BIOLOGICAL SYSTEMS AS GUIDANCE FOR SUSTAINABLE AND ENVIRONMENTALLY FRIENDLY INNOVATIONS

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Abstract: Although innovative progress and environmental issues are more important than ever before, most innovations still fail or pollute and harm the environment. The environment is extremely dynamic and complex and it is therefore almost impossible to predict the degree of sustainability yielded by individual innovations in the longer term. However, environmental sustainability is the primary objective of many future innovations. Although a lot of money and time have been spent, existing natural innovations in biological systems are often overlooked by organizations and institutions. Evolution meant that sustainable solutions had efficiently developed for over 3.8 billion years, separating the inefficient from the efficient. Artificial and biological systems are similar to the extent that solutions can be analogically adapted. Literature reviews from various disciplines will reveal the similarities, while further case study and concept will substantiate the theoretical approach. This paper does not indicate what humanity can extract from nature, but what humanity can learn from it. It also suggests that evolutionary development is not confined to biological systems.

Keywords: Sustainability, analogy, biological systems, Bio-mimicry, systems analysis, environmental economics, innovation

BIOLOŠKI SISTEMI KOT VODNIKI
ZA TRAJNOSTNE IN OKOLJU PRIJAZNE INOVACIJE

Povzetek: Čeprav so inovacijski proces in okoljevarstvene težave pomembne kot še nikoli prej, je večina inovacij še vedno neuspešnih oziroma škodljiva za okolje. Ekosistem je zelo dinamičen in kompleksen sistem in zaradi tega je dolgoročna napoved učinka trajnostnega razvoja inovacij skoraj nemogoča, vsekakor pa je glavni cilj bodočih inovacij prav ta. Organizacije in inštitucije porabijo veliko denarja in časa, istočasno pa spregledajo obstoječe inovacije v bioloških sistemih. Evolucija razvija trajnostne inovacije uspešno že več kot 3.8 milijard let in uspešno ločuje učinkovite od neučinkovitih. Od človeka ustvarjeni sistemi in ekosistemi so si zelo podobni, tako da je prevzem rešitev iz enega sistema v drugega v obliki analogij zelo primeren. Razodetje podobnosti med obema sistemoma v interdisciplinarni literaturi bomo v tem članku podprli s primerom dobre prakse in praktičnim konceptom. Ta članek ne usmerja na možen izkoristek naravnega napredka, temveč na možen pouk za človeka. Prav tako pa namiguje, da evolucijski razvoj ni omejen samo na ekosistem.

Ključne besede: trajnostni razvoj, analogije, ekosistemi, sistemske analize, evolucijska ekonomija, inovacije

Introduction

Fostering innovation is often considered an important element of sustainable development. Due to the environmental complexity and dynamics of change, innovations are generally associated with uncertainty and it is almost impossible to predict the degree of sustainability and environmental impact yielded by individual innovations in the longer term (Sartorius, 2006). A further problem lies in the evaluation of environmental issues, which in terms of individual satisfaction and some individual pleasures are not consistent (Hodgson, 2008). Considering the assumptions, the present and future innovation processes lie jammed between short-term and long-term goals. The contribution of Schumpeter on the role of innovation and technology corresponds to a shift of focus from short-run patterns to long-run dynamics (Schumpeter, 1934). The evolutionary theory delivers a similar theoretical concept for sustainability in which the term is not defined as static goal, but rather as a process of development where innovations have to prove their capability to adapt, that is, to readily change from less to more sustainable innovations (Sartorius, 2006). However, in order to be able to develop such a process objectively it is necessary to provide a (requisitely) holistic perspective of innovation. Based on a systems thinking perspective it is therefore the main objective to have a look at the often overlooked – in short-term perspective - side effects (Steiner, 2006). Organizations and institutions spend a lot of money and time to follow that progress. However the existing innovations in biological systems are still being overlooked by the majority of those organizations and institutions, despite the similarities between biological and human-made systems. Evolution develops efficient, effective, and sustainable solutions and has learned: what works, what is appropriate and what lasts. Bio-mimicry uses an ecological standard to judge the "rightness" of existing innovations and future innovations to come. It introduces what humanity can learn from nature, and not, what it can extract from the natural world (Benyus, 1998). The social-economic, especially environmental economic systems can greatly benefit from the approaches and insights of evolutionary systems (evolutionary economics) (van den Bergh, 2007). The case-study of Airbus 380 and the concepts of the Zebra air-conditioning system will substantiate the theoretical approach.

Problems with current innovation

The era where production and trade used to matter more than survival, is an era that has caused profit to kill profit because short-term goals may create higher costs in the longer term (Potocan & Mulej, 2003). Innovations play a crucial role, not only in economic development, but also in maintaining the sustainability of this development, in avoiding the destruction of the natural environment and exhaustion of natural resources (Sartorius, 2006). As a means of increasing wealth, income and power, both on a national and international level, innovative short-term solutions are sufficient. Problems occur when innovations need to be sustainable for the natural environment and resources. Long-term perspectives should be included in the development strategy and this also creates a need for long-term predictions. Due to the complexity and dynamics of socio-economic systems, such predictions are usually/mostly unrealistic (Sartorius, 2006). Furthermore, people misunderstand the various system peculiarities and characteristics, such as the speed and change in behaviour of the underlying systems (Steiner, 2006) and the lack of holism and interdisciplinary approach in innovation process (Mulej, et al., 2008). Consequently, the long-term perspectives bring too much of uncertainty and increased risk and as a result, the long-term perspectives are ignored or are not taken seriously. However, innovations towards sustainability are often associated with substantial costs. It is often the case that environmental innovations internalize external costs and the innovator does not receive adequate compensation (Sartorius, 2006). As a result the crucial role of the innovator must be emphasized (Steiner, 2006). An obvious problem with the utilitarian approach is the evaluation of environmental issues according to individual satisfaction and individual benefits, which cannot usually be reconciled with ecological issues and sustainability (Hodgson, 2008). Under such circumstances, innovation is understood as an integrated process which avoids environmental externalities right from the beginning (Sartorius, 2006). In order to meaningfully use analogies, specific system's conditions are required in order to allow learning among different systems (Steiner, 2006). Microeconomic objectives are still the priority in the R&D process; this is so despite the fact that the elements of an evolutionary framework to policy issues related to environmental sustainability could be observed from the mid-1990s (Nill & Kemp, 2009). Evolutionary economics may offer a theoretical solution for system failures that are connected with the facilitating structure. However, the facilitating structure is not sufficiently developed for innovation (Nill & Kemp, 2009), and it is still the case that more than 80% of innovations processes fail (Keupp & Gassmann, 2008) or are environmentally unfriendly.

Evolutionary approach

The role of Darwinian concepts (variation, inheritance and selection) has been a matter of conversation in evolutionary economics from its very beginnings. The seminal approach to this topic was taken by Veblen (1898) and Schumpeter (1912). The approaches taken by Veblen, on the one hand, and Schumpeter, on the other, reflect the opposing views, attributing and denying relevance to Darwinian concepts (Witt, 2006). The idea of generalizing Darwinism was later revived by Childe (1951), Dawkins (1976), Hayek (1988), Dennett (1995) and others (Aldrich, Hodgson, Hull, Knudsen, Mokyr, & Vanberg, 2008). Further scientific discussions, currently taking place, consist of relevant insights from the evolutionary biology of man-made systems (Campbell, Nelson & Winter, Mayr, Knudsen and Hodgson, in: Witt, 2006). The interdisciplinary dialogue in the 21st century led the discussion towards a common point of view, that the theory of Universal Darwinism (inheritance, selection and variation) (Dawkins, 1983) is not suitable for man-made systems. The estimated relevance has to be found in sub-theories like the theory of evolution states, theory of common descent or theory of the multiplication of species (Cordes, 2006). Relevant for this paper is the evolutionary point of view for time perspectives.

Evolutionary economics does not divide the long-term and a short-term perspective; what it does is combining them – the sub-theory of evolution states (Cordes, 2006). The classical contribution of Schumpeter on the role of innovation and technology corresponds to a shift in focus from short-run patterns to long-run dynamics (Schumpeter, 1934). The similar theoretical concept delivers the evolutionary theory for sustainability, in which the term is not defined as static goal but rather as a process of development, where innovations have to prove their capability to adapt, that is, to readily change from less to more sustainable innovations (Sartorius, 2006).

Nature has done this for more than 3.8 billion years. It develops efficient solutions and filters out the inefficient ones. Nature's solutions are being challenged constantly by our complex and dynamic environment. Those who cannot adapt quickly enough are being extracted via natural selection. The adaptation process lies in Darwin's concepts of variation, inheritance and selection (Hodgson, 1997). Darwinism involves a general theory of evolution including all open and complex systems (Hodgson, 2002). This theory expresses discontentment with static or equilibrium-oriented theories (Hodgson, 2009) and also makes it clear that environmental issues should not be ignored in the R&D process. Schumpeter himself required a disequilibrium approach to the study of innovation, structural change and growth and also the interdisciplinary diffusion of advanced knowledge (Castellacci, 2008). The idea to see evolution as guidance is not so new anymore but it is still surprising and a missed opportunity that evolutionary thought has been so rarely invoked to allow us to understand better the causes of environmental problems as well as the characteristics of and limits to solutions (van den Bergh, 2007).

Analogies

Economists and ecologists were brought together to develop theories and policies that are superior to those derived from narrow utilitarian and cost-effective approaches (Hodgson, 2008). Man-made and biological systems are similar to the extent (van den Bergh, 2007) that solutions can be adapted. We should not consider what we can extract or even copy from nature, but what we can learn from it (Nachtigall, 2008; Benyus, 1998). It is important that we use natural systems as guidance and we do not make the mistake of extracting biological metaphors. The danger of extracting the biological metaphors lies in:

- Copying and trying to adjust the development process;
- Reducing the complexity by using common theoretical basis.

A prime example of such a mistake is the Holocaust, where Hitler tried to adjust the developmental process (Steiner, 2006). Hitler believed that the human gene pool could be improved by using selective breeding, similar to how farmers breed superior strains of cattle. This involved, at the very least, preventing the ‘inferior races’ from mixing with those judged superior, in order to reduce contamination of the latter’s gene pool. The ‘superior race’ belief was based on the theory of group inequality within each species, a major presumption and requirement of Darwin’s original ‘survival of the fittest’ theory. Hitler´s philosophy culminated in the ‘final solution’, the extermination of approximately six million Jews and four million other people who belonged to what German scientists judged as ‘inferior races’ (Bergman, 1999).

Using a common theoretical background such as survival of the fittest reduces the complexity of the observed system which further defines the potential danger of extracting biological metaphors. Hence, the Universal Darwinian to the scheme of variation, inheritance and selection cannot be taken as the theoretical basis for building analogies to be integrated into the complex economic systems. For example, the universal Darwinian explains human learning, intentionality, and deliberative behavior, but is ill-suited to grasp the dynamics of cultural evolution that are based on evolved cognitive capabilities. Human intentionality and deliberation play a crucial role in this aspect of cultural evolution, particularly in the selection of technologies, products, and routines of behavior. An essential attribute of any selection is the stability of selective characteristics and environment over time (Cordes, 2006). We have to search for more formal similarities using broad connections established by metaphors. By doing this vital work, and by helping to form analogies, the influence of metaphors is neither superficial nor preliminary (Hodgson, 2002).

As an alternative to biological analogies Foster defines (Foster, 1997) the theory of self-organization. It is not only the tinkering of ad hoc or possibility served on a silver platter, it is an appearance shaped and honed by selection (Kauffmann, 1993). In this self-organizing system, impulses come from the interactions internal to the system, without intervention by external directing influences. This lack of self-organization can have order imposed on it through various directives such as blueprints or recipes, or through pre-existing patterns in the environment (Camazine, Deneubourg, Franks, Sneyd, Theraulaz, & Bonabeau, 2001). The learning process includes the system’s internal interactions and the interaction between the system and the environment (Hodgson, 2009). The extensive literature of modern biology points to the importance of cooperation and unselfish behavior (Hodgson, 2002).

From all the complex systems and structures that may self-organize due to the forces of nature, there is no assurance for survival and reproduction; otherwise there would be no natural selection (Hodgson, 2002). Hence, the natural systems are in constant development and what is important is the implementation of sustainable development – so called second-order sustainability where the dynamic interrelation between the innovation rather than the innovations itself are refers (Sartorius, 2006). Socio-economic systems can learn a lot from natural systems especially in the fields of dynamic versus static, long-term perspectives in innovation processes and the ability to cope with complexity. Technical science understands the importance of natural creations - BIONIC, much more in detail as the socio-economical science. BIONOMICS is one of the scientific fields to use nature as guidance (Rothschild, 1990). Hence BIOMIMICRY (Benyus, 1998) can be seen as a common scientific field of both BIONIC (Nachtigall, 2008) and BIONOMICS. This means that evolutionary development is not confined to biological systems (Benyus, 1998).

In order to substantiate this theory, a practical case study and concept will be presented in the next part of the paper. The case study Air-Base 380 is one of the latest examples of how we can take guidance and learn from nature. Airbus’s problems with the development of the world’s largest passenger aeroplane were widely publicised in the media. However, very few publicised the fast and efficient solution presented by the air whirl (Discovery, 2008).

The second case concerns the Zebras air-conditioning concept, which in comparison with man-made solutions, is much more efficient, sustainable and environmentally friendly. The concept will show how the evolutionary approach uses the given resources to develop innovations. Hence, nature does not have to find new materials to be able to develop new abilities; it uses the given resources in the environment.

Case study, Airbus 380

One of the latest examples of a successful analogy comes from the Airbus Company, via the development of the Airbus A380. The size of the wings and the weight of the airplane lead the top of the wings to create a large air whirl which destabilizes the whole airplane. The technician calculated the proportions of the whole aeroplane and came to the conclusion that the White-Eagle has the same proportions. However, the White-Eagle can manage the resistance on the top of its wings very successfully. The trick lies in the bent feathers on the top of the wings.

The Airbus engineers engaged this solution and found out that the bent feathers smoothly transmitted the air over the wings and in this way completely eliminated the wind whirls. The engineers extracted the solution in form of an analogy and built a bent spoiler on the top of the wings. With such a discovery the company has solved a major problem without formally incurring costs and with no additional weight (Discovery, 2008).

This is only one example of how problems can be solved if nature is seen as the guiding field for human development.

Figure 1; White-Eagle, bent feathers on top of the wings

Figure 2; Airbus 380; with installed spoiler on top of the wings

Concept of Zebra air-conditioning system

The global temperature is rising due to environmental changes and the pollution caused by humans. The summer temperatures are getting higher and higher and the majority of homes are equipped with air-conditioning devices.

The energy efficiency of a conventional cooling system lies at 27%, the improved FIG systems increase efficiency by more than 2.5 times (77%). The efficiency measured in cooling water lies at 61% (Staats & Weil, 1969). Calculated according to 40 m^2 with 2.5 m ceiling you need a cooling power of 3.2 kW. Quotient between the volume and the required energy is 32 (Delo in dom, 2008).

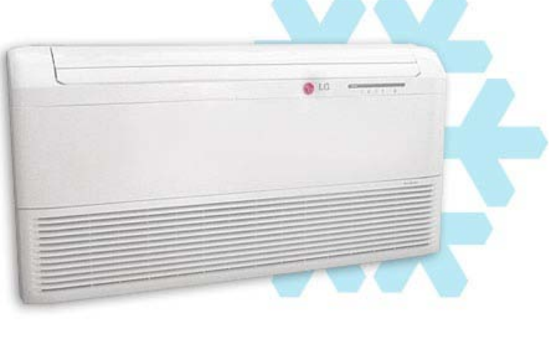

Figure 3; classic air-conditioning device

Nature invented solutions where only solar energy and thermodynamic principles are used. The beautiful stripes of a Zebra have two main purposes. Firstly, they prevent hunters from choosing Zebras as a meal and secondly give the Zebra the ability to maintain top speed for longer than the hunter by cooling their bodies. A lion cannot, from a distance, identify a single animal provided the Zebras are standing close together. The stripes create the illusion of one animal for the lion, which sees everything in black-and-white. The second benefit of the black and white Zebra stripes lies in resisting the heat in the hot savanna. The concept is very simple, in the sun the black stripes heat up more than the white stripes. As a result the air above the black stripes gets hotter and lighter than the air above white stripes. Thermodynamic principles, which state that wind is a natural phenomenon indicate, that the lighter air rises and is replaced with heavier, cooler air. This means that the air constantly moves around the Zebras skin actively cooling its body. This constant cooling activity enables the animals to run faster and maintain a high speed for longer than their hunters (Marshallsay & Luxton, 2005).

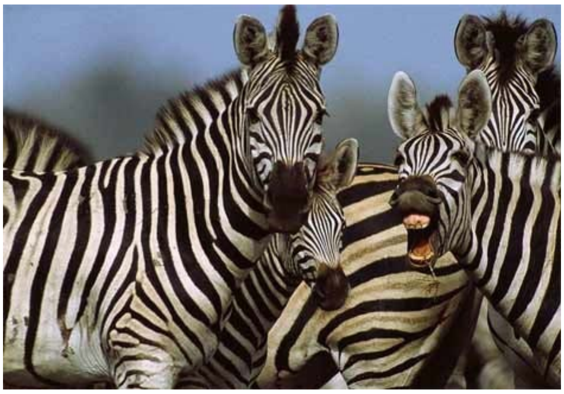

Figure 4; Zebra with black-and-white air-conditioning system

Nature develops solutions with resources present in the environment. Humans have to realize that material development does not lead to survival (van Weenen, 2000). The sustainability approach toward problem-solving process lies in developing solutions from natural resources and not the other way around.

Conclusion

There is a marked difference in the development of various systems. Biological systems have lasted for over 3.8 billion years, while socio-economical systems have lasted for approximately 190.000 years. The sustainability of living organisms has proved to be much greater than that of products found on the market today. As sustainability is becoming crucial to human, social and economical development, humanity must realize that ecosystems present a great deal of sustainable solutions. We do not have to discover fire over and over again, we just have to look for solutions in nature and integrate them into the human social-economical system. Natural solutions can be used in socio-economic systems in the form of an appropriate analogy. This paper has shown that many conditions are similar to nature; that natural solutions should not only be used but must be used, if the human race intends to save the planet and continue developing. In order to inhabit this planet, we should not just live with nature, but work with nature and learn how to use our natural resources in a sustainable way.

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