Analysing terrorism from a systems thinking perspective

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by Lukas Schoenenberger, Andrea Schenker-Wicki and Mathias Beck

Abstract

Given the complexity of terrorism, solutions based on single factors are destined to fail. Systems thinking offers various tools for helping researchers and policy makers comprehend terrorism in its entirety. We have developed a semi-quantitative systems thinking approach for characterising relationships between variables critical to terrorism and their impact on the system as a whole. For a better understanding of the mechanisms underlying terrorism, we present a 16-variable model characterising the critical components of terrorism and perform a series of highly focused analyses. We show how to determine which variables are best suited for government intervention, describing in detail their effects on the key variable—the political influence of a terrorist network. We also offer insights into how to elicit variables that destabilise and ultimately break down these networks. Because we clarify our novel approach with fictional data, the primary importance of this paper lies in the new framework for reasoning that it provides.

Keywords: *counter-terrorism, systems theory, methodology*

Introduction

The war against terrorism [1] ("war on terror") has lasted for over 10 years, costing approximately 1,5 million lives in Iraq and tens of thousands of lives in Afghanistan and Pakistan, demonstrating the obvious need for alternative anti-terror measures. [2] [3] [4] [5] [6] We argue that it is time to rethink counterterrorist measures and present an unconventional approach to understanding terrorism, by analysing it from a systems thinking perspective.

Maani and Cavana [7] define systems thinking as "a scientific field of knowledge for understanding change and complexity through the study of dynamic cause and effect over time." Systems thinking is a method of capturing complex issues in a holistic way. Its focus lies on the interrelations of crucial variables in a given framework. This approach substantially facilitates the understanding of the behavior of complex systems, enabling us to make predictions about any system's evolution and to propose potential measures for changing the system's dynamics. Only one study thus far has connected terrorism with systems thinking modeling: Grynkewich [8] models the financial subsystem of the Salafist Group for Preaching and Combat. He focuses primarily on only one element of terrorism, fundraising. In contrast, we build a generic model that includes 16 key variables of terrorism.

We have combined and further developed the ideas of Vester [9], Gomez and Probst [10], and Huerlimann [11] to conceptualise our systems thinking approach. [12] In this study, we show the enormous potential of such an approach by applying it to terrorism. We illustrate this method with a model that combines different key aspects of terrorism. The idea for our model is derived from *The Art of Interconnected Thinking*, a 2007 book by Frederic Vester, originally a German professor of biochemistry and a member of the Club of Rome. Vester studied the control and regulation mechanisms in living cells, especially the causes of cancer. Following his academic career, he developed a unique approach to systems thinking, one that he called "interconnected thinking," and adapted the biological model to the political sphere, including an analysis of terrorism. He called that model "terror prevention" and published the first results of his analysis just a few

days after September 11, 2001. Following that, Vester proposed to develop the model further in collaboration with the Technical Support Working Group of the U.S. Department of Defense. [13]

While using many of the same variables that Vester uses, we have adapted his model for our specific analysis. In contrast to the focus of Vester's model on the U.S. response to terrorism in the post-September 11, 2001 era, we build a more generic model that is not attached to a specific cultural context. In particular, we reduce the set of variables from 20 to 16 to enhance the structural clarity of the model [14]. Our modeling procedures are otherwise similar to the pioneering work of Vester on which they are based. Because we clarify our approach using fictional data, the relevance of our work lies in the analytical framework that it provides, not in any specific recommendations for policy makers.

We argue that one particular variable—the political influence that a terrorist network can garner—is the key variable, i.e., the most important goal for any terrorist network. After demonstrating the criticality of this key variable, we then ask and answer corollary questions:

- What other variables—in addition to the political influence of a terrorist network—have a substantial impact on our model and therefore represent possible intervention points for governments?
- What effects do these variables have on the key variable that we have identified?

Finally, we tackle the issue of how governments can destabilise terrorist networks:

- Which bundles of variables must governments eliminate or defuse if they are to undermine a terrorist network efficiently?

With the aid of simple algorithms, we can model the dynamics of a terrorist network. We argue that an intervention variable must be highly interlinked and should quickly disseminate changes throughout the system. Applied to our model are three variables suited for government intervention: "control of overreaction," "effectiveness of anti-terror measures," and "anti-terror support by moderate forces." We have identified these variables after a series of highly focused analyses. The variable "control of overreaction" means that a country is capable of reacting proportionately to a terrorist attack. The danger always exists that governments make highly emotional decisions in such situations and tend to overreact. Often retaliation measures are disproportionally severe, hurting not only the terrorist network itself but also civilians, aggravating problems related to terrorism, and leading to a substantial boost in the recruitment of new terrorists. [15] [16] The second variable, "effectiveness of anti-terror measures," is of crucial importance for the careful planning and executing of military operations. Retaliatory actions should strike the Achilles' heel of the terrorist network and weaken it over the long term but with the fewest possible civilian casualties. The third variable appropriate for intervention is "anti-terror support by moderate forces." Moderate forces are population groups (within a hostile country, area, or organisation) that are opposed to terrorism. These groups are important allies in countries with active terrorist networks. [17] [18]

We describe in detail the impacts of "effectiveness of anti-terror measures" and "anti-terror support by moderate forces" on our key variable—the political influence of a terrorist network. Of the two, "effectiveness of anti-terror measures" is the most successful variable in reducing the political influence of a terrorist network in our model. In the final section, we analyse the stability of our model by removing single and multiple variables. To completely defuse our model, we must remove five variables: "recruitment of potential terrorists," "impact of attacks," "media reports," "financial and material resources," and "negative perception of industrial countries."

Systems Thinking

A systems thinking approach [19] differs substantially from traditional reductionist approaches, which continuously divide the subject of interest into further specialised disciplines and focus on a small number of linear causal relationships between phenomena, explaining them in terms of their smallest identifiable parts (e.g., classical mechanics, cell biology, and axiomatic set theory). However, these traditional approaches often lead to incorrect results and create inappropriate incentives in conjunction with complex systems (e.g., problems related to a company). [20] In contrast, systems thinking concentrates on how a subject of interest interacts with other variables. Rather than breaking a system down into smaller components, systems thinking expands the view of a user, taking into account increasingly greater numbers of interactions.

Systems thinking implies that the variables of a system have to be considered in a dynamic way and requires thinking in terms of processes. Systems thinking focuses, on the one hand, on the interactions between the different variables in a certain system *and*, on the other hand, on the interactions between the different variables and the system as a whole. Feedback processes are very important. Those processes can be either direct or indirect and can dramatically influence the behaviour of a system.

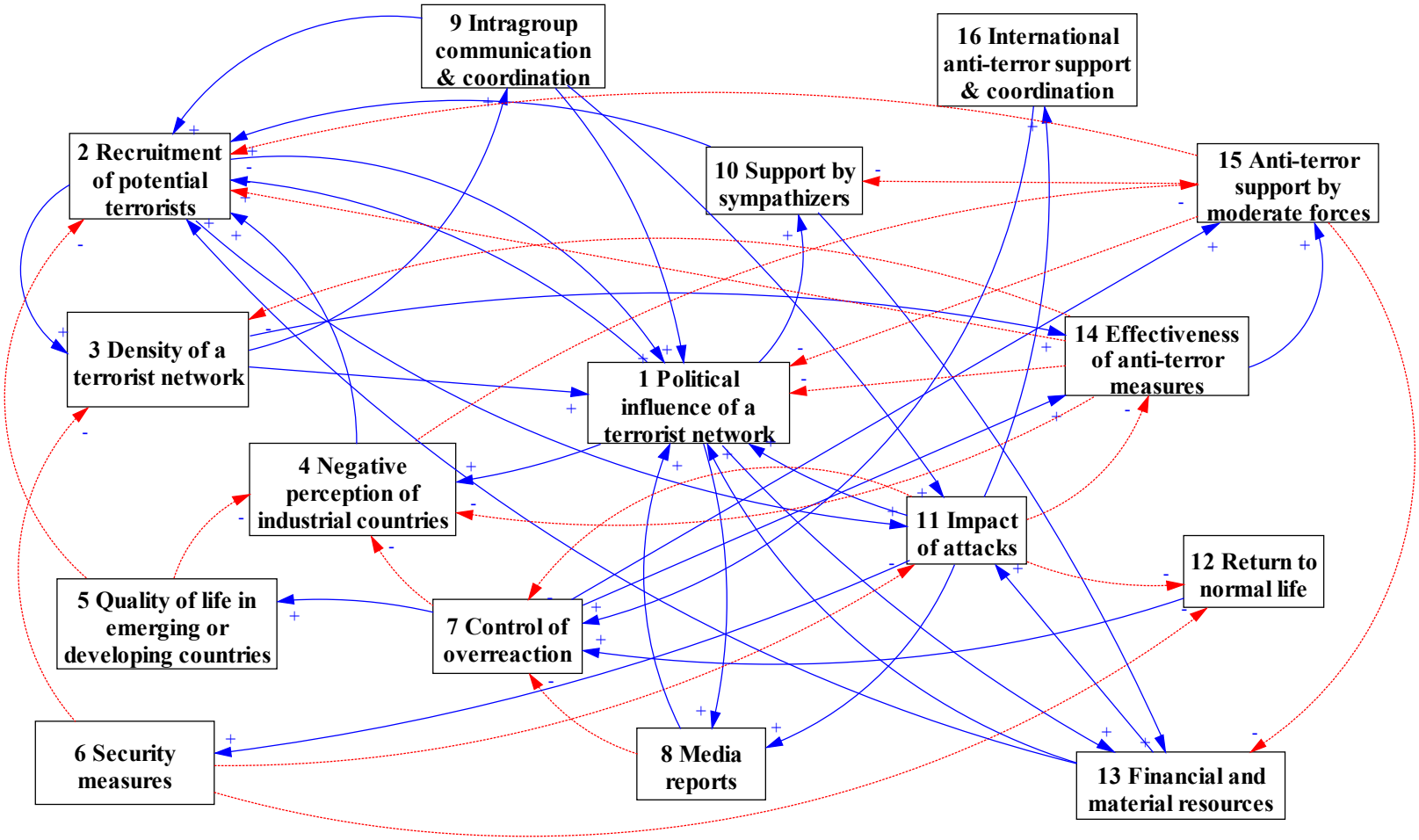
To use systems thinking, we establish a model of the most important stakeholders, their objectives, and their relationships. In general, the relationship between two variables can be either positive or negative. A positive relationship means that an increase in variable A leads to an increase in variable B; conversely, a negative one implies that an increase in variable A leads to a decrease in variable B. To perform our analysis, we must specify the type of relationship between two variables, the strength of their interaction, and the time required for one variable to influence another.

The systems thinking approach detailed in this article lacks the possibility of validation: the goodness or suitability of our results cannot be tested before they are actually implemented. This is a clear limitation compared to more quantitative methods like system dynamics, where simulation allows for the optimisation and verification of results. However, quantitative analysis methods require a great deal of data, which is very difficult to collect and severely limited in terrorism research. For this reason, our methodology is at the moment the best available option for researchers examining terrorism.

Modeling Terrorism

As previously stated, our 16-variable model is based on the one established by Frederic Vester. We have adapted his model (see Figure 1) to better fit developments in terrorism research over the past decade. Vester, a pioneer in systems thinking, was able to graphically depict the impact of the post-September 11, 2001, countermeasures taken by the U.S. government. In his preliminary conclusions—based on the model's dynamics—he emphasised that pursuing the head of a terrorist network has only a very small impact on that network and does not destabilise it.

Figure 1. *The 16-Variable Model*



Building on Vester's model, we shift the focus to the international community, encompassing many states that could be affected by terrorism instead of assuming that the U.S. is the only potential victim of terrorist attacks. Our reason is that, since September 11, 2001, major terrorist attacks have taken place outside the U.S., such as in Bali (2002) and in London (2005). [21] [22] While the attacks in Bali and London claimed fewer lives than the September 11, 2001, attacks, they nevertheless had disastrous consequences. Al-Qaeda played an important role in both attacks: The London attack was carried out by a group with the same ideology as Al-Qaeda's, [23] and the Indonesian terror branch "Jeemah Islamiah" was responsible for the Bali attack. [24] The model in Figure 1 presents the activities of a large, internationally active terrorist network such as Al-Qaeda.

Our model comprises 16 influencing variables containing all stakeholders involved in terror activities, i.e., stakeholders identified as aggressors, victims, or governments. The interconnections between the variables can be either positive (solid blue lines) or negative (dotted red lines). The model shows both the impacts of terrorist attacks and the impacts of countermeasures taken by governments. Our model is admittedly simplified but powerful enough to represent basic processes in a terrorist network.

The Variables in the Model

Table 1 presents the 16 variables in our model with a brief description of each.

Table 1: All Variables used in Model	
(1) Political influence of a terrorist network	A terrorist network's attempt to increase or at least to stabilise its political influence [25] [26]
(2) Recruitment of potential terrorists	People's willingness to join a terrorist network, and, in extreme cases, even to sacrifice their lives as in the case of suicide bombers [27]
(3) Density of a terrorist network	The number of terrorists per area (region/country) [28] [29]
(4) Negative perception of industrial countries	The level of denial and bitterness re Western standards and ideologies [30]
(5) Quality of life in emerging or developing countries	Factors such as political rights, freedom, education, GDP per capita, safety
(6) Security measures	All government measures for protecting the civil population from a terrorist attack
(7) Control of overreaction	Governments' ability to avoid disproportionately severe reactions immediately following a terrorist attack.
(8) Media reports	Press releases covering terrorism
(9) Intragroup communication and coordination	Collaboration and knowledge exchange among terrorists in a network
(10) Support by sympathisers	Level of local support for the terrorist network, necessary to purchase resources. [31]
(11) Impact of attacks	Three factors for attack magnitude: symbolism of the attack, number of people injured or killed, and economic damage [32] [33] [34]
(12) Return to normal life	The population's process of returning to "ordinary business" after a terrorist attack [35]
(13) Financial and material resources	Financial and material inflows into the terrorist network [36] [37] [38] [39]

(14) Effectiveness of anti-terror measures	Magnitude of both civilian casualties and damage to the terrorist network
(15) Anti-terror support by moderate forces	Level of support by moderate forces: anti-terror population groups in a hostile country, area, or organisation
(16) International anti-terror support and coordination	International anti-terror support and all anti-terror measures taken by allied governments, institutions, and organisations

Analysis of the Model

We build a model to illustrate how the different variables are linked. We want to know in which *direction* one variable influences another and whether this influence happens immediately or with *delay*. To quantify impact and time delay, we use two matrices: a cross-impact matrix and a cross-time matrix. The data within the matrices are solely for illustrative purposes, and do not represent validated data for one obvious reason: detailed data on terrorist networks is closely guarded (i.e., classified) government information and certainly not available to researchers restricted to the use of open sources. Therefore, we use illustrative details to show the usefulness of our model. The goal of this section is to present a new method as to how security experts and policy makers could approach terrorism. [40]

Impact of the Different Variables

To describe the influence of each variable, we use a cross-impact matrix. In contrast to Gomes and Probst [41] or Vester [42], we value only direct relationships. To indicate the strength of the relationships between the variables in our model, we use the following code:

Table 2: Codes for Describing the Impact		
-1	⇔	**inversely proportional**
Variable B reacts inversely proportionally in reference to a shift in variable A.		
0 (empty)	⇔	**no influence**
No direct link exists between variables A and B		
+1	⇔	**proportional**
Variable B reacts proportionally to a shift in variable A.		

Consequently, we evaluate each link between two variables as either +1 or -1. Although we could also expand the range of code with "disproportionately" low (2/3) and high (3/2) impact values, for illustrative reasons we choose in this paper to use proportional and inversely proportional effects.

Table 3: Cross-impact Matrix

	Variable name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	AS
1	Political influence of a terrorist network		1		1				1		1			1				5
2	Recruitment of potential terrorists	1		1								1						3
3	Density of a terrorist network	1								1					1			3
4	Negative perception of industrial countries		1													-1		2
5	Quality of life in emerging or developing countries		-1		-1													2
6	Security measures			-1								-1	-1					3
7	Control of overreaction				-1	1									1	1		4
8	Media reports	1						-1										2
9	Intragroup communication & coordination	1	1									1						3
10	Support by sympathisers		1											1				2
11	Impact of attacks	1					1	-1	1				-1		-1		1	7
12	Return to normal life							1										1
13	Financial and material resources	1	1									1						3
14	Effectiveness of anti-terror measures	-1	-1	-1	-1											1		5
15	Anti-terror support by moderate forces	-1	-1								-1			-1				4
16	International anti-terror support & coordination							1										1
	PS	8	8	3	4	1	1	4	2	1	2	4	2	3	3	3	1	
	Degree of cross-linking (AS + PS)	13	11	6	6	3	4	8	4	4	4	11	3	6	8	7	2	

The *active sum* (AS in the last column on the right), is the sum of all of the direct influences (outgoing flows) that can be attributed to a certain variable, i.e., the sum of the values in the row of a single variable. The active sum thus indicates how strongly this variable affects or dominates the system, with a high active sum indicating great influence. The *passive sum* (PS second to last column) is the sum of all of the incoming flows and indicates how strongly the system affects or dominates a variable. To calculate the incoming and outgoing flows, one can take only the absolute values into account.

The *degree of cross-linking* depicts how strongly the different influencing factors are interconnected. A higher number indicates that a variable is more essential for the survival of the system. Thus the removal of a highly interlinked element from the system may lead to the system's partial or complete collapse.

In our model, we are mostly interested in the dynamic evolution of the "political influence of a terrorist network." This variable, which shows the highest degree of cross-linking (13), is crucially important. In addition, this variable has more ingoing than outgoing links, meaning that as an influencing factor it is very sensitive to changes in our model. The variables "recruitment of potential terrorists" and "impact of attacks" are also of particular significance. While both have a high degree of cross-linking, they differ in the ratio of the active sum to the passive sum (i.e., as "impact of attacks" has the highest active sum, the entire model is sensitive to any change in this specific variable).

These findings of the cross-impact matrix are not surprising. To maintain a certain level of political influence, a terrorist network must rely on the continuous hiring of new manpower and must execute terror attacks that feature high symbolic value. Therefore, these variables occupy a central position in our model.

Time Delay

In systems thinking, time plays a major role. We want to know how a system or network develops over time. If we adjust one variable, the effect will not spread immediately through the system. Therefore, we must include delays in our model. To accommodate time in this setup, we construct a cross-time matrix (see Table 5). The procedure is analogous to the construction of the cross-impact matrix. Again, for the sake of complexity and clarity, we take only direct links into account. The matrix is compiled with the data in Table 4.

Table 4: Codes for Indicating Time Delay		
0 (empty)	⇔	**no influence**
There is no direct link between variable A and B; consequently, no delays can occur		
1	⇔	**short-term (< 1 year)**
If variable B reacts with a short time delay to a change in variable A		
2	⇔	**middle-term (1-3 years)**
If variable B reacts with a moderate time delay to a change in variable A		
4	⇔	**long-term (> 3 years)**
If variable B reacts with a long time delay to a change in variable A		

To avoid bias, we must associate the time categories with real numbers and code the categories proportionally. Depending on the system, the time categories can refer to different times.

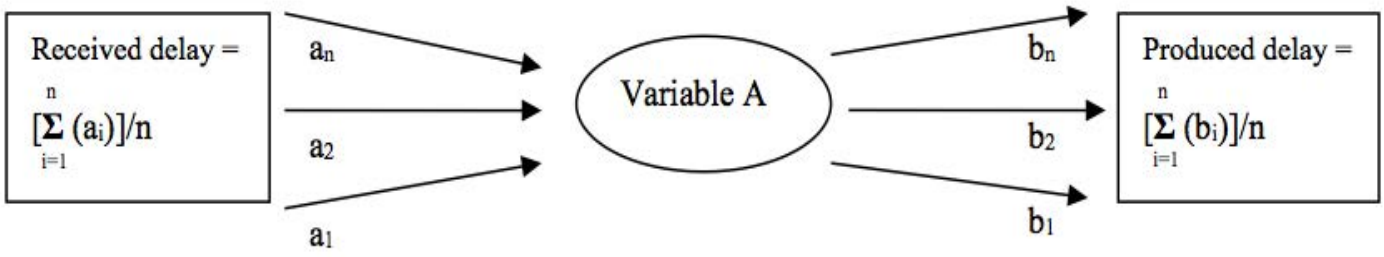
Table 5: Cross-time matrix

	Variable name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	PD
1	Political influence of a terrorist network		2		4				1		1			2				2.0
2	Recruitment of potential terrorists	2		1								2						1.7
3	Density of a terrorist network	2								1					2			1.7
4	Negative perception of industrial countries		4													1		2.5
5	Quality of life in emerging or developing c.		4		4													4.0
6	Security measures			1								1	1					1.0
7	Control of overreaction				1	1									1	2		1.3
8	Media reports	1						1										1.0
9	Intragroup communication & coordination	2	2									2						2.0
10	Support by sympathisers		1											2				1.5
11	Impact of attacks	1					1	1	1				1		1		1	1.0
12	Return to normal life							1										1.0
13	Financial and material resources	2	2									2						2.0
14	Effectiveness of anti-terror measures	1	1	1	1											1		1.0
15	Anti-terror support by moderate forces	4	2								4			4				3.5
16	International anti-terror support & coord.							2										2.0
	RD	1.9	2.3	1.0	2.5	1.0	1.0	1.3	1.0	1.0	2.5	1.8	1.0	2.7	1.3	1.3	1.0	

In Table 5, *produced delay* (PD - last column on the right) and *received delay* (bottom row) show the mean values of every row (produced delay) and column (received delay).

Figure 2 is a schematic representation of produced and received delay with respect to a variable A. Produced delay is the average time an impulse needs to reach a subsequent node from variable A. This is a measure of how much delay a variable causes in the entire system.

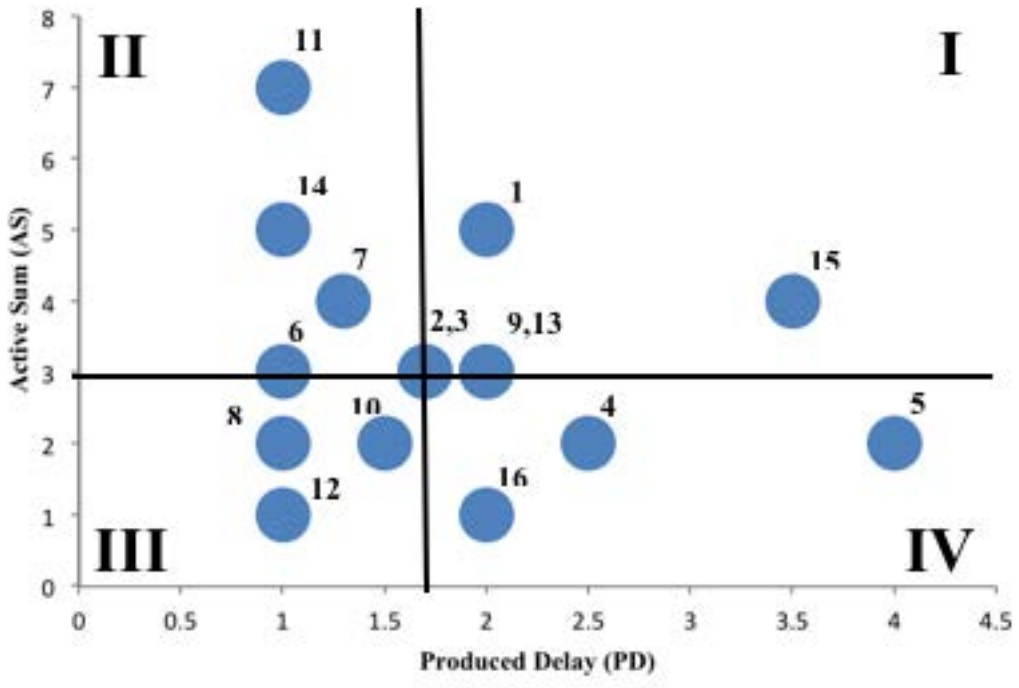
Figure 2. *Produced and Received Delay*



Intervention Variables

From a systems thinking perspective, determining which variables are suited for intervention is important. These variables must have a great impact on the entire system and act with little or no time delay. To identify such variables, we must combine the cross-impact and cross-time matrices. More precisely, we create a graph (see Figure 3) with the produced delay (time) on the x-axis and the active sum (impact) on the y-axis.

Figure 3. *Best Intervention Variables*



The graph in Figure 3 is divided into four quadrants [43], each representing a specific cluster of variables with respect to impact and delay. An ideal intervention variable should have a dominant position in the

system and thus a high number of outgoing links (high active sum). In addition, an appropriate variable for intervention should quickly spread stimuli throughout the system (low produced delay). Therefore, the best intervention variables are found in the upper-left quadrant, which is labeled with a Roman numeral two (II). Variables in the upper-right quadrant (I) can also be interesting for government interventions due to their high impact on the system. However, the effects of these variables on the system only unfold after a significant time delay.

By definition an intervention variable must be one that policy makers can control. This criterion excludes variables 11 ("impact of attacks") in quadrant II and 1 ("political influence of a terrorist network") in quadrant I from being ideal interventions, because individuals outside the terrorist network cannot influence these variables. Variables 14 ("effectiveness of anti-terror measures") and 7 ("control of overreaction") satisfy the criteria of being both ideal and controllable. In other words, for a government that actively fights terrorism, choosing the most effective anti-terror measures (causing minimal civilian casualties) to weaken the terrorist network is crucial. In addition "control of overreaction" is an essential variable in any terrorist network, because terrorists aim to provoke disproportionate and rash post-assault retaliations. These retaliations tend to facilitate the recruitment of new terrorists and damage the reputation of the retaliating country. Therefore, for government policy makers, the use of a control mechanism relative to premature and blind retaliation is very important. Variable 15 ("anti-terror support by moderate forces") in quadrant I is another intervention option for decision makers. However although this variable has considerable impact on the entire model, it acts very slowly.

Due to their small impact on the model the variables in the lower quadrants, III and IV, are essentially useless for policy maker.

Path Analysis

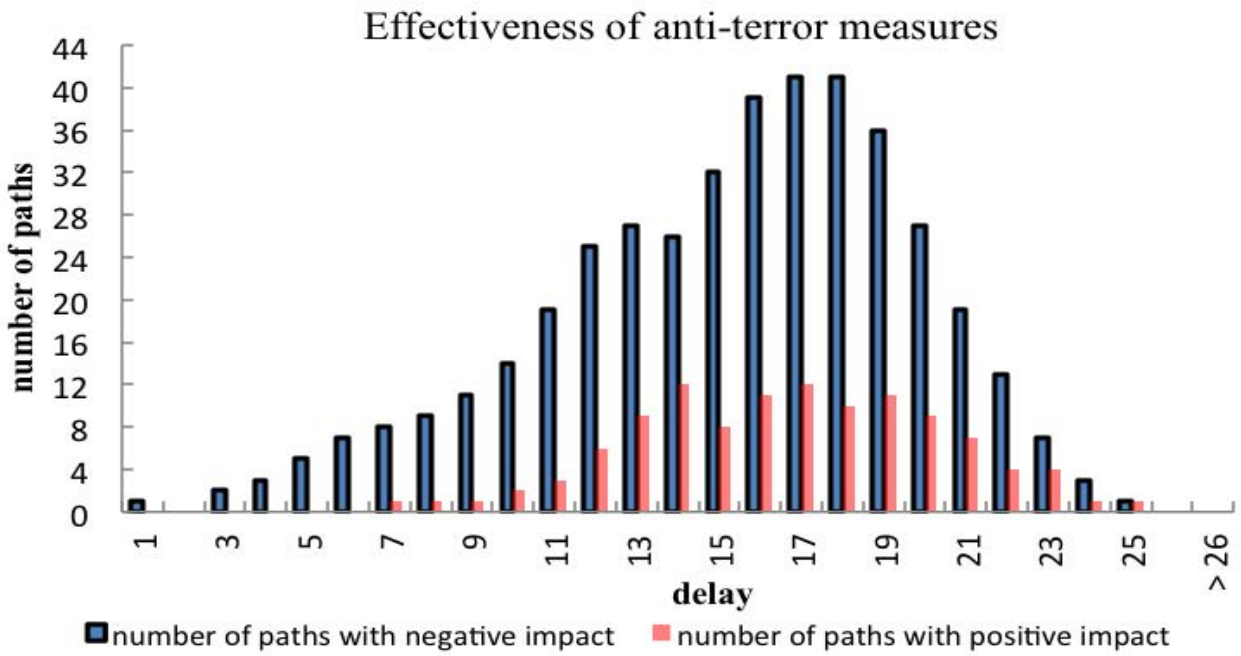
We now analyse the consequences of intensifying (i.e.,positively stimulating) the intervention variables that we have identified. We are interested in measuring their effects on the most important variable: the political influence of a terrorist network (variable 1). To do so, we have to conduct path analyses. A "path" is a sequence of links connecting a starting variable to a target variable. [44] In complex networks such as our model, hundreds of paths potentially lie between two nodes. The following questions are of particular value in this context:

- How many different paths in our model exist from the intervention variable to the target variable ("political influence of the terrorist network")?
- When do these paths arrive at the target variable (time delay)?
- What is their effect?

To calculate the different paths and their corresponding effect and delay, we applied a pathfinder algorithm. The algorithm takes the initial variable and searches for all possible paths toward a target node. [45] Each path is unique, and a node can be crossed only once per path.

Figure 4 displays the results of the first path analysis between the intervention variable "effectiveness of anti-terror measures" (variable 14) and the target variable "political influence of a terrorist network" (variable 1).

Figure 4. *Frequency Distributions of all Paths between Variables 14 and 1*



In total, 529 possible paths conjoin these two variables. Represented by dark, framed bars, the vast majority (416) of these paths have a negative impact on the political influence of a terrorist network. However, 113 paths boost the political influence of a terrorist network (bright, unframed bars). These results confirm the obvious: the better the effectiveness of anti-terror measures by a retaliating country, the less the political influence of a terrorist network.

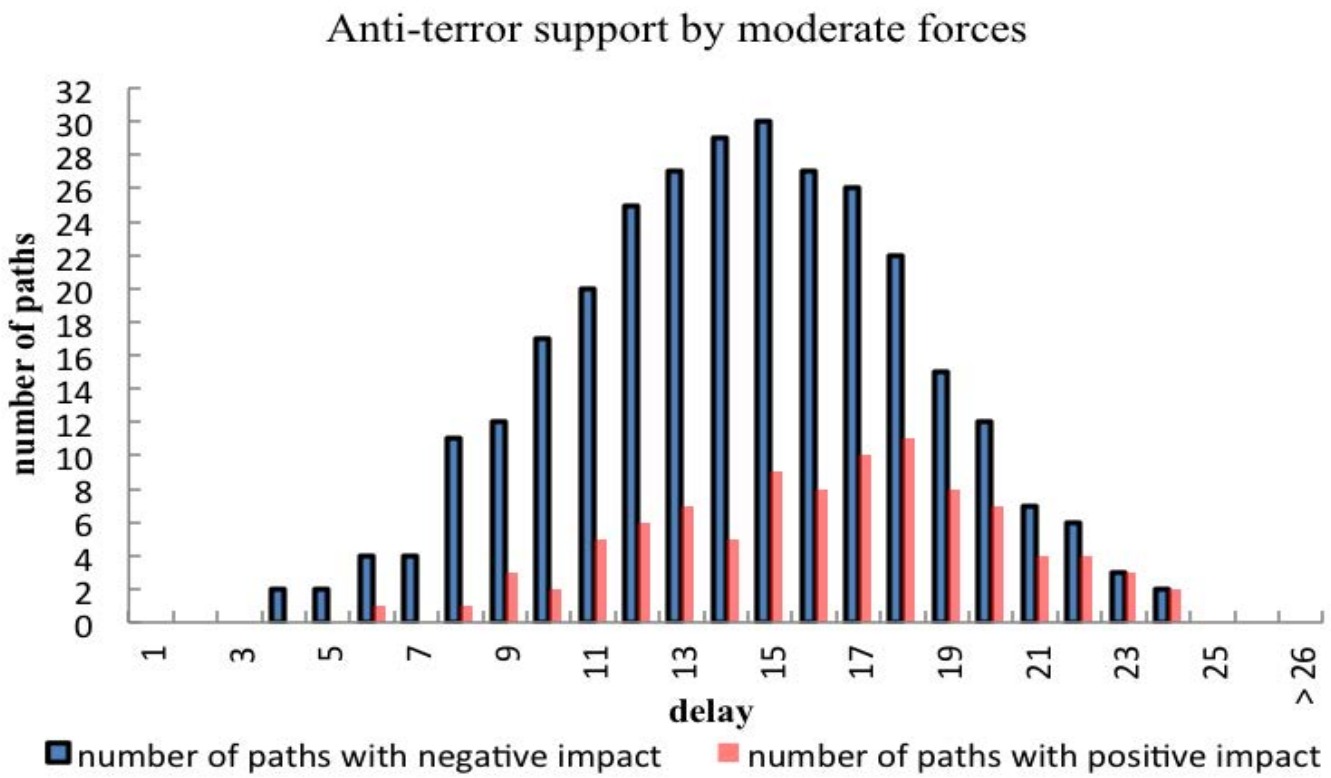
We propose that the ratio between the total number of negative and positive paths is a reasonable measure for comparing different intervention variables and for determining which is the most effective in reducing the political influence of a terrorist network. For variable 14 ("effectiveness of anti-terror measures"), this means:

Total number of negative paths / total number of positive paths = 416 / 113 = 3.68

Now we examine more closely the two distributions (dark and bright) that Figure 4 depicts. Although the delay values on the x-axis have no explanatory power per se, in relation to other distributions we can nonetheless make a statement using these values: The frequency distribution resulting from the negative paths is negatively skewed. In comparison with a Gaussian distribution, the left tail is longer, and the mass center is located on the right side. The extended left tail implies that improving the effectiveness of anti-terror measures will have a substantial and immediate negative effect on the political influence of a terrorist network. However, due to the asymmetry of this distribution, the median lies slightly to the right. Consequently, it takes a long time for the full effect to be measurable in the target variable. The frequency distribution resulting from the positive paths will never be detectable and is completely overlapped by the other distribution.

For comparison, we now show the results of a second path analysis between intervention variable 15, "anti-terror support by moderate forces," and variable 1, "the political influence of a terrorist network" (see figure 5).

Figure 5. *Frequency Distributions of all Paths between Variables 15 and 1*



Between these two variables, we have 399 paths in total. The ratio between the total number of negative and positive paths is 3.16. Therefore, "anti-terror support by moderate forces" has a considerable negative impact on the political influence of a terrorist network, but it is certainly less striking than intervention variable 14.

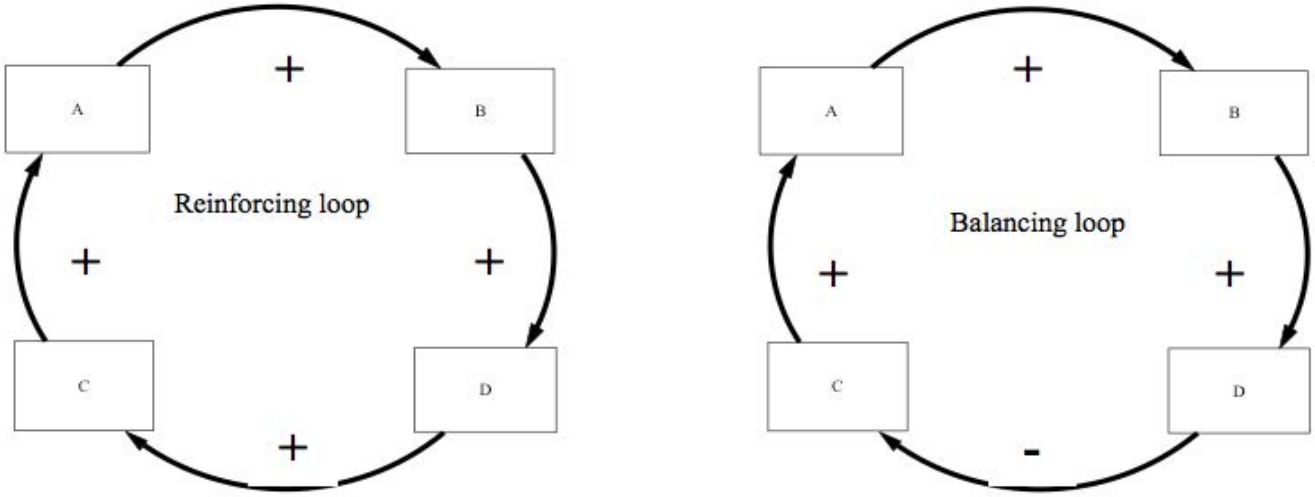
The dark frequency distribution is approximately bell-shaped, meaning that the tail regions are thin and that the mass is concentrated around the mean. Therefore, little or no negative effect is detectable within a short period. In contrast to variable 14, "effectiveness of anti-terror measures," it takes less time for variable 15 to have its full effect on the target variable. Remarkably, the medians of the two distributions differ significantly. In Figure 5, when the dark distribution is peaking, the other is still rising. Consequently, we measure only little or no negative impact on the political influence of a terrorist network in the long run, because an increasing number of paths are aiding the terrorist network.

Model Stability

In this section we analyse the structure of our 16-variable model in more detail. In particular, we look at feedback cycles that play a crucial role for model stability. In systems, feedback loops are structural elements that mostly determine their stability. [46] Feedback cycles are closed loops starting and ending at the same node. This structure implies that a change in an involved variable affects not only subsequent elements but also the changing variable itself.

Feedback loops are generally classified into two categories: "reinforcing" or "positive" feedback cycles and "balancing" or "negative" feedback cycles. [47] Figure 6 illustrates the difference between these two different feedback systems.

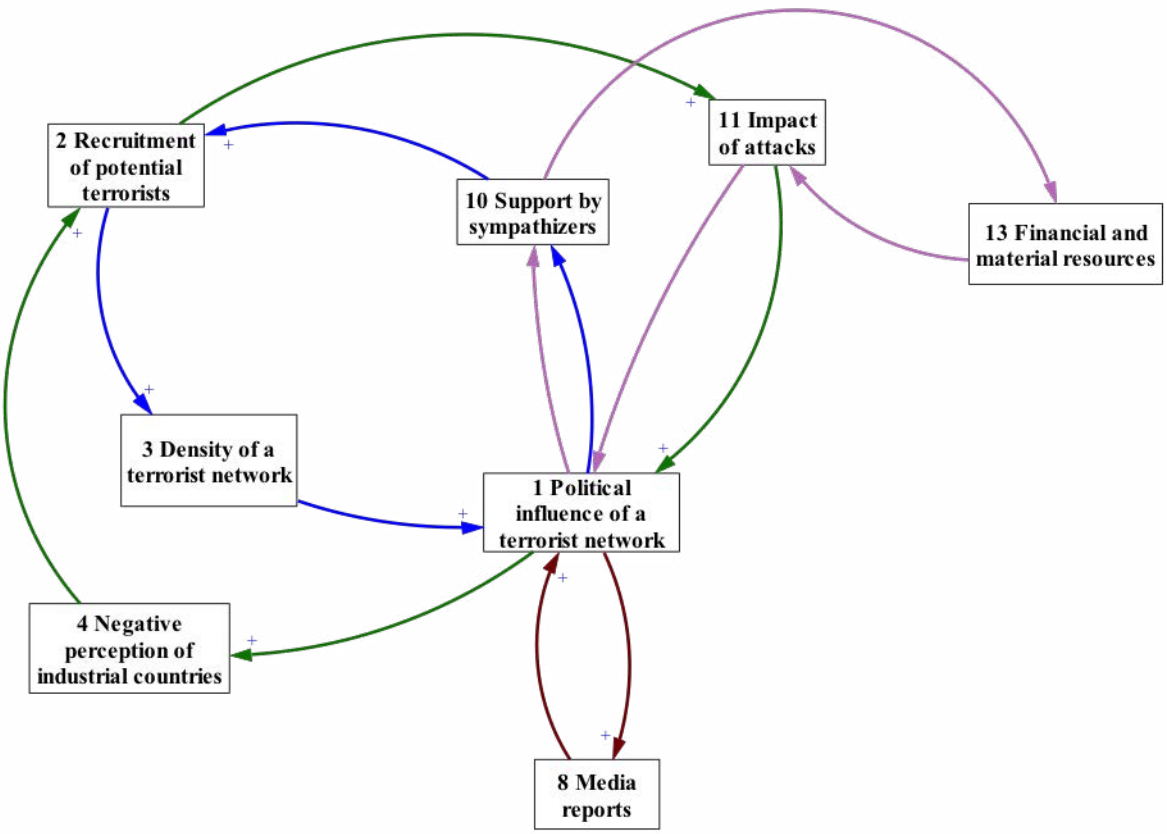
Figure 6. *Reinforcing and Balancing Feedback Loops*



Reinforcing feedback cycles are destabilising factors in a system. Each variable involved is either growing or declining over time. In short, positive feedback loops boost or amplify whatever is occurring in the system. In contrast to reinforcing cycles, balancing feedback loops equilibrate the system. If variable A is stimulated positively, the impulse will change polarity during the loop and have a negative impact on variable A. Therefore, negative feedback cycles are self-correcting and contribute to stability. [48]

Figure 7 depicts the four primary positive feedback cycles that increase the political influence of a terrorist network. For better visualisation, we add two additional links between the variable pairs 1/10 and 1/11.

Figure 7. *Central Reinforcing Feedback Loops*



There is one small feedback cycle, including variable 8, "media reports," and variable 1, "the political influence of a terrorist network." The remaining feedback loops are bigger, each containing four variables. Importantly, three variables ("recruitment of potential terrorists," "support by sympathisers," and "impact of attacks") participate in two feedback cycles at a time.

To better explain the model's structure, we apply a search algorithm on feedback cycles. [49] The following issues are important in this context:

- How many different feedback loops appear in our model?
- What is the ratio between reinforcing and balancing feedback loops?
- What are the consequences relative to model stability if single or multiple variables are removed?

The third point is of special value for policy makers. They need to know which variables or combination of variables they must focus on to break down any terrorist networks. Table 6 summarises the results of this particular analysis. The second row of Table 6 refers to the whole 16-variable model in Figure 1, showing the results if no variable were removed from the model. The entire model contains 2,450 feedback loops indicating a highly interconnected and complex network. A majority of these loops are reinforcing (1,824) and a smaller fraction are balancing (626). The smallest loop is composed of two nodes (min. path), whereas the biggest loop includes 13 nodes (max. path).

The last column in Table 6 shows the ratio between the total number of negative and positive paths incoming on variable 1, "political influence of a terrorist network." We use again a pathfinder algorithm to count all possible paths connecting any node in the model with the target node—variable 1. As long as this value lies below 1, a net positive effect exists on the political influence of a terrorist network. For our entire model, this value is 0.81; there are more positive paths leading to variable 1 than negative paths, so the political influence of the terrorist network is generally strengthened by the variables in our model.

From the third row onwards, Table 6 shows the results if we start removing variables from our model. First we extract single variables, then bundles of variables to study the consequences of those removals for the number and composition of reinforcing and balancing feedback loops. The ultimate goal of this analysis is to find a combination of variables that, if removed from the model, causes the number of reinforcing feedback loops to drop to zero. This finding will reveal the particular combination of variables that, if they are addressed or diffused by a government, would efficiently fight the processes that boost the political influence of a terrorist network.

Table 6: Policy on/off Analysis

removed variable(s)	# feedbacks	# reinforcing (+)	# balancing (-)	min. path	max. path	# remaining feedbacks (in %)	ratio ingoing paths on 1
Intact network	2450	1824	626	2	13	100.00%	0.81
1	405	297	108	2	12	16.53%	-
2	296	232	64	2	12	12.08%	0.76
3	859	730	129	2	11	35.06%	0.68
4	937	707	230	2	12	38.24%	0.79
5	1911	1465	446	2	13	78.00%	0.69
6	1910	1430	480	2	13	77.96%	0.87
7	376	290	86	2	10	15.35%	0.73
8	1649	1179	470	2	13	67.31%	0.88
9	1560	1121	439	2	13	63.67%	0.85
10	1253	938	315	2	12	51.14%	0.85
11	192	128	64	2	11	7.84%	1.1
12	1798	1238	560	2	13	73.39%	0.9
13	694	545	149	2	12	28.33%	0.87
14	954	732	222	2	13	38.94%	0.64
15	568	434	134	2	12	23.18%	0.61
16	2124	1791	333	2	13	86.69%	0.68
8;10;13	267	199	68	2	11	10.90%	1
10;11;13	72	51	21	2	9	2.94%	1.08
4;10;11	49	35	14	2	9	2.00%	1.12
2;11;3	22	22	0	2	8	0.90%	1
2;10;11	18	17	1	2	7	0.73%	1.04
2;4;11	13	12	1	2	7	0.53%	1.05
2;11;13	11	10	1	2	6	0.45%	1.06
2;11;8	6	5	1	2	5	0.24%	2.05
2;11;8;13;4	1	0	1	2	2	0.041%	2.4

To effectively reduce the political influence of a terrorist network, one must break the central reinforcing feedback loops displayed in Figure 7. Variable 11 ("impact of attacks"), which is part of two positive feedback loops, has the greatest effect on model stability. If this variable is removed from the model, the total number of feedback loops will decrease by approximately 92%. This finding is not at all surprising, because each terrorist network plans and executes attacks to cause the most severe physical and psychological damage. Therefore, it is of great importance for every country threatened by terrorism to protect potential targets in the best possible way: by protecting particular buildings and places that have great historic value and those that attract many people. Another key variable is the "recruitment of potential terrorists," the fuel in the terrorist network. Stopping recruitment would cause the total number of feedback loops to drop by roughly 88%. However, reducing or even stopping the inflow of new terrorists is a complex task, requiring both a large amount of time and resources and a deep understanding of the underlying motives that lead young people to join a terrorist network. Often, a lack of future prospects in poor and underdeveloped countries provides the breeding ground for joining a terrorist organisation.

However, the separate removal of variables 11 ("impact of attacks") and 2 ("recruitment of potential terrorists") does not lead to a complete crush of our model—both interventions reduce the number of feedbacks significantly but there remain hundreds of positive feedbacks in the model. This means that to perfectly break the model, we need to eliminate or defuse several variables until no single positive feedback loop—one that reinforces the political influence of a terrorist network—remains in the model. Already, Vester [8] has suggested that a complete dissolution of a terrorist network is only possible by simultaneously tackling multiple variables of these networks.

We achieve the best results by removing variables 2, 11, 8, 13, and 4 ("recruitment of potential terrorist," "impact of attacks," "media reports," "financial and material resources," and "negative perception of industrial countries"). Effectively targeting these variables completely crushes our model, leaving only one negative feedback loop remaining. Media reports play a crucial role in the context of terrorism. Attacks that generate a large amount of media reportage help to strengthen the political influence of a terrorist network. Therefore, the press should strike the right balance between informing and over-informing the public about terror attacks. Obviously terrorists are dependent on financial and material resources (variable 13). Experts have estimated Al-Qaeda's budget for 2001-2004 at 20-50 million dollars, meaning that Al-Qaeda was at that time incredibly well funded. [32] Governments combating terrorism should try to identify the sources of these funds and cap them. In the end, countries threatened by terrorism should also ask themselves why they are so negatively perceived in those countries where the terrorists originate from (variable 4). Tackling this combination of variables also has a strong positive effect on the ratio between the total number of negative and positive paths leading to variable 1, as displayed in the last column in Table 6. This ratio rises to 2.4, implying that 2.4 times more negative paths exist than positive ones. In short, eliminating the combination of variables discovered by our analysis reduces the political influence of a terrorist network systematically for this particular network.

Conclusion

This article presents a new method for dealing with terrorism. As terrorism is a complex problem, simple solutions focusing on only one factor are destined to fail. Given that we must understand terrorism in its entirety, systems thinking offers tools for reaching this goal. The key to success thus lies in the modeling process. To accurately produce reliable outcomes, a model must reflect the most relevant influencing factors and their interdependencies. Our model does precisely that. [50]

Once a well-grounded model is available, policy makers can perform different analyses from the field of systems thinking. First, however, they must characterise each relationship and answer the following two questions: How strongly does one variable influence another? How long does it take for this effect to be measurable?

A graph in which time and effect are mirrored enables the deduction of the best intervention variables in the system. By definition, an intervention variable has a dominant position (high active sum) and quickly distributes stimuli throughout the system (low produced delay). In our model, we found three variables suitable for intervention: (1) control of overreaction, (2) effectiveness of anti-terror measures, and (3) anti-terror support by moderate forces.

Next, we studied in detail the effects of two intervention variables on the political influence of a terrorist network. Because more than one connecting path exists between the intervention and the target variable, we applied a pathfinder algorithm to reveal all possible routes. One astonishing result is that both "effectiveness of anti-terror measures," and "anti-terror support by moderate forces" show not only a dominant negative effect but also a small enhancing effect on the political influence of a terrorist network.

Finally, we tested the model's stability by removing single and multiple variables. To completely break down our terror model, we must approach the problem in five different areas: (1) recruitment of potential terrorist, (2) impact of attacks, (3) media reports, (4) financial and material resources, and (5) negative perception of industrial countries.

The methodology presented in this article addresses two important weaknesses of multidimensional analysis methods in the terrorism research literature [51]: First, our approach explicitly considers temporality as a crucial element in modeling terrorism, which has been neglected up to now. Second, by assigning positive and negative weights to all relationships in the model, we evade the problem of treating variables uniformly. The range of weights can also be expanded to include "disproportionately" low (2/3) and high (3/2) impact values—adding more specificity but also more complexity to the analysis process.

The model in Figure 1 is based on Vester's work that combined key aspect of international terrorism threatening the United States at the beginning of this century. We have adapted his model by taking into account that terrorism matters for the whole international community rather than only the U.S., thus analysing "globalised" terrorism. Our model is not limited to that scale: it is easily adaptable to national or local forms of terrorism. The 16 variables used in our model are highly aggregated and would be changed if the focus were to be a national terrorist network. In such a case, the modeling process starts with the identification of all relevant stakeholders in the specific national terrorism context and with the deduction of new key variables representing stakeholder interests.

The one drawback of our method is its limited ability to employ validation tests. In contrast to simulation methods, our semi-quantitative systems thinking approach does not allow checking the validity of the results before they are actually implemented. Nonetheless, we strongly recommend that policy makers use our systems thinking tools to find long-term sustainable solutions for complex issues in business and society. [52] In addition, we emphasise that the method presented in this paper is an expert tool. A potential user needs to have extensive knowledge about the subject of analysis, otherwise no reliable outcome can be achieved.

At this point we can describe feedback in a qualitative and descriptive manner. Therefore, future research should be directed towards a better formal understanding of feedback structures in a complex system.

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Notes

[1] This paper follows Paul Pillar's definition of terrorism as having four essential characteristics: (1) It always has a political character, thus ruling out violence in conjunction with financial interests; (2) the target choice is non-random, thus involving in-depth preparation and a planning phase; (3) terrorism strikes the civil population intentionally, affecting non-combatants; and (4) the terrorist network itself is composed of non-state actors. See Paul R. Pillar, *Terrorism and U.S. Foreign Policy* (Washington, D.C.: Brookings Institution Press, 2001), pp.13-20.

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[12] The approach presented in this paper is detailed in: Mathias Beck, Lukas Schoenenberger and Andrea Schenker-Wicki, "How Managers Can Deal with Complex Issues: A Semi-Quantitative Analysis Method of Causal Loop Diagrams Based on Matrices" (UZH Business Working Paper No. 323, Department of Business Administration, University of Zurich, 2012).

[13] Frederic Vester, op. cit., pp. 318-327.

[14] We omit seven variables that Vester uses: „successful protection," "quality of life in democracies," "learning from the shock," "damages on civilians," "damages on economy," "U.S. anti-terror actions," and "acceptance of U.S.-actions." Instead we introduce three new variables: "media reports," "intragroup communication & coordination," and "support by sympathisers", taking account of current trends in terrorism research.

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