Game Theory as a Tool of Crisis Management in a Company

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Abstract: Terrorism - phenomena that is classified as one of the most serious threat of today. Research and development of counter-terrorism strategies have become a part of international and national organizations and private company policy. Czech Republic is a region that would not be threatened by international terrorism, but extremism and terrorism is considered as significant security threat by Czech authorities. At the national and international level, the issue of extremism and terrorism is increasingly studied using game theory. Authors argue that it is not possible to examine various conflict participants, without consideration of their reaction and interaction. Game Theory is a tool that allows to analyze individual decisions, so it is increasingly being used in development of security strategies. This work deals with the Czech extremist and terrorist scene and possible terrorist attack on a regional company. Based on available information obtained by analyzing domestic extremism and terrorism, and a description of the chosen company there was designed model of security scenarios and rules, which can be used as a support tool for decision-making. The scenarios were then tested with a suitable part of Game Theory.

Key-Words: -Terrorism, Game Theory, management, crisis, Prisoner´s dilemma, security, scenario, rules

1 Introduction

Most definitions of terrorism coincide in saying that this phenomenon is described as an act of violence used to reach goal
s by means of intimidation and fear. However, who are terrorists? What is their motivation? Why do we pay such a great attention to this topic, knowing that compared to fatal injuries occurred in road accidents or consequences of the food shortage, the number of terrorism victims is much lower? Terrorism seems to influence the public opinion equally as the academic world, while the image of an irrationally thinking and acting terrorist has been shifting towards a more thorough research of the conflict reasons and motivation of terrorist acts and their modelling. *"Game Theory plays more important role in the defence economy study. It also plays a role in the study of conflict, negotiation, keeping peace, competition, armament and weapons trade."*[1].

What is the way a state or private subject can use to effectively protect from a terrorist attack? What is the cost related to such defence? Is it effective to negotiate with terrorists? Terrorism related questions, among others, can be reasonably answered with the help of Game Theory (further referred to as GT*). "Current application of the Game Theory methods in the study of terrorism consists of the following elements: assessment of strategies how individual states allot the finance for the fight against terrorism and to solve the post-attack situation, terrorism-relating insurance risk assessment, determining the conditions under which the non-negotiation strategies discourage terrorists."* [2]

2 Problem Formulation

Following the terrorist attacks of 11thSeptember 2001, the GT became an increasingly discussed subject of terrorism-relating issues. Successfully planned and completed attacks demonstrated the firm rational background in terrorist decision making processes. Rationality of at least one of the actors as well as the game strategies selection are among the basic GT prerequisites. As an example can be used installation of metal detectors at airports in 1973, followed by an immediate replacement of aircraft hijacking by kidnapping people (mainly diplomats, politicians and state officials). As soon as

safety measures against people abductions increased, terrorists replaced them by suicide attacks. GT is therefore a suitable tool to study terrorism, because it reflects interaction between an attacked subject and a terrorist, while individual steps are mutually depending and cannot be analyzed separately. In other words, one or two parties play a passive role not reacting to actions taken by the counterparty. At least one party (a player in GT terminology) acts in a way to maximize their profit. In this context, attacked subjects and terrorists act with the aim to gain a strategic advantage. The GT seems to be a suitable tool for terrorism study due to several reasons:

a) GT describes terrorist and government actions as mutually dependent
b) Governments and terrorists are rational actors who react to counterparty´s actions
c) Governments and terrorists act in a way to gain a strategic advantage
d) Governments and terrorists act to maximize their profit (aircraft hijacking - see above)
e) Governments and terrorists make decisions in the situation of incomplete information [3]

2.1 Basic Aspects of Game Theory

GT is a science dealing with decision making in conflict situations. A conflicting situation may occur in numerous cases. *"The notion of a game in modern Game Theory has a very general meaning that involves both the drawing-room games such as chess or poker, but in principle, any conflicting situation among individuals, enterprises, armies, states, political parties and species"*. [4]
For a suitable analysis of individual situations, GT uses mainly mathematical structures, psychology, sociology or economy. The game objective is a strategy based on the analysis of an aggregate of decision-making unit. *"The one who takes an attempt in strategic behaviour should be clear about several aspects, the first one being the objective to approach."* [5]

Another characteristic feature of GT is decision making under uncertain circumstances. Valenčík [6] defines the GT as a "*theory of decision-making models in the conditions of uncertainty, where the subject (a player) disposes of information about a certain number of possible situations, but not about all of them.*"

The objectiveis choice of optimal strategy at respecting the assumed strategy or steps to be taken by other player or players. A specific situation is in question, where individual players mutually react, change strategies and create countermeasures. A player or participant can be individual, a pair or a group. Decision-making of individual players are done based on different strategies. The GT is applied in many fields. An example can be economy, sociology, political science, cybernetics and biology. GT can describe numerous specific phenomena, such as relations among people, competitions, war and political conflicts. In historical perspective, GT signs can be identified already in the works by ancient philosophers: For example, Platon´sRepublicarationally analyzes the options of a soldier expecting enemy´s attack. Development of GT has been largely influenced by the development of the theory of probability in the 17^{th} century and by later attempts in using mathematical structures for games analysis (chess, poker and checker) to get an overview of strategiesand options of individual players.
The first realusing of GT is connected with John von Neumann and Oskar Morgenstern and their works from 1928. They determined the theoretical background of GT and made an evidence of the basic sentence of matrix games, which is a mathematical utterance of a so called Minimax. In the analysis of salon games, authors described a conflict situation by means of mathematical structures, while discovering a concordance in conflict situations structure in the economic and military environment. The work Game Theory and Economic Behaviour from 1944 gave background to mathematical applications in conflict situations study, later called Game Theory. Another personality who developedGTwas J.F. Nash who dealt with non-cooperation conflict situations. The notion of Nash Equilibrium is suitable in solving conflicts where participants comply with the conditions of rational decision making, having complete information about the options, preferences and strategies of other players. Game Theory has been further processed and developed (Selten, R., Shapley, L., S., Harsanyi, J., Dantzig, G., B.); and some of the works were rewarded by the Nobel Price. In 1994, Nash, Selten and Harsanyi were awarded the Nobel Price for the analysis of the non-cooperative games equilibrium. Israeli mathematician Aumann and American economist Schelling got the Nobel Price in 2005 for economy (application of GTon conflict behaviour problems, explanation of business and price wars). GThas been

recently used in a number of scientific fields, such as economy, trade, neology, informatics, political science and philosophy.
The basic prerequisites for a GT application are the following:

a) At least one player is rational
b) All the players know the rules which are unchanged during one game
c) Players are familiar with the values in the game and know the loss and profit amounts[7]

One of the essential terms in a GT is a general model – a game in a standard form that is understood as a triplet of aggregates.

$((1,2,..,n),(S_1,..,S_n),(Z_1,..,Z_n))$
$(1,2,..,n)$ - sum of players
$(S_1,..,S_n)$ -sum of strategies
$(Z_1,..,Z_n)$ -sum of players payoff functions

Players are numbered with natural numbers. Important condition of this model is to differentiate individual players and to know their number, which is at least two. Each i^{th} player has its strategy - S_i. Strategies can be understood as a description of a player´s procedure through the game, or its sequence of steps selected during the game. If standard game is in question, then players choose strategy $xi \in S_i$. All strategies selected by all the players in one game then determine the value of payoff function $Z_i (x_1,..,x_n)$ for an i^{th} player.
Individual games can be differed by the following criteria:

a) Number of players

A minimum number of players is two. Usually a maximum numbers of players isfinite (a finite players number game).

b) Rationality of players

Despite a basic prerequisite of the GTbelongs rational behaviour. Individual players differentiate between two extreme attitudes. The first is a so called "intelligent player" who behaves rationally. The second extreme is a random-selection player.

c) Strategies

Strategies can have limited and unlimited number. Considering the Rock-Scissors-Paper, it is a final-strategy game. If a player chooses a real number of a certain interval, then an unlimited strategy is in question.

d) Cooperation

Games can be divided into cooperative and non-cooperative type. The basic prerequisite of non-cooperative games is that individual players cannot cooperate. They are not allowed to make coalitions or agree upon next steps to be taken. Communication barriers of the players can be predetermined by the environment, game circumstances or such communication may be banned by a regulation or a law.
When deciding within the framework of the GT, the following decision-making situations may occur:

a) Decision can be assessed using a single-value characteristics
b) Decision can be assessed by more than single characteristics
c) Decision where at least one player is rational
d) Decision where more than one player are rational
e) Non-conflicting decision (non-conflicting strategy)
f) Conflicting decision (more rational players) [7]

Another essential aspect of games classification is player´s goal, dividing players to intelligent and non-intelligent ones. An intelligent player is a rationally thinking subject who sufficiently understands his/her strategies and has a defined objective. Non-intelligent player is often so called nature and it could be natural phenomena, such as weather, earthquake, etc.

2.2 Examples of Game Theory Use

GT is used in the design of future anti-terrorist policies and safety strategies. Sandler and Arce [3] modelled a situation, by tools of GT, where the government faces the decision whether and when they should accept terrorist´s requirements. It is generally known that among the pillars of the US government anti-terrorist policy is the "no-concessions-to-terrorists" strategy. The authors complement this strategy by conditions stemming from the GT application. The first one reflects attitude of the government that is required to be persistent at any circumstances. The second condition is incomplete information on the terrorist side about the governmental anti-terrorist measures.

Another example of the GTusing is "competition" in implementing safety measures in different countries. Sandler and Arce use the GT [3] for the description of what they call "intimidation race". There are two countries that are potentially

endangered by a terrorist group. Providing that one country increases the cost of safety then the terrorist-attack-relating costs grow proportionally. However, such a situation represents a negative externality of another country, because the terrorist-attack-relating cost in the other country decrease. In consequence, the second country increases its safety-relating costs because they attempt to reduce the probability of being an alternative terrorist attack target. If the second country increases safety measures (and the relating costs) above the level of the firstly mentioned country, the negative externality transfers onto the first country. This scenario shows that individual countries overvalue the costs required for their safety.

3 Application of Game Theory

Typical example and probably the most discussed example of the GT used in safety science is so called prisoner´s dilemma. Players are introduced to a situation where a crime has been committed and two suspects, A and B, have been arrested. Evidence is incomplete and it is very difficult to give a proof to any of the suspects. Both the suspects are investigated separately (A does not know about the B´s decisions and vice versa) and both are given the following option:

a) If one of suspects confesses to the crime while the other does not, then the one who confessed will be jailed for one year, while the other for ten years.
b) If both confess, the imprisonment will be seven years.
c) If none of them confesses, then the imprisonment shall be three years

		A	
		confession	non - confession
B	confession	7,7	1,10
	non - confession	10,1	3,3

Fig. 1 Prisoner´s dilemma [author]

Decision making will be firstly analyzed from the A´s point of view. Prisoner A does not know about the B´s reaction, trying to reach a maximum advantage for himself. Matrix at Fig. 1shows that if B confesses, A will also benefit from the confession. In such case the sentence is seven years. If he refuses to confess to the crime, the sentence is ten years. If prisoner B refuses to confess, it is also an advantage for A to confess because the sentence shall be one year only; compared to the three years in the case of a refusal. Prisoner B will make the same decisions. The result will be confession on both sides and a sentence of seven years´ imprisonment for each.
If neither confesses, they will be sentenced for three years. Therefore confession presents a dominant strategy. The dominant strategy closely relates to the Nash Equilibrium: *"If each player follows the most suitable strategy for himself, i.e. dominant strategy, then a deflection from such strategy, while the other player (players) sticks to the dominant strategy, will mean an adverse situation for the first player."* [6]

3.1 Prisoner´s Dilemma and Choice of Active or Reactive Policy

Prisoner´s dilemma is situation where individual players in the game (countries, companies, individuals) follow their dominant strategy, which in reality leads to a resultant disadvantage. Prisoner´s dilemma can be used in decision-making processes in performing contracts about armament or company restraint trade agreements. Sandler and Arce [3] apply prisoner´s dilemma on a situation when governments choose between active and reactive anti-terrorist policies. Active policy focuses on an open and active fight against terrorism, consisting of:

a) Search for and liquidation of terrorists
b) Destruction of resources and terrorist infrastructure
c) Active monitoring of terrorist activities
d) Prevention from terrorists and their sponsors

If the active anti-terrorist policy executed by one country is successful and a terrorist unit is liquidated, then other states tend to rely on active measures of other states. In such case the "black passenger" effect occurs and the risk and cost relating to an active fight against terrorism are borne by one state, while the other only profit from the prospective benefits. Reactive policy is typical mainly in the solution of terrorist attack consequences. The black passenger effect is demonstrated by means of the prisoner´s dilemma in the following matrix:

USA \ EU	active	non - active
active	2,2	-2,4
non - active	4,-2	0,0

Fig. 2 Application of prisoner´s dilemma[author]

There are two players- USA and EU. Both states face a potential threat of a terrorist attack and they are obligated to agree upon applying an active anti-terrorist policy. A necessary prerequisite is an active policy benefit amounting at four and costs of six for the country that pursues active policy.
If USA are to apply active policy and EU is the state that only makes use of the relating benefits (black passenger), then the EU gains the profit of four. USA gain -2 (4-6). The costs amounting at six will be deducted from the gained profit four. In the opposite event, if black passenger is USA, the profit will be opposite. If both countries apply active policy, then each of them gains an advantage of two (6 – 2 x 4). The result is a prisoner´s dilemma game in which none of countries intends to apply active anti-terrorist policy.

3.2 Use of the Game Theory in Czech Company

Research into terrorism and the GT application focuses exclusively on international terrorism. Certain opportunities exist to generalize a given situation, assuming that individual players are subjects making rational decisions using logically defined strategies. Therefore the research in most cases is applied the above indicated prisoner´s dilemma or other game format, often of a non-cooperative type with a zero sum total.

Application of theGT on a company in the Czech environment has numerous specifics. It is often required to use the GT dealing with decision making under uncertainty. While a company, company management or an authority (government, local administration) can be considered a rationally thinking player with the ability to use different strategies, it is quite difficult to define a terrorist using the same method. Czech extremist and terrorist scene has its specific features that make it impossible to consider Czech terrorist as a rational player.

a) Czech terrorists, those of them who are able and willing to use violence, mostly do not plan their actions thoroughly; acts of violence have often character of a spontaneous attack with minimum rate of planning.
b) Czech terrorist groups show only a limited rate of organization. The structure and organization can be identified at the extremist associations acting within the Czech political scene, e.g. the Workers' Party of Social Justice. Such parties, regarding their position, use terrorist methods with a very low probability.
c) Another problematic area is lack of homogeneity of the Czech terrorism scene that in principle makes it impossible to determine “terrorist” or “terrorist group” as a generalized term enabling its further practical use.

Terrorist attack is considered as external and consciousthreat. Such treat could trigger other crisissituations in company. Terrorist or terrorist attack is understood to be the first player and the crisisevents represent its strategies. The second player is company that has set of scenarios presenting the use of resources, tools and rules used if there is the need to react. For the purpose of this work it was chosen producer of chemicals as a model company whose location is near any town or city in The Czech Republic. The possibility of terrorist actions is given by considerable accumulation of potentially hazardous equipment and substances whose accident should in some cases have an impact on human lives and the environment. This is related to a significant psychological effect of such action. Suppose that company uses more passive than reactive security policy. "*Reactive policy includes security that measures the mitigate attack and its consequences*" [3]. Typical example of passive policy is to increase the physical security barriers (metal detectors at airports, increasing the number of security staff). Active policyis based on direct actions against terrorists and their supporters or sponsors. This may be searching and destroying terrorist training camps, a direct attack against terrorist cells, but also freezing accounts, the infiltration of terrorists, monitoring of security reality, cooperation with authorities, training and information security staff.
It was mentioned that Czech terrorist cannot be considered as rational player for using GT theoretical frame. For company, which is considered

as the second player, is prove of rationality in decision - making and planning not necessary. It is obvious that an immediate company reality cannot be described by a mere interaction of the two players. In the event of crisis situation, depending on the degree of seriousness, other actors exist (police, rescue service, firefighting department, local and state administration bodies, media and local citizens).

Functioning security system must be able to highlight the crisis and advises company management on how to respond appropriately to involved danger. In this work, the proposed theoretical framework uses several scenarios and security rules, whose main objective is to inform and to advise how to rationally react just after the terrorist attack. The results of the subsequent use of appropriate scenarios show that set of possible scenarios proposed by commonalities of possible emergencies(EMs) is an appropriate tool for assessing and quantifying the initial costs associated with the intervention minimizes the consequences of terrorist attack.

Proposed model use different scenarios which are based on possiblecrisis situations and Company Security Advisory System (CSAS) as a tool to help with first response reaction. From the previous chapter that partially dealt with issue of extremism, terrorism and company comes several significant facts that have influenced the direction of next steps:

a) Czech extremist and terrorist scene is diverse and there are numerous opinions and approaches from extremist groups which operate in the Czech political system, only some of them are armed groups theoretically able to carry out a terrorist attack, so it is very difficult to clearly define a terrorist or terrorist group.
b) Attacks on private entities that meet the definition of a terrorist attack, has been in past in the Czech Republic committed and valued at the cost to repair the damage.
c) Subsequent valuation of terrorist attack that is trigger of incident can be quantifying by damages to property, environment and other related costs. Quantification of the loss of human lives is generally considered to be problematic.

3.3 Design and Procedure of the Model

It is obvious that when you try to approach the theoretical framework or modelas much reality every effort hit to problem of complexity. In this work, the problem is solved so that the primary aim of the model is not to find concrete solutions to complex security reality, which may be an appropriate continuation of research. Main objective is to create a theoretical framework that will describe relation between terrorist attack and company and allow react in crisis. In the model there are only two players (terrorist attack and Central Security Authority - CSA). Terrorist attack is considered to be the trigger of incident or series of them that could be considered as summary of company crisis situations.

Terrorist attack is considered as internal and external threat of company, to which should be added also that it is intentional threat. This threat, as already mentioned, becomes possible trigger of emergency which is for the purposes of this article combined into several groups on the basis of the same characteristics. Terrorist attack (first player) is defined by number of emergencies subsequently merged into groups. The second player is CSA, which has a set of scenarios that present the deployment of resources, tools and rules prepared and used in case that the need has arisen to respond to emergency.

3.4 Players Who Entering the Game, Characteristics and Strategies

The model in this work is designed to support CBA´s decision making in crisis situations. Proposed scenarios are elaborated with regard to the immediate responseof CBA, and security measures in the form of scenarios gauge the threat of terrorism from the perspective of one who resists attack.

Definition 1
P = (P1, P2)
P1 ... terrorist attack - irrational player (nature)
P2 ... CBA - rational player

Terrorist Attack

Terrorist attack is considered to be the first player (P1), which triggers emergency. Possible sets of emergencies that may occur after the terrorist attacks, let bethe strategy of the first player. If S1 is marked as a set of strategies of the first player, then:

Definition 2
$S1 = (t_1,t_2,t_3 \ldots t_N)$ where N is natural number
t... strategy of the first player (the set of clusters)

Deployment of available resources have not only dimension of the quantity and severity. Thus, the higher the degree of seriousness of emergency, the more available resources should be deployed and vice versa for minor emergency is more efficient to use less. The decision to deploy the available units must also consider the appropriate structure. Individual events may also concatenate. It is therefore a system based on the principle of priority the higher priority takes precedence over lower. Each strategy is identified priority D, which represents ascending order numeric value, where 1 is the lowest priority.

Definition 3
D = (1, 2, 3,....N), where N is a natural number

Company - CSA
CSA is managing authority representing the security interests of the company. CSA becomes the second player (P2), which has the ability to use the suggested scenarios and security measures as an immediate response to the resulting emergency. Possible scenarios are then the second player´s strategies. Let S2 be the set of strategies of the second player, then:

Definition 4
$S2 = (c_1,c_2,c_3,\ldots c_N)$ where N is natural number
c...the second player´s strategy (different scenarios of available resources)

P2 tries to maximize profit, and its reward is presented as to minimize the damage. P1 is indifferent player who causes damage for P2, while P2 wants to stop either or minimize it.

3.5 Developing a Company Security Advisory System (CSAS)

GT is tool that captures the interactions, allows to model, and thereby helps to rationally make decisions in crisis situations caused by terrorist attack. Due to the model, in addition to the identification and development of other steps there is also need to define some degree of rules corresponding to the various degrees of risk, allowing, among other things, mutual cooperation of security staff. Coalitions are intended groups of security staff, which is assigned the same security scenario and system rules, which is represented by the level of threat.

There are 4 threat levels and its security rules:

Low Level
- Maintain and develop communication with Emergency service, update, SR, which helps in dealing with crisis situations.
- Include crisis communication into business strategy.
- Identify competencies in case of evacuation and update evacuation plans
- If possible, provide an alternative place where in case of emergency will work administration of company.
- Training staff in first aid.
- Training employee´s behavior in case of occurring emergency, printing and distribution of brochures on this topic among employees.
- Provide available information about behavior in case of occurring emergency that can provide Emergency service.
- Be careful to suspicious activity and notify the Department of Security.
- Provide communication about safety in the enterprise.
- Ensure that all the necessary equipment for the ensuing emergency is ready to be deployed.

General Level
- Increase attention to suspicious activity and notify the Department of Security.
- Cooperation with external experts in assessing security risks and proposed safety measures.
- Contact the local authorities for the coordination of activities in case of occurred emergency.

Medium Level
- Be sensitive to suspicious activity and notify the Department of Security.
- Use emergency plans, especially in the area of synchronization and continuity rescue operations.
- If necessary, support the existing security system through an external security company.
- Apprise with current situation business partners.
- Regularly inform about the current situation Emergency service.

High Level
- Listen to the latest information from the company radio.
- Focus on suspicious activity and report it immediately to CBA.
- Direct cooperation with employees, citizens living close to campus, local government, Emergency

service and other institutions operating in the field of crisis management.
- Decide whether you must enclose the entire company or just division.
- Prepare for difficult working conditions and limited resources.
- Ensure that all support for the company's employees (medical assistance, presence of experts in crisis management, psychologist).

3.6 Security scenarios

This work provideshow to react immediately after the crisis. The initial decision is difficult in terms of lack of information and time constraints, while respecting the hierarchy:

a) to prevent the consequences of human life,
b) to prevent the environmental damage,
c) to prevent the damage to property.

Scenarios and safety rules were designed to CSA had tool that will support the initial decision in a crisis that must be primarily:

a) quick,
b) most accurate in view of the nature of emergency,
c) adequate to deploy resources.

There should be identified number of different security scenarios depends on each company but the key thing is that those scenarios capture first respond reaction of company represented CSA. For to purpose of this work there is used necessary simplifying, so the first scenario is for **fire**, the second **explosion** and the third **leakage.**

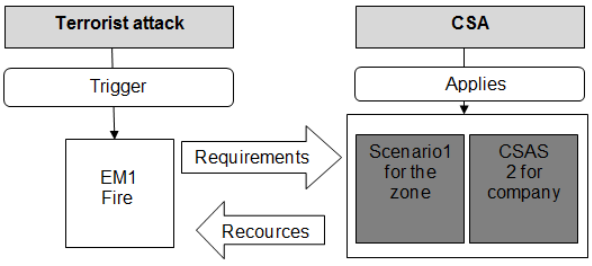

Figure 3 Fire, Scenario1 and CSAS2 [author]

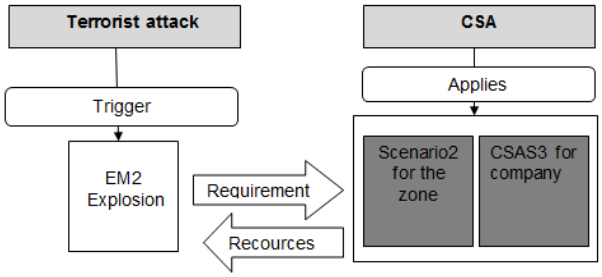

Figure 4 Explosion, Scenario2 and CSAS3 [author]

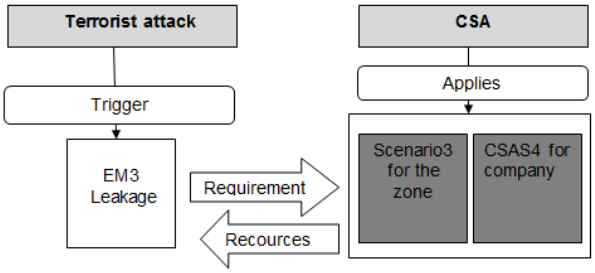

Figure 5Leakage, Scenario3 and CSAS4 [author]

3.7 Testing Scenarios Using Game Theory

Individual combinations of scenarios may be analyzed using GT where P1 is represented by terrorist attack and P2 is company represented by CSA. Compared to models in literature to there must be done major modifications:

a) Terrorist or a terrorist group in the Czech Republic are not considered capable of rational and long - term planning.
b) To generalize the definition of terrorists and to use it when building the model is misleading in Czech conditions.
c) Games prisoner's dilemma - type or non-cooperative zero-sum games, which are used in research on international terrorism are not appropriate to create models in this work.

Theoretical framework of GT was generally introduced in the previous chapters, where were inter alia mentioned that the key factor is the rationality. Under this assumption can be divided games:

a) Games of intelligent players
b) Games of unintelligent players

Unintelligent player is often referred as a nature, as that term expresses a large proportion of chance and irrationality in its behavior, but also results from the application of GT in predictions of natural phenomena (weather, earthquakes, etc.).

From the above it follows that the decision situation may arise two possibilities:

a) One player knows the probability with which events or strategy of the second player occurs. In this case, it is decision making under risk.
b) Player 1 does not know the probability with which events or strategy of the second player occurs. In this case, it is the decision making under uncertainty.

In games under uncertainty arises problem of specifying optimal choice of strategy against games of two rational players. Authors dealing with applications GT to international terrorism often use zero - sum game, where one player gains the cost or "negative gain", which does not seem to be suitable for this work. Decision making under uncertainty is the most problematic area of decision making, because there is no purely scientifically proven decision - making criteria. Optimal solution for games against nature is designed with a tool that can be calledthe principles or definition of optimality, which are used to determine the optimal strategy for games against nature (decision making under uncertainty). Final choice is often performed by intuition, experience and the current conditions.

The most widely used and also the most popular of them are:

a) Minimax rule and Maximax rule
b) Laplace´s rule
c) Hurwicz´s rule
d) Savage´s rule

Based on these rules will be tested in tables 2,3,4,5 and6 decision - making situations in the company.Decision - making matrix describes the decision situation, in which the rows are emergencies (EM1,EM2,EM3) representing the first player´s strategy S1 = (t1,t2,t3). Columns are scenarios (decision situation), which are strategies of the second player S2 = (c1,c2,c3).

Definition of payout matrix

Combinations (t1, t2, t3) and (c1, c2, c3), which should be developed in collaboration with company (crisis management department),represent success of intervention and are reported in % in the payout matrix.

Table 1 Payout matrix [author]

	Decision – making situation		
Reality	Scenario1	Scenario2	Scenario3
EM1	95	70	58
EM2	75	85	65
EM3	40	45	80

a) Minimax rule and Maximax rule

Decision-making situations and its solution according to Minimax and Maximax rules are described in Table 2.

Minimax rule
Definition 5
$\max_j \min_i x_{ij} \text{or} \min_j \max_i x_{ij}$
Minimax rule represent pessimistic approach where the best from the worst is chosen.

Maximax rule
Definition 6
$\max_j \max_i x_{ij} \text{or} \min_j \min_i x_{ij}$
Maximax rule represent optmistic approach where the best from the best is chosen.

Table 2 Analysis of the CSA decision criteria for Minimax and Maximax [author]

	Decision – making situation		
Reality	Scenario1	Scenario2	Scenario3
EM1	95	70	58
EM2	75	85	65
EM3	40	45	80
$\min x_{ij}$	**40**	**45**	**58**
$\max x_{ij}$	**95**	**85**	**80**

According Definition 5:
$\max_j (40,45,58) = 58$ for $j = 3$

CSA in the pessimistic approach chosen on the basis of Minimax rule Scenario 3, efficiency is the least favorable circumstances (occurs EM) is relatively high.

According Definition 6
max_j (95,85,80) = 95 for j = 1

CSA in case of optimistic approach choose on the basis of Maximax rule Scenario 1, as in the case of the most favorable situation (occurs EM1) will get the highest efficiency.

b) Laplace's rule

Table 3 shows calculation of the Laplace´s rule which is based on the determination of median (EX) of individual decisions (scenarios). Optimal decision is the biggest median in the case of revenues and in the case of costs is the smallest.

Table 3 Analysis of the CSA´s decision in the case of Laplace´s rule [author]

	Decision – making situation			
Reality	Probability	Scenario1	Scenario2	Scenario3
EM1	1/3	95	70	58
EM2	1/3	75	85	65
EM3	1/3	40	45	80
EX		**70**	**66,77**	**66,67**

According to Laplace's rule applies:
max_{EX} (70, 66,77, 67,67) = 70 for j = 1

After comparing the mean values for each scenario as an optimal decision to use for CSA is Scenario 1.

c) Hurwicz´s rule

According to definition of Hurwitz rule, Table 4 calculates optimal decision in case of optimistic a pessimistic expectations.

Definition 7
$f(\beta) = \beta * o_{ij} + (1 - \beta) * p_{ij}$
$o_{ij} = max_i x_{ij}$...optimistic matrix output (column maximum)
$p_{ij} = min_i x_{ij}$...pessimistic matrix output (column minimum)
β…coefficient of optimism (choice of value depends on crisis manager)

For CSA it is the optimal solution that takes for function f (β) the maximum value, coefficient of optimism is a number from the interval <0,1>. If optimism, it is closer to 1, where pessimism it is closer to 0.

Table 4 Analysis of CSA decision in the case Hurwicz´s rule [author]

	Decision – making situation		
Reality	Scenario1	Scenario2	Scenario3
EM1	95	70	58
EM2	75	85	65
EM3	40	45	80
$P_j = min_i x_{ij}$	**40**	**45**	**60**
$O_j = max_i x_{ij}$	**95**	**85**	**80**
f(β)	95* β + 40*(1- β)	85* β + 45*(1- β)	80* β + 58*(1- β)
f(0,8)	**84**	**77**	**75,6**
f(0,3)	**56,5**	**57**	**64,6**

Calculating the optimal decision by Hurwicz´s rule indicate that if optimistic expectations (f (0,8)) CSA would chose Scenario1, which corresponds to the smallest level of danger, it is deployed at least units and thus produced the lowest cost. In the case of significantly pessimistic expectations based on maximum value of criteria, it is Scenario3, a scenario that corresponds to most serious EM3 and the associated highest costs.,

d) Savage´s rule

Table 5 is used to calculate the matrix of missed opportunities. Table 6 specifying the minimum of

individual choice of scenario and defines the situation which minimize the loss of opportunity

Definition 8
$K_{ij}=max_j - x_{ij}$ for all i = 1,2,3,.....,I
Each value is deducted from row maximum. The values are than put into the Table 6.

Table 5 Calculations for matrix of missed opportunities [author]

	Decision – making situation			
Reality	Scenario 1	Scenario 2	Scenario 3	max_j
EM1	95	70	58	**95**
EM2	75	85	65	**85**
EM3	40	45	80	**80**

Table 6 Analysis of decision in the case of Savage´s rule [author]

	Decision – making situation		
Reality	Scenario1	Scenario2	Scenario3
EM1	0	25	37
EM2	10	0	20
EM3	40	35	0
$max_i k_{ij}$	**40**	**35**	**37**

min_j (40,35,37) = 3 for j=2

In case of Savage´s rules, it is advantageous to choose Scenario2, because in this case, the greatest loss of opportunity is minimized.

Testing of proposed scenarios shows how significant influence has human factor (knowledge, experience, ability to decide instantly) and current information. Security scenario and CSASthus become tools to help CSA in decision - making in extreme conditions, reducing the risk of loss of life, environment and the property of company.

4 Conclusion

Effective management of crisis situations arising from terrorist attacks and the associated need to examine extremism and terrorism using new methods dramatically increased especially after the 9/11. For this reason, the relation between terrorists and governments, private sector, objectives of terrorists and other actors is in recent decades increasingly studied by Game Theory which becomes not only the means to study this issue, but also effective crisis management tool helping create counter - terrorism strategy, policy and mitigation actions. Opportunity to present previously difficult measurable data with the numeric values with subsequent analysis and model creation opens a new space for the direction of research not only in the management of crisis situations, but also in research in the field of security sciences.

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