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Understanding Crisis. A System Dynamics Approach

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Abstract

The article discusses how a crisis can be interpreted from the Systems Dynamics and Science point of view. It points at the beginning to the lack of formal definition of crisis and intuitive application of this term to diverse situation. Crisis is seen as a collapse of the system structure and invasion into its systemic properties: connectivity, closure, and stability. A simple simulation model of the Kaibab Plateau problem (predator – prey) is developed. Its simulation shows that sometimes crisis solution is more dangerous that crisis itself, and that in self–regulating systems (most complex systems are self–regulating) the system itself is capable of re–gaing its pre–crisis stage.

1. Introduction

Amazingly, the concept of crisis, although so often used in various analyses and common language, has not been reached by a precise, scientific definition. Most encyclopedias and vocabularies use this term frivolously judging that readers do understand what has not been correctly approached by sciences. For instance, Encyclopedia Britannica does not contain an explicit definition of the crisis term. Instead, it invites us to explore other terms for which crisis plays an important role. Other publications use freely the term in its applicative context without defining the concept and explaining its contents and nature.

In presented paper we attempt to analyze the concept of the crisis assuming that crisis is complex and dynamic phenomenon. Brief presentation of how contemporary literature deals with this concept precedes mainstream of our analysis. Our focus will highlight crisis as normal state of any system and a simple, abstract situation will be used for this purpose. This situation will be converted into a simple mental model which, in turn, will give rise to formal model and simple simulation. Simulation results and their analysis lead us to proposing some hypotheses regarding the dynamic nature of the crisis.

2. What is crisis?

Lacking a formal and commonly accepted definition of crisis, we should turn our attention to two sources that possibly shed some light on this concept. First – in the literature the term crisis is used frequently and in different contexts. And secondly – crisis, basically due to its dramatic connotation, has played an important role in human practice and has been extensively applied to many situations.

Most available information sources, even if they do not define the term crisis more closely, point to its dynamism. Enciclopedia Britannica (vol. 3, pp. 387–388) does not contain any definition and convey readers to another term – climax – admitting that apparently crisis cannot be explained and understood as a standalone phenomenon. Crisis stems from Greek term "ladder" and it is associated with climax as literary construction. In literary fiction, climax is the point at which the highest level of interest and emotional response is expected. And further (p. 388) – "...in the structure of a play the climax, or crisis (author's underline), is the decisive moment, or turning point, at which the rising action of the play is reversed to falling action". As it will be shown later, the Encyclopedia Britannica's conception of the crisis is very close to what will be presented and analyzed in this paper.

According to other opinions, the term *crisis* comes from the Greek noun *krisis* (choice, decision, judgment), deriving from the Greek verb *krinein* (to decide). The rhetorical terminology points to crisis as the turning point in a decision, illness, or argument. Its frequent appearance with reference to historical events, periods, or processes goes back to late XVIII century, and then it has become a catchall term for a crucial or decisive stage or state of affairs.

The history of the notion of crisis veers between failed attempts at precise definition and its inflation and devaluation as a tool of analysis (probably the latter best characterizes contemporary writings). Leaving alone more specific analysis, if we are to consider a set of circumstances as crises, they must occur in the course of specific events for which they constitute critical episodes in a life cycle, indices of structural dysfunction, or corollaries of revolution. For this reason the rhetoric of crisis is usually charged with drama, developed as narrative, objectified as analysis, and pinned to empirical data, in this exact order. Therefore, scientific and rational analysis is subordinated to previous dramatic assessment of the circumstances that have occurred.

Two comprehensive entries on crisis in the International Encyclopedia of the Social Sciences (1968) and the first Dictionary of the History of Ideas (1968) emphasized, respectively, "unrestricted usage" and continuing "uncertainty." Substantial number of studies had accumulated on crises with contextual reference to political, economic, moral, and psychological dimensions. The most exacting definitions were abstract and redundant, and while suggestive connections were being made across various fields, they came at the expense of conceptual clarity and coherence.

The widespread interest in and development of crisis studies had peaked by the early 1970s. Toward the last decade of XX century, the language of crisis was worn out by overuse, in particular with reference to political writings and analyses. The big crisis

debates among historians mostly receded before the emphasis on long–term structural trends, the dismantling of so–called grand narratives, the deconstruction of the rhetoric of history, and the unfazed appreciation that conflict and confrontation were not the exception but the rule in history. In particular, political writings after the fall of the Berlin Wall claiming new, after Cold War world, pointed to crisis as a normal state of affairs preceding structural changes in a broader context in which crisis belongs. The most concerted theoretical attention to crisis came from political scientists who continued to model schematic strategies for "crisis management," especially in international affairs. They salvaged analytical precision only by abstract model building and academic distinctions such as a sequence of phases of international crises from onset and escalation to de–escalation and impact.

Another worth mentioning development of this term is very recent and has occurred in the early twenty–first century. Social movements and numerous governmental and non–governmental institutions, have appropriated the term as a watchword to promote attention and intervention in many publicly acclaimed causes ("crisis" of genocide, minority rights, HIV–AIDS, environmental degradation, or economic globalization). Such a context and manner of making use of the term "crisis" along with the extent of everyday usage, have ranked it down to an all–purpose slogan or a banal cliché.

It is not ironic that the major impetus to the development of contemporary crisis theory grew out of a psychiatrists' involvement in an area of human tragedy. Numerous writers have recounted the events first reported by Dr. Erich Lindemann in his classic article in 1944[1], where he is reporting on survivors of the disastrous Cocoanut Grove nightclub fire of 1942, in which over 490 persons finally died, were taken to Massachusetts General Hospital, where Dr. Lindemann began to notice certain characteristic responses on the part of those who had lost close relatives in the fire. The article and Lindemann's analysis has originated many research and psychological intervention streams, exisiting and striving up–to–day. As the result, in psychology and psychiatry, "crisis" is defined as "an upset in a steady state, a critical turning point leading to better or worse, a disruption or breakdown in a person's or family's normal or usual pattern of functioning. The upset, or disequilibrium, is usually acute in the sense that it is of recent origin. A crisis constitutes then circumstances or situations which cannot be resolved by one's customary problem–solving resources. In this sense:

- a crisis is different from a problem or an emergency. While a problem may create stress and be difficult to solve, sometimes the family or individual is capable of finding a solution. Consequently, a problem that can be resolved by an individual or a family is not a crisis.
- contrary to crisis, an emergency is a sudden, pressing necessity, such as when a life is in danger because of an accident, a suicide attempt, or family violence. It requires immediate attention by specialists trained to respond to life–threatening events. If a situation can wait a longer time for a response, it is a crisis and not an emergency.

[1] Cited after: A Tribut to Erich Lindemann, in: "American Journal of Community Psychology", Volume 12, Number 5 / October, 1984.

Psychology and psychiatry claim that there are three basic elements of a crisis—a stressful situation, difficulty in coping, and the timing of intervention—interact and make each crisis unique. Apparently, this approach, although dominating in classic and contemporary psychological crisis theory, is lacking precision and objectivity. "Stressful situation", "difficulty in coping" and "timing of intervention" are all depending on the crisis–holder and interventor's assessment/emotions and they not only determine the "uniqueness" of the crisis but also influence on whether or not a situation deserves be called as crisis.
It would be acceptable if the term crisis has been only applied to human life and belong to the psychology and psychiatric domain. Nevertheless, ss it was mentioned, crisis concept has been gradually (yet effectively) transferred to other areas of human and social practice. In management, where crisis has become one of the most popular (and abused) buzzwords, crisis is conceived as "situations causing a significant business disruption which stimulates extensive media coverage" (crisis). The public scrutiny that is a result from this media coverage often affects the normal operations of the company and can have a (negative) financial, political, legal and governmental impact. Substantial value destruction is to be feared of, especially when the crisis is not handled well in the perception of the media / public opinion.2 . Similar opinions can be found in Barton (2000) and Fink (2000).
In this article we seek more agent–free conception of the crisis phenomenon. If a scientific category is to be subject to methodologically correct analysis, transferred then to real situation/objects in which crisis is to be identified, then we need to create a foundation that is resistant and independent on subjective meanings, interpretation, and assessments. At least one theoretical current and tradition could be evoked here – General Systems Theory and other systems approaches deriving from there. Beginning during the 1930's and accelerating after WW II, scientists and philosophers from a number of different disciplines began to publish and discuss a series of papers on the common properties found in all systems. This search for universal laws pertaining to all systems came to be called General Systems Theory and it has not only borrowed heavily from a number of disciplines but has also made important contributions to them. Among those most affected are: biology, chemistry, computer science, economics, information theory, operations research, philosophy, physics, psychology, and sociology. In particular, Ludwig von Bertalannfy, co–founder of the General System Theory, has drawn attention to ecological properties of the crisis within a system.
A system may be defined as any set of two or more interdependent parts which has a relatively high degree of closure, connectivity, and stability. Under such a broad definition, virtually any pair of persons or objects can be considered as a potential system since at some level of specificity it can usually be demonstrated that "everything is related to everything else." Clearly such a definition is almost useless without the three important qualifiers. It is those qualifiers which make this particular definition of a system especially useful by providing the criteria needed to evaluate the quality of the system being considered:

- **Connectivity** – the degree of internal interdependence of a system – is reflected by exchanges occurring between the parts making up a system. If two or more parts

[2] http://www.valuebasedmanagement.net/methods_crisis_management_advice.html

of a system are highly interdependent, they must engage in a large number of interactions. If no interactions occur between the parts of a system, they are not interdependent and therefore they do not make up a system. Interactions may be made up of material goods, information, energy, services or even intangibles such as love and affection. Clearly some types of interchanges are more important than others and their volume and frequency of occurrence must also be considered. Direct measurement and comparison of interactions is extremely difficult in most situations, however. If we assume for the moment that all types of interactions are of equal significance, we may define the degree of connectivity of a system as the proportion of all those interactions which occur within the system compared to the maximum number of interactions which could theoretically occur. Connectivity tends to be less for large systems than for small systems. This is also a natural occurrence since increasing the number of components in a system increases the number of possible interactions which could occur within the system exponentially.

- **Closure** is a similar concept with the same measure of the number of interactions which occur among the parts of the system conceived as a fraction of all interactions occurred in a system. Put another way, system closure is the number of interactions which both begin and end within the system divided by the number of interactions which either begin or end within the system. Closure is thus reflecting the number of feedback loops in which a given part is involved. Notably, closure tends to be greater for large systems than for small systems. This is a natural occurrence since expanding the size of a system to include additional components usually, but not always, transforms a number of external interactions into internal interactions.
- **Stability**, the third definitional property of a system, refers to the relative length of time the system exists or recurs in substantially the same form. Since most systems are in continual change and evolution, the interpretation of stability is subject to considerable variation depending upon the needs of the particular observer.

3. Playground for crisis analysis – construction

As there is no objective definition of the crisis, we sought a situation perceived as such. It is the case of the Kaibab Plateau, widely presented (see e.g. Wilkinson 2004) and commonly used for didactic purposes as the simulation model (Sterman 2000). Kaibab Plateau is situated on the north side of the Grand Canyon in Arizona in the USA and consists of some 30,000 hectares. Prior to 1907 the deer herd there numbered about 4,000. In 1907, a law was passed banning all hunting of deer from the area. In addition, during the period from 1906 to 1931 almost 800 mountain lions were shot or trapped. As a result of the extermination of the Kaibab Plateau mountain lions and other natural enemies of the deer, the deer population begun to grow. By 1918 the deer population increased tenfold, and by 1924 the herd had reached 100,000. Then it started to decrease and by 1936 to 1940 it was around 10,000.

The deer feed on grass. Their natural predators in the region are primarily cougars (mountain lions). Another predators are ranchers wishing to graze maximum herds with minimum competition from other grazers (deer) and from the natural predators of the area (coyotes), and hunters wishing to maximize the sport opportunities (deer hunting).

In 1906, President Theodore Roosevelt established the Grand Canyon National Game Preserve on the Kaibab Plateau. His intention was to protect the mule deer from over-hunting by humans and predation by natural enemies. He knew that human activities had depleted wildlife species throughout the country, and only a few locations in the West still contained the numbers that had flourished a few decades earlier. Roosevelt hoped that future generations of wildlife enthusiasts would be able to visit the Kaibab Plateau to witness an abundance of wildlife not remaining elsewhere. His intention was to avoid upcoming crisis in the Kaibab Plateau ecology...

Kaibab Plateau model is presented below (Fig. 1). It is significantly simplified model as many important aspects of this habitat have not been considered here. It consists of three founding components: population of deer, population of predators, and graze food. The equations underlying the model define the relationships among all these components; for limited space reason they have been omitted in the text. In general, the population of deer and predators are governed by the concept of "carrying capacity" – the number of population members that can survive under existing conditions. When the size of either deer or predators population equals the carrying capacity, the population growth rate is zero. When the population size exceeds the carrying capacity, the growth rate becomes a negative number and the population decreases. In the case of an uncontrolled deer population explosion with insufficient predators, the population declines dramatically because the overbrowsed vegetation simply cannot support the high ratio of deer. Consequently, the deer die from starvation and disease, and the population rapidly declines. Similarly is for deer's predators. An extensive and mathematically sound models were extensively presented uder the "predator – prey" headline.

Over the time, the instances where the situation was described as "critical" and requiring an immediate intervention to lessen perceived crisis have been numerous. Farmers complained that an excessive deer population had deprived cattle from grazing; hunters claimed that the area could have easily accommodated larger mountain lions population; environmentalists insisted that both hunters and farmers should have been removed from lobbying in favor of their particular interests. And the Nature has been operating its own way...

In 1907 the deer population was unusually low with only 4,000 head. The carrying capacity was 30,000 at this time, so a massive campaign was waged against the natural enemies of the Between the years of 1907 and 1923, the natural predators of deer (mountain lions, wolves and coyotes) were eliminated by hunters in order to increase the deer population. As the following graph shows rather dramatically, the deer population increased rapidly to 100,000 by 1924, but then died off rapidly to a mere 10,000 by 1939. Because of severe overgrazing by excessive populations of deer, the carrying capacity of this region was reduced to approximately 10,000 in 1939, and the deer population was reduced accordingly.

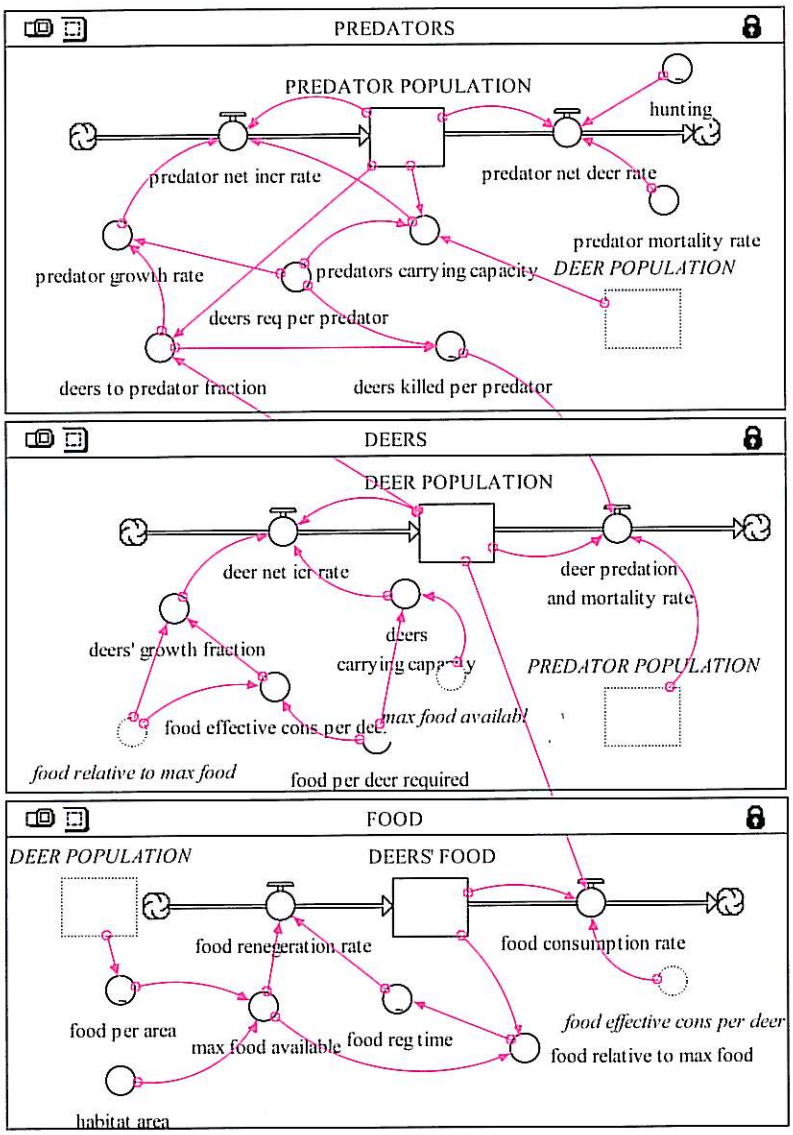

Figure 1. Kaibab Plateau (simplified model of predator–prey)

Source: author's elaboration based on Roberts (1983), Sterman (2000)deer.

The scenario which actually happened in the Kaibab Plateau of northern Arizona between the years of 1907 and 2007 is presented as the diagram of the behavior over time (see: Fig. 2). As the Kaibab Plateau model in this article differs from its predecessors, the results are also different. The differences, however, are only numerical and they do not point to any qualitative discrepancy between the logic of ecological order in previous works on Kaibab Plateau and the one used here.

4. Crisis – where is it?

Let's go back to Encyclopedia Britannica insight – "...the climax, or crisis (author's underline), is the decisive moment, or turning point, at which the rising action of the play is reversed to falling action". Obviously, the only climax (crisis) occurs around 1925 when the deer population rises to almost 100,000. Perhaps it is not so obvious... Did it happen before? If so – when...? Or it would happen after 1925 – providing that T. Roosevelt had not established protective zone? What would have happened there then?
Let's start with the assumption that no political nor administrative intervention happened in the Kaibab Plateau. All concerns for future generations go away and deer and their predators are on their own. What would happen?

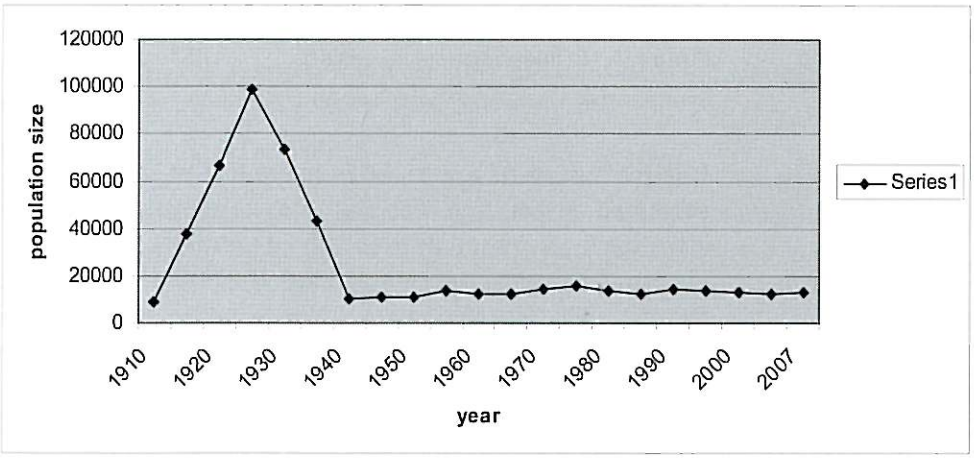

Figure 2. Deer population over time – playground for crisis

Source: author's elaboration based on simulation results

In answering above questions we ought to assume that there were two triggers for future population growth: first – prohibition/no prohibition of shooting cougars, and second – prohibition/no prohibitions of shooting deer. Both can be confined to the same value as it was the question of administrative ruling and the authorities could determine the amount and features of exterminated population. Let's assume that no such regulative order was issued. What would have happened? Another simulation with presented assumptions is shown in Fig. 3.
Both diagrams could be misleading unless we pay attention to the axis "Y" – in previous diagram (Fig. 2) it reached 100,000 and now it peaked 9,000. It is 10 times less. In terms of the deer population the difference over time is not significant. The only exception are the years 1915 – 1935 where the population was rising and falling, respectively. Figure 3 presents deer population under the assumption that no policy was introduced to the Kaibab Platea, and Fir. 4 shows both scenarios – the one that actually did happen

(line dotted with straight rectangles – peaking around 1930) and another showing the deer population if no action would have been taken to protect them (relatively flat line).

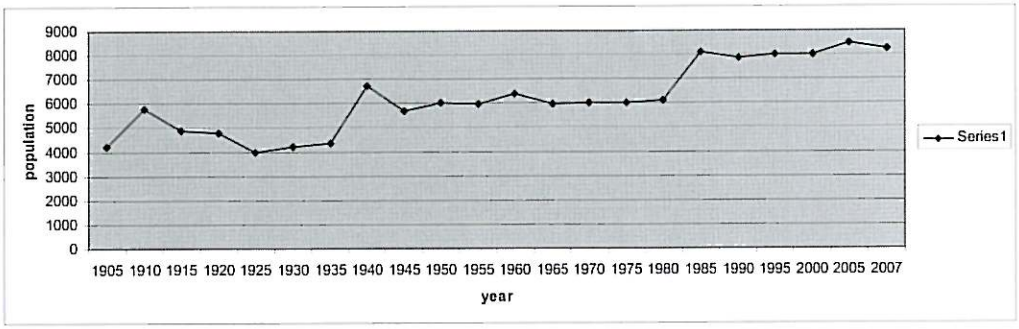

Figure 3. No intervention – no crisis ?

Source: author's elaboration based on simulation results

It is interesting to scrutinize many claims of alleged ecological crisis that had been submitted at that time. The rise of the population was the result of ecologists' action alarming federal administration about unsufficient number of deer living in the Kaibab Plateau. Obviously, its rise to almost 100,000 deer was the expected solution to crisis. However, what was the crisis solution to environmentalists, formed another crisis to other actors – farmers – for whom such a big population of deer was jeopardizing the existence of their herds. It is important to add that following President Roosevelt's order, no change in Kaibab Plateau administrative policy did take place and farmers' and hunters' expectation were not taken into consideration.

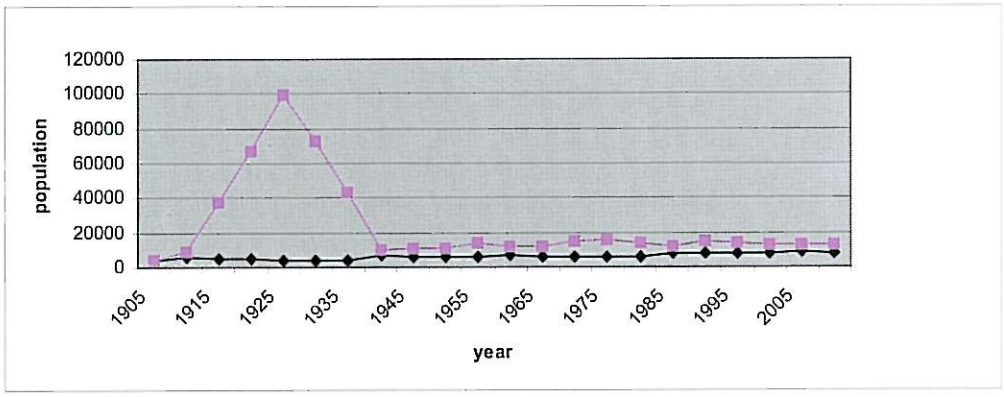

Figure 4. Deer population – two scenarios

Source: author's elaboration based on simulation results.

Apparently, there were conditions to maintain – or even increase – deer population. No such thing happened, however. Despite these conditions the Nature took over and equilibried the ecology of the Kaibab Plateau. Interestingly, the mountain lions population did not visibly react to the abundance of deer and after initial extermination quickly regained its number.

5. Crisis revisited

Our management knowledge and systems are dominated by fear, reflected in their reactive character. We react to external forces perceived as a threat which – when exceeds "normal" value – are shown as crisis. Counteracting crisis becomes a typical management strategy, reinforced by short–term results of crisis solving strategy (increase in deer population). As a consequence we manage systems from crisis to crisis, waiting for the next one and expecting those instances of change enforced by crisis. Thus, from the management point of view crisis is not the state of affairs – it is a process.

The crisis process is inscribing into a generic structure of systems. By generic structure we understand the composition of dynamic flows occurring in a system. In our example of the Kaibab Plateau several flows can be identified. Most important of them is the flow going into and coming from the populations of deer and predators – deer born and deer killed by predators and hunters, predators born and killed by famine and hunters. We are inclined not to watch these flows but rather their results. The question is why? Probably humans are not very well prepared for a world of slowly developing threats. Instead, we use some notions of triggering points claiming to describe a situation as reaching the crisis point. We wait until gradual changes develop into crises. And those who wait, they define crises. Therefore, crisis is agent–based; the trap is the function of caught in the trap.

From the System Dynamics perspective there are two types of crisis. First – there are crises caused by generic structure of systems – symptom of their degeneration. Examples – soil erosion, global warming, financial crisis, and so forth. These, and many more situations, are produced by the generic structure and little can be done about unless we know how to change that structure. For the Kaibab Plateau, however, things pose differently:

a. Crisis are caused by agents; simple mechanism operates here: we adopt certain variable(s) value as crisis indicator, and when that variable goes out of the arbitrarily defined tolerance level we vigorously act towards increasing/decreasing this variable value. While doing this we often:
b. Act against the generic structure of a system, and most likely we evoke crisis as that system fight back (which is called "counterintuitive behavior"); in particular, we invade:
   - Stability – the relative length of time the system exists or recurs in substantially the same form; crisis is the intervention in system stability altering normal be-

havior of that system and its parts (e.g. deer population); normal behavior is described by sy stemic relations existing among parts of the system – in our example that would be relationshipos between deer population and food available and predators' population. Kaibab Plateau tability was warranted by them and forced increase/decrease in one components could not pass without altering others. Stability depends thus on:

- Connectivity – the whole network of interconnections existing within a system. Some of them are more important than others as they determine the mechanism of the stability – those are connections that begin and end within a system. Thus:
- Closure – number and arrangement of feedback loops existing within the system. In particular, positive feedback loops cause the increase of values of interconnected variables which – under some circumstance and depending on agents' criteria – may be considered crisis. In turn, negative feedback loops, especially perceived in a relatively short time, stabilize the system and counteract crises. The intervention in such a subtle and sensitive structure is very dangerous and usually produce unexpected results. Therefore:

c. crisis situation – if left unattended – will frequently re–establish initial state (self–solution and self–regulation).

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