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Risk, Threat, Danger, Vulnerability, etc.: Prediction and Anticipation of Systemic Disturbances in Security Theory

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1. Introduction

Contemporary discourse on security has been dominated by general considerations in which attention is paid to consequences of deepening and broadening of meaning of the term security. Critical approaches, assessment of the sense of human security or extension of the sense of security to provision of public goods are dominating the discourse on security. Only in some cases a question is being asked: What security is about?

Usually security is dealt with such concepts as threat, danger, risk, vulnerability, resilience, etc. In the present discussions we can even observe replacement of the term threat with the concept of risk ("risk society") (Beck 1986, 1992, 1999).

As to make the discussion on security more relevant to the needs of policy making, it is necessary to identify attributes of security in a systemic sense. It has been already accomplished by this author in the research project of AFES-PRESS[1]. Other members of AFES-PRESS and associated authors also have conducted research on the role of prediction in security theory, or on the role of time and space in theoretical considerations on security. Results of research have been published in a book edited by an international team of scholars under auspices of AFES-PRESS (Hexagon Series published by Springer Verlag). In the book this author has proposed a core concept of security including basic components of any discourse on security – threat, risk, securitization, referent object, disturbance, vulnerability, etc.

Prediction and anticipation can be regarded as important (if not the most important!) factors in any application of the utterance of security. Therefore it is necessary to study how attributes (characteristics) of the concepts used in every discourse on

[1] The paper partly draws on the previous works of the author (Mesjasz 2008. 2008a) and is also based upon the fragments which will be included in further books published in the Hexagon Series.

security can be identified and interpreted. In the contemporary considerations such terms as risk, threat, vulnerability, resilience and similar ones are more frequently applied in studies on broadened and deepened ideas of security.

It is obviously not possible the define those terms unequivocally but at the same time it is not acceptable that in too many instances they are used as freely interpreted notions, almost "buzzwords". It is thus necessary to elaborate more detailed and precise definitions of those terms along with identification of the links between their interpretations and applications in policy making.

The aim of this draft paper is to provide a deepened interpretation of such terms as threat, risk, vulnerability in relation to security-oriented considerations based upon systems thinking. The limits of prediction and anticipation in identification of threats, risks and vulnerabilities is the second topic of analysis.

The basic epistemological assumptions of research on the role of prediction and anticipation in analysis of risk and similar concepts will stem both from mathematical modeling, including the so-called complexity approach (complex systems approach) ("hard" complexity) and qualitative complex systems discourse ("soft" complexity).

2. Prediction, forecast and anticipation in social sciences

Leaving for further analysis the sense of causality and explanation, it may be initially stated that prediction is the key element of scientific reasoning (Popper 1974). Prediction is associated with such terms as forecasting, predictability and prophecy. In the basic meaning prediction is a statement or claim that a particular event will occur in the future. Narrowing the sense of prediction, it may be added that the place and time of event are known as well.

Relations between the terms prediction and forecast are not clearly explained. In linguistic terms to predict means:…to make known beforehand, to foretell the future. To forecast is defined as:…to predict on the basis of scientific observation and applied experience (e.g. in meteorology), or by simple estimate of probability (New Webster's Dictionary 1992). According to some interpretations forecast is a prediction based on knowledge of past behavior (Doran 1999, p. 11). In other scholarly texts a difference is made between prediction and forecast with the latter being closer connected with scientific base, namely probability calculus. In general, the term prediction has a broader meaning and it will be the main focus of interest in the paper.

A difference can be made between informal, or common sense prediction and scientific prediction[2]. Scientific prediction is a rigorous (often quantitative) statement about what will happen under specific conditions, typically expressed in the form *If A is true, then B will be also true*. The scientific method is built on testing predictions which are logical consequences of scientific theories. Theories, in turn, are designed to allow for prediction of phenomena from underlying principles.

In the social sciences a complete prediction allows for answering to three questions: “what is likely to occur?”; “when it will occur?”; and “how it will occur?”. Most of predictions are only partial ones.

A distinction can be made between the contingent and non-contingent prediction or forecast. Contingent prediction, or conditional prediction is based upon “if, then” assumption. In the non-contingent prediction the future events are depicted in a straightforward manner (Singer 1999).

Another typology allows to distinguish two types of prediction, an “intentional” prediction and an “outcome” prediction. The former concerns actions of an actor while the latter relates to the states independent from the actions of the predicting subject, so it is closer to forecasting.

Prediction can be interpreted as a selection of one world from infinite number of “potential worlds” which can emerge from any given set of circumstances. This interpretation immediately brings about a question of causality. First of all it must be underlined that causality may be interpreted as objective when proved with logical on empirical evidence. At the same time causality has also an intersubjective character. Observers (participants) agree that a specific course of events has led to a specific outcome although it is not certain whether both cause and effect are unique and cannot be replaced.

Prediction is also associated with anticipation, i.e. expectation or making decision upon the predicted states of the future, beliefs, etc.

Predictive power of a scientific theory is its ability to generate testable predictions. Theories with strong predictive power are heavily valued, because these predictions can often encourage the falsification of the theory. It is different from explanatory or descriptive power, by which already-known phenomena are explained by a given theory, in that it presents a new and novel test of theoretical understanding.

[2] The definitions of prediction and associate notions were collected from Internet encyclopedic sources, e.g. (http://en.wikipedia.org) and the similar. They will be critically evaluated in the further editing process.

Scientific ideas without *any* predictive power are known as "conjectures", or, at worst, "pseudoscience". Because they cannot be tested or falsified in any way, there is no way to determine whether they are true or false, and so they are not afforded the label of "scientific theory". What is even more important, theories without any predictive power have not any explanative power of causal relations as well.

Predictability is enhanced by existence of structural constraints. They could be of a static character (conditions, barriers) or they can take shape of patterns in dynamics of a system (individual). It is especially valid for cyclical behavior - assuming that the cause for circularity is known, evolutionary behavio – assuming that the mechanisms of evolution are identifiable, which is not frequently the case and path dependency – assuming that the impact of the past events on the future is known.

Prediction is associated with explanation of the links between phenomena. Being aware of the differences between causal links and correlations it must be emphasized that causality is not necessarily associated with prediction. Causality may be also identified ex post and in such case two situation may be identified:

- retrospection, i.e. explanation of the links between the past events which not necessarily would be repeated in the future,
- retrodiction, i.e. prediction based upon an assumption, "what, if" in which the present knowledge of the developments in the past and of the actual state are used for predictions of different courses of events.

Predictability meaning a capability of predicting refers to the links between the observer and the observed. Making predictions depends on the capabilities of an observer to describe the phenomenon with the variables which can be observed and given appropriate meaning, including measurement. Any disturbance of this cognitive interaction, dependent on an observer or not leads to occurrence of uncertainty and risk.

Predictability is also related to contingency, especially in social sciences and policy. In contingency thinking it is assumed that we cannot plan since all is dependent on present, sometimes very small causes. However, it must be also recalled that even if the events are contingent, the humans must plan. Actions cannot be completely spontaneous (contingent). "We could not live and remain sane in a world that was totally composed of contingent factors ….and while we adapt and modify our behavior when contingency does occur, on a day-to-day basis we work on the (correct) assumption that all is not contingent (Webb 1995).

If full knowledge regarding options, outcomes and the various states of the world is available, the task of making a decision becomes straightforward process of selecting the action whose outcome maximizes the decision criteria – "decision making under certainty conditions" (Luce and Raiffa 1957, p. 13).

Certainty and predictability are frequently confused with determinism. As it was put by Sokal and Bricmont (1998, p. 140): "Determinism depends on what Nature does (independently of us), while predictability depends in part on Nature and in part on us". So certainty of the observers may mean determinism but not always. By the same token, deterministic phenomena are not always certain to the observers. The point is that we simply may not know the difference if it is not visible in a given moment of inquiry.

While prediction can be associated with an observer (predictor) it is also necessary to refer to the state of environment, or of himself/herself he/she is relating in the cognitive processes. Here it is worthwhile to recall a well-known typology taken from decision theory and economics. According to already mentioned ideas of Knight (1921) uncertainty is randomness with unknowable probabilities and risk is randomness with knowable probabilities.

Prediction may include various patterns of future behavior of objects under study. According to Bhaskar (1986, p. 217) (Patomäki, 2006, p. 10) in future scenarios, significant events are transformative in one way or another in the nodal points. Such nodal points include: (1) connector points, which interpose one into another type of process; (2) branch points, foreclosing certain possible lines of development; (3) jump points, creating a new horizon of possibilities; (4) saddle points, inducing stasis or even regression; (5) break points, actually consisting in or substantively contributing to a rupture of social structures and/or their constellation in a totality; (6) trigger points, initiating or powerfully augmenting such a transformative process; (7) predisposing points, securing the satisfaction of the enabling conditions for such a process, e.g. the inception of a (tendentially) auto-subversive tendency.

Another challenge of prediction comes from the character of changes, no matter whether positive or negative. The simplest are known and predictable, then known but not predictable and the last ones, unknown, sometimes even unthinkable.

Prediction with mathematical models must fulfill a basic condition - a proper identification/understanding of a system, whose functioning/behavior is to be predicted. It means that in mathematical models the parameters of description and of for prediction are adequately selected, then a relevant model is built, and subsequently the parameters are correctly measured.

This step reminds building a "central metaphor" guiding the cognition process. In the following steps, the metaphor can be decompose and subsequently parameters can be operationalized as to enable further research – description, prediction, etc. For example using the central metaphors social system as machine/chaotic system/beehive/learning system, etc. may lead to various understandings and to different patterns of control.

3. Methodology of research and limits of prediction of social phenomena

The characteristics of prediction, forecasting, predictability and anticipation lead to the fundamental questions – how prediction and anticipation in social science are accomplished made or, what are the methods of achieving descriptions of possible future courses of events in a society at macro, mezzo and micro levels?

Prediction of changes in nature, society and in their interactions, are the point of interest of the future studies. The subjects and methods of futures studies include possible, probable, and desirable variations or alternative transformations of the present, both social and "natural" (i.e. independent of human impact)[3]. Futures studies often examines not only possible but also probable, preferable, and wildcard futures, which are low probability but high impact events, should they occur.

Usually the objects of interest of future studies are multidimensional. Future studies is also an interdisciplinary exercise deriving from mathematics, economics, physics, sociology, psychology, history, geography, engineering. Therefore in a natural way future studies is closely associated with systems thinking/approach/complexity studies, or whatever we may call it. There are dozens of methods applied in futures studies such as, for example, Delphi method, environmental scanning, morphological analysis, scenario planning, future history, simulation, trend analysis, path dependency models, social network analysis and many others.

In the broadest sense they can be divided into quantitative and qualitative. The basic and most "scientific" source of methods in futures studies is science, especially physics and chemistry, where predictions are based upon various kinds of mathematical models, which can be reduced to three types. First deterministic models in which regularities in space and time are captured by mechanistic models. Second, where it is possible to grasp irregular patterns with the use of stochastic models. Three, models of broadly defined complexity, "deterministic chaos".

Wherever possible mathematical models can be applied in social sciences, either in studying the relations between society and nature, or when it is possible to elaborate more or

[3] Similarly as in the case of complexity studies, where the term „complexity science" would be too far-reaching to apply the term "futurology" also seems somehow confusing. The future as such does not exist so the area of research is just the state of minds of researchers thinking about the future.

less reality-relevant mathematical models of social phenomena, e.g. econometrics, simulation models.

Although mathematical modeling seems an appropriate instrument of prediction/forecasting/anticipation but in social sciences its applications are not undisputable. First and foremost, applications of mathematical models in social sciences are also exposed to the fundamental limitations. In the case of classical, Newtonian models it is a mechanistic reduction. In the case of stochastic processes additional limits are coming to the fore. The random character of phenomena is an effect of perception and development of science may discover other patterns of regularities or a new kind of irregularity. In the case of the former, non-linearity, complexity, emerging properties and chaotic behavior can be recalled.

. Limitations of prediction of stochastic processes also lie in the foundations of mathematical modeling. Computational complexity, computational (algorithmic intractability) determine the limits of application of mathematical models and computer simulation in those processes (Biggiero 2001), (Chaitin 2001)[4].

Since social systems are "complexities of complexities" understanding the barriers of prediction of behavior of social systems requires a broader survey, including obviously the barriers of mathematical modeling.

In the most fundamental sense, in which the impact of post-modernism/post-structuralism is not incidental, social phenomena (social systems) are a mixture of a tangible component - physical and biological processes with an intangible intersubjective component emerging in the discourse. In a linguistically-oriented approach the discourse on social systems includes metaphors, analogies and mathematical models. In such an approach barriers of prediction begin not only at the epistemological level (the future is unknown) but also at the ontological level. There are multiple possible futures created in the social discourse and they are shaped by various subjective factors determined by independent, "natural" processes as well as actions and utterances of the conscious individuals – participants/observers.

If a social system is a product of discourse of participants/observers then prediction, which is based upon identification of regularities acquires a specific character. On the one hand, it must be drawn upon physical, or tangible regularities associated with social system, e.g. geography, demography, biology, industrial activities. On the other, it must relate to the processes of creating regularities in intangible components of social systems emerging thanks

[4] Limitations of prediction of non-deterministic phenomena result also from probability theory paradoxes, which partly reflect the fundamental (http://en.wikipedia.org/wiki/Category:Probability_theory_paradoxes, 12 June 2007).

communication and coordination of actions. It is thus easy to conclude that prediction of behavior of social systems is based upon the regularities resulting from learning process, and at the same time can be also viewed as a part of learning process. In addition, prediction and anticipation of social phenomena can be distorted by a normative bias. Instead of asking what is possible and plausible, a question may by asked what is necessary or needed?

Reference to social learning brings about the main source of complexity of social systems i.e. reflexivity and self-reflexivity. Regularities generated by social systems can be brought about by homeostatic causal loops, self-regulation through feedback and reflexive self-regulation.

The above interpretation of prediction of behavior of social systems is very preliminary but should be sufficient for further considerations. In more advanced sociological inquiry into the nature of social systems and prediction more attention is usually paid to the definitions of social systems, open systems and already mentioned “soft” complexity (Luhmann 1991, 1993), (Patomäki 2006, 2008).

Without delving into ontological discussions on possible futures, the barriers of prediction of behavior of social systems can be reduced to two interrelated groups – epistemological limitations at the levels of individuals (observers and actors) and social limitations resulting in interactions of those individuals.

Typology of epistemological barriers include:

- limitations of mathematical models, which in some cases, e.g. non-linearity and indeterminism, computational complexity, computational (algorithmic intractability) can be treated as an ontological limitation, i.e. it’s is not only limited cognition but existence of such entities,
- natural cognitive limitations of observer – limited physiological capability to identify and process variables (information) depicting phenomenon (phenomena) under scrutiny; they are also causes of “bounded rationality” (Simon 1997) and framing and prospect theory (Kahneman and Tversky 1979),
- scope and time horizon – broad long-term predictions are more susceptible for emergence of other unpredicted (unpredictable changes),
- zebra principle – the reasons are known afterwards, but could not have been predicted beforehand; it particularly concerns the cognitive and decision making processes of political leaders (Webb 1995),

Social barriers of prediction of social processes include:

- sociopolitical influence (external pressure, conformism, political correctness),

- normative distortions in prediction and anticipation,
- socio-cultural factors – culturally-determined interpretations of risk, cultural bias in prediction and anticipation,
- self-defeating and self-fulfilling prophecies – the impact of an observer/participant/predictor,
- inherent limitations of intersubjectivity exposed in post-modernist and constructivist approaches, e.g. disturbance in communication, deficiencies in transfer of meaning.

5. Prediction in security theory and policy

5.1.Systemic interpretation of security

The following questions should be a point of departure in any considerations on contemporary interpretations of security:

1. What are the characteristics of a social collectivity (or system) which can be depicted as secure?
2. How can those characteristics be specified in a more detailed form, not only with a broad but superficial and sometimes contradictory meaning?

Presence or absence of security of any social system or an individual, i.e. of circumstances threatening their existence and compelling to undertake extraordinary activities, can be translated into a collection of simple systemic characteristics. This collection can be called the „core concept" of security since all its elements can be identified in any attempt to define security both objectively and stemming from various securitization discourses.

The expectation for the continued existence of any social system is the key element of the assessment of its security. Of course, for living systems and some social systems, the predicted termination of its existence is also a part of its set of norms. If survival or the predicted decay are the aims of existence, a kind of desired state, then any disturbance negatively affecting that process requires countermeasures. Thus a normative notion disturbance (disruption) – actual or potential could be associated with such terms as danger, threat, challenge, vulnerability and risk who's meaning also requires further elucidation. To guarantee clarity of considerations several ideas from systems thinking such as stability, instability, discontinuity, complexity and several others are not applicable at this level of general considerations. But a closer look at their meaning may identify numerous simplifications and contradictions (Mesjasz 1999, 2006, 2008).

“Disturbance” refers to any object and can be caused by internal and external factors, or by a mixture of both. The disturbance should be identified by any observer-participant (internal, external), and if securitized – regarded as threatening an actual status (existence?) of the system (individual), should lead to appropriate actions.

The control theory is used irrespective its deficiencies due to constructivist limitations. Social systems are treated as constructs made by observers or participants initially in their cognitive processes and later in the social discourse. The term social systems is used interchangeably with collectivities since in a constructivist approach the systems are created by observers or participants from any social collectivities, e.g. a system constructed solely for the purpose of the study. This approach does not allow responding unequivocally what social systems are but permits to circumvent the search for a universal definition of those systems.[5]

Similarly, in order to limit the too general character of the core concept of security, a neutral concept of an impulse influencing a system is replaced with a negatively valued notion of disturbance. Thus, the core concept of security is a kind of framework for all normative discussions on existence and survival of any social collectivities and individuals. Although it is designed for ordering the discourse on relatively well-defined, “technical” aspects of security, it can also be helpful to introduce an additional rigour in the discussions on security based on broadly defined terms, like identity, or „freedom from fear”. To discuss such ideas it is necessary to understand the sense of the words „game”. The „core scheme” of security can be extended in various directions by a combination of these attributes:

1. *Reference object*: state, region, alliance, society, various social groups, nations, minorities, ethnic groups, individuals, global system;
2. *Areas where existential disturbances (threats) are emerging (sectors)*: political, military, economic, ecological, societal, informational.
3. *Methods of prediction* (*identification*) *of disruptions*: from search for „objective” threats to subjectively perceived threats, also resulting from social discourse („securitization”).
4. *Methods of planning and performing extraordinary actions* (*anticipation*) aimed at monitoring, preventing or eliminating existential threats (Fig.1).

[5] An epistemological and ontological background for this application of the systems approach can be found in Midgley (2003).

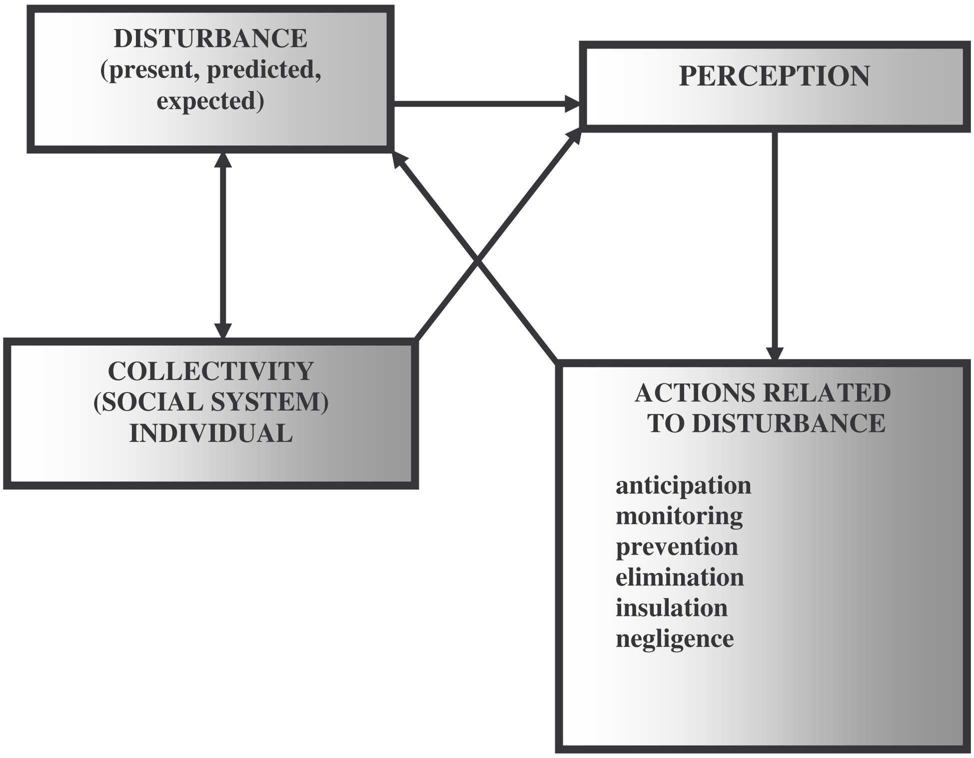

Figure 1: The Core Concept of Security.

Source: Mesjasz (2008)

Additional attention must be paid to changing interpretations of the scheme in „widening" and „deepening" the meaning of security. In classical, state-oriented interpretations of security, the disturbance (threat) could be resulting from purposive actions by a clearly defined „threatener" undermining actual or potential existence of a threatened object (system). In the widened and deepened interpretations of security, the disturbances are not so easily identified. If security is understood as the absence of unusual disturbances requiring extraordinary measures, then the questions are arising what is unusual (threatening) disturbance, how it can be identified (predicted), and what does extraordinary mean?

In systemic terms an idea of securitization is equivalent to the identification of external and internal changes perceived as actually or potentially disturbing a given state (equilibrium?) and in an ultimate resort terminating the existence of a social system and of its elements (individuals). Here it can only cursorily be mentioned that prediction of disturbances in the process of securitization also requires more precise considerations. Securitization allows defining the extraordinary character of actions which are to be undertaken in response to the disturbances.

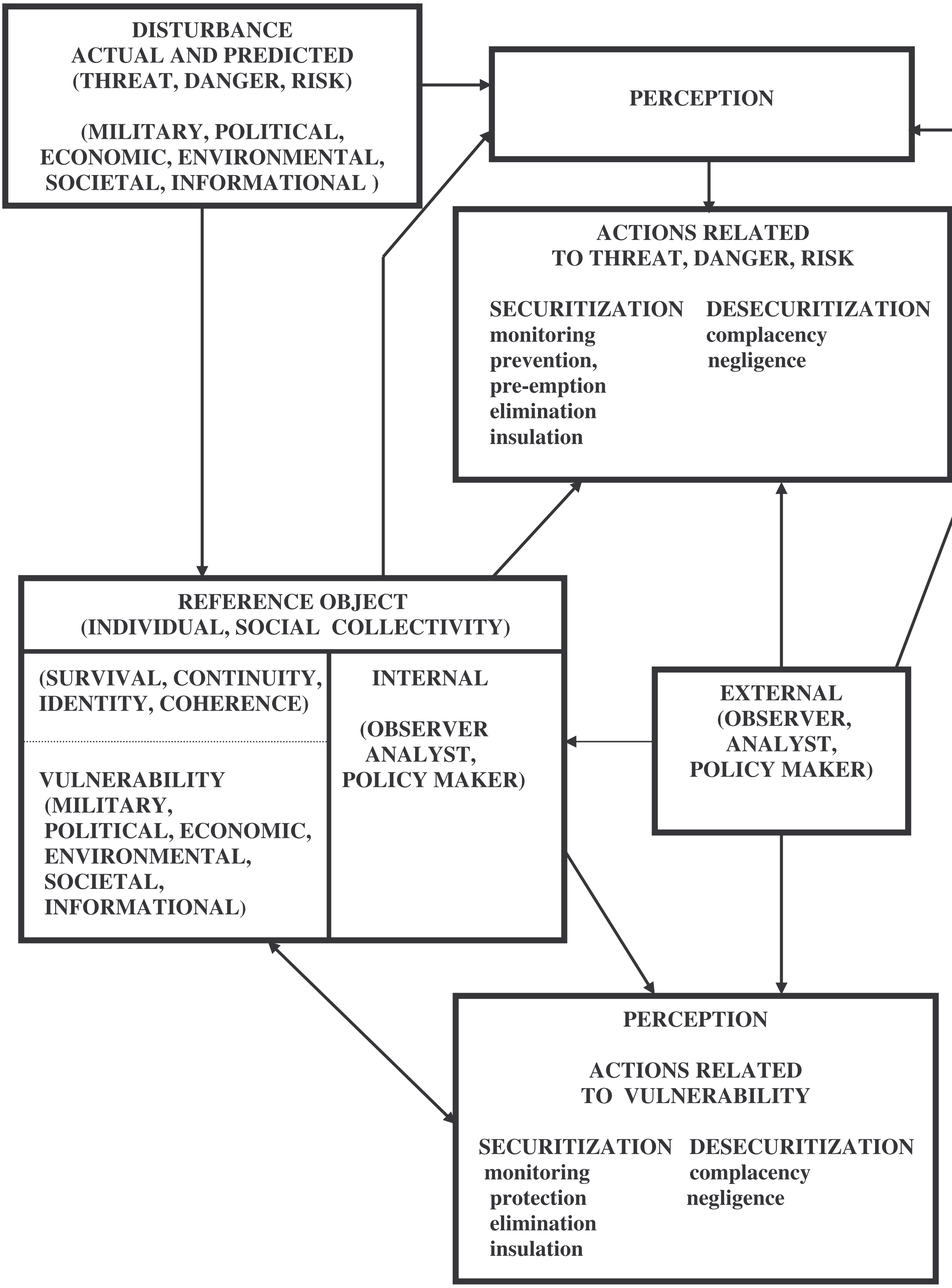

Figure 2. Systemic Framework of Security.

The core concept of security (Fig.1) is a point of departure for developing a broader framework idea of security which can be used for studying the links between security treated as attributes of social systems and various concepts defined as systems thinking, systems approach or complex systems studies (Fig.2). This scheme cannot capture all aspects of security but offers a foundation for more rigorous considerations on security and its attributes, and for the discourse on all concepts associated with security.

5.2. Definitions of risk

Since risk is defined subjectively then definitions of risk depend on specific applications and situational contexts. In each area of application, the term risk as "qualified" aspect of uncertainty has its own characteristics. In a common sense interpretation risk is related to the expected losses which can be caused by a risky event and to the probability of this event. The harsher the loss and the more likely the event, the worse the risk.

It is difficult to prepare a homogeneous typology of definitions of risk. They can differ according to their objective and subjective character. Therefore the typology presented herein includes but several representative definitions.

Objective (positivist, quantifiable, probabilistic) definitions of risk

Risk as a measurable category is defined several ways. In the simplest, "pseudo-mathematical" way, risk is usually presented as a product of hazard, value, vulnerability, capacity, etc. The definitions presented in the table are obviously not always operationalizable, but in many instances they are used for quantifications of differently understood risk.

Table. 1. Quantifiable interpretations of risk

Total risk = Impact of hazard x Elements at risk x Vulnerability of elements at risk (Blong, 1996, citing UNESCO)
"'Risk' is the probability of a loss, and this depends on three elements, hazard, vulnerability and exposure". If any of these three elements in risk increases or decreases, then risk increases or decreases respectively. (Crichton 1999)
Risk = Hazard x Vulnerability x Value (of the threatened area) x Preparedness (De La Cruz-Reyna 1996)
"Risk (i.e. 'total risk') means the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk. "Total risk can be expressed in pseudo-mathematical form as: Risk(total) = Hazard x Elements at Risk x Vulnerability"

(Granger et al. 1999)
Risk = Probability x Consequences (Helm 1996)
"Risk is a combination of the chance of a particular event, with the impact that the event would cause if it occurred. Risk therefore has two components – the chance (or probability) of an event occurring and the impact (or consequence)associated with that event. The consequence of an event may be either desirable or undesirable…In some, but not all cases, therefore a convenient single measure of the importance of a risk is given by: Risk = Probability × Consequence." (Sayers et al. 2002)
"Risk is the actual exposure of something of human value to a hazard and is often regarded as the combination of probability and loss". (Smith 1996)
"Risk might be defined simply as the probability of the occurrence of an undesired event [but] be better described as the probability of a hazard contributing to a potential disaster…importantly, it involves consideration of vulnerability to the hazard". (Stenchion 1997)
Risk is "Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability". (UN DHA 1992)
Risk as a probability of damages is closely related to hazards occurrence and severity, but at least as significantly to numerous other components: the *vulnerability* of the exposed unit, its *capacity* to anticipate, resist (*resistance* or *robustness*), face the adverse consequences of the impact (*coping*), and adapt to come back to an acceptable state (*resilience*). It can be said therefore, that risk is a function of hazard, vulnerability, resistance and resilience, the first two being multiplicators of risk, and the last ones divisors: R = f (H, V / Rtce, Rlce) (Nathan 2007).
"Pseudo" formalizations of risk have been begun with R = H + V (Blaikie and al. 1994), replaced by R = V x H in order to show the combination between hazards and vulnerabilities that shape risk. As some scholars have argued that societies also have capacities to lessen risk, the variable C appeared, as in UN/ISDR (2002), p 24: R = H x V /C. Others (ZEF Bonn (2002), p 11) have tried V = H - C (coping) (Nathan 2007).
Business Continuity / Disaster Planning formulation of Risk = Threat x Vulnerability x Impact

Source: (Kelman 2003), (Nathan 2007)

Other quantitative definitions of risk represent but various interpretations of uncertainty and/or losses. It must be underlined that in some cases risk is not always defined as a negative category. Risk in finance is often defined as the unexpected variability or volatility of returns, and thus includes both potential worse than expected as well as better than expected returns. References to negative risk below should be read as applying to positive impacts or opportunity (e.g. for loss read "loss or gain") unless the context precludes.

This interpretation can be called “teleological” (from “telos”) as expressing the relation to goal achievement.

The definition:

Risk = Hazard x Vulnerability x Potential Loss

is similar to the Business Continuity / Disaster Planning formulation of

Risk = Threat x Vulnerability x Impact

which is also used in some types of security risk analysis.

In statistics risk is often mapped to the probability of some event which is seen as undesirable. Usually the probability of that event and some assessment of its expected harm must be combined into a believable scenario (an outcome) which combines the set of risk, regret and reward probabilities into an expected value for that outcome. This definition can be related to expected utility in economics.

In statistical decision theory, the risk function of an estimator $\delta(x)$ for a parameter θ, calculated from some observables x; is defined as the expectation value of the loss function L:[6]

$$R(\theta, \delta(x)) = \int L(\theta, \delta(x)) \times f(x|\theta)\, dx$$

where:

- $\delta(x)$ = estimator
- θ = the parameter of the estimator

Means of assessing risk vary widely between professions. Indeed, they may define these professions; for example, a doctor manages medical risk, while a civil engineer manages risk of structural failure. A professional code of ethics is usually focused on risk assessment and mitigation (by the professional on behalf of client, public, society or life in general).

Some industries manage risk in a highly quantified and numerate way. These include the nuclear power and aircraft industries, where the possible failure of a complex series of engineered systems could result in highly undesirable outcomes. The usual measure of risk for a class of events is then, where P is probability and C is consequence. The total risk is then the sum of the individual class-risks.

A specific definition of risk which cannot be assigned to any of the above groups was proposed by Holton (2004). In his proposal definition of risk is built upon the concept of exposure. Risk entails two essential components: exposure and uncertainty and can be treated as an exposure to an uncertain proposition.

[6] This formula is drawn from the entry „risk” in Wikipedia (http://en.wikipedia.org/wiki/Risk), 5 March 2007.

5.3. Dealing with risk, hazard, threat and vulnerability

Since negotiating with exposure to risk may occur under different conditions – natural disasters, military, political, economic and social threats, therefore it is necessary to she the relations between definitions of risk and other negatively assessed circumstances.

The basic vocabulary of risk-associated concepts embodies the following terms: threat, danger, hazard, resilience, robustness, vulnerability,

Detailed analysis of the links between interpretations of those terms and of risk goes beyond the scope of this paper. A scheme of interdependence between some of them and a specific quasi-mathematical formula has been proposed by Crichton (1999) as the "Risk Triangle".

Figure 3. Risk Triangle
Source: Crichton (1999, p.102).

The links between elements of the triangle can be represented by the quasi-mathematical equation:

Risk (Total) = Hazard x Elements at Risk [Exposure] x Vulnerability

Changing society creates a new environment for negotiating. According to some interpretations, understanding risk requires new theories extending the concept of risk society to a general theory of risk in reflexive modernity. The literature on governmentality and risk refers to Foucault (1991) and his concept of a new style of governance in modernity. In this approach (regularly rather understood as a method than a theory), risk is mainly understood as a concept produced entirely socially. There is no outer world, which forces society to respond to risk. Instead risk is understood as a specific way how to shape and control populations and to govern societies - from governmentality of risk to the governance of uncertainty (Zinn 2006).

More precisely defined ways of governing uncertainty and risk include such approaches as risk management, risk assessment. Usually five steps in the risk management process can be distinguished:

- identification of exposure to loss,
- evaluation of the loss exposure and available risk management techniques,
- selection of risk management techniques,
- implementation of a risk management program, and
- monitor the risk management program.

Risk assessment is a step in the risk management process. Risk assessment is measuring two quantities of the risk R, the magnitude of the potential loss L, and the probability p that the loss will occur.

It is worthwhile to remind that risk cannot be eliminated therefore such concepts as risk acceptance level and risk homeostasis can be proposed. The concept of risk homeostasis proposed by Wilde's (1994) suggests that individuals, and by extension communities and societies, maintain a specific level of risk irrespective of external influences. If we build walls along rivers and coasts to alter flood hazard parameters under certain circumstances, then we will build more property in floodable areas, reduce our preparedness, and behave differently so as to increase our vulnerability The overall risk does not change. Unless the "target risk", the risk we are willing to tolerate or accept, can be altered, external measures do little to reduce total risk over the long-term (Kelman 2003).

4. Complexity studies and prediction in security studies

4.1. Meanings of complexity

There is no commonly accepted definition of complexity. Although it seems neither needed nor achievable but it leads to numerous confusions, trivializations and abuses both in theory and in practice – everybody may have different associations when referring tom intuitively interpreted complexity. First attempts to study complex entities go back to Weaver (1948: disorganized and organized complexity), Simon (1962: Architecture of Complexity) and Ashby (1963: Law of Requisite Variety). In explaining complexity Seth Lloyd (1989) identified 31 definitions. Later, according to Horgan (1997: 303) this number increased to 45.

Numerous definitions of complexity have been put before (Waldrop 1992), (Gell-Mann 1995), (Kauffman 1993, 1995), (Holland 1995), (Bak 1996), (Bar-Yam 1997), (Biggiero 2001). The impossibility to decompose this entity and its incomprehensibility are facets of complexity. According to Gell-Mann (1995) complexity is a function of the interactions between elements in a system. Nicolis and Prigogine (1989) prefer measures of complexity based on system "behaviour" rather than system interactions. Behaviour is also a basis of analysis and description of Complex Adaptive Systems (CAS), (Holland 1995).

To avoid lengthy typological considerations, it is also assumed that complex systems studies are regarded as a part of systems thinking (Mesjasz 1988; Midgley 2003). Even more difficult are definitions of "studies of complexity" and "complex systems studies". The use of the terms "complexity theory", or "complexity science" seems premature, although an idea of the "emerging sciences of complexity" was proposed (Waldrop 1992). These challenges were referred to by Horgan (1995) in: "From Complexity to Perplexity".

The basic ideas concepts of complexity studies are: dynamical system, complexity and chaos. A dynamical system is a set of inter-connected elements that change and evolve in time (Schuster, 1984). A change in each element depends on influences from other elements. Due to these mutual influences, the system as a whole evolves in time.

Complex systems exhibit non-linear behaviour that is referred to as positive feedback where internal or external changes to a system produce amplifying[7] effects[8]. Non-linear systems can generate a specific temporal behaviour which is called chaos. Chaotic behaviour can be observed in time series as data points that appear random, and devoid of any pattern but show a deeper, underlying effect. During unstable periods, such as chaos, non-linear sy-stems are susceptible to shocks (sometimes very small). This phenomenon, called 'sensitivity to initial conditions' and popularized as the Edward Lorenz's 'butterfly effect', exemplifies the cases, where a small change may generate a disproportionate change (Gleick 1997). The major lesson of nonlinear dynamics is that a dynamical system does not have to be "complex" or to be described by a large set of equations, in order for the system to exhibit chaos -- all

[7] Stanislaw Ulam once remarked that discerning non-linear phenomena and their mathematical models was "like defining the bulk of zoology by calling it the study of 'non-elephant animals'." His point, clearly, was that the vast majority of mathematical equations and natural phenomena are nonlinear, with linearity being the exceptional, but important, case (Campbell 1997, p. 218).

[8] It should be also mentioned that the divide linear is predictable and non-linear is not predictable, is a simplification. For instance, Newton's equations for the two-body Kepler problem (the Sun and one planet) are non-linear and yet explicitly solvable. It means that non-linearity not always leads to chaos. At the same time the fundamental equation of quantum mechanics, the Schrödinger's equation is absolutely linear (Sokal & Bricmont 1998, p. 144-145).

that is needed is three or more variables and some embedded nonlinearity (Ilachinski 1996, p. 57).

Complexity can be also characterized by a multitude of other ideas such as artificial life, attractors, bifurcations, co-evolution, edge of chaos, spontaneous self-organization, learning, fractals, power law, self-organized criticality, instability, irreducibility, adaptability, and far-from-equilibrium-states. These concepts have been developed predominantly by the scholars associated with the Santa Fe Institute, and Gottfried Mayer-Kress in particular (Campbell and Mayer-Kress 1989), (Grossman and Mayer-Kress 1989), (Forrest and Mayer-Kress 1991).

In addition, the works of Ilya Prigogine on thermodynamics (dissipative structures, far-from-equilibrium systems) (1997, 2003) and of Herman Haken (2004) on synergetics have also influenced the complexity discourse[9].

Among the most recent ideas of complex research are scale-free networks discovered by Albert-László Barabási (2003). After finding that various networks, including social and biological ones, had heavy-tailed degree distributions, Barabási and co-workers coined the term 'scale-free network' to describe the class of networks that exhibit a power-law degree distribution, which they presumed to describe all real world networks of interest.

These ideas based upon mathematical modelling can be called 'hard' complexity research in analogy to 'hard' systems thinking.[10] There is also another link between "hard" and "soft" complexity research. In 1980s the language of chaos, complexity, non-linearity, etc., was included, sometimes with criticism to the ideas of postmodernism. In one of its foundational texts, "The Postmodern Condition" Jean-François Lyotard (1984), leaned heavily on fractal geometry as an example of the "paradoxes" that purported to show how the rationalism of science would be its own undoing. Another postmodernist author, N. Katherine Hayles (1990) noted that the recursive nature of fractal algorithms and nonlinear dynamical systems increased uncertainty in ways that were analogous to the application of reflexive thinking in postmodern philosophy and its undermining of truth foundations[11].

The "soft" complexity research, or "soft" systems thinking, includes ideas of complexity elaborated in other areas of cybernetics and systems thinking, social sciences and in psychology. Initially, "hard" and "soft" systems thinking were developed almost

[9] All those concepts listed here in alphabetical order are described in detailed in writings quoted in Bibliography and in a vast literature on chaos, complexity and non-linearity.
[10] The term soft complexity science is used, among others, by Richardson and Cilliers (2001).
[11] Errors and abuses of analogies and metaphors drawn from complex systems research in postmodernist writings have been described by Sokal and Bricmont (1998).

independently but after the growing impact of mathematical modelling, the authors of qualitative concepts began to treat the "hard" complexity analogies and metaphors as a source of new ideas.

Subjectivity is the first aspect of complexity in the "soft" approach. Following this reasoning, from the perspective of the second-order cybernetics, or in a broader approach, constructivism (Glasersfeld 1995), (Biggiero 2001), complexity is not an intrinsic property of an object but rather depends on the observer. Usually it is stated that "complexity, like beauty is in the eyes of the beholder".

To identify a meaning of complexity based on some properties of the relationships between observers (human or cognitive systems) and observed systems (all systems) Biggiero (2001, p. 3) treats predictability of behaviour of an entity as the fundamental criterion for distinguishing various kinds of complexity. He proposes three classes of complexity: (a) deterministically or stochastically unpredictable objects; (b) predictable objects with infinite computational capacity; and (c) predictable objects with a transcomputational capacity. From this typology, he defined 'observed irreducible complexity' (OIC) as those states of unpredictability, which allow to classify an object in one of these three classes. This definition distinguishes complexity semantically in the new sense.

Biggiero's typologies lead to two conclusions for studying social systems. *First*, self-reference characterizes the first class, which relates to many forms of undecidability and interactions among observing systems (Foerster 1982). This property favours the subjective interpretations of complexity. *Second*, human systems are characterized by the presence of all sources and types of complexity. Thus, human systems are the "complexities of complexities" (Biggiero 2001, p. 4-6).

In the social sciences, and particularly in sociology, special attention is given to the concepts of complexity of social systems proposed by Niklas Luhmann. As one of a few authors, he attempted to provide a comprehensive definition of a social system based solely on communication and on the concept of *autopoiesis* (self-creation) of biological systems. According to Luhmann, a complex system is one where there are more possibilities than can be actualized. *Complexity of operations* means that the number of possible relations becomes too large with respect to the capacity of elements to establish relations. It means that complexity enforces selection. The other concept of complexity is defined as a problem of *observation.* If a system has to select its relations itself, it is difficult to foresee what relations it will select, for even if a particular selection is known, it is not possible to deduce which selections would be made (Luhmann 1990, p. 81). The idea of complexity of Luhmann is also used in defining risk in social systems. The large number of elements in a given system means that not all elements can relate to all other elements. Complexity means the need for selectivity, and the need for selectivity means contingency, and contingency means risk (Luhmann 1993).

Complexity of social system developed by Luhmann is strongly linked to self-reference since reduction of complexity is also a property of the system's own self-observation, because no system can possess total self-insight. This phenomenon is representative for epistemology of modern social sciences, where observation and self-observation, reflexivity and self-reflexivity, and subsequently, self-reference are playing a growing role. According to this interpretation, social systems are becoming self-observing, self-reflexive entities trying to solve arising problems through the processes of adaptation (learning). The ideas of a system containing models of environment is also developed in ""hard" complexity approach. In the CAS (Complex Adaptive Systems) internal models (mechanisms) are an essential allowing for anticipation and prediction (Holland 1995).

Ideas originated in systems thinking and complexity studies are used in security-oriented research as models, analogies and metaphors. According to this distinction, the term 'model' is used only for mathematical structures. Mathematical models in complexity studies can be applied in three areas: computing-based experimental mathematics, high precision measurement made across various disciplines and confirming 'universality' of complexity properties and rigorous mathematical studies embodying new analytical models, theorems and results.

Models, analogies and metaphors are instruments of theories in social sciences and are applied for description, explanatory of causal relations, prediction, anticipation, normative approach, prescription, retrospection, retrodiction, control and regulation. It is also worthwhile to add that models, analogies and metaphors deriving from systems thinking/complexity studies are gaining a special significance in the social sciences. They are treated as 'scientific' and obtain supplementary political influence resulting from 'sound' normative (precisely prescriptive), legitimacy in any debate on security theory and policy.

It must be mentioned that contrary to physics, chemistry and biology, where only mathematical models are applied in prediction, in social sciences it is also the qualitative considerations are used in prediction. Therefore the role of analogies and metaphors taken from complexity studies must be taken into account.

4.2. Complexity of social systems, security and prediction

In the early 21st Century the challenge of predictability has acquired a new significance in social life and social theory. Unpredicted overwhelming changes, e.g. the collapse of the Soviet empire, new threats and vulnerabilities, e.g. environmental threats, terrorism, increasing vulnerability of technological structure of modern civilization, frequently summarized as growing complexity of the world (whatever that complexity might mean), stir a question: Are we living in the "Risk Society"? (Beck 1986, 1992, 1999). Or, perhaps we have to think about "Predictable Surprises" (Bazerman and Watkins 2004), or even we have to agree that we have to accept "Imperfect Knowledge Economics" (Frydman and Godlberg 2007). In such circumstances the term "complexity" used frequently as a kind of mantra, or "buzzword" has gained a specific role in the language of modern science and social practice.

At the same time "complexity scholars", i.e. the authors claiming to study complexity of nature and society, purposively or not, stimulate expectations of practice by assigning marketing-like titles to their works and courses – "Hidden Order", "Harnessing Complexity", Order out of Chaos", "Understanding Complex Organizations", etc.

The demand from practitioners (policy makers, military planners, managers) and attempts to provide response by scholarly community is nothing unusual by itself. A new element in that discourse between practice and "complexity studies" is resulting from awareness of limited possibility, or even impossibility of prediction of social phenomena, especially at macro and mezo scales. Such an epistemological pessimism can be acceptable in academic discourse but cannot be transferred to practice. Security policy, economic policy and management are most representative examples of the areas in which prediction is a foundation for actions. An "early warning" is sometimes essential. That is why the need for relevant predictions constitutes a foundation of normative social sciences like security theory and management theory.

A question is thus arising. If unpredictability or low reliability of prediction is a key feature of complexity of social phenomena, so what ideas drawn from complexity studies can help policy-oriented social sciences in better understanding the sense of prediction and its limitations.

This question is of a special significance in policy-oriented, normative sciences dealing with social phenomena – economics, finance, management theory, security-related areas (international relations, security theory, peace and conflict studies), which aim not only at description and explanation, but also at providing guidance for action. In such areas prediction is the one of main objectives of research.

Human knowledge is bounded by two limitations of prediction. The first one is stemming from the very "objective" character of external reality number of elements, their interactions, decomposition, etc. The second one is resulting from limitations of human cognition. As a matter of fact they booth overlap and are composed of more elementary factors. The latter barrier is a result of a mixture of psychological and social constraints. In any social prediction, and in security theory and policy in particular, a special challenge is associated with "unthinkable" situations. So perhaps complexity based discourse on prediction can be helpful in explaining why "unthinkable" becomes unthinkable.

By its very nature, the need for prediction was always an inherent part of any considerations on international security, internal security, safety, etc. In the early writings, in a kind of proto-theory of security in international relations, a successful prediction of threats, or limits of prediction, and resulting form them possibility of counteractions, i.e. possibility of control of one's own actions and potential actions of an enemy were always the key issues – Hobbes, Clausewitz, Sun Tzu, etc.

In security theory understood as a policy science non-contingent predictability plays only a limited role and contingent prediction (if, then) is dominating.

Development of security theory in a significant extent can be reduced to the elaboration of methods of enhancement of capabilities of prediction of negatively valued disturbances - threats (risks, dangers), and improvement of understanding the reasons for their unpredictability. It concerns both warning against emergence of those threats, including a long- and short-term predictions (early warning) as well as prediction of actions (policy making) and reactions to those actions, etc., etc.

Applications of ideas taken from complexity studies in analysis of the role of prediction in security theory and policy have to refer to the meaning of broadened and deepened interpretations of security and to the links between new ideas of security and definitions of complexity. They are reflected in epistemological (cognitive) and socio-political limitations of prediction in security theory and policy.

Epistemological determinants

Assuming that in a systemic interpretation threats to security can be defined as disturbances, both surprising and not surprising, the latter especially important for broadened and deepened sense of security, e.g human security, it is necessary to enumerate possible threatening situations.

Firstly the threats (disturbances) may be known and predictable, e.g. pain as a result of injury. Secondly, the disturbances may be knows but unpredictable, e.g. when, where and how a hurricane will strike. Thirdly, unknown threats, sometimes even unthinkable. The last ones are especially important in security theory and policy. Initially it was a key issue in military thinking (surprise) but at present growing complexity of socio-economic systems, including new threats, e.g. terrorism, makes them even more important in all sectors of widened security discourse.

The first epistemological determinant influencing prediction not only in security theory and in social sciences and in virtually entire all human knowledge, are the discoveries in mathematics, physics and chemistry made in the 1970s and in the 1980s, which were labeled as science of complexity, chaos theory, far-from-equilibrium systems, etc. Although they are predominantly applicable in rigorous mathematical models which can hardly be directly transferred to socials sciences they gave ground for emergence a vast collection of writings, frequently trivialized, on chaos, complexity and non-linearity in social sciences, including obviously IR and security studies. In the discourse on security theory the concepts drawn from "complexity science", chaos theory, non-linearity were used not only as mathematical models but they have become a source field for metaphors and analogies[12]. The impact of those ideas upon security research has been and still is broadly discussed although numerous simplification in their applications often require further elucidation[13].

It is also worthwhile to underline that the chaos theory by exposing sensitivity of changes to the initial conditions (small cause-big effect), the famous "butterfly effect", has allowed to reaffirm "scientifically", a phenomenon which is self-evident, i.e. that frequently big changes are completely dependent on very small initial impulses (the 'Cleopatra's nose' idea of history).

The use of models and metaphors deriving from the concepts of complex systems allows to observe that non-linear dynamics makes clear that chaotic dynamics ought not be misinterpreted to mean random dynamics.

According to Ilachinski (1996, p. 56) the most important lesson of deterministic chaos is that dynamical behavior that appears to be chaotic or random often contains an embedded

[12] In social sciences it is frequently forgotten that non-linearity may have three interpretations and a non-linear system is not necessarily chaotic (Sokal and Bricmont 1998, p. 140-145).
[13] For further comprehensive elucidation of the links between complexity studies and security theory and policy – see Ilachinski (1996, 1996a), (Rosenau 1990, 1997, 2002)

regularity. If this embedded regularity can be uncovered and identified, it can potentially be exploited by the decision maker:

- short term predictions; given sufficient data, time series analysis permits one to make short-term predictions about a system's behavior, even if the system is chaotic; moreover, these prediction can be made even when the underlying dynamics is not known.
- long-term trends; if the attractors of a system are known or can be approximated (say, from available historical time series data), long-term trends can be predicted; knowledge about visitation frequencies of points on an attractor provides insight into the probabilities of various possible outcomes; Lyapunov exponents quantify the limits of predictability.
- qualitative understanding of a social system[14]; the information dimension can be used to estimate the minimum number of variables needed to describe a system; moreover, if a system can be shown to have a small non-integer dimension, it is probable that the underlying dynamics are due to nonlinearities and are not random.

It must be added that far from being unmanageable, chaos is in fact to some extent predictable and manageable (Hübler, 2005). Hübler states that in the management of chaos, the more unstable the causal field, the gentler must be the touch in trying to control the dynamics of the phenomena in question. Heavy handed control tactics might work with simpler attractors but for more complex ones prediction control efforts lose efficacy.

When presenting inspiration from chaos theory and complexity theory, or better, complexity theories on prediction-oriented security analyses, it is worthwhile to remember that already in the 1960s in sociology the first doubts on prediction in social sciences were cast due to the Heisenberg Principle which was used as to illustrate the impact of observer upon the subject of the study and which was to a large extent frequently abused afterwards. Even at present the works are appearing in which reference to the links between security issues, the first Gulf War and quantum mechanics are made at a metaphorical level (Glynn 1995). Validity of that kind of metaphors, at least at the level of policy oriented language seems rather dubious.

The second barrier of predictability is associated with the very definition and identification of social systems. Social systems are both cognitive constructs and composition of tangible elements. Taking into account the intangible aspects of social systems any research soon faces the barriers of self-reference, recurrence, etc., Even assuming a simplification that a social system can described with relevant parameters there is always a barrier of their relevance and measurement. Since it is not always possible it can be concluded that prediction is impaired already at the stage of system identification.

The third epistemological obstacle of prediction in security-related studies has been already mentioned earlier when the inherent limits of mathematical modeling going to the very foundations of mathematics have been described with reference to the works by Chaitin (2001) (Kolmogorov or Chaitin complexity of the prediction problem – the length of the shortest programme that generates the prediction (taking the program to include the initial data as well as the instructions), and Wolfram (2002) (Computational Irreducibility).

The fourth epistemological factor influencing prediction-oriented discourse in security studies was associated with development of post-modernist and post-structuralist approaches. Taking in a simplified way, by putting stress on subjectivity, intersubjectivity and discourse, post-modernism denies any possibility of prediction (Hopf 1988), (Der Derian and Shapiro 1989), (Webb 1995). This research approach developed in several so-called critical writings on security rejects possibility of prediction, even with the use of mathematical models since mathematics is also regarded not as an objective instrument of identification of invariants in the social phenomena, but as a social construct (Albert and Hilkermeier 2003) (Patomäki 2006, 2008).

It should be underlined that in one of the most influential books on security (Buzan et al., 1998) post-modernism, in not an orthodox form, is the foundation of security as an "act of speech" and of securitization. The authors of that book do not deny possibilities of prediction, they simply do not express openly their views on that topic. The fact that security is becoming a subjective (or inter-subjective) category moves attention from traditional approaches to enhance predictability to the investigations into cognitive processes, social communication, decision-making processes. And this makes prediction even less feasible, since it is becoming dependent on the studies of mental processes of individuals, not only key decision makers but also on all actors involved in the securitization processes.

There are also several attempts to make a kind of synthesis of the concepts of complexity and chaos with the ideas of post-modernism. Usually they are built upon application of metaphors and analogies of chaos, non-linearity and other "fashionable" utterances drawn from the vocabulary of complexity studies. Some of them refer to the limits of prediction in non-linear or chaotic discourse and if well-grounded in security theory they can provide new insights, predominantly for description and explanation although the

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[14] Ilachinski (1996, p. 59) focuses solely on battlefield,

language of security theory and policy enriched with those terms could be also useful in predictive, normative and regulatory approaches.

Applications of the language taken from complexity studies may have sometimes a completely abusive character. On the contrary, in some cases they were based upon superficial, simplified and scientistic speculations as it was shown in the case of the (in) famous "Sokal Hoax" (Sokal and Bricmont 1998).

Obviously, the above two epistemological limitations of predictability cannot be completely eliminated but at least they negative impact can be compensated if the researchers and policy makers in security-related fields are aware of the following rules:

- mathematical models of social systems based upon complex systems ("hard" complexity studies) should be made with deep understanding of formal sense of the models and deep understanding of social phenomena which are modeled,
- there is not any unique models of complexity, usually in recent studies they are linked with Complex Adaptive Systems although in some other writings reference is made to synergetics (Haken 1997), thermodynamics, both classical and non-equilibrium thermodynamics (Prigogine 1997, 2003), (Prigogine and Stengers 1984).
- models and analogies drawn from various areas of "hard" complexity studies should be applied only when it is possible to explain their usefulness, not only when they seem to reflect the intuitions of the users.

Associated with the above one is the fifth factor - broadening and deepening of the meaning of security. While for a narrowly defined state military security predictions based upon more or less advanced mathematical modeling including, for example, game theory or statistical research, seemed legitimate, thus for numerous interpretations of security in different sectors any universal methods of prediction do not seem relevant. In such a case only specific methods applied to more or less precisely defined issues may help in identification of the future states of the world.

It should be taken into account that broadening and deepening of the sense of security is associated with "securitization". In such case the aforementioned limitations of prediction in intersubjectivity must be taken into consideration.

The sixth epistemological barrier of prediction is deriving from a constructivist character of contemporary definitions of security. If the threat is a product of intersubjective discourse, or "securitizing" move, thus its prediction can be also viewed as a process in which objective characteristics of threats are mixed with subjective interpretations.

Both classical "subjective" and an intersubjective approach to threats brings to the fore another, seventh, barrier of prediction. In the core concept of security threat is associated with a disruptive rapid change (disturbance) thus prediction focus on possible appearance of disruptive negatively assessed change. But in some cases the threats are not unexpected but may be prolonged like, for example, excessive use of natural resources. Therefore prediction of their occurrence does not concern just events but may be based upon analysis of processes. In that case it is necessary to identify which gradual processes/phenomena assessed positively may bring about negative consequences – the "boiling-frog parable" (Senge 1990, p. 22).

The last, eighth epistemological barrier of prediction in security theory, is stemming from natural limitations of human reasoning expressed in bounded rationality (Simon 1997) and prospect theory (Kahneman and Tversky 1997)

The above collection of epistemological barriers or prediction in security theory and policy is neither complete nor precise. Threats viewed as results of discourse may lead to the situation when prediction cannot solely rely upon mathematical modeling but should also be supported with a proper psychological, social and political context. i.e. prediction in the right moment for the right people. In such case two kinds of complexity can be involved. "Hard" complexity based uniquely on mathematical modeling and "soft" complexity providing the context for elaboration of the models and for interpretation of their results. In another situation, when mathematical modeling is irrelevant or impossible, the language of analogies and metaphors provided by "soft" complexity can be used in creating qualitative predictions.

Sociopolitical determinants

First and foremost, it is the increased complexity of social systems treated as a socio-political phenomenon characterizing the modern world adds new constraints to the already well-known epistemological barriers of predictability. Complexity of the world significantly undermine two traditional pillars of prediction – possibility of reduction the relations to more or less simple causal and separable links, and possibility of application of inductive reasoning based upon extrapolation of earlier trends. In the complex world with overwhelming amount of information it is becoming less plausible to expect that the past events will be continued according to the same patterns. This incapability of humanity to deal not only with prediction, but with comprehending of the complex world has received a catchy term "the ingenuity gap" (Homer-Dixon 2002). By the same token it may be added that modern complex "risk society" produces risk due to its complexity (Beck 1986, 1992, 1999).

The second sociopolitical factor, an unexpected and to a large extent unpredicted collapse of the Soviet empire, is putting in doubt prediction capabilities not only of the security studies as a scientific domain. It also cast shadow on the intellectual qualities of people involved in that field as well as on social credibility and legitimacy of institutions dealing professionally with prediction of security threats. After the end of the Cold War representatives of all areas of security-related disciplines have found themselves in a very discomforting intellectual position. Thousands of "sovietologists" and "kremlinologists" were faced by a fact that their analyses, or better discourse, proved almost useless in making at least partly successful long-term and medium-term predictions.

Only a few authors, Karl W. Deutsch (1954), a Soviet dissident, Andrei Amalrik (1970) and a sociologist, Randall Collins (1986) heralded the imminent collapse of the Soviet system. Amalrik's visions were based on intuitions and knowledge of the Soviet reality. Deutsch saw the roots of failure of the Soviet system in inherent contradictions and pathologies in centralised systems of governance, while Collins' prediction was more rigorous, deriving from analysis of geopolitical forces standing behind the dynamic of change in the USSR.

Majority of theoreticians and policy planners in economics and in politics, both in the East and in the West, were not able to make predictions increasing their readiness to implement new solutions after the collapse of the USSR. The reasons for such a course of event were assessed by several leading IR scholars (Gaddis 1992), (Hopf 1993), (Singer 1999).

Obviously, it was not the first time when security theory and policy were confronted with surprising course of events. Predictions of Norman Angell's (1910) "Great Illusion", or the vision of the year 2000 elaborated by Kahn and Weiner (1967) did not prove correct.

The case of unexpected and unpredicted peaceful demise of the Soviet Union can be connected with the third sociopolitical factor determining predictability in security theory and policy which is resulting from psychological and social mechanisms distorting the processes of prediction by individuals and by institutions. These mechanisms are associated with psychological, social and political constraints. It frequently happens that some of the predictions are suppressed due to various mechanisms of inhibition at the level of individuals, e.g. routine or excessive self-confidence and lack of self-criticism. There are also numerous social mechanisms inhibiting prediction, various forms of more or less open censorship - political correctness, political and cultural constraints, institutional inertia, self-delusion, etc.

The above socio-political constraints are perfectly reflected in a comment made by Hopf in the discussion on the reasons for failures of prediction of an unexpected end of the Cold War. “Can anyone imagine a senior international relations scholar applying to the Carnegie Endowment in 1972 for a research grant to investigate the conditions under which Moscow would most likely voluntarily relinquish control over Eastern Europe?” (Hopf 1993, p. 207).

In an extreme form it may lead to a situation when some security scholars, advisors and policy makers would refrain from presented all possible scenarios since they might be afraid of preparing “politically incorrect worst case scenario”. Some more recent cases, e.g. confusion around existence of the WMD in Iraq may only raise doubts if institutions professionally involved in gathering information and providing scenarios and advice are not subdued to the mechanisms of political influence distorting validity of their analyses.

In this case a special place is taken by “unthinkable threats”. A few questions are immediately arising. Why are they unthinkable? Is it due to basic epistemological reasons, or due to some known and not yet known psychological and socio-political limitations? Are there any socio-political constraints of self-blindening?[15]

Emergence of global terrorism, sometimes on a mass-scale is the fourth sociopolitical factor having a strong impact on prediction in contemporary security theory and subsequently, on security policy. Limited predictability or complete unpredictability are the essential parts of the methods of terrorist warfare. Due to scale and increased complexity of social systems making them highly vulnerable to unsophisticated yet damaging threats, limits of predictability of terrorist attacks increase their social impact.

The fifth sociopolitical factor determining prediction in security theory and policy is resulting from a kind of “information asymmetry” or “uneven knowledge” especially significant in security-oriented research. It is easy to come to the conclusion when reading the works in IR that the so-called empirical basis of research, and alas, theoretical generalizations, is in most cases based upon openly available sources – media, reports, etc. Even in not so much security sensitive considerations there are always the distortions resulting from natural barriers of social communication. However, in security discourse the barrier of secrecy is an inherent factor. Therefore any critically thinking analyst may feel discomfort realizing that his/her research on security sensitive issues may be put in doubt or even ridiculed when a true state of affairs is disclosed, say, twenty or more years later.

[15] It would be perhaps worthwhile to re-read the book by Barbara Tuchman (1984) „The March of Folly” with the use of concepts taken from the discourse on the role of prediction in politics and security.

All the above limitations of prediction contribute to descriptive uses of the term complexity with various metaphorical interpretations in security-related discourse. In terms of more precisely defined ideas the sense of prediction in security studies can be described with both "hard" and "soft" complexity.

As a source of inspiration for analysis of the links between complexity, prediction and security, an idea by Fellman and and Wright (2003) can be described. Although the authors use develop their concept for assessing prediction of terrorist activities, their idea seems very relevant to more general considerations on security.

In most cases threats to security in all sectors fall into the category of irreducible complexity and ambiguity. In terms of formal properties of the system, security threats fall somewhere between the purely chaotic and the fully deterministic realms, which we represent as a non-linear dynamical system, characterized by a low-order chaotic attractor.

Such phenomena, which exhibit regularity but not periodicity (i.e., locally random, but globally defined), can be predicted and controlled with two approaches applied by Farmer (2001) to prediction of terrorist actions. These approaches can be extended to any security threat (disturbance) in all security sectors. One is to predict the detailed trajectory that the system will take. To predict the trajectory of something, you have to understand all the details and keep track of every little thing. This is particularly so when it involves a large number of independent actors, each of which is difficult to predict. The other road to prediction and control is to change the system in a more fundamental way. Change the parameters and get rid of the behavior you don't want.

It may be thus concluded that although total predictivity is impossible, in security-oriented research a limited prediction is possible at several aggregate levels – beginning from the global, through inter-state and state, and ending with non state actors and group behavior – mid-range level. Fellman and Wright (2003) link the mid-range level with improving the performance of those organizations tasked with preventing or combating terrorism. This can be achieved not at the level of state leadership, and not at the level of mapping and predicting the behavior of each individual terrorist, but rather at an intermediate or organizational level - "action at the mid-range".

5. Prediction and critical approaches in security studies

All the above discussion of the links between complex systems and prediction in security-oriented considerations were based upon classical, rationalist assumptions.

Mathematical models and analogies, and metaphors deriving from them were used according to neo-positivist, more or less empirically supported studies.

As it was stated previously in contemporary security theory, the idea of security is deepened and broadened, threats have lost objective character and are perceived as an outcome of intersubjective discourse leading to securitization. This approach can be divided into two basic trends. The first one developed under influence of postmodernism, poststructuralism, social constructivism, and the second, influenced by critical realism. All those ideas can be directly linked with "soft", verbally described complexity.

Similarly as in other social studies based upon modern ideas of social sciences deriving from Jean Baudrillard, Jacques Derrida, Michel Foucault criticism is addressed against (neo)positivism, rationality, prediction and control of social phenomena. Subsequently, limitations of prediction in critical approaches in security theory can be divided into two, partly overlapping groups. The first includes limitations stemming from subjectivity and intersubjectivity and the second, resulting from critical realism.

Diffusion of ideas of postmodernism, poststructuralism opened the way for the-so-called critical trend in theory of International Relations, and in security theory (Hopf 1998), (Webb 1995) (Critical Approaches to Security in Europe: A Networked Manifesto 2006) (Guzzini & Jung 2004) .

This criticism is becoming somehow discomforting for the mainstream theory of deepened and broadened security theory as well as for alternative trends, such as peace research. The simplified essence of the problem results from that fact that in postmodernism and constructivism, both meaning and reality are socially constructed. Subsequently, any temporal regularities which could be a basis for prediction cannot be treated as true, "objective" regularities used in mathematical modeling. If prediction is impossible, and even if technical discussions on the barriers on prediction are purposeless, thus discourse on security is facing a challenge – how to define threats, risks, etc. Even in the already mentioned idea of securitization some assumptions about the future state of events are unavoidable.

An attempt of linking critical approach in security theory with constructive proposal about prediction has been made by Heikki Patomäki (2006, 2008). His main assumption is that "Notwithstanding the lack of stable regularities, the whole point behind the peace and security studies is that they should contribute to the better understanding of the future conditions of peace and security" (Patomäki 2008, p. 6).

The dilemma between the need for prediction in security theory and policy and impossibilities and limits of prediction unsolvable in post-modernist and post-structuralist approaches is dealt with the use of a specific ontological and epistemological approach.

The point of departure of discussion is critical realism, a philosophical approach that defends the critical and emancipatory potential of rational (scientific and philosophical) enquiry against both positivist, broadly defined, and 'postmodern' challenges. Its approach emphasises the importance of distinguishing between epistemological and ontological questions and the significance of objectivity properly understood for a critical project. Its conception of philosophy and social science is a socially situated, but not socially determined one, which maintains the possibility for objective critique to motivate social change.

Critical realism is presently most commonly associated with the works of Roy Bhaskar (1975/1997, 1978). Bhaskar developed a general philosophy of science that he described as transcendental realism, and a special philosophy of the human sciences that he called critical naturalism. The two terms were elided by other authors to form the umbrella term critical realism[16].

Transcendental realism attempts to establish that in order for scientific investigation to take place, the object of that investigation must have real, manipulable, internal mechanisms that can be *actualised* to produce particular outcomes. This is what we do when we conduct experiments. This stands in contrast to empiricist scientists' claim that all scientists can do is observe the relationship between cause and effect. Whilst empiricism, and positivism more generally, locate causal relationships at the level of events, Critical Realism locates them at the level of the generative mechanism, arguing that causal relationships are irreducible to empirical constant conjunctions of David Hume's doctrine. Regularities are not stable and/or are not perceived as stable. In other words, a constant conjunctive relationship between events is neither sufficient nor even necessary to establish a causal relationship.

Critical naturalism argues that the transcendental realist model of science is equally applicable to both the physical and the human worlds. However, study of the human world is something fundamentally different from studying the physical world. Critical naturalism therefore prescribes social scientific method which seeks to identify the mechanisms producing social events, but with a recognition that these are in a much greater state of flux than they are in the physical world (as human structures change much more readily than those of, say, a leaf). In particular, we must understand that human agency is made possible by

[16] Introduction to critical realism is partly based upon the Wikipedia (http://en.wikipedia.org/wiki/Critical_realism), 17 August 2007.

social structures that themselves require the reproduction of certain actions/pre-conditions. Further, the individuals that inhabit these social structures are capable of consciously reflecting upon, and changing, the actions that produce them.

The concept of an open system is one of the foundations of reasoning in critical realism. Following Bhaskar (1978, p. 76-86), Patomäki (2008, p. 4) depicts an open system as an opposition to a closed system. In a closed system extrinsic and intrinsic conditions remain constant. Although external influencers exert some impact on a system its structure can be treated as given or constant, or at least isomorphic in time.

Wherever possible, in laboratory experiments researchers may create artificial extrinsic closures to identify the causally powerful mechanisms which can be also relevant to open systems. Similar closures are not possible in social systems and due to their reflective character they cannot be treated as closed in which any constant regularities (conjunctions) exist.

The distinction which can be made in theoretical discussions is somehow abstract and it should be agreed that it is not always possible to delineate an open or a closed system. Patomäki's (2006, p. 5) approach to prediction in security discourse refers directly and indirectly to qualitative complexity theory when he reminds that social systems are not only self-reflexive but also self-producing (autopoietic)[17].

Therefore in a flux of social processes always exist some not-so-well-structured patterns. The economist Tony Lawson calls such patterns "demi-regularities" or "demi-regs," by which he means "a partial event regularity which *prima facie* indicates the occasional, but less than universal, actualization of a mechanism or tendency, over a definite region of time-space" (1997, p. 204). In security theory and policy democratization in the last twenty years, increased number of people living in urban areas or technology-led arms race can be treated as exemplary demi-regs.

The general ideas of demi-regs and their limitations in prediction translate into some specific features of those who describe reality and attempt to make predictions. From a broad variety of characteristics described by Patomäki (2007, p. 7) the following ones can be mentioned:

- interference between a subject's interest in an object and his/her knowledge (conscious - lying, semiconscious – wishful thinking, unconscious – rationalization of motivation; mystifications or reifications of social structures (Bhaskar 1979, p. 74),
- failure to see the particular image schemas, categorical structures, prototypes, frames

[17] Patomäki's reference to the concept of social autopoiesis creates a link with "soft" complexity of social systems analyzed by Niklas Luhmann .

or metaphors that give rise to particular forms of reasoning; human thought is mostly unconscious, abstract concepts are largely metaphorical, and embodied reason is emotionally engaged (Lakoff and Johnson 1999),

- the effects of social processes may be presented as being beyond the reach of human influence (reification of social systems),
- pathological learning (self-destructive learning) resulting from will and power, which may lead to overvaluation of the past against the present and the future, the overvaluation of experiences acquired in a limited environment against the vastness of the universe around us; and the overvaluation of present expectations against all possibilities of surprise, discovery and change (Deutsch 1963, p. 248).

While postmodernism and postructuralism do not provide any constructive and operationalizable recommendation for prediction, critical realism provides a background for more productive approaches. Critical realist ontology, frequently applying the metaphors of deriving from the discourse on complexity, explains why there are multiple possible futures. The actual is only a part of the real world, which also consists of nonactualised possibilities and unexercised powers of the already existing structures and mechanisms that are transfactually efficacious in open systems. Furthermore, emergence is also real. It is possible that new powers, structures and mechanisms emerge and existing ones may disappear. Patomäki (2006, p. 9)

Critical realism also brings about a strong normative load. In an interpretation presented by Patomäki (2006, p. 10-11) Bhaskar is concerned less with the methodology of studying multiple possible futures than with establishing the ontological and epistemological grounds for emancipatory social transformations. Rather than theorising further on possible futures, he is mostly interested in establishing an abstract direction for emancipatory change and explicating conditions for the possibility and success of emancipation, emphasising the role played by the social sciences.

For Bhaskar (1979, p. 43-44), critical social sciences must be involved in making better futures. Society is both the ever-present condition (the material and formal cause) and the continually-reproduced outcome of human agency.

Like Ricoeur, Bhaskar argues that this ontological condition makes the relationship between a researcher and his/her object of knowledge more complicated than in the natural sciences. Although (also contemporary) social objects usually exist and function independently of the researcher, subject and object are nonetheless related both internally and externally.

Normative load of prediction makes the process even more complex and diminishes expectations for predictions assessed in traditional terms of plausibility and accuracy. Using another vantage point it may be stated that prediction is treated as a learning process and critical realism adds a normative approach to that process[18]. Therefore, improving prediction is equivalent to improvement of both individual and social learning.

If regularities in social systems are always purely self-reflective, or at least are under partial influence of self-reflective human decisions and actions thus in predicting social phenomena, social, psychological and cultural factors must be taken into account. An orthodox interpretation of reflexivity in social systems may lead to the conclusion of limited relevance of application of mathematical modeling in studying "reified" social phenomena.

Due to statistical character of some social phenomena, e.g. urban dynamics, exploitation of natural resources, financial markets, the human factor – self-reflexive decision and action is not so openly influential/visible. Thus in such cases a higher degree of objectivization ("reification") is acceptable and mathematical modeling/simulation taken from science can be used for prediction.

Recommendations for prediction in security-oriented sciences which results from critical realists concepts can be summarized as follows. The concepts of 'open system' and 'contrastive demi-regularity' are also essential to futures studies. Patomäki (2006, p. 29-30) has argued for redefining an open system in terms of self-organising systems and in accordance with recent developments in the life and cognitive sciences. Demi-regs can also result, perhaps indirectly, from homeostatic causal loops, self-regulation via feedback and reflexive self-regulation, i.e. from internal restructuring aimed at some kind of order and regularity. Regularities are not therefore necessarily indicative of any sort of closure but may result from the active monitoring and regulation of conditions and processes. Despite the existence of self-producing and -regulating systems, the analysis of unintended consequences must be a central focus in all contexts. Self-regulation may be absent, inefficient, illusory, contradictory or self-defeating and unintended consequences may in fact play the main role in sustaining social mechanisms and structures.

Despite advanced theoretical considerations, the main conclusions about prediction stemming from critical approaches in security studies are relatively simple.

First and foremost, any prediction cannot be made "objective" and various trends of social sciences methodology differ solely in the method of defining approaches to subjectivity. In

[18] Prediction as a learning process has been widely used in normative, prediction-oriented management theory in the scenario planning (van der Heijden 1996).

consequence of that stress should be put on creating scenarios reflecting deep cultural and psychological patterns. Creating scenarios should be viewed as a specific case of story-telling determined by culture and interests of the story tellers.

Second, prediction can be viewed as creating scenarios of possible futures in a self-reflexive process of learning. Scenarios should be thoroughly and deeply analyzed as to disclose possible deeper meaning. It is not sufficient to identify some relevant demi-regs and then specify the geo-historical conditions for their continuation. These empirical facts and their meaning and implications should first be critically examined.

Third, reflexive monitoring of temporal action requires that actors themselves tell stories about the past, the present and the future. They also know that (many) others are equally concerned about anticipating future developments. Moreover, structured and reflexive anticipations may also constitute a part of the organising rules and principles in a social system. The case in point is an organisation that plans its future actions on the basis of various anticipations and forecasts. Actors may also try to shape others' anticipations in a variety of ways. For example, modern ideologies and propaganda are often based on creating and repeating particular—and frequently categorically false—anticipations of better futures. Moreover, anticipations of particular futures can sometimes be part of a strategic game between actors. When information is asymmetric, actors may also try to manipulate anticipations made by others.

Fourth, according to the fundamental idea of prediction based upon critical approaches, scenario making is not a value-free, objective process. On contrary, it is always needed to make scenarios a part of social normative learning. So any manipulation of others' anticipations should be avoided. Patomäki (2006, p. 28) concludes: "Social scientific scenarios should be public and based on criticisable intersubjective truth-judgments…..A study of possible futures also involves manifold ethico-political choices; the building of scenarios for possible futures always has a moral aspect. For example, if we have good reasons to believe in the possibility of a nuclear war, we should use our story-telling capacities in making a contribution towards avoiding that outcome. Constructing scenarios about desirable and feasible futures is a legitimate task for the social sciences".

6. Conclusions

The above survey allows for drawing several conclusions stemming from applications of complex systems models in prediction in security-related research and policy. First and foremost, it has to be emphasized that the aim of the study was to assess how complex systems models can help in better understanding limitations of prediction of risk, threats etc., in security studies, and not to study if prediction can be directly improved with the use of those models. It must be also added that although the conclusions refer to security-oriented research they can be extended to other normative domains of social theories, like for example, management.

Prediction is one of the aims of mathematical modeling of natural phenomena. This aim is much more limited when related to social systems. “Traditional” mathematical methods applied in normative social sciences or security studies, aimed predominantly at increasing predictive capabilities – operations research, early versions of systems analysis.

Broadly defined complexity models, including the so-called chaos, applied in physics and biology helped to disclose limitations undermining traditional expectations about possibilities of prediction. Those barriers of predictability, along with other specific barriers, typical for social sciences, can be also be referred to in the discussions on security theory and policy.

The most important conclusion deriving from the use of complex systems models in security research relates to some early expectations explicitly and/or tacitly included in applications of mathematical modeling in that domain. These expectations expressed in early versions of systems analysis and sometimes continued since then were based upon the assumptions that limits to prediction can be overcome thanks to better mathematical models, more data, and more efficient number crunching hardware. The first limitations of that way of reasoning derived from the concept of bounded rationality by Herbert Simon (1997). Discovery of properties of non-linear models exposing various forms of chaotic behavior provided final proofs for unavoidable barriers of prediction in any mathematicized social studies.

The above conclusions are rather well-known and the paper only provides just another recollection of the barriers.

Deeper insights stemming from applications of complex systems concepts in security research are resulting from deeper understanding of dynamics of social systems achieved with the use of those concepts applied both as mathematical models, and analogies and metaphors. Thanks to more subtle description and explanation of causal links allowing for discovery of otherwise concealed phenomena, prediction of behavior of social systems can be improved indirectly, although some ameliorations of direct predictions are also possible.

Complexity models paradoxically show that stable regularities in observed phenomena do not exist. So the usefulness of those models for prediction is twofold. Firstly, help in better understanding of the phenomena under study thus in some way enhance predictive capabilities.

Here some conclusions by Ilachinski (1996, p. 56) can be recalled. The most important lesson of deterministic chaos is that dynamical behaviour that appears to be chaotic or random often contains an embedded regularity. If this embedded regularity can be uncovered and identified, it can potentially be exploited by the decision maker for short-term predictions about a system's behaviour. Long-term trends can also predicted if the attractors of a system are known or can be approximated (say, from available historical time series data). The information dimension can be used to estimate the minimum number of variables needed to describe a system; moreover, if a system can be shown to have a small non-integer dimension, it is probable that the underlying dynamics are due to non-linearity and are not random.

Secondly, complexity models are helpful in disclosing new limitations of prediction that in consequence leads to better prediction – we know better what is not predictable. Such a situation is to some extent similar to the consequences of quantum mechanics although a thorough discussion of that parallel remains far outside of this study.

It must be also added that the conclusions refer both to traditional, (objective) interpretations of security and broadened and deepened interpretations of security viewed as a result of intersubjective discourse. Mathematical models are closely linked with traditional understanding of "objective" security, while models, analogies and metaphors are applied in qualitative considerations and in constructivist, broadened and deepened ideas of security deriving from "securitization" proposed by Copenhagen School. .

A specific example of Complex Adaptive Systems can be also recalled. On the one hand they allow for more reality-relevant mathematical models illustrating "emerging properties". They do not enhance predictive capabilities directly but in many instances provide unexpected, non-intuitional heuristically valuable solutions. ;

In the field of "objective" security, most important expectations can be associated with mathematical modeling. More advanced models and more efficient number crunching undoubtedly will allow to elaborate models simulating various security-oriented phenomena. This line of research is rather obvious.

The less evident direction of development of applications of complex systems ideas in security theory and policy is associated with qualitative, or "soft" complexity ideas. It concerns all of the above areas described in the survey, beginning from classical IR theory and ending with warfare principles. A mathematical model may allow prediction but absence of understanding of its context and real limitations can make its usefulness limited.

Therefore it seems that in the future research on security more attention should be given to epistemological foundations and qualitative interpretations of complexity. It would help in better comprehending the context of applications of complexity-based mathematical models in security research. Going further, it may be added that perhaps a synthesis of “hard” complexity with “soft” complexity could become a new instrument of better understanding prediction and its limitations in security-related discourse in all areas, beginning from typical academic deliberations and ending with combat-related analyses.

Two final arguments for new research on epistemological foundations of applications of complexity models in security and on qualitative interpretations of complexity are resulting from a current situation in military security studies and military planning. While specialists and various government and non-government think-tanks deliver more and more sophisticated mathematical models, it happens frequently that those models are not properly applied due to some contextual, socio-political context. This author proposes to call this phenomenon “politically correct worst case scenarios”.

Better understanding socio-political context of elaboration and implementation of predictive complexity-based models in security research and policy requires deepened studies in which a mixed quantitative-qualitative approach to complexity seems necessary.

The second argument for developing qualitative-quantitative methodology of complexity-based modeling in all areas of security-oriented research is stemming from the very character of the asymmetric warfare and increasing significance of understanding of consequences of cognitive processes of actors. Modern complexity modeling, especially Complex Adaptive Systems and/or agent-based modeling allow for more advanced studies of cognitive processes of agents involved, should it be politicians, military commanders, terrorists and the like. What remains unknown are the patterns how collective behavior is determined by cognitive processes of the agents, i.e. how individual learning determines collective learning and what kind of barriers may emerge out of that. The mixed approach based upon quantitative-qualitative complexity methodology seems to be most adequate in that case. It should allow to eliminate the threat of elaboration of “politically correct worst case security scenarios”.

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