The London School of Economics
and Political Science

In The Opponent's Shoes – Modelling Dynamic Preferences of Malicious Agents

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I declare that my thesis consists of 38,750 words.

Statement of conjoint work

I confirm that Paper I and Paper III were jointly co-authored with Dr Gilberto Montibeller and I contributed 70% and 80% respectively of this work. I contributed to 100% on Paper II. The breakdown of contribution is summarised in the table below:

	Sumitra Sribhashyam (Candidate)	Dr Gilberto Montibeller (1st Supervisor)
Chapters 1, 2 & 6	Writing and compilation of the chapters, establishing methodology, establishing the framework, preparation of tables and figures.	Supervised and assisted with compiling the chapters, editing.
Paper I	Writing and compilation of the paper, compilation of references for the literature review, analysis of the results, and determining the resulting prescriptions, preparation of tables and figures.	Proposed the direction of the paper, supervised and assisted with compiling the paper, editing, and co-author of the paper.
Paper II	Writing and compilation of the paper, established study design, build study, data gathering, analysis of results, compilation of references for the literature review, preparation of tables and figures.	
Paper III	Writing and compilation of the paper, established framework, data gathering, model building, analysis of results, compilation of references for the literature review, preparation of tables and figures.	Supervised and assisted with compiling the paper, suggested a focus on utility instead of value and proposed the extensions of independence conditions through time, editing, reviewing the paper as per the major, then minor revision for publication, and co-author of the paper.

Table 1 Statement of conjoint work

Statement of inclusion of previous work

I can confirm that some of the preliminary work done in Paper III was the result of previous study (for the MSc in Operational Research) I undertook at the London School of Economics and Political Science. This work included gathering data on terrorism strikes.

Abstract

Given the increasing concerns over insecurity caused by terrorism, and the difficulty in quantifying the risk of crime or violent outbreaks in general, several experts have highlighted the importance of understanding the objectives and motivations of terrorists. If one could infer their preferences, it would be possible to understand better their possible nefarious actions in order to guide efforts towards proper counter-terrorism measures. Indeed, one way to anticipate terrorists' actions in counter-terrorism analysis is to consider their judgments when modelling the decisions they might make. Such judgments will drive their chosen actions. Current efforts in modelling terrorist decision making make several assumptions such as rationality of the agents, agents who have a set of constant and ordered preferences, with the ability to perform a cost benefit analysis of their alternatives, among others. However, are such assumptions reasonable? This research seeks to analyse the types of assumptions made across various models for counter-terrorism analysis that represent the agents' judgments and discuss their suitability from a descriptive point of view by drawing knowledge from the fields of behavioural decision analysis, politics, philosophy of choice, public choice and conflict management in terrorism. This research then explores the modelling implications resulting from this insight and provides some recommendations as to how some of these assumptions could be modified in order to describe terrorists' preferences more accurately. An empirical research is also carried out, to analyse the effect of anger on the prioritisation of objectives, and to confirm the findings drawn from secondary research. Subsequently, we present a way of addressing some of the areas highlighted in the critical analysis. We suggest modelling state-dependent judgements of a terrorist organisation – making the assumption it behaves as an individual – via a multi-attribute utility model that incorporates state-dependent priorities to account for preference change caused by exogenous triggers and representing the environment as a system dynamics model.

List of Publications By Candidate

Published Journal Papers

Sri Bhashyam, S., Montibeller, G., 2012. Modeling State-Dependent Priorities of Malicious Agents. Decision Analysis 9, 172–185.

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Dedication

I would like to dedicate this thesis to my mother and father. Their patience, moral and financial support, and their understanding throughout my *extended* studies is gratefully appreciated.

Chapter 1

Introduction

> If you know the enemy and know yourself,
> you need not fear the result of a hundred battles.
> If you know yourself but not the enemy,
> for every victory gained you will also suffer a defeat.
> If you know neither the enemy nor yourself, you will succumb in every battle.
> Sun Tzu – The Art of War (Tzu and Giles, 2008, p. 52)

1.1 Context Setting & Motivation for the Research

Purposeful acts of violence, such as those perpetrated by terrorists, are a ubiquitous worldwide phenomenon. Recently, violence has been recognised as a cause of concern for the economic development of a country and global social instability. Governments are increasingly under pressure to find ways to tackle the issue (United Nations Human Settlements Programme, 2007).

Since the 9/11 New York and the later 7/7 London terrorist strikes, and more recently the Boston Marathon bombing, governments and security officials increasingly have had to try to find ways to protect the public against attacks. Concerns over what needs to be protected and how has become a growing issue. Indeed, the fight against terrorism has become more and more difficult. Some experts, such as Richardson (2007), even go to the extent of saying the fight against terrorism can never be won, it is therefore natural for governments to turn towards preventive measures.

Preventive measures have typically focussed on assessing threats using qualitative means by seeking expert judgement from underwriters, for instance. Now with the capacity brought by mathematical modelling, there exist new ways of modelling threats which lie in the remit of risk analysis (Broder 2000; 2006; Woo 2003). In risk modelling, the choice of methodologies to assess risks are dependent on the source of that risk. Statistical-based analysis such as Probabilistic Risk Analysis (see Bedford and Cooke 2001 for an overview of uses) are best suited for the analysis of risks occurring from natural or random events. On the other hand, risks caused by the action of an intelligent agent who is trying to achieve specific goals requires different means (Bier, 2006). As terrorism has an adversarial nature, the agent is going to react strategically when attacking. Therefore, pre-emptive means against one type of strike may increase the risks of another strike (Bier et al., 2005; Brown and Cox, Jr., 2011; Guikema and Aven, 2010; Kardes and Hall, 2005). Because of this, the task of the

Department of Homeland Security (DHS) is to "identify and prioritise the risks - understanding the threat, the vulnerability, and the consequences. And then we have to apply our resources in a cost-effective manner, […]" (Chertoff, 2007), which requires an understanding of the various types of strikes terrorists are considering and the consequences of counter terrorism policies and actions (Ezell et al., 2010; Keeney and von Winterfeldt, 2011). Decision making models such as Multi-Attribute Utility Theory have recently been used in counter-terrorism analysis, and are built from the perspective of the terrorists (Keeney and von Winterfeldt, 2009; Merrick and McLay, 2010; Rosoff and John, 2009). However, unlike most Decision Analysis modelling situations, modellers do not have access to the terrorists as decision makers. This means that such models have to be based on several assumptions concerning the objectives such agents have and the way they choose to maximise their utility. Hence, as suggested by Rosoff & John (2009), it is crucial to gain a greater knowledge of the malicious agents' objective function to better understand the threat they cause. Thus, if one could infer their preferences, it would be possible to have more insight into their potential nefarious actions in order to guide efforts towards pre-empting those criminal acts. This may help with reducing the insecure climate caused by the phenomenon of terrorism.

To model terrorists' judgement, it is necessary to have insight into three areas of decision-making. First, as decision models are based on deriving an optimal solution given a number of objectives, an understanding of what drives terrorists is required. Classic decision-making approaches such as Multi-Attribute Utility Theory make the assumptions that the set of objectives and their weights remain static over time. However, objective weights, or priorities, have been seen to change over time depending on the scenario a decision maker is facing (Kornbluth, 1992). Therefore, the ranking derived from such models can only be considered as an accurate representation of an agent's preferences at the time the model was built. In the context of terrorism, where the agents adapt their strategies depending on the situation (Bier et al., 2005; Brown and Cox, Jr., 2011; Guikema and Aven, 2010; Kardes and Hall, 2005), it appears essential to capture the dynamic nature of the prioritisation of objectives in order to provide some useful insight.

Second, insight into the elements that influence judgement and hence decision-making can help with making models more realistic and descriptively accurate for risk analysis. Various elements are subject to have an impact on a decision maker's judgement, including framing effects (Tversky and Kahneman, 1981), the amount of time available to make the decision (Wittmann and Paulus, 2009, 2008) and the effect of visceral factors (Lerner and Keltner, 2000; Lerner and Tiedens, 2006; Loewenstein, 2000). Visceral factors such as anger can affect risk attitude, the evaluation of outcomes and their perceived likelihood (Lerner and Keltner, 2000; Lerner and Tiedens, 2006). In this research, we only focus on capturing the latter effects. Indeed, the changes that can be incurred by such factors are non-negligible as their impacts

can be significant, influencing both the agents and the environment in which they operate (Loewenstein 1996; 1999; 2000). We expect terrorists – both the organisation and the terrorists carrying out the orders – to be especially prone to visceral factors. Furthermore, because of its systematic influence, the effect of visceral factors is much more predictable than other effects such as cognitive deliberations, for instance (Loewenstein, 2000).

Finally, gaining an understanding of how this kind of insight can be integrated to model such behaviours is necessary for developing a framework for combining the objectives of terrorists, and their changes over time.

The aims of this research are twofold. First, it is to help make the assumptions of counter-terrorism more realistic and descriptively accurate for risk analysis. To do so, this research will attempt to provide some insight into the malicious agent's objective function to better understand what they are trying to achieve, by trying to identify changes in an agent's prioritisation of objectives and consequently the preference ordering for certain types of strikes. Second, this research aims to develop a framework, which will try to infer a terrorist preference ordering of harmful acts. To do this, we will draw from the fields of decision analysis, the formation of preferences, and the different areas surrounding terrorism (such as politics and conflict management). This dynamic framework will be based on their value system, their objectives and on the state of a system. Such a framework may help anticipate a motivation to cause social unrest by disruptive agents, by modelling their preference change over time and its impact on their choice of a harmful action.

In the rest of this chapter, we will highlight the assumptions commonly made in current models for counter-terrorism analysis and the resulting implications for this research. We present the objectives of this research, the methodology we have used to achieve them, and finally, we provide the outline of this thesis.

1.2 Questions Arising from the Assumptions Made in Current Models

Before we discuss further, it is important to have an understanding of who the decision maker modelled is. Terrorists can be classified into the following categories:

a. Sponsor state – sponsors one or more terrorist organisations,
b. Terrorist organisation recruits, manages, and leads terrorist cells,
c. Terrorist cell – trained operational units,
d. Terrorist – active but not suicidal, and
e. Terrorist – suicidal.

Commonly, models for counter-terrorism analysis look at decisions made by terrorist organisations (b), who may be devising the strategies. Models which are modelling

decision at a micro level involve the categories c, d and e. The questions highlighted in this section relate to terrorists belonging to the categories b, to e.

Models for counter-terrorism analysis have a common aim: modelling the occurrence of uncertain threats caused by terrorists. However, they are all based on strong assumptions, which can be arguable in the context of terrorism. These important assumptions can be broadly classified under the categories outlined below.

- **The rationality of the adversary and their ability to formulate the problem and compute the best outcome**

  One of the main assumptions made in counter-terrorism models concerns the rationality of terrorists - they assume that these agents will choose the branch maximising the consequences of an attack. But is it always reasonable to assume the adversary has the ability to assess the parameters involved in each strategy to determine the branch returning the highest expected utility? This assumption can be plausible in some cases, but it becomes more debatable when the scenario involves strikes at the more complex end of the spectrum. This also requires us to know the terrorists' utility function, which can be challenging. Indeed, modellers do not have access to them. In most models, terrorists are assumed to be political utility maximisers. However, their actions often do not seem to support this view. Whilst they have been seen to make their choices of strikes, locations and timing strategically, they also engage in actions that go against their political aims. Some of these include refusing to engage peacefully in democratic processes, conducting anonymous attacks, or eradicating competitive terrorist organisations that share their goals, and having changing goals as the situation progresses (Abrahms, 2008).

  Whether terrorists are rational or not will inform us on whether models of expected utility theory can be adequately used to model terrorists' decision-making. The following question, therefore, arises:

  If terrorists are rational utility maximisers, what objectives are we omitting which would then explain their behaviour?

- **The utility functions of the adversary – what are the goals being maximised and are they stable?**

  Most traditional decision models usually assume preferences to be static, and hence tend to ignore the potential for the agents to change their initial preferences through the decision process (Bennett and Howard, 1996; von Auer, 1998). Empirical research has shown that new information and changes in the environment have an impact on preferences and their ordering (Bradley, 2009; Hansson and Grüne-Yanoff, 2009; Loewenstein and Angner, 2003; Loewenstein et al., 2003). Hansson & Grüne-Yanoff (2009) explain that for complex situations, choices do not originate from a stable set of preferences. Moreover, according to Bradley (2009), what an agent's choices and preferences depend on include his/her

convictions, desires, and these convictions depend among other things on the information he/she possesses. For these reasons, preferences are dependent on the environment, resulting in a potential preference ordering, which may differ at various points in time.

So is it reasonable to assume that terrorists' preferences are static, and if not, what should we take into account?

This research will explore the literature on terrorism to further understand what motivates terrorists' actions to determine whether models of political expected utility are sufficient to describe terrorists' decision-making, and if not, what needs to be considered.

- **The ability of the defenders and attackers to assess uncertainties and evaluate the alternatives involved in the decision**

Counter-terrorism models, in particular those using Probabilistic Risk Analysis, rely heavily on the availability of intelligence data and expert knowledge. In the case of terrorism, this type of data is scarce and in most cases classified. Furthermore, providing an assessment of uncertainties, such as the likelihood of success of the attacker given a certain strike, requires modellers to make several assumptions. These include postulating that terrorists view the world objectively, and that their own belief of success/failure is unbiased.

Given what we discussed earlier regarding preference change due to new information, emotions and changes in the environment, the following questions arise:

Are terrorists' preferences static and how can a Multi-Attribute Utility Theory model capture dynamicity of preferences?

Do the triggers that motivate terrorists have an impact on their preferences and judgements?

This research will investigate the dynamic aspects that could potentially lead to a change in preference ordering. This could help in inferring an opponent's preference ordering based on their value system, their objectives and on the state of a system. Incorporating such dynamicity in a framework may help anticipate a motivation to commit criminal acts by disruptive agents, by modelling their preference change over time and its impact on their choice of a harmful action.

In the next section, we detail the objectives of this research further.

1.3 Research Aims and Objectives

This research has two main aims. First, it is to help make the assumptions of counter-terrorism more realistic and descriptively accurate for risk analysis. Second, it is to develop a dynamic framework, which will help in inferring an opponent's preference ordering based on their value system, their objectives and on the state of a system.

One way to anticipate terrorists' actions is to consider their judgements when modelling the decisions they might make - such judgements will drive their chosen actions - so proper counter-terrorism measures may be adopted. The current modelling techniques employed in counter-terrorism modelling make several assumptions regarding the terrorist as a decision maker. However, the prescriptive advice drawn from such models require these models to be requisite (Phillips, 1984). Consequently, one of the important underlying elements of these models is the adequacy of the assumptions, and the understanding of the decision maker modelled. In this section, we summarise the key objectives this research seeks to explore and address.

The focus will be on modelling preference change induced by changes in priorities – in this research, we concentrate on changes in preference caused by various exogenous triggers. Such a modelling approach may help improve the understanding of agents' dynamic preferences and hence their behaviour, but also may help in better anticipating potential risks of violence outbreaks based on changes in the environment.

Achieving these two aims involved a multidisciplinary approach, which included investigating the following fields within the context of terrorism: conflict management and politics, the theory of choice, public choice, behavioural decision theory, expected utility theory, and multi-attribute utility theory.

In summary, the main objectives of this thesis are:

1. To critically analyse the assumptions made in counter-terrorism modelling. To bring knowledge from the fields of behavioural decision-making and psychology to provide insight into how decision-making is influenced by the effect of the visceral factor anger, an emotion terrorists are likely to be subject to. To bring knowledge from the various fields surrounding terrorism to provide insight into what influences terrorist's decision making. In particular, analysing differences between types of terrorists, the characteristics of their rationality, the goals that drive them, and psychological elements which might affect their judgement.
2. To contextualise this knowledge within modelling terrorist decision making using multi-attribute utility theory and provide some prescriptive guidelines.
3. To empirically examine the effect of anger – an emotion we expect terrorists to be prone to – on the prioritisation of objectives, focussing in particular on terrorist objectives.

4. Based on hypothetical data, to develop a dynamic framework for capturing preference rankings that does not require the assumption of static preferences, by integrating system dynamics with multi-attribute utility theory to capture the effect of visceral factors on priorities.

1.4 Research Methodology

To achieve the aims and objectives as outlined in sections 1.2 and 0, this research involved a sequential approach based on several steps. We started with a qualitative approach, which guided the quantitative requirements for the subsequent steps. Then a framework that captured the aspects of the decision-making process of terrorists was constructed. According to Meredith et al. (1989), such an approach requires the assumption that we can model causal relationships, i.e. that a change in a value of a variable α will lead to a certain consequence dependent on that variable, $f(\alpha)$.

As noted by Bertrand and Fransoo (2002), it is rare to find an explicitly defined range over which the variables change, and challenging to find quantitatively well-defined causal relationships. Because of this, predictions made by the models are not always unambiguous and verifiable. The nature of our research problem involves variables that are poorly defined quantitatively. Indeed, the level of anger, and other visceral factors cannot be explicitly expressed. Their levels have causal quantitative impacts on other dependent variables, which are also not well defined. Such models fall into the category of axiomatic quantitative modelling, as opposed to empirical quantitative modelling (Bertrand and Fransoo, 2002). In contrast to the former, empirical quantitative modelling requires models to be validated with reality, which given the nature of the application and the lack of available data would not have been feasible.

In line with the axiomatic type of research, what we are concerned with is gaining greater insight into the structure of a problem, how variables in the defined model behave when certain other variables are changed. This is done by proposing a model representing a situation that is based on logical procedures. From such a representation, consequences can be derived and solutions to the given problem can be proposed (Roy, 1993). This is based on making several assumptions about the behaviour of a set of variables (Bertrand and Fransoo, 2002; Meredith et al., 1989; Roy, 1993).

Axiomatic research can take two directions, normative and descriptive. The former approach is geared towards providing an understanding of processes to prescribe means of improving solutions currently available. These improved solutions can take the form of policies, strategies and other types of interventions to tackle an issue. On the other hand, the descriptive approach is concerned with providing an understanding of the processes within the model via the use of mathematical emulation (Bertrand and Fransoo, 2002; Meredith et al., 1989).

Given our investigation of various methodologies, we found that combining the normative and descriptive axiomatic approaches were best suited to achieving our research aims. Indeed, we are interested in both providing some insight into how the variables within the models are changing, as well as providing some prescriptive advice given the analysed behaviours. The research model by Mitroff et al. (1974) propose four phases to the research approach as outlined in Figure 1-1.

In the next section, we describe the relationships across the three papers, and highlight the research methods we have used in each.

1.5 Thesis Outline – Relationships between Papers

As highlighted in section 1.2, current models for counter-terrorism analysis are based on strong assumptions relating to terrorists as decision makers. As the theory and findings in this area are scattered among several fields (conflict management, politics, and anthropology, for instance), there is a lack of prescriptive insight for modellers in the field of decision and risk analysis. For this reason, we have chosen to take a deductive approach to enable us to deduce some initial hypotheses relating to observed patterns in terrorist decision-making (Bryman, 2012). This was done through the use of accepted principles in the domain of rationality and behavioural sciences (Saunders et al., 2009).

An inductive approach could also have been used. Indeed, this approach's main strength lies in its ability to develop an understanding of an agent's interpretation of the social world. For this reason, this approach has been favoured in social sciences as opposed to the deductive approach (Saunders et al., 2009). However, because of the inability to have access to the decision maker (i.e. terrorists) to analyse their patterns, we found the deductive approach more appropriate.

In *Chapter 2: "Time, Decisions, Visceral Factors & Modelling Preferences",* we give an overview of the underlying theories behind this research. We explore the theory of preferences and decisions from the perspective of economics, philosophy and psychology. We illustrate these concepts using a classic case of preference change: Ulysses and the Sirens. We provide a brief overview of the main frameworks used to model time dependent preferences. Furthermore, we also describe the different approaches used to model decisions and preferences in the context of terrorism, looking, in particular, at the cases where Expected Utility Theory (EUT) and expert elicitation are used. We briefly describe the key characteristics of the methods.

The chapters that follow are standalone papers, aimed at different types of journals. Given their standalone nature, some repetitions of theoretical concepts were inevitable. Each paper is preceded with a prelude to ease the transition between them and for clarity.

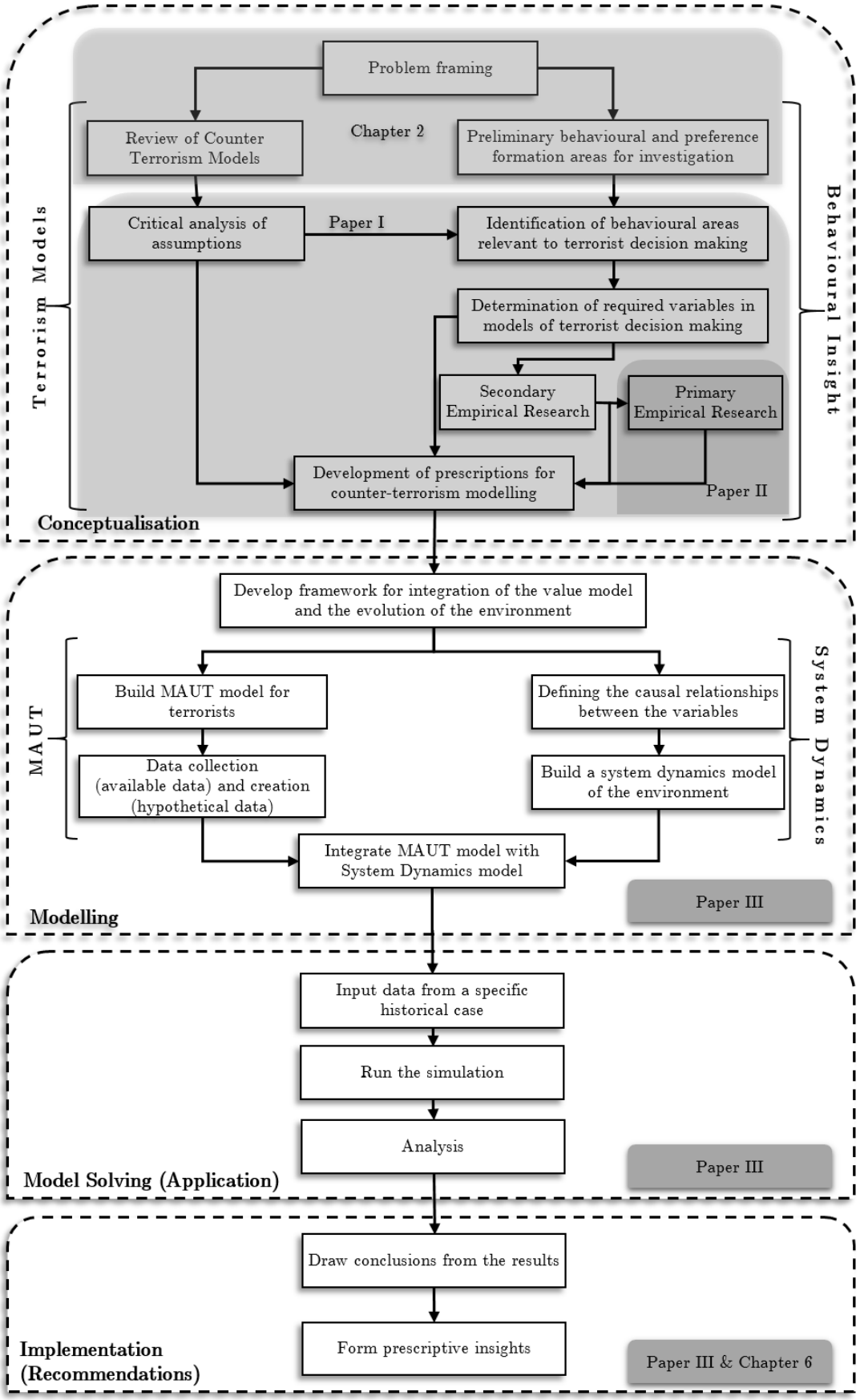

Figure 1-1 Schematic diagram showing the detailed steps undertaken in the research and where they are developed into chapters and papers

In *Paper I: "In the Opponent's Shoes: On Modelling Terrorists' Judgements For Counter-Terrorism Analysis"*, we explore the types of assumptions made across various models that represent malicious agents' judgements and discuss their suitability from a descriptive point of view. Subsequently, we discuss how some of these assumptions could be modified in order to describe terrorists' preferences more accurately by drawing knowledge from the fields of politics, philosophy of choice, public choice, and conflict management in terrorism. Such insight, we hope, will help make the assumptions of these models more realistic for risk analysis. This paper was aimed for submission to a journal of management science nature, such as *Risk Analysis*.

In *Paper I,* anger is highlighted as one of the factors that can have a significant impact on terrorist decision-making, and in particular, on the prioritisation of their objectives. Building on this insight, in *Paper II: "Rational Self-Destruction: The Effect of Anger on the Prioritisation of Self-Destructive Objectives"*, we describe a study of the impact of anger on the prioritisation of objectives, some of which were self-destructive. We also analyse the impact of such emotions on the preferences of self-destructive actions, and discuss the implications of the findings within the context of modelling preferences, in particular, those of terrorists. This paper was aimed for submission to a journal of a behavioural science nature, such as the *Journal of Behavioral Decision Making*.

The empirical study of emotional impact on judgement and decision making in *Paper II* was based on the Appraisal-Tendency Framework. This framework suggests that specific emotions will have distinct impacts on judgements due to depth and content of processing (Lerner and Keltner, 2001, 2000; Lerner and Tiedens, 2006). Drawing from the analysis carried out in *Paper I,* we were interested on and tested for anger. A component of the Appraisal-Tendency Framework requires the analysis of the effects of another emotion of the same valence, but that differs in terms of another dimension. We chose to test for fear, which is of a negative valence like anger, but of opposite certainty dimension. Indeed, anger is considered to belong to the type of emotions related with a sense of certainty, while fear tend to be linked with a sense of uncertainty (Roseman, 1984; Scherer, 1984; Smith and Ellsworth, 1985). Similar to studies testing the effect of emotions on decision making (Ariely and Loewenstein, 2006; Isen and Geva, 1987; Isen and Patrick, 1983; Isen, 2001; Lerner and Keltner, 2001, 2000; Lerner et al., 1998; Loewenstein et al., 1997; Small and Lerner, 2008; Tiedens and Linton, 2001), we have adopted a controlled experiment to analyse the impact of these two emotions.

Whilst so far, research within the field of terrorism modelling has assumed static preferences of terrorists, empirical research has shown that priorities may change over time. One of the factors that can have a significant impact and of particular relevance to the context of terrorism is the effect of anger on decision-making. This was highlighted in *Paper I* and the empirical study carried out and described in *Paper II.*

In *Paper III: "Modeling State-Dependent Priorities of Malicious Agents",* by combining the theory derived above, we used System Dynamics to model the system surrounding the malicious agents in question. This could indicate the evolution of the variables in the environment that would trigger the fluctuations of the visceral factors experienced by the malicious agents.

System Dynamics is a simulation modelling technique that has been used to model the behaviour of systems over time. This provides decision makers with a deeper understanding of the systems, the causal effects, and feedback mechanisms enabling them to create and optimise control policies (Coyle, 1996; Forrester, 1969, 1968; Richardson and Pugh, 1981; Sterman, 2001, 2000). Furthermore, due to the highly complex and inter-related nature of the causal factors behind violence outbreaks, a holistic approach is required in order to approach the phenomenon. System Dynamics has indeed been used to model the behaviour of a broad range of systems. This tool has the potential to both visually highlight interrelated relationships and to describe mathematically the non-linear behaviour of effects over time (Chamberlain, 2007; Ellis, 2003; Gil et al., 2005; Grynkewich and Reifel, 2006; Saeed, 2009; Skarin et al., 2009).

By integrating System Dynamics to the agent's Multi-Attribute Utility Theory model, the proposed framework will allow us to investigate how to infer the impact of the visceral factors on the weights assigned to the objectives. This could help have a better understanding of what motivates malicious agents and hence have a greater insight into their preference patterns. This framework can be used to infer how terrorists' priorities may change over time and their impact on their choice of a harmful action.

We suggest modelling state-dependent priorities of a terrorist organisation – making the assumption it behaves as an individual decision maker – via a multi-attribute utility model that incorporates dynamic priorities to account for preference change caused by exogenous triggers. We model a possible terrorist's multi-attribute utility function as well as a System Dynamics model representing the terrorist situation. Combining the two approaches would inform how the agents may re-prioritise their objectives in response to changes in their environment and hence their behaviour. This may help in better anticipating potential risks of violence outbreaks based on changes in the environment. Finally, we show how a preference ordering can be derived from them and highlight how such an analysis may support risk management in this context.

This last paper was published in the American journal Decision Analysis:

Sri Bhashyam, S., Montibeller, G., 2012. Modeling State-Dependent Priorities of Malicious Agents. Decision Analysis 9, 172–185.

1.6 Chapter 1 References

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Chapter 2

Time, Decisions, Visceral Factors & Modelling Preferences

Chapter 1 has highlighted the key questions that this research seeks to explore and address. We highlighted the three areas of decision-making where insight is necessary to model terrorists' judgement.

First, understanding what drives terrorists, i.e. what their objectives are, is required in order to describe their preferences and judgement using decision analytical models. Traditional decision models tend to ignore the potential for the agents to change their initial preferences through the decision process (Bradley, 2009; Hansson and Grüne-Yanoff, 2009; Loewenstein and Angner, 2003; Loewenstein et al., 2003). The dynamicity of preferences is especially relevant in the context of models for counter-terrorism analysis. Indeed, some of terrorists' actions can lead us to think terrorists' do not have static preferences (Cordes et al., 1984; Landes, 1978; Mickolus, 1980).

Second, to help make models more realistic and descriptively accurate for risk analysis, further insight into the elements which influence judgement and decision making can inform how changes should be defined and viewed. Factors such as anger can affect risk attitude and the evaluation of outcomes and their likelihood (Lerner and Keltner, 2000; Lerner and Tiedens, 2006). In this research, we focus on capturing effects from such factors, as they can incur non-negligible influences both the agents and the environment in which they operate (Loewenstein 1996; 1999; 2000). Furthermore, because of its systematic influence, the effect of visceral factors is much more predictable than other effects such as cognitive deliberations, for instance (Loewenstein, 2000).

Finally, by gaining an understanding of how such insight can be integrated in order to model this kind of behaviours, we can attempt to develop framework for combining the objectives of terrorists, and their changes over time into a model. This may help anticipate a motivation provoke a state of terror.

This chapter thus explores preference change and discusses the factors influencing it in context of this research. It begins with the paradigm case of Ulysses and the sirens as an illustration to formalise a well-known case of preference change, before providing an overview of the psychological ramifications behind the phenomenon of preference change in the second subsection. Finally, the last sections provide an overview of how

time dependent preferences have been modelled, and the current modelling techniques used in counter-terrorism decision analytical models.

2.1 Ulysses and the Sirens

Before discussing the theory behind preference change, and how visceral factors (one of the exogenous determinants of preference change) contribute to changes in preferences, we begin by an illustration of preference change using the case of Ulysses and the sirens.

> "You must bind me very tight,
> Standing me up against the step of the mast
> And lashed to the mast itself so that I cannot stir from the spot.
> And if I beg and command you to release me,
> You must tighten and add to my bonds."
> Homer – The Odyssey (Homer et al., 2002, p. 161)

The legend of Ulysses and the sirens is a paradigm case often used to illustrate various aspects of time dependent decisions, and dynamic inconsistencies leading to preference change. These include inter-temporal discount rates, binding and self-control (Baron, 2008), naive or myopic sophisticated choice mechanisms (Elster, 2000; Hammond, 1997), decision frames (Tversky and Kahneman, 1981) among other things. Here, this metaphor is used to describe how preference changes could be explained by assuming that Ulysses wanted to pursue multiple objectives and that there is a potential for preferences to change due to a change in priorities caused by changes in the environment.

In the legend, Ulysses is faced with the choice to either sail towards the sirens to listen to their enchanting singing, and consequently be lured to his demise and that of his crew, or sail away as advised by the sorceress Circe. Ulysses' decision can be described by the following decision tree (Figure 2-1). At the initial node, Ulysses can decide to either sail towards the sirens, and either fall into the addictive behaviour *(a)*, or, after having indulged his curiosity, desist before sailing into the rocks *(b)*, or by avoid the sirens completely, following Circe's advice *(c)*. Initially, at time 0 (decision node n_0), Ulysses would favour alternative *(b)* to *(c)*, and finally *(a)*, which is the worst one as it leads to death ($b \; P_0 \; c \; P_0 \; a$, where P_0 stands for 'Preferred to' at time 0).

However, sailors deciding to move to the next node with the intention to reach the initial most preferred alternative (b) are faced with another decision. In the case of sailing towards the sirens and listening to their singing, there is a switch in preferences, leading sailors to now prefer alternative *(a)* (initially the worst alternative) to alternative *(b)* ($a \; P_1 \; b$) at time 1 (decision node n_1).

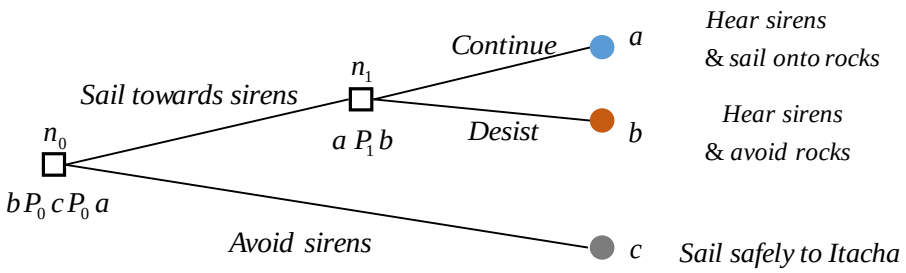

Figure 2-1: Ulysses' Decision Tree

What is of interest in this research is the importance of taking into account a potential for preference change, as illustrated by Ulysses' tale. Traditional decision models for the most part, are static, and hence tend to ignore the potential for the agents to change their initial preferences through the decision process (Bennett and Howard, 1996; von Auer, 1998). Fixing a preference ordering at the beginning of a decision process and ignoring aspects leading to a potential change how objectives are prioritised can lead to an evaluation of performances that does not reflect the one that a rational agent would have gone through to evaluate his/her alternatives at each decision node.

Let us now analyse Ulysses' problem using a multi-criteria decision analysis framework (Belton and Stewart, 2001; Öztürk et al., 2005; Roy, 2005). Using a value focussed thinking approach (Keeney, 1996), we can presume what his values could have been, and assess how these influence his preferences. An interpretation of the legend would have Ulysses' objectives as follows: the hero wishes to return to Ithaca, by maximising his life expectancy, and that of his crew (minimise collateral damage) and enjoy the sail back home, which are displayed in the following value tree (Figure 2-2).

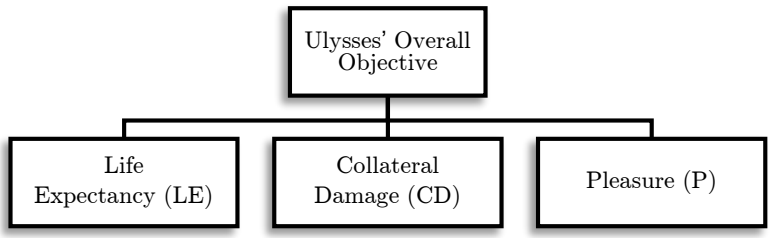

Figure 2-2: Ulysses Value Tree

Ulysses preference ordering can then be derived by calculating the overall performance of each alternative which depends on the weights (relative importance given the range of attributes) Ulysses would give to each objective. Thus, the overall performances at time t of alternatives $j = a, b, c$, would be:

$$V_j^t = \sum_i w_i^t * v_{i,j}^t \quad (1)$$

With w_i^t the weights at time t for each objectives $\mathrm{i} = \mathrm{LE}, \mathrm{CD}, \mathrm{P}$,

And $v_{i,j}^t$ the partial performance at time t of alternatives $\mathrm{j} = \mathrm{a}, \mathrm{b}, \mathrm{c}$ on the i^{th} objective

The partial performances are assessed on an interval scale ranging between zero for the lower bound (worst performing alternative on the i^{th} objective) and one hundred for the upper bound (best-performing performing alternative on the i^{th} objective).

Let us assume we are at the initial node, n_0 where Ulysses has to decide between the three alternatives. Ulysses being King of Ithaca is responsible for the lives of his crew, but most importantly the people of Ithaca, and hence we could infer his weights to be:

$$w_{LE}^0 > w_{CD}^0 \gg w_P^0 \quad (2)$$

In other words, his first and foremost objective is to remain alive (LE), followed by ensuring the safety of his crew (CD), and finally, indulging with some pleasant or enriching adventures (P).

Following this, we can infer the following relationships between the partial performances of each alternative vis-à-vis the objective of Life Expectancy:

$$v_{LE,a}^0 \ll v_{LE,b}^0 \leq v_{LE,c}^0 \quad (3)$$

i.e. the performance of alternative *(a)* on Life Expectancy is far lesser than the two others (in fact if the lower bound of the scale is zero, then $v_{LE,a}^0 = 0$, as it leads to death of Ulysses and the crew). In addition, alternative *(b)* is at least as good as alternative *(c)* (similarly, if the upper bound of the scale is one hundred, then $v_{LE,c}^0 = 100$ as Ulysses and his crew safely sail away with alternative *(c)*.

A similar relationship can be written for the performance of each alternative vis-à-vis Collateral Damage:

$$\mathbf{v_{CD,a}^0 \ll v_{CD,b}^0 \leq v_{CD,c}^0} \quad (4)$$

Similarly, we also have $\mathbf{v^0_{CD,a}} = 0$, as it leads to death of Ulysses and the crew and $\mathbf{v^0_{CD,c}} = \mathbf{100}$).

Finally, we can infer the following relationships of partial performances vis-à-vis the last objective.

$$\mathbf{v^0_{P,c}} \ll \mathbf{v^0_{P,b}} < \mathbf{v^0_{P,a}} \qquad \textit{(5)}$$

i.e. the pleasure obtained from alternative *(c)* is far lesser than the two other. (Similarly, $v^0_{P,c} = 0$ as it is the lower bound in this case, Ulysses does not get to listen to the sirens at all), and because alternative *(b)* only enables Ulysses to listen to the Sirens for a limited time only, it is not as good as alternative *(a)* (which is the upper bound, and hence $v^0_{P,a} = 100$*).*

Hence, we can now derive the preference order by calculating the overall performances of each alternative: From **(1)** we have:

$$V^0_a = w^0_P * 100$$

$$V^0_b = w^0_{LE} * v^0_{LE,b} + w^0_{CD} * v^0_{CD,b} + w^0_P * v^0_{P,b}$$

$$V^0_c = w^0_{LE} * 100 + w^0_{CD} * 100$$

From this relationships, we can derive Ulysses' preference ordering at time 0, and we find that b P_0 c and c P_0 a, hence, by transitivity of preferences b P_0 c P_0 a (see Appendix 2.A for details).

Following this method, Ulysses' best alternative would be to try and reach point *(b)* in the decision tree (Figure 2-1), and according to this decision framework, having fixed the weights, he would manage to reach point b, as the preference ordering would remain stable, i.e. $b\ P_1\ a$, which is not the case.

We argue that one way to explain the preference change can be represented by a change in weights in moving from n_0 and n_1. Within this new environment, a new evaluation would be performed at n_1. Ulysses' objectives remain the same and the partial performances can be assumed stable, the relative importance of the objectives could change. In addition, because alternative *(c)* is no longer available, an adjustment of the relative performances is required, and we have the following new relationships:

$$\boldsymbol{v^1_{LE,a}} \ll \boldsymbol{v^1_{LE,b}} \quad \mathbf{(6)}$$

Similarly to the partial performances at time 0, we have $v^1_{LE,a} = 0$ as it is the lower bound, and $v^1_{LE,b} = 100$ as it is the upper bound.

A similar relationship can be written for the performance of each alternative vis-à-vis Collateral Damage:

$$\mathbf{v^1_{CD,a} \ll v^1_{CD,b}} \quad (7)$$

Similarly, we also have $v^1_{CD,a} = 0$, and $v^0_{CD,b} = 100$

Finally,

$$\mathbf{v^1_{P,b} < v^1_{P,a}} \quad (8)$$

With $v^1_{P,b} = 0$, and $v^1_{P,a} = 100$.

Due to the addictive behaviour, it could be that

$$\boldsymbol{w^0_{LE} > w^0_{CD} \gg w^0_P} \text{ has evolved into } \boldsymbol{w^1_P \gg w^1_{LE} > w^1_{CD}} \quad (9)$$

i.e. now Ulysses mostly cares about his enjoyment by listening to the sirens longer, regardless of the risks incurred to his life and the ones of his crew, explaining the preference change at time 1 (node n_1) into aP_1b.

Similarly as was done for time 0, we can derive the preference ordering and we find that when

$$\mathbf{w^1_P > w^1_{LE} + w^1_{CD}}$$

we can observe at n_1 $\mathbf{V^1_a - V^1_b > 0 \Longrightarrow aP_1b}$ (see Appendix 2.A for details)

Graphically, this can be described by the figures below, which show an illustration of the possible evolution of the overall performances and the weights as Ulysses travels closer to the Sirens, i.e. between n_0 and n_1 (see Figure 2-3, Figure 2-4). The closer Ulysses travels towards the siren, the longer he is exposed to their singing, which has an effect on the weights. While the those on Life Expectancy and Collateral Damage decreases over time (due to the exposure to the singing), the one on Pleasure increases, thus at some point, cause a change of preference between alternative *(a)* and *(b)* before reaching n_1 .

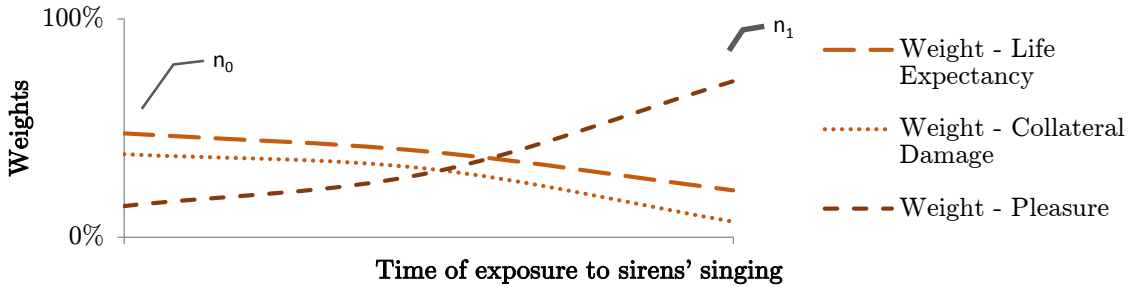

Figure 2-3 Evolution of Weights

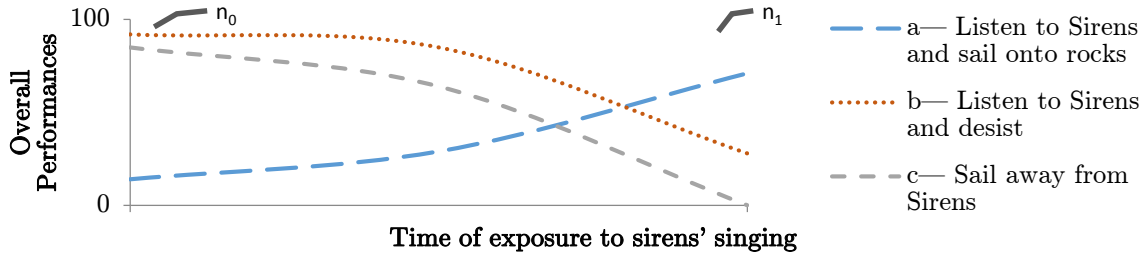

Figure 2-4 Evolution of Overall Performances

From this simple example, it appears that static decision models may not be sufficient to describe an agent's preference pattern over time when priorities change. However, if we could adapt a multi-criteria framework, so it would incorporate the potential for weight variation arising from changes in the environment, then we believe it would be possible to build a dynamic framework that could help in systematically evaluating potential changes in preferences. To do so, it is necessary to understand the psychological ramifications behind preference change in order to understand what could cause weights to vary over time. These are described in the next subsection.

2.2 Preference Change

> "Knowing how people' s preferences change over time will go some way toward explaining and predicting their behaviour"
> (Loewenstein and Angner, 2003, p. 327)

This section begins by discussing the debate between the two schools of thoughts regarding how preference change should be defined and viewed. Subsequently, an overview of how visceral factors (one of the exogenous determinants of preference change) contribute to changes in preferences is provided.

2.2.1 Debate

Preference formation is not a new topic of research, and has been investigated in various fields, from economics to philosophy, psychology, anthropology, among others. However, due to the complexity of the phenomenon, the progress has been slow and has not yet brought a consensus about what leads to preference formation and what characterise tastes (Loewenstein et al., 2003).

Indeed, on the topic of preference change, there are two schools of thought. In their famous essay, "De Gustibus Non Est Disputandum", Stigler & Becker (1977, p.76) state

> *" One does not argue over tastes for the same reason that one does not argue over the Rocky Mountains – both are there, will be there next year, too, and are the same to all men."*

This school of thought argues that tastes and preferences are stable over time, and do not vary significantly between individuals. They argue that their hypothesis of stable tastes/preferences enabled better predictions as to observable behaviour. Stigler and Becker's thesis makes a distinction between final preferences and underlying preferences. Whilst final preferences may change over time (a preferred model of a car for instance), they treat the underlying preferences as constant (the image one wishes to achieve by owning a certain model of a car).

On the other hand, Simon (1981) disagrees with the stable preference school, arguing that as new experiences produce new tastes, considering utility functions as fixed entities is unrealistic. Instead, he proposes to regard those as evolving structures that describe the changes in tastes using a 'production function'. The production function is defined by the utility gained from the new/accumulated experiences. The case of the change of preferences between n_0 and n_1 in the case of Ulysses and the sirens is due to an increase in consumption (in this case, listening to the sirens) which increases his preferences for it as in habit formation (Hammond, 1997; Loewenstein and Angner, 2003).

If $u(c_\tau, s_\tau)$ is Ulysses utility function, with c, the consumption (listening to the sirens), and s the habit stock (how long he has been listening to the sirens), then his marginal utility gained from listening to the sirens increases the longer he listens to them, formally:

$$\frac{\partial^2 u(c,s)}{\partial c \partial s} > 0,$$

and as the activity as a harmful impact on Ulysses' overall utility, we have:

$$\frac{\partial u(c,s)}{\partial s} < 0.$$

The framework this research aims to build consists of compromising between the concepts proposed by the two schools of thought. We suggest keeping the objectives of the agents in question stable over time. However, to model potential changes in preferences, a production function similar to the one described by Simon, is used to determine potential changes in priorities. As described by the case of Ulysses and the Sirens, new weights are elicited at n_1 that take into account the new information, and new experiences that the agent has gone through and may affect the relative importance given to each objective.

The next subsection will provide an understanding of the determinants of preference change that may affect the types of agents this research focuses on.

2.2.2 Visceral factors and preference change

> « Ce n' est jamais à cause d' un état d' esprit qui n' est pas destiné à durer
> Que l' on prend des résolutions définitives. »
> Marcel Proust – A la recherche du temps perdu. A l' ombre des jeunes filles en fleurs
> (Proust, 1927, p. 142)
>
> "It is always thus, impelled by a state of mind which is destined not to last,
> That we make our irrevocable decisions."
> Marcel Proust – Remembrance of Things Past: Within a Budding Grove

Sources of preference change can be split into two main categories: endogenous and exogenous. The first one arises when the utility of a consumption depends on the past consumptions, i.e. someone's tastes today are influenced by what has been 'tasted' previously (Hammond, 1976; Loewenstein et al., 2003). Sources of exogenous preferences change include emotions and visceral factors, which are covered in this section (for a deeper treatment of the other determinants of preference change, see Loewenstein & Angner 2003).

Visceral factors denote certain types of emotions, drive states and feeling states; such factors, for instance, include anger, fear, hunger, and other cravings. These factors affect preferences in the sense that they have a motivating effect on people's behaviour by altering their needs or desires. For example, hunger will lead to a heightened preference for food, thirst for drinks, or anger for aggression. In the case of Ulysses, stimulation from listening to the sirens will lead to a heightened preference to sail closer in order to hear more. Because such factors are driven biologically, they are susceptible to have a strong impact on altering preferences. Indeed, Loewenstein & Angner (2003) explain that tastes are partly determined by biological processes which regulate the human body. These processes are there to ensure homeostasis[1] is maintained. Following some sort of discomfort, transient changes in preferences are induced specifically in order to reinstate balance (Elster, 1998; Frederick et al., 2002; Loewenstein and Angner, 2003; Loewenstein, 2000, 1996).

Contrary to popular belief, Loewenstein (2000) explains that the influence of visceral factors on behaviour being highly systematic is much more predictable than cognitive deliberations, for instance. For this reason, such behaviours can be modelled, and one way to achieve it is using state-dependent preferences.

We can formally express an agent's instantaneous utility function as follows:

$$u(c_\tau, s_\tau)$$

[1] Human homeostasis consists of physiological reactions aimed at regulating and stabilising the body in response to fluctuations caused by the external environment.

where c_τ represents the vector of consumption activities states in period τ, for e.g. the level of aggressive behaviour, s_τ represents the vector of visceral states in period τ, for e.g. the level of anger.

Then, taking Loewenstein's analogy of the application of the carrot and the stick, the carrot can be represented as:

$$\frac{\partial^2 u(c,s)}{\partial c \partial s} \geq 0,$$

which describes the marginal utility of c that is increasing in s, in other words, the angrier one is, the more utility he/she will gain from aggression.

The stick, denoting the negative impact of the discomfort experienced on the overall utility is represented by:

$$\frac{\partial u(c^0,s)}{\partial s} < 0,$$

where c^0 represents a zero consumption (for e.g. not indulging in aggressive behaviour).

Because of its transient character, economists have generally shied away from the idea of modelling behaviours caused by visceral factors. However, the changes incurred by such factors can have significant impacts on both the agent and the environment in which he operates (Loewenstein 1996; 1999; 2000), which is especially the case in the context of this research.

Indeed, if one wants to anticipate a motivation to cause social unrest by disruptive agents, visceral factors appear to be a fundamental element of the modelling aspect. As Loewenstein states,

> *" To predict or make sense of viscerally driven behaviour, it is necessary to incorporate visceral factors into models of economic behaviour" (2000, p.431).*

In the next section, a brief overview of the various types of time dependent models is provided.

2.3 Overview of Modelling Time Dependent Preferences

From what has been discussed in the previous sections, it appears necessary to provide an overview of the various means that have been employed to model the impact of the aforementioned factors on preferences. The first subsection aims to provide a brief overview of the main frameworks used to model time-dependent preferences.

The appearance of new mathematical models has enabled a greater flexibility in modelling dynamic utility. Such models can be sub-divided into two categories, models without instantaneous utility (universal utility models), as opposed to models based

on instantaneous utility (recursive, additive and myopic utility models). The four types of models are described briefly below; for a detailed survey of the literature, see von Auer (1998).

- **Recursive utility models**

  In recursive utility models, the utility is derived by adding the aggregate utility from future consumption to the utility gained from the present consumption. In addition, as the future is assumed a separable entity from the present and the past, recursive models do not allow habits to be modelled.

- **Additive utility models**

  Additive utility models take into account habit formation (derived from past consumption) as well as the utility from future consumption, which is discounted.

- **Myopic utility models**

  Myopic utility models are a subset of the additive utility models, describing a short-sighted behaviour. In addition to discounting the future entirely, i.e. does not take into account the future consumption when evaluating the current consumption, the agent also chooses to ignore his/her future preferences. This is defined as a naive choice mechanism (Strotz 1955; von Auer 1998; 1999).

- **Universal utility models**

  Universal utility models are the most general types of utility models. The three models described above are special cases of universal models. Unlike these, universal utility models do not only look at the instantaneous utility, they also look at the intertemporal utility function for any period t, each of which depend on past consumptions.

In addition to these models, some other methods have been explored.

- **Dynamic decision models**

  Classic decision models have favoured modelling decision from a static point of view, that is with a stable set of objectives and attributes. Some studies, however, have been conducted to capture dynamic nature of decisions from a time-dependency point of view. Intertemporal decision models, for instance, can help make trade-offs between the present costs of a policy versus its future benefits (Harvey, 1995, 1992). Rios-Insua et al., (2004) develop a decision support system capturing multiple conflicting objectives that consequences span over several time periods. Optimal strategies are determined by modelling different discounting methods and by allowing imprecise multi-attribute additive utility model.

  On the other hand, cognitive science and psychology have paid particular attention to this area. The effect of the availability of time to decide and an

individual's duration perception, has been researched (Diederich, 1997; Wittmann and Paulus, 2009, 2008).

Decision Field Theory (DFT) stands aside from static-deterministic theories; instead, it provides a dynamical-stochastic description of decision-making. Rather than approaching decision-making from a rational decision-maker point of view, DFT aims to model the psychological processes involved in decision-making. In such models, preferences evolve over time, and factors which determine the evolution include the motivational value of an outcome (Townsend and Busemeyer, 1995)

- **Other methods**

Besides these models, more recently, other types of time dependent preference models have been developed, which incorporate multi-attribute aspect of decisions. Time dependent preferences have also been investigated in multi-criteria problems since the early 1990's by integrating Multi-Criteria Decision Analysis (MCDA) with other techniques, such as goal programming (Agrell et al., 1998; Caballero et al., 1998; Hämäläinen and Mäntysaari, 2001; Kornbluth, 1992) , machine learning (Natarajan and Tadepalli, 2005), and by integrating time discounting (Atherton and French, 1998; French et al., 2005). Similarly, the influence of the environment on multi-criteria problems has been investigated by integrating MCDA with system dynamics (SD) since the early 1980's (Andersen and Rohrbaugh, 1992; Bell et al., 2003, 2001; Brans et al., 1998; Dennis et al., 1983; Gardiner and Ford, 1980; Gruver et al., 1984; Kunsch and Springael, 2008; Macharis, 2000; Papamichail and Robertson, 2005; Santos et al., 2008; Springael et al., 2002).

These models attempt to provide a framework enabling a decision maker to evaluate alternatives having effects over a long time period. They do so by taking into account the future state of preferences into the overall performance evaluation of the alternatives. However, they do not provide a model that enables anticipation of changes regarding how objectives are prioritised in future states.

To contextualise modelling preferences and decisions within our research application, in the next section, we describe the different methods used to model uncertainty and decisions in counter-terrorism analysis.

2.4 Modelling Uncertainty & Decisions in Counter-Terrorism Analysis – An Overview

In this section, we provide an overview of the different approaches used to model threats caused by terrorism, looking, in particular, at the cases where Expected Utility Theory (EUT) and expert elicitation are used. We briefly describe the key characteristics of the methods.

2.4.1 Logic Trees & Influence Diagrams

In natural hazard analysis, such as earthquakes, and failure experienced in engineered processes, Logic Trees such as Event Trees (ET) and Decision Trees (DT) have been extensively developed (Bedford and Cooke, 2001). Conversely, DTs have not yet been explored as extensively in the context of terrorism. For a comprehensive review of the use of these approaches within the context of terrorism, see Ezell et al. (2010) and Merrick and Parnell (2011).

Logic trees (Probability Trees, ETs, DTs) and Influence Diagrams (ID) provide a useful framework for the analysis of uncertainty by formalising various scenarios that describe the sequence of events leading to the various outcomes that can be expected (Ezell et al., 2010; Paté-Cornell, 2007).

Probabilistic Risk Analysis (PRA) in the context of terrorism threats aims to model the situations and decisions from the perspective of the defender's preferences. By deriving a ranking of risks, i.e. a ranking of the attacks terrorists might potentially employ, the defender can then decide how to allocate resources to protect against them. In these traditional models, the risks are determined based on the evaluation of three parameters. These parameters are the threat (the probability that an attack would occur), the vulnerability (given the timing, location and type of attack, the probability that damages occur), and the consequences (given the timing, location and type of attack, the expected extent to which the damage occurs). These are subjective judgements elicited by experts (Willis and Corporation, 2005; Willis, 2007). Similar risk functions have been used in the literature (Dillon et al., 2009; von Winterfeldt and Rosoff, 2005).

Von Winterfeldt & O'Sullivan (2006) use a DT approach along with sensitivity analysis to assess the cost-effectiveness of Man-Portable Air Defence Systems countermeasures. They do so by comparing different types of attacks, their probability of success and impact on the economy. Pinker (2007) uses IDs to describe and formalise the risks and defence mechanisms into a structure to highlight the main issues which policy makers face. The aim is to support the joint optimisation of two types of defensive mechanisms (public warnings and the deployment of physical resources) by improving the understanding of the effects and interactions between these two mechanisms. Bakir (2008) investigates various counter measures to secure

cargos at ports of entry using DTs. Building on the work of Bakir (2008) and Keeney (2007), Merrick & McLay (2010) look at the impact of screening policies on deterring terrorists from using nuclear attacks by incorporating additional objectives. Their solution however, is sensitive to parameters relating to both the uncertainties faced and those representing the objectives of the decision makers. Bakir & Von Winterfeldt (2011) make policy recommendations for means to scan containers against nuclear or radiological weapons using a DT. Similarly, their solution is also sensitive to certain key parameters such as the probability of an attempted attack and the probability of its success.

A recent trend also includes the use of DTs and IDs to model decisions from the point of view of the attacker (Ezell et al., 2010; Keeney, 2007; Rosoff and John, 2009). In this case, the attacker's preferences are estimated to try to infer their favoured attacks (Ezell et al., 2010). Keeney (2007) developed value models for both the Department of Homeland Security (DHS) and terrorist organisations to evaluate various counter-terrorism means and highlight possible terrorist priorities and actions. Rosoff & John (2009) developed an MAUT model embedded in a simulation that generates attack based risk profiles and probabilities of a terrorist leader selecting each attack. Expert elicitation is sought as a proxy for building the MAUT from the point of view of a terrorist organisation.

One of the benefits of these methods is that they provide a framework to structure of large sets of information and relationships between actions and consequences (Paté-Cornell and Guikema, 2002; Pinker, 2007). It also enables the decomposition of events leading to the final uncertainty of the consequence, thus aiding the elicitation of probabilities for these events (Ezell et al., 2010; Keeney and von Winterfeldt, 1991). Such a benefit is especially relevant in this case, where these assessments have to reflect the degrees of beliefs of an agent we do not have access to.

2.4.2 Game Theoretical Models

In an attempt to capture the interactions between the defender and the attacker, a feature that is difficult to do using PRA, Game Theory (GT) has been extensively researched in the context of terrorism (Hausken and Zhuang, 2011; Wilson and Olwell, 2006; Zhuang and Bier, 2007). There is a wealth of literature in the context of resource-allocation decisions for the protection of potential targets (Bier et al., 2007b; Major, 2002; Wilson and Olwell, 2006; Zhuang and Bier, 2007), and in the context of hostage situations and negotiation analysis (Atkinson, 1999; Corsi, 1981; Lapan and Sandler, 1988). For an excellent review on the development in games in the context of terrorism, see Sandler & Siqueira (2009) and Kardes (2005).

Two types of methods can be used in GT: games of complete information, and games of incomplete information. In both cases, the same assumptions as those in a DT are made. Players are assumed to be rational and intelligent, i.e. able to compute which

alternative best achieve their goals, thus will know which option will maximise their goals. Whilst in games of complete information the assumption of knowing what these goals are is made, games of incomplete information do not require this assumption. GT has been adapted to account for incomplete information regarding one of the players. In cases where probability distributions from different players are not consistent, multiple utilities can be used in the game (Harsanyi, 2004). GT models with asymmetric information include studies by Lapan & Sandler (1993) and Arce & Sandler (2007) where knowledge is updated through the game. In these studies, a distinction can be made as to the types of choice models, continuous choices for both players (Major, 2002; Zhuang and Bier, 2007), continuous choices for the defender, discrete for the attacker (Bier et al., 2007b).

2.4.3 Adversarial Risk Analysis (ARA)

In an attempt to capture the benefits of both PRA and GT approaches, Adversarial Risk Analysis (ARA) has recently been investigated. GT on its own does not capture the risk aspect of the threat, whilst PRA on its own does not capture the interactive nature of adversarial threats. Hence, these approaches have been combined to try to further the insight that could be gained. ARA attempts to capture the risk associated with the attacks, as well as the preferences of both the defender and the attackers.

Paté-Cornell & Guikema (2002) were the first to combine the two approaches, using GT and influence diagrams to order and structure the large breadth of information, which describes terrorist threats. By showing the links between the various actions and consequences, their model is used to set priorities among both threat and countermeasures. Two separate influence diagrams are used to represent with one, the terrorists' behaviour, and with the other, the government's decisions, which they call a two-sided model. Their models are single period, which means that at each period, variables are updated to reflect of an action taken, or new information is gained. More recently, Parnell et al. (2010) developed a probabilistic defender-attacker-defender model which captures the decisions of both the defender and attacker at various stages, as well as the uncertainties related to the implementation detection and outcomes of the attacks. Rios and Rios Insua (2012) analysed various standard counterterrorism models, illustrating the application of ARA to the same problems with the aim of supporting the decisions of a defender against an attacker. In their model, they attempt to predict the attacker's decision behaviour using subjective utility theory, and making the assumption the attacker is rational.

2.4.4 Other Simulation Methods

Other simulation methods which use an agent's objective to try to infer preferences include Multi Agent Simulations (MAS) and machine learning. MAS are being increasingly used by the government to model terrorist activities. These MAS have been designed as an educating simulator, to train analysts to uncover terrorists within the society, or even plots within a given time and budget. Further, this tool has been used by the army to decide upon the best attack/defence strategies during a conflict, by simulating them on the MAS and observing the resulting scenario (Lucas et al., 2007)

A key research project using this technique is the work by Weaver et al. (2001) which is partly funded by the CIA and the Defence Intelligence Agency. This simulation program is used to assist intelligence analysts in their job of tracking down terrorists (Goldstein, 2006). More recent work in MAS attempts to connect several elements, such as personality, emotions, and cognitions in their simulation of decision models (Silverman et al., 2006a, 2006b). These simulations, unlike the approaches described earlier, focus on the behaviour of individuals as well as collaborations between individuals in that simulation (Morrison and Cohen, 2006). Similar assumptions have to be made as to their behaviour and decision making abilities.

Reinforcement learning, a machine learning technique, can be used within the context of terrorism. It enables the simulation of sequential decision-making problems in the case of large state spaces (which can be more difficult with DT as mentioned above). It also has the potential for modelling the dynamicity of preferences (Natarajan and Tadepalli, 2005) and to capture the effect of emotions (El-Nasr et al., 2000). However, to our knowledge, terrorists' preferences using machine learning has not been explored.

2.5 Conclusions

This chapter has explored preference change and highlighted the factors influencing it in context of this research. We provided an overview of the psychological ramifications behind the phenomenon of preference change. In the context of terrorist decision making, these main factors are the effects of visceral factors on judgements and preferences. These can cause impulsive behaviours as individuals are compelled to take action to restore balance. As such, they are also likely to discount heavily the future when evaluating a course of action. Furthermore, their ability to process information can as well be affected (Lerner and Keltner, 2001, 2000; Lerner and Tiedens, 2006; Loewenstein and Angner, 2003; Loewenstein, 2000, 1999, 1996).

As seen in section 2.4, one way to anticipate terrorists' actions is to consider their judgements when modelling the decisions they might make. However, in the context of terrorism, modellers encounter a difficulty: the non-availability of the decision maker from whom to elicit preferences and judgements. As such, these models have

to be based on several assumptions with regards to the objectives such agents have and the way they chose to maximise their utility.

Given the empirical insight from the area of psychology, and the current modelling techniques, the following questions arise:

- Knowing preferences appear altered due to exogenous triggers, how can a MAUT model capture their dynamicity? Do the triggers, which motivate terrorists, have an impact on their preferences and judgements?
- One main assumption in current models for counter-terrorism analysis consists of the rationality of terrorists. But can they be considered as rational decision makers? If so, what is the utility they try to maximise? Are they solely political expected utility maximisers?

2.6 Chapter 2 References

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Appendix 2.A Ulysses' MCDA model

Ulysses preference ordering can then be derived by calculating the overall performance of each alternative which depends on the weights (relative importance given the range of attributes) Ulysses would give to each objective. Thus, the overall performances at time t of alternatives $j = a, b, c$, would be:

$$\mathbf{V_j^t = \sum_i w_i^t * v_{i,j}^t} \qquad (1)$$

With w_i^t the weights at time t for each objectives $i = LE, CD, P,$

and $v_{i,j}^t$ the partial performance at time t of alternatives

$j = a, b, c$ on the i^{th} objective

The partial performances are assessed on an interval scale ranging between zero for the lower bound (worst performing alternative on the i^{th} objective) and one hundred for the upper bound (best performing alternative on the i^{th} objective).

Let us assume we are at the initial node, n_0 where Ulysses has to decide between the three alternatives. Ulysses being King of Ithaca, is responsible for the lives of his crew, but most importantly the people of Ithaca, and hence we could infer his weights to be:

$$\boldsymbol{w_{LE}^0 > w_{CD}^0 \gg w_P^0} \qquad (2)$$

In other words, his first and foremost objective is to remain alive (LE), followed by ensuring the lives of his crew (CD), and finally, indulge with some pleasant or enriching adventures (P).

Following, we can infer the following relationships between the partial performances of each alternative vis-à-vis the objective of Life Expectancy:

$$\boldsymbol{v_{LE,a}^0 \ll v_{LE,b}^0 \leq v_{LE,c}^0} \quad (3)$$

i.e. the performance of alternative *(a)* on Life Expectancy is far lesser than the two others (in fact if the lower bound of the scale is zero, then $v_{LE,a}^0 = 0$, as it leads to death of Ulysses and the crew). In addition, alternative *(b)* is at least as good as alternative *(c)* (similarly, if the upper bound of the scale is hundred, then $v_{LE,c}^0 = 100$ as Ulysses and his crew safely sail away with alternative *(c)*).

A similar relationship can be written for the performance of each alternative vis-à-vis Collateral Damage:

$$\mathbf{v_{CD,a}^0 \ll v_{CD,b}^0 \leq v_{CD,c}^0} \quad (4)$$

(Similarly to the Life Expectancy partial performances, we also have $v^0_{CD,a} = 0$, as it leads to death of Ulysses and the crew and $v^0_{CD,c} = 100$)

Finally, we can infer the following relationships of partial performances vis-à-vis the last objective.

$$\mathbf{v^0_{P,c} \ll v^0_{P,b} < v^0_{P,a}} \qquad (5)$$

i.e. the pleasure obtained from alternative *(c)* is far lesser than the two other. (Similarly, $v^0_{P,c} = 0$ as it is the lower bound in this case, Ulysses does not get to listen to the sirens at all), and because alternative b only enables Ulysses to listen to the Sirens for a limited time only, it is not as good as alternative *(a)* (which is the upper bound, and hence $v^0_{P,a} = 100$).

Hence, we can now derive the preference order by calculating the overall performances of each alternative: From **(1)** we have:

$$V^0_a = w^0_P * 100$$

$$V^0_b = w^0_{LE} * v^0_{LE,b} + w^0_{CD} * v^0_{CD,b} + w^0_P * v^0_{P,b}$$

$$V^0_c = w^0_{LE} * 100 + w^0_{CD} * 100$$

Let us derive the preference relation between alternative *(c)* and alternative *(b)* by looking at the sign of $V^0_c - V^0_b$

$$V^0_c - V^0_b = w^0_{LE} * \left(100 - v^0_{LE,b}\right) + w^0_{CD} * \left(100 - v^0_{CD,b}\right) + w^0_P * \left(-v^0_{P,b}\right)$$

From **(3)** and **(4)** we have $\left(100 - v^0_{LE,b}\right) \geq 0$ and $\left(100 - v^0_{CD,b}\right) \geq 0$,

And, from the assumption made in **(3)** and **(4)**, we can say that at that point we have $\left(100 - v^0_{LE,b}\right)$ and $\left(100 - v^0_{CD,b}\right)$ which are very small compared to $v^0_{P,b}$, hence

$$V^0_c - V^0_b = w^0_{LE} * \left(100 - v^0_{LE,b}\right) + w^0_{CD} * \left(100 - v^0_{CD,b}\right) + w^0_P * \left(-v^0_{P,b}\right) \leq 0$$

But as we have from **(5)** $v^0_{P,b} \gg v^0_{P,c}$ hence, $v^0_{P,b} > 0$

Therefore,

$$V^0_c - V^0_b < 0$$

$$\text{or } V^0_c < V^0_b \Longrightarrow bP_0c \blacksquare$$

Similarly, let us derive the preference relation between alternative *(c)* and alternative *(a)* by looking at the sign of $V^0_a - V^0_c$:

$$V_a^0 - V_c^0 = w_{LE}^0 * (-100) + w_{CD}^0 * (-100) + w_P^0 * 100$$

So,

$$V_a^0 - V_c^0 = (-w_{LE}^0 - w_{CD}^0 + w_P^0) * 100$$

And, from the assumption made in **(2)**, we can say that at that point we have the relationship: $w_P^0 \ll (w_{LE}^0 + w_{CD}^0)$ hence,

$$(-w_{LE}^0 - w_{CD}^0 + w_P^0) * 100 \ll 0$$

Hence

$$V_a^0 - V_c^0 \ll 0$$

$$\text{or } V_a^0 < V_c^0 \Longrightarrow cP_0a \blacksquare$$

Hence, by transitivity of preferences, at n_0, we have bP_0c and $cP_0a \implies bP_0cP_0a$ ■

Following this method, Ulysses' best alternative would be to try and reach point *(b)* in the decision tree (Figure 2-1), and according to this decision framework, having fixed the weights, he would manage to reach point *(b)*, as the preference ordering would remain stable, i.e. bP_1a, which is not the case.

We argue that one way to explain the preference change can be represented by a change in weights in moving from n_0 and n_1. Within this new environment, a new evaluation would be performed at n_1. Whilst Ulysses' objectives remain the same and the partial performances can be assumed stable, the relative importance of the objectives could change. In addition, because alternative *(c)* is no longer available, an adjustment of the relative performances is required, and we have the following new relationships:

$$v_{LE,a}^1 \ll v_{LE,b}^1 \quad (6)$$

Similarly to the partial performances at time 0, we have $v_{LE,a}^1 = 0$, and $v_{LE,b}^1 = 100$ as they are the lower and upper bound respectively.

A similar relationship can be written for the performance of each alternative vis-à-vis Collateral Damage:

$$v_{CD,a}^1 \ll v_{CD,b}^1 \quad (7)$$

Similarly, we also have $v_{CD,a}^1 = 0$, and $v_{CD,b}^1 = 100$.

Finally,

$$\mathbf{v^1_{P,b} < v^1_{P,a}} \qquad (8)$$

With, $v^1_{P,b} = 0$, and $v^1_{P,a} = 100$.

After having listened to the sirens for a while, it could be that

$$\mathbf{w^0_{LE} > w^0_{CD} \gg w^0_P} \text{ has evolved into } \mathbf{w^1_P \gg w^1_{LE} > w^1_{CD}} \ (9)$$

i.e. now Ulysses mostly cares about his enjoyment by listening to the sirens longer, regardless of the risks incurred to his life and the ones of his crew, explaining the preference change at time 1 (node n_1) into aP_1b.

Let us formalise the new relationships at n_1. Similarly, let us look at the sign of $V^1_a - V^1_b$ as was done for n_0, from (1), (6), (7), (8), we have:

$$V^1_a - V^1_b = w^1_{LE} * (-100) + w^1_{CD} * (-100) + w^1_P * (100)$$

Hence, when

$$w^1_P > w^1_{LE} + w^1_{CD}$$

we can observe at n_1 $V^1_a - V^1_b > 0 \Longrightarrow aP_1b$ ■

Prelude to Chapter 3
In the Opponent's Shoes:
On Modelling Terrorists' Judgements for Counter-Terrorism Analysis

The previous chapter explored the theory behind preference change and highlighted the factors influencing it. We provided an overview of the psychological ramifications behind the phenomenon of preference change. In the context of terrorist decision-making, these main factors are the effects of visceral factors on judgements and preferences.

We saw that one way to anticipate terrorists' actions is to consider their judgements when modelling the decisions they might make. However, non-availability of the decision maker, from whom to elicit preferences and judgement, renders modellers' task challenging. As such, these models have to be based on several assumptions concerning the objectives that such agents have and the way they chose to maximise their utility.

Using secondary research in terrorism and behavioural decision-making fields, we seek in this first paper to answer questions raised in the previous chapters. Specifically, these are:

- Knowing preferences appear altered due to exogenous triggers, how can a Multi-Attribute Utility Theory model capture their dynamicity? Do the triggers, which motivate terrorists, have an impact on their preferences and judgements?
- One main assumption in current models for counter-terrorism analysis consists of the rationality of terrorists. However, can they be considered as rational decision makers? If so, what is the utility they try to maximise? Are they solely political expected utility maximisers?

Chapter 3

In the Opponent's Shoes: On Modelling Terrorists' Judgements for Counter-Terrorism Analysis

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ABSTRACT

Terrorism is caused by the actions of malicious agents against society. One way to anticipate terrorists' actions in counter-terrorism analysis is to consider their judgements when modelling the decisions they might make - such judgements will drive their chosen actions - so proper counterterrorism measures may be adopted. Nevertheless, several assumptions – such as rationality of the agents, agents who have a set of constant and ordered preferences, with the ability to perform a cost-benefit analysis of their alternatives, among others - need to be made in those models. However, are such assumptions reasonable? In this paper, we analyse the types of assumptions made across various counter-terrorism analytical models that represent malicious agents' judgements and discuss their suitability from a descriptive point of view. Subsequently, we suggest how some of these assumptions could be modified to describe terrorists' preferences more accurately, by drawing knowledge from the fields of behavioural decision analysis, politics, and philosophy of choice, public choice, and conflict management in terrorism. Such insight, we hope, might help make the assumptions of these models more realistic for risk analysis.

Key-words: Terrorism, value models, decision making, rationality, probabilistic risk analysis, descriptive validity

> Ira furor brevis est. Anger is a short madness.
> Horace Book I, epistle ii, line 62 c. 20 BC and 14 BC

3.1 Introduction

Probabilistic Risk Analysis includes various methods, such as event trees, decision trees, and influence diagrams. Initially developed in nuclear engineering (Bier et al., 2007a; Kaplan and Garrick, 1981; Starr, 1969), traditional Probabilistic Risk Analysis has been used to evaluate the chances of natural random events, such as earthquakes or mechanical failures, as well as in the context of counter-terrorism. Methods such as event trees, decision trees and influence diagrams have been used to represent the sequence of events leading to a consequence, and decompose the uncertainties leading to outcomes (Ezell et al., 2010; Keeney and von Winterfeldt, 2011; Keeney, 2007; Rosoff and John, 2009). Some of the recent work in this domain include the research by Bakir and von Winterfeldt, (2011); Bakir, (2008); Merrick and McLay, (2010); Merrick and Parnell, (2011); Parnell et al., (2010); von Winterfeldt and O'Sullivan, (2006).

In risk modelling, a distinction has to be made concerning the source of that risk, as it will have an impact on the choice of methodology. Risks caused by natural or random events contain a chance component, which can be adequately modelled using statistical-based analyses such as Probabilistic Risk Analysis, see Bedford and Cooke (2001) for an overview of uses. However, treating the risks caused by the action of an agent as random events is not always appropriate, making Probabilistic Risk Analysis less adequate (NRC, 2010, 2008). Unlike these events, the actions of an agent are driven by their need to achieve certain goals (Bier, 2006). Terrorism falls into this category. Its adversarial nature means the adversary behaves strategically. Pre-emptive methods taken against one type of attack may increase the risk of another type of attack (Bier et al., 2005; Brown and Cox, Jr., 2011; Guikema and Aven, 2010; Kardes and Hall, 2005).

Contrary to most Decision Analysis models, in the counter-terrorism context, modellers do not have access to terrorists as decision makers. Hence, the objectives such agents might use and the way they chose to maximise their utility can only be based on assumptions. Typically, current methods model the utility maximisation of one or two main objectives that are used to evaluate a fixed set of alternatives.

Most counter-terrorism modelling methods are idealised and based on several assumptions about how terrorists make decisions and their judgements. These include the rationality of the adversary and their ability to formulate the problem and

compute the best outcome; knowing the adversary's utility functions of the adversary – what are the goals being maximised; and the ability of the defenders and attackers to assess uncertainties and evaluate the alternatives involved in the decision. However, how realistic are these assumptions in light of what we know from the fields of behavioural decision analysis, politics, and the philosophy of choice, public choice, and conflict management in terrorism?

Making such normative assumptions may be unrealistic and could therefore lead to wrong counter-terrorism measures. Indeed, modelling risks using traditional Probabilistic Risk Analysis methods does not account for how an attacker might respond to the actions of the defender (Brown and Cox, Jr., 2011). We believe terrorism models could be more informed by empirical findings from the fields discussed above, which have not been widely researched in risk analytical models for counter-terrorism analysis. Extending the breadth of understanding of terrorists as decision makers, what their objectives are and what influences them could help towards increasing the validity of the models from a descriptive point of view. We hope this can help in the management of risk caused by terrorism. This paper will attempt add some insight in that area by critically analysing several elements influencing the way terrorist make decisions.

This paper is composed of the following sections. We first provide a short overview of Expected Utility Theory, Multi Attribute Utility Theory, then the various methods used in the context of counter-terrorism modelling and we discuss the validity of the assumptions made in such models in relation to the type of decision maker we face (depending on whether it is an organisation, an active, or a suicidal terrorist). Subsequently, we show the relevance and considerations to be made when modelling decisions of a terrorist, tying in empirical evidence from behavioural decision-making as well as evidence from the terrorism literature. Finally, we explore the implications of this insight for current decision models.

3.2 Modelling Uncertainties and Decisions

In this section, we review the main approaches to modelling threats caused by terrorism. In each of these approaches, certain assumptions need to be made. These can be broadly classified under two categories: uncertainties (regarding an attacker's decision, capability, and success, and defender's success) and decisions (based on the preferences of the defender and attacker). Probabilistic Risk Analysis (PRA) relies heavily on modelling uncertainties, using expert elicitation to capture the probabilities associated to them. Game Theory (GT) on the other hand relies on modelling a situation based on the decisions of the players, making the assumptions that both actors are rational. As Adversarial Risk Analysis (ARA) combines both approaches, it needs to make assumptions in both categories.

3.2.1 Key Modelling Methods in Counter-Terrorism Analysis

PRA in the context of terrorism threats aims to model the situations and decisions from the perspective of the defender's preferences. By deriving a ranking of risks, i.e. a ranking of the attacks terrorists might potentially employ, the defender can then decide how to allocate resources to protect against them. In these traditional models, the risks are determined based on the evaluation of three parameters. These are the threat (the probability that an attack would occur), the vulnerability (given the timing, location and type of attack, the probability that damages occur), and the consequences (given the timing, location and type of attack, the expected extent to which the damage occurs). These parameters are subjective judgements elicited by expert (Willis and Corporation, 2005; Willis, 2007). Similar risk functions have been used throughout the literature (Dillon et al., 2009; von Winterfeldt and Rosoff, 2005). Key work in this area includes that of Von Winterfeldt & O'Sullivan (2006), Pinker (2007), Bakir (2008) Keeney (2007), Merrick & McLay (2010) and Bakir & Von Winterfeldt (2011).

A recent trend in modelling terrorism using a decision analytical approach includes the use of Decision Trees (DTs) and Influence Diagrams (IDs) to model decisions from the point of view of the attacker (Ezell et al., 2010; Keeney, 2007; Rosoff and John, 2009). In this case, the attacker's preferences are estimated in order to try to infer their favoured attacks (Ezell et al., 2010). Keeney (2007) developed value models for both the Department of Homeland Security (DHS) and terrorist organisations to evaluate various counter-terrorism means and highlight possible terrorist priorities and actions. Rosoff & John (2009) developed an MAUT model embedded in a simulation which generated attack-based risk profiles and probabilities of a terrorist leader selecting each attack. The authors used expert elicitation as a proxy for building the MAUT from the point of view of a terrorist organisation.

In an attempt to capture the interactions between the defender and the attacker, a feature that is difficult to do using PRA, GT has been extensively researched in the context of terrorism (Hausken and Zhuang, 2011; Wilson and Olwell, 2006; Zhuang and Bier, 2007). There is a wealth of literature in the context of resource-allocation decisions for the protection of potential targets (Bier et al., 2007b; Major, 2002; Wilson and Olwell, 2006; Zhuang and Bier, 2007), and in the context of hostage situations and negotiation analysis (Atkinson, 1999; Corsi, 1981; Lapan and Sandler, 1988). For an excellent review on the development in games in the context of terrorism, see Sandler & Siqueira (2009) and Kardes (2005).

To capture the benefits of both PRA and GT approaches, ARA has recently been suggested. GT on its own does not capture the risk aspect of the threat, whilst PRA

on its own does not capture the interactive nature of adversarial threats. Hence, these approaches have been combined to try to further the insight that could be gained. ARA attempts to capture the risk associated with the attacks, as well as the preferences of both the defender and the attackers. Paté-Cornell & Guikema (2002) were the first to combine the two approaches, using influence diagrams to order and structure the large breadth of information that describe terrorist threats and GT. More recently, Parnell et al. (2010) developed a probabilistic defender-attacker-defender model which captures the decisions of both the defender and attacker at various stages, as well as the uncertainties related to the implementation detection and outcomes of the attacks. Rios and Rios Insua (2012) analyse different counter-terrorism models, illustrating the application of ARA to the same problems with the aim of supporting the decisions of a defender against an attacker.

3.2.2 Key Modelling Assumptions in Counter-Terrorism Analysis Models

In the context of counter-terrorism analysis, PRA analytical tools, and other modelling methods, including DTs and GTs, make similar strong assumptions. These can be categorised into the following themes:

- **The rationality of the adversary and their ability to formulate the problem and compute the best outcome**

In models which represent terrorists' decisions (such as GT and modelling LTs or IDs from the point of view of the attacker), the issue of the rationality of the decision maker arises. Following the standard models of decisions under uncertainty, agents are regarded as rational decision makers who maximise expected utility (Sheffrin, 1996).

It should be noted that rationality can be described by two distinct concepts: Simon's concept of substantive rationality and the psychologist's view of procedural rationality. Whilst the former is concerned with whether a behaviour is adequate given the desire to achieve a given set of goals, the latter only describes a behaviour which has been reasonably deliberated (Simon, 1986). In the models we describe here, the concept of rationality adopted is the substantive one.

Under this premise, and provided that an agent satisfies Savage's axioms of rationality (North, 1968 see Appendix 3.A), his/her choices can be explained using von Neumann and Morgerstern' Expected Utility Theory (EUT). In this case, Mono or Multi Attribute Utility Theory (MAUT) can be used to model the utility of an agent's choice (see Appendix 3.B). This requires the knowledge of the set of objectives the agent is trying to achieve, and this set is assumed to remain consistent. In this context,

modellers therefore expect terrorists to be able to choose the branch maximising the consequences of an attack, i.e. that they are utility maximisers.

- **The utility functions of the adversary – what are the goals being maximised?**

Modelling terrorist decision-making using GT, ARA or using DT from the terrorists' perspective requires us to know their utility function. The challenging part here is about the ability to determine what the adversary is trying to achieve. Given the terrorist rationality proposition, which enables the assumption of consequence maximisation to be made, modellers need to know which consequences terrorists are trying to maximise.

In order to capture the lack of knowledge about the attack's preferences, GT has been adapted to account for incomplete information regarding one of the players. In cases where probability distributions from different players are not consistent, multiple utilities can be used in the game (Harsanyi, 2004). GT models of asymmetric information include studies by Lapan & Sandler (1993) and Arce & Sandler (2007) where knowledge is updated through the game.

- **The ability of the defenders and attackers to assess uncertainties and evaluate the alternatives involved in the decision**

PRA relies heavily on the availability of intelligence data as well as expert knowledge to assess the parameters involved in the models. These are, for instance, the likelihood of the attacker's success given a particular strike, and the defender's success in preventing it. To do that requires the assumption that terrorists view the world objectively, for example, that his/her perception of the probabilities of achieving certain consequences is not biased.

In the context of terrorism, quantifying uncertainties (relating, for instance, to the capabilities of an attacker or the probabilities of success) can be problematic due to the lack of data. In such cases, subjective expert elicitation is sought to obtain these values. For an overview of subjective expert elicitation, see Hora (2007).

Based on EUT and MAUT, several types of models have been developed with the aim of attempting to infer preferences of agents. Because modellers use this normative decision model to infer the preferences of an agent, it is essential to understand the descriptive elements that may affect this decision maker and examine if and how these assumptions might be violated.

3.3 Validity of Assumptions – Implications for Modelling Terrorism Decision Making

PRA analytical tools, and other modelling methods, including DTs and GTs, as we have discussed, make several main assumptions:

- The rationality of the adversary and their ability to formulate the problem and compute the best outcome
- The utility functions of the adversary – what are the goals being maximised
- The ability of the defenders and attackers to assess uncertainties and evaluate the alternatives involved in the decision

It has been argued that given the above assumptions, counter-terrorism models can provide some interesting insight as to what a rational player might do, but that it is not necessarily what the players will end up choosing in reality. In other words, the solution observed arises from a normative view rather than a descriptive one (Ezell et al., 2010).

Decision makers can be subject to various biases; these can be induced by external influences, such as the availability of data, but can also be influenced by the state of mind in which the agent finds himself. In fact, research has shown that strong emotions such as passions or visceral factors can have an important and non-negligible influence on decision-making (Loewenstein, 2000). Gaining an understanding of these factors can be especially useful in order to develop stronger models to describe terrorism decision-making, which are based on assumptions that are more realistic. In this section, we highlight several issues relating to their validity and propose some alterations.

Before discussing further, it is worthwhile clarifying who we mean by a decision maker. Terrorists can be classified into the following categories:

a. Sponsor state – sponsors one or more terrorist organisations,
b. Terrorist organisation recruits, manages, and leads terrorist cells,
c. Terrorist cell – trained operational units,
d. Terrorist – active but not suicidal, and
e. Terrorist – suicidal.

Commonly, models for counter-terrorism analysis look at decisions made by terrorist organisations, category b, - these might be the ones making overall decisions regarding strategies. Other models, which are describing a situation at a more micro-level, such as those for negotiation analysis, involve the categories c, d and e. In this research, the decision makers we focus on relate to terrorists belonging to the categories b, to e. Further, we make the assumption that categories b and c might behave as an

individual decision maker. We consider that agents belonging to the categories d and e have free will. In other words, they are acting the strategy that was decided by the organisation, but they are free to decide not to carry out the act should they change their mind.

In the following sections, we will first discuss the issues surrounding the above assumptions by referring to findings from the fields of behavioural decision analysis, politics, and the philosophy of choice, public choice, and conflict management in terrorism. We subsequently discuss the implications of these findings on the assumptions made in terrorism modelling. Specifically, we provide some guidelines for relaxing some of the assumptions and adjusting some of them.

3.3.1 The Terrorist as a Rational Decision Maker

A key assumption in most decision models, specifically, is that the players are rational decision makers. In particular, this is the case in GT, ARA, and DTs when they are used from the view of a terrorist. This enables modellers to gain an insight on the sort of decisions that might be made. A significant question therefore arises: Can terrorists be considered as rational decision makers, or homo economicus? In other words, can they be considered as agents seeking to maximise utility? In addition, if that is the case, what is the utility they try to maximise? This assumption can be reasonable in some cases, but more arguable when looking at attacks at the more complex end of the spectrum. Indeed, Ezell et al. (2010) note that bioterrorism, for instance, requires a certain level of technical skills to make those assessments, and it would be unsafe to assume the adversary has them (Simon, 1986; van Hees and Roy, 2007).

The following subsection critically analyses the literature on terrorism rationality as well as provide some recommendations for relaxing the concept of rationality to describe terrorists' decision-making.

3.3.1.1 Inconsistencies in Terrorist Decision Making

Terrorists' rationality may be questioned from an economic point of view for several reasons. Their choice of actions may not always be achieving the best outcome in terms of their long-term objectives: political benefits (Keeney and von Winterfeldt, 2009). Furthermore, their chosen targets may also not invariably be the ones providing the optimal outcome given their set of objectives (Abrahms, 2008; McCormick, 2003).

Such inconsistencies in decision-making can be explained by several elements. First, terrorists, as any decision makers, may not escape the effect of bounded rationality (Simon, 1986). Bounded rationality theories do not require certain assumptions of standard expected utility theories to be met. In particular, the set of alternatives available to the decision makers is not fixed, probabilities of outcomes may not be known by them. Furthermore, as they may be limited in computational ability, they

may resort to other choice strategies rather than maximising a utility function (Simon, 1982).

As terrorists operate in groups, McCormick (2003) argues it might be necessary to view those as the product of organisational decision-making to understand their decisions.

Whilst terrorists will, similarly to organisations, use heuristics to evaluate options and outcomes to make their decisions, they do so to the extreme, taking a black-and-white view of the world, otherwise called splitting (Maras, 2012; Post, 1984). This then distorts their view of themselves, their enemy, and hence the way they will evaluate their options and the resulting outcomes (McCormick, 2003).

3.3.1.2 Is the Terrorist a Homo Economicus Agent? Modelling Considerations

An important consideration concerns the types of terrorists we face. Caplan (2006) classifies them into three categories, Sympathisers, Active terrorists and Suicidal terrorists, each type having different characteristics. Knowing which type of terrorists we are dealing with can give us an indication to the type of rational behaviour we can expect from them. Indeed, Caplan (2006) argues that although terrorists are not perfectly rational, if we relax the concept as we discuss below, we can consider them rational. In order to analyse terrorists' rationality, it is useful to look at the three standards of a rational decision maker (or homo economicus): Responsiveness to incentives, Narrow self-interest, Rational expectations.

- **Responsiveness to incentives**

Terrorists are observed to have a negatively-sloped demand curve, in other words, riskier tactics are used only if they are the more effective tactic (Berman and Laitin, 2005; Hoffman and McCormick, 2004).

The view that terrorists will make trade-offs between costs, and political benefits is supported by empirical evidence. Indeed, their choice of targets, their strategies, and tactics are made using careful evaluations of economic costs, risks, time, and likelihood of success. They also have seen to be strategic in varying the levels of risk in their 'portfolio' of attacks, and choose an offensive strategy that both minimises resources and maximises damage and probability of success (Abrahms, 2004; Cordes et al., 1984; Landes, 1978; Mickolus, 1980; Pape, 2003; Rios and Rios Insua, 2012).

Furthermore, terrorists are versatile in their choices; in other words, they can adapt rapidly to changes in the environment. For instance, they have been seen to change targets quickly if security had been tightened at an original chosen target (Cordes et al., 1984; Mickolus, 1980; Woo, 2006).

We can argue that suicide tactics, for instance, can be considered as rational, since they are quite cost-effective in terms of aimed casualties and lives claimed. On average, a Palestinian suicide strike costs $150, and compared to other strikes worldwide, achieves four times as many deaths, to over six times in Israel (and twenty six times more victims). Furthermore, these strikes are observed mostly when there are no other viable alternatives (Berman and Laitin, 2005; Hoffman and McCormick, 2004).

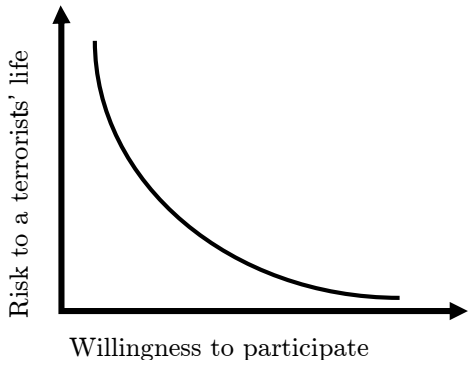

Figure 3-1: Relationship between the willingness to participate given the risk to a terrorist' s life - Negatively sloped demand curve

Narrow self-interest

Another characteristic of a rational decision maker is that he or she is narrowly self-interested. In other words, a rational decision maker will not engage in actions in which they are entirely disinterested. Here the questions relate to the rationality of terrorists for engaging in such costly behaviour to gain little or nothing in return. With regards to sympathisers, as Caplan (2006) argues, we can safely make the assumption of narrow self-interest. On the other hand, in the case of active and suicidal terrorists, it may be less straightforward.

It must be noted that the concept of narrow self-interest has been criticised for its validity; indeed, it appears to be an arbitrary limitation. Sen (1977) raises the point that commitment, for instance, violates certain concepts of rationality as economists see it. In this particular case, the evaluation of the act goes beyond the quality of the consequence; rather, a decision maker would judge the value of the act by the rules of behaviour or the meaning of the act itself.

If we relaxed this somewhat rigid assumption of narrow self-interest, we could still consider active and suicidal terrorists as rational under this condition. Indeed, interviews of failed suicidal terrorists revealed that their reasons for this sacrifice lie in the cause they serve, and not because of the benefits their family would have received (Merari et al., 2009). This also suggests that in the case of suicidal terrorists, the agents value their cause more than their lives, and hence evaluate the

consequences of the act according to the cause rather than the consequence to themselves.

Rational expectations

Another consideration that we can make about terrorists is whether their expectations or beliefs are rational. Economists refer to such expectations when actors make assessments which are unbiased, in other words, the assessed values should average around the true value of the variable (Sheffrin, 1996). So is this the case for terrorists?

Their rationality is often questioned because of the beliefs they have. For instance, the sacrifice of a suicide bomber would lead him to obtain life in paradise in the company of seventy-two virgins. From this view, the length of life on earth, compared to that in Paradise is negligible (Oliver & Steinberg 2006).

Caplan (2006) however, argues we need to look further as this does not suffice to justify terrorists' rationality. What proof do terrorists have that they would gain such a thing? One proposition suggested is a model of rational irrationality (Caplan 2000, 2001), whereby there is an added benefit in holding beliefs that are evidently against their benefit. Caplan (2006, p.98) proposes this benefit could be a psychological one, such as giving people a "sense of meaning and personal identity". In this way, if the costs of holding the beliefs and these are balanced, we can view this choice as a rational estimate of its cost. In other words, "people genuinely embrace irrational beliefs, but remain rational enough to adjust their convictions when the cost of irrationality has a spike" (Caplan, 2006, p. 101).

In fact, interviews with failed Palestinian suicidal terrorists enabled to gain some psychological insight into what might drive terrorists to sacrifice their lives (Merari et al., 2009). In majority, the failed terrorists had two main traits: susceptibility to social influence, and people of authority; and sub-clinical suicidal characteristics, some of which due to depression of post-traumatic stress syndrome. To some extent, these traits can explain their self-destructive act.

The failed suicidal terrorists were characterised with "a narrow prospective and a constricted experience of reality. They have fewer available resources for planning and implementing deliberate strategies of coping with decision making, and they are more likely to show inept and ineffective ways to cope with ordinary experience of daily living" (Merari et al., 2009, p. 94). Furthermore, they are seen to have a dependent and avoidant personality style, which distinguishes them from other types of active terrorists. Such personalities tend to internalise their anger and other emotions making them more prone to becoming martyrs. Their low self-esteem makes them look for interpersonal relationships, guidance, and care. In contrast, other types of active

terrorists were impulsive and emotionally unstable; a personality style more prone to externalise their emotions (Merari et al., 2009).

In the next subsection, we analyse the modelling implications of relaxing the standards of rationality for the different types of terrorists.

3.3.1.3 Considerations Relating Relaxing the Assumption of Rationality

Whilst we can safely assume Sympathisers behave according to the three standards of a rational decision maker, these standards need to be relaxed for the Active and Suicidal terrorists. In this section, we provide some considerations and suggestions to reflect the standards being relaxed depending on the types of terrorists with which we are dealing.

- **Explaining the inconsistencies**

  A greater understanding of the dynamics inside terrorist organisations could provide some insight into their group dynamics. As discussed earlier, given terrorists operate mostly in groups (McCormick, 2003), analysing their decision-making from the perspective of organisational making could then enhance the descriptive validity of models describing their decision-making process.

- **Responsiveness to incentives**

  As discussed in the previous section, the three types of terrorists (Sympathisers, Active, and Suicidal) are considered to respond to incentives.

  Such behaviour can enable us to guide assessing the probability of a particular strike being selected (if using DTs from the defender's view), or the attractiveness of a certain strike based on how risky the environment is in a particular location. We can then make the assumption that if in a certain location, a strike S, has an efficiency e and a level of risk r, it will be preferred to a strike S', with efficiency e' and a level of risk r' if $e > e'$ and $r \leq r'$.

- **Narrow self-interest**

  A rational decision maker will not engage in actions in which he/she is entirely disinterested. Whilst it is safe to assume that Sympathisers act according to narrow self-interest principles, the case of Active and Suicidal terrorists requires some adjustments to be made.

  The question in the case of active and suicidal terrorists is what benefit they value in their behaviour. Therefore, it may be useful to have an understanding of what benefits the adversary might gain from being an active terrorist. These types

of terrorists evaluate the consequences of their act according to the cause they serve rather than the consequences to themselves. One way to reflect this could be by assigning a relatively higher weight on objectives relating to the benefits to the cause resulting from the act than the weight assigned to the cost to the terrorist's life. Such objectives are discussed further in subsection 3.3.2.3.

- **Rational expectations**

A distinction has to be made between Active and Suicidal terrorists.

Active terrorists – agents seeking to externalise their emotions

Active terrorist may be close to adhering to the standard of rational expectation. Therefore, it is also important to revaluate the defenders' understanding of what the adversary believes is worth believing, in other words, what the defenders think contributes to the adversary's utility from engaging in terrorism.

Indeed, as we saw earlier, even though the agent might choose to have irrational beliefs (some that are devoid of evidence, for instance), they would not have them if they did not gain some sort of benefits from them. It has been found that active terrorists are impulsive, emotionally unstable and are prone to externalise their emotions (Merari et al., 2009). Acting out their anger could therefore be a benefit that justifies the cost of engaging in terrorism. Should the costs of having these beliefs become too high, one might expect them to modify their thoughts on the matter. Consequently, this is likely to have an impact on the utility functions as well as the probability of a strike being chosen. Therefore, when describing the utility of active terrorists, modellers should incorporate the benefit gained from externalising their anger.

Suicidal terrorists – agents seeking attention

Caplan (2006) does not support suicidal terrorists having rational expectations. Even as the cost rises, some suicidal terrorists will choose to carry on and die rather than revaluate their beliefs, as observed by the research carried out by Merari et al. (2009) who interviewed failed suicidal terrorists (some of whom had pressed the trigger, but the devices had failed).

In order to model adequately suicidal terrorist decision-making, and how to evaluate the attractiveness of suicidal terrorism, it may be useful to have an understanding of the benefits that suicidal terrorists seek from such an act. In their case, the psychological benefits can explain suicidal terrorists' willingness to participate in such a self-destructive act. Their personality type makes them seek care and guidance from stronger personality figures. The benefit they seek when becoming martyrs or victims is the attention they would get from it. The utilities

describing what suicidal terrorists may gain from engaging in terrorism should incorporate this element.

If we, therefore, posit that terrorists can be considered as rational actors who will maximise a utility, the question remains as to what utility they are trying to maximize. In the next subsection, we look at what added benefit terrorists might find in engaging such costly acts, and discuss what type of utility we should expect them to be maximising.

3.3.2 Terrorists as Utility Maximisers

In this section, we discuss the validity of the dominant view relating to terrorists being politically motivated. Providing some empirical evidence from areas such as psychology, terrorism, political violence, political science and, international security, we present some suggestions regarding the element to include when modelling the utility of a terrorist.

3.3.2.1 Are Terrorists Political Utility Maximisers?

As discussed in section 3.3.1.2, the view that terrorists will make trade-offs between costs and political benefits, is supported by empirical evidence. Target and strikes are carefully chosen to balance costs, risks time and likelihood of success (Cordes et al., 1984; Landes, 1978; Mickolus, 1980; Pape, 2003; Rios and Rios Insua, 2012). For this reason, the dominant view suggests that terrorists are political utility maximisers (Keeney and von Winterfeldt, 2009). Formally, terrorism becomes an attractive form of protest when the political benefits gained by terrorism outweigh the costs, but this does not always seem observed (Abrahms, 2008).

Could it be then that terrorism was a means to achieve something quite different? If some of their actions lead us to doubt their rationality because it goes against their political goals, maybe it could be that certain objectives important to terrorism have not been considered.

In addition to the political benefits, Abrahms (2008) also points out other benefits to take into account, which are not related to political ones. Indeed, individuals seem to want to belong to a terrorist group for the social aspect of it. This can explain why, even though beneficial to them politically, terrorists are reluctant to participate in peaceful or democratic negotiations.

Thus, one objective modellers need to take into account is maximising the viability of terrorist units. As Abrahms, (2008 p.101) highlights,

> *"terrorist organisations behave more as social solidarity maximizers than as political maximizers."*

To our knowledge, most decision models do not consider these.

In the next subsection, we analyse the implications of these additional benefits that terrorists consider.

3.3.2.2 Do Modellers Know What Terrorists want?

One assumption made in decision models relates to the ability for decision-makers to clearly identify and formulate a set of relevant objectives they want to achieve and against which they will evaluate their alternatives. To some extent, it is reasonable to make this assumption in the terrorism context. Terrorists have been seen to choose attacks that offer the best compromise between the operational aspects, such as costs and feasibility, and the benefits gained out of the strike. Further, the psychological study of "Self Martyrs"/"Suicide Bombers" and organisers of suicide attacks done by Merari et al. (2009) revealed that the organisers had high coping resources which enabled them to plan strategically. However, various terrorism models of preferences, do not consider all the objectives terrorists might consider.

- **Avoid over-simplifying models**

  In the evaluation homeland security decisions, Keeney & von Winterfeldt (2011) focus on two main objectives, minimising the loss of lives and the costs of the decisions when evaluating policies. This assumes terrorists would only consider a strike based on these two objectives, but is that an adequate representation of how terrorists would evaluate objectives?

  A strong assumption in several models, especially in game theoretical ones, is that objectives are diametrically opposed, which is not necessarily always the case. Each side may have additional objectives that the other side may not consider. For instance, Paté-Cornell & Guikema (2002) evaluate various types of strikes based on the symbolism of the attack, the amount of destruction done and the extent of political destabilisation caused. Even as this helps simplify the model, terrorists may consider other objectives, such as causing panic, as we highlighted above.

- **Extend the objectives against which strikes are evaluated**

  Based on the variety of attacks used by terrorists, we argue that the objectives, which are generally used in counter-terrorism models, may not always be sufficient. Take the case of the Anthrax attack in 2001, for instance. The strike did not cause many casualties relative to other types of attacks (five deaths). On the other hand, a widespread panic, nationwide disrupted mail delivery as well as costs of $1 billion resulted from the strike (Cordesman, 2005). More recently, the shut-down of Boston following the marathon bombing is estimated to cost around $1 billion (Plummer, 2013).

According to Richardson (2007), Kydd and Walter (2006), the benefits sought by terrorism can be grouped into the following categories:

- **Revenge** by causing damage in terms of loss of human lives and economic losses
- **Renown** by the delivery of a symbolic message
- **Reaction** such as achieving a regime change, territorial change, policy change, social control, or maintaining the status quo

In the next subsection, we provide some suggested objectives to be included in terrorists' utility functions.

3.3.2.3 Suggested inclusion of further objectives in terrorists' utility functions

Defining and eliciting the objectives that need to be included in the decision models can be challenging for several reasons. First, it requires an understanding of what the adversary is trying to maximise.

The effectiveness of a strike can be measured using various attributes, and choosing the wrong attribute could lead to the model providing a solution that does not solve the problem at hand. To illustrate, we take the case of the Anthrax attack. If the effectiveness were measured in terms of lives lost, this strike would be deemed to underperform. On the other hand, if the effectiveness were measured in terms of its psychological and economical impacts and disruptions, then it would perform higher than a suicide attack.

Abrahms (2008) suggests that additional benefits to that of political ones need to be taken into account, which are summarised in Table 3-1. Whilst trying to use tactics to gain a political change, terrorists' strategies will also include an element that will ensure their existence is continued and justified. This can mean resisting to participate in negotiations, or rejecting them. Some of their goals and means to achieve them can be detrimental to their cause, such as remaining competitive through destroying competing terrorism groups. When building counter-terrorism analysis models, risk analysts need to devote more effort into understanding what the objectives that drive the terrorism organisation are. Some research into their goals has been done, but is focussing on the political objectives driving terrorists (Keeney and von Winterfeldt, 2009; Kydd and Walter, 2006; Pape, 2003).

As highlighted in the previous section, identifying objectives terrorists may consider is done using subjective judgement based on intelligence data or expert knowledge. This means that errors can arise from misinterpreting this information. Further, modellers also make the assumption terrorists may be more sophisticated than they

actually are and have the ability to formulate a relevant set of objectives given the circumstances.

3.3.3 How Do Terrorists Evaluate Alternatives and Uncertainties?

When evaluating the utility of alternatives and likelihood of outcomes, decision makers are subject to two main factors, bounded rationality that may cause violating some axioms, and the effect of emotions. As Elster (2000, p.7) highlights,

> *"when we act under the influence of passions, they may cause us to deviate from plans laid in a cooler moment."*

In decision models, specifically DTs and GT, assumptions are made concerning the utility functions and the probabilities assigned to consequences (Rios and Rios Insua, 2012). Indeed, given the issues arising from the non-availability of data, modellers rely heavily on making highly subjective assessments. These have been argued to represent only degrees of beliefs, and hence that the situation/game modelled may not be one that reflects reality. The solution suggested by these models may therefore not be an answer to the problem a defender is trying to solve (Ezell et al., 2010; Guikema and Aven, 2010).

Two areas of concern arise. One surrounds the extent of the validity of these estimated values. The other consideration to be made is whether these values are up to date, i.e. have they taken into account any changes in the environment and or the actions of the defenders. These could have an impact on the utility functions and probabilities of the attacker.

The following two subsections will provide some theoretical background relating to the descriptive elements involved in decision making before providing some prescriptive advice as to how these could be incorporated in the third subsection.

3.3.3.1 Is the Influence of Visceral Factors on Decision Making Negligible?

Can we reasonably assume that terrorists are capable of formulating a set of objectives that will enable them to evaluate what the best-performing option is when under the influence of emotions? According to Merari et al. (2009), suicide bombers and their organisers are especially prone to the influence of emotions.

When looking at terrorism decision-making, the effect of passions or visceral factors might need to be taken into account. Passions or visceral factors are strong emotions such as anger, fear, love, cravings. Because of their strength and the state in which they put the individual into, they cause a temporary change of behaviour. This modified behaviour can be described as irrational; indeed, the individuals seem to act against their own interest. Passions, visceral factors and negative emotions have an

impact on the way agents evaluate probabilities, their risk attitude and the way they view performances of options (Loewenstein and O'Donoghue, 2007).

Ends	Means
1. *Prolong their existence*	Using strategies that instead of promoting policy concessions from the defender, hardens their willingness to make them Lack of success even for prolonged length of time does not make the group give up and disband. They create new issues to remain relevant when their political aims are no longer actual
2. Ensure their continued viability	Avoiding to peacefully engage in democratic processes
3. Avoid disbanding	Often rejecting negotiated settlements even though they offer substantial policy concessions
4. Guarantee their survival	Adopting unstable political goals that can never be fully fulfilled
5. *Avert organisation-threatening reprisals*	Conducting anonymous attacks, even though they preclude the possibility of coercing policy concessions
6. Remain competitive	Eradicate competitive terrorist organisation with identical ideologies that compete for members, regardless of the adverse effect it might have on their political cause

Table 3-1 Terrorists' additional means-ends objectives (Adapted from Abrahms 2008, p.102)

The effects of passions and visceral factors can be categorised into four main streams. Because cognition is temporarily distorted, decision makers' evaluation of an outcome's probability or the outcome itself is altered. Furthermore, they may become blind to certain consequences, and look only at consequences made salient by the passions. Decision makers' will is altered and weakened such that, options which outcome is worse than others are chosen. These effects also have implications towards the way modellers evaluate how decision makers discount time. Indeed, if the deliberative system evaluates equally long and short-term consequences, the affective system will put a much greater emphasis on short-term outcomes (Loewenstein and O'Donoghue, 2007). Passions and visceral factors influence an agent to behave extremely myopically, and to seek the immediate rewards, disregarding any detrimental effects, such as the effects observed in addiction. In the context of

terrorism, this phenomenon is especially observed in the case of suicide bombers or self-martyrs (Merari et al., 2009).

Specifically, it has been shown that negative affective states may influence decision-making in various ways, including altering the agent's decision process, or shaping the agent's motives. It has been suggested that distinct states may lead to different influences (Isen and Geva, 1987; Isen and Patrick, 1983; Lerner and Keltner, 2001, 2000; Loewenstein and Lerner, 2003; Wright and Bower, 1992). For instance, research on the impact of sexual arousal and decision-making has demonstrated the importance of situational forces on preferences and which way these swerve depending on the emotional state (Ariely and Loewenstein, 2006; Loewenstein et al., 1997). Similarly, research suggests that certain emotional states, such as sadness or fear induce biases favouring different types of attributes. Whereas anxious individuals would favour low-risk/low-reward options, sad individuals are biased in favour of high-risk/high-reward options (Raghunathan and Pham, 1999).

3.3.3.2 Time Frames of Decisions – Do Preferences Remain Static Over Time?

Modellers need to consider the temporal dimension of decisions and its effects on preferences. For instance, the design of most decision analytical models, such as that of Rosoff & John (2009), is mostly valid at the time it was built. Indeed, the values, preferences, and utilities modelled are considered static; they do not account for potential changes in objectives, or fluctuations in beliefs over time. These changes can occur for various reasons, such as changes in the environment or changes in terrorist leaders.

Terrorists' motivations include a reaction to an event. Therefore, understanding what the objectives terrorists might wish to maximise at a given moment requires the understanding of the state of the environment, and the recent actions from the defender. Modelling causal relationships we believe can help in providing an insight on the prioritisation of objectives. Certain modelling tools, such as System Dynamics provide the platform to evolve with time, or gain an insight on the directions towards which distinct variables might be moving. However, GT or DTs need to be updated accordingly, and can be done using Bayesian Updating (Paté-Cornell and Guikema, 2002).

The uncertainties that terrorists face and which are most often modelled are the probabilities of acquiring the material required to perform the strike. Subsequently, the likelihood of success of a strike needs to be determined. Questions arise as to whether terrorists are able to estimate accurately the probability of being detected and their strike being prevented, as well as on the other hand, look at the degree to

which their strike might be successful. This requires modellers to make further assumptions as to the extent of their knowledge regarding the defensive capabilities of the defenders. However, assuming this was the case, do they have the ability to estimate the required probabilities involved in complex attacks?

Furthermore, as visceral factors have a strong impact on the assessment of the performance of alternatives, risk attitudes and the assessments of probabilities are also altered. Empirical research, in fact, shows that emotions have a non-negligible impact on the judgement of risk (Isen and Geva, 1987; Isen and Patrick, 1983; Lerner and Keltner, 2001, 2000; Loewenstein et al., 2001). Fear in particular influenced risk assessments by inflating them, whereas anger did the opposite. Additionally, fear induces risk-averse choices, whereas the opposite is observed with anger (Lerner and Keltner, 2001, 2000; Wright and Bower, 1992).

3.3.3.3 Suggested Considerations when Modelling Terrorist Evaluation of Alternatives and Uncertainties

Once objectives have been determined, there are still some challenging issues to bear in mind. DT and GT models require an assessment of how alternatives would be scored by the adversary. Does the adversary have the ability to formulate the problem and compute the best outcome? This is arguable, given the circumstances in which the decision makers might be.

We believe considering the impact that emotions and visceral factors have on the assessment of options can provide support and guidance to interpret the data and estimate how terrorists might score options. Considerations we suggest are classified into four main categories:

1. **Myopic Decision Makers**

Given the visceral factors terrorists might be experiencing, empirical research supports they would have the tendency to prioritise short-term objectives rather than long-term ones. In this case, the objective function should consider this to provide a more descriptively accurate picture. Consequently, models could heavily discount time, so for instance, in an MAUT model, a much heavier weight should be allocated to the short-term objectives that one would expect to assign in circumstances where the agents would not be subject to strong emotions.

2. **Altered View of Objectives**

The emotional impact will cause certain objectives to be more important in terrorists' mind, and might result in several other objectives being omitted from the objective function. The objectives made more salient due to visceral factors are not always rational, in other words, the consequences arising from fulfilling these objectives can

be detrimental to the agent – as observed in the case of road rage (Loewenstein, 2000, 1996). Allocating more weight – if not all in some extreme cases – to some of the objectives less geared towards achieving their political gain and more towards the 'social aspect' of the terrorist organisation may capture this behaviour. These objectives are summarised in Table 3-1.

3. Utility Functions/Risk Attitude

As discussed earlier, emotions can have a non-negligible impact on decision makers. Empirical research shows how certain negative emotions have an impact on risk attitudes (Raghunathan and Pham, 1999). Fearful agents' choices appear more risk-averse, whereas anger leads to the opposite behaviour (Lerner and Keltner, 2001; Lerner and Tiedens, 2006).

Taking into account these varying risk attitudes in MAUT models can be done by adjusting the shape of the utility functions of the agents within the MAUT models. Indeed, different risk attitudes could have an impact on the ranking of options.

The level of emotion experienced by the terrorists will need to be represented by the steepness of the utility function; the stronger the emotion experienced, the steeper the utility function will be. Furthermore, the shape of the utility function will depend on the type of emotion experienced. A terrorist experiencing fear will have a concave utility function (risk aversion); in contrast, a terrorist experiencing anger will have a convex utility function (risk proneness).

4. Biased Assessment of Uncertainties

When incorporating probabilistic assessment from the point of view of the terrorists, it is important to bear in mind that decision makers are often prone to biased assessments. This can arise from various factors, including overconfidence, representativeness, etc. (Bazerman, 2005). Therefore, assuming that the adversary is a well-calibrated and unbiased decision maker may not be realistic. As highlighted earlier, visceral factors can worsen the effects further, thus the performance of alternatives, and risk assessments is bound to be altered.

Hence, when assessing the performance of certain strikes and their likelihood of success from the view of the terrorists, their state of mind should be considered when building the model. In particular, we suggest that the inferred judgements made by terrorists be adjusted as follows to reflect the impact of visceral factors.

Terrorists under the influence of fear (suicidal terrorists, for example) will tend to be more pessimistic (Lerner and Keltner, 2001, 2000), hence, the probabilities of success of a strike, and the probabilities of the risk they encounter should be scored lower and higher respectively. On the other hand, terrorists under the influence of anger

(sympathisers or active terrorists) will tend to be more optimistic (Lerner and Keltner, 2001, 2000), thus, the probabilities of success of a strike, or the probabilities of the risk they encounter should be scored higher and lower accordingly. Incorporating the biased views of terrorists based on their emotions (fear or anger) could add to the descriptive validity of the models.

In Table 3-2, we summarise the key areas of concern and our suggested considerations when building terrorism models.

Area of Concern	Key Modelling Considerations
Responding to Incentives	Actions taken by the defender can have an impact on the actions the attacker will take. Sympathisers, active and suicidal terrorists all respond to incentives. This means that if measures are taken to strengthen the security against one type of strike (hence increasing the risk of terrorists being caught, the attractiveness of this strike will diminish. As a result, other strikes will be perceived as more attractive. This causal variation in the attractiveness of strikes caused by the effect of the defender might be captured by updating the partial utilities of the relevant strikes.
Terrorists and Narrow Selfishness	A rational decision maker will not engage in actions in which they are disinterested. The question in the case of active and suicidal terrorists is what benefit they value in their behaviour Such terrorists evaluate the consequences of their act according to the cause they serve rather than the consequences to themselves. One way to reflect this could be by assigning a relatively higher weight on objectives relating to the benefits to the cause resulting from the act than the weight assigned to the cost to the terrorist's life. See examples of benefits described in Table 3-1.

Area of Concern	Key Modelling Considerations
Terrorists and Rational Expectations	This area concerns whether terrorists' expectations or beliefs are rational. Active terrorists behave as social solidarity maximisers, rather than political maximisers and seek to prolong the viability of the units for the social benefits it provides. In DTs (from the perspective of the terrorists), GT or ARA models representing decisions of Active terrorists may: ■ Include the social benefits involved with terrorism (for instance, those described in Table 3-1) ■ Include the psychological benefit of violence, these are means to act out their emotions (anger) Suicidal terrorists' behaviour can be considered rational if the utility gained from being a martyr in terms of care and attention received in included. In DTs (from the perspective of the terrorists), GT or ARA models representing decisions of Suicidal terrorists may: ■ Include the utility gained from taking the status of martyr or victim. These are means to gain attention.
Time discounting	Terrorists can be considered as myopic decision makers, modellers may: ■ Assign greater relative weight to short-term objectives to reflect these are prioritised over long-term ones ■ Omit, in certain extreme cases, long-term objectives, such as gaining political concessions
Altered view of Objectives	Visceral factors cloud judgement; certain objectives, even self-destructive ones are prioritised. Analysts may thus: assign a greater relative weight to objectives contributing to prolong the existence of the terrorist organisation.
Utility functions: Risk attitudes	Visceral factors affect risk attitudes in the following way: ■ Fear renders agents to be risk-averse, hence when dealing with terrorists prone to fear (for instance, suicidal terrorists), their utility function should have a steeper concave shape. ■ Anger renders agents to be risk-seeking, hence, when dealing with terrorists prone to anger (for instance, active terrorists and terrorist leaders), their utility function should have a steeper convex shape.

Area of Concern	Key Modelling Considerations
Biased Assessment of Uncertainties	Visceral factors affect risk assessments in the following way: ■ Fear makes agents more pessimistic and hence lowers their perception of being in control or successful, thus when dealing with terrorists prone to fear (for instance, suicidal terrorists), analysts may use a lower perceived probability of success. ■ Anger makes agents more optimistic, they have a higher perception of being in control, hence when dealing with terrorists prone to anger (for instance, active terrorists and terrorist leaders), and analysts may use a higher perceived probability of success.

Table 3-2 Summary of Modelling Considerations

3.4 Conclusions and Directions for Further Research

This article has reviewed some of the modelling approaches based on Expected Utility Theory and Multi-Attribute Utility Theory for analysis of terrorism risk and highlighted their main assumptions and limitations. The aim of these types of models has been developed in an attempt to infer preferences of agents.

Whilst these tools can provide interesting insight into how decisions might be made, or how a game may be played, the insights gained from these analyses seem geared towards a normative view. We argue it is essential to understand the descriptive elements, which may affect this decision maker and examine if these assumptions might be violated, and if so, how they are violated.

One main consideration is the nature of the threat. Terrorism, unlike engineered systems and natural hazards, is caused by human intent. Contrary to the latter ones, the cause of the threat is an adversary who is going to consider the actions of the defender before acting. This therefore requires some adjustments to be made to how the risk is assessed.

Indeed, the adversary is going to modify their behaviour given their knowledge of what the defender is planning. Therefore, a strong understanding of what their rational behaviour consists of is required to provide some insight into how they might adapt to the situation. Evidence shows terrorists are not likely to take risks if they can avoid them. Thus, an increase in costs associated to their lives may lead most of them (Sympathisers and Active Terrorists, in contrast to Suicidal Terrorists) to review their beliefs and adjust them as explained by the concepts of responsiveness to incentives, narrow self-interest and rational expectations.

Further, we argue that several psychological factors need to be taken into considerations. One of them is the effects of visceral factors on decision-making. These effects are shown empirically to be non-negligible. Preferences appear temporarily altered under the influence of strong emotions. This can lead to risk attitudes being modified, goals being restructured, priorities changed, and risk assessments being altered. For instance, certain objectives, not always leading to positive consequences, are made more salient for a certain period and emotions such as fear and anger lead to pessimistic and optimistic risk assessments respectively. Not considering these effects when modelling judgements of terrorists using Probabilistic Risk Analysis methods can render their solutions even more biased.

Incorporating such insight into the modelling process of Probabilistic Risk Analysis, Game Theory, and Adversarial Risk Analysis methods may help increase the validity of the models from a descriptive point of view. Hence this may help with the management of risk caused by terrorism. To do so, further research into the impact of psychological factors (in particular, particular visceral factors) can help. It would be interesting to see empirical evidence showing if and how priorities are changed through the influence of visceral factors, and if agents would increase the prioritisation of objectives that are counterproductive to their goals.

3.5 Chapter 3 References

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Appendix 3.A Axioms of Rationality

The four axioms of rationality are as follows (French, 1986; North, 1968).

$$Let\ A, B, and\ C\ be\ three\ prizes\ or\ outcomes\ resulting\ from\ a\ lottery.$$

- **Axiom 1 Transitivity:** The decision maker's preferences between prizes or lotteries can be established in an unambiguous manner.

$$if\ A \gtrsim B, B \gtrsim C \implies A \gtrsim C$$

- **Axiom 2 Continuity:** There exists a lottery between the worst and best outcome, which the decision maker is indifferent between that lottery and a mid-point consequence C.

  $if\ A > C > B,\ \exists\, p, 0 < p < 1\ such\ that\ C \sim (p, A; 1 - p, B)$ i.e. the decision maker is indifferent between receiving C or the lottery $(p, A; 1 - p, B)$ as a prize.

- **Axiom 3 Reduction of compound lotteries:** a decision maker is indifferent between a multi-stage lottery and a single stage lottery.

$$\big(p, A\,; 1 - p, (p', B; 1 - p', C)\big) \sim (p, A\,;\, p' - pp', B; 1 - p - p' + pp', C)$$

- **Axiom 4 Independence of irrelevant alternatives:** The preferences between two prizes A and B holds independently of a third prize.

$$if\ A > B\ then\ \forall\ C\ and\ p \in (0,1], \qquad then\ (p, A;\ 1 - p, C) > (p, B;\ 1 - p, C)$$

Appendix 3.B Axioms for Expected Utility

The expected utility of an alternative is described as follows (Keeney and Raiffa, 1993).

Let the set of attributes X be defined as $\{X_1, \dots, X_n\}$ where X_i may either be a vector or scalar attribute. Let the consequences be designated by $x \equiv (x_1, \dots, x_n)$, where x_i represents a specific amount of X_i for $i = 1, \dots n$. Assuming the set of assumptions outlined in Appendix 3.A, let the utility function u be designated by $u(x)$ or $u(x_1, \dots, x_n)$ of the form:

$$u(x_1, \dots, x_n) = f[u_1(x_1), \dots, u_n(x_n)]$$

where f is a scalar − valued function, and u_i is a utility function of X_i

Finally, let $p_j \in \mathcal{P}$ represent the probability of a state within the set of possible states, for $j = 1, \dots m$.

In the case of discrete variables, the expected utility is defined as:

$$\mathrm{E}[u(x)] = \sum_{1}^{m} p_j u(x_1, \dots, x_n) = \sum_{1}^{m} p_j f[u_1(o_1), \dots, u_j(o_j), k_1, \dots, k_m] \quad (10)$$

where p_j is the probability of outcome j, u_i is a utility function of X_i, and f is a scalar − valued funtion

Similarly, in the case of continuous variables, the expected utility of an alternative resulting from a random outcome $\bar{x}$ is then defined by the following equation:

$$\mathrm{E}[u(\bar{x})] = \int_{-\infty}^{+\infty} u(x) f(x) dx \quad (11)$$

where the random outcomes x are described by the probability distribution $f(x)$

In MAUT, we can distinguish two main cases. One is mono-objective case, $i = 1$ and is straightforward to model. In contrast, when $i > 1$, further conditions need to be met for a multi-attribute utility function (Keeney and Raiffa, 1993). We distinguish two cases, the additive, and the multiplicative utility functions.

Assuming preference independence (i.e. that the preference over one attribute does not depend on the level of the other attributes), and utility independence (i.e. that two attributes x and $x'$are independent when conditional preferences for lotteries on x given x' do not depend on the particular level of x'), we can use an additive utility function. In this case, the expected utility is represented as follows:

$$\mathrm{E}[u(x)] = \sum_{1}^{m} p_j u(x_1, \dots, x_n) = \sum_{1}^{m} p_j \sum_{1}^{n} w_i u_i(x_i) \quad (12)$$

where p_j is the probability of outcome j, u_i is a utility function of X_i, and w_i is a scaling constant

On the other hand, in cases where preference and utility independence conditions are not met, a multiplicative model needs to be used, where the utility function is:

$$1 + wu(x_1, \dots, x_n) = \prod_{1}^{m} [1 + ww_i u_i(o_i)], w \neq 0$$

where p_j is the probability of outcome j, u_i is a utility function of X_i, and w and w_i are scaling constants

Prelude to Chapter 4

Rational Self-Destruction – The effect of Anger on the Prioritisation of Self-Destructive Objectives

In *Paper I,* after having explored the types of assumptions made across various models that represent malicious agents' judgements, we discussed their suitability from a descriptive point of view. We discussed how the effect of visceral factors can have significant effects on judgement and decision-making. Anger is highlighted as one of the factors that can have a non-negligible impact on terrorist decision-making, and specifically, on the prioritisation of their objectives. From the literature, anger is likely to be a key underlying emotion that drives the strategy of terrorists – this can arise from offensive actions from the west. Fear is also an emotion that can be relevant in the context of terrorism, but this emotion is likely to be felt before the execution of a strike. In this research, we are interested in understanding the selection of a strike, where anger more than fear would play a role.

These findings were based on behavioural secondary research, and more evidence seems needed to put them in context with terrorist decision-making. To this end, *Paper II* undertakes the analysis of visceral factors (anger and fear, in particular) on the prioritisation of objectives. An empirical study is carried out to evaluate the impact the effect of these emotions on the prioritisation of objectives, some of which were self-destructive in the long term. We also analyse the impact of such emotions on the preferences of self-destructive actions, and discuss the implications of the findings in the context of modelling preferences, specifically those of terrorists.

The study, which aims to build on the current research relating to the impact of visceral factors on decision-making, used scenarios to elicit the desired emotions. These scenarios were written such that participants could relate to them, and which replicated, as close as possible, the types of emotions perceived by people supporting, or part of a terrorist group.

Using a between-subject design, each participant was assigned to a treatment randomly. They were asked to prioritise three objectives in relation to the scenario. Subsequently, the participants were asked to rate a number of actions describing a range of behaviours.

As predicted, the study found that anger had an impact on the prioritisation of revenge and success. In addition, a number of actions were perceived more (and less) attractive if they were self-destructive (and productive respectively). We discuss the implication of such findings on models of terrorism decision making.

Chapter 4

Rational Self-Destruction – The Effect of Anger on the Prioritisation of Self-Destructive Objectives

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ABSTRACT

An experimental study was used to examine the impact of certain visceral factors on the prioritisation of long-term self-destructive (Revenge) versus long-term productive (Reputation and Success) objectives and the preferences for long-term self-destructive versus long-term productive actions. We hypothesised that participants who were in a state of anger and fear would assign a greater priority to self-destructive objectives, and would find certain self-destructive actions more attractive than productive actions (in the long term). To test these hypotheses, we assigned participants randomly to three conditions (Anger, Fear, and Neutral). They were then asked to rank, and priorities to the objectives in the form of swing-weights, conforming to the multi-attribute value analysis framework. Subsequently, they were made to score the attractiveness of a number of actions in five different categories. Self-reported anger was found to have an impact on the prioritisation of revenge and success, given the hypothetical scenario, and as predicted, a number of actions were perceived more (and less) attractive if they were self-destructive (and productive respectively). Such results have theoretical impacts in the context of models representing terrorism decision making. Indeed, current models are based on the assumption of rational choice, and do not take the impact of visceral factors into account. These implications are discussed.

Key-words: Rationality, value models, decision making, behaviour decision making, visceral factors, anger, fear, preferences, dynamic priorities

« Ce n' est jamais à cause d' un é tat d' esprit qui n' est pas destiné à durer
Que l' on prend des ré solutions dé finitives. ¸
Marcel Proust – A la recherche du temps perdu. A l' ombre des jeunes filles en fleurs
(Proust, 1927, p. 142)

"It is always thus, impelled by a state of mind which is destined not to last,
That we make our irrevocable decisions."
Marcel Proust – Remembrance of Things Past: Within a Budding Grove

4.1 Introduction

If, as Becker and Murphy (1988) define them, "rational consumers maximise utility from stable preferences as they try to anticipate the future consequences of their choices", then, similarly to addictions, choosing self-destructive behaviours must be the antithesis of rational behaviour. Agents' preferences can vary widely depending on a variety of factors and in some cases, seem to follow irrational and unpredictable patterns. Road-rage, addiction to tobacco, alcohol, procrastination, and engaging in acts of extremism are examples of actions going against an agent's long-term interest. Could it be that certain factors have an important effect on judgement and decision making whereby the agents' observed preferences do not seem to lead them towards achieving the long term objectives these agents have?

Economists have argued that addictions could be explained by theories of rationality (Becker and Murphy, 1988; Iannaccone, 1986; Stigler and Becker, 1977), but behavioural economists have also suggested visceral factors could account for these self-destructive behaviours (Loewenstein, 2000, 1996). Such factors have a non-negligible effect on preferences. They act as a motivational force, which can influence people's behaviour by altering their needs or desires. Given that these factors are driven biologically, preferences are susceptible to be strongly impacted by such factors. Indeed, Loewenstein & Angner (2003) explain that tastes are partly determined by biological processes, which regulate the human body. These processes are there to ensure homeostasis (a physiological reactions aimed at regulating and stabilising the body in response to fluctuations caused by the external environment) is maintained. Following some sort of discomfort, transient changes in preferences are induced specifically in order to reinstate balance. As their influence is highly systematic, they are relatively predictable (Elster, 1998; Frederick et al., 2002; Loewenstein and Angner, 2003; Loewenstein, 2000, 1996; Rolls, 2000).

Empirical research has found that certain types of affective states (such as anger, happiness, fear) influence decision-making in opposite ways, including altering the agent's decision process, or shaping the agent's motives. Furthermore, it has been suggested that different kinds emotions, even though within the same valence, may lead to distinct influences (Ariely and Loewenstein, 2006; Bodenhausen et al., 1994; Isen and Geva, 1987; Lerner and Tiedens, 2006; Lerner et al., 1998; Loewenstein, 2000, 1996; Wright and Bower, 1992).

Agents involved in acts of violence, criminal behaviour and more particularly, acts taking the form of terrorism are expected to be driven by high level of visceral factors, in particular, anger and possibly, fear. Given emotions act as systems of rewards and punishments, motivating us towards achieving certain goals (Rolls, 2000), we would expect their choices to be inevitably shaped differently than by agents having more neutral emotions. Therefore, further insight into how agents prioritise their goals and how the attractiveness of specific actions is dependent on visceral factors could be helpful to better understand their actions and model their decisions.

Whereas the role and influence of affect on judgement and behaviours has been widely researched in social psychology, neuroscience and decision science, there has been little research on formalising this influence into traditional decision models (Loewenstein and O' Donoghue, 2007; Loewenstein, 2000). However, a new trend in models for counter-terrorism analysis has been to model decisions of terrorists from their perspective using decision analytical methods. This therefore calls for an understanding of how such methods can capture the impact of visceral factors.

Following the Appraisal-Tendency Framework, the experiment conducted as part of this study was designed to test if a state of anger – a key emotion in the context of terrorism – and fear had an impact on the prioritisation of long-term self-destructive versus long-term productive objectives (Revenge versus Reputation and Success respectively). Furthermore, we tested the attractiveness of long-term self-destructive versus long-term productive actions (the attractiveness of a range of actions to succeed in the bid, their preference for a range of aggressive behaviours, their willingness to engage in contentious behaviour as a response to an injustice, their endorsement of third parties engaging in contentious behaviours, their willingness to compromise productivity/image to respond to a conflict).

In addition to bringing some insight in the context of counter-terrorism modelling, this study could have some potential contributions of a descriptive nature. Anger has received substantial attention in the fields of behavioural decision-making and cognition. Lerner and Tiedens (2006) highlight that in the United States, anger is one of the most commonly experienced emotions. It also rarely goes unnoticed by neither those subject to it or those perceiving it. Finally, anger is an emotion that has the potential to carry over to unrelated judgments and decisions. Thus, this study could contribute to adding some insight to current findings relating to how anger affects

depth of processing of information under the influence of anger – in particular by analysing how anger affects the prioritisation objectives, some of which with long-term negative impacts on the decision maker.

This paper first provides an overview of the characteristics of terrorists as a decision maker. We then discuss the relevance of the effect of visceral factors, and anger in particular, in the analysis of terrorist decision-making. Subsequently, we describe the study carried out, and its results. Finally, we discuss the implication of the results in modelling terrorist decision making for counter-terrorism analysis and outline the limitations of our study.

4.2 The Decision Maker in Context – The Terrorist

Terrorism rationality is supported by empirical evidence, indeed, according to numerous psychological studies, terrorists are not insane (Richardson, 2007);

> *"[Terrorists] rationally and carefully calibrate their tactics to exploit their enemy's weaknesses and ensure maximum effect" (Richardson, 2007, p. 32).*

In particular, Mickolus (1980) observed terrorists rank the performance of their tactics according to economic costs, risks, time, and likelihood of confrontation with authorities. Their choice of attack strategy has been seen to be based on a hedging strategy, with portfolio of strikes which varying levels of risks (Sandler and Scott, 1987).

In addition, terrorists adapt very quickly to changes in the environment, such as governmental interventions (Cordes et al., 1984; Landes, 1978; Mickolus, 1980). When protection levels are heightened, terrorists have been seen to engage in target substitution strategies, whereby they have selected a softer target, achieving similar levels of impact at lesser costs and risks (Woo 2002; 2003; 2004; 2006). Woo (2006, p.1) states:

> *"Terrorists have to be intelligent in order to make an impact in asymmetric warfare."*

According to Richardson (2007), operational aspects aside, terrorists have three main objectives which they use to choose and evaluate their alternatives; the ' 3R' s' :

- **Revenge:** Terrorists want to achieve revenge for the wrongs that have been done to them. For instance, they want to kill as many people, if not more, as their enemies have killed.
- **Renown:** Terrorists want renown. They want to be recognised as being powerful, and they want to be remembered for what they have achieved. "The larger the number of casualties, the more innovative the tactic, the greater the symbolic significance of the target, the more heinous the crime, the more

publicity accrues to the perpetrators."(Richardson, 2007, p. 121). "The more I'm talked about the more dangerous I appear. That's all the better for me" (The Jackal, cited in Richardson 2007, p.122).

- **Reaction:** From their attacks, terrorists expect some reactions from their opponent. In the case of Al Qaeda, they want "to remove the external influence and return to the rule of traditional Islamic law, called Sharia" (Richardson, 2007, p. 83).

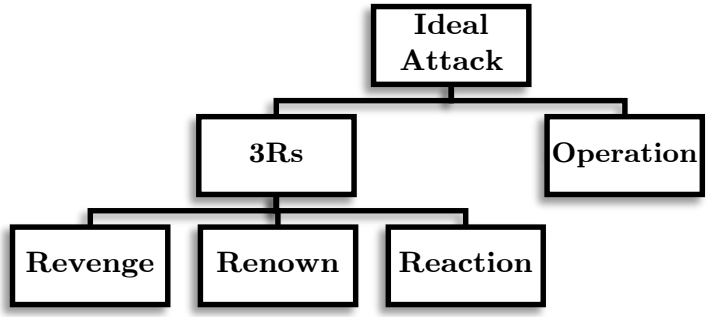

Figure 4-1: Terrorists' Value Tree

The profile that has been drawn by terrorists can be seen as rational agents with objectives they try to optimise (as illustrated by the value tree showed in Figure 4-1). However, despite the evidences stated above, there have been several cases of inconsistencies in terrorist decision making which has led researchers to question terrorists' rationality. Sri Bhashyam and Montibeller (2013) argue that this assessment could be due to some of the assumptions made in terrorism modelling being too rigid. Among other things, they have highlighted that the impact of visceral factors, might need to be taken into account when looking at the prioritisation of objectives. Incorporating these impacts into the process of counter-terrorism analysis models such as Game Theory, and Adversarial Risk Analysis methods may help increase the validity of the models from a descriptive point of view. In turn, this may help with the analysis of the risks caused by terrorism and provide some insight to support decisions towards counter-terrorism measures. Indeed, if modellers could have a better understanding of what motivates malicious agents, then they would be in a better position to anticipate unrest they cause. In the next section, we describe the experiment carried out.

4.3 Visceral Factors and Terrorism – Relevance of the Research

Preference construction or formation is not a new area of research. It has received interdisciplinary interest, from economics to philosophy, anthropology, and especially psychology. The complexity of the phenomenon, however, means that the progress has been slow (Loewenstein et al., 2003).

Two schools of thoughts exist on the topic of preference change. One school of thought argues that tastes and preferences are stable over time and do not vary significantly between individuals. According to this school of thought, whilst final preferences may change over time (a terrorist's preferred type of strike, for instance), they treat the underlying preferences as constant (the impact a terrorist aims to achieve by using a certain type of strike) (Stigler and Becker, 1977).

Simon (1981), on the other hand, argues that as new experiences produce new tastes, hence considering utility functions as fixed entities is unrealistic. Instead, he proposes to regard those as evolving structures that describe the changes in tastes using a 'production function' . The production function is defined by the utility gained from the new/accumulated experiences. Decision makers have also been seen to alter their priorities (weights on objectives) depending on the situations with which they were faced, using fewer objectives the more turbulent the situations were (Kornbluth, 1992).

One significant element triggering preference change is the influence emotion has on judgement and decision-making, which has been of interest to behavioural researchers. The Appraisal-Tendency Framework (ATF) was proposed to evaluate how specific emotions affect judgement and decision making (Lerner and Keltner, 2001, 2000; Lerner and Tiedens, 2006). According to this framework, emotions are thought to have cognitive and motivational properties, which are evident at both a biological and behavioural level. Appraisal-tendencies are defined as

> *"goal-directed processes through which emotions exert effects on judgement and choice until the emotion-eliciting problem is resolved" (Lerner and Keltner, 2000, p. 477).*

Anger, in particular, has been found to trigger the need to change the situation, as well as acting against the person or hurdle through various means, such as fighting, and hurting that object (Frijda et al., 1989). By doing so, the agent's aim is to restore the situation as it used to be prior to having been angered (Lerner and Keltner, 2001). In the process, visceral factors, including anger, influence the cognitive processes by focussing judgement and thoughts on the event which triggered the visceral factors (Johnson-Laird and Oatley, 1992; Lazarus, 1991; Schwarz, 1990; Simon, 1967).

The effect of visceral factors and the effect of anger and fear in particular, on preferences are of concern in the context of terrorism. Through interviews of terrorists, Merari et al. (2009) found suicide bombers and their organisers to be particularly

prone to the influence of emotions. From the literature, anger is likely to be a key underlying emotion that drives the strategy of terrorists – this can arise from offensive actions from the west. Fear is also an emotion that can be relevant in the context of terrorism, but this emotion is likely to occur much later in the decision process, and after the decision has been taken to adopt a certain strike as a strategy. In this research, we are interested in understanding the selection of a strike, where anger more than fear would play a role.

In situations where agents are motivated to commit acts of terror, emotions are fundamental elements that need to be taken into account. As Loewenstein states,

> "to predict or make sense of viscerally driven behavior, it is necessary to incorporate visceral factors into models of economic behavior" *(2000, p.431).*

When considering the effects of visceral factors on decision-making, research shows that particular emotions, distinct by not only their valence but also their certainty dimension can have implications for cognitive processing. Hence, as anger is considered to belong to the type of emotions related with a sense of certainty, while fear tend to be linked with a sense of uncertainty, these emotions can have different effects (Roseman, 1984; Scherer, 1984; Smith and Ellsworth, 1985). In the context of terrorism decision making, the types of influence anger and fear can have that are of particular interest can be classified in the following way: belief and attitude formation and depth of processing.

Belief and attitude formation. Visceral factors affect belief and attitude formation. Indeed, research has found that emotions have certain impacts on the estimation of probabilities and agent's attitudes towards risk (Isen and Geva, 1987; Isen and Patrick, 1983; Lerner and Keltner, 2001). In particular, and of relevance in the terrorism context, anger and fear have opposite effects on these estimations. Whilst anger tends to render agents overconfident (hence their perceived belief of succeeding is inflated from what it would be otherwise), fear tends to make them under confident. A similar pattern has been observed on risk attitudes. On the one hand, fearful agents tend to make risk-averse choices, on the other, angry agents were observed to make risk-seeking choices (Lerner and Keltner, 2001, 2000; Lerner and Tiedens, 2006).

Depth of processing. The depth and quality of information processing are also affected by the influence of visceral factors, with positive affect generally favouring better quality decision making (Isen and Means, 1983; Isen, 2001; Lerner and Tiedens, 2006). However, emotional valence may not be enough to analyse the effect of visceral factors on decision-making. Indeed, anger and fear, even though emotions from the same valence, have opposite effects on decision-making. Research on the effect of anger has shown that information processing is relatively automatic and superficial, and based on knowledge readily available. Furthermore, angry people have been found to be prone to impulsivity, and make ill-advised decisions. In particular, anger has been

found to trigger heuristic processing, decrease the attention given to the quality of arguments, induce stereotype thinking, increase punitive attributions and give harsher punishments (Bodenhausen et al., 1994; Kuhl, 1983; Lerner and Tiedens, 2006; Lerner et al., 1998; Tiedens, 2001). As opposed to anger, fear, anxiety or worry being associated with a sense of uncertainty can result in more systematic processing (Tiedens and Linton, 2001).

As visceral factors make certain consequences more salient, agents may disregard other consequences they would have otherwise considered when not under their influence. Specifically, agents will tend to behave relatively more myopically, prioritising short-term consequences much more than long-term ones. This myopic prioritisation can be explained by the type of situation in which the emotion arises. For instance, anger mostly stems from situations being generated by conflict or disputes. Because of that, the literature suggests people may have developed a reflex to react quickly and make use of heuristics by way of evaluating actions to remedy the problem. Hence, this can render agents to be impulsive and rash in their actions (Bodenhausen et al., 1994; Kuhl, 1983; Lerner and Tiedens, 2006; Loewenstein and O' Donoghue, 2007). In the case of terrorism, this myopic decision-making is especially observed in the case of suicide bombers or self-martyrs (Merari et al., 2009).

In this study, we focus on the impact of anger and fear on depth of information processing. Based on the literature, it seems reasonable to predict that the prioritisation of objectives and the attractiveness of various actions in angry, fearful, and neutral agents would differ. In particular, we look at the prioritisation of specific objectives relating to terrorists' objectives and attractiveness of productive and self-destructive actions.

4.4 The Study

This study aims to build on the current research relating to the impact of visceral factors – anger and fear in particular –on decision-making. We aim to examine how anger and fear will influence the prioritisation of objectives and the attractiveness of certain options.

In particular, we suggest the emotions will temporarily affect the prioritisation of long-term self-destructive objectives versus long-term productive objectives ones. We chose to examine three specific objectives, Revenge, Reputation and Success, to represent the terrorists' objectives that were described earlier in their value tree, see Figure 4-1.

Given the effect of prioritisation of short-term objectives over long-term ones, we also expect that angered participants will find actions representing the personal involvement in succeeding a task less attractive than otherwise. On the other hand, fear arising from a sense of uncertainty, we expect the opposite behaviour, i.e. long-term objectives would be prioritised.

Furthermore, we expect angered participants to find behaviours enabling restoring the situation as it was prior to the offence, as well as those enabling punishments. Thus, we expect confrontational, contentious, behaviours more attractive in the angered state than neutral. In addition, as anger has been found to trigger heuristic processing, hence rendering decision making impulsive and reckless, we expect the willingness to compromise productivity and image to respond to a conflict. Contrasting with anger, we expect participants to find behaviours favouring succeeding in the project more preferred to behaviours that could be detrimental, such as confrontational and contentious behaviours.

In the next section, we propose an experiment whereby the participants would be exposed to a visceral factor after which their preferences and judgement/decision process making process will be evaluated.

4.4.1 Method

Participants. The research participants were a group of 76 students at the London School of Economics (LSE), 27 females (36%), between the ages of 18 and 29 (mean age 21 years old). The participants were recruited from the summer school course 'Judgement and Decision Making for Management'. In exchange for participating, they received a tour of the newly built behavioural lab. The visit included some explanations of the types of studies that are run and how, in relation to the course they were undertaking at the summer school. In addition, the participants were told that by taking part, a donation of £1 per student would be donated to the NSPCC charity (National Society for the Prevention of Cruelty to Children www.nspcc.org.uk). Before the study was administered, the participants were informed about the experiment, and that it might involve the possibility of feeling some negative emotions or discomfort in relation to some aspects of the questions asked. The participants were reassured their participation would be anonymous and could cease taking part in the study at any time. Furthermore, they were informed the study had been designed to provide them with a reflective tool that was directly linked with one of the lectures during the course.

Affect manipulation. Affect manipulation can be done a number of ways. Giving subjects a bag of sweet or a gift certificate from McDonald's has been used by Isen and Geva (1987); and Isen and Patrick (1983). Wright and Bower (1992) used hypnosis, and Raghunathan and Pham (1999) asked participants to read scenarios depicting a situation to induce various emotions.

To test whether visceral factors momentarily altered the elements highlighted above, we chose the use of scenarios that participants could relate to, and which attempted to replicate as close as possible the types of emotions perceived by people supporting, or part of a terrorist group. The scenarios therefore had to incorporate a sense of belonging to a cause, which was one that was personal and important to the

protagonist. Then, to emulate the triggers of visceral factors in terrorists, the scenarios had to include a sense of being wronged via betrayal, and fear via loss of resources.

To do so, the three scenarios involved the protagonist running an inherited family business, and the opportunity to participate in an international bid had arisen. These scenarios depicted a situation where the cause was highly personal to the protagonist, similarly to how terrorists would consider their cause. Depending on the treatment administered to the participants, one of the scenarios then involved being betrayed by their business partner. This was to emulate the government (i.e. the enemy of the terrorists) interfering and preventing the protagonist from achieving their goals. Another scenario involved their business partner being unfairly arrested to emulate a case were terrorist leaders being arrested killed; hence reducing the capabilities of a terrorist cell (see Appendix 4.A).

4.4.2 Design

The experimental design was a between-subjects design (described in Table 4-1). Each treatment was administered randomly, and each participant was given 30 minutes to complete the questions. A between-subject design was chosen over a within-subject design to exclude range and carryover effects that can limit interpretation of the results. Furthermore, the experiment consisted of asking around twenty questions for each treatment, which meant that a within-subject design would have required participants to answer sixty questions. In addition to the other effects, we expected tiredness to have a negative effect on the quality of responses (Greenwald, 1976; Poulton, 1973).

Experimental Conditions	N
Treatment 1 N – Neutral Scenario	23
Treatment 2 ANG – Scenario Triggering Anger	18
Treatment 3 ANX – Scenario Triggering Fear	18
Analysis – Treatment 1 Versus Treatment 2	23 Versus 18
Analysis – Treatment 1 Versus Treatment 3	23 Versus 18

Table 4-1 The three experimental conditions

Procedure. The research participants were gathered in the LSE Behavioural lab, where they were assigned to a cubicle with a computer. They were provided with a link to a web-based questionnaire.

Dependent variables. The questionnaire included standard demographic items in order to determine sample characteristics. In addition, the participants were asked to assess how they were feeling by rating how well a range of statements described their emotional state. We used a six-point Likert scale, ranging from 1 (very slightly or not at all) to 6 (extremely). The emotional states included the states of interest (Anger, Fear) and others (Happiness, Depressed or Sad, Content or Relaxed, Frustrated, Contempt or Disdain, Frustrated, Impatient). These measures were derived from several research papers on decision making and emotions (Lerner and Keltner, 2001; Lerner et al., 2004; Small and Lerner, 2008).

Three experimental conditions were tested. The participants were randomly assigned one of the three scenarios, asked to read it, and instructed to relate to the protagonist as best they could, so they would be able to experience what the protagonist thought and felt. Following the affect manipulation, the participants were presented with the emotion-related dependent measures, which included eliciting their priorities for the different objectives and determining the attractiveness of several actions as outlined earlier.

Emotion-related priorities. In order to test the effect of the emotional state on the prioritisation of objectives, we used the swing weighting technique, as in Multi-Criteria Decision Analysis (a well established procedure for eliciting weights in multi-attribute value analysis, see Belton and Stewart (2001) for a comprehensive description of the steps in the elicitation process). The participants were asked to assign Swing Weights to three objectives (Revenge, Reputation, and Success, as displayed in Figure 4-2) in relation to the scenario with which they were presented.

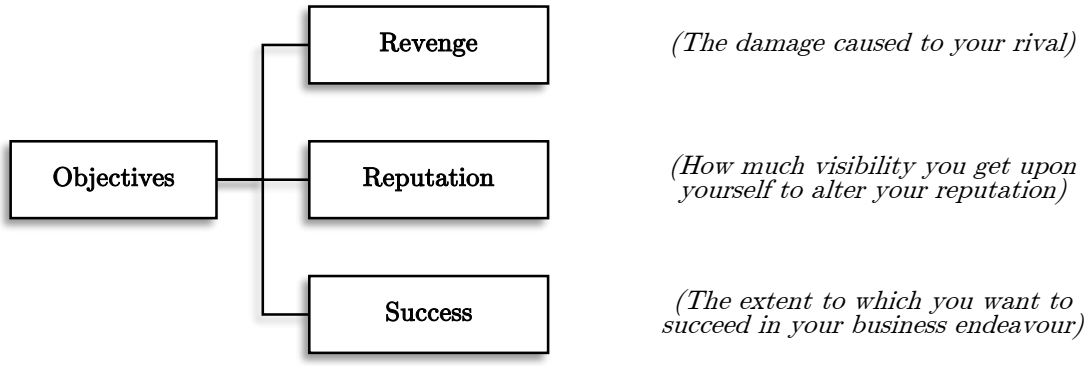

Figure 4-2 Scenario Value Tree

To enable an adequate elicitation of swing weights, we first asked the participants to rank the three objectives by dragging each objectives in the order they desired (see Figure 4-3). The next question presented the objectives ordered as per what the participant had answered in the previous question, and the first objective was rated

with 100. The participants were then instructed to rate the other objectives relatively to the 100 points assigned to that first weight and the upper and lower bounds of each objectives. The upper and lower bounds were selected so the ranges for each objective were as similar as possible (see Figure 4-4). Each participant was presented with the three objectives randomly to minimise the effect of order in the ranking of objectives.

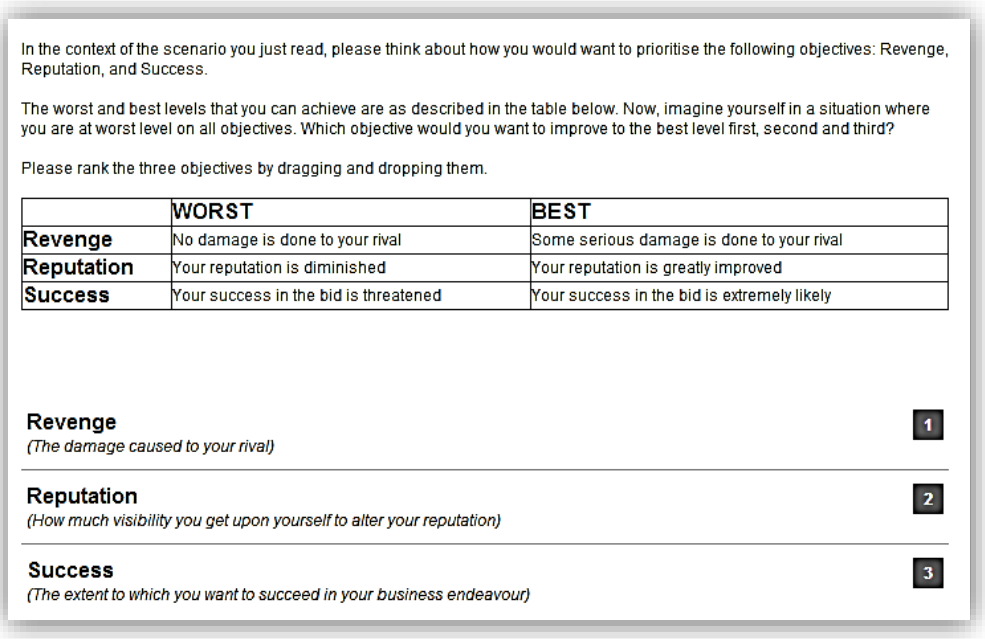

Figure 4-3 Ranking objectives

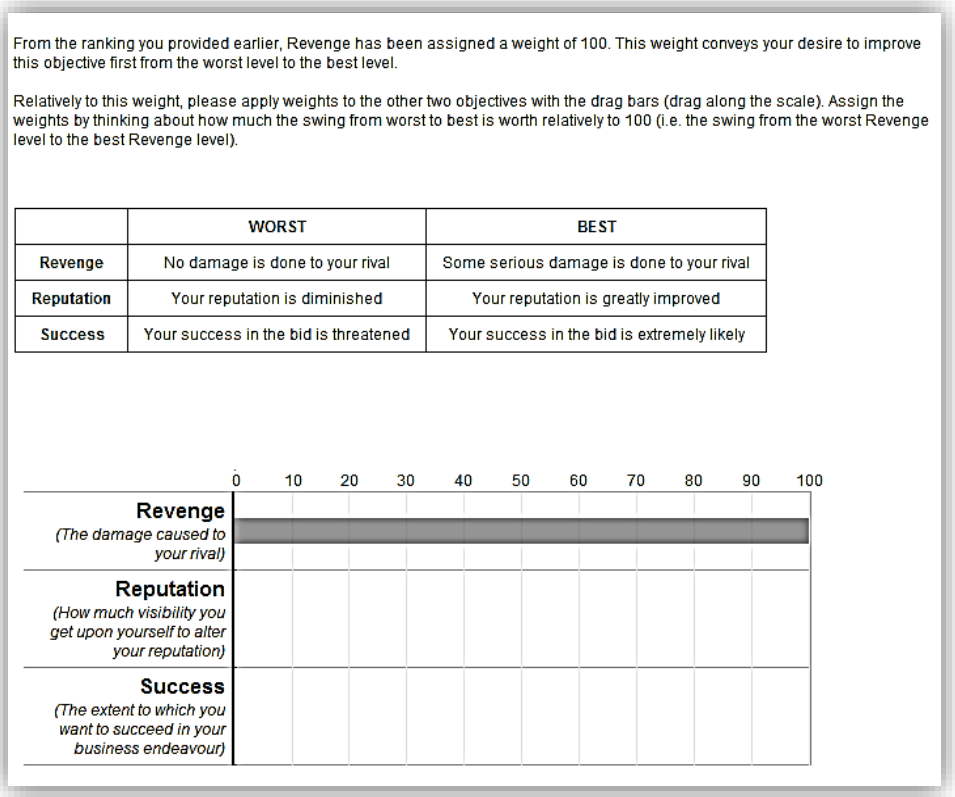

Figure 4-4 Eliciting Swing Weights

Emotion-related attractiveness of actions. Following the ranking and weighting of objectives, the participants were presented with a range of questions. The participants were asked to rate them using a scale ranging from 0: 'strongly disagree' to 100: 'strongly agree' using a visual scroll bar. The questions were presented into five modules aimed at addressing the issues highlighted earlier. Each module contained the description of a range of actions that are increasing in intensity towards achieving a certain goal.

To test the attractiveness of a range of actions representing personal involvement, the participants were asked whether they would commit themselves fully to the bid, would financially invest their own savings for the bid, and take a loan in their names to fund the activities.

To assess their preference for a range of confrontational behaviours, the participants were asked if they would raise their voice at, swear privately at their business partner, and speak ill of them to other people.

To test their willingness to engage in contentious behaviour, the participants were asked if they would find it acceptable to exaggerate facts in their favour, spread rumours and make false claims about the events to damage their business partner's reputation to their colleagues, and to the press or using social media websites.

To test if they would endorse third parties engaging in contentious behaviours, we asked the participants, whether they would find it acceptable for co-workers to exaggerate facts in their favour, spread rumours about the events to damage their business partner's reputation, and confront their business partner publicly.

To test their willingness to compromise productivity/image, the participants were asked if they would engage in a confrontation if it meant compromising their participation in the bid, damage their image, and reduce their change of winning the bid.

The questions asked are summarised in Table 4-2.

	Questions
Personal Commitment	1. Would you commit yourself fully to succeed in the bid (proposal) for a partnership with the international organisation? 2. Would you invest a great share of your savings into the bid (proposal) for a partnership with the international organisation if you thought it helped improve its quality and chances of success? 3. Would you take a loan in your name to fund the activities involved in the bid (proposal) for a partnership with the international organisation if you thought it helped improve your chances of success?
Confrontational Actions	1. Would you privately raise your voice at your business partner? 2. Would you privately swear at your business partner? 3. Would you speak ill of your business partner to other people?
Contentious actions	1. Would you find it acceptable to exaggerate facts in your favour as long as you remain generally truthful to the events? 2. Would you spread rumours or make false claims about the events if you thought it might damage your business partner's reputation even though it would not turn the situation to your advantage? 3. Would you spread rumours or make false claims about the event to the press, on blogs or various networking sites such as Facebook and Twitter even though it would not turn the situation to your advantage?
Endorsing contentious actions by others	1. Would you find it acceptable for your co-workers to exaggerate facts in their and your favour as long as they remain generally truthful to the events? 2. Would you find it acceptable for your co-workers to spread rumours or make false claims about the event to the press, on blogs or various networking sites such as Facebook and Twitter even though it would not turn the situation to their or your advantage? 3. Would you condone (forgive) your co-worker for confronting your business partner publically?
Compromising success or image	1. Would you engage in a confrontation if it meant you would not prepare sufficiently to participate in the bid (proposal) for a partnership with the international organisation? 2. Would you engage in a confrontation if it meant you would miss participating in the bid (proposal) for a partnership with the international organisation? 3. Would you engage in a confrontation with your business partner if it damaged your business image and reduce your chances of winning the bid (proposal) for a partnership with the international organisation?

Table 4-2 Questions testing the emotion-related attractiveness of actions

4.4.3 Results

Manipulation checks. Prior to analysing the results, we first looked at whether the emotional treatment had taken effect by performing an analysis on the self-reported emotional state. A paired t-test showed that the manipulation was successful for Treatment 2 (Anger), but not so successful for the Treatment 3 (Fear). Indeed, in Treatment 3, the Fear levels showed only an increase of 1.28 ($p < .001$) (scored on a 6 point Likert scale). In contrast, the Anger levels in Treatment 2 increased by 2.5 ($p < .001$). A minimal change in mood was observed in the Neutral group, which might have been induced by the nature of the questions: the Nervous or state Fear showed an increase of 0.65 ($p = .01$), and Anger increased by 1.22 ($p < .001$). Table 4-3 summarises the paired t-test comparing the differences in means of self-reported level of Fear and Anger pre and post treatment.

Treatment	Emotion	Manipulation Check				*t*	*df*	*p*
		Pre		Post				
Neutral	Fear	1.26	(1.05)	1.91	(1.56)	-2.47	22	.01
	Anger	.43	(.73)	1.65	(1.61)	-3.66	22	<.001
Anger	Fear	1.50	(1.55)	1.94	(1.53)	-.91	17	.37
	Anger	1.00	(1.33)	3.50	(1.72)	-5.21	17	<.001
Fear	Fear	.61	(.85)	1.89	(1.57)	-3.55	17	<.001
	Anger	.28	(.67)	1.44	(1.50)	-3.70	17	<.001

Table 4-3 Paired t-test comparing the differences in mean self-reported emotions pre and post treatment

A One-way ANOVA further confirmed that Treatment 3 (Fear) was not successful. Self-reported fear was not significantly reported $F(2,56) = .006, p = .994$, on the other hand, participants reported significantly more anger after Treatment 2 $F(2,56) = 9.09, p < 0.0001$. Post hoc comparisons using the Tukey HSD test indicated that the mean levels for Treatment 2 (Anger) ($M = 3.5, SD = 1.73$) were significantly different from Treatment 1 (Neutral) ($M = 1.65, SD = 1.61$). However, Treatment 3 ($M = 1.44\, SD = 1.5$) did not significantly differ from Treatment 1.

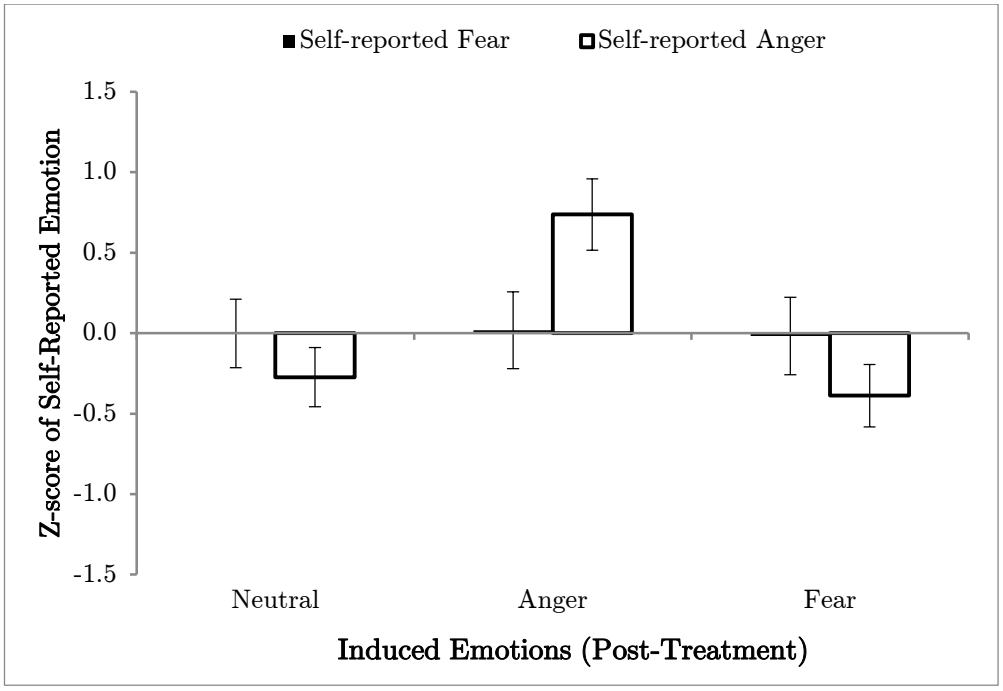

Figure 4-5 illustrates the z-score of self-reported emotions for Fear and Nervousness and Anger in the three treatments.

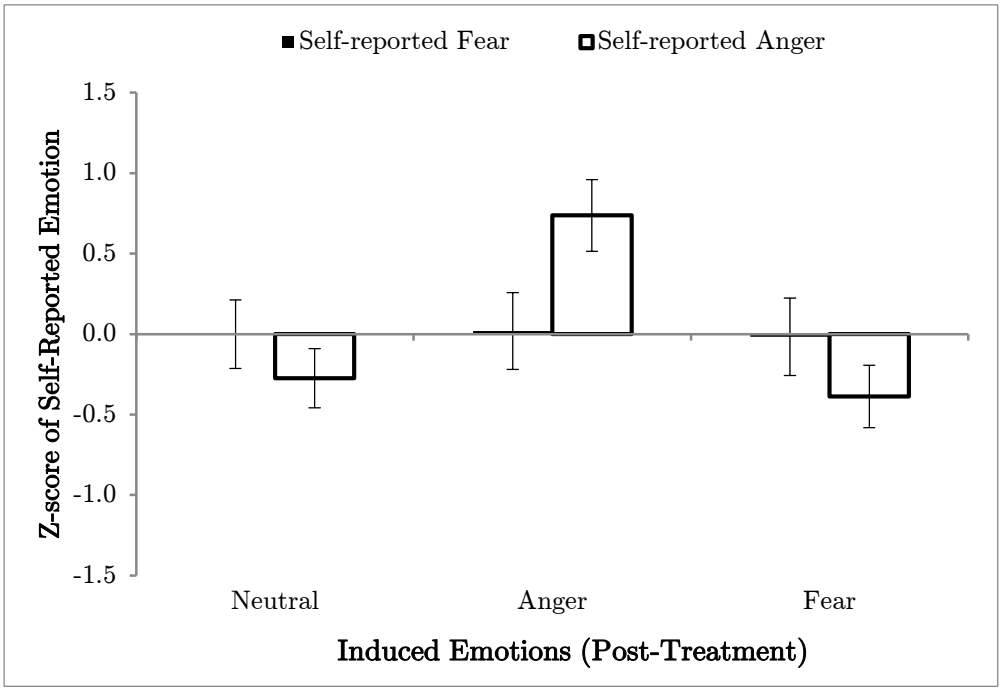

Figure 4-5 Self-reported emotion post-treatment.
Error bars represent standard errors of the mean.

Inferential analyses.

In line with similar studies examining the effect of emotions on preferences and choices (Isen and Geva, 1987; Isen and Patrick, 1983; Small and Lerner, 2008; Tiedens, 2001), we analysed the relationships between the means in each different treatment. This was done in two parts; we first analysed the influence of anger on the prioritisation of objectives and then on the attractiveness of various actions.

First, a Shapiro-Wilk test was performed to test for normality, which showed that the data were approximately normally distributed for all groups. A Levene's test confirmed homogeneity of variances. We then checked for outliers in the weights' data by eliminating all data points outside the "whiskers" from their respective box plots. Consequently, we removed one outlier in the weight for reputation as well as some other outliers in the attractiveness of various actions.

Prioritisation of objectives. A one-way between subjects ANOVA was conducted to compare the effect of two negative emotions on the prioritisation of objectives (Revenge, Reputation, and Success) and the attractiveness of certain actions in a state of anger, fear (Treatment 2 and 3), and neutral (Treatment 1, the control group) conditions.

The results showed that emotions did not have a significant effect on the prioritisation of the three objectives Revenge, Reputation, and Success at the $p < .05$ level for the three conditions $[F(2,56) = 2.174, p = .123], [F(2,56) = .071, p = .932], [F(2,56) = 2.330, p = .107]$ respectively. This could be explained because the fear treatment did not work.

An independent-samples t-test was then conducted instead to compare the prioritisation of objectives between Treatment 1 and Treatment 2 (omitting the results of Treatment 3). The study found that there was a significant difference in the prioritisation of Revenge and Success (depicted by the normalised weights) for the anger ($M_{REVENGE}$=21, $SD_{REVENGE}$=*7.30;* $M_{SUCCESS}$=40, $SD_{SUCCESS}$=*5.78*) and neutral ($M_{REVENGE}$=15, $SD_{REVENGE}$=*9.25;* $M_{SUCCESS}$=45, $SD_{SUCCESS}$=*8.58*) conditions; $t_{REVENGE}(39)$=-2.09, $p_{REVENGE}$=.04 and $t_{SUCCESS}(39)$=2.140, $p_{SUCCESS}$=.04 (summarised in Table 4-4). We note that the effect size for the weights of Revenge and Success were (d=.72, d=.68) was found to exceed Cohen's convention for a medium effect (d=.50) (Cohen, 1992). These results suggest that anger really does have effect on the prioritisation of certain objectives. Specifically, our results suggest that under the influence of anger, agents prioritise revenge more than when not angry, and the opposite is observed for success, this was observed for up to 5% on average, as seen in Figure 4-6. These results are not surprising. Indeed, the literature suggests that under the influence of visceral factors, agents have the tendency to prioritise goals mitigating the visceral factors (Loewenstein, 1999).

Normalised Weights	Treatment				*t*	*df*	*p*	*Effect Size*
	Neutral		Anger					
Revenge	15_a	(9.25)	21_b	(7.30)	-2.09	39	.04	0.72**
Reputation	39_a	(5.34)	40_a	(6.39)	-.27	38	.79	0.17*
Success	45_a	(8.58)	40_b	(5.78)	2.14	39	.04	0.68**

Note: Values in the same row and sub table not sharing the same subscript are significantly different at $p < 0.05$ in the two-sided test of equality for column means. Cohen's d effect size: *, **, *** represent small, medium, and large effect sizes respectively.

Table 4-4 ***t-test comparing the impact of Anger and Neutral emotional state on the prioritisation of objectives***

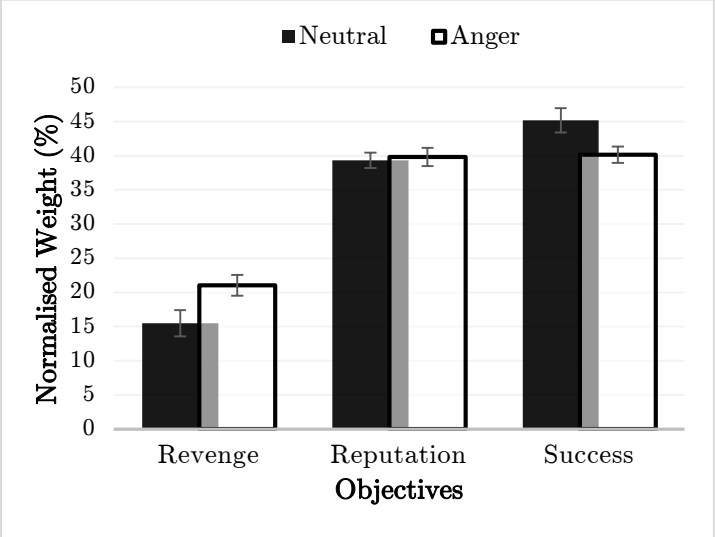

Figure 4-6 Normalised weights for Treatment 1 (Neutral) & 2 (Anger). Error bars represent standard errors of the mean.

Attractiveness of various actions. We then conducted fifteen independent-samples t-test for each of the questions to compare the attractiveness of certain actions in angered and neutral emotional conditions. To facilitate the analysis, the results are analysed in five different categories (personal commitment, confrontational actions, contentious actions, endorsing contentious actions by others, and actions compromising success and image). The significant results are highlighted here, and all the results are summarised in Table 4-5.

There were no differences between the angered and neutral treatments for the questions relating to the personal commitment to the success of the bid. However, the next questions, which dealt with confrontational actions, were significantly influenced by anger. In the angered treatment, respondents found actions such as raising their voice at and swearing at business partner more attractive compared to the participants in the neutral treatment. Speaking ill of their business partner to other people was also found more attractive, but less significantly so. In each of these questions, the effect sizes were found to exceed Cohen's convention for a medium effect (*d=.50*), hence, it is possible that a larger sample size would provide more significant results (Cohen, 1992). There were no differences between angered and neutral treatments for the questions relating to contentious actions, endorsing contentious actions by other people, or compromising actions.

	Treatment				*Diff*	*t*	*df*	*p*	*Effect Size*
	Neutral		Anger						
Personal Commitment 1 (N)	78_a	(16.23)	85_a	(16.79)	-7	-1.20	37	.24	.42*
Personal Commitment 2 (N)	60_a	(26.27)	54_a	(24.66)	6	.78	39	.44	.24*
Personal Commitment 3 (N)	54_a	(20.17)	51_a	(25.66)	3	.41	39	.68	.13*
Confrontational Action 1 (A)	43_a	(32.25)	66_b	(36.74)	23	-2.07	39	.05	.67**
Confrontational Action 2 (A)	31_a	(31.21)	55_b	(42.43)	24	-2.11	39	.04	.64**
Confrontational Action 3 (A)	20_a	(22.69)	37_a	(35.62)	17	-1.84	39	.07	.57**
Contentious Action 1 (A)	40_a	(24.84)	34_a	(33.32)	-6	.70	39	.49	.20*
Contentious Action 2 (A)	01_a	(2.53)	09_a	(26.44)	8	-1.26	32	.22	.43*
Contentious Action 3 (A)	01_a	(2.46)	02_a	(2.63)	1	-.12	32	.90	.39*
Endorsing contentious actions 1 (A)	33_a	(32.54)	27_a	(29.95)	-6	.57	39	.57	.19*
Endorsing contentious actions 2 (A)	05_a	(7.16)	03_a	(4.68)	-2	.74	36	.46	.33*
Endorsing contentious actions 3 (A)	41_a	(29.05)	44_a	(27.15)	3	-.32	39	.75	.11*
Compromising actions 1 (A)	16_a	(24.26)	10_a	(12.64)	-6	.79	31	.44	.31*
Compromising actions 2 (A)	00_a	(.24)	04_b	(8.19)	4	-2.08	31	.05	.69**
Compromising actions 3 (A)	08_a	(12.76)	05_a	(11.38)	-3	.54	34	.59	.25*

Note: Values in the same row and sub table not sharing the same subscript are significantly different at $p < 0.05$ in the two-sided test of equality for column means. Cohen's d effect size: *, **, *** represent small, medium and large effect sizes respectively (Cohen, 1992).

The expected higher response is marked with A for Angered, or N for Neutral

Table 4-5 t-test comparing the impact of Anger and Neutral emotional state on the attractiveness of a range of actions

We note that this study was aimed at analysing the effect of anger on the preferences for various behaviours including aggressive, contentious and destructive ones. However, the types of participants in this study (university students) were unlikely to be prone to engage in the types of behaviours described in the study (similarly as Tiedens (2001) points out in their study). This might explain the lack of differences between treatments observed for certain actions, unlike what was expected.

4.5 Discussion and Implications

In our study, we analysed the effect of anger on the prioritisation of self-destructive versus productive objectives. In addition, we tested the attractiveness of long-term self-destructive versus short and long-term productive actions (such as the attractiveness of a range of actions to succeed in the bid; a range of aggressive behaviours; their willingness to engage in contentious behaviour as a response to an injustice; the endorsement of third parties engaging in contentious behaviours; and their willingness to compromise productivity/image to respond to a conflict).

Our results supported the prediction that anger would be associated with an increase in the prioritisation of the revenge objective and a decrease in the prioritisation of the success objective. These results are consistent with other findings in the literature showing that emotional states have an impact on decision making, in particular anger has an impact on depth of processing (Lerner et al., 1998; Small and Lerner, 2008; Tiedens, 2001). An increase in the prioritisation of revenge and a decrease of the prioritisation of success is also consistent with findings of decision makers becoming myopic under the influence of visceral factors (Loewenstein, 2000). Indeed, revenge and success are respectively short-term and long-term objectives.

Three activities stood out as being much more attractive when subjects were angry, than when not: privately raising their voice and swearing at their business partner. Speaking ill of their business partner was also found more attractive, though less significantly so. This is consistent with the objective of revenge having been scored higher in the angered state. This is consistent with findings that certain objectives can become eclipsed under the influence of anger. Similar findings were drawn from other studies: due to arousal, goals which did not lead to achieving sexual fulfilment were clouded out (Loewenstein and O' Donoghue, 2007).

Such findings have important implications on modelling terrorist decision making for counter-terrorism analysis. Indeed, agents involved in terrorism may be subject to high levels of anger, which can also fluctuate depending on the outside environment, and actions of their opponents. The results of this study and the findings from the literature suggest that this would have an impact on their judgement and decision-making, which must be considered in counter-terrorism policies.

Research has found that following an offence that triggers feelings of anger, agents are compelled to take action to restore the situation as it was. By doing so, certain objectives not pertaining to achieving this goal are clouded out whilst objectives enabling a confrontation or harming the sources of the conflict. In addition, time can be discounted as agents can become myopic in their decision-making. In particular, this research has confirmed a tendency to have an altered view of objectives under the influence of anger. Indeed, we observed an increase in weight for the objective revenge whereas the weight for success decreased in the angered state, versus the neutral one.

Research has highlighted that terrorists' objectives might include prolonging the existence of their organisations (possibly for revenge), even if it is at the expense of not achieving their political goals (Abrahms, 2008). The results of this study contribute to support this insight, and suggest that anger might exacerbate this tendency.

As this study showed that anger could have an impact on how the objective revenge and success were prioritised, it appears necessary for counter-terrorism models to allow for this type of changes to be captured and their impact analysed. Such changes might potentially have an impact on the overall ranking of terrorists' preferred options. Indeed, some models are quite sensitive to various variables (for example Bakir and von Winterfeldt, 2011; Bakir, 2008), where changes in priorities due to anger could be especially relevant.

Such findings also provide some avenues for further research in counter-terrorism modelling using decision analytical methods. In this type of modelling, the decision maker whose preferences are being modelled is not available, and hence their preferences need to be inferred. Expanding the current frameworks used in the context of counter-terrorism to include the impact of visceral factors (as in Loewenstein & O'Donoghue (2007), see Figure 4-7) could help make counter-terrorism model more descriptively valid, and hence help have more insight into terrorists' behaviour.

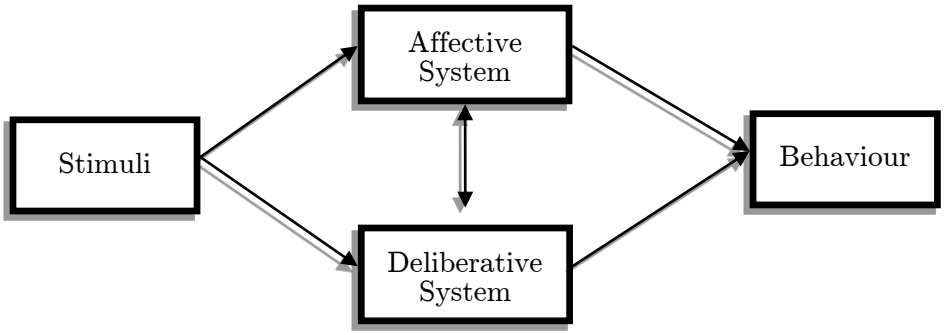

Figure 4-7 Schematic representation of the model from Loewenstein & O'Donoghue (2007)

4.6 Limitations and Directions for Future Research

This study on the effect of anger and fear on the prioritisation of objectives is subject to several methodological limitations. Given that the participants used were mostly from foreign countries, and hence English was not their mother tongue, it is possible that this reduced the effectiveness of the treatment. In fact, the fear treatment was not effective. Other methods of mood inductions could have been used, which could have had different effects. For instance, mood recall techniques as used by Tiedens (2001) could have led to different results. Furthermore, we do not expect that the level of emotions felt by the participants is as high as those we expect the terrorists to experience themselves. In addition, cognitive tasks generally washes away the effect of emotions, and therefore it is likely that the emotions felt after the mood induction decreased towards the end of the test. We also relied on self-reported level of feelings rather than using physiological/neurological means to measure their feelings.

As suggested by Ariely and Loewenstein (2006), it is impossible to determine with certainty the actual behaviour of the agents in the situations we have described without observing them. However, previous research on hot-cold empathy gaps has shown agents often do not predict correctly how they will choose to behave in an emotional state different to their current one. In fact, they underestimate the effect of visceral factors on their behaviour (Ariely and Loewenstein, 2006; Bouffard, 2002; Loewenstein et al., 1997). Therefore, it might be safe to come to the conclusion that the agents' predictions of their priorities and preferences are more accurate under the influence of anger than when they are in a neutral emotional state.

In this study, to compare priorities assigned to the objectives valued by terrorists, we imposed the list of objectives to be prioritised. However, it is possible that much more striking results could have been found on the prioritisation had we not presented these specific ones, but instead elicited objectives from them. Decision makers are generally not good at articulating relevant objectives for consequential decisions (Bond et al., 2008). It is highly likely that the productive objectives (reputation and success)

were weighed at all because they were presented to the participants. Indeed, decision makers have been found to rate omitted objectives almost as high as those generated on their own. This can be explained by visceral factors as they tend to cloud judgement, and temporarily make certain objectives much less salient in a decision maker's mind (Bond et al., 2008; Loewenstein, 2000).

Another limitation of this research is that the sample included both male and female participants. Given terrorism has been a male-dominated environment (the involvement of females in terrorism increasing but not yet so prosminent (Galvin, 1983; Jacques and Taylor, 2008)), it is possible that this study does not describe effects generalising terrorists decision making. This study shows that agents do prioritise objectives differently under the influence of anger, in particular, they prioritised revenge more than success in an angered state, however this does not show whether male and female agents prioritise differently. The sample we had did not allow us to analyse the effect of gender on the prioritisation of objectives.

Furthermore, this study aimed to examine the effect of emotions on the prioritisation of revenge, reputation and success, and the preferences for various behaviours including aggressive, contentious and destructive ones. Given the participants in this study were university students, the types of behaviours described in our study might not have impacted their lives (similarly as Tiedens (2001) points out in their study). It might be useful to conduct a similar study with individuals with a background more prone to aggressive and self-destructive behaviours, as they might better resemble terrorists.

Finally, the participants were tested after having followed several lectures of a behavioural decision making course, and therefore it is possible that their awareness of how affect and other situational elements can impact decision-making would have had an effect on the way they answered. Having said that, given the significance of the current results, it is possible that if the participants had had no prior behavioural insight, more striking results could have been observed.

Further research, which could be conducted in the same context as this study, includes the changing risk attitudes of agents, and their level of confidence. As highlighted earlier in this paper, different types of visceral factors, such as anger and fear, have opposite effects on risk attitudes and levels of confidence (Isen and Geva, 1987; Isen and Patrick, 1983; Lerner and Keltner, 2001, 2000; Lerner and Tiedens, 2006). In the context of terrorism, it would be interesting to test how utility functions vary concerning actions that have a self-destructive component to them, and how their level of confidence varies depending on their level of fear and anger.

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4.7 Chapter 4 References

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Appendix 4.A Scenarios for Study

Scenario 1: (Neutral)

Imagine the following scenario and try to experience the events described in the scenario as vividly as possible and to imagine what you would feel like if you were in this situation.

A couple of years ago, you inherited your family business, which has been a successful, well known and profitable firm for several generations. Your family has invested much of money and time in the business, making it very much an integral part of your lives.

Whilst your family are still active in the day-to-day business, they have made you one of the primary shareholders.

Therefore, you now run the business alongside your business partner. He has been a close family friend and you have known him since you were a young child.

Since you have been young, he and his family have been an integral part of your life. Your parents often invited him and his family, to family weekend dinners, and you often went on family holidays together. Ever since you can remember, you have considered him as much part of your family as an uncle would be. From the very early stages of you joining the board of directors, he has also supported you and advised you with the decisions that had to be made in growing the business.

Recently, a very well known international organisation has approached you to put a bid for a partnership with them. This is a one-time opportunity to be able to grow your business abroad and get a substantial amount of visibility on your business name. There is a lot of money at stake in this endeavour, but the payoff could be truly vast and you and your colleagues are working towards that aim.

Scenario 2: (Anger caused by betrayal)

Imagine the following scenario and try to experience the events described in the scenario as vividly as possible and to imagine what you would feel like if you were in this situation.

A couple of years ago, you inherited your family business, which has been a successful, well known and profitable firm for several generations. Your family has invested much of money and time in the business, making it very much an integral part of your lives.

Whilst your family are still active in the day-to-day business, they have made you one of the primary shareholders.

Therefore, you now run the business alongside your business partner. He has been a close family friend and you have known him since you were a young child.

Since you have been young, he and his family have been an integral part of your life. Your parents often invited him and his family, to family weekend dinners, and you often went on family holidays together. Ever since you can remember, you have considered him as much part of your family as an uncle would be. From the very early stages of you joining the board of directors, he has also supported you and advised you with the decisions that had to be made.

Recently, a very well known international organisation has approached you to put a bid for a partnership with them. This is a one-time opportunity to be able to grow your business abroad and get a substantial amount of visibility on your business name. There is a lot of money at stake in this endeavour, but the payoff could be truly vast and you and your colleagues are working towards that aim.

Unfortunately, you have just learned terrible news. Your business partner and close friend has been selling trade secrets to your biggest competitor. Given the ties you had with your business partner, such news came as a terrible shock and you as well as your family are quite devastated from the betrayal of your family friend.

Even more, such information being revealed has resulted in a dramatic loss of business, as a great share of your clients are now seeking business from your competitor. On top of having lost your competitive edge, your ability to perform well in the bid is seriously threatened.

Scenario 3: (Fear by loss of key individual)

Imagine the following scenario and try to experience the events described in the scenario as vividly as possible and to imagine what you would feel like if you were in this situation.

A couple of years ago, you inherited your family business, which has been a successful, well known and profitable firm for several generations. Your family has invested much of money and time in the business, making it very much an integral part of your lives.

Whilst your family are still active in the day-to-day business, they have made you one of the primary shareholders.

Therefore, you now run the business alongside your business partner. He has been a close family friend and you have known him since you were a young child.

Since you have been young, he and his family have been an integral part of your life. Your parents often invited him and his family, to family weekend dinners, and you often went on family holidays together. Ever since you can remember, you have considered him as much part of your family as an uncle would be. From the very early stages of you joining the board of directors, he has also supported you and advised you with the decisions that had to be made.

Recently, a very well known international organisation has approached you to put a bid for a partnership with them. This is a one-time opportunity to be able to grow your business abroad and get a substantial amount of visibility on your business name. There is a lot of money at stake in this endeavour, but the payoff could be truly vast and you and your colleagues are working towards that aim.

Unfortunately, you have just learned terrible news. Your business partner and close friend *has* been arrested on criminal claims (unrelated to your business).

Given the ties you had with your business partner, such news came as a terrible shock and you as well as your family are quite devastated by what has happened to your family friend.

Even more, his departure from the business is likely to result in a dramatic loss of business, as a great share of your clients might seek business from your competitor. On top of possibly losing your competitive edge, your ability to perform well in the bid is seriously threatened.

Prelude to Chapter 5
Modeling State-Dependent Priorities of Malicious Agents

To develop a framework for combining the objectives of terrorists and their changes over time, two main aspects need to the taken into account. These are an understanding of what drives terrorists, secondly insight into how their behaviour is influenced by visceral factors. In *Paper I,* we discussed the suitability of assumptions made in counter-terrorism models from a descriptive point of view. We highlighted how the effect of visceral factors can have significant effects on judgement and decision-making. In particular, anger is highlighted as one of the factors that can have an important influence on terrorist decision-making, and specifically, on the prioritisation of their objectives.

Following from these findings, in, *Paper II* we undertook a study to analyse the effect of anger on the prioritisation of objectives. Some of these objectives were self-destructive in the long term, as in the case of terrorism. Self-reported anger was found to have an impact on the prioritisation of revenge over success-related objectives, given the hypothetical scenario, and as predicted, a number of actions were perceived more (and less) attractive if they were self-destructive (and productive respectively).

In this third paper, we seek to address the impacts that the findings from the two previous papers have on models representing terrorism decision making. We outline the framework that could be taken to assess preferences altered by visceral factors, taking into account how weights could be dependent on the visceral state of the agents and show how such an analysis may support risk management in this context. The agents modelled here represent the terrorist organisation, but we make the assumption that it behave as an individual.

To try to infer the visceral factors, we suggest in the third paper using System Dynamics by modelling the system terrorists. This could indicate the evolution of the variables in the environment that would trigger the fluctuations of the visceral factors experienced by the malicious agents. By integrating SD to the agent's Multi-Attribute Utility Theory model, the proposed framework will investigate how to infer the impact of the anger on the weights assigned to the objectives. This could help have a better understanding of what motivates malicious agents and hence have more insight into their preference patterns. Combining the two approaches would inform how the agents may re-prioritise their objectives in response to changes in their environment and so their behaviour. This may also help in better anticipating potential risks of violence outbreaks based on changes in the environment.

The following is the exact copy of the journal paper referenced here:

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Chapter 5

Modeling State-Dependent Priorities of Malicious Agents

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With ever-increasing terror threats, governments and security officials would benefit from a better understanding of what motivates terrorists to cause social unrest. A recent research trend is on gaining greater knowledge about the values of malicious agents to help manage the risk of terrorism. As a result, there seems to be the potential to use decision analysis as a means to model what may drive malicious agents to commit harmful actions. So far, research on this topic has assumed static preferences of such agents. In this paper, we present a framework that may be used to infer how terrorists' priorities may change over time and their impact on their choice of a harmful action. We suggest modeling state-dependent priorities of a terrorist group via a multi-criteria model that incorporates state-dependent priorities to account for preference change caused by exogenous triggers and representing the environment as a system dynamics model. We describe how terrorists' visceral factors may affect the prioritization of objectives, and show how such an analysis may support risk management in this context.

Key words: terrorism; terrorist threats; multiattribute utility theory; value models; state-dependent priorities

> If you know the enemy and know yourself,
> you need not fear the result of a hundred battles.
> If you know yourself but not the enemy,
> for every victory gained you will also suffer a defeat.
> If you know neither the enemy nor yourself, you will succumb in every battle.
> Sun Tzu – The Art of War (Tzu and Giles, 2008, p. 52)

> "To predict or make sense of viscerally driven behaviour, it is necessary to incorporate visceral factors into models of economic behaviour" (2000, p.431).

5.1 Introduction

Since the 9/11 and the later 7/7 terrorist strikes in New York and London respectively, governments and security officials increasingly try to find ways to protect the public against attacks and, hence, concerns over what needs to be protected has become a growing issue. The complexities security officials face when assessing threats and their prevention lie in the inherent intricacy in predicting crime or violence outbreaks (WHO 2002; Broder 2006). By its own nature violence, and more specifically terrorism, is complex and interrelated, with varying root causes and risk factors (WHO 2002; Linotte 2007).

The evaluation of terrorist threats can be classified into two main branches. One approach is to try to determine the likelihood of such events. Achieving this can be done by including subjective probabilistic elicitation from expert judgment. With the capacity brought by mathematical modeling, another way of modeling threats have been made available which consists of the field of risk analysis (Broder 2006; Woo 2006). On the other hand, for threats involving human intent, actions of the different parties have to be taken into account when identifying potential proactive measures. In these cases, game theoretic models have been the most commonly used methods (Major 2002; Woo 2006; Wilson & Olwell 2006; Hausken & Zhuang 2011). Other widely applied mathematical models used in this context include Markov chains and adaptive learning processes and decision analytic models (Paté-Cornell & Guikema 2002; Haynes et al. 2005; von Winterfeldt & O'Sullivan 2006). More recent frameworks include the use of decision analysis and sequential game theory, in which an adaptive decision maker can be represented and hence the resulting variation in risk can be observed (Merrick and Parnell, 2011; Parnell et al., 2010; Rios and Rios Insua, 2012).

A different perspective, and a recent research trend in this field, is trying to better understand the values of malicious agents, to better support the management of terrorism risk. In fact Rosoff & John (2009) suggest it is crucial to have more knowledge of the malicious agents' objective function to gain some insight on the threat they cause. They suggest using subjective probabilistic elicitation along with a multi-attribute utility model to generate a risk profile for each type of attacks (Rosoff

& John 2009). Similarly, other researchers suggest including terrorists' objectives in the assessment of risk (Keeney 2007; Merrick & McLay 2010).

This trend assumes that terrorists behave rationally (substantive rationality as described by Simon (1981)), whereby they seek to choose the right course of action according to their goals and values. Indeed, empirical evidence from numerous psychological studies supports this view (Richardson 2007; English 2010). Woo (2006) and Enders & Sandler (2006) point out that some level of intelligence and rational thinking is required for an entity to make an impact in asymmetric warfare. Mickolus (1980) observed terrorists rank the performance of their tactics according to economic costs, risks, time, and likelihood of confrontation with authorities and overall benefits. Characteristics of terrorism can further inform us on terrorists' objectives. Acts of terrorism are motivated by a political issue, and through means primarily involving either violence or the threat of violence, terrorists seek to communicate a message to their political opponent and the rest of the world (Mickolus 1980; Cordes et al. 1984; Drake 1998; Woo 2006; Richardson 2007; Enders & Sandler 2006; English 2010).

The traditional decision models used to model terrorist values assume a stable and static set of priorities, and hence tend to ignore the potential for the agents to change their initial preferences through the decision process (Bennett & Howard 1996; von Auer 1998). However, terrorists adapt very quickly to changes in the environment, such as governmental interventions by engaging in target substitution strategies whereby they have selected a softer target that achieved similar levels of impact at lesser costs and risks (Mickolus 1980; Cordes et al. 1984). Given such an adaptive behavior, a framework to model their priorities and preferences should examine what they would prefer given a certain state of the environment.

In addition, empirical research has shown that preferences may be influenced by changes in the environment and emotional states (Loewenstein 2000; Loewenstein & Angner 2003; Loewenstein & Lerner 2003). Picard (2000) argues that emotions are a component necessary in computer models of human behavior and decision making. This is especially relevant when trying to predict, or make sense, of viscerally driven behavior, such as violent crimes. Hence, in the context of terrorism, it appears crucial to look at the effect of the environment, because violent acts may arise from exogenous triggers, such as political issues. This could be done by incorporating visceral factors into models of economic behavior (Loewenstein 2000).

In this context, our aim in this paper is thus to present a framework that may be used to infer how terrorists' priorities would change over time and examine the impacts of these changes on their choice of a harmful action. To do so, we try to have a better understanding of their choice mechanism, what motivates terrorists and the reasons behind the assumptions we are making, focusing on Islamist groups.

We suggest modeling their state-dependent priorities via a multi-attribute utility model that incorporates state-dependent priorities to account for preference changes caused by exogenous triggers, representing the environment as a system dynamics (SD) model. We describe how the visceral factors may have impact on the prioritization of objectives, and show how such an analysis may support risk management in this context. If authorities could infer how malicious agents' priorities change based on the state of the environment, we believe they might be better placed to understand terrorists' motivations and guide efforts towards pre-empting their malevolent actions. The motivation of this research lies in providing insights into inferring decision making of inaccessible decision makers.

Our framework does not make any descriptive claims. Rather it seeks to provide a means to describe what a rational malicious agent with state-dependent priorities would prefer. We illustrate the framework by analyzing how the situation prior to the the Lockerbie bombing in 1988 could have been modeled and analyzed.

This paper consists of three sections. Firstly, we provide the theoretical assumptions behind the approach we are taking, and present the resulting framework we are proposing. Subsequently, we illustrate how the framework may be used in the case of terrorism, by assessing the terrorists' state-dependent priorities. Finally, using the case of the Lockerbie bombing, we illustrate how the model could be used to generate insights into the priorities and hence preferences of the terrorists based on a certain state and provide directions for further research.

5.2 Theoretical Model – State-Dependent Priorities

Modeling preferences of an agent who has multiple objectives can be done using Multi Attribute Utility Theory (MAUT), where the overall utility of each alternative can be assessed based on the utility of each alternative on each objective, and the relative importance of the latter (Keeney & Raiffa 1993; Keeney 1996; Belton & Stewart 2001). Generally, this framework assumes that the weights, or relative importance attached to the objectives, are fixed.

However, empirical research has shown that new information and changes in the environment have an impact on preferences and their ordering (Loewenstein & Angner 2003; Loewenstein et al. 2003; Hansson & Grüne-Yanoff 2009; Bradley 2009). Hansson & Grüne-Yanoff (2009) explain that for complex situations, choices do not originate from a stable set of preferences. Moreover, according to Bradley (2009), an agent's choices and preferences depend on his/her opinions and desires, and these depend among other things on the information s/he possesses. For these reasons, priorities and preferences may be dependent on the environment, resulting in a potential preference ordering which may differ at various points in time.

In the next sub-section, we expand on the effects of the environment on an agent's priorities, and comment on why it might be useful to consider these effects. The framework we suggest to achieve this is discussed further in the subsequent sub-section.

5.2.1 State-dependent priorities

Emotions can have an important influence on decision-making by altering the way in which decision makers may approach a problem, the way they perceive the probabilities or outcomes and even their behaviors (Loewenstein and Lerner, 2003). Models of decisions which simulate the influence of various types of emotions have been researched in the field of artificial intelligence (for a comprehensive review, see El-Nasr et al. (2000)).

Emotions can be broadly classified into two main categories, core affect and prototypical emotional episodes. The former refers to the elementary consciously accessible affective feelings experienced by a person. The latter refers to rare emotional responses triggered by external events (Russell and Barrett, 1999). In this paper, we focus our attention on the role of prototypical emotional episodes triggered by visceral factors on decision-making, more specifically on its effect on the prioritization of objectives. Visceral factors denote certain types of emotions, drive states and feeling states; such factors for instance include anger, fear, hunger and other cravings. These factors have an influence on preferences in the sense that they have a motivating effect on people's behavior by altering their needs or desires. For instance, anger will lead to a heightened preference for aggression. Because such factors are driven biologically, they are likely to have a strong impact on preferences preferences. Following some sort of discomfort, transient changes in preferences are induced specifically to reinstate balance (Elster, 1998; Frederick et al., 2002; Loewenstein and Angner, 2003; Loewenstein, 2000, 1996). This can be described by "all goals other than that of mitigating the visceral factor [being virtually crowded out]" (Loewenstein, 1999, p. 236).

In behavioral economics, such effects are modeled using state-dependent preferences, which provide an agent's instantaneous utility function given a certain visceral state. The instantaneous utility $u = f(c_\tau, s_\tau)$, is hence described as a function of the consumption activities (in our context, aggressive behavior) and the visceral states (similarly in this situation, anger) in period τ. Furthermore, the marginal utility of c gained as s increases is described by the following relationship, $\frac{\partial^2 u(c,s)}{\partial c \partial s} \geq 0$ (i.e. the utility gained from aggression increases as the level of anger increases). For more details on calculating the instantaneous utility, refer to Loewenstein (2000).

Similarly, we want to model the impact of visceral factors on priorities. To do so, we propose using an MAUT framework where the agents seek to maximize the utility

gained from an action but the weights are state-dependent. One way of translating the model described above is as follows:

- Weights assigned to objectives which contribute to fulfilling the craving (i.e. mitigating the visceral factor) would increase as the stock of a visceral factor (such as level of anger) increases
- Weights assigned to objectives countering the fulfillment of the craving would decrease as the stock of the visceral factor increases.

Formally, our malicious agent has a set of alternatives (potential strikes) $A = \{a_1, \dots, a_i\}$, is pursuing objectives $O = \{o_1, \dots, o_k\}$, and makes trade-offs between the objectives using weights that are dependent on the effect of the visceral factors, $W(s_t) = \{w_1(s_t), \dots, w_k(s_t)\}$, where s_t denotes the stock of visceral factors at time t. The malicious agent seeks to maximize the utility gained from the alternatives (potential strikes). The main variation from the traditional MAUT framework lies thus in how the relative importance of objectives is modeled.

Given the new assumption of state-dependent weights, it is necessary to make a change to the set of general independence conditions required, if one wants to use a simple MAUT additive model for calculating the overall utilities U_i of alternatives i. In addition to utility independence and additive independence, we also assume that future states are independent from the present one. This also implies that we are able to measure the future partial utilities of the alternatives independently from the present utilities. This seems to be a reasonable assumption given that the decision makers are likely to behave myopically under such circumstances. Indeed, empirical research suggests individuals tend to discount the future when under the effect of visceral factors (Loewenstein, 2000). Hence, because emotions play a great part in acts of violence, it may be less realistic to assume terrorists are critically thinking about all the subsequent consequences whilst contemplating on a criminal act.

Formally, we assume that the utility independence condition can be extended to all states of T, where $T = \{t_0, \dots, t_N)$ represents the set of time states. If attribute X is utility independent to attribute Y at t_0, then the same preference relationships will be assumed for future states $t_1, \dots, t_N$, i.e., supposing that at t_0 consequence B is indifferent to the lottery yielding either A or C with a probability of 0.5 each, then we assume that this relationship can be translated to all levels of t. Hence, at t_1 the same consequence B will be indifferent to a lottery yielding A or C with a probability of 0.5 each (see Figure 5-1).

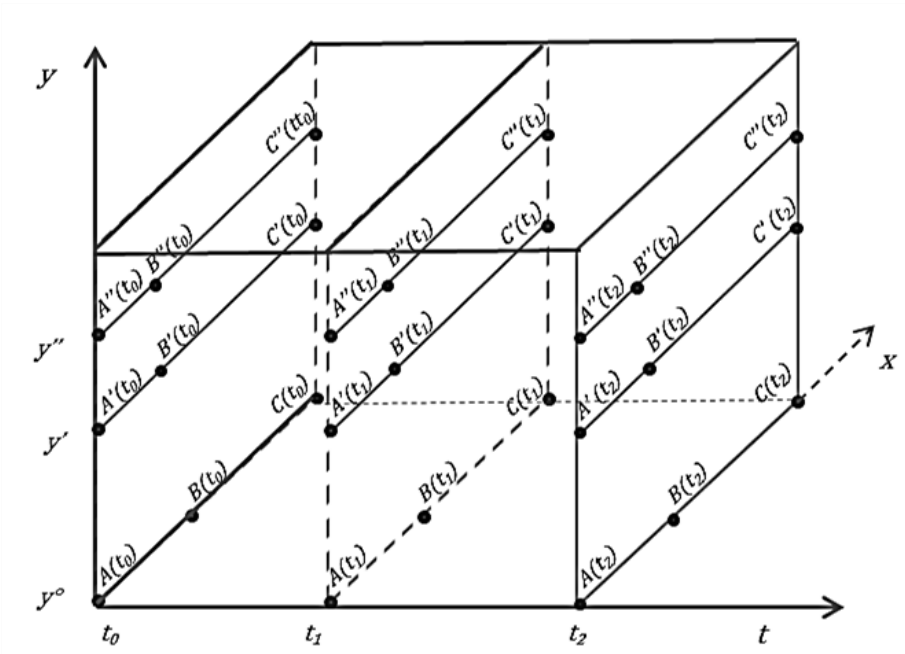


Figure 5-1: Illustration utility independence through time (adapted from (Keeney, 1996, p. 136))

We also assume that the additive independence condition can be extended to all states of T. Suppose at t_0 we have two lotteries L_1 and L_2 (as described in Figure 5-2), with L_1 yielding $\{x^0, y^0\}$ or $\{x', y'\}$ equal probabilities, and L_2 yielding $\{x^0, y'\}$ or $\{x', y^0\}$ equal probabilities. Then, by definition, they yield the same marginal probability distribution on each of the attributes X and Y, as defined in Figure 5-2. If X and Y are additive independent, the agent must be indifferent between lotteries L_1 and L_2. This additive independence condition is assumed to hold through time, i.e. the agent will be indifferent between the same lotteries at $t_1 \dots t_N$, (see Figure 5-2). For a more in depth discussion of all independence conditions see (Keeney, 1996).

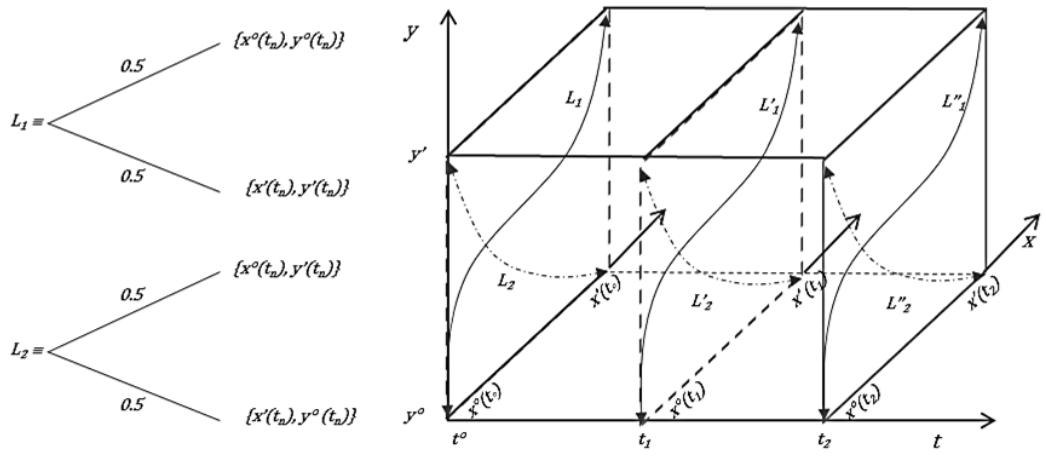


Figure 5-2: Illustration of additive independence through time (adapted from (Keeney, 1996, p. 137))

Given these assumptions, we could formally assess the overall utility at time t of the i–th alternative as follows:

$$U_i(t) = \sum_k w_k(s_t) u_{i,k} \quad (1)$$

With $w_k(s_t)$ the state − dependent weights at time t for each objective k

and $u_{i,k}$ the partial utilities of alternative i on the k^{th} objective, as discussed in the next subsection, see Equation 2

Although predicting the effects of visceral factors can be done relatively easily, it may not be as straightforward to model the triggers that cause them to arise. In fact, because these factors are correlated with the external environment, they are prone to oscillate over time (Loewenstein, 1999). The next sub-section explains how we suggest modeling the external environment and its impact on the state dependent weights using System Dynamics.

5.2.2 Modeling the State-dependent priorities

Inferring the state of the visceral factors involves an understanding of the system surrounding the malicious agents in question. By determining the evolution of the environment, or more specifically, the evolution of the variables that represent the triggers of the visceral factors, we could then infer the state of the visceral factors. We suggest using System Dynamics (SD) to model the environment; for details see Forrester (1968); and in the context of terrorism, see Grynkewich and Reifel (2006), and Chamberlain (2007).

We believe there is a potential to integrate MAUT and SD in a single framework to address the effects of the environment on visceral factors, and in turn, on priorities. This type of hybrid modeling is not new. Indeed, it has been used for policy analysis purposes and for modeling judgments (Andersen and Rohrbaugh, 1992; Gardiner and Ford, 1980; Gruver et al., 1984); for performance evaluation purposes (Santos et al., 2008); for designing and evaluating long and short term strategies in socio-economic control (Brans et al., 1998; Kunsch and Springael, 2008; Kunsch et al., 1999); and for designing policies by looking at how preferences may be influenced to improve systems, it has been investigated by Springael et al. (2002) in the context of traffic commuters. However, as far as we are aware, there has been no work on how to model the impact of the environment, and more specifically, how visceral factors may have an impact on priorities.

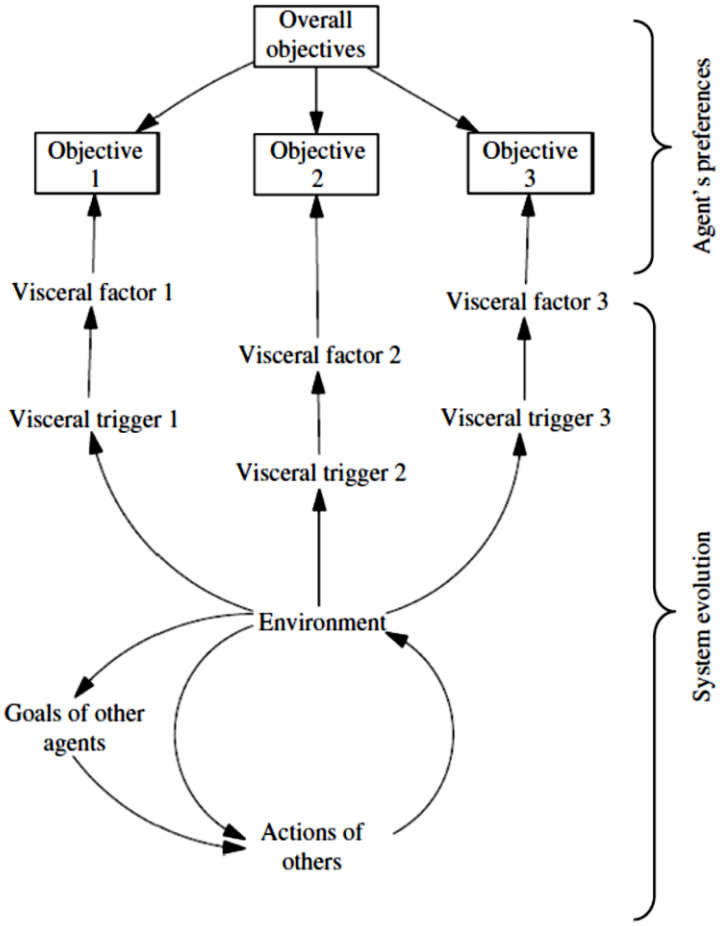


Figure 5-3: Modeling State-dependent priorities with MAUT & SD

Combining the two approaches may inform how the agents re-prioritize their objectives in response to changes in their environment. Conceptually, we represent the triggers within the environment that will alter the weights of the agent's objectives. Numerically, the model informs us the extent to which the swing weights may be altered. As illustrated by Figure 5-3, the swing weights may be inferred by extracting the information from the state of the system, more specifically the level of variables (quantifying the visceral triggers) susceptible to having an impact on the visceral factors (Visceral triggers 1, 2, and 3). For instance, supposing one of the visceral factors (let us say "anger") has been triggered by an event in the environment (for instance Visceral Trigger 1), this, in turn, triggers Objective 1 (let us say "desire for aggression"). Using rates, which reflect how sensitive the visceral factor is to that particular event, we simulate how the level of desire for aggression increases (see Equation 2 below). The swing weights are determined as follows, $\max_{k}(sw_k) = 100$; the values of the other swing weights are determined relatively to the highest one. Finally, we normalize them to get $w_k(s_t)$ which is used to calculate the utilities of the agent's alternatives (as per Equation 1):

$$\boldsymbol{LO_k(t) = f(\alpha_k * LVT_k(t))} \qquad \textbf{(2)}$$

where,

- $LO_k(t)$: *is the Level of the Craving for the Objective k at time t*
- α_k: *is the sensitivity of the level of the visceral trigger k, and*
- $LVT_k(t)$: *is the level of the Visceral Trigger k at time t.*

The next section illustrates the application of such a framework in the context of terrorism, and provides an example of how the relative importance of Revenge is determined using the model. Using the Lockerbie bombing case as an example, we examine how terrorists' state-dependent priorities could have been modeled and how the results may be analyzed.

5.3 Application – Assessing Terrorists' State-dependent priorities

This section describes the use of the framework in practice. We illustrate how one might assess terrorists' state-dependent priorities and describe the way a decision analyst may formalize an interpretation of their values. Subsequently, we provide an overview of how their visceral states may be modeled to infer the state-dependent weights. Finally, we show how a preference ordering may be derived from them.

5.3.1 Deriving an MAUT Model for Terrorists

The first step towards modeling terrorists' priorities consists of defining the objectives that terrorists would use to evaluate the attack, which would offer the best trade-off between the operational side (costs) of an attack and its benefits (whether it achieves their intended goal). According to the literature, the objectives they try to achieve can be formalized along three main categories Revenge, Renown, and Reaction (the 3 R's) (English, 2010; Richardson, 2007).

These may be defined more extensively by finding the attributes that terrorists might be using to evaluate alternatives against each objective. The literature suggests terrorists seek to achieve Revenge in terms of the resulting casualties on the opponents' side as well as short and long-term economic damage they can cause to their opponents. Similarly, attributes for the other objectives were defined, as summarized in Table 5-1.

For the purpose of this example, we have adapted the list of alternatives, i.e. strikes, suggested by the National Center for Risk and Economic Analysis of Terrorism Events (CREATE) (Rosoff and John, 2009): Improvised Explosive Device (IED) in a public place; Surface to air missiles or Man-portable air-defense systems (MANPADS) attack on airplane; Portable nuclear device in major city (Nuclear);

Explosions on mass transports (Transports); Detonation of dirty bomb (Dirty Bomb); and Biological release in a major city/special event (Biological Release).

	Objectives	Attributes
Maximize Attack	Revenge	Max –Westerners/non Islamic casualties
		Max - Short term economic damage
		Max - Long term economic damage
	Renown	Max – Media coverage (Instill fear in the western world)
		Max – Number of supporters/insurgents (Popular support)
	Reaction	Min – Intervention of the western world in Middle east affairs
	Operations	Min – Cost
		Min – Resources

Table 5-1: International Terrorists' Objectives and Attributes (Note: Data from McCormick, 2003; Mickolus, 1980; Richardson, 2007; Rosoff and John, 2009; Sandler and Lapan, 1988)

From the strikes' characteristics and the attributes (see Table 5-1), we inferred their partial utilities (see Table 5-2). These were assessed on an interval scale ranging between zero for the lower bound (worst performing strike on the k^{th} objective) and one hundred for the upper bound (best performing strike on the k^{th} objective). This was done using information from several publicly available sources, which we used to evaluate the utility of each strike on each objective as a terrorist might have done, see Appendix 5.A for more details. (In practice, expert judgments would need to inform such parameters).

	Revenge	Renown	Reaction	Operations
No attack	0	0	0	100
IED	20	40	40	80
MANPADS Attack	45	5	10	5
Portable nuclear device	100	100	100	0
Explosions on mass transport	60	75	60	30
Detonation of dirty bomb	10	90	70	40
Biological release	5	50	10	5

Table 5-2: Partial Utilities of Possible International Terrorist Strikes

5.3.2 Determining the Impact of the Environment on Objectives' Weights

To assess the evaluation of the state-dependent priorities against each objective, factors contributing to increase the visceral states (or visceral triggers) were modeled for the example. Figure 5-4 shows the stock and flow diagram built to model the dynamic nature of the environment surrounding terrorists and its effects. This enabled us to infer the state-dependent priorities on the three main objectives. The model was adapted from Lin et al. (2007) and Choucri et al. (2007) to incorporate the visceral triggers and their effect on the objectives. (It is important to note that these levels calculated by the model are inferred parameters, as discussed section 5.3.3.1).

Box 1 in Figure 5-4 describes the evolution of the number of opponents within the system. This increases through recruitment, which occurs from the elements modeled in Box 3, and is reduced through the effect of governmental interventions (Box 2). Box 4 describes how the visceral triggers affect the objectives (Revenge, Renown and Reaction). The extent to which the visceral factors are triggered is determined by the external intervention imposed upon the terrorists or the regime of their country. A desire for Revenge may be triggered by Islamic states being attacked.

The desire for revenge is then determined by looking at the number of casualties, and its effects. Formally, we use a logarithmic function to model this effect to reflect the law of diminishing returns. Equation 3 describes the calculations:

$$Effect\ of\ Death\ on\ Revenge = LOGN(Population\ Removed * Sensitivity\ on\ Casualties\ rate)$$

The effect of death on revenge is then used to determine how the revenge desire is changing, taking into account the amount of time required for the terrorists to react.

$$Change\ in\ Revenge = \frac{(Revenge\ Desire * Effect\ of\ Death\ on\ Revenge - Revenge\ Desire)}{Adjustment\ time} \quad (3)$$

Finally, the model calculates the evolution of the revenge desire using the following differential equation:

$$Revenge\ Desire(t) = Revenge\ Desire(t - dt) + (Change\ in\ Revenge) * dt$$

A desire for Renown, i.e. to be famous or dangerous and hence powerful, may be triggered by terrorists being captured or killed. The level of craving for Reaction is influenced by the level of involvement of the Western world in the Islamic world. The more Western governments are involved in Middle East affairs (economically, politically and militarily), the more terrorists want their government to retaliate (Drake, 1998; Gearty, 2004; Richardson, 2007; Woo, 2006). Similarly to the calculation

of the desire for Revenge, we determine those last two desires using differential equations.

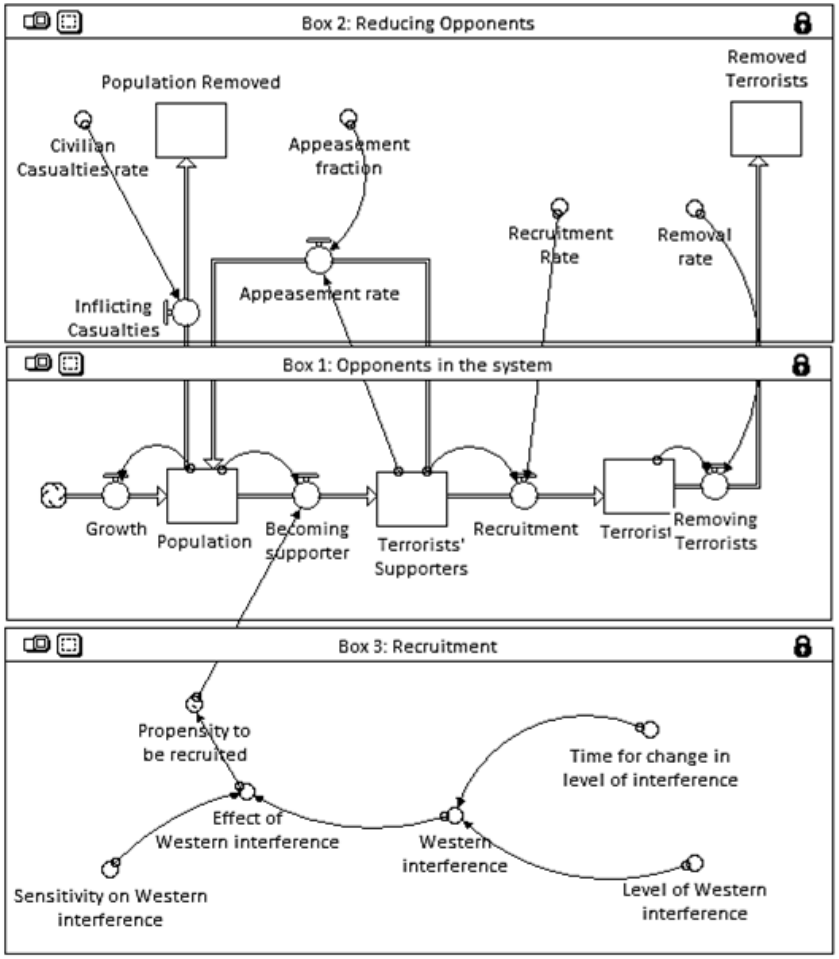
5.3.3 Uses of State-Dependent Priorities as a Means to Better Understand Current Threats

Using the SD model as described in the previous sub-section, we derived the state-dependent weights $w_k(\boldsymbol{s_t})$ at time t for each objective k, and in turn, inferred the overall utilities of the various strikes which the terrorists may consider. Subsequently, we used Equation *(1)* to calculate the overall utilities at time t of alternative i. Once the model was built, the variables in the model were calibrated to reflect the current state of the environment.

To illustrate the use of the framework, let us look at the case of the Lockerbie tragedy caused by the bomb in the Pan Am flight 103 in 1988 (D'Amato, 2009). Between 1981 and 1986, several incidents between the US and Libya occurred, affecting Libya's forces and its population. After the Libyan government allegedly retaliated, by bombing a West Berlin nightclub often frequented by US soldiers in April 1986, the US struck back and caused dozens of military and civilian casualties. More importantly, Gaddafi's adopted daughter was killed in an airstrike. Then, in September 1986, there were at least 20 fatalities after the Pan Am flight 73 was hijacked, which Gaddafi was accused of sponsoring. Two years later, a bomb was placed in Pan Am flight 103, causing 207 fatalities near Lockerbie in the UK. It was only in 2003 that the Libyan government formally admitted to have sponsored the strike.

5.3.3.1 Calibration of the model to reflect the situation prior to the Lockerbie bombing

Suppose we are in April 1986 and want to use the model we proposed to determine the impact of the US strikes against Tripoli and Benghazi on the state of priorities of various possible strikes. (These are described in 5.3.1 with the exception of the MANPADS, dirty bombs and nuclear devices, because these are relatively newer threats not available at the time (Kelly, 2002; Linotte, 2007).). To do so, the relevant variables are calibrated to reflect the current situation between Libya and the US. Quantitative variables such as the number of casualties and the extent of economic losses incurred by Libya are inputted in relevant nodes within the SD model. In our model, these variables are depicted by the 'Population removed', and the 'Level of Western interference' respectively.



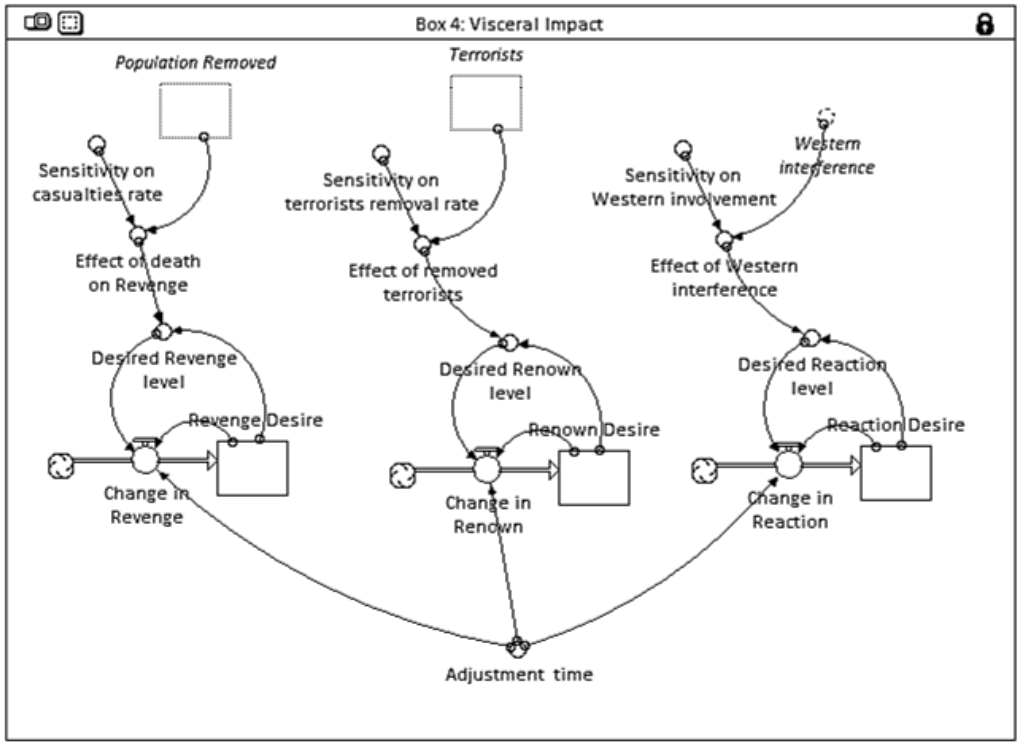


Figure 5-4: Stock and Flow model of the terrorism system and triggers of visceral states

Because of the nature of some of the variables, some subjectivity is involved in their calibration and expert assessment as well as consulting the Islamic media may bring insight into such values. For instance, in the Lockerbie case, not all of the fatalities may be perceived the same way, in particular, the loss caused by the death of Gaddafi's adopted daughter would need to be reflected in the model. A possible way would be to inflate the number of fatalities to a figure that we believe Gaddafi and the Libyan population might perceive equivalent to the baby's death.

Similarly, expert assessment would need to be sought, to determine the initial level of the visceral factors (Revenge, Renown and Reaction) before the events occurred, and how sensitive the entity (Libya) is to the various exogenous factors. These sensitivity levels partially determine how much the visceral factors are going to be impacted by changes in the environment (such as casualties inflicted, for instance). Once again, the media and experts may be consulted to consolidate the calibration of variables, because these would vary between entities studied. Incidents such as warnings or threats made may be useful to evaluate those levels. In the case of the Lockerbie bombing, several warnings had been made. For the purpose of the illustration, we have hypothesized on those values.

5.3.3.2 Analysis of the results based on the dynamic MAUT behavior

Here, we discuss how the model could be used to gain insight into how to help manage the risks of possible repercussions of certain actions performed by the Western countries if they escalated, or if no actions are taken to mitigate the issues. There are two main elements of the model that a decision analyst may want to focus on, the evolution of the weights on the objectives (the 3 R's), and the evolution of the overall utility of the alternatives. The two types of behavior of interest are discussed below.

Observed changes in weights

It could be that whilst the weights on the objectives are changing, the preference ordering of the alternatives considered remains relatively static. For instance, the weight on Revenge may be relatively higher than that of the other two weights (see the initial three months in Figure 5-5), but their preferred strike is a bomb in public transport (see Figure 5-6. Based on the attributes the entity is using to measure the performance of options against Revenge (i.e. casualties and economic damage), we can infer the agent would want to strike a larger plane and close to their opponent's land (to increase the number of casualties and economic damage). It appears that such behavior occurred in the case of the Lockerbie bombing. Indeed, Libya chose to strike a plane on two occasions, and the second time, opted for a strike that caused more deaths and economic damage.

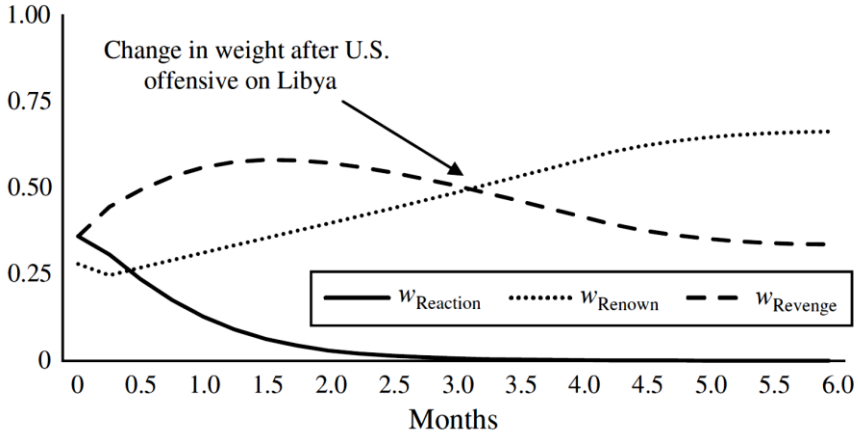


Figure 5-5: State-Dependent Weights Example

Observed changes in preference ordering

Visceral factors are likely to increase if no mitigating actions are taken, either by the entity (Libya), or by its opponent (the US). Overtime, the stock of visceral factors may increase to such a level that we may observe large enough changes in weights, which in turn may affect the preference ordering. In this case, security officials may need to consider directing efforts to protect the population against the emerging threat that the model highlights (IED and Transport), as displayed in the example in Figure 5-6[2]. Alternatively, a more proactive stance could be considered, such as initiating dialogues to try to lessen the visceral factors of the entity.

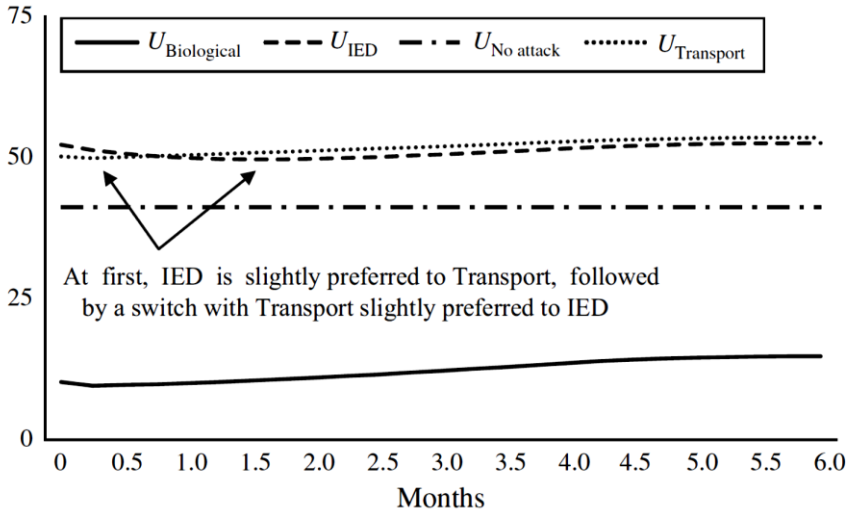


Figure 5-6: State-Dependent Preferences Example

[2] Note that in Figure 6 and 7, the utility of 'No attack' remains constant. This is due to the partial utilities on the 3 R's being zero (worst performing option), and therefore we do not observe a variation in overall utility even as the weights on the 3 R's varies.

5.3.3.3 Using the model to evaluate policies

Another potential use of the model is to modify the MAUT section of the model in terms of the partial performances of the attacks. For instance, consider a situation where a policy was put in place that could substantially reduce the effectiveness of a certain strike concerning certain objectives. We could infer which other attack would be deemed a suitable replacement. Indeed, as discussed in Section 5.1, terrorists sometimes have engaged in substitution strategies to still achieve their objectives. It is therefore essential, when devising deterrence policies, to consider the potential side effects these might have. In fact, they could sometimes be as harmful as if no actions had been taken, and additional policies may have to be put in place to mitigate the side effects by protecting 'the next best thing'. For instance, Figure 5-7 illustrates how strengthening security against IEDs in public places may affect the state of preferences.

5.4 Discussion and Direction for Further Research

Research suggests that to gain insights on the threat that malicious agents might cause, it is crucial to have more knowledge of their objective function (Rosoff & John 2009) and further suggests that agents' objective weights (or priorities) are subject to changes depending on various exogenous triggers (Loewenstein and Angner, 2003; Loewenstein, 2000). However, traditional models usually assume a stable and static set of preferences (Bennett and Howard, 1996; von Auer, 1998). Such an assumption in the case of a terrorism context, where violent acts may arise from exogenous triggers such as political issues, may not be suitable.

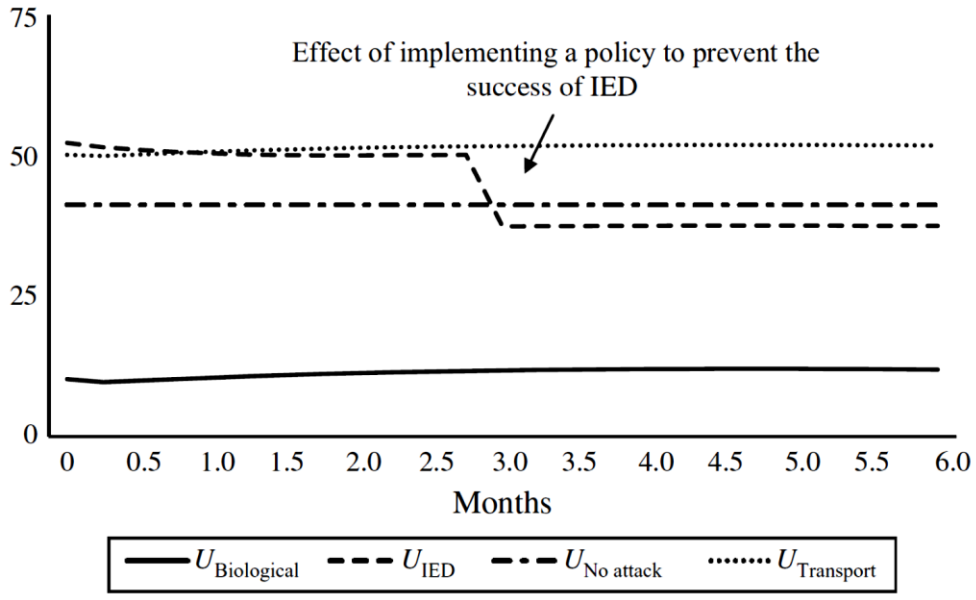


Figure 5-7: State-Dependent Preference Ordering (impact of a policy)

To account for these effects, our paper has suggested a framework for modeling state-dependent priorities in Multi-Attribute Utility models, to help in inferring the valuation of alternative types of strikes by malicious agents. By incorporating the effects of visceral factors, the proposed framework may infer the relative weights assigned to the objectives the agents seek to achieve. This may help in cases where one does not have direct access to the agents' preferences. In the case of terrorism, for instance, understanding what triggers certain visceral factors, such as anger, might be useful in better understanding the impact of such triggers on terrorists' evaluation of various types of attacks.

Using the Lockerbie bombing to illustrate the framework, we described how the model could be analyzed to infer possible changes in priorities, and thus preferences, and how this could affect the strikes terrorists may consider. In so doing, this research has sought to provide insights into inferring decision making of inaccessible decision makers. Nevertheless, as in any decision model, the framework has some limitations, both theoretical and practical. From a theoretical perspective, there are shortcomings arising from the implicit and explicit assumptions we have made to model behaviors. Specifically, we assume that the terrorists, as an entity, are rational decision makers, which may be a reasonable assumption only as far as a terrorist cell is concerned (McCormick, 2003). However, it is also possible to observe some irrational actions committed by terrorists, (Drake, 1998; McCormick, 2003). But, as Broder (2006, p.78) explains,

> *"The prediction of crime, like risk analysis, is an inexact science and is often based on the professional's best educated guess. The methodologies used to predict crime are subject to more debate than those of risk analysis."*

Similarly, the proposed framework cannot claim to be predicting the exact preference ordering of the opponents. However, it may provide a useful support for learning and understanding the ramifications behind terrorism, what triggers the strikes and hence may help us be better prepared and equipped against it.

From a practical point of view, the limitations of the proposed model could be dealt with by gathering more accurate data and, possibly, the model could be expanded by using expert elicitation in the field of terrorism, similarly to the work of Rosoff & John (2009). A challenge is that terrorism data is scarce and most of it is highly classified. Furthermore, by generalizing the proposed framework, we hope it could be used and applied in other areas concerning violence (such as gang violence) to assist in policymaking in the management of risk caused by violence outbreaks.

We hope the suggested framework could also open some avenues for further research. On a theoretical front, we believe there is potential to investigate the extent to which visceral factors have an impact on objectives' weights and how this may be modeled formally. Indeed, despite the importance of visceral factors in decision-making (Loewenstein and O'Donoghue, 2007; Loewenstein et al., 1997; Raghunathan and

Pham, 1999), the current literature suggests that little work has been done in the field of decision analysis or economics to account for the effects of visceral factors on the formal modeling of evaluation of options (Loewenstein and O'Donoghue, 2007; Loewenstein, 2000). In addition, one of the main assumptions and limitations of the model we suggested lies in the fixed utility functions (stability of the agent's risk attitudes over time), which may not necessarily always be the case. However, research shows that visceral factors may have an impact on utility (Loewenstein and O'Donoghue, 2007; Loewenstein et al., 1997; Raghunathan and Pham, 1999) suggesting that further research should be done on dynamic utility functions. Furthermore, a greater understanding of terrorists' utility functions and their priorities could be helpful if incorporated in Adversarial Risk Analysis (ARA) models (for instance, in models such as the one proposed by Parnell et al. (2010) where defenders and attackers have diametrically opposed objectives).

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5.5 Chapter 5 References

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Appendix 5.A Performances of Terrorists' Alternatives

Improvised Explosive Device (IED)

Production & Execution. IEDs are the easiest weapons to prepare and execute, indeed it does not require specific knowledge, or a special infrastructure. Any terrorist member can build an IED from instructions they would find on the internet, or would have received by the organization. The material used to build this type of bomb can be found easily from medical and agricultural supplies (Defense Update, 2006).

IEDs can be used in a variety of ways, including placing them within cars, burying them under ground, or even placing them on a human being. IEDs can then be detonated by remote controls. Because this type of weapon can take different forms and formats, it is very difficult to put systems in place to detect them. This is the reason why the majority of attacks performed by terrorists are done using this technique (Defense Update, 2006).

Impact. Depending on the size of the bomb, and where it is placed, IEDs can cause several casualties. This method cannot be classified in the same categories as a weapon of mass destruction, because the number of casualties is relatively low compared to other types of attacks.

MANPADS attack on airplane

Production & Execution. MANPADS (Man-portable air-defense systems) can be bought on the black market, and cost between a few 100 dollars to almost ß million dollars depending whether the model is old or new (Congressional Research Service, 2006).

There have been several unsuccessful attacks so far in Baghdad, Iraq and Kenya (Security Service MI5, 2011; von Winterfeldt and O'Sullivan, 2006), however it is not certain how easy it would be for terrorists to acquire or bring such a weapon in western countries.

Impact. The economic impact of MANPADS could rise up to $250 billion, and depending on the type of plane targeted there could be up to 400 casualties to (von Winterfeldt and O' Sullivan, 2006).

Portable nuclear device in major city

Production & Execution. "The warhead of a suitcase nuke or suitcase bomb consists of a tube with two pieces of uranium, which, when rammed together, would cause a blast. Some sort of firing unit and a device that would need to be decoded to cause detonation may be included in the " suitcase." (National Terror Alert, 15:00:37)

Hence it would be quite challenging and costly for terrorists groups to make or acquire these types of weapons (Bakir and Kardes, 2011; Maerli et al., 2003; Richardson, 2007).

Impact. The impact of such a strike would score quite high on each of the 3 R' s objectives, as they would cause extensive damage, in loss of lives and economical terms (Richardson, 2007).

Explosions on mass transports

Production & Execution. From all the other types of strikes, this one is the most feasible, as shown by the number attacks of this type having occurred in the world. The resources and knowledge required are minimal, relatively to the other types. The obstacles that the perpetrators would face are the increasing security levels. However, these are still quite low in train and subway stations.

Impact. The impact compared to the other types of attacks is relatively low, so this type of attack will not score very high on the revenge objective. Depending on the countries such attacks may get more or less reaction from the government; indeed, such attacks are so common in some countries that the reaction from their government would not be as high as in the UK for instance.

Detonation of dirty bomb

Production & Execution. Terrorist groups will need to acquire radioactive components, which is a difficult thing to achieve. Indeed, the materials which can be stolen from hospitals or laboratories are not suitable to make this type of bomb. On the other hand, if they manage to acquire such materials by stealing them or through the black market, they would manage to construct such a weapon (U.S. Department of Homeland Security, 2006)

Impact. Dirty bombs are more disruptive than harmful; they would cause panic within the public and fewer victims compared to other types of strikes. The psychological effect is quite high, therefore would satisfy the terrorist desire for renown, but would not score high on their revenge objectives (Richardson, 2007).

Biological release in a major city/special event

Production & Execution. Even though they are easy to acquire, the successful execution of biological weapons is very difficult. Indeed, producing large quantities of biological agents require the appropriate infrastructure. On the other hand, if terrorists have been successful in producing them, it is quite difficult for authorities to detect them (Richardson, 2007).

Impact. This sort of weapon has not caused a significant number of casualties; however, Richardson (2007) points out terrorists have often tried successfully to instigate fear in the public by acquiring this sort of weapons even though they do not intend to use them.

Chapter 6

Conclusions and Further Research Directions

Unlike in cases of risks arising by natural or random events, preventive measures taken against a type of risk caused by the action of a malicious intelligent agent (such as terrorists) may lead to another action becoming more likely (Bier et al., 2005; Brown and Cox, Jr., 2011; Guikema and Aven, 2010; Kardes and Hall, 2005). This has led to a focus on understanding the threat, the vulnerability and the consequences of risks in the effort of identifying and prioritising them (Chertoff, 2007). To do so requires gaining insight into the various types of strikes terrorists are considering as well as an understanding of the consequences counter terrorism policies and actions might have (Ezell et al., 2010; Keeney and von Winterfeldt, 2011). Recently, models of a decision analytical flavour been used for counter-terrorism analysis, and are built from the perspective of terrorists to try to determine which targets they would value most.

A challenge in using decision analysis in this context lies in the unavailability of the agent whose decision, preferences and judgements we are modelling. Because of this, such models are largely based on strong assumptions. Hence, Rosoff & John (2009) have highlighted the importance in gaining more insight into what the malicious agents' objective function is to better understand the threat they cause. Thus being able to infer their preferences would enable one to have more insight into their potential nefarious actions. This would guide pre-emptive efforts against their criminal acts, and hence may help with reducing the feeling of insecurity caused by terrorism.

This research explored three aspects of terrorist judgement. First, in order to describe terrorists' preferences and judgements using decision models such as Multi-Attribute Utility Theory, we investigated the objectives that drive terrorists. While traditional decision models tend to ignore the potential for the agents to change their initial preferences through the decision process (Bennett and Howard, 1996; von Auer, 1998), dynamic preferences have been observed empirically. In fact, the dynamicity of preferences is especially relevant in the context of models for counter-terrorism analysis due to the adversarial nature of terrorism, with the actions of the defender and attacker based on each other's action (Bier et al., 2005; Brown and Cox, Jr., 2011; Guikema and Aven, 2010; Kardes and Hall, 2005).

The second area of terrorist decision-making that we explored concerns how their judgement is influenced. We believe that having more descriptive insight into these

influences could help with making models more realistic and descriptively accurate for risk analysis. Visceral factors, in particular anger, have the potential to affect a decision maker's judgement, including affecting his/her risk attitude and his/her evaluation of outcomes and their likelihood (Lerner and Keltner, 2000; Lerner and Tiedens, 2006). In this research, we focussed on capturing such effects, as they can incur non-negligible influences on both the agents and the environment in which they operate (Loewenstein 1996; 1999; 2000).

Finally, integrating the insight gained into the areas mentioned into modelling behaviours with a malicious intent, we attempted to develop a framework for combining the objectives of terrorists, and their changes over time. The resulting model may help anticipate a motivation to cause social unrest by terrorists. We used the resulting model to illustrate the prescriptive insight that could be gained for counter-terrorism analysis.

This research had four main objectives. First, it consisted of critically analysing the assumptions made in counter-terrorism modelling, using knowledge from the fields surrounding terrorism – including conflict management and politics, the theory of choice, public choice, behavioural decision theory, expected utility theory, and Multi-Attribute Utility Theory – to provide insight into what influences terrorists' decision making. Specifically, we analysed differences between types of terrorists, the characteristics of their rationality, the goals that drive them, and psychological elements, on judgement. Second, we carried out an empirical study of the impact of the visceral factor anger on terrorists' prioritisation of objectives. Given the confrontational nature of terrorism, anger is in fact an emotion terrorists might be prone to feel. Third, we contextualised this knowledge within modelling terrorist decision making using multi-attribute utility theory. Finally, based on this insight and hypothetical data, we developed a dynamic framework for capturing preference rankings that does not require the assumption of static preferences, by integrating system dynamics with multi-attribute utility theory to capture the effect of visceral factors on priorities.

Through these objectives, we hope to help with the inference of an opponent's preference ordering based on their value system, their objectives and on the state of a system. We achieved these objectives via the following main steps:

1. **Critical analysis of assumptions made in counter-terrorism modelling and characteristics of terrorists as decision makers:**

   Adopting a multidisciplinary approach (conflict management and politics, the theory of choice, public choice), determining the characteristics of terrorists was done by providing a comprehensive understanding of terrorists as decision makers, what might influence their decision making, and relate it to Expected Utility Theory and Multi-Attribute Utility Theory. Furthermore, knowledge was brought from the fields of behavioural decision-making and psychology to provide insight

into how decision making is influenced by the effect of visceral factors, in particular anger and fear. To support these findings, an empirical study was carried out to analyse the effect of anger on the prioritisation of objectives relevant to what terrorists might have.

2. **Prescriptive guidelines on relaxing current modelling assumptions:**

   Using the insight from the characteristics of terrorists as a decision maker, we provided prescriptive guidelines on two aspects: first, on how to modify and relax the assumptions made when modelling terrorists' judgement and preferences, and second to model these more accurately from a descriptive point of view.

3. **Empirical study to examine the effect of anger on the prioritisation of objectives:**

   Using an experimental study, we examined the impact that anger has on the prioritisation of long-term self-destructive objectives (Revenge) versus long-term productive objectives (Reputation and Success), and the preferences for long-term self-destructive versus long-term productive actions. Self-reported anger was found to have an impact on the prioritisation of Revenge compared to Success, given the hypothetical scenario, and as predicted, a number of actions were perceived more (and less) attractive if they were self-destructive (and productive, respectively).

4. **Development of a framework capturing dynamic priorities:**

   Drawing from the prescriptive insight, we developed a framework capturing dynamic preference rankings that does not require the assumption of static preferences. This framework may be used to infer how terrorists' priorities may change over time through the effect of visceral factors, and their impact on their choice of a harmful action. We suggested modelling state-dependent priorities of a terrorist group via a multi-attribute model that incorporates state-dependent priorities to account for preference change caused by exogenous triggers, and representing the environment as a system dynamics model. We described how terrorists' visceral factors may affect the prioritisation of objectives and show how such an analysis may support risk management in this context.

In order to achieve the aims of this research outlined above, we conducted several types of investigations. The original contributions of each are discussed in detail in the next section.

6.1 Potential Research Contributions

Achieving the aims of this research was carried out within three research papers. We summarise their objectives and the main findings in the following subsections.

6.1.1 Considerations when Modelling Terrorist Decision Making

In the first paper, *'In the Opponent's Shoes: On Modelling Terrorists' Judgements for Counter-Terrorism Analysis'*, we conducted a critical review of the main assumptions

and limitations of models for counter-terrorism analysis with the aim of suggesting some modifications to describe terrorists' preferences more accurately.

Given that terrorism is a type of threat distinct from those caused by engineered systems and natural hazards, the means used to assess its risk need to be adjusted. Indeed, they need to include a crucial element: human judgement and intent (Bedford and Cooke, 2001; Bier, 2006). Current models are idealised and based on a number of assumptions.

Empirical research and theories from various fields show that these normative assumptions may be unrealistic, and hence could lead to wrong counter-terrorism measures (Brown and Cox, Jr., 2011; Ezell et al., 2010; Lerner and Tiedens, 2006; Loewenstein, 2000). We believe that management of risk caused by terrorism could be enhanced through increasing the validity of models from a descriptive point of view. To do so, our research was aimed at extending the understanding of terrorists as decision makers, what their objectives are and what affects them by analysing several elements influencing how terrorists make decisions.

Through our research, we found if we relaxed the assumptions of rationality, then terrorists could be considered as rational decision makers. Terrorists respond to incentives, and the actions taken by the defender will contribute to terrorists changing preferences (Berman and Laitin, 2005; Hoffman and McCormick, 2004). Terrorists also follow narrow selfishness principles, but rather than evaluating the consequences of their act to themselves, they appraise them according to how well they serve their cause (Caplan, 2006; Merari et al., 2009). Finally, terrorists can be considered to have rational expectations; however these vary depending on the type of terrorists we are modelling. For instance, active terrorists behave as social solidarity maximisers. The advantages of being involved in terrorism arise from the social aspect of it, as well as the psychological benefit of violence. For suicidal terrorists, the benefits arise from being martyrs (Caplan, 2006; Merari et al., 2009).

Terrorists can be viewed as utility maximisers, but unlike the dominant view that suggests they are political maximisers, our research suggests non-political benefits may be involved that equally drive terrorists' actions (Abrahms, 2008; Cordes et al., 1984; Landes, 1978; Mickolus, 1980; Pape, 2003; Rios and Rios Insua, 2012).

Finally, as research has showed that visceral factors, and anger in particular, can have strong effect on judgement and decision-making (Lerner and Tiedens, 2006), we believe the way modellers infer how terrorists evaluate alternatives and uncertainties should be adjusted. Terrorists can be considered as myopic decision makers. Because of the effect of anger, their view of objectives can be altered, potentially leading to a change in priorities. Indeed, objectives that are not necessarily contributing to their cause could be weighed more heavily. Finally, terrorists' risk attitudes and their perception of uncertainties can also be altered by the effect of visceral factors. Anger can make decision makers risk-seeking, optimistic and overconfident. On the other

hand, fear has the opposite effect, making decision makers risk averse, and pessimistic (Isen and Geva, 1987; Isen and Patrick, 1983; Lerner and Keltner, 2001, 2000; Loewenstein and Lerner, 2003; Wright and Bower, 1992).

6.1.2 The impact of anger on the prioritisation of self-destructive objectives

In the second paper, *"Rational Self-Destruction: The effect of Anger on the Prioritisation of Self-Destructive Objectives"*, we carried out a study of the impact of anger on the prioritisation of objectives, some of which were self-destructive. The influence of anger on judgement and decision-making has implications in the context of modelling preferences, in particular those of terrorists. So far, research in the field of terrorism modelling has assumed static preferences of terrorists, but empirical research has shown that priorities may change over time. The effect of anger on decision-making is of particular interest in this research as terrorists, being involved in acts of violence, are expected to be driven by high level of anger. Recent counter-terrorism modelling focuses on building decision analytical models from the perspective of terrorists, and such a modelling approach benefits from an understanding of the impact of anger on the terrorists as decision makers. Hence, following on from the insight gained in the first paper, we furthered our research on the effect of anger on the prioritisation of objectives.

Through the study, we tested if a state of anger had an impact on the prioritisation of long-term self-destructive (Revenge) versus long-term productive (Reputation and Success) objectives of decision makers. In addition, we tested the attractiveness of long-term self-destructive versus long-term productive actions.

Consistent with current research on the effects of anger on decision-making, our results showed that anger was associated with an increase in the prioritisation of the revenge and a decrease in the prioritisation of success. This can be explained by anger compelling agents to act towards restoring the situation as it was prior to having angered, causing certain objectives not directly pertaining to this goal to be clouded out (Lerner et al., 1998; Small and Lerner, 2008; Tiedens, 2001). The results of our study support the suggestion that terrorists' objectives might include prolonging the existence of their organisations (possibly for the purpose of revenge), even if those objectives are counter-productive towards achieving their political goals (Abrahms, 2008).

6.1.3 Modelling State-dependent priorities of malicious agents

Our final paper: *"Modelling State-Dependent Priorities of Malicious Agents"* is based the findings from the study carried out in *Paper II* and the insight from the current literature described in *Paper I* and is used to allow for potential changes in priorities triggered by varying levels of anger to be captured. Through this, we hope to improve the descriptive validity and hence the quality of counter-terrorism policies.

In this paper, we presented a framework that may be used to infer how terrorists' priorities may change over time and their impact on their choice of a harmful action. By incorporating the effects of visceral factors, the proposed framework may infer the relative weights assigned to the objectives the agents seek to achieve. This may help in cases where one does not have direct access to the agents' preferences. In the case of terrorism understanding what triggers certain visceral factors, such as anger, will be useful in better understanding the impact of such triggers on terrorists' evaluation of various types of attacks (Lerner and Tiedens, 2006; Merari et al., 2009). To account for these effects, our paper has suggested a framework for modelling state-dependent priorities in Multi-Attribute Utility models, to help in inferring the evaluation of alternative types of strikes by malicious agents. This was done by combining a system dynamics model representing the terrorist situation into a Multi-Attribute Utility model. Combining the two methods has been done before, it has been used for policy analysis purposes and for modeling judgments (Andersen and Rohrbaugh, 1992; Gardiner and Ford, 1980; Gruver et al., 1984); for performance evaluation purposes (Santos et al., 2008); for designing and evaluating long and short term strategies in socio-economic control (Brans et al., 1998; Kunsch and Springael, 2008; Kunsch et al., 1999); and for designing policies by looking at how preferences may be influenced to improve systems, it has been investigated by Springael et al. (2002) in the context of traffic commuters. In our case, we described how terrorists' visceral factors may affect the prioritisation of objectives and showed how such an analysis could support risk management in this context. Finally, we showed how a preference ordering could be derived from them.

We used the Lockerbie bombing case to illustrate the framework, and to describe how the model could be analysed to infer possible changes in priorities - thus preferences - and how this could affect the strikes terrorists may consider. In so doing, this research has sought to provide insights into inferring decision making of inaccessible decision makers.

As with any research and decision model, our approach and framework have some limitations, both theoretical and practical. These are discussed in the next section.

6.2 Limitations and Further Research Directions

In trying to achieve our objectives, our research is subject to several limitations and there are areas that have not been investigated. Further research in those areas could help strengthen the research and the insight that could be added to counter-terrorism models, which we discuss below.

Terrorists' Judgements. Our first paper has adopted a multidisciplinary approach to determine the characteristics of terrorists as decision makers. However, our findings were mostly drawn from secondary research. Therefore, this research could benefit from further research to be carried out on a primary level. In particular, whilst studies

have been carried out on the political objectives of terrorists (Keeney and von Winterfeldt, 2009; Kydd and Walter, 2006; Pape, 2003), modelling terrorist values requires additional insight to be gained into non-political objectives, i.e. the social aspect of a terrorist organisation. If empirical research was carried out to understand the non-political motivations of agents joining and participating in terrorist organisations, this could enhance the descriptive validity of models describing terrorist preferences. This could be helpful if incorporated in Adversarial Risk Analysis models, where defenders and attackers have diametrically opposed objectives. Indeed, as models currently focus on the political motivations of terrorists, the results they generate may be biased.

Furthermore, our research as focused on looking at cognitive decision making at the level of an individual agents, and thus we made the assumption that a terrorist organisation behaves as an individual. Further research should be carried out to investigate the nature of terrorist decision making at an organisational behaviour level.

Psychological Factors. This research has highlighted the impact of psychological factors (in particular visceral factors) on terrorist judgement and decision-making. An empirical study was carried out to analyse the effect of anger on the depth of processing, in particular the prioritisation of objectives in a context comparable to terrorist's situations. The study carried out on the effect of anger on the prioritisation of objectives was subject to several methodological limitations. These include the sample of participants used to carry out the survey, the method used for the mood induction, and the way we elicited participants' priorities. For instance, a sample that held more similarities with terrorists – such as a sample of males prone to violence – could have provided more significant and reliable results. Furthermore, our sample included participants whose mother tongue was not English, and it is likely that this could have affected the effectiveness of the emotional treatment as they were asked to read and engage with a written scenario. Other mood induction methods involving videos could have been used in addition to the scenario to strengthen the emotional effect.

Other influences have been found to be linked with this anger, such as biased risk attitudes and uncertainty assessment that our study did not investigate. The insight gained through *Paper I* and *Paper II* has opened avenues for investigating the impact of visceral factors on risk attitudes, and the level of confidence of agents involved in terrorism and violence. Therefore, we hope further research is carried out in two main areas. Empirical work on how risk attitudes vary when actions have a self-destructive component to them, and investigating how agents' level of confidence varies depending on their level of fear and anger, could contribute to enhancing the descriptive validity of models for counter-terrorism analysis.

Our Framework. As in any decision models, several assumptions were made, and some shortcomings arise from these. Specifically, in our model, we made the assumptions that terrorists were seeking to achieve the following objectives: maximise revenge, renown, and reaction from the defender, but also minimise operational elements associated with performing a strike. As we saw in *Paper I,* social benefits derived from terrorism can be sought by the agents, which have not been included in our model.

Furthermore, whilst we have allowed for the priorities for the first three objectives (revenge, renown and reaction) to be dynamic, we have assumed the priorities associated with the operational elements to remain static. This could be a reasonable assumption within a certain timescale. However, should the actions of the defender severely deplete the resources of terrorists, the weights on minimising the operational elements would need to be adjusted.

Another assumption and limitation of the model we suggested lies in the fixed utility functions (stability of the agent's risk attitudes over time) and the evaluation of strikes based on utilities as opposed to expected utility (assumption of equal probability of success), which may not necessarily always be the case. Indeed, as we saw in *Paper I*, research shows that visceral factors may have an impact on agents' risk attitudes (hence utility functions) as well as their levels of confidence (hence terrorists' perceived probabilities of various events) (Isen and Geva, 1987; Isen and Patrick, 1983; Lerner and Keltner, 2001, 2000; Lerner and Tiedens, 2006; Raghunathan and Pham, 1999).

We also assumed that the terrorists, as an entity, are rational decision makers, which may be a reasonable assumption only as far as a terrorist cell is concerned (McCormick, 2003). However, it is also possible to observe some irrational actions committed by terrorists, such as suicidal ones. Indeed, as we saw in *Paper I,* this type of terrorist may not always be considered fully rational (Caplan, 2006; Drake, 1998; McCormick, 2003). But, as Broder (2006, p.78) explains,

> *"The prediction of crime, like risk analysis, is an inexact science and is often based on the professional's best educated guess. The methodologies used to predict crime are subject to more debate than those of risk analysis."*

Whilst the proposed framework cannot claim to be predicting the exact preference ordering of the opponents, it may provide a useful tool for learning and understanding the ramifications behind terrorism, what triggers the strikes and hence may help be better prepared and equipped against it. We also hope the suggested framework could open avenues for further research in the area of models for counter-terrorism analysis.

The limitations of our proposed model could be dealt with by gathering more accurate data and, possibly, expanded by using expert elicitation in the field of terrorism, similarly to the work of Rosoff & John (2009).

Furthermore, we hope that, following empirical studies on the areas of the influence of anger on risk attitudes and confidence level, further research is carried out on

capturing the potential dynamicity of utility functions and perceived probabilities within multi-attribute utility models. In so doing, this could help enhance making the modelling of inaccessible decision makers more descriptively accurate.

Finally, by generalising the proposed framework, we hope it could be used and applied in other areas of violence (such as gang violence) to assist in policymaking in the management of risk caused by violence outbreaks.

6.3 Chapter 6 References

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