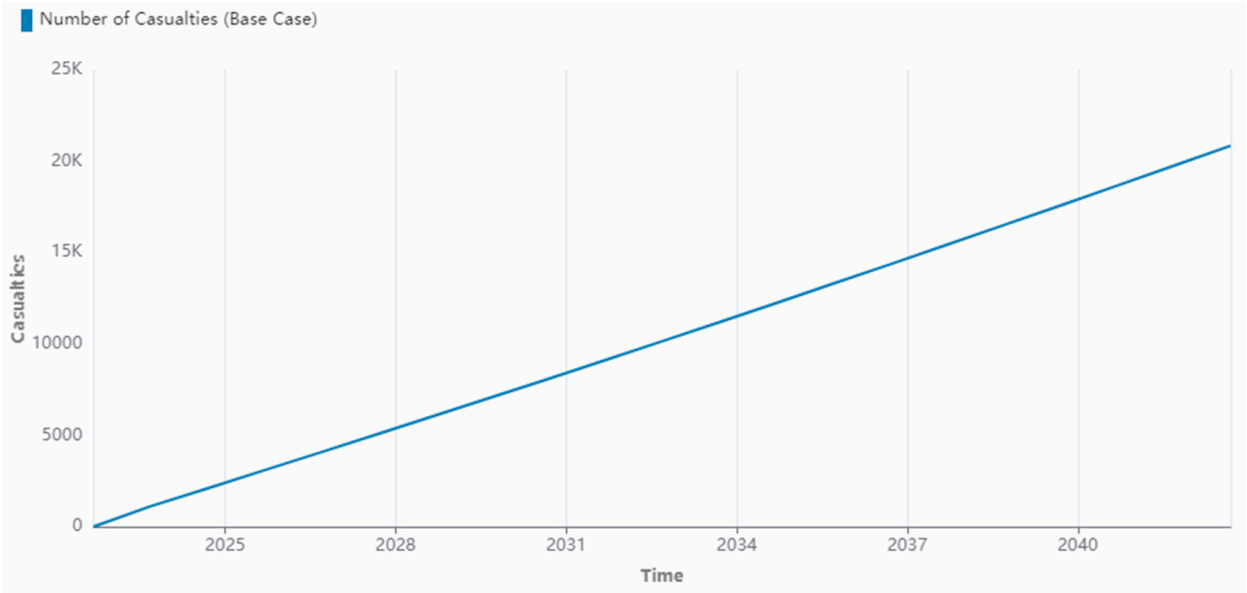

Figure 8. Baseline casualties. Source: Silico.app, based on authors' own elaboration.

In Figure 9, the blue line represents the trend of radicalized individuals, while the red one that of the recruited terrorists. A first observation is that the trend of the radicalized individuals stock; as can be seen it follows a slight "S" curve, in which it slowly accelerates its growth before beginning to reach a plateau. This occurs because, as we have seen, the number of casualties will increase our radicalization rate; as such, after the first few ticks of the simulation our casualties grow, causing the radicalization rate to grow and give the stock behavior over time an S shape. Focusing instead on the recruitment rate, as can be seen, the two values are hardly comparable. The radicalized individuals will number in

the tens of thousands, while the recruited individuals number in the tens. As such, we can see a fundamental asymmetry between the needs of the terrorist group and the availability of radicalized individuals. Indeed, the supply is far larger than the demand, given that terrorists do not require a large amount of trained attackers to reach their desired casualties. This would seem to suggest that as long as the terrorist group is large enough and, as such, able to train its needed quantity of prepared attackers, they will always have enough supply to reach their goals.

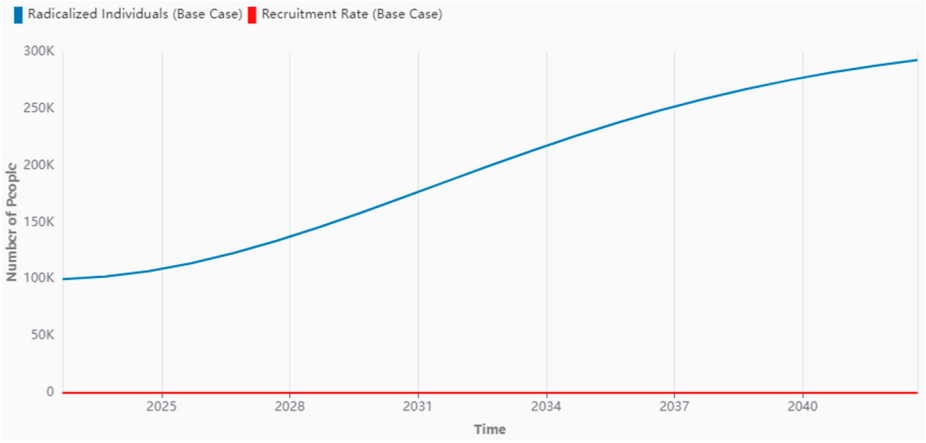

Figure 9. Baseline radicalized individuals and recruitment rate. Source: Silico.app, based on authors' own elaboration.

The question that arises, then, is: "what if the terror group had less territory under its control?" As we have seen, the controlled territory is important, as it is both a source of income and provides training grounds. As such, it is worthwhile to investigate what effect a smaller amount of territory will have on our casualties. We will run a new simulation, this time reducing the amount of controlled territory to a tenth of the baseline, only 1000 square kilometers, in order to investigate this issue. The results may be seen in Table 4 and Figure 10.

Table 4. "Low territory" variable adjustment. Source: authors' own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	22,000	22,000
Twitter Accounts (Number of Accounts)	1000	1000
Facebook Radical Content Views (Number of Views)	10,000	10,000
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	66	66
Deradicalization over time (% of People)	0	0
Territory Controlled (Km^2)	**100,000**	**1000**

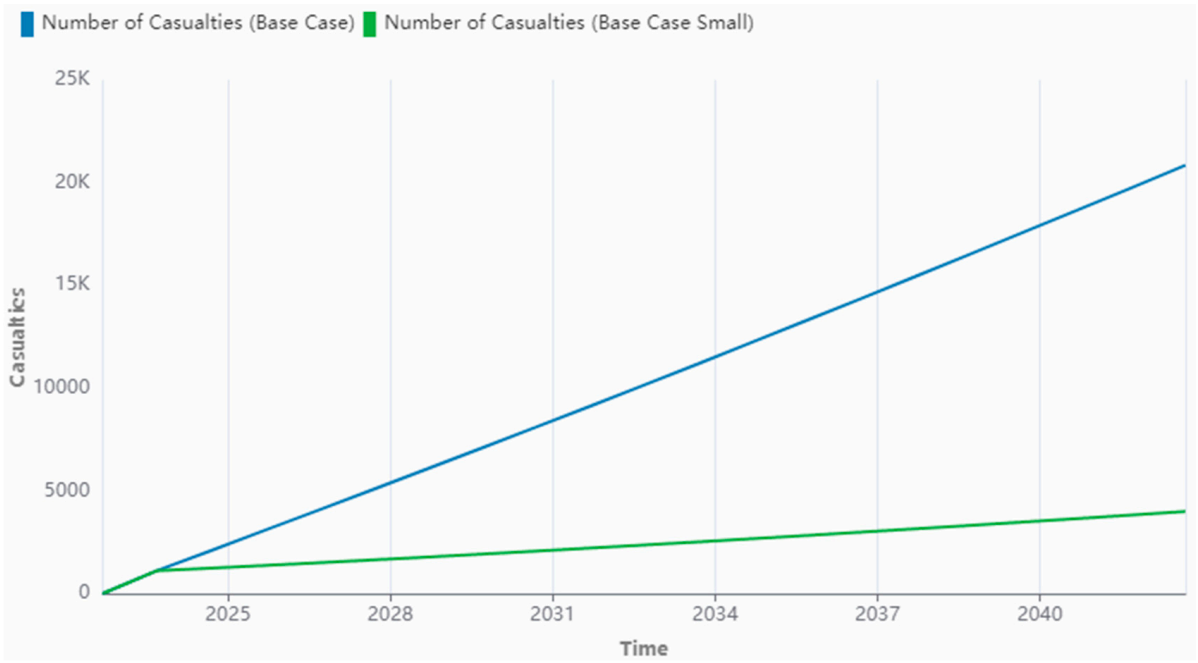

Figure 10. Casualties with maximum reduction of controlled territory. Source: Silico.app, based on authors' own elaboration.

The results are dramatic: the total number of casualties drops to 3966, a significant departure from our baseline. It is clear to see that the controlled territory of a terrorist organization (and as a consequence, their funds, training camps, weapon supplies, etc.) are crucial in determining their capacity to damage the west. Furthermore, the reduction in casualties will cause a drop in the radicalization rate, as a consequence also reducing the attacks carried out by lone wolves.

As such, we have concluded our baseline simulations and have gained some important insights for the identification of leverage points for policy intervention. The first observation is an important one, as we have determined that there is a large asymmetry between supply and demand in terms of the recruitment needs of a terror organization. Due to the strategies employed by terrorists in their attacks against the west (suicide bombing, etc.), they do not need a large amount of combat force, meaning a relatively low demand. On the other hand, the radicalized individuals that may become terrorists will always number far higher than the demand, meaning that terrorist organizations that are "large" enough will never have a lack of possible recruits. Furthermore, we have seen that the size of a terror group in terms of territory controlled is crucial in determining the amount of damage they may inflict on the west. This may seem an obvious statement, however what is interesting here is to understand the mechanics behind this relationship and use it to understand past and future dynamics. We will explore this notion as we begin to plot out possible policy interventions.

4.3. High Leverage Points for Policies

We will now start to model possible policy solutions, using the insight gained from our baseline simulations. It should be noted that these policy solutions are not excessively concerned with implementing realistic adjustments; the objective of the simulations in this section is to identify which types of policy create the most positive variation in the observed outcomes. In other words, we are looking for leverage points, points in which modifications made will produce noticeable changes in the final values observed in the simulations. Our baseline simulations have provided us with two main scenarios in which to model policies: the first is if the terror group is large, and the second is if it is small. These two scenarios will entail different strategies, and as such we must investigate possible policies for both.

4.4. Large Terror Groups

We will begin by considering the scenario in which the terrorist group has a large amount of territory under its control, signifying that it is relatively powerful. Various different interventions were tested, however the most effective are highlighted in the Tables 5–7 and Figure 11, which compares three different scenarios to the baseline simulation.

Table 5. "Reduce controlled territory" variable adjustment. Source: authors' own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	22,000	22,000
Twitter Accounts (Number of Accounts)	1000	1000
Facebook Radical Content Views (Number of Views)	10,000	10,000
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	66	66
Deradicalization over time (% of People)	0	0
Territory Controlled (Km^2)	**100,000**	**100,000–10,000 *per tick, starting from tick 2 (min 1000)***

Table 6. "Reduce lethality" variable adjustment. Source: author's own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	22,000	22,000
Twitter Accounts (Number of Accounts)	1000	1000
Facebook Radical Content Views (Number of Views)	10,000	10,000
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	**66**	**66 *until tick* 2, *then* 33 *for the rest of the simulation***
Deradicalization over time (% of People)	0	0
Territory Controlled (Km^2)	100,000	100,000

As may be seen in Figure 11, it was discovered that the best courses of action, ranked by effectiveness, are as follows:

1. Reduce the controlled territory of the group while also reducing their lethality.
2. Reduce the controlled territory of the group.
3. Reduce the lethality of the group.

Table 7. "Reduce territory and lethality" variable adjustment. Source: authors' own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	22,000	22,000
Twitter Accounts (Number of Accounts)	1000	1000
Facebook Radical Content Views (Number of Views)	10,000	10,000
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	**66**	**66** ***until tick*** **2,** ***then*** **33** ***for the rest of the simulation***
Deradicalization over time (% of People)	0	0
Territory Controlled (Km^2)	**100,000**	**100,000–10,000** ***per tick, starting from tick 2 (min 1000)***

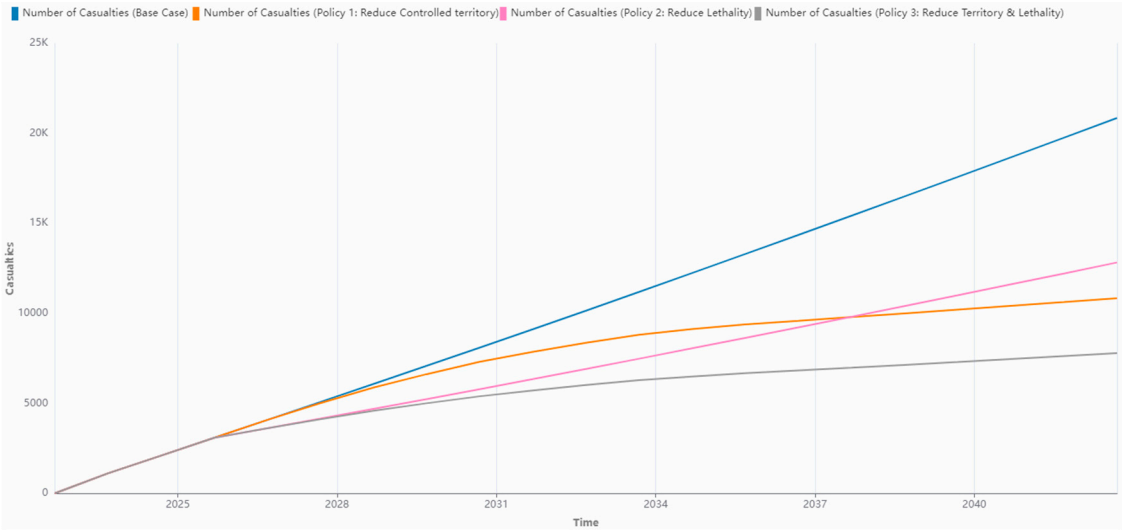

Figure 11. Policy performance comparison. Source: Silico.app, based on authors' own elaboration.

These policies will all reduce the number of casualties, however the first two will also change the trend of casualties, allowing for more long-term effects. While reducing territory is a simple policy to understand, some explanation regarding what "reducing lethality" means is warranted, given that it is less immediately obvious what types of policy this is inviting. Recall that the *lethality* variable has been defined as the number of casualties a single trained terrorist is able to produce on average. To reduce *lethality*, we must find a way to make it so that a trained terrorist is not able to perform at maximum capacity; in other words, we want to reduce the effectiveness of terrorists after they have been trained and begin plotting attacks. Policies that achieve this are those that focus on improving the capacity of national security entities to counter terrorism inside their own borders, such as the improvement of intelligence network's ability to identify and foil plots, or the improvement of law enforcement capacity to respond to attacks if they are launched. A point worth highlighting pertains to the combined policy; notice how given the nature of the integral relationships between stocks and flows, the combined action on two variables can produce a combined effect that is different from a linear combination. In other words, the combined policy produces exponentially better results, "shifting the curve" more than one would expect. If we consider these policies, we may notice that we are not suggesting

revolutionary new strategies; indeed, these policies have been employed in the past, both versus Al Qaeda and ISIS, and have indeed been successful. The original contribution being made, however, is understanding why these policies are successful; it is one thing to see that something works, it is another to understand why. In our case, we can see that reducing the territory of a group is effective specifically because it is limiting their preparation capacity. By removing their territory (and thus funding) they are unable to train and prepare new terrorists, leading to a decrease in their capacity to inflict damage, as may be seen in Figures 12 and 13:

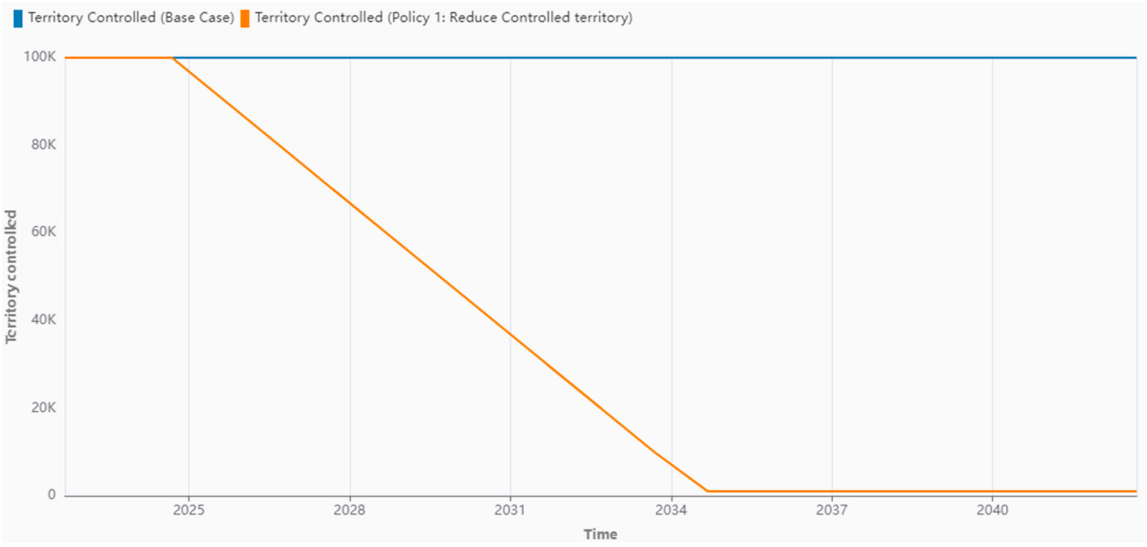

Figure 12. Change in controlled territory, source: Silico.app, based on authors' own elaboration.

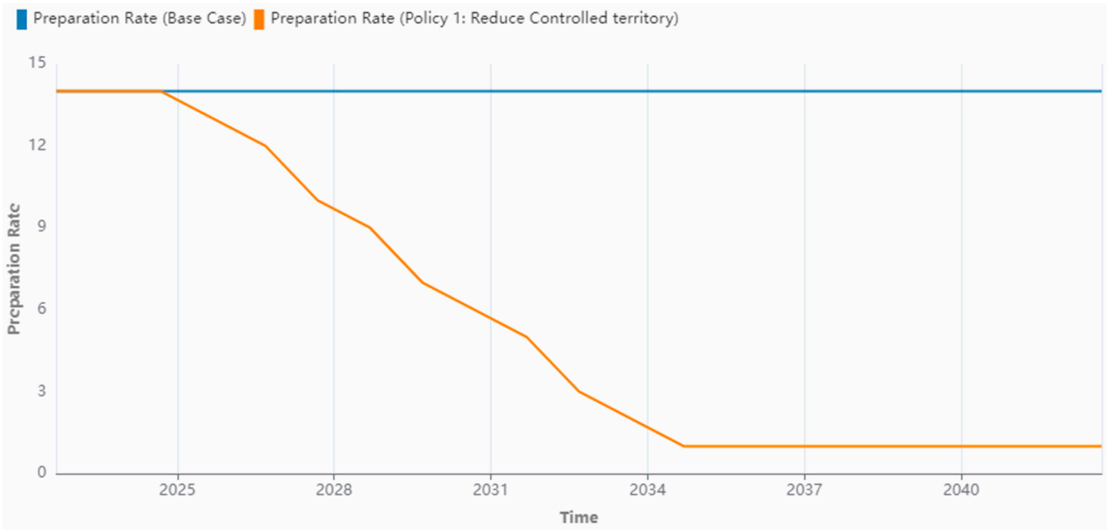

Figure 13. Preparation rate change as territory drops, source: Silico.app, based on authors' own elaboration.

If this specific mechanism did not exist, this relationship would not hold, and reducing their territory would have little effect. However, it may soon be that this relationship will not be as pronounced, as new communication technologies may allow for recruitment and training to occur without the need for large amount of funds or territory. Indeed, the policies suggested above have been used and they have succeeded, yet terror attacks continue, only following a new paradigm. Lone wolf attacks seem to be the premier strategy used by terror groups that do not have a lot of territory; instead of training highly lethal operatives, terror groups seek to use the over-supply of radicalized individuals in other

way. If they cannot recruit them, they can push them to carry out attacks on their own, intensifying their digital propaganda and outreach and supplying them with knowledge on how to carry out attacks. In other words, rather than transforming a select few into highly effective soldiers, they can push the radicalized individuals to take up arms independently, knowing that there is a large supply of them. Of course, one may wonder whether there is a need to envision different types of policy at all and whether the same strategies used against large groups would work against small ones. The reality is that if we are envisioning a small group we are already imagining that the group has very little territory and rather than relying on a low number of trained terrorists uses less lethal lone wolves. In other words, the identified leverage points of territory and lethality have already been squeezed dry and concentrating further on these leverage points risk alluding to unrealistic policies that prose unreasonable goals such as "total elimination of a terror groups territory" or "train law enforcement to a degree that they are able to fully eliminate casualties once an attack is launched". Furthermore, policies which are specific to small groups will be largely ineffective against large ones, as shall be demonstrated shortly. As such, while it is useful to know how to combat large terrorist groups, we must now consider how to combat smaller groups that use lone wolf attacks as their main weapon.

4.5. Small Terror Groups

Lone wolves, as we have highlighted, are the modus operandi of "modern" terror groups. Lone wolves are a strategy that take advantage of the asymmetry between supply and demand, but in a different way. Instead of highly training a few, terror groups seek to keep the stock of radicalized individuals high so that they will produce more lone wolf attackers over time. As such, the main policy goal we must pursue is that of reducing the stock of radicalized individuals, consequently lowering the casualties. Once again, various courses of action were tested, with the most promising being highlighted in Tables 8–10 and Figure 14.

Table 8. "Reduce digital contact" variable adjustment. Source: authors' own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	**22,000**	**11,000** ***at tick 1 and 0 from tick 2 onwards***
Twitter Accounts (Number of Accounts)	**1000**	**500** ***at tick 1 and 0 from tick 2 onwards***
Facebook Radical Content Views (Number of Views)	**10,000**	**5000** ***at tick 1 and 0 from tick 2 onwards***
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	66	66
Deradicalization over time (% of People)	0	0
Territory Controlled (Km^2)	**100,000**	**1000**

Table 9. "Increase deradicalization" variable adjustment. Source: authors own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	22,000	22,000
Twitter Accounts (Number of Accounts)	1000	1000
Facebook Radical Content Views (Number of Views)	10,000	10,000
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	66	66
Deradicalization over time (% of People)	**0**	**+0.05** ***per tick, starting from tick 2,*** **(*max* 0.7)**
Territory Controlled (Km^2)	**100,000**	**1000**

Table 10. "Reduce digital contact and increase deradicalization" variable adjustment. Source: authors" own elaboration.

VARIABLE	BASE CASE VALUE	SCENARIO VALUE
Immigrants (Number of People)	23,700,000	23,700,000
Poverty (Number of People)	96,500,000	96,500,000
Low Education (Number of People)	102,812,300	102,812,300
Dark Web Users (Number of People)	**22,000**	**11,000** ***at tick 1 and 0 from tick 2 onwards***
Twitter Accounts (Number of Accounts)	**1000**	**500** ***at tick 1 and 0 from tick 2 onwards***
Facebook Radical Content Views (Number of Views)	**10,000**	**5000** ***at tick 1 and 0 from tick 2 onwards***
Level of Ambition (Number of People)	1000	1000
Non-Prepared Lethality	6	6
Lethality (Number of People)	66	66
Deradicalization over time (% of People)	***0***	***+0.05 per tick, starting from tick 2, (max 0.7)***
Territory Controlled (Km^2)	***100,000***	***1000***

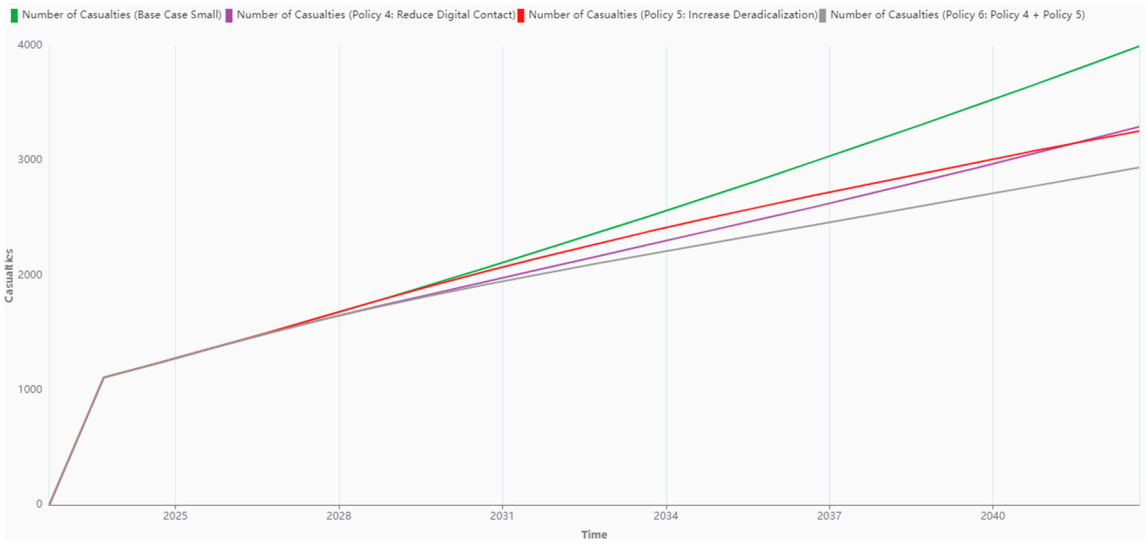

Figure 14. Small terror group policy performance comparison, source: Silico.app, based on authors' own elaboration.

As may be seen in the above graph, the following three policies, listed in order of effectiveness, are the most effective in countering small terror groups:

1. Censor digital terror propaganda and implement deradicalization programs;
2. Implement deradicalization programs;
3. Censor digital terror propaganda.

Of these, the first two will produce better results in the long run as compared to the third, however all three policies will succeed in reducing casualties by a notable amount. Policies that would seek to create more structural reforms that remove the conditions for radicalization produce very little return for the amount of effort, and as such are not recommended if the goal is to reduce casualties. Furthermore, the lethality of lone wolves is very low, save for outliers, meaning that the improved attack response policy that seeks to reduce lethality would not produce worthwhile effects either. As such, the best way to combat lone wolves is to remove the material that radicalizes individuals while attempting to re-integrate radicals into the general population: these relationships may be seen in the Figures 15–17:

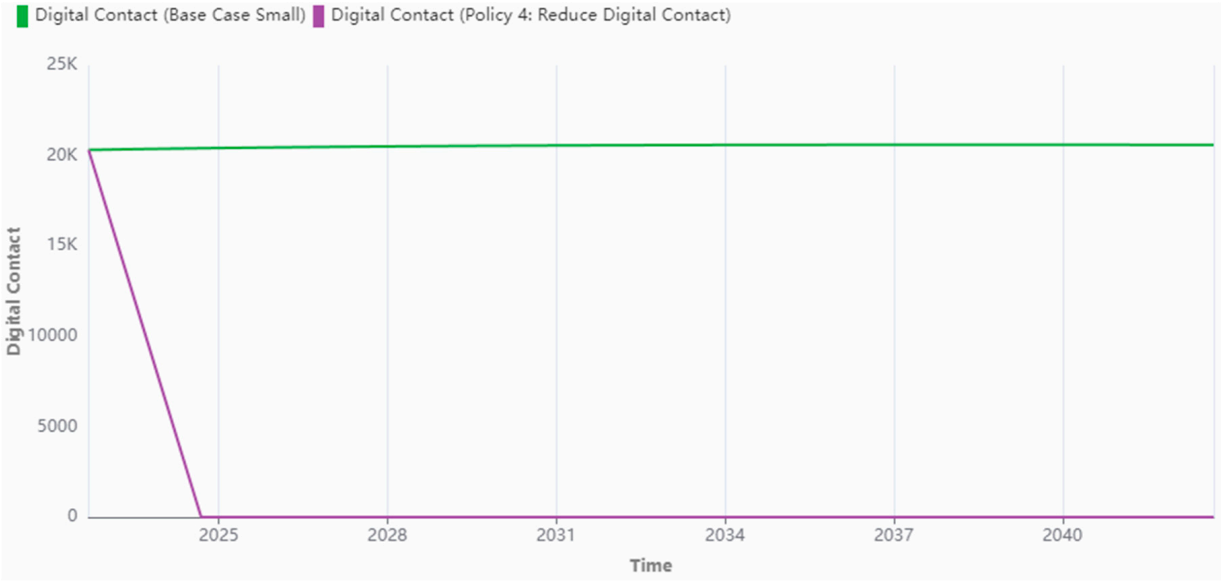

Figure 15. Digital contact removal policy, source: Silico.app, based on authors' own elaboration.

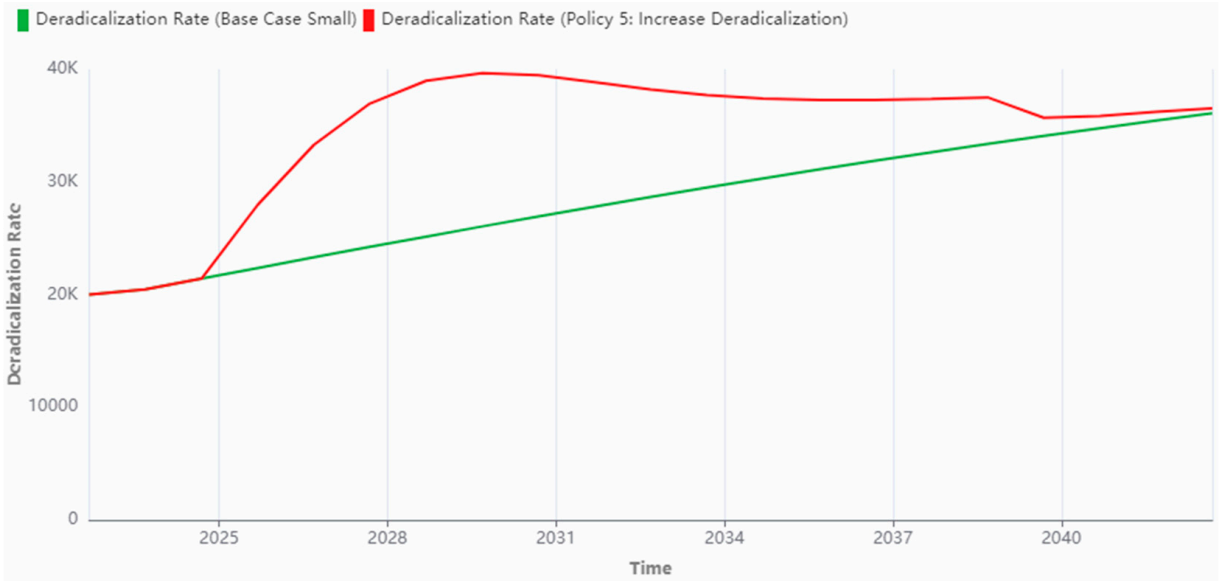

Figure 16. Deradicalization increase policy, source: Silico.app, based on authors' own elaboration.

The second element (deradicalization increase) of this policy is the most complicated to implement but is still feasible and will produce results; the first element (digital contact removal) on the other hand requires less "effort" and will produce effects in the short term, as such it is a good "next-best' policy. As a final consideration, one may wonder whether the policies used to combat small groups may be effective against large groups. Indeed, as was argued previously, transposing the policies used against large groups to a small group scenario makes little sense, given that a small group will already be at the "minimum" values of lethality and controlled territory. Applying the policies which work against a small group, on the other hand, is feasible, and as such merits investigation. The results of applying the same policies used against small groups in a large group scenario may be seen in Figure 18.

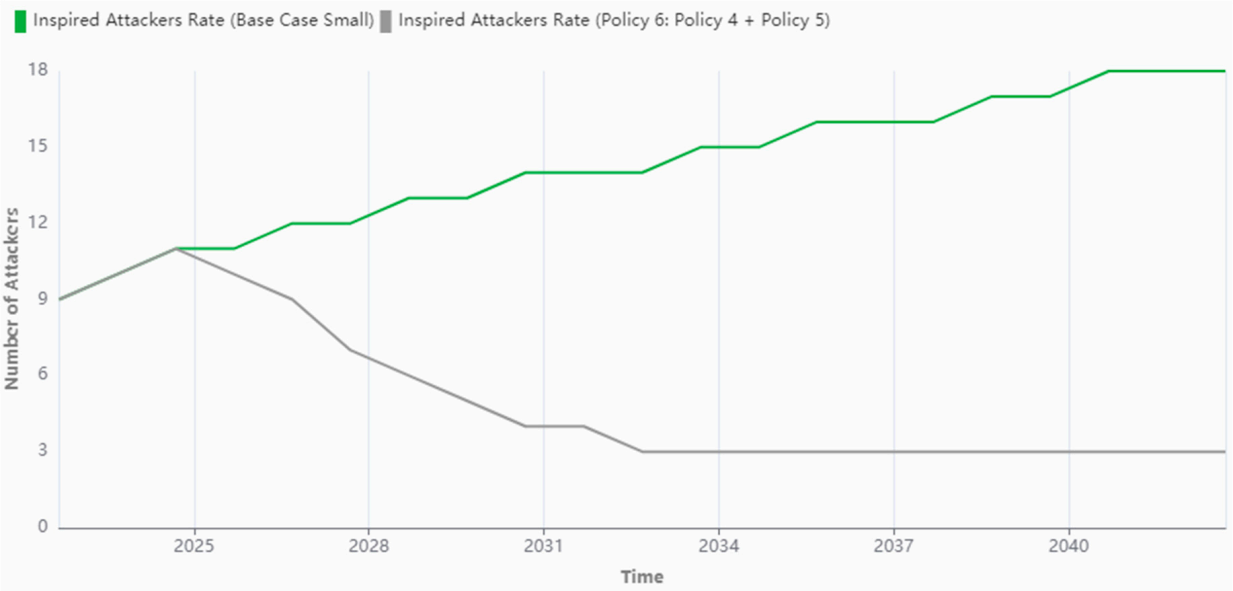

Figure 17. Change in attacker rate with combined policy plan, source: Silico.app, based on authors' own elaboration.

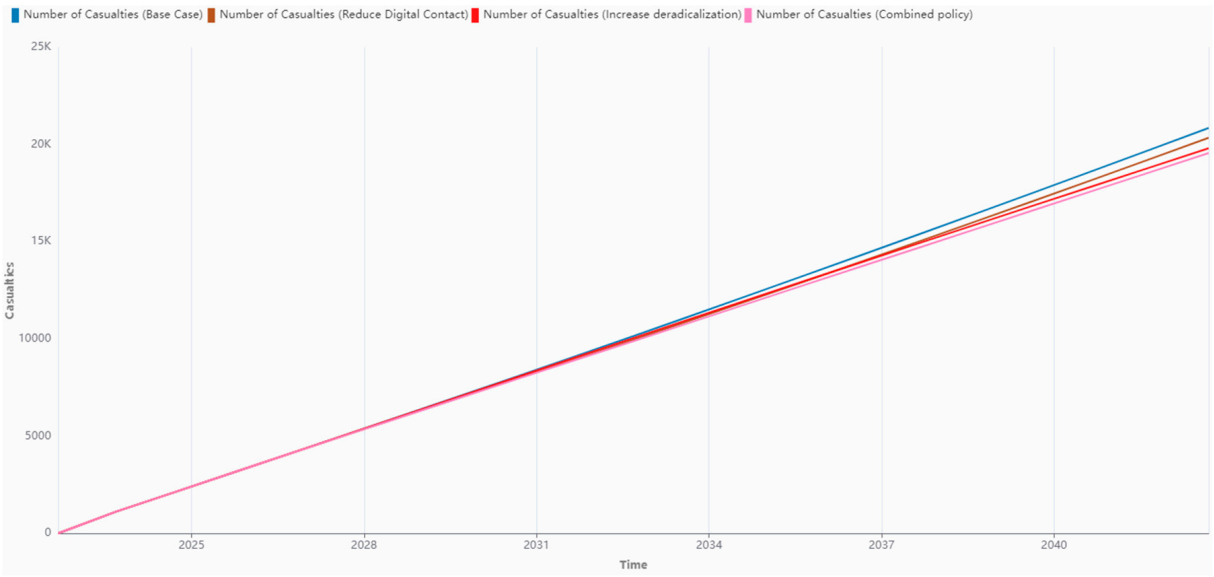

Figure 18. Application of "small group" policies in a large group scenario, source: Silico.app, based on authors' own elaboration.

As may be seen, utilizing small group policies against a large group will be largely ineffective. The reason for this is to be found in the earlier described asymmetry of the model, according to which there is a surplus of radicalized individuals as compared to the recruitment needs of the terrorists. As such, small group policies which focus on attempting to reduce radicalized individuals to combat the phenomena of lone wolf attacks, will never be strong enough to overcome this asymmetry. Understanding this asymmetry is fundamental in understanding the difference between the modus operandi of large groups and that of small groups, and why policy intervention must change according to the type of group that is confronted.

5. Discussion and Conclusions

To summarize, we have utilized a breadth of literature and data regarding terrorism in the west in order to construct a model that may describe the issue in practical, numerical terms. This model produced several findings, summarized in Table 11, including the fact that System Dynamics is an important tool that allows for counter terrorism strategy to become faster in its deployment and more efficient in its results.

Table 11. Summary of policy intervention effects on outputs. Source, authors' own elaboration.

	INPUTS	OUTPUTS (At Tick 20)
Policy 1: Reduce Territory (Large Terror Group)	The *Controlled Territory* has been reduced by 10,000 Km^2 per tick, down to a minimum of 1000 Km^2.	*Casualties* drops from 20,850 to 10,836; *Combat Force* drops from 14 to 1; *Lone Wolves* drop from 29 to 25; *Radicalized Individuals* drops from 293,078 to 246,645; *At Risk Individuals* increases from 195,515 to 260,816.
Policy 2: Reduce Lethality (Large Terror Group)	*Lethality* has been halved from 66 to 33, starting from tick 2.	*Casualties* drops from 20,850 to 12,822; *Lone Wolves* drop from 29 to 25; *Radicalized Individuals* drops from 293,078 to 255,049; *At Risk Individuals* increases from 195,515 to 256,342.
Policy 3: Reduce Territory and Lethality (Large Terror Group)	The *Controlled Territory* has been reduced by 10,000 Km^2 per tick, down to a minimum of 1000 Km^2; *Lethality* has been halved from 66 to 33, starting from tick 2.	*Casualties* drops from 20,850 to 7788; *Combat Force* drops from 14 to 1; *Lone Wolves* drop from 29 to 23; *Radicalized Individuals* drops from 293,078 to 223,044; *At Risk Individuals* increases from 195,515 to 300,308.
Policy 4: Reduce Digital Contact (Small Terror Group)	*Digital Contact* has been halved at tick 1 and reduced to 0 from tick 2 onwards.	*Casualties* drops from 3966 to 3294; *Lone Wolves* drops from 18 to 10; *Radicalized Individuals* drops from 180,496 to 95,746; *At Risk Individuals* increases from 373,989 to 524,709.
Policy 5: Increase Deradicalization (Small Terror Group)	*Deradicalization Over Time* is increased by 0.05 per tick, starting from tick 2, until a maximum of 0.7.	*Casualties* drops from 3966 to 3258; *Lone Wolves* drops from 18 to 5; *Radicalized Individuals* drops from 180,496 to 40,605.
Policy 6: Reduce Digital Contact & Increase Deradicalization (Small Terror Group)	*Digital Contact* has been halved at tick 1 and reduced to 0 from tick 2 onwards; *Deradicalization Over Time* is increased by 0.05 per tick, starting from tick 2, until a maximum of 0.7.	*Casualties* drops from 3966 to 2940; *Lone Wolves* drops from 18 to 3; *Radicalized Individuals* drops from 180,496 to 22,635; *At Risk Individuals* increases from 373,989 to 530,996.

First and foremost, we have discovered that there is a clear supply and demand dynamic in terms of terror attacks; there is a supply of radicals and a demand for terrorists, both trained and lone wolves. There is a large asymmetry between the supply and demand, as the need for terrorists numbers in the tens, while the supply of radicals in the thousands. This asymmetry is worse when dealing with a large terror group, so much so that, if the group is large enough, they will have no issue in taking advantage of frustrated western populations. In this scenario, policies that seek to reduce this malcontent will not be able to compensate the asymmetry in the system, meaning that the best solution is a direct approach, either through targeting the terror group itself, or through improving the capacity to respond to attacks. On the other hand, if the terror group is small and unable to take advantage of the stock of radicals directly, it will rely on lone wolf attacks; this type of attack has been the main one perpetrated against Europe in recent years, as highlighted by Europol, and consists in the independent action of a radical that is "egged on" by a terrorist group.

To this end, to push for more lone wolf attacks a terror group will have to intensify its propaganda activity in order to push these individuals over the edge, allowing for them to attack the west without having to actually send any trained terrorists in. The key to making these kinds of attacks work lies in the necessity for the terror group to have a large audience; they need to be able to reach a large amount of people, in the hopes that at least 1 in 10,000 is fragile enough that their message will push him or her to action. As such, lone wolf attacks are reliant on the internet and new communication technologies, and their rise is

largely due to these technologies. However, lone wolf attacks are triggered on the "supply" side of the model, meaning they occur before the asymmetries inherent in the system are active; in other words, reducing radicalized individuals in this case will have a more noticeable effect on the casualties, meaning that policies that seek to limit radicalization or increase deradicalization will be far more effective. What is interesting to note is that our findings match the observed reality. Aside from the "real-word" simulation conducted to prove our model as descriptive, we can observe that the model is able to match the historical evolution of terrorism in the west. Indeed, when groups such as Al Qaeda and ISIS were at their peak in terms of size, the attacks perpetrated were carried out by trained operatives that produced large quantities of casualties. Consider as an example 9/11 for Al Qaeda, or the November 2015 Attacks for ISIS; both these attacks occurred at points of high territorial extension of the respective groups, were carried out by a relatively large number of operatives and produced catastrophic damage. On the other hand, as the groups have lost power, these types of attacks have phased out, and we have seen an increase in lone wolf strategies. This evolution is consistent with the prediction of our model: large groups will output many trained operatives, small groups will be noticed through lone wolf attacks. At this point it may be argued that the system is not producing any worthwhile information; it reflects reality, and when the policies suggested were pursed in the past (such as the reduction of Al Qaeda territory through the War on Terror) the results were positive. In this sense, it seems that the policy suggestions are redundant; this is not the case. What is important to the model and the policy recommendations is not that the outcomes are close to reality; what is important is why we observe these reality matching outcomes. Indeed, we can deduce that lower territory will equal less attacks, but our model can tell us why this happens, due to the decrease in the preparation capacity of the terror group. We can observe how easy it was for terror groups to recruit western citizens to their cause, but the model can tell us why this occurred, due to the fundamental asymmetry between supply and demand. We can observe how lone wolf attacks increased, but the model will tell us why this happened, thanks to the digital propaganda made through new communication avenues of terror groups that have seen their preparation capacity gutted. As such, the policy suggestions are not born out of mere historical study; they are made through the thorough examination of history to construct a model that is able to place what we know in a new light, telling us exactly how terrorism "ticks" and how our interventions will affect the issue. However, the contribution of our model is not limited to these policy suggestions; due to how it is constructed, it may be used as a predictive tool as well, allowing us to anticipate how many casualties we may expect. We are able to do this thanks to the way the model functions; given that all its values are interconnected, a change in one value may precede a change in another. As such, if we are able to observe that one element of the system is on an upwards trend, we are able to predict how the rest of the system will react. Through the identification of these "locations" in the model, we are able to insert a collection of indicators and warnings that are able to signal to us when a change in the system is about to occur before it happens. A few practical examples will help understand what is meant: in our system the digital propaganda activity of a terror group is connected to their ambition; if they wish to increase casualties they will intensify their online efforts. As such, if we observe a heighted online activity of a terror group it may be understood as a warning bell that said group raised their level of ambition, meaning we may expect an intensification in their activity. As another example, if we notice that many citizens are being recruited by a terror group we can deduce that their recruitment capacity is high; it follows then, that they have a large enough amount of territory to sustain this capacity, meaning their preparation capacity is high and we may expect more trained terrorist attacks. If we observe the controlled territory of a terror group to be low, we may expect more lone wolf attacks; vice-versa, if we observe an increase in lone wolf attacks we can deduce that our stock of radicals is very large and/or a terror group is carrying out intense propaganda activity. These are just some of the ways the system may be used as a tool, allowing us to anticipate changes in our expected casualties before they happen. If

the model is used in this way, this anticipatory quality may be used to implement counter policy before we even observe any change, allowing us to be more effective by sidestepping the usual delay between observing an outcome and planning a strategy. It is clear how such a tool can be useful to our stated goal of creating policies that aim to reduce the casualties caused by terrorism, and it must be recalled that the model used in the present paper is still somewhat limited in scope. Indeed, the model in its current, initial form presents some limitations that must be recalled. First, as concerns the construction of the model, it is at present based on five primary sources, which present models and theories to understand radicalization and terrorism. Future research may envision expanding the literary inputs of the model in order to capture a more complete picture of the issue. Second, the construction of the model and selection of variable has been limited by issues of data availability. Indeed, some aspects that are highlighted in the literature, such as cognitive openings, are difficult to measure inside the model due to the fact that limited data is available; even proxy variables result difficult to envision. Third, the model has been calibrated primarily on the basis of ISIS as a terror group representative; while the use of only one group is not inherently a limitation, the expansion and inclusion of other groups will allow for the model to cover a wider reality in future developments. Finally, as a consequence of the above limitations, the simulations conducted cover a short time period (20 years) and a limited geographical extension (Europe); future research may envision making use of more sources and datasets in order to expand both the analyzed timeframe and the geographical extension of reference. If the findings here are expanded upon, more data is collected, and the model is expanded its "power" will increase, allowing for more accurate predictions and thus more accurate policy proposals. In this sense, the present paper has provided a taste of what contributions a systemic approach to terrorism may make; further evolution of the model created and the creation of new ones, focusing on specific aspects of the issue will allow for counter terrorism policy to become more efficient, quicker to design, and more focused on key leverage points. As such, as the present paper has argued, System Dynamics could become a great asset to counter terrorism studies and policy planning and going forward it should be further implemented and expanded upon in order to further leverage all the advantages that have been presented.

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