Technical Limits of ICT for Enterprises' Innovations

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***Abstract**: The paper deals with technical limits of ICT for enterprises' innovations. ICT is now a key asset for the competitiveness of enterprises. It became the main stream of doing business well. These days we come to era where enterprises are fully dependant on ICT. We would try to describe more deeply the impacts of such a dependence and underlying problems. In context of the necessary new innovations of enterprises, we will focus more on the negative aspects of being dependent on ICT with the technological architecture of hard systems. Based on the need to apply a systems approach we will also provide a suggestion as to how to model these limits in a system's manner.*

Keywords: Technical limits of innovation, ICT, Enterprise, Systems thinking, Diffusion model, Information management, Causal loop model

1. Introduction

Based on eminent phenomena, today's world is automatically drawn together in the pursuit of *complexity* and of building *knowledge society,* which is well-known within Richardson's work last year (for example [16]), and of building *innovative society*, so-named in Mulej's innovation theory work [12], among others.
The aim of the paper is to discuss the innovation diffusion of ICT on the one hand and show the limits of ICT, particularly its technical limits, on the other hand, and also provide a suggestion as to how to model these limits in an objective manner. In connected, competitive, globalized world innovation is understood as a *competitive advantage*. It turns out it is *innovation* more than *optimalization of processes* that leads to success of enterprises. Enterprises are always looking for new and evolutionary solutions and opportunities, as demonstrated by [10].

The relationship between innovation and ICT has been the subject of many analyses. For example ([1], p.70) state, "ICT is a part of innovation, or it is the innovation itself." They also state that "ICT is one of the information system sources; it effectively supports development and innovation in adaption and usage". "Business is subject to continuous changes implicated by technological advances", as demonstrated by ([21], p.12). These quotations are highly accurate as a theoretical framework for our examination.

No matter how much of this text is concerning *technological innovation*, technologies are not the only form of innovation. Innovations may include new business methods or, generally speaking, new concepts or new approaches. There is some evidence that various approaches to innovation exist, foremost *hard models* focused on technical programs and soft models focused on organizational programs. Empirical studies (for example [18]) show that *soft model* approaches have greater success in achieving innovation.

The reasoning of the *research methodology*, which is used in the paper, is to look at the innovation problems from a different point of view than do traditional approaches. For this purpose we are trying to understand both, the *systemic nature of technology* and the *human factor* of using ICT in enterprises.

Based on the need to apply a systems approach within the practice of informatics, this paper focuses on the methodology of systems thinking. Systems thinking is a mindset for understanding how things work; as demonstrated by (Bellinger, 2009). The approach of systems thinking provides a conceptual framework; the authors emphasize the nature of the interaction between the elements of the system and the circular causality by means of information feedback loops. Systems points of view come to light as useful paths for solving problems connected with complex systems and their economic growth (see [14]) and for better decisions and politics [4].

In order to gain an insight into the behavior of ICT sector, the first part of the paper shall focus on various models of innovation diffusion. The second part of the paper shall focus on technical limits of ICT for innovations. This part of the paper shows technical limits of ICT as impacts of hardware and software architecture and absence of self evolving mechanism and consciousness in it. Subsequently, in order to deduce the causal relationships between the key indicators of enterprise IS and the companies' innovation, we shall propose a model of feedback loops that should prove the necessity of systematic approach in the area of computer science. The paper follows up on research completed by [11].

2. Dynamism of Innovations in ICT Business

According to *National Innovation Initiative*, published by *U. S. Council on Competitiveness*, innovation is the most important factor dictating enterprise success. When we focus on the ICT sector that provides a supply for ICT innovations in other sectors or, as the case may be, the in the whole national economy, mainly in the ICT sector the work productivity in enterprises has grown [9].

Thanks to the growth of ICT productivity, functionality is increasing while prices go down, as described by *Moore's Law*. According to this law, the prices of the integrated circuits decrease by fifty percent every 18 months. If the prices stay the same their efficiency doubles. [8] show that, with the exception of the computer industry, there has never been a very large market for mass production that takes rapid technological improvement into account.

2.1 Models for Innovation Diffusion

In ICT, the typical way to compete with competitors is by decreasing productivity time. The enterprise needs to quickly invent new products and implement them to the market. Most of the ICT products prefer the strategy of hitting the mass market rather than “exceptional market“ and maximizing the profit with great volumes of production. It is believed that the price of a product is the key to winning the market. The enterprises try to be at top of lowest price competition rather than being on top of innovation (see [15]).

A different but also very effective way to create and maintain company growth is called *disruptive innovation diffusion*. According to [6], disruptive innovation diffusion is an innovation which is quite evolutionary and discontinuous, and customers accept new paradigms. Two examples are the first personal computer from Apple and accounting software QuickBooks by Intuit. These products emerged in a market that did not at first target the masses, but rather supposed that their customers, mainly businesses, needed all the power and functionality offered by traditional companies. Ultimately, while other companies went out of business, these products managed to dominate because they chose to innovate and adapt themselves to accommodate use by the average person.

Invention of PC can also be understood as disruptive innovation diffusion because minicomputers from the end of nineteen eighties offered more power, functionality and capability than customers could use. The PC was a new choice for people who accepted less functionality for lower price. PDA and i-Pod will probably follow this example.

Discussing innovations, we have to mention, that distribution of many new products roughly mimics logarithmic curves. The *logarithmic model* contains two *feed-back positive loops*, generating accelerating growth in the short term and a *negative feedback*, which slows the growth down as the number of units is getting near capacity. Diffusion of innovation usually contains many different *positive feed-backs*. For example, availability of software for company support is a very attractive feature for a PC product. Software engineers for company support will always write software for platforms with the biggest market potential. This means that the more installed computers and the more software written for them generates a larger variety for potential customers and the larger amount of installed computers.

The *Bass diffusion model* and wide spread extension of *Logarithmic model* with concept of external source of information has become very useful in advertising, and it is widely used in technology management (see [19]).

3. Technical Limits of ICT for Innovations

ICT is widely used for precise and fast algorithmization and computers offer very good service in terms of fulfilling given tasks (of hard system type) with *exact input* and *exact output*. This can be easily used in places where changes in the calculation process do not change or rarely change. Otherwise a skilled developer must change the *code* and update the *algorithms*. This *correction mechanism* is a small step in the innovation process of software. Innovations where hardware change is incorporated are more difficult because of necessary software migration and technological upgrade issues. This is based on architecture of computers and these principles will last unless paradigm change in architecture like [12] is used for different handling with information and understanding information.

Humans evolve and their adaptability to changes in environment is the key success factor in life competition. Competition among enterprises and competitiveness on markets is analogically similar situation. The paradox is that in this larger scale system enterprises with good innovative and adaptive attitude have obviously better results but these days we use hard technology that does not correspond to flexibility of adaptability and self evolution.

Evolution is a dynamic process but IS/ICT is a static tool. The more static tools in dynamic system we use, the less flexibility we have to perform innovations. Thus evolving gets much harder when we have to count with static parts of the system. We discuss later how the innovation, updates and upgrades of IT correspond to evolution level of IT. IT/ICT is a great tool for automation of same processes, therefore it is the trend of these days to use this technologies in many branches where computers were not used before. The reason is the speed-up and effectiveness of using this tool. It used to be the competitive advantage, but now everyone uses this technology, so it is no longer competitive advantage, but a kind of trap from some point of view, because administration, taking care, innovating, reprogramming, updating, understanding, specifying, implementing and deploying is the cost for having IS/ICT, but from the global point of view, it is just new cost to count with. It is like the difference between riding a bike and a car. We can easily manage our bike, but we need to go to the service checks with the car. We get much more far with car, but we need to pay fuel. We are paying for hardware, software, IS, but it is much harder to understand complexly why we need it, how it supports the main business process, whether the architecture correspond to the visions of the top management. Now management cannot easily control and check the efficiency of the information system because professionals are for every part of the IS life cycle. The knowledge is spread among software architect, analytics, programmers, Q&A and tester, deployers, project managers, but the whole complex understanding of purpose and need of all parts of the system vanished as it became too complex and hard to understand it all. This kind of trap allowed great speed-up, but has a limit of effective growth, because unless there is some element that can understand the whole and also has ability to innovate and evolve the static parts of the system, there are limits that cannot be passed. One of them is the speed of adaptability and the flexibility to adapt. The other limit is the necessary upgrade of static parts which needs the understanding the purpose and right settings of the processes that use IS/ICT.

3.1 Enterprise IS

Now let's consider some issues when evolving to larger scales of the same principles. First of all we can consider large enterprise with several divisions that need to be harmonized from the *technological and process point of view*. We could face the question: How much energy and what resources are needed to manage ICT to evolve in the same speed as the *enterprise evolution process* changes the enterprise's needs for ICT services? We should also ask whether or not the effectiveness, flexibility and amount in the larger scale are still effective when we focus on innovations. The problems can be documented when large enterprise IS are installed in large scale international enterprises. Human beings evolve naturally continuously, but ICT mainly evolves in steps even though they can be small like hot-fixes or smaller updates. Larger steps are upgrades or entirely new *architectures of information systems*. Humans are basically learning continuously and their mental models are constantly changing on the grounds of reality and information feedback, but IS is updated in steps based on innovation needs (see Fig.1). The problem is much thornier due to the fact that truly creative organizations must continue to implement learning systems.

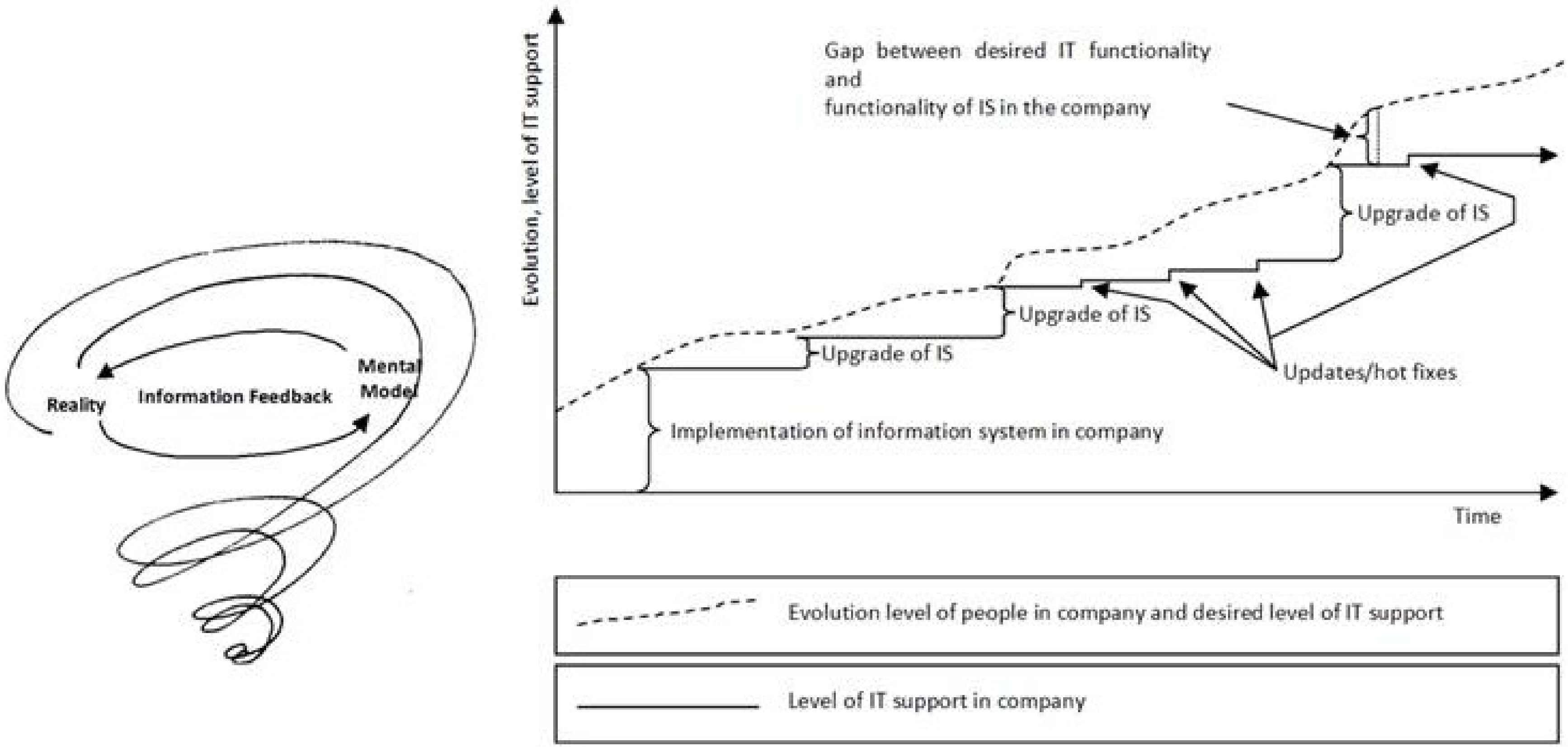

Fig. 1: Differences between kinds of *development (Source: authors)*

This distinctness is the causal reason for many issues with low flexibility of ICT for current needs that change quickly in the turbulent environment. Adaptations in processes where the users become better suited to use newly implemented information technology must also be taken into account. Even though resistance to changes is a typical attribute of most people, humans rather adapt to ICT than managing ICT to adapt to humans needs. This is why the architecture of ICT should be revised and these issues should be taken into account. The *dependence on ICT* is therefore a very dangerous factor for innovations and economical growth. In larger scales ICT brings many limitations and can be the cause of enterprise's stagnation.

As we showed in part 2 "Dynamism of Innovations in ICT Business", the usual reason to accelerate innovation cycle is to get from research to market as quickly as possible. The question is, if it should be otherwise in ICT area. The cycle should take a short time to allow research to start as late as possible. Then the producer of ICT will have time to find out all requirements of its users and will provide the technology that people really need.

This and the described fact that IS is updated in steps based on innovation needs, could be a chance for disruptive innovators. Never-ending innovations of recently lead companies, overloading customers with technological functionality and services could turn against them.

3.2 Information Management

In the end it is very important to accent the role of *information management,* which plays an important part in the problems mentioned above. ICT is a technological base of information management. Information management is shown by [5] as activities focused on managing of all information assets used by an *enterprise*. Management plays a leading role in the guiding and enforcement of innovation; on the other side, thanks to innovation within ICT, some activities in information management are performed by machine, creating additional spaces for management's own creativity (and further innovations). Information management is also important for maintaining close contact between ICT manufacturers and their customers on the part of the enterprises. Successful implementation of innovations is not possible unless ICT manufacturers are well acquainted with their customers and theirs needs as well as their changing demands on technology.

3.3 Governmental Limits of ICT for Innovation

Another consideration is the limit on ICT set by the government. ICT innovation is a dominant factor in global *economic growth*. According to [7], who have provided a 2005-2008 time-analysis of determinants influencing a share of the ICT sector of GDP for the EU countries, the ICT sector part of GDP oscillates at about 5% and at the same time causally influences productivity of all other economic sectors. This is one of the main reasons why governments try to manage the rate of innovation activities within ICT and to set limits and other restrictions for innovation. Concerning governmental support, [19] funds that companies depend too much on ICT innovation for money from structural founds, i.e. support from the EU. Concerning *governmental limits*, we see significant problems in tight-money policy, tax policy, depreciation policy, and inadequate tax allowance. The paper by [13] shows that the design of *economic instruments* could have low effectiveness in post-communist countries, where market instruments have a short history.

4. Modeling of Technical Limits of ICT

The positive effects of ICT on enterprises are obvious. As known as soon as the enterprise slows down in terms of innovation it has very negative consequences. Being on top of the innovations process is the only resource for competitive advantage.

Thus, dynamic aspects and tools for simulation of innovation policy should be discussed. In terms of dynamics it might look as if it were self-reinforcing *causal loops*, which are using *feedback* to strengthen enterprises resources and fuel the companies' innovation. The *causal loops model* is a graphical tool with a higher level of generality and robustness. There is a system thinking paradigm used as a main point of view. The present prevailing paradigm of thought is based on the simple causality of observed processes, and with such an approach the recognition of the impact of different policies is very complicated. The system approach paradigm is based on a principle of relating every cause to its impact and to every other cause with a feed-back loop. This is shifting the approach from a simple (one-way) causality to loop causality, from mutually independent factors to mutually dependent ones [17].

Our causal loop model aids in visualizing how interrelated variables - *Economic Growth*, *Innovation level*, *Evolution of innovation process*, *Gap of desired functionality x implemented functionality* and *Implemented technology*, *Rate Adaptation* - affect one another. The model consists of a set of nodes representing the variables connected together. The relationships between these variables, represented by arrows, can be labeled as *positive* or *negative*[1]. The described model consists of four loops, two of them *reinforcing* and two *balancing*[2]. As displayed, it does not necessarily have to be that way, there are limits which weaken the *self-reinforcing effect* and might stop it at all (see Fig. 2).

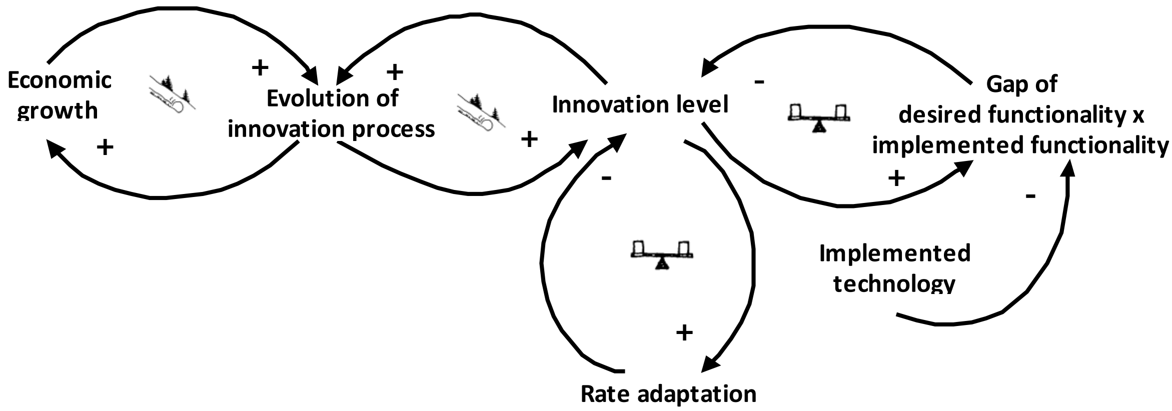

Fig. 2: Causal loop model of the companies' innovation *(Source: Authors)*

The main variable determining dynamic of the described model is the *Innovation level*. The behavior of the depicted system follows from the interaction of its components. If the GAP is not sustainable, the IS is upgraded and the innovation process and the subsequent economic growth are kick started. The structure of our described model and it's reinforcing and balancing feedbacks cause the fact that the dynamics of the innovation process will take the shape of an S-curve (see Fig. 3). Unless the necessary upgrade of the IS takes place, the growth slows down and stagnation or even collapse may follow.

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[1] *"Positive causal link means that the two nodes change in the same direction, i.e. if the node in which the link starts decreases, the other node also decreases. Similarly, if the node in which the link starts increases, the other node increases. Negative causal link means that the two nodes change in opposite directions, i.e. if the node in which the link starts increases, then the other node decreases, and vice versa" (wikipedia, 2011). Symbol is + or S for positive causal link, symbol is - or O for negative causal link).*

[2] *"To determine if a causal loop is reinforcing or balancing, one can start with an assumption and follow the loop around. The loop is:*
- reinforcing if, after going around the loop, one ends up with the same result as the initial assumption.
- balancing if the result contradicts the initial assumption" (wikipedia, 2011). Symbol is + , R or  *for reinforcing feedback, and symbol is -, B or*  *for balancing feedback).*

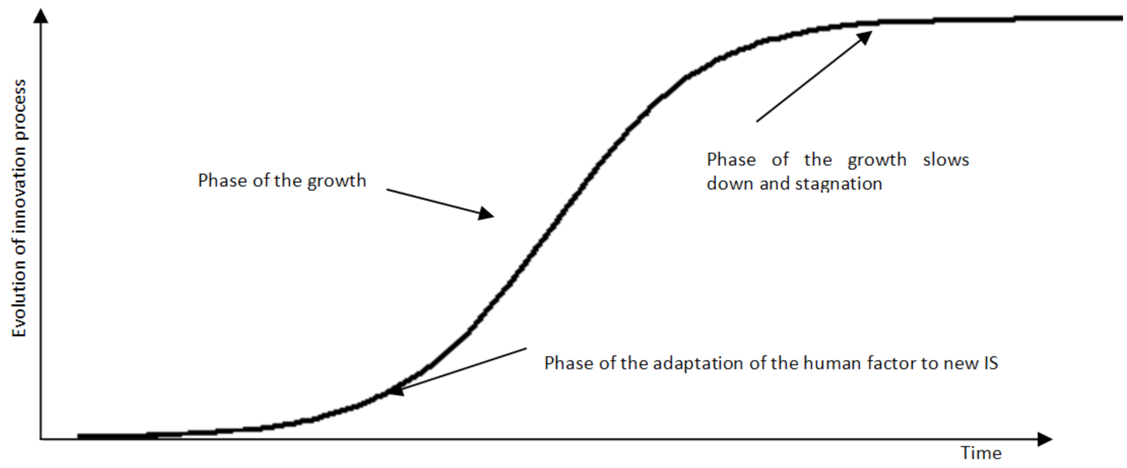

Fig. 3: S - curve of evolution of innovation process *(Source: Authors)*

5. Conclusion

This paper analyzes the dynamism of innovations in the ICT business: ICT is a field where changes in technology happen very fast. Furthermore, this paper offers a deeper examination of the impacts of IT dependence of enterprises. We have focused primarily on the negative consequences of being dependent on ICT that has the technological architecture of hard systems. Systems thinking itself was founded as a prospective set of tools that enables us to more comprehensively understand the technical limits of ICT, and structure and dynamics' impact on the innovation process. The systems approach to innovations applied herein allowed us to show a different view vis-à-vis traditional linear approaches that cannot fully solve the problems in the area of innovation because they do not consider the inner structure of the dynamics that lead to emergence behavior. Systems thinking and it's causal-loop modeling would assist with better decision-making in innovation policy, could test decision-making strategies and policies, and more easily predict the behavior of complex company systems. In these ways, the other described limits of ICT could be made visible.

The problem of whether to use or not use the ICT technology does not stand, the question is what amount of this technology is most efficient for companies, and primarily when to upgrade IS to prevent limitations of the economic growth due to technical limits of ICT. Enterprises would then be able to focus on reengineering of organizational processes immediately linked to human factors, rather than focusing on technical aspects of IS. Enterprises are fully dependant on ICT, at the same time technologies cannot expect to have an impact themselves if no companies use them to innovate. While using ICT, people still have most of the work. The whole paradigm would have to change if technology was not limited to innovation and economic growth. Producers of ICT would probably have an understanding of individuals' needs, what customers use ICT for and why they use it. Instead of technological innovations, they should react more flexibly to demands on innovations from enterprises. Enterprises would then be able to focus on reengineering of organizational processes immediately linked to human factors, rather than focusing on technical aspects of IS.

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References

[1] BASL, J., GALA, L., 2009. The Role of ICT in Business Innovation. Jindrichuv Hradec 09.09.2009 – 11.09.2009, In: *IDIMT-2009 System and Humans – A Complex Relationship,* Linz : Trauner Verlag universitat, pp. 67-76, ISBN-978-3-85499-624-8

[2] BELLINGER, G., 2004. *Systems Thinking: An Operational Perspective of the Universe*, [online] on <http://www.systems-thinking.org/systhink/systhink.htm>

[3] BRIXI, R., BRIXI, S., 2009. The Association Reactor in a Human-like Robot Architecture Concept: An Interdisciplinary Approach. Jindrichuv Hradec 09.09.2009 – 11.09.2009, In: *IDIMT-2009 System and Humans – A Complex Relationship,* Linz : Trauner Verlag universitat, pp. 297-308, ISBN-978-3-85499-624-8

[4] BURIANOVA, E.: *Modelovani systemu na podporu rozhodovani s vyuzitim metody systemove dynamiky*. Rizeni vedy, vyzkumu a vyvoje a jejich trendy, Ostrava: Ostravska univerzita v Ostrave, 2007, pp. 17-20, OU, ISBN-978-80-7368

[5] DOUCEK, P., 2010. *Informacni management – vymezeni, ulohy a role [Information management – determination, roles and challanges]*. In: Doucek, P. Informacni management, Praha : PROFESSIONAL PUBLISHING, pp. 13-27, ISBN-978-80-7431-010-2

[6] GEORGANTZAS, N.C., KATSAMAKAS, E., 2009. Disruptive Internet-service innovation diffusion. *Human Systems Management*. Vol. 28, Num. 4, pp.163-181, ISSN-0167-2533

[7] HANCLOVA, J., DOUCEK, P., 2011. Education and ICT sector in the EU (Panel-national application). In: *Proceedings of the 8th International Conference Efficiency and Responsibility in Education,* Prague: Czech University of Life Sciences Prague, pp. 84-92, ISBN-978-80-213-2183-0

[8] JANDOS, J., VORISEK, J., 2009. Enterprise Web 2.0 What is it really? Marrakech 09.11.2009 – 10.11.2009. In: *Knowledge Management and Innovation in Advancing Economies: Analyses & Solutions* [CD-ROM], New York: IBiMA, pp. 1-6, ISBN-978-0-9821489-2-1

[9] LELEK, T., 2009. Dynamický model nové ekonomiky. *Scientific Papers of the University of Pardubice, Series D, Faculty of Economics and Administration*, vol. 14, no. 14, pp. 142-147, ISSN-1211-555X

[10] MILDEOVA, S., 2010. *System Dynamics Supporting Complexity Management: Case Studies from a Small Economy within an Economic Integration Environment*. In: Tait, A., Richardson, K. A. (ed.). Complexity and Knowledge Management: Understanding the Role of Knowledge in the Management of Social Networks, Charlotte: IAP - Information Age Publishing, pp. 261-277, ISBN-978-1-60752-355-0 / 978-1-60752-356-7

[11] MILDEOVA, S., BRIXI, R., 2011. The Limits of ICT for Innovations and Economic Growth. Jindrichuv Hradec 07.09.2011 – 09.09.2011, In: *IDIMT-2011*, Linz : Trauner Verlag universität, pp. 157-164, ISBN-978-3-85499-873-0

[12] MULEJ, M., 2006. Systems, cybernetics and innovations - Introduction. *KYBERNETES*. Volume: 35, Issue: 7-8, pp. 939-941, ISSN-0368-492X

[13] PAVEL, J., SLAVIKOVA, L., JILKOVA, J., 2009. Ekonomicke nastroje v politice zivotniho prostredi: drahe dane a nizka ucinnost [Economic Instruments of Environmental Policy: Costly Taxes and Low Effectiveness]. *Ekonomicky casopis,* Vol. 57, Num. 2, pp. 132-144, ISSN-0013-3035

[14] POTUZAKOVA, Z., MILDEOVA, S., 2011. Systemovy pristup ke konceptu flexicurity [Systems Approach to Concept of Flexicurity]. *Politicka ekonomie,* Vol.59, Num.2, pp. 224-241, ISSN-0032-3233

[15] PROKESCH, S. E., 1993. Mastering Chaos at the High-Tech Frontier: An Interview with Silicon Graphics ś Ed McCracken. *Harvard Business Review*, Vol. 71, Nov.-Dec.1993, pp. 134-144, ISSN- 0017-8012

[16] RICHARDSON, K. A., GOLDSTEIN, J. (ed.)., 2007. *Classic Complexity: From the Abstract to the Concrete.* ISCE Publishing, ISBN-978-0-97916-883-3

[17] RICHMOND, B., 1993. Systems thinking: critical thinking skills for the 1990s and beyond, *System Dynamics Review*, Vol. 9, no. 2,. New York, USA: John Wiley & Sons, Ltd. pp. 113-133, ISSN-0883-7066

[18] SALGE, M., 2008. *The Role of Goal-Setting and Commitment in Continuous Improvement Processes*, [online] on <http://systemdynamics.org/conferences/2008/proceed/papers/SALGE413.pdf>

[19] STRICIK, M., HAJDUOVA, Z., 2011. Inovacne aktivity malych a strednych podnikov [Innovation activities of SMEs]. *Podnikova revue Business Review*., Vol. X, Num. 21, ISSN-1335-9746

[20] SVATA, V., 2011. IS Audit Considerations in Respect of Current Economic Environment. *Journal of Systems Integration,* Vol 2, No 1, pp. 12-20, ISSN 1804-2724

[21] *Wikipedia - Causal loop diagram*. Wikipedia. [online] on <http://en.wikipedia.org/wiki/Causal_loop_diagram>

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