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CLIMATE CHANGE: A THEORETICAL REVIEW

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ABSTRACT

Climate Change has been undoubtedly the most illustrious environmental issue since late 20th century. But neither the discourse merely emerged during that time, nor it was problematized in the same way since its onset. History of Climate Change discourse reveals that from a purely scientific concern it has turned into a public agenda that is nowadays more inclined to be development problem. Transformations have brought about a complete new paradigm every time. This article presents a theoretical analysis of the Climate Change discourse and to do so it captured the underlying philosophy of the issue using Thomas Kuhn's well-known thesis of 'paradigm shift'. In particular it discusses about the crisis that lead the issue towards transformations; explores key perspectives around the crisis thus representation of the issue in the environmental discourse over the time. While this paper establishes that with the beginning of the 21st century, the discourse entered into a new paradigm and will reach to a critical point by the end of 2012, it finally postulates some measures that the discourse might integrate with the existing to advance beyond that point.

KEY WORDS

climate change, anthropogenic, eco-centric paradigm, anthropocentric paradigm, post-Kyoto

CLASSIFICATION

JEL: Q54, Q56
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INTRODUCTION

'Climate Change', the most uttered environmental term of present time has been used to refer to the change in modern climate brought predominantly by human being. It is perhaps one of the most serious environmental issues that today's world population facing [1-3] though the issue is not new [4]. Ever since it emerged in the early nineteenth century, upto late twentieth century the issue was a topic discussed exclusively within the scientific society [4, 5]. In the mid to-late 1980s it first emerged on the public agenda [5, 6]. Since then, in one hand, it has been manifested by the believers that consequence of human activities on world climate has reached to an alarming state and posing critical threats to physical, socio-economic structures. On the other hand, the sceptics have presented fairly enough evidence to disqualify the anthropogenic trait of Climate Change. Again, the Climate Change advocates among them have debated over the appropriate methods of addressing the eminent issue. Thus with increasing public involvement in the Climate Change discourse and ensuing awareness regarding the potential risks and uncertainties attached to the issue, it has been debated and problematized from diverse standpoints.

While there has constant debate over the degree and agent of the change, methods to address the emerging risks but no doubt and debate over the fact that climate has been changing from the very beginning of the Earth's history [7]. How has this ever changing climate encountered this anthropogenic attribute over the time? In quest of the answer, the second part of this paper presents a brief definition of Climate Change and the way of manifestation of the issue in the environmental discourse over time. History of Climate Change discourse displays shift in angles from which the issue has been characterized and addressed time to time [4]. Hence the third part examines the key perspectives of Climate Change and the assumptions that lie behind them as they relate to the larger debate surrounding the issue. This part in other words, attemts to analyze the philosophical background of the Climate Change science. The final part presents some hints perceived based on the analysis of problems in a new paradigm.

AIMS AND OBJECTIVES

This paper aims to present an overview of the trend of the Climate Change issue in broader environmental discourse. To achieve this goal, the specific objective of the artilce is to analyse the history of gradual manifestation of the issue and predict a future path of the prominent discourse.

MATERIALS AND METHODS

The paper approached to achieve the objectives and aim through review and careful consultation of relevant journal papers, periodicals, books, international policy regimes, websites and papers of different agencies. However, there is a big group of Climate Change sceptics who deny the anthropogenic Climate Change, this essay didn't incorporate that stream of this discourse rather focuses on the stream boosted by the Climate Change believers. This is due to the author's contention that the perspective led by the believers make the issue survive and progress hence it's rational to discuss about this only.

To analyze the issue theoretically the paper has framed the overall Climate Change discourse through Thomas Kuhn's [8] 'Structure of Scientific Revolutions'. Through this, he, against the conventional 'uniformitarian' conception of scientific progress as a continuous process of stockpiling facts and techniques, suggested a 'catastrophist' view that the process has been subject to periodic breakdowns and changes of direction [9]. While Kuhn [8] argued instead of linear accumulation of new knowledge, progression of science had gone through periodic

revolutions, he suggested three distinct phases of science: 'pre-science', 'normal science' and 'revolutionary science'. 'Pre-science' comes first, and it lacks from a central paradigm. 'Pre-science' is followed by 'normal science' when the practitioners community by 'puzzle solving' approches to enlarge the central paradigm. When this paradigm becomes successful it solves unprecedented problems. Then on building up of some anomalous results, science reaches to a 'crisis'. At this point a new paradigm is accepted that incorporates the old results along with the anomalous results into a single framework. This he characterized as 'revolutionary science'. However, Kuhnian thesis of emphasised role of paradigm and paradigm shifts in the evolution of the natural sciences has been regarded as one of the most influential contribution in 20th century's philosophy of science, it has been increasingly applied in social science since its advent [10]. While Kuhn's work has greatly influnced social science, for instace, in shaping up 'postmodernist' view, Kunin and Weaver [10] noted that economics offered the greatest potential for the fruitful appliclation of Kuhn's scheme among the social sciences. Scholars like Gordon [11], Coats [9] has directly used Kuhn's work in economics to analyze its structure of development.

Analysis of the history of Climate Change discourse suggests it has been spread over three centuries and it had seemingly has gone through transformations over the time. The transformations regarding the central perspectives around the issue has time to time shaped up the investigations and addressing measures. Hence to capture a philosophical overview of the development of the subject under scrutiny i.e. Climate Change, the paper devised it's research based on Kuhn's 'Structure of Scientific Revolutions'.

CHARACTERIZING AND HISTORICIZING CLIMATE CHANGE

Literally 'Climate Change' denotes to long-term change in the statistical distribution of weather patterns (e.g. temperature, precipitation etc.) over decades to millions years of time. Climate on earth has changed on all time scales even since long before human activity could have played a role in its transformation [7]. But UNFCCC [12] defined Climate Change as "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*". However, the IPCC definition of Climate Change includes change due to natural variability alongside human activity [13]. Australian Government's DCCEE [14] in its website described Climate Change- '*our climate is changing, largely due to the observed increases in human produced greenhouse gases. Greenhouse gases absorb heat from the sun in the atmosphere and reduce the amount of heat escaping into space. This extra heat has been found to be the primary cause of observed changes in the climate system over the 20th century*'. Thus in the environmental discourse different stakeholders have characterized Climate Change as mainly the change in modern climate augmented by human activities. And the adverse human activities for example burning fossil fuel, deforestation etc. are considered likely to bring change in some climatic aspects which are briefly presented in the Table 1. Also while talking about Climate Change, these are the features that the term mainly entails.

The term Climate Change however through definitions, policy propagation qualifies as a negative anthropogenic Climate Change in its present meaning, at the onset it did not really appreciated its harmful brunt [4]. The discourse is believed to be started by French mathematician and physician Jean Fourier in 1824 when he described greenhouse effect that's in fact in the core of the climate debate, in his article published at the 'Annales de la Chimie et de Physique' [4]. About half a century later Arrhenius [17] published first calculation of global warming from human emissions of CO2 though Keeling was the first to measure accurately CO2 in the Earth's atmosphere in 1960 [18]. Vlassopoulos [4] notes that

Table 1. Aspects of Climate Change and perceived implications.

Climatic Features		Implications of Change
Global Warming	GHG concentration	Emission of Green House Gases thorough industrialization, travelling etc. is increasing the GHG concentration in the atmosphere. At this moment CO2 concentration is at its highest concentration[1] in 650 000 years – 393 ppm [15]
	Change in world temperature	GHG concentration along with some other issues leads to warming the world. Earth has warmed since 1880. Most of this warming has occurred since the 1970s, with the 20 warmest years having occurred since 1981 and with all 10 of the warmest years occurring in the past 12 years [15] Being central to the issue predominantly, Global warming brings about change in following different features of the human environment
Ozone layer depletion		A slow, steady decline of about 4 % per decade in the total volume of ozone in Earth's stratosphere (the ozone layer) since the late 1970s is estimated [16] which is likely to bring health implications (different cancerous diseases), augmenting extreme weather events (desertification, drought) through opening the curtain that was protecting earth from hazardous sun rays
Shrinking ice sheets		Greenland lost 150 km^3 to 250 km^3 (36 mi^3 to 60 mi^3) of ice per year between 2002 and 2006 and Antarctica lost about 152 km^3 (36 mi^3) of ice between 2002 and 2005 [15]. This on the other hand contributing to the next problem sea level rise.
Rise in Sea Level		Global sea level rose about 17 cm (6,7 in) in the last century [15]. Continual increase is very likely to inundate many island states, low-lying delta regions leaving their population having no land to inhabit.
Ocean Acidification		Since 1750 the CO_2 content of the Earth's oceans has been increasing and it is currently increasing about 2 billion tons per year which has increased ocean acidity by about 30 % [15].
Warming Oceans		With the top 700 m (about 2300 ft) of ocean showing warming of 0,16 °C since 1969 due to absorbed increased heat of the Earth [15]. These two changes are likely to bring massive change/destruction in ocean habitations.

climatic variations were perceived precisely as a scientific issue until 1970, hence the debate was mostly confined to the scientific community of climatologists and relevant research was fragmented into different university endeavours only.

AIP [19] maintains that the rise of environmentalism in the early 1970s raised public doubts about the benefits of human activity for the planet which in other way turned the curiosity about climate into anxious concern. Since then concern about anthropogenic global degradation spreads which ignited numbers of international cooperation, programs and meeting to date of concerned stakeholders including representatives from interested community other than the scientist only [4, 19]. Programs and meetings in 70s appear to take place to explore and acknowledge the extent of anthropogenic Climate Change. Global Atmospheric Research Program (GARP) organized by World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) in 1974 is an example in this regard. It was aimed to examine the highly complex problem of the physical basis of

climate [20]. Another example could be the first World Climate Conference (WCC) organized by the WMO in 1979. Whereas, some significant events in 1980s and 90s, can be said, were inclined to devise methods to address it. For example, Montreal Protocol of the Vienna Convention in 1987 imposes international restrictions on emission of ozone-destroying gases. Two major events in 1990s, one, '92 conference in Rio-de-Janeiro produces UN Framework Convention on Climate Change and another '97 International conference produces Kyoto Protocol (came into effect in 2005) that set targets for industrialized nations to reduce greenhouse gas emissions [18]. Kyoto Protocol is regarded the most significant commitment in addressing Global Climate Change so far. That's why as it expires at the end of 2012, through different conventions, from UNFCCC to the latest Conference of the Parties (COP-17) to the convention, held in November–December 2011 in Durban, South Africa, the world nations are continuing to strive to negotiate what may become the post-Kyoto [21].

KEY PERSPECTIVES AND ASSUMPTIONS IN CLIMATE CHANGE DISCOURSE

While Climate Change discourse has been spread over three centuries it encountered some crisis resulting from perspectives of the concerned community (e.g. scientific) of the time based on relevant assumptions. This triggured investigations, following research knowledge had been gathered and established in the society that became the normal science. Later following counter perspectives there arose crisis again and a shift in the normal science accordingly which prevailed for a period again and thus the discourse goes on with revolution of the established normal science. Drawing upon the historicization in the earlier part of the essay and review of other related literature, I would like to suggest that Climate Change discourse so far belonged to three different paradigms, each changed with development of certain perspectives based on relevant assumptions[2] (Fig. 1). The period before the first 'crisis', can be described as the 'pre-science' period as per Kuhn [8].

The first 'crisis' that begins the climate study can be said 'lack of knowledge about the changing climate', in other words it was 'curiosity' about the climate as noted by AIP [19]. Hence, FoE [22] suggestion for Benjamin Franklin as the pioneer of the discourse (as he started climate studies in the 1763) seems more likely to me, following that crisis. However, Weart [18] and Vlassopoulos [4] suggest the beginning of the discourse in 19th century by Fourier. Notwithstanding this debate, from the very beginning investigation into Climate Change science being driven by 'curiosity' or 'in pursuit of Climate Change knowledge', very rationally attracted exclusively the scientific society in particular the climatologists till the next crisis in 1970's. The study of increased CO2 emissions, and the effects of burning coal to the earth's temperature by Arrhenius, later Fourier did not appreciate its negative impact. It demonstrated that during this time Climate Change belonged to a state guided by an 'objective view' (neutral to any Eco-centric or Anthropocentric view) shaped by the notion that it was completely a scientific issue [4].

Climate Change discourse in modern era (precisely from 1970s) confronted crisis that portrayed through the public doubts about the positive outcome of human activity for the planet that was augmented by rising environmentalism [19]. This, AIP [19] noted, transformed the society's 'curiosity' into 'anxious concern'. The modern society has been characterized as the 'risk society' [23] where Sociologists recognized anxiety about high consequence risks (e. g. global warming) as major theme of it [4]. Hence the transformation was a viable reflection of modern society. This crisis leads towards wider participation of stakeholders and inclusion of societal perspective along with scientific view in the discourse [4]. For example, Global Atmospheric Research Program (GARP) of 1974. Though it was entirely

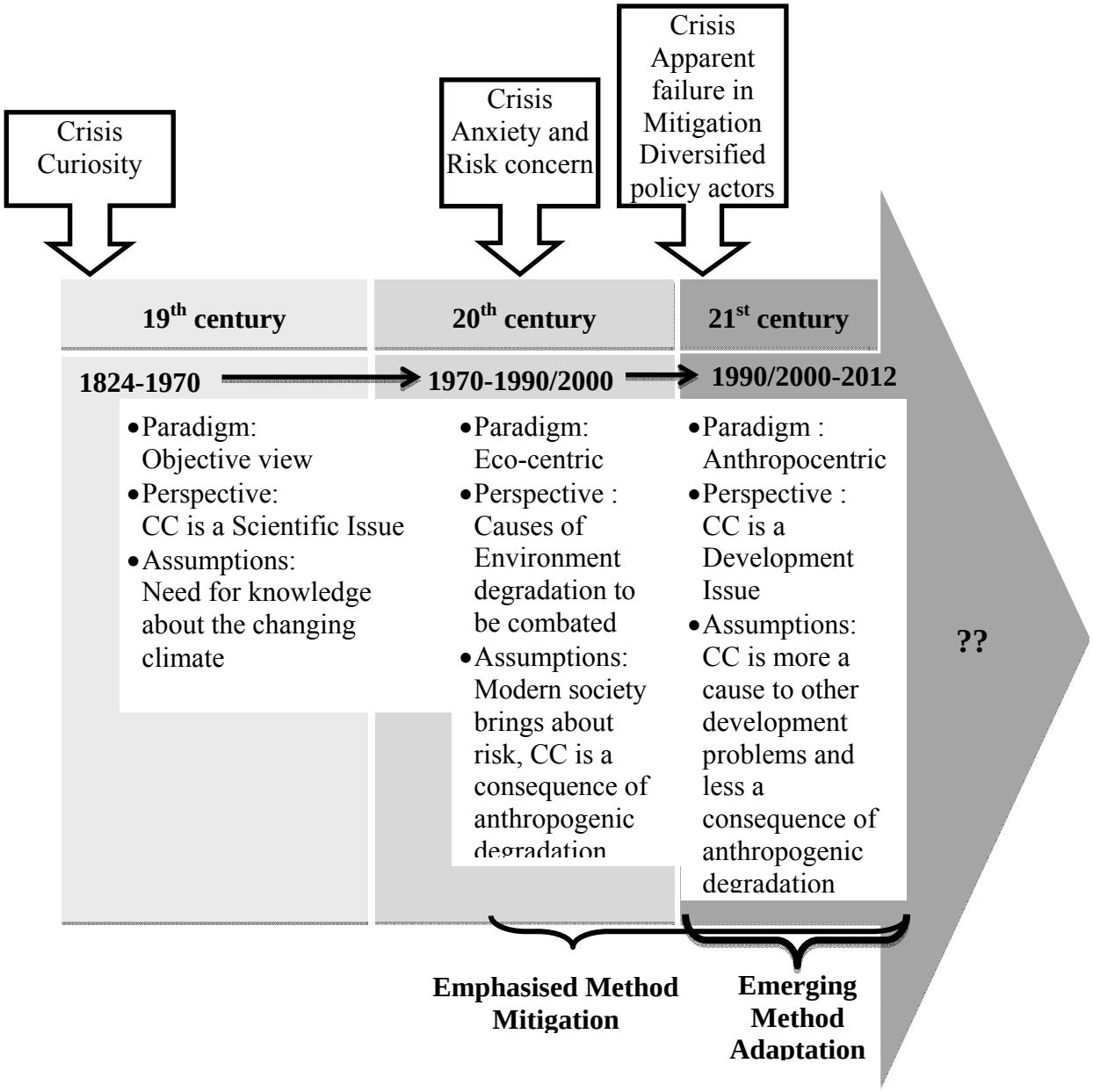

Figure 1. Structure of revolution of the Climate Change discourse.

a scientific meeting, the participants were experts ranging from climate scientists to researchers on energy, land use or water resources. Ausubel [24] noted that the meeting specifically focused on the effects of climatic hazards for developing countries and the potential of greenhouse effects to question the sustainability of the industrial civilization. 1979s World Climate Conference (WCC) is believed to be the first to give a clear definition of human induced Climate Change as a major environmental problem which also identified Climate Change as an autonomous public problem to be addressed by the establishment of environmental policies [4]. This paved way for World Meteorological Organization (WMO) and United Nations Environmental Program (UNEP) to be the main institutional actors in the arena while the first one insured the scientific expertise and the second one insured the policy expertise [4]. This situation, Vlassopoulos [4] notes, placed emphasis on the *cause of Climate Change*, in particular, global warming and '*Mitigation'* measures as addressing method. Kyoto Protocol is an example of this trend which was meant to be setting binding targets for industrialized nations. Vlassopoulos [4] however agreed that Kyoto Protocol and UNFCCC did some work on *Adaptation* but it was of minimal importance.

Mee [25] suggested a shift in the debate followed 'how to deliver Sustainable Development' rather than 'how to protect the environment' in new century following the World Summit on Sustainable Development (WSSD) in 2002. However Vlassopoulos [4] maintains the trend pointed by Mee was prominent in 1970s and 80s, started declining in 1990s after the UN's 92 Rio-de-Janeiro Conference on Environment and Development. He further notes the term "global warming" was experiencing a gradual definitional shift since 90s while it was moving *from* an autonomous environmental problem whose causes (particularly CO2) must be combated *to* being discussed as the cause of other global public problems that are threatening humanity's wellbeing. According to him this considers Climate Change less as one of the consequences of anthropogenic environmental degradation and more as one of the causes of other major problems e.g. development, migration, security etc. [4]. This implies, while the previous period (1970s-80s) climate change was analysed as a physical process within a normal scientific paradigm belongs to an 'Eco-centric' paradigm, the later part till date belongs to an 'Anthropocentric' paradigm. The crises triggered the change in paradigm could be recognized as: lack of commitment by certain big GHG-emitter countries or failure in achieving the set target for Mitigation, the inappropriate application of the emissions trading system and a growing diversity of the policy actors who are approaching the issue with their own management [4].

CLIMATE CHANGE IN A NEW PARADIGM

Although the shift in the global perspective brought about a paradigm shift in Climate Change discourse recently in the new millennium, the discourse in post 2012 is deemed to face some crisis. Those might not challenge the status quo of the paradigm but will require significant adjustment in relevant policy making.

First, due to the definitional shift or change in perspective (from Climate Change as a cause of Environmental degradation to Climate Change as a development issue), a diverse range of public authorities are coming into managing Climate Change problem. Vlassopoulos [4, 26] noted different dimensions of this incorporation of diverse public authorities in policy making of a problem like Climate Change. He maintains while it is more about legitimization of the concerned authority's footing, power in the arena, the definition or characterization of the problem and the policy measure comes according to the specific authority's view. For example, a scientific authority would find the cause GHG emission and other natural phenomena creating 'Climate Change' problem and the consequence is environmental degradation including drought, sea-level rise, extreme weather events etc. whereas a development organization would perceive Climate Change and the relevant degradation as the cause of the problem 'underdevelopment' which is resulting into hunger, poverty disaster risk etc. [27]. Hence different structure will articulate its own rationale of victimization and responsibility attribution and this along with leading to different policy solutions will also influence the recognition of authority to one or another policy sector [4]. Without a common framework to articulate relevant policy it would be difficult to proceed on a time beyond Kyoto Protocol.

Second, manifold problems around further 'Mitigation' measures subsequent to the end of Kyoto Protocol in 2012 are being anticipated. While Kyoto Protocol was appreciated as an acceptable or good first step by some scholars [28, 29], it was "Deeply Flawed" an agreement to many of the analysts [30-32] due to its ambitious targets applying only to a very short term (2008-2012) and merely to some industrialized nations [21]. Hence any post-Kyoto 'Mitigation' mechanism need to take in account the criticisms that Kyoto Protocol faced in order to establish an effective 'Mitigation' measures. This is further essential in order to

address the scientific consensus regarding the likelihood of future Climate Change caused by already grown anthropogenic emissions of GHGs since the negotiation of the Protocol [33, 34].

Third, the significant method to address Climate Change so far has been 'Mitigation' considering 'Adaptation' as a less important one that has been mentioned earlier, but some authors e.g., Parry *et al.* [35] maintained that 'Mitigation' and 'Adaptation' are complementary to each other. For example, Ingham *et al.* [36] argued that greenhouse gas mitigation reduces the speed of global Climate Change, so that societies can gain time through investing in 'Mitigation' which in turn can reduce the costs of 'Adaptation'. Backstrand and Lovbrand [37] noted climate 'Mitigation' and 'Adaptation' has been represented as parallel processes in the IPCC's fourth assessment report that more and more puts stress on development and 'Adaptation' needs and attempts to redress the climate problem in a more locally oriented Sustainable Development theme. Thus a growing support for considering 'Adaptation' as a method of similar importance following the Anthropogenic paradigm in the Climate Change discourse has already been launched through different initiatives. But as a matter of fact despite the growing acceptance of 'Adaptation' as the second pillar of climate policy there is no change in post-Kyoto negotiation institutional framework to appreciate the change [4].

In the face of these challenges the paradigm is envisaged to advance beyond 2012 successfully with incorporation of some initiatives and rearrangement[2] (Fig. 2). First of all, it needs to destabilize the status quo of existing international and national environmental actors in policy making who tend to incorporate the new development, impact-adaptation dimensions into their administrative structures to reconfirm their institutional leading position in Climate Change field. Instead of that, a process should be initiated (probably like the 'UN system delivering as one' which is aimed to achieve a coordinated action-oriented approach to the global and multifaceted challenge of Climate Change) to engage the new actors brought on stage by the new paradigm [4].

Ending of Kyoto Protocol's timeframe is not only posing an uncertainty, reflecting positively, it will create scope for wider and deeper international participation to address the global nature of the climate problem as well as the weaknesses of the Kyoto Protocol [21]. To ensure this Olmstead and Stavins [21] suggested a key element to be present in any post-Kyoto negotiation that is *a framework to expand participation to ensure that the most important industrialized and developing nations are involved in meaningful ways*.

Expanded participation in emission cutting specially including the key developing nations is very necessary to make an effective negotiation. If not earlier, by the year 2020 the developing countries are likely to account for more than half of global emissions [38-40]. Only China emitted 8 % of global anthropogenic CO_2 in 1981 and about 21 % by 2008 [41, 42]. Hence, emerging economies, particularly China, India and Brazil, should engage to limit their carbon footprints [21]. Other than this reason, developing countries are also in a favoured position to cut emission as they provide the greatest opportunities for low-cost emissions reductions [30].

This expanded participation is likely to bring twofold advantage: first, likelihood of endorsement a new binding target by US as promised will be done on bringing the key developing nations under binding target [21], and second, it could augment the 'Adaptation' process. Tubiana *et al.* [43] argued that the developed countries accepted to consider the 'Adaptation' demands coming from developing countries were founded in a win-win compromise, developed world will be willing to mobilize enough resources for 'Adaptation' if the developing side offers something significant in exchange. To continue with an emphasis on 'Adaptation' alongside 'Mitigation', hence, it requires a wider participation to be ensured.

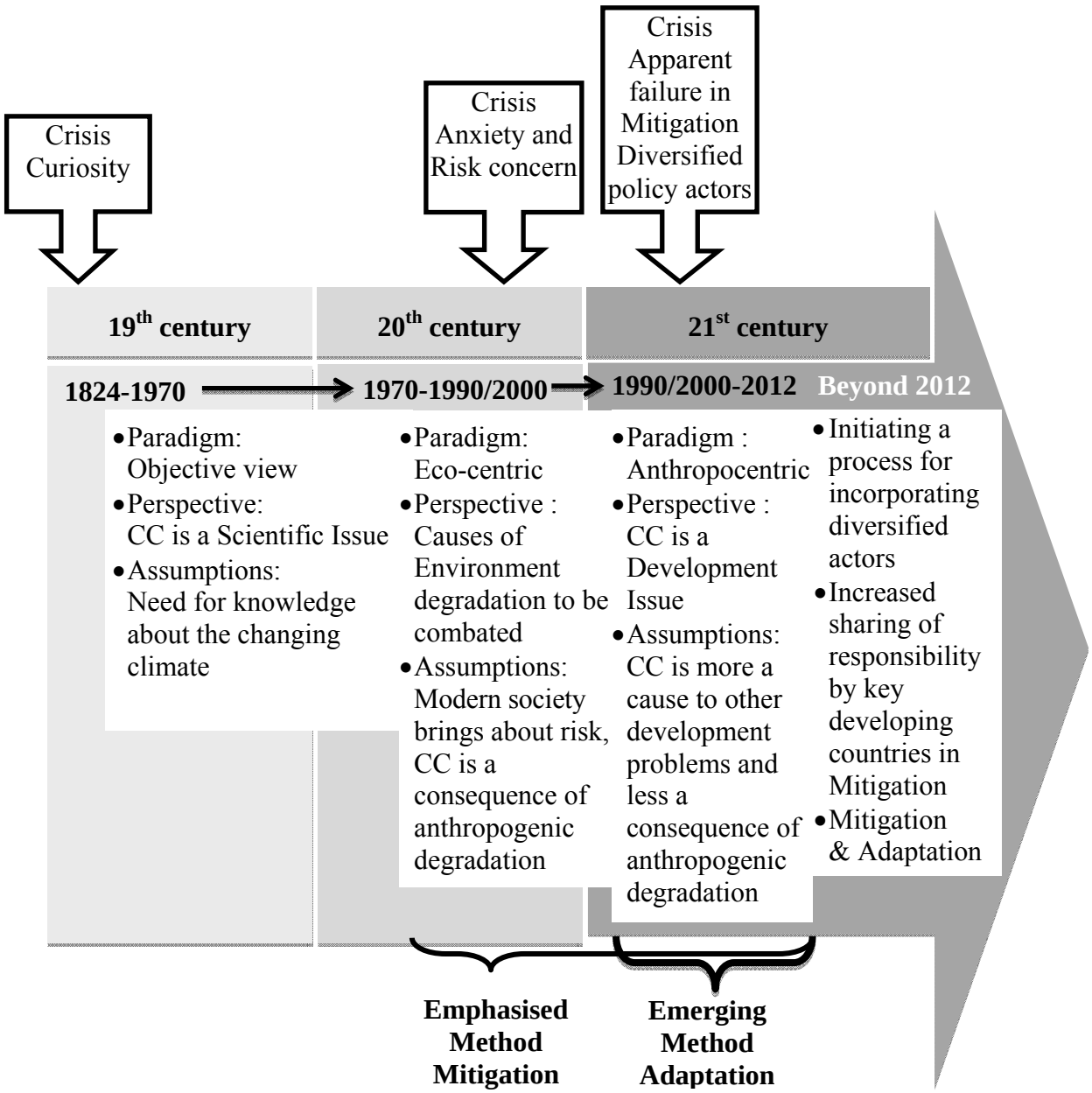

Figure 2. Structure of revolution of the Climate Change discourse with proposed measure beyond 2012.

CONCLUSIONS

The analysis of Climate Change discourse shows that the issue from its initial perspective of 'an entirely scientific issue' moved to be the cause of 'Environmental Degradation' and finally in recent time has turned something much larger and going beyond environmental degradation (Vlassopoulos [4] quotes a personal interview with one UNDP representative, 2010). The change or transformation of the underlying philosophy around the issue has been occurring due to confrontation with newly emerged perspectives among the concerned community. Every time a revolution in the existing philosophy is evident (Fig. 1). Thus, based on the trend, it is anticipated that in the new millennium the shift in the concern from environmental degradation to human wellbeing in other words 'Eco-centric' to an 'Anthropocentric' paradigm is expected to be continuing with a number of correcting measures (Fig. 2) like inclusion of diversified actors, increased responisbility of pertinent

developing nations in mitigation target instead of differntiated responsibility and equal emphasise on mitigation and adaption.

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REMARKS

[1]Data has been collated from the 'Home' section of the referred website.

[2]Developed by the author based on literature referred in the 'Key perspectives & assumptions in Climate Change discourse' section.

[3]Modification conceived based on review of materials referred in 'Climate Change in a new paradigm' section.

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KLIMATSKE PROMJENE: TEORIJSKI PREGLED

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SAŽETAK

Klimatske promjene nesumnjivo su najuočljivije potanje o okolišu od kraja XX. stoljeća. Ali niti je diskurs nastao tijekom tog vremena, niti je razmatran na isti način od nastanka. Povijest diskursa klimatskih promjena pokazuje kako se taj diskurs od znanstvenog pitanja pretvorio u javnu agendu koja se danas najviše razmatra kao pitanje razvoja. Pretvorbe su svaki put dovele do potpuno nove paradigme. Ovaj rad predstavlja teorijsku analizu diskursa klimatskih promjena, zbog čega su obuhvaćeni filozofski temelji u vidu pojma promjene paradigme T. Kuhna. Posebno, razmatraju se krize koje su prethodile pretvorbama diskursa, istražuju glavna stajališta o krizama i shodno tome predstavljanja teme u diskursu okoliša tijekom vremena. Prema ovom radu diskurs je na početku XXI. stoljeća ušao u novu paradigmu i dostigao kritičnu točku krajem 2012. godine. Rad naposljetku postulira mjere koje diskurs treba uključiti kako bi se i nadalje razvijao.

KLJUČNE RIJEČI

klimatske promjene, antropogeno, ekocentrična paradigma, antropocentrična paradigma, post-Kyoto

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REAPPRAISAL OF RATIONAL CHOICE THEORY

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ABSTRACT

The value of rational choice theory (RCT) for the social sciences has long been contested. Much time has been spent by economists and critics on the pervasive but elusive concept of rationality. The critiques mainly challenge the basis of the utility theorem. Several articles on the misuse of mathematics in economics have already appeared in the literature. As N. Bouleau stated, "On several occasions, however, one feels that the criticism is that the math is being misused and should be developed in some other direction (e.g. a statistical analysis of the financial tendencies that polarize wealth and income, or a study of the positive feedback mechanisms, etc.). This leaves certain dissatisfaction – on a philosophical level." The aim of this paper is to present a decision theory, yields intention (logos) and valuation (existence). Here we present a new mathematical representation of RCT, which leads to a dynamic economic theory. We discuss the philosophical or meta-economical problems, which are needed for the successful applications of mathematics.

KEY WORDS

rational choice theory, dynamic economic theory

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INTRODUCTION

The value of rational choice theory (RCT) for the social sciences has long been contested. Much time has been spent by economists and critics on the pervasive but elusive concept of rationality. The critiques mainly challenge the basis of the utility theorem. Several articles on the misuse of mathematics in economics have already appeared in the literature. As Bouleau stated, "On several occasions, however, one feels that the criticism is that the math is being misused and should be developed in some other direction (e.g. a statistical analysis of the financial tendencies that polarize wealth and income, or a study of the positive feedback mechanisms, etc.). This leaves a certain dissatisfaction – on a philosophical level." [1]. Here we present a new mathematical representation of RCT, which leads to a dynamic economic theory. We discuss the philosophical or meta-economical problems, which are needed for the successful applications of mathematics.

The basic novelty is that we start from a phenomenological description of decisions. The main question is not what to choose from the possibilities, but why we choose something and how it changes our environment. Economy is complex system. Basic interactions are the exchanges and transformations (productions, consumption, ...). Agents exchange material, energy, money and information, so they change themselves and simultaneously they change their environment [2, 3]. The economic activity is modeled as transformation and transport of commodities (materials) owned by the agents. Rate of transformations (production intensity), and the rate of transport are given by decisions. Our approach is a new formal description of economic activity which corresponds to the bookkeeping practice, instead of starting from necessity and from equilibrium. As this approach is considered as uninteresting – it was not elaborated, thus have to introduce some new concepts, which are present in the colloquial economics, but they do not appear in the textbooks.

In our previous works we accepted the false idea, that utility maximization principle is the only way to implement the rational choice theorem. We proposed our postulates to replace this. Nevertheless, a careful analysis revealed that our approach is a valid mathematical representation of the RCT. For descriptive economic investigations our results show that for the application of RCT, a time aggregation must be applied, which demands for a new model of decision makers. Depending on the level of aggregation we get two approaches. The first model is the well-known Homo Economicus (HE), which leads to the present equilibrium economics. The other approach is called Homo Sapiens Economicus (HSE), which yields dynamic economics. For HSE a force law replaces the maximization rule; the expected wealth increase behaves such as the economic driving force. The result is complex, dynamic economics. These formal dynamic equations of an economic system will be coupled non-linear equations. Forecast would need a huge quantity of empirical data. Nevertheless, as the system is more complex than physical non-linear systems, they show that generally there is no equilibrium or there are several equilibrium states. Conclusions, economic results from the pure equilibrium theory have less relevance for the real economic world, as there is no argument to assume that real economic systems tend to equilibrium in case of multiple equilibria. This questions the applicability of some aspects of the neoclassical economics. For the analysis of the markets it makes untenable the efficient market hypothesis, being the fundamental idea of mainstream. As Davidson stated "Whether they declare themselves Monetarists, Rational Expectation theorists, Neoclassical Synthesis [Old] Keynesians or New Keynesians, the backbone of their mainstream theories is the efficient market analysis where the future can be known." [4].

In this paper first we will show a result type approach of economics, which describes the changes in stock. Introduced concepts are helping to understand the dynamic formalization of changes, but they are not answering, why an economic agent does his/her activity. The second part of the paper shows the basics of the RCT, namely the postulates and the required constraints in philosophical as well as in mathematical levels. On the basis of RCT we can interpret the wealth (Z) function, which governs our decisions in an abstract level. Function Z has several attributes. One of them is that we can observe the economic valuation of agents. In the end we get a new model for decisions. With some extra constraints on the aggregation process we get HE, which gives us price-value equilibrium. If we skip the extra constraints then we get HSE, with unique valuation, which yields a dynamic approach.

Main message of HSE is that a new economic theory is possible and needed. We hope that the present paper is a step into this direction.

DESCRIPTION OF ECONOMIC ACTIVITY IN REAL TIME – RESULT TYPE APPROACH

An important part of economic activity is related to the production and trade of the goods. In this chapter we focus on a formal description of the changes of the stocks and goods. In the description of human activities, there is a connection between decisions and changes on the goods. But this connection is pure causality. Describing the changes of the stock of goods, bookkeeping practice offers a method called the balance method. Rewriting them in the form of equations for the changes of the stock of goods it gives a bit different formulation to the accustomed. The main aim is to describe decisions related to the change of the quantity of goods (production, consumption, or trade). But what do we call goods? Goods – is anything, which can be characterized by its stock and can be changed by a process selected by decisions, and the person is not indifferent to have it. It can be material, or immaterial, as for instance money or knowledge. An agent can be an individual, or a group of individuals, firm, company, who is able to make decisions. This decision selects the activity, which will result in the expected changes after a certain time, so the role of time and the time dependence in economics is different to natural sciences. For the sake of formalization, Symbol X^a_i is the notation for the stock of the i-th good of agent a, where $a = 0, 1, ..., N$, $\underline{a}$ identifies the agent, $a = 0$ is used for nature, furthermore $i = 0, 1, 2, ..., N_g$ identifies the type of the good and $i = 0$ is used for the money stock owned by the agent.

Quantity of a good change in activities selected by decisions: voluntary changes, and there are involuntary changes, called forced processes. They can be of natural or of social origin. Aging, wearing are always present. Tax paying or robbery are examples of social origin. They must be considered as exogenous changes. Formally the balance equation can be written, as

$$\mathrm{d}X^a_i(t)/\mathrm{d}t = D^a_i(t) + C^a_i(t), \qquad (1)$$

where $\mathrm{d}X^a_i(t)/\mathrm{d}t$ is the change of stock of the i-th good of agent a at time t while $D^a_i(t)$ is the change of the stock of the i-th good of agent a at time t due to activities selected by decisions and $C^a_i(t)$ is the change of the stock of the i-th good of agent a at time t due to involuntary processes.

It is important here, that we use differential equations for the sake of consistency (see below), but continuity is not necessary, moreover the observed time is usually an interval.

An activity means a change in the stocks of goods. Symbol $A_i(t_0, t)$ is for the change of the i-th good at time t in the activity, which was selected at time t_0. Here we assumed that in a moment there is one decision, which causes only one activity. At time t the activities that

started before may result in change, so change of the stock of the i-th good of agent *a* at time *t* is the sum of the results of activities started before, formally

$$D^a{}_i(t) = \int_0^t A_i(t_0, t)\mathrm{d}t\,, \tag{2}$$

It is a very complicated formula, but well-known in the bookkeeping practice. It is not written in this exact form, but the problem can be formulated in this way. For example, an agent pays in advance and the product is delivered two weeks later, or vica versa.

Now the effect of activity selected at t_o is investigated. During the activity the change of goods is not continuous,

$$\mathrm{d}X^a{}_i(t)/\mathrm{d}t = A^a{}_i(t_0, t) + C^a{}_i(t). \tag{3}$$

Imagine a baker. The selected activity is to make bread. The input materials are consumed at the beginning, the electricity consumption is continuous during the baking process, and the bread appears only at the end of the process. Time based description of economic activities is possible, but it needs such details, that are not important, and hardly available for an economic description. In economic description the activities are characterized by the results. For the sake of shorter forms the vector notation will be used, example, $X^a{}_i(t) = \underline{X}^a$. The result of the activity is the total change of stocks during the activity, that is

$$R(t_0) = \int_{t_0}^{t_0+T^{t0}} \underline{A}(t_0, t)\mathrm{d}t\,, \tag{4}$$

where $\underline{R}(t_0)$ is an n-dimensional vector and the components show the change of the stock of the relevant good. This feature gives two further characteristics of the activity: (i) the total time span of the activity, when all the changes aimed by the activity take place, denoted as T^{to} and (ii) the time span of the action, $T^{t0}{}_s$, which is defined as the actual time spent with the activity.

Stock changes caused by the this activity in the result based approach are

$$\underline{X}^a(t_0 + T) = \underline{X}^a(t_0) + \underline{r}\cdot\underline{R}^a(t_0) + \underline{C}^a(t, T), \text{ if } T < T^{t0}, \tag{5}$$

where the components of vector $\underline{r}$ are between 0 and 1, expressing the fact that they are not known, when the actual change occurs in the whole interval

$$\underline{X}^a(t_0 + T) = \underline{X}^a(t_0) + \underline{R}^a(t_0) + \underline{C}^a(t, T), \text{ if } T \geq T^{t0}. \tag{6}$$

As the result type description one can define the stock change but after the end of the activity.

Nevertheless, not all $\underline{R}$ are different. The activities selected in different moments probably have different time histories, but in result type approach the same result can occur several times. It is more convenient to use an index, which distinguishes the results. The effective decision $\underline{R}(t_0)$ can be written into a more transparent form. The results of activities can be classified. We say that activities are of the same type, if the results satisfy the relation $\underline{R}(t_0) = c\, R_i(t_1)$.

A new index, *K*, is introduced to characterize the type. We select one element, preferably the smallest one, as the unit activity e^{K_i}. The detailed description of the unit activity is given elsewhere [5]. The multiplying factor *c* can be interpreted as the intensity of the activity *K*. We use the symbol for it, J^K, so

$$R_i(t_0) = J^K(t_0)\, e^{K_i}\,, \tag{7}$$

or, in vector notation,

$$\underline{R}(t_0) = J^K(t_0)\, \underline{e}^{K_i}\,. \tag{8}$$

Sometimes it is worthwhile to distinguish the activities by the partners. Instead of K a double index b,k can be applied, where b identifies the partner. Then e^{ab,k_i} is the k-th unit activity with partner b, aa is for activities without partner, and $J^{ab,k}$ is the intensity of this activity.

Every agent activity is characterized by the unit activity e^{aK_i}, by the intensity of activity J^{aK}, by the total time T^{aK} and by the time spent on the activity, t^{aK_S}. If the agent a selects the activity K with intensity J^{aK}, then the result is:

$$X^a{}_i(t + T^K) = X^a{}_i(t) + J^{aK} e^{aK_i} + C^a{}_i(t, T). \tag{9}$$

In result type description, it is a must that the activity selected is performed with the selected stock changes. Changes of activities during the activity process are out of the scope of the result-type description. We can see that in the result type approach time must be quantized, because the overlapping of activities, their consequences and realizations are not in the same time. Nevertheless there is no information about the timing of the changes inside the quantum. In a quantum several different activities are present. For a real time dependent description a time aggregation is needed, which means that we ask the stocks at t, $t + T$ and $t + 2T$ moments, and the changes inside T intervals is not considered except the activities, namely here it is assumed that the environment does not change in the T intervals. In result type description, that is in an economic approach, one has to neglect the possibility that activity type is modified during the activity process itself. Similarly, the changes of environment, the technological change, the market changes, simply all the changes have to be neglected for the selected activity.

BALANCE EQUATION IN RESULT-TYPE APPROACH, IN THE QUANTIZED TIME

Change of the stock of the i-th good of agent a at time interval $(t, t + T)$ is

$$D^a{}_i(t, T) = \int_t^{t+T} \int_0^{t'} A_i(t_0, t')\mathrm{d}t_0\mathrm{d}t', \tag{10}$$

and in result-type description

$$D^a{}_i(t, T) = \int_t^{t+T} R_i(t', t')\mathrm{d}t' = \sum_{kb}\left[J^{abk}(t, T)e^{abk_i} + d^{abk_i}\right], \tag{11}$$

where d is for the uncertainty, which originates in the activities that started before but finished in the interval, or that were started but were not finished. In the practical life d is well-known. In bookkeeping practice, in time of balance closing they introduced some operations to diminish this effect. The larger the T, the smaller the d, but on the other hand the time resolution decreases, so for a real description an optimal choice has to be defined.

Stock of the i-th good at time $t + T$ can be written as

$$X^a{}_i(t + T^K) = X^a{}_i(t) + \sum_{kb}\left[J^{abk}(t, T)e^{abk_i} + d^{abk_i}\right] + C^a{}_i(t, T). \tag{12}$$

where $X_i(t)$ is the stock of the i-th good at time t, $J^{ak}(t, T)$ is the intensity of activities started and finished in the $(t, t + T)$ time interval, C is for the changes not selected by decisions, and d is uncertainty.

In the following we assume, that T is selected such a way, that one can neglect the effect of uncertainty. T' must not be bigger than the maximal quantum time. In quantized time the change of stocks has the form.

$$X^a{}_i(t + T) = X^a{}_i(t) + \sum_{kT} J^{ak}(t, T')e^{ak_i} + C^a{}_i(t, T). \tag{13}$$

In quantized time, an agent has a different role compared to real time models. In reality, activity is selected. In economic description, that is in quantized time, the decision is to select

$\sum_{kT} J^{ak}(t,T')e^{ak_i}$. But it is another question, how to choose the activity. In the following section the goal is to make formal description of the choice.

Before proceeding, let us emphasize that there is a difference between describing individual and quantized decision. The acting laws are different. Physics showed that there are difference laws in microscopic and macroscopic – aggregated behaviour. In physics the microscopic level is reversible, and can be described with optimization principles, while the aggregated macroscopic level is irreversible, and governed by the entropy production principle. However, this aggregation is not the same as in physics, where the aggregation is done for the large number of particles. In economics the agents are different; this type of aggregation cannot be applied, only in some special cases.

Time aggregation has more resemblance to the quantum mechanic problem, the transition from microscopic to macroscopic behavior. The analogy is not perfect, but important, not perfect because the real time description refers to the microscopic level (to the quantum world), while the aggregated description to the macroscopic one. Important, because quantum mechanic like description pehaps can give new insights to the modeling of individual decisions. Nevertheless, it is out of the scope of the present paper. We cite only the basic result of quantum mechanics. The laws of physics are different in the micro and in the macro world. The economic man has to introduce for the model of economic activity, and it not simply the aggregation of the individual behavior. First the model of individual decisions is needed.

RATIONAL CHOICE THEORY

Rational choice theory in this aspect is about what activity to choose. For the model of individual decisions the starting point is that an activity is selected by the agent from the set of recognized possibilities, which are characterized by the set $E^{Ra} = \{e^{aK}\}$. The agent selects the type and intensity of activity. The criterion for the selection is well-known. The best is selected [6]. There are no arguments why to select the worse. The problem is that this statement does not tell anything about the selection method, and there is no interpretation of the best. It tells only to the observer, which was the best activity for the agent in the moment t_0, the selected one.

Rational choice theory gives a reasonable description of the selection process. It states that the best is selected by the expected result of the activity. Albeit, it is not a general truth. In reality the form of action and its details can also be important. Compulsive shopping behavior is an example, when the activity is more important than the result [7]. Nevertheless, for the economic decisions or rational choices it seems to be a reasonable assumption that the expected result is the basis of our decisions. Rational choice theory is the idea that individuals make choices to maximize benefit while minimizing cost. It postulates that when making a decision, individuals first weigh the expected positive benefits against the expected negative consequences, and then base their choice on what they think will ultimately benefit them the most. The basic law of human actions is formulated as a separate postulate.

POSTULATE I.

Postulate I.: an individual acts as if balancing costs against benefits to arrive at action that maximizes personal advantage.

The rationality postulate is generally considered the paradigmatic core of economics, but there is no unique understanding. As Vanberg summarized it: “The status of the postulate is very different in the different branches. It is considered either as an empirically testable explanatory theory, or as a non-refutable axiomatic doctrine or as a ‘metaphysical statement’,

while still others regard it as a normative principle that 'tells us how, as rational agents, we ought to choose" [8]. These approaches are different by the representation of the cost benefit analysis. The cost and benefit are defined by the agent and also the meaning of the personal advantage. In normative theories there are attempts to give objective evaluations, but in economic description the subjective evaluation is a must. We follow L. von Mises' approach to economics. The rationality principle is a mere definition. To say that human action is 'rational' according to Mises is the same as saying that it is subjectively meaningful, purposeful or goal directed. He therefore concludes: "Human action is necessarily always rational. The term 'rational action' is therefore pleonastic and must be rejected as such" [9; p.18]. There can be no irrational purposeful economic actions. "Behavioral responses that do not qualify as purposeful actions, such as accidental body movements or purely mechanical reflexes, simply fall outside the explanatory domain of rational choice theory" [9; p.20].

Mises comment states that for every observed decision there is a hidden cost-benefit analysis. The success of a model is defined by the validity of the cost-benefit model. Economic decisions give a model for that.

ECONOMIC DECISIONS

The better or worse distinction is a subjective evaluation of the agent. These decisions can be divided into two groups, economic and non-economic decisions. In case of economic decisions the cost and benefit arise from the relevant changes of stocks. As for instance, when the baker makes the bread the input materials and the services (electricity, ...) represent the cost and the benefit is the bread, or when shopping the money is the cost and the product purchased is the benefit. In non-economic activities the cost or the benefit is not represented by them. A trivial example is to give money to a beggar. Nevertheless, it is well discussed, that this action is not irrational, if one considers the psychological welfare of the agent. If it is incorporated into the symbolic goods, then the result of the action, to give money to the beggar, leads to a better state for the agent. Whether a decision is economic or does not depend on the modeler, which goods are included into the description. If the symbolic goods are not taken into account, then such type of actions are not in the decision part, but they belong to the constrained processes. Similarly, the consumption can be a decision, if the symbolic goods contain the physiological state, or a constrained process, if it is not present. There are mixed cases also, when the decision is partially economic, but not fully. Scientists, especially the economists, give an example. On the basis of economic price evaluation it is much better to do business than science. The question is, what kind of goods are included by the modeler.

For that part of economic decisions, which concern the activities of changes of the stock of goods a rationality criteria is that the agent selects the activity if the result leads him/her to a better state.

POSTULATE II.

Postulate II: An economic activity is selected by the agent in the hope that leads to a better state.

This postulate is universally valid, if it is violated, then there is an error in the model of the agent, something is missing from the description. Economic decisions are based on RCT, so the agent is able to evaluate the effect of an activity, that is she/he can answer for the question, whether $\underline{X}$ or $\underline{X} + \underline{R}$ is better, it means that there is a preference order in the set of the stocks of goods.

We make two further mathematical assumptions, which are needed for the formalism, namely:

- **Partial Completeness** is the known part of the set of good stock states can be ranked in an order of preference (indifference between two or more is possible),

- **Transitivity**, if state $\underline{X}_1$ is preferred to $\underline{X}_2$, and state $\underline{X}_2$ is preferred to $\underline{X}_3$, then $\underline{X}_1$ is preferred to $\underline{X}_3$.

As these preference ordering is the result of a learning process the transitivity is not general truth, but the effect of a recognized in-transitivity can causes a cognitive dissonance, and everybody tends to eliminate it, so it is an acceptable assumption.

The agent is characterized by the wealth function, Z with the property

$$Z(X_1) > Z(X_2). \tag{14}$$

if state $\underline{X}_1$ is preferred to $\underline{X}_2$. Z may seem to be very similar to the utility function. The postulates are the same, except the continuity one, which is not needed. This is a basic difference in the postulates. Also in case of utility the postulate demands for the selection of the best. In the wealth function (Z) the evaluation of the result is demanded. Z is not assigned to the result of decisions, as the utility, but to the ownership of stocks. In a special case the change of Z will be the utility function, as it will be described later.

Overall, Z is quantity, which is expected to be increased in the production and trade processes, and it reflects the valuation of the total stock of goods. It coincides with the colloquial notion of the wealth, except that it is a subjective measure, and it is not measured in monetary terms. It is the measure of those parts of happiness which originates in the ownership of the goods. It is not the hedonistic concept, but the Aristotelian, eudaimonic concept of happiness; wealth is a part of happiness, which is related to the ownership of the goods [10]. Ljubormirsky [11] summarized an empirical results that for individuals psycho-genetic factors gives 50 % of the happiness, 40 % is from the voluntary actions and 10 % from the ownership of goods (material and symbolic). To distinguish it the everyday use of the word, which is bounded to the money, we call it z-wealth, or wealth function.

MEASURE OF WEALTH

Wealth function Z, is a subjective measure: that is, it is only in the human mind, it does not exist outside of the human mind. This subjectivity does not mean arbitrariness. The wealth governs the decisions, so the circumstances define which is the "fit" form, if the form does not fit to the natural and social environment then the agent (individual or firm) will lose. The agents learn the valuation, expressed by the wealth function, and they modify it reflecting the experiences. Function Z cannot be directly measured. Nevertheless it governs our decisions, and from the observations of decisions some of its properties can be revealed. Z expresses the valuation of the resources.

Properties of Z:

1. since z-wealth is a positive attribute, a function that measures z-wealth must be non-negative,
2. all resources, material, symbolic goods and money that are owned by the economic agent are included within the function. On the other hand, in economic models, one can prepare simplified models. As it was discussed, the distinction between decision governed and constrained processes depends on the model,
3. an increase in the agent's ownership of stocks of beneficial goods or money results, ceteris paribus, is an increase in the agent's z-wealth,
4. the z-wealth change caused by the change of the stock of goods expresses the increase of happiness, which coincides our definition of value. Starting from the definition of value given by Menger: "To have value, a good must assure the satisfaction of needs that would not be provided for if we did not have it at our command. But whether it does so in a direct or in an indirect manner is quite irrelevant when the existence of value in the general sense of the term is in question." [12].

The z-wealth change in case of dX_i change of the i-th good in first order is

$$dZ = Z(X_1, X_2, ..., X_i + dX_i, ..., X_n) - Z(X_1, X_2, ..., X_i, ..., X_n) = w_i dX_i. \quad (15)$$

where the $w_i = dZ/dX_i$ symbol means the subjective z-wealth value of the i-th resource, as it is the increment of z-wealth, due to the infinitesimally small quantity of the i-th resource. We call it z-value[1]. For normal goods the z-value is positive, and it is a decreasing function of the stock of resource in a quantum. If the supply of any class of resource is so great that every demand is met, then the increase of the resource does not mean „better life", so it must not lead to the increase of wealth, then value is zero or negative if it causes further problems. If, in any class of resource, the supply is not sufficient to meet the demand for satisfaction then the increase of the stock increases the wealth, and value rises. For cultural goods the typical behavior is that the value increases with the quantity. It is also important, that the valuation does not depend just the Gossen laws. It has other factors also.

A special good, money has also a z-value, if $X_n = M$ the symbol for money, then the z-wealth change with dM money change is:

$$dZ = Z(X_1, X_2, ..., X_i, ..., M + dM) - Z(X_1, X_2, ..., X_i, ..., M) = w_M dM. \quad (16)$$

With this definition of z-wealth and z-value the money has also a subjective value. It is the change of wealth due the increase of money stock. Neoclassical economics in the standard form does not deal with the value of the money. However it is a historical fact, that the subjective utility of money was introduced by Bernoulli in 1738. He proposed a solution for the St. Petersburg Paradox based on the notion of expected utility. Bernoulli proposal was that utility (of the money) is a logarithmic function of the amount of money [13, 14]. Bernoilli's utility of money coincides with the z-value of the money. The appearance of the value of money opens a new way for the optimization of economic processes [15-17].

DESCRIPTION OF ACTIVITIES WITH *Z*

With the postulates and Z function we can describe the selection method of the activity in an abstract level. In a trade activity, when q_i quantity of the i-th good is bought for m money, the change of Z is

$$dZ = Z(X_1, X_2, ..., X_i + q_i, ..., M - m) - Z(X_1, X_2, ..., X_i, ..., M) = w_i q_i - w_M m > 0. \quad (17)$$

The inequality holds for rational choice. It can be rewritten in a more transparent form

$$dZ = w_M \left(\frac{w_i}{w_M} - \frac{m}{q_i} \right) q_i = w_M (v_i - p_i) q_i, \quad (18)$$

where p_i is the price, and v_i is the value in monetary units. If and only if the system stays in equilibrium, the values equal the prices In equilibrium exchange the z-wealth of the agent does not change. In non-equilibrium activity $dZ > 0$ and dZ/w_M is the z-wealth production in monetary units. That is the colloquial wealth change; we call it wealth increase, or gain, or value production. The quantity

$$G^i = (v_i - p_i) q_i, \quad (19)$$

is the gain of the i-th activity (if previously we assumed that the i-th activity is this exchange). More generaly,

$$G^K = \sum_i v_i J^K e^{K_i} . \quad (20)$$

which is a form valid in linear approximation, while in the general nonlinear case one has

$$G^K = Z(\underline{X} + J^K \underline{e}^K) - Z(\underline{X}). \quad (21)$$

The gain sums up the value produced and the value sacrificed, the result is the net value production. Our aim to maximize the wealth, or the gain. The choice is the selection of J^K. A simple and straightforward solution is the optimization. Quantity J^K will be selected to maximize *G*. The situation in the z-wealth approach is different, compared to the utility approach. For the introduction of *Z* it was not postulated that *Z* is maximized. The rational choice theorem (postulate I.) ask for the maximization of *Z*, but in the reality it is a conditional optimization. It would be a rather strong and artificial assumption, that *G* contains all the cost and benefit, that is, to assume that only stock changes are important in economics. It is well-known that the ethical norms and the cost of the violation of these norms also matter.

For the optimization of *Z* one has to define the boundary conditions, too:

- an agent in reality has a hierarchical decision; first he/she selects a group of activities, and selects the activity only from the group,
- ethical norms and confidence also effect the decisions. The exchange is always based on the expectations, and a well-known partner has an advantage.

Individual decisions cannot be described by *Z* alone. Nevertheless, observations of individual decisions give information about *Z*. Present formalism offers an alternative way for the description of decisions. The expected gain is the driving force for our actions. We act, if there is a hope for gain. Generally it is valid also, that the higher is the expected gain, the higher is our willingness to act, that is J^K is defined by the driving force. We define the driving force as the gain of the unit activity for a simple trade process, as

$$F^{\mathrm{i}} = v_{\mathrm{i}} - p_{\mathrm{i}}, \tag{22}$$

which is just the value and price difference. In general form, for any activity the unit activity and the values define the force:

$$F^K = \sum_{\mathrm{i}} v_{\mathrm{i}} e^{K_{\mathrm{i}}} . \tag{23}$$

The relation of gain and force is

$$G^K = J^K F^K. \tag{24}$$

Postulate II. states that $G \geq 0$ for actions selected. J^K *is* usually non-negative. In case of traders who sell and buy the same good, it can be of both signs. For traders, the postulate II. states that $J > 0$, that is the trader buys if the value is higher than the price, and $J < 0$ in the opposite case. In the other cases gain of unit activity has the property, that $J = 0$ if $F \leq 0$ and the greater the *F* the larger the *J*. The expected gain, the value production is the driving force for our activities. It suggests for the linear case

$$J^K = L^K F^K. \tag{25}$$

in which *L* couples the driving force to the intensity of the action. *L* is called motivation. The higher the motivation, the higher the action. In general case

$$J^K = J^K(F^1, F^2, F^3, ...). \tag{26}$$

Introduction of the motivation solves the second problem, listed in the boundary condition of the choice. Confidence, ethical norms can be incorporated into the motivation or in the force law. Nevertheless, for individual decisions this approach is not easily applicable, as it does not solve the problem of the selection of *K*. It answers only for the determination of the intensity, if the type of activity is selected. $F > 0$ does not imply $J > 0$, as in a moment only one activity can be selected.

There is a way to overcome this difficulty: aggregation in time as we do in the result type description.

RATIONAL CHOICE IN QUANTIZED TIME

Describing the real selection of the individual decision seems impossible, because the time overlapping activities and time difference between decisions and theirs realization. To solve this problem we must aggregate in time.

Agents are characterized by the stock of the goods, $\underline{X}^a$, by the z-wealth $Z^a(\underline{X}^a)$, by the set of recognized set of possibilities for activities and by the unit activities $\underline{e}^{aK}$. In quantized time the change of stocks takes the form.

$$X^a{}_{\mathrm{i}}(t+T) = X^a{}_{\mathrm{i}}(t) + \sum_{kT} J^{abk}(t,T')e^{ak}{}_{\mathrm{i}} + C^a{}_{\mathrm{i}}(t,T). \tag{27}$$

In economics, that is in quantized time, an agent has to select $\sum_{bkT} J^{abk}(t,T')e^{abk}{}_{\mathrm{i}}$. There are two ways of modeling that problem, namely:

- selection is done for $\underline{q} = \sum_{kT} J^{abk}(t,T')\underline{e}^{abk}$,
- selection is done for J^{abk}.

First approach leads to the HE description, to an equilibrium world. Second approach is a new description.

THE FORM OF HOMO ECONOMICUS

In the aggregated form the summation is done for the type of activities and for the partners as well:

$$\underline{q}^a = \sum_{kbT} J^{abk}(t,T')\underline{e}^{ak} . \tag{28}$$

The result is average quantities, gains and dehumanized activities in the quantum. Economic environment is replaced by an average, equilibrium economic system, which made the description value-blind and it is called market. This HE is bounded to equilibrium economic systems.

In this scenario selection problem for HE is formally the same as for individuals, he/she selects the best $\underline{q}$. The RCT gives the maximization principle. As aggregation makes it impossible, to take into account the constraints, the selection principle for the aggregated decision is the maximum of Z.

With one more philosophical constraint, in neoclassical economics the money cost appears only as a budget constrain, so the selection problem is

$$\max\{Z(\underline{X}+\underline{q}) - Z(\underline{X})\}, \text{ with } \Delta M = m. \tag{29}$$

As the description is bounded to equilibrium, there is no time, no stock change in time, so $\underline{X}$ is constant, Z equals the utility function and the choice is described by the following:

$$u(q) = Z(\underline{X}+\underline{q}) - Z(\underline{X}). \tag{30}$$

The price for it is the loss of dynamics. Further, which became a source of controversies, it remained hidden that the HE model is only for the aggregated decisions. Let us summarise the main properties of HE in this approach:

1. HE is a model for the individuals, for the consumers. For producers there is different decision formalism,
2. HE sees only the aggregated, averaged, "equilibrium" market, where is one unique price for every good,
3. choice possibilities are defined by the set of the consumption baskets $\{\underline{q}\}$,
4. budget constraint is externally fixed,
5. perfect information, which is an euphemism, as it implies that HE knows all the prices[2].
6. the selection is done by the utility maximization.

Nobel Laureate Robert Solow [18] has characterized – tongue at least partially in cheek, one supposes – three central 'structural' pillars of economic theory as "greed, rationality and equilibrium". By 'greed' Solow apparently means 'selfishly purposeful behavior', that is the essence of utility maximization individuals, with price based budget constraint. By 'rationality' Solow apparently means that agents belonging to the subspecies Homo Economicus understand their own preferences and make optimal, utility maximizing decisions based on that understanding and on whatever budgetary constraints are applicable.

THE FORM OF HOMO SAPIENS ECONOMICUS

We return to that aggregation, which is without activity aggregation. HSE selects J^{abK}, and for every activity the agents assigns the diving force, $F^{ab,k}$. The objections against force law for individual decisions disappear in the aggregated decisions. In quantized time generally it is valid, that if $F > 0$ then $J > 0$. We assume that the agent selects the activity based on the driving force.

This gives us the properties and results of HSE. Postulate II. is valid for all type of economic agent, so the HSE is model of individuals as well as firms, companies and organizations. HSE is a model for activities concerning the changes of goods, so it is a model for production and trade decisions. Its characteristics are:

1. HSE is characterized by the stock of goods $\underline{X}$,
2. the valuation of the agent is done on the basis of the wealth function, Z,
3. the activity set $\{\underline{e}^K\}$,
4. force law:

$$J^K = J^K(F^1, F^2, F^3, ...). \tag{31}$$

When cross effects can be neglected, one obtains

$$J^{ab,k} = J^{ab,k}(F^{ab,k}). \tag{32}$$

As $J = 0$ if $F = 0$, the first approximation is the linear relation

$$J^{ab,k} = L^{ab,k}F^{ab,k}. \tag{33}$$

Quantity $L^{ab,k}$ couples the intensity and the force, we call it motivation. It reflects the ethical norms, and also the confidence. It is also a result of learning. This is an experimentally observable relation. The well-known supply-demand curves can be reinterpreted in HSE approach. Consider the case, when agent a sells the i-th good to agent b at price p. Driving force for agent a is:

$$F^a = p - v^a{}_{\mathrm{i}}. \tag{34}$$

Driving force for agent b

$$F^b = v^a{}_{\mathrm{i}} - p. \tag{35}$$

For small forces the linear relation can be applied, for larger forces a less steep increase is probable. These relations plotted give the usual Supply-demand curves. Difference is that instead of classical elasticity, r the motivation, L is used. The relation between L and r is

$$L = r\,p_0/f(p_0). \tag{35}$$

From supply-demand curves numerical value of L, and that of the monetary values of goods can be learned.

The result is a new model of economic agent, Homo Sapiens Economicus. Then HE is a special case of HSE. Differences of the behaviour arise from the restrictions built in HE. Characteristics of HSE are:

1. HSE is a model for all type of economic agents; it works for individuals, as well as for firms, for companies or for organizations. It is a model for consumers and producers,

2. HSE sees the partners, so there is no need for the aggregated, averaged, "equilibrium" market, there is no one unique price for the goods. The prices are fixed by the agents. There can be bargaining, or a part of the agents are price makers, while the others are price takers,
3. choice possibilities are defined by the set of the unit activities $\{\underline{e}\}$. Technological changes, innovations and the knowledge of the agents appear in the transformation of this set. Development usually increases the set, also some elements also disappear from the set. For instance the set of the activities for my grandmother contained elements, which are missing from my set of activities. She could prepare homemade soap, which knowledge is missing for me,
4. budget constraint is present only in the form, that the money stock must be non-negative. Loans, dept has to be handled as goods, naturally with negative value,
5. reasonable information. Agents do not know all possible activities, which are available to him/her, he/she works only as the known part. Similarly he/she does not know all the partners. It is reflected in the force law, J^{ab} is zero for the unknown partners,
6. selection is done by the force law. Agents want to select outcomes that increase their wealth, and to avoid losses (on the other hand it is not assumed that more of any good is always preferable to less),
7. agent is characterized by the function $Z^a(\underline{X})$ and in linear cases with the motivation $\underline{L}^a$ (in general case the $J = J(F)$ relation).

For the mathematical model we apply the mathematical postulate. Mathematical representation of HSE needs the knowledge of the following quantities:
1. quantities of the stock of goods, $\underline{X}$ owned by the agent,
2. wealth function Z,
3. activity set $\{\underline{e}^{aK}\}$,
4. motivation $\underline{L}^{a,K}$.

Unfavourable outcomes cannot always be avoided, because even if the agent has perfect knowledge, the result of decision will be the expected one, which is not always the case, circumstances and the knowledge can change between decision and outcome. The longer the delay between decision and consequence, the more likely it is that the outcome will be different from the expected outcome. The difference between expectation and reality can be unfavorable in terms of the agent's values and priorities. In this case the agent will (or may) change the valuation, or the force law – on the basis of the reliability of the partner. This type of modifications can be done based on the knowledge change. Observing the success and failure of other agents can be sources of changes in the form of valuation expressed by Z. Knowledge changes the activity set, which may modify also the valuation and the force law. Useful knowledge (and skill) accumulates as a result of experience and inadvertent learning, but the learning process cannot be avoided.

In economic models these changes must be incorporated, that is the description is inherently in the developing path. Nevertheless it is a reliable program that in the first stage of the implementation this development is neglected, and then the equation system will describe the market mechanism.

CONCLUSIONS

Homo Sapiens Economicus offers a less restrictive mathematical representation of rational choice theorem, than Homo Economicus. Homo Sapiens Economicus allows us to observe the valuation of the agents. In this approach it is possible to build a dynamic economics, which was the intention.

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REMARK

[1]It is really similar to the marginal rate of substitution (MRS), the main difference is MRS is always relative, it is comparison the goods, while Z-value is a parameter for one good.

[2]He is a cynic, by the definition of Oscar Wilde: "What is a cynic? A man who knows the price of everything and the value of nothing".

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PREISPITIVANJE TEORIJE RACIONALNOG IZBORA

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SAŽETAK

Značenje teorije racionalnog izbora je u društvenim znanostima odavna osporavana. Kritičari su mnogo vremena posvetili uvjerljivom ali i nedohvatljivom konceptu racionalnosti. Kritike su najviše upućivane temeljima teorema korisnosti. Već se nekoliko radova o krivoj uporabi matematike u ekonomiji pojavilo u literaturi. Kao što je N. Bouleau izjavio,"U nekoliko slučajeva, međutim, osjeća se kritika kako je matematika krivo uporabljena i kako mora biti uporabljena u drugom pravcu (npr. u pravcu statističke analize financijskih nastojanja polarizacije bogatstva i prihoda, ili u pravcu mehanizama pozitivne povratne veze, itd.). Na filozofskoj razini to ostavlja nezadovoljstvo." Cilj ovog rada je prezentirati teoriju odlučivanja, namjere prisvajanja i vrednovanja. Predstavljamo novu matematičku reprezentaciju teorije racionalnog izbora koja vodi do dinamičke ekonomske teorije. Razmatramo filozofske i meta-ekonomske probleme koji su potrebni za uspješnu primjenu matematike.

KLJUČNE RIJEČI

teorija racionalnog izbora, dinamička ekonomska teorija

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PRICE THEORY AND MONEY COUPLED: SOME REMARKS ON THE AYRES-MARTINÁS THEORY

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ABSTRACT

The main concern of economic science is to explain the Wealth of Nations. This tradition implies on the one hand, that wealth must be evaluated i.e.: economic science must elaborate a price theory; on the other hand, money should be integrated in economic theories because prices are expressed in monetary terms. Mainstream economic theory succeeds in price determination (with some limits) but fails on money integration, while non-mainstream monetary models succeed on money integration but fail on price determination. In this paper I argue that the Ayres-Martinás theoretical framework is a promising tentative to cope with this challenge of economic science.

KEY WORDS

microeconomic foundations, macroeconomics

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INTRODUCTION

General equilibrium theory, though facing serious flaws, still constitutes the core of economic thinking. The ideological reason – or explication in terms of paradigms [1] – is clear as also summarised by Soros [2]: "In the absence of equilibrium, the contention that free markets lead to the optimum allocation of resources loses its justification. The supposedly scientific theory that has been used to validate it turns out to be an axiomatic structure whose conclusions are contained in its assumptions and are not necessarily supported by the empirical evidence. The resemblance to Marxism, which also claimed scientific status for its tenets, is too close for comfort."

If ideological aspects are ignored, one should admit that the general equilibrium theory is a "theory of the determination of prices" [3]. Hence, general equilibrium theory responds one of the core questions of the inquiry into the Wealth of Nations [4]. Probably, this is the reason why it is so popular in spite of the fact that out of equilibrium states clearly spoil the price adjustment convergence to the predetermined equilibrium price: "If the supply and demand curves are not independently given, how are market prices determined? If we look at the behavior of financial markets, we find that instead of tending toward equilibrium, prices continue to fluctuate relative to the expectations of buyers and sellers. There are prolonged periods when prices are moving away from any theoretical equilibrium. Even if they eventually show a tendency to return, the equilibrium is not the same as it would have been without the intervening period. Yet the concept of equilibrium endures. It is easy to see why: without it, economics could not say how prices are determined" [2].

Connected to this price adjustment problem, a coherent adjustment process is unimaginable without money. From practical considerations, a theory without money for economic policy has very limited scope: "... the condition that supply and demand are independently given cannot be reconciled with reality, at least as far as the financial markets are concerned – and financial markets play a crucial role in the allocation of resources ..." [2]. Unfortunately, proper integration of money into the general equilibrium theory is not yet solved.

The empirical evidence on the importance of money led non mainstream monetary economists to break with the starting point of the general equilibrium theory in favour of a departure from money. Though these models capture monetary flows, they fail on the proper determination of prices.

Schematically the present state of the art is as follows. We have a price theory but no money, or vice versa we have money but no determination of prices. Consequently, the core problem is to construct a macroeconomic theory (include money) with micro-foundations (price determination).

In this paper I examine the Ayres-Martinás theoretical framework [5] as a promising tentative to solve this problem of constructing a coherent micro-founded model with money.

In the first point, I discuss some problems hindering the proper integration of money into the general equilibrium framework in a perspective to determine minimal conditions for the integration of money. In the second point, I briefly discuss some of the major properties of non mainstream monetary models in the perspective of defining the minimal conditions of useful model of money. At the same time I explain why one should go further and cannot stop at the non mainstream monetary models. Finally, I show that the Ayres-Martinás theoretical framework is compatible with these minimal requirements.

LESSONS FROM THE GENERAL EQUILIBRIUM THEORY: SOME PREREQUISITES FOR THE INTEGRATION OF MONEY

The main idea of the general equilibrium theory is that economic agents exchange commodities with each other at will on the markets. An exchange can suffer from technical or informational difficulties. The technical difficulty is simply that the double coincidence of wants does not hold. The informational difficulty is that economic agents have no knowledge on the state of the overall economy, that is to say they do not know at which price markets clear. These two difficulties are evacuated by the fictive agent of the "Walrasian auctioneer". But the fable of the Walrasian auctioneer takes us far from the description of a decentralised market economy (unless there is no fundamental difference between a centralised and a decentralised economy). If the Walrasian auctioneer is eliminated, the coherence of the general equilibrium theory is also ruined:

1) if agents do not know when prices are at their equilibrium level, then they may make exchanges at non equilibrium prices. As a consequence, the equilibrium also changes [6]. Hence, the adjustment mechanism between two states cannot be omitted, which is equivalent to the abandon of the equilibrium analysis,
2) connected to the previous problem of the convergence to the predetermined equilibrium, there is no insurance that the way of the realisation of exchanges does not influence this price adjustment path. That is to say, if exchanges are not realised by the help of the Walrasian auctioneer, but by the help of money, it is possible that the equilibrium state changes. For standard monetary theory, the problem of money is hence simply a problem of selection between equilibrium states [7]. However, the Hahn problem [8, 9] shows that one cannot stop at this point for a coherent model: in fact, the variable called money can have zero price in equilibrium. That is to say this variable cannot fulfil any functions of money: it is not money. Inversely the question can be raised: even if this variable has positive price, is it money? Thus, the coherent integration of money is equivalent to the identification of money in the model. For more than half century, this integration into the general equilibrium theory has failed. The major problems causing the inconsistencies were the following:
   - stock-flow problem. The original problem is the incoherence of the Walrasian period with any detailed representation of exchanges [9]. The need for the detailed representation comes from the standard function attributed to money – it is a means of exchange (one can make exchanges within the period by the help of money). This function is clearly incompatible with the notion of the period: a period is an interval of time between two instant during which none of the actions are represented, including exchanges. Let put aside this aspect of the problem. In order to get to the main point, this stock-flow problem should be considered from another perspective: the term "commodity" in modern economics stands for stock and flow variables at the same time. I note that Walras' original theory is free of this fundamental confusion (nevertheless it was him who gave rise to this confusion): in his theory a commodity should be considered as a flow (service of a thing) and capital is a stock (thing itself). Hence, it is not surprising that the stock-flow problem appears in monetary theory. The assumptions that hid this problem are: one period models and the existence of exclusively perishable goods. In order to face the problem of integration of money these assumptions must be abandoned [10].
   - the utility concept is intended to evaluate commodities. A commodity is a useful thing. Things can be characterised by physical properties, that is to say a commodity derives its utility from the physical properties of the thing. In that sense, a financial asset is not a

thing: the fact that for example money is printed on gold, on a piece of paper, or it is not printed at all does not change the usefulness of it. Hence, we cannot use the utility concept for the evaluation of financial assets (including money). The problem is harsher if we think of financial liabilities (for example a debt) as counter-part of a financial asset: is a liability also a commodity? As a result, financial assets are excluded from the decisional problem of the economic agent: they are calculated as residual variables (overall balance at the end of period).

LESSONS DRAWN FROM NON MAINSTREAM MONETARY MODELS

Let us put aside debates on the essence of money as integral part of a proper theory of money [11, 12], and let us focus only on practical considerations. In that case the difference between models aiming at properly integrating money into theories in order to describe the functioning of our modern monetary economies can be reduced simply to differences in mathematical constraints.

In that sense, the core question of adequate modelling is the following: What kind of constraints characterise at best monetary economies?

Not surprisingly, adepts of non-mainstream monetary models believe that financial constraints characterise at best monetary economies; in other terms they believe that financial constraints have decisive effect on the evolution path of our economies (see e.g. [13]).

The obvious question follows: Do financial constraints have other nature than natural constraints?

The general answer is positive: Money creation does not obey to the conservation low of physical objects. Loosely speaking money is created ex nihilo.

To continue this line of thought, the next question is: Why these financial constraints are not simply added to the natural constraints? In other terms, why financial constraints are not formulated analogously to the balance equations of real things? In brief, why the whole story becomes an issue?

The reason why the integration of these financial constraints into the general equilibrium analysis is not obvious is the following: the general equilibrium analysis uses demand and supply functions derived from the utility and the profit maximisation programs when formulates the balance equations. The problem is that the excess demand function of any financial asset (as well as money) cannot be deduced from these maximisation programs. As already mentioned, this is because on the one hand, financial assets cannot enter into the utility function and on the other hand these assets cannot enter into the profit maximisation program. They are simply calculated as residual variables (overall balance at the end of period).

Non-mainstream monetary models do not solve this problem. They simply avoid it: without micro-foundations there is no need and obligation to formulate the underlying individual behaviour.

The final question can be raised: If at the end the individual constraints sum up to an overall constraint and if this overall constraint is correct, then why should we bother ourselves with the micro-foundations?

The answer lies in the core problem of economic theory, from the perspective of the Wealth of Nations. In spite of its inconsistencies, the general equilibrium analysis provides a price theory – a theory on the determination of (relative) prices. But non mainstream monetary models fail on this point. Thus, from theoretical point of view we should have micro-foundations in order to have a complete theory; from practical considerations to avoid the limited scope of possible investigations.

Hence, in the next point I examine whether there is any promising attempt that can solve the coherent integration of money and price theory at the same time.

THE AYRES-MARTINÁS THEORETICAL FRAMEWORK – A BRIEF DISCUSSION

In the previous point I concluded that the present state of art is as follows: either we have a price theory without proper integration of money or vie versa. I remembered that from theoretical point of view, the omission of money underlies the mainstream price theory because money can affect prices. From practical considerations, the omission of either money (general equilibrium theory) or of price theory (non mainstream monetary models) restraints the possible scope of economic investigations. That is why it is important to construct a micro-founded theory which is compatible with money.

In the followings I argue that the Ayres-Martinás model is a promising framework in that sense. Naturally, further research will say the last verdict.

The basic idea of the Ayres-Martinás theoretical framework is the same as the basic idea of the mainstream economic theory (economic agents are free to make exchanges on the market). In order to focus on the main elements elucidated in the previous points and in order to compare the two theoretical structures, let us consider a simple pure exchange economy in a given period with consumable things and money.

Let us consider the temporary equilibrium version of the general equilibrium theory with external money as being the only durable commodity where agents live just two periods. The problem of the consumer in this setting is to maximise its utility under the budget constraint:

$$\text{Max } U(x_t, x_{t+1}),$$
$$p_t x_t + m_t = p_t e_t + e_m,$$
$$p^e_{t+1} x_{t+1} = p^e_{t+1} e_{t+1} + m_t,$$

where x_t is the consumption in period t (commodity: stock or flow), m_t is money stock hold at the end of period t, e_t is the initial endowment in period t, p_t is the price in period t and p^e_{t+1} is the price in period $t + 1$ as expected by the agent in period t (supposed to be the same for all agents).

The solution of this program is the demand functions as a function of prices, i.e.:

$$x_t(p_t, p^e_{t+1}).$$

Prices are determined from the equilibrium condition when demand equals supply for each period t:

$$\sum_i x^i_t(p_t, p^e_{t+1}) = \sum_i e^i_t,$$

The problem of an economic agent in the Ayres-Martinás theoretical framework can be written as:

$$\mathrm{d}Z(X_t, m_t) \geq 0,$$

where X_t is stock (let us call also commodity). The solution of this program using the identity that of buying for money: $p_t \mathrm{d}X_t = -\mathrm{d}m_t$ is:

$$\mathrm{d}X_t = L(v_t - p_t), \quad v_t = \frac{\partial Z}{\partial X_t}\left(\frac{\partial Z}{\partial m_t}\right)^{-1},$$

with L taken to be a constant, for the sake of simplicity. Prices are determined by the help of the balance equation that

$$\sum_{\mathrm{i}} \mathrm{d}X_t^{\mathrm{i}} = 0.$$

Let us discuss the Ayres-Martinás theoretical framework on the basis of the minimal requirements determined in the previous points:

1) the first obvious observation is that the Ayres-Martinás theoretical framework, like the general equilibrium theory, can determine prices. Hence, it provides a price theory,
2) as to the limits of the general equilibrium price determination, the second obvious observation is that the Ayres-Martinás theoretical framework does not require convergence to any predetermined state furthermore it does not require any convergence at all as opposed to the general equilibrium theory. In fact, the Ayres-Martinás theoretical framework is a non-equilibrium model and economic agents do not maximise (they accept just better offers). This formal difference follows simply from the fact, that the formalism of the Ayres-Martinás theoretical framework is inspired by the non-equilibrium thermodynamics in physics, while the formalism of the general equilibrium analysis is inspired by the equilibrium thermodynamics [14]. It also follows that the price determination of the general equilibrium theory is just a special case of the Ayres-Martinás theoretical framework,
3) the third obvious observation is that time is not necessarily divided into periods in the Ayres-Martinás model, thus the problem of the realisation of exchange can be represented. This leads us to the problem of money,
4) the fourth observation is that in the Ayres-Martinás model money is put in nominal terms into the evaluation function while in the general equilibrium theory it cannot be integrated into the utility function. Grandmont shows [15]: the integration of money in real terms into the utility function is equivalent to the non-integration of money into the utility function if budget constraints are correctly modified. This treatment of money is the result of some very fundamental differences between the two theories,
5) the utility function's arguments are commodities. The utility function shows the utility that consumption represents for the agent. The consumption means the consumption of the services of stocks. Thus, the arguments of the utility function are flows. In most of the time there is a definite relationship between the stock of thing (one piece of apple) and the flow of service of the stock of thing (delicious fruit which satisfies for some time the consumer who eats it up). I mean on definite relationship that the amount of the service does not depend on prices; and the amount of stock determines the amount of flow. Hence, the stock of thing put directly into the utility function is an acceptable simplification. That is why one can see stocks (peace of apple) and flows (hair cut) at the same time in the utility function. When there is no definite relationship between the thing itself and the service of this thing, one must distinguish between the stocks and flows. If one considers not just perishable goods the whole story becomes more complex, but it is not the point here. All I wanted to emphasise is that the lack of definite relationship is the reason why money in nominal terms cannot be put into the utility function. The service of the stock of money (flow) depends on the exchange value of the money stock.

The fact that money in nominal terms is put into the evaluation function of the agent in the Ayres-Martinás theoretical framework clearly shows that this evaluation function is:

- not the utility function. That is why it is better to denote it not by $U(\cdot)$ but rather by another letter, let us say $Z(\cdot)$.
- the arguments of $Z(\cdot)$ are stocks. Hence, there is no confusion between stocks and flows. That is why I denoted the commodity with X (stock) instead of x (stock or flow?).

- the nature of the evaluation function leads us to philosophical considerations. The philosophical considerations and possible interpretations require a thorough analysis. The work on this fundamental point is not finished [16]. Nevertheless, I firmly believe that this work cannot end up in failure. The reason is the following: all economists depart implicitly from the axiom that evaluation of wealth exist in some form, because economists want to make an inquiry into the causes of wealth of nations. In order to say which nation or agent is richer, one should be able to compare different set of wealth. That is to say, agents must have some ordering on wealth. The utility concept is one possible ordering. But I do believe that it is not the only possible evaluation concept.

This brief discussion shows that the Ayres-Martinás theoretical framework fulfils the minimal requirements that we have fixed for the proper integration of money into a price theory:

1) it is a non-equilibrium theory, hence out of equilibrium states are represented;
2) there is no confusion between stocks and flows; the arguments of the evaluation function of the agents are stocks;
3) the evaluation concept is not the utility concept. Hence all stocks (including money) can enter into the decision problem of the agents;

We can conclude that the Ayres-Martinás theoretical framework is not based on the concepts of the general equilibrium theory; it can be considered as a new theoretical framework. The purpose of this paper was not and couldn't be to give a detailed proof on each point. Much work is needed to arrive to the level of sophistic elaboration of the general equilibrium theory. As an excuse, I remember that it took a couple of decades to elaborate the general equilibrium theory, too.

CONCLUSIONS

The main concern of economic science in the Smithian tradition is to explain the Wealth of Nations. This tradition implies two fundamental tasks of economic science. On the one hand, wealth must be expressed in a one dimension variable in order to make possible the comparison of wealth; i.e.: economic science must elaborate a price theory. On the other hand, money should be integrated in economic theories because prices are expressed in monetary terms. Mainstream economic theory succeeds in price determination (with some limits) but fails on money integration, while non-mainstream monetary models succeed on money integration but fail on price determination.

In this paper I argued that the Ayres-Matrinás theoretical framework is a promising tentative to cope with this challenge of economic science. At first glance, the fundamental concepts of the Ayres-Martinás theoretical framework do not exclude the integration of money into a price theory as opposed to the mainstream economic theory. Because the arguments of the evaluation function of the economic agents are stocks (including money) and out of equilibrium states are represented.

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VEZA TEORIJE CIJENA I NOVCA: NAPOMENE O TEORIJI AYRES-MARTINÁS

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SAŽETAK

Glavni zadatak ekonomske znanosti je objašnjenje bogatstva naroda. S jedne strane ta tradicija podrazumijeva da bogatstvo treba izvrijediti, tj. ekonomske znanosti trebaju razraditi teoriju cijena. S druge strane, novac treba integrirati u ekonomsku teoriju jer su cijene izražene u novčanim terminima. Glavna ekonomska teorija uspjela je u određivanju cijena (uz određena ograničenja) ali nije uspjela u integraciji novca, dok je ostala ekonomska teorija uspjela integrirati novac ali ne i odrediti cijene. U ovom radu zastupam stav da je Ayres-Martinás teorijski okvir perspektivni pristup bavljenja ovim izazovom ekonomske znanosti.

KLJUČNE RIJEČI

temelji mikroekonomije, makroekonomija

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EXTENDING LIFE CONCEPTS TO COMPLEX SYSTEMS*

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ABSTRACT

There is still no consensus definition of complex systems. This article explores, as a heuristic approach, the possibility of using notions associated with life as transversal concepts for defining complex systems. This approach is developed within a general classification of systems, with complex systems considered as a general 'living things' category and living organisms as a specialised class within this category. Concepts associated with life are first explored in the context of complex systems: birth, death and lifetime, adaptation, ontogeny and growth, reproduction. Thereafter, a refutation approach is used to test the proposed classification against a set of diverse systems, including a reference case, edge cases and immaterial complex systems. The summary of this analysis is then used to generate a definition of complex systems, based on the proposal, and within the background of cybernetics, complex adaptive systems and biology. Using notions such as 'birth' or 'lifespan' as transversal concepts may be of heuristic value for the generic characterization of complex systems, opening up new lines of research for improving their definition.

KEY WORDS

complex systems, life concepts, refutation approach, heuristic

CLASSIFICATION

JEL: Z13
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INTRODUCTION

Since the pioneering studies on cybernetics [1, 2] general systems theory [3, 4] and systems science [5] and the advent of computers, researchers in the field of complex systems science have developed a dense and diverse body of knowledge concerning the characteristics, structures, processes and behaviours associated with the notion of 'complex systems' [6, 7]. Many avenues have been explored, but there is still no consensus definition of complex systems [8-10] or of some of their kernel concepts, such as emergence [6, 11]. However, even very diverse complex systems can be seen to have features in common [12].

Within 'complex systems' research, increasing numbers of relationships are being established between complex systems and life sciences concepts [12]. Relationships are commonly established such that living organisms are considered to be the archetypes of elaborate *complex systems*, e.g., [13, 14]. However, attempts to qualify complex non-living systems as living or life-like [15] entities are less frequent and concern few examples such as rivers [16], social [17] or cultural [18] structures. Moreover, in such situations, authors generally refer to complex adaptive systems [19, 20], which are particularly sophisticated instances of complex systems (great diversity, organisation, long history).

This contribution lies within the framework of complex system definition and, in some ways follows on from the work of Kauffman [21], who suggested that life, as a probable consequence of random chemical processes, is an almost common fundamental process of Nature. We explore the proposition of using some life definitions as unifying properties of complex systems, whether sophisticated complex adaptive systems or simple non-linear entities [22]. Examination of the correspondence between complex systems in general and concepts associated with 'living systems' fits into the framework of analogies [23]. It may lead to the controlled generalization of basic characteristics of 'living things' and the establishment of a kernel for the definition of complex systems [24]. The advantage of this approach is its heuristic value for **exploring and examining the uniqueness of complex systems**. It does not call into question established knowledge about life, generated through biology, a key branch of science, by seminal authors such as Buffon, Lamarck, Darwin, Haldane [25], Ruffié [26] or Maturana and Varela [27].

We first describe this proposal within a general classification of composite systems. We then explore its consequences, by focusing on a subset of distinctive properties bound to living and complex systems science. We then initiate a stepwise validation/refutation process, in which we consider complex systems at the edges of the definition and their status as "living entities" within the terms of the proposal. A synthetic overview is then presented, with a discussion of the consequences of this proposal.

ESSENTIAL FEATURES OF THE PROPOSAL

The approach adopted here is based on the description of composite systems, one of the foundations of complex systems theories [28]. Multiple criteria have been proposed for the classification of systems into levels [29], e.g., the intuitive classification, on nine levels, of complexity from static to symbolic established by Boulding [3] and revised by Von Bertalanffy [4]. Each of these classifications includes parts accounting for living and non-living systems. These attempts to classify systems have provided different viewpoints on systems but none has emerged as a clear reference for further construction [30]. For the sake of simplicity, we illustrate our proposal with a simplified, four-level scheme. The illustration in Figure 1 establishes a hierarchy of composite systems beginning from mere collections of entities (e.g., books on a shelf or pebbles on a beach), to cybernetic systems (e.g.,

manufactured machines) and complex systems, of which living organisms are a specific case (Figure 1a). In the proposal discussed here (Figure 1b), complex systems are considered to have the basic properties of living organisms, which they are therefore considered to resemble. This modifies the top level of the hierarchy, with the concept of 'life' extended to the more general complex systems category, which we hereby arbitrarily name 'living things'. Within the proposal, organisms become a special case of 'living things'. For the purposes of discussion, they could be described as 'real living' or 'eu-living' organisms (the prefix "eu" here indicates "true" or "genuine").

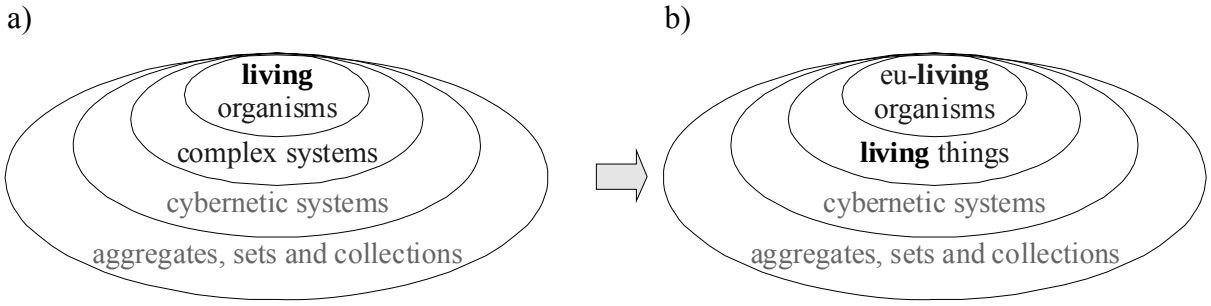

Figure 1. Illustration of the proposal considered here, within a possible classification of composite items. The successive concentric circles formalise the progressive specialisation of each category. Each smaller circle is included within a larger circle and represents a specialisation of that larger circle. Classifications: a) the common sense, b) the proposed modification to the common sense classification.

METHOD

This proposal will be examined in three steps. The first is based on the notion that 'living systems', like 'complex systems' [31], are not clearly defined [32] and are usually based on a set of properties and concepts [33]. It is therefore possible that some of the concepts and properties commonly attributed to living organisms (e.g., birth, death, lifespan) could be extended to complex systems and included in the definition of these systems, whereas other notions are specific and be reserved for the definition of living organisms (e.g., reproduction).

We therefore need to consider the concepts associated with life and complex systems. We will thus explore a subset of emblematic concepts pertaining to the definition of life or complex systems and determine (i) the status of these concepts in the framework of the proposal and (ii) the validity of the change proposed given the particular meaning of these concepts.

The second step relates to the highly diverse nature of existing complex systems. If the change in classification is considered acceptable, it would imply that each and every complex systems fulfils the change proposed and could therefore be considered a 'living thing'. Moreover, most instances of complex systems (macromolecule, river delta, market, etc.) seem to constitute a unique case with a particular combination of complex systems features. **Each should therefore be considered as a particular potential objection to the proposal**. We have taken the considerable diversity of specific cases into account, by examining the validity of the proposal in a stepwise refutation approach based on the search for counter-examples. In this approach, a diverse set of systems is progressively compared with the 'living things' paradigm proposed. For each instance, we use a back and forth process in which we simultaneously (i) determine the "composite item" category (collections, cybernetic

systems, ‘living things’, complex adaptive systems or organisms) to which each example belongs and (ii) incrementally refine the distinctive features of each category within the set of concepts characterising living organisms, including those discussed in the preceding step.

Finally, we attempt to bring together the results obtained in the first two steps in a summary, with the aim of supporting, invalidating or refining the limits of validity of the proposal and its heuristic value for clarifying either the essential nature of complex and living systems or the distinction between the two classes.

POSITIONING CONCEPTS WITHIN THE CLASSIFICATION PROPOSED

Life is usually defined by a set of properties but different authors make use of different sets of properties, e.g. [15, 26, 34, 35]. Nevertheless, within the existing definitions, a common set of life traits can be identified that are either self-evident or form a consensus. We will consider these prominent concepts in the light of the proposal and focus particularly on those concepts that could separate ‘life’ from the biological concept of ‘an organism’: emergence, birth, death and lifespan, adaptation, ontogeny and growth, history and evolution, reproduction, diversity, input and organisation, adaptation and self, homeostasis and autopoiesis.

Emergence has often been described in complex systems sciences [6, 33] but it has not been specified whether this property is identical in nature in living organisms and complex systems. In the proposal, the emergence of an entity, or monad (Plato in [36]), from a set of interacting components equates to bringing a recognisable ‘living thing’ into existence (essentially, a phenomenon of ‘birth’). The acquisition of an identity through emergence thus becomes one of the cornerstones of the equivalence between complex systems and ‘living things’. It may follow that the whole hierarchy of Nature, from quarks to animals [19], ecosystems [37-39] and galactic filaments [40], could be unified into a full hierarchy of ‘living things’. With some justification, the concept of birth is identified as an essential feature of living organisms. If the proposal is consistent, birth should be transferable to the definition of complex systems (‘living things’), which is a much broader set than that of ‘eu-living’ organisms. The status of the ‘death’ concept is more questionable as it may rely on a relative viewpoint, as in the case of transformation, metamorphosis or reproduction. The difficulties associated with this particular concept are discussed below.

Ontogeny, **morphogenesis**, **maturation**, **learning**, **history**, **growth** or **evolution** refer to processes resembling the irreversible stepwise construction of the system over a given time period (a ‘lifespan’ in the proposal). This notably places these systems in opposition to engineered systems, which can be planned from the outset by human work and this distinction may constitute a frontier between cybernetic systems and complex systems/’living things’. Any emerging system capable of evolution, ontogeny or history (a ‘lifespan’) would thus belong to the ‘living things’/complex systems category. This ‘lifespan’ central notion is bound to the distinction between a system and its environment [41, 42]. A system emerges in a changing environment, with which it establishes relationships with **irreversible** effects.

Two levels of irreversible dynamics may be considered: a ‘light’ level in which successive changes are not memorised (river water irreversibly becomes lake water and then waterfalls etc.) and real adaptation, corresponding to ontogenetic growth in which change and adaptation to change leave an imprint on the living system, affecting its future behaviour and fate (a community becomes a society, a civilisation, etc.).

Autonomous **adaptation** is a key concept used to describe living organisms [43, 44]. In complex systems science, it is usually associated with the particular category of complex adaptive systems [19-20]. The range of complex adaptive systems extends well beyond the subset of biological organisms. It includes biological substructures such as the immune

system [45] as well as non-living (in the strict classical sense of the term) items, such as markets [46], fisheries [47], industry [48], language [49], groups (Smith in [17, 50]) or the Internet [51]. This property cannot therefore be considered to characterise living organisms. Instead, it may relate to a less specialised 'complex adaptive systems' category close to the living organisms category. This raises questions about the true nature of the distinction between complex adaptive systems and organisms. For example, more often than not, as in the above examples, non-biological complex adaptive systems are supersets of biological items (e.g., an ant colony) or are driven by biological items (e.g., stock market, industry). This distinction therefore requires clarification as far as the property of adaptation is concerned.

Together with adaptation, organisation, birth and lifespan, reproduction is a fundamental feature, and possibly the essential characteristic of living organisms. It allows a species to adapt to change through Darwinian evolution and to perpetuate itself after the death of a given organism. Within the specific context of this proposal, reproduction would be interpreted as a specific instantiation of processes enabling living organisms (i) to prolong lifespan (e.g., of a species), (ii) to develop and to conserve adaptive features. This specificity may constitute one of the threshold properties characterising the uppermost organisms or 'eu-living organisms' level.

Homeostasis, like **autopoiesis** [27, 52], is often identified as a characteristic of living systems [53]. These two properties play different roles in the existence of a system. Homeostasis relates to the cybernetic feedback mechanisms involved in maintaining the stationary state of a structure, within a flow of input and output, whereas autopoiesis refers to the closure of the system and is an essential element completing the existence of living organisms. Homeostasis and autopoiesis may constitute two facets of a general unity or identity conservation property characterising life. Within this definition relating to the conservation of systems as existing things, homeostasis and autopoiesis would ensure the conservation of a unit identity over a given time (i.e., as long as efficient homeostatic and autopoietic processes are possible). These notions would therefore lead to and be associated with the 'lifespan' feature of 'living things'.

Other important properties or concepts would have to be reconsidered in the light of this proposal. **Input** for example is a characteristic feature of living organisms (e.g., intake, information coming from the environment, sense organs). However, this property is also a characteristic of cybernetics systems [2]. The 'input' property is therefore a feature pertaining to the lower level cybernetic systems category and should not be considered for evaluating the distinction between proposed 'living things' and organisms. **Organisation** and **self-organisation** are widely perceived as properties of both complex systems and life; they may take very diverse forms, from physics to chemistry to biology; from organs to hierarchies of structures. Kauffman [54] established that self-organisation was a necessary property for the emergence of life. However, Ashby [55] described self-organisation in simple composite machines long ago. Organisation thus remains a concept that is difficult to classify. It seems to be common to all composite systems, from simple collections to living beings (e.g., Figure 1a can be considered a representation of the different levels of organisation).

Finally, in this incomplete overview of life and complex systems features, several major contributions in the field of complex systems have identified **diversity** as an important **property** for the control [56], development [15] or viability [57] of complex systems. The concept of 'diversity', or 'polymorphism' in biological contexts, has also been identified as a fundamental property of life (see e.g., [26]). Within the context of the proposal, it remains unclear whether diversity is an integral part of 'living things' or whether it is required only for certain upper-level functions, such as differentiation, variation and selection.

CLASSIFYING COMPLEX SYSTEMS ITEMS

The second major change implied by this proposal is the need to apply the 'living things" concept to the highly diverse set of complex systems. In the framework of a refutation approach, the validity or limitations of the proposal are explored incrementally by studying the properties and classification of archetypal examples of composite systems. We select, with arbitrary illustrations, various archetypal situations, ranging from obvious complex systems, to complex systems at the edges of the definition (undiversified, transforming systems), to immaterial systems and manufactured complex systems. In the words of [58], the examples selected have been chosen arbitrarily from thousands of possibilities and may not be the best to appeal to a reader. However they provide an illustration of the approach used to examine the proposal and its characteristic stepwise nature. This approach is summarised in Table 1.

As a reference, we first consider the example of a vertebrate, located at the 'living organism' level of the hierarchical classification. A vertebrate is characterised by the set of all features and properties to be discussed: indeed, it is composed of diverse elements; it emerges as a recognisable entity within its environment (wholeness); it is organised, autopoietic, homeostatic (transducing an equilibrium between input and output); it has organs and a metabolism, comes to life, dies, grows, changes form through ontogenic processes, matures and evolves with irreversible dynamics. It can reproduce, move, take up and supply energy and information to and from its environment and adapt to inner and outer changes. This establishes the framework within which 'living things' could be identified and potentially distinguished from 'eu-living' organisms.

At the edge of the proposal, a breaking wave of water is a complex physical set of interacting identical elements. Its fluidity and liquidity emerge from the interaction of its particles in an appropriate environment. It is unusual in that it persists for only a short time, but it could nonetheless be considered to have a 'birth', 'death' and 'lifespan'. It is organised by the constraints of the surrounding masses of water and air within which it evolves (irreversible

Table 1. Classifying example systems (columns) relative to the notions associated with life (rows). The blocks refer to properties which would be a) specific to living organisms, b) related to 'lifespan' and c) related to 'birth'. For each comparison, the property is observable, not observable or questionable.

		archetype	at the edge of the definition			immaterial		manufactured
		VERTEBRATE	Breaking water WAVE	ROCK (human time scale)	ROCK (geological time scale)	IDEA	FIRE	Conway's game of life GLIDER
a)	metabolism	*					*	*
	reproduction	*				*	*	*
	functional organisation	*				*	*	*
	dispersal, motion	*	*		*	*	*	*
	diversity of composing items	*		*	*	*		
b)	ontogenesis, evolution, growth (1)	*			*	*	?	
	irreversible dynamics, history	*	*	*	*	*	*	
	transformation, tipping, adaptation	*	*	*	*	*	*	*
	openness - homeostasis	*	*		*	*	*	*
	autopoiesis	*	*	*	?	*	?	
	death	*	*	*	?	?	*	*
	'lifespan'	*	*	*	?	?	*	*
c)	identity, unity, wholeness	*	*	*	?	?	*	*
	emergence	*	*	*	*	*	*	*
	'birth'	*	*	*	?	*	*	*

(1) with imprinting of change and self

legend:	*	?	
	YES	QUESTIONABLE	NO

tipping) and, once it achieves the status of a wave, its structure is maintained by molecular cohesion (simple autopoiesis) although the wave exists for only a short period of time. During this time, the wave also conserves its dynamic cohesion and homeostasis through the incorporation and release of water molecules. If considered as a living thing, these properties would constitute a first kernel for establishing a definition of 'living things'/complex systems. However, a wave does not display ontogenic growth or maturation and has no reproductive mechanism. Furthermore, the molecules constituting a wave are not diversified and do not give the wave the necessary creativity for self-adaptation [59]. In the framework of this incremental refutation approach, and as previously proposed, diversity and ontogeny would therefore need to be considered as non-essential properties of 'living things'.

At another edge of the classification proposed, the status of a rock is also debatable. As long as it is recognisable by its shape, it is an existing entity emerging from a diversified set of interacting minerals. It may be structured (e.g., geode) and may thus react specifically to shocks, given its particular structure (e.g., as described by sculptors). Nevertheless, its main characteristic is its stability, mostly linked to its being an orderly [51] and closed system, that is, an inanimate object. This distinctive feature excludes rocks from even the cybernetic system category.

However, over the geological time scale, a rock is not static and may irreversibly tip into new forms (e.g., transformation into lava, river sand, silt, etc.) depending on the successive environmental events to which it is subjected. Over a long time scale, a stable rock could be considered analogous to the diapause, hibernation or dormancy (such as ticks remaining dormant for 18 years before finding a mammal on which to settle [60]) phase subsystem of a larger complex system/'living thing' involved in a perpetual life cycle. This definition pushes to the limits of the lifespan concept, but without actually refuting it: At a geological time scale, the very different possible shape of the rock resembles the pupa-butterfly classification problem. It follows from the transformation or tipping perspective, common to both complex systems [59] and living organisms, that the 'death' concept is somewhat problematic in this case (as also seen in the examples below).

Various immaterial items, such as languages [49], meetings [15], innovation [61], and culture [18], are also considered to be complex systems. For the proposed classification to be valid, it would also be necessary to include these items in the 'living things' category. The example selected here for this category is that of an idea or a meme [18] developed by a single person or spread throughout a population. An idea can reproduce by dissemination between the individuals of a population and is organised into several different components (premises, references, arguments etc.). An idea continually adapts to successive inputs. However, it is also questionable whether the notion of 'death' can be applied to an idea, as ideas are again more likely to undergo transformation. The property of motion depends on the context. It may characterise an idea disseminating within a population or society, but not an idea as a living thing within a single individual developing it.

A fire is another type of immaterial system. It is also clearly an emerging item, living, dying, changing form and irreversibly evolving in close relation to its environment. An observer may perceive it as feeding on the environment and adapting its strength to the outer temperature and oxygen. It establishes a hot environment maximising the combustion of its fuel. It can disseminate, grow and mature to an established fire before being extinguished. Within the classification system proposed, a fire thus appears to reach the benchmark of the most sophisticated 'living things'. As in the example of an 'idea', fire remains an immaterial item, the simple result of the highly exothermic oxidation of a fuel by the ambient air, with energy released as heat and light, giving 'birth' to a visible fire.

Computers are cybernetic machines, but their output may take the form of complex systems [62]. They therefore provide a useful model for exploring the 'vitality' of complex manufactured systems. A dynamic glider cellular automaton [63] moving and reproducing in a grid may be considered a parsimonious example for this comparison. Indeed, as soon as it has a sufficient lifespan, this entity emerges as a recognisable item to the observer. A glider thus 'comes to life', can 'mate' with 'another' and 'produce' 'offspring' (e.g., the Gosper Glider Gun p30 [63]). It 'dies' by dissolution if the environment (the grid) is not isotropic (i.e., when the glider 'meets' other black cells). It takes input from its environment as it depends on the state of its neighbouring cells. The rules of the glider resemble metabolic function (cells are metaphors for a localised organism or population) and its topology, crucial for its survival, resembles functional organisation. A glider could not be considered autopoietic: even if the only reason for its existence is to maintain itself as a 'living' glider, no mechanisms are implemented within the model to ensure this property. Moreover, the glider does not display growth or ontogeny. In an isotropic environment, some gliders would not 'die' (within the software run). Therefore, if the glider is to be considered as a living thing, within the framework of the proposed classification, autopoiesis and irreversible growth or ontogeny could not be considered essential properties of 'living things'. We suggest the following alternative, that a glider, as an artefact, cannot be considered to be a living thing despite its unsettling behaviour.

SUMMARY AND DISCUSSION

The items used to decipher the limits of each composite system category are indicative and remain a preliminary illustration of possible ways to evaluate this proposed classification. Further testing of this proposal will require the accumulation of additional complex systems examples for exploration. Given this limitation, and in the light of the concepts and items examined, we can try to outline the distinctive features of composite items based on the arguments set out above. In summary, 'living things' (*i.e.*, all complex systems):

> *Simultaneously come into existence (life) through an emergent process, acquire the status of a recognisable entity (a monad), which is inseparable, and enters into a relationship with a surrounding environment. The existence, wholeness or identity of the unit is maintained throughout its 'lifespan' by conservation forces (of which autopoiesis and homeostasis would be particular instances). 'Living things' have an irreversible history/evolution/fate within a changing environment during their 'lifespan' without the compulsory need for memorisation and self-elaboration. Adaptation is therefore not a necessary element of the definition and a changing environment may be sufficient to produce irreversible changes in a given complex system. 'Living things' die by losing their integrity (their existence), although this is not an absolute condition. Indeed, transformation is a limiting but frequent case that must also be considered (rock to sand or lava, caterpillar to butterfly). Finally, the status of 'living things' is scale-dependent (as in the rock example) and observer-dependent (as in the cases of fire and memes).*

This viewpoint leads to the refined representation proposed in Fig. 2.

Organisms ('eu-living' organisms) could be distinguished from other 'living things' by being organised (self-organised) into subsystems (organs), some of which are dedicated to reproduction. Any complex system endowed with reproductive machinery mechanisms making it possible (i) to perpetuate and (ii) to generate variety and Darwinian selection would be classified as an organism. This is the case for living beings with genes and for culture with memes [18]. Complex adaptive systems are not necessarily capable of reproduction (e.g., a brain)

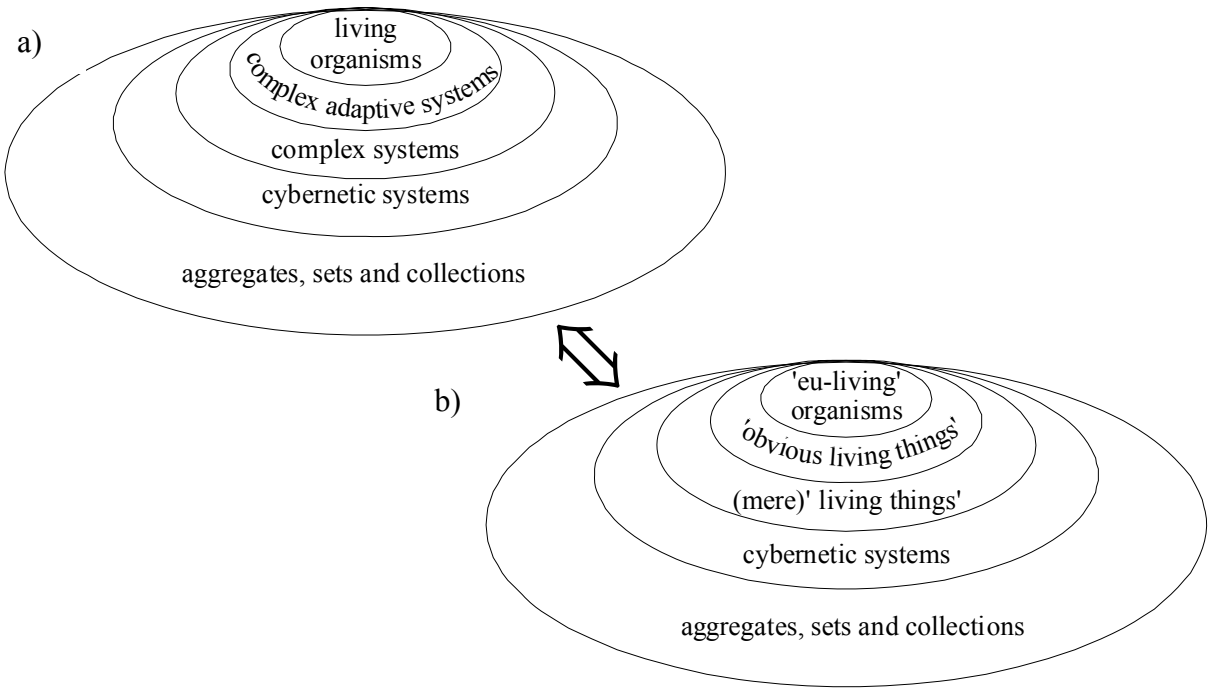

Figure 1. Refining the proposal: a) diagram similar to that presented in Figure 1, except that it distinguishes the complex adaptive systems category within the classification proposed, b) complex adaptive systems ('obvious living things') become a specialised category of complex systems ('mere living things').

and should therefore be distinguished from organisms. They may be considered to constitute a specialised category of 'living things' with the property of ontogenic adaptation. Systems such as stock markets, cities, forests, organs and cells display clear life-like behaviour [15]. These systems of the complex adaptive system type could be called 'obvious living things'.

Within this perspective, living would then be distinguished from cybernetics systems, which would encompass manufactured things designed for a purpose. Going upward in the hierarchical classification, organisms ('eu-living' organisms) would become a specialised category of complex adaptive systems with the property of a prolonged 'lifespan' through reproduction or dissemination and the archetypal case of Darwinian evolution. Finally, as this proposed classification aims to encompass all complex systems, it should also account for abstract or immaterial systems, which may be considered either as 'mere living things' (e.g., project), 'obvious living things' (e.g., idea, theory) or possibly 'eu-living' organisms (e.g., discipline, culture). In this sense, materiality would not be a criterion for the characterisation of complex 'living' entities.

CONCLUSIONS

This work does not aim to provide a canonical definition for complex systems. However, the 'living thing' approach can be seen as a step towards such a definition. Indeed, the potential of the heuristic approach lies principally in the understanding gleaned from efforts to refute the proposal and, hence, to clarify the boundaries of the "complex system" concept.

A potential practical advantage of this approach is that it allows any complex systems to be analysed in the light of the same 'living things' concepts. For example, it could be interesting to use the notions of 'birth' or specific 'lifespan' (e.g., given an observer scale) to characterise

any complex system from any field of study, medicine, economics, psychology [64] or physics; this could help to develop generic formalisation in integrated models, e.g., mechanistically rich models [65], where diverse sets of systems interact.

Beyond these practical aspects, these concepts could be considered common features of natural things in general. The proposal would then generate a scenario in which billions of 'living things' would be continually coming to 'life' and 'dying' or 'tipping' (without necessarily 'reproducing'). This would occur at each and every scale in Nature, from 10^{-35} m to 10^{27} m [66] and from the life span of the Universe to that of the tiniest spark, given the perpetual renewal and modification of relationships in both the material and immaterial worlds.

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PROŠIRENJE KONCEPTA ŽIVOTA NA KOMPLEKSNE SUSTAVE

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SAŽETAK

Još uvijek ne postoji konsenzus oko definicije kompleksnih sustava. Ovaj članak heuristički istražuje mogućnost uporabe pojmova vezanih uz život kao transverzalnih koncepta za definiranje kompleksnih sustava. Navedeni pristup razvijen je u okviru opće klasifikacije sustava. Pritom se kompleksne sustave razmatra u općoj kategoriji 'živih stvari' unutar koje posebnu klasu čine živa bića. Koncepti pridruženi životu kao prvo su itraženi u kontekstu kompleksnih sustava: rođenje, smrt i trajanje života, adaptacija, ontogeneza i rast, razmnožavanje. Nakon toga, pristup opovrgavanja je primijenjen za testiranje predložene klasifikacije na različitim sustavima. Pritom su uključeni referentni sustavi, krajnji slučajevi sustava te nematerijalni kompleksni sustavi. Sažetak analize zatim se koristi za generiranje definicije kompleksnih sustava pomoću pojma kompleksnih adaptivnih sustava i biologije, uz podlogu kibernetike. Uporaba pojmova kao što su 'rođenje' ili 'životni vijek' u vidu transverzalnih koncepta može biti od heurističke vrijednosti za generičku karakterizaciju kompleksnih sustava, čime se otvaraju novi pravci istraživanja za unaprijeđenje njihove definicije.

KLJUČNE RIJEČI

kompleksni sustavi, koncept života, pristup opovrgavanja, heuristika

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MULTI-EQUILIBRIA REGULATION AGENT-BASED MODEL OF OPINION DYNAMICS IN SOCIAL NETWORKS

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ABSTRACT

This article investigates the Multiple Equilibria Regulation (MER) model, i.e., an agent-based simulation model, to represent opinion dynamics in social networks. It relies on a small set of micro-prerequisites (intra-individual balance and confidence bound), leading to emergence of (non)stationary macro-outcomes. These outcomes may refer to consensus, polarization or fragmentation of opinions about taxation (e.g., congestion pricing) or other policy measures, according to the way communication is structured. In contrast with other models of opinion dynamics, it allows for the impact of both the regulation of intra-personal discrepancy and the interpersonal variability of opinions on social learning and network dynamics. Several simulation experiments are presented to demonstrate, through the MER model, the role of different network structures (complete, star, cellular automata, small-world and random graphs) on opinion formation dynamics and the overall evolution of the system. The findings can help to identify specific topological characteristics, such as density, number of neighbourhoods and critical nodes-agents, that affect the stability and system dynamics. This knowledge can be used to better organize the information diffusion and learning in the community, enhance the predictability of outcomes and manage possible conflicts. It is shown that a small-world organization, which depicts more realistic aspects of real-life and virtual social systems, provides increased predictability and stability towards a less fragmented and more manageable grouping of opinions, compared to random networks. Such macro-level organizations may be enhanced with use of web-based technologies to increase the density of communication and public acceptability of policy measures.

KEY WORDS

agent-based models, social networks, opinion dynamics, communication topology, unpredictability

CLASSIFICATION

JEL: C63, D72, D74, D78, D83, D85, H30
PACS: 89.75.-k

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INTRODUCTION

In recent years, social sciences have embraced simulation techniques as a new powerful tool to explore the dynamics of social systems. Agent-based models (ABMs) constitute a fruitful approach to simulate and analyze complex phenomena observed in social networks. They typically rely on a set of simple rules pertaining to the behavior of agents, in order to determine the minimal conditions under which these phenomena emerge. A basic problem encountered by researchers is that of understanding emergence and, especially, the relationship between micro and macro properties of complex systems [1, 2]. Such systems can be described either in terms of the properties and behavior of their individual agents or the system as a whole. The explanation of the emergence of macroscopic societal regularities, such as norms or price equilibria, from the micro level behavior of agents requires some *generative* ('bottom-up') mechanism [3], through which decentralized local interactions of heterogeneous autonomous agents generate the given regularity.

In this context, ABMs of social networks can simulate the emergence of community-wide economic and political outcomes, based on the individual behavior and interaction dynamics of network agents. The agents can refer to consumers/voters, firms/political parties, and market, regulatory and administrative authorities. The outcomes may correspond to a diverse range of (desired or strategic) states, like the resolution of conflict situations and achievement of consensus to economic measures, political decisions or social actions concerning specific population groups. Other applications with economic perspective encompass the study of interaction dynamics among consumer agents [4] as well as among company executives within a firm and between different firms [5], to represent changes in organizational structure, price formation and competition conditions in the market. Furthermore, such models can provide insight into agents' voting behavior, the rise and fall of political parties and others.

The interaction dynamics depends on the topology of communication between agents, as the degree of connectedness and position (or centrality) of each (type of) agent in the network can decisively affect final outcomes, in terms of efficiency, equilibrium and other network properties [6-10]. Specifically, agents change/update their own opinion about a subject (e.g., an economic perception about an investment decision or a political view), in accordance with some type of learning process, which will lead to the formation of a belief on that subject and affect their final decision. At the macro level, this process, referred to as *social learning* [11], effectively aggregates information about individual opinions and beliefs, based on own-experience, communication with others, and observation of others' actions, to result in a (range of) uniform opinion(s) or social belief(s) about some economic or social situation. The ABM simulation of that process in social networks can help us to obtain a deeper understanding on how information propagates through the network and people form their beliefs and learn from each other. In particular, it allows investigating how the action of different hierarchical corporate structures, advertising, media and political and other institutional agents (opinion leaders), which give rise to alternative communication topologies, can influence opinion and belief formation (social learning process) in the network.

In the current literature of social ABMs, the final state that represents a specific economic or social situation typically emerges as a single system-aggregate and stationary equilibrium regime. On the contrary, this article builds on the concept of Multiple Equilibria Regulation (MER), which allows for the impact of both the regulation of intra-personal discrepancy and the interpersonal variability of opinions between agents on the social learning and network dynamics. The MER model constitutes an agent-based simulation model of opinion dynamics, which generates some types of macro-outcomes that have not been observed

before in the literature. These outcomes emerge from a small set of local-micro prerequisites and reflect the 'struggle' of agents to equilibrate their interactions both socially and internally. Although in a macro view, individuality (and heterogeneity) may be completely suppressed, in a micro view, individuality is always present. None of the agents used in the following simulations has the same trajectory with another. For a psychologist centered in individuality, the trajectories of all the individuals have nothing in common between them, while, for a sociologist, the formation of a 'group' closely relates to the behavior of agents and may end up in a consensus. The primary aim of the article is to investigate, through the MER model, the role of different types of network structures (topologies) on opinion formation dynamics and the overall evolution of the system.

MODELS OF OPINION DYNAMICS

This section reviews the literature and presents a concise comparison of the MER model, originally introduced in [12, 13], with three other well-known representative ABMs of opinion dynamics, i.e., those of the Axelrod's *Dissemination of Culture* (DoC) [14], Latané and Nowak's *Dynamic Social Impact Theory* (DSIT) [15] and Hegselmann and Krause's *Bounded Confidence* (BoC) [16]. The principal aim is not to investigate and compare the models in full length, but mainly to present their basic properties and characteristics (see Table 1), in order to clarify the resemblances and differences with the MER model and facilitate its analytical presentation in the next section. In this table, the properties of the MER model are primarily based on the adoption of a Cellular Automation (CA) topology (whose description is provided later in the text) to represent the position of and interactions among agents. However, it is noted that several other network structures or topologies can be well adopted (see later). DeMarzo, Vayanos, and Zwiebel [17] dealt with general network structures by assuming that agents follow a specific belief updating rule and (erroneously) treat new iterations of information as independent of previous iterations. They reported an intuitive relationship between the position of an agent in the network and the resulting impact on beliefs and opinions. The aforementioned studies constitute important steps in developing a more sound understanding of how interaction structure affects information, dissemination and belief formation.

All four models of opinion dynamics generate group formations, that is, distinct patterns of opinions' holders. More specifically, Axelrod's model generates clustering and survival of a number of cultures, by supposing that agents who are similar to each other are likely to interact and then become even more similar. Latanè and Nowak's model generates the survival of the minority and is organized in spatial clusters, by supposing that agents are influenced by the persuasiveness of the group members, the 'social distance' from the other agents and the number of group members. The Bounded Confidence model generates either consensus or polarization or fragmentation, supposing that agents tend to adopt the opinions of other agents that are similar to their own (within a bound of confidence). Under certain conditions, the MER model generates a chaotic society that never rests in a final steady state. The resulting clusters are continually transformed and agents usually change clusters. The latter model allows producing and examining competing micro-specifications of patterns of opinions which have equivalent generative power [3], i.e., their generated macro-structures fit the macro-data equally well.

As it is shown in Table 1, the crucial difference of the MER model, in relation to the other models, lies on simulating the intra-agents' behavior, i.e., regulation of intra-personal discrepancies in the opinion-making of each agent in order to balance internally. According to the settings of parameters and locality in communication, the outcome of the MER model is unpredictable [18] and it may never end to a final (stationary) state, compared to all the other

Table 1. Comparison of the four agent-based models of opinion dynamics or social influence, along their sequential steps (continued on the next page).

Model I.	**Model II.**	**Model III.**	**Model IV.**
Axelrod's Model of Dissemination of Culture (DoC)	**Latané's and Nowak's Model of Dynamic Social Impact Theory (DSIT)**	**Bounded Confidence Model (BoC)**	**MER Model**
1. Problem addressed			
How many cultural regions will survive in a society	The problem of consolidation: how and when minorities will decline or disappear and when they will survive or even grow	The classical question of reaching a consensus or disagreement leading to polarization; how many clusters of opinions will survive	The dynamics of opinions in an agent--based simulated society (and the property of unpredictability)
2. Random initial state			
Sequential updating		**Synchronous updating**	
Algorithm with stochastic processes		**Deterministic algorithm**	
3. Number of agents			
4 up to 10,000[1]	1600	100	100
4. Properties of agents			
Discrete opinions: each agent has a culture composed of five features; each feature has ten traits and the value of the culture is discrete, an integer between 1 and 99999	Discrete opinions: each agent has a binary opinion: yes or no (the value of the opinion is discrete, 0 or 1)	Continuous opinions: each agent has an opinion that is a real number belonging to the interval [0, 1] (continuous value)	Continuous opinions: each agent has two opinions. Opinions are real numbers from the interval [0, 1] (continuous value) and are considered to be 'opposite' to one another (structure)
5. Inter-agents' behavior algorithm			
Each agent is influenced by (i) other agents in the proximity and (ii) the agents that have a similar culture (the degree of similarity increases the probability for having an interaction)	The 'impact' of a group of agents on an individual agent is a multiplicative function of the 'persuasiveness' of the group members, their 'social distance' from the individual and the number of members	Each agent is influenced by other agents that (i) have opinion inside a bound of confidence and (ii) are located in the proximity (and same locality)	Each agent is influenced by other agents that (i) have opinion inside a bound of confidence and (ii) are located in the proximity (and same locality)
6. Intra-agents' behavior algorithm			
None	None	None	Each agent assesses his/her own opinion and makes changes to it to balance internally
7. Results-emergent properties			
Clustering			
Local convergence can generate global polarization			
Predictable after simulation			***Unpredictability*; the model is chaotic[2]**
Ending in a final steady state-Static equilibrium achieved			**Never ending in a final state[2] – Dynamical equilibrium**

Table 1. Comparison of the four agent-based models of opinion dynamics or social influence, along their sequential steps (continuation from the previous page).

Model I.	Model II.	Model III.	Model IV.
Axelrod's Model of Dissemination of Culture (DoC)	**Latané's and Nowak's Model of Dynamic Social Impact Theory (DSIT)**	**Bounded Confidence Model (BoC)**	**MER Model**
The number of stable regions (or cultures or clusters) reached at the final state increases when: a) the number of features decreases, b) the amount of traits increases, c) the neighborhood size decreases and d) the size of the territory increases. Then, it reaches a maximum and next the number of stable regions decreases again. The simulation ends when each zone has exactly one region. Cultural similarity between adjacent sites in the same cultural zone tends to increase. Boundaries within cultural zones tend to dissolve, but the boundaries between cultural zones tend to be stable.	Opinion clusters emerge and remain in equilibrium, over a wide range of assumptions and parameters. The agents are clustered spatially into cohesive subgroups and the minority survives with minority members located near each other, often near the border.	The number of clusters in the final state depends on a) the magnitude of the bound of confidence and b) the size of the neighborhood[3]. Extreme opinions are under one sided influence and move direction centre. At the extremes, opinions condense. Condensed regions attract opinions from less populated areas within their bound of confidence reach. The opinion profile splits at some points and the sub-profiles (clusters, opinion world, communities) do no longer interact.	The number of clusters formed has not yet been investigated in detail. Since there is not a final state (in some parameter settings) the agents' group membership is not stable. Each agent even if belongs to a cluster does not loose his/her atomism. The clusters move and exchange members on a macro level while, at the same time, the agents move constantly on the micro level as well.
After a certain number of interactions, the agents' society splits into separated 'cultural worlds' or 'opinion worlds' that do no longer interact.			The agents are interwoven with each other. At any iteration, a slight change in an agent's opinion affects the opinions of all other agents after a small number of iterations.

models which finalize in a steady state. The complex dynamics of the MER model is attributed to the facts that the agents' group membership is not stable, since the members are constantly moved and exchanged, and a slight change in an agent's opinion may affect the opinions of all other agents.

THE MULTI-EQUILIBRIA REGULATION MODEL

The main parameters of the MER model are the bound of confidence ε and the intra-regulation factor ψ. The magnitude of ε sets out the proximity rule, so that affects how many 'groups' or 'clusters of agents' opinions are formed. Consensus means that all agents reach

the same final opinion and it takes place for ε values around 0,3 or higher. The polarization signifies those agents' populations that end up divided into two clusters and fragmentation stands for a configuration of more than two clusters of opinions for smaller values of ε. The magnitude of ε does not change the dynamical behavior of the system in almost all cases. Namely, the system can be either (more or less) predictable or unpredictable (especially, when being purely chaotic) regardless of ε. Only if ε is extremely small, e.g. $\varepsilon = 0{,}01$, can prevent the agents from interacting, in which case the system will remain motionless. In the following example, the confidence bound is set equal to $\varepsilon = 0{,}1$.

The intra-regulation factor ψ constitutes the so called interior balance correction factor. The magnitude of ψ can affect the opinion clustering and dynamical behavior of the system. A value of $\psi = 0{,}5$ stands for a type of agent who under-correct his/her opinion. These agents *underestimate* the significance of internal balance and ascribe a minor importance to intra-individual equilibrium. A value of $\psi = 1$ signifies that agents correct their opinions in an *equal manner*. This type of agent has a decision-making structure that assigns an equal importance to both the social and intra-individual equilibrium. A value of $\psi = 1{,}5$ means that agents over-correct their opinions. Thus, they *overestimate* the significance of internal balance and ascribe a minor importance to social equilibrium.

Let us assume a society of 100 agents, each of them has two initial opinions #1 and #2 concerning the same social/economic/political issue. This contradictory structure of opinions or beliefs for the same issue may be interpreted by the antagonistic co-existence of the cognitive and affectual dimensions of an agent's personality, which may compete to each other; however, this structure may also give raise to various others debatable interpretations in the fields of social psychology, sociophysics, social simulation and complexity. For instance, Tessone and Toral [19] assumed that one preference in some individuals is stronger than the others and this structure changes through the best-fit responses of individual to population dynamics.

The two opinions here follow a structure, wherein opinion #1 goes the other direction than opinion #2. The example used here comes from the transport market and refers to the local public advisory referendum for the imposition of a congestion (or environmental) tax in the city of Stockholm. The citizens, who were asked to vote yes or no, approved (by about 52%) the permanent implementation of the measure of congestion pricing in September 2006, in conjunction with the general election that time, after a trial period of almost seven months. Let us suppose that opinion #1 concerns the no-toll regime (absence of congestion tolls) and opinion #2 the toll regime (congestion pricing). The simulation of personality traits of each agent in the social context is important for such cases and markets, since the affiliation with social networks is limiting choice by accountability to network norms; thus, it can be considered as an efficient decision-making strategy for agents [20].

The MER model relies on the two tendencies of agents towards social and intra-individual equilibrium, which allows the *joint assessment* of both opinions. Several factors Z_i may co-exist and influence the opinions of agent i towards the one or the other direction. On the one hand, an agent i can positively assess congestion pricing because of the expected travel time savings when moving or searching street parking in the city, favorable environmental attitude, anticipated gains due to changes in land values, positive own-experience from the pilot application in the trial period, and positive information or observation from other congestion pricing implementations worldwide [21]. On the other hand, the same agent can negatively assess congestion pricing because of the opposite position of the political party that he/she supports, equity issues, fear of markets, memory lapses, error of perception, stress of information gathering and pressure from social norms [20, 22, 23].

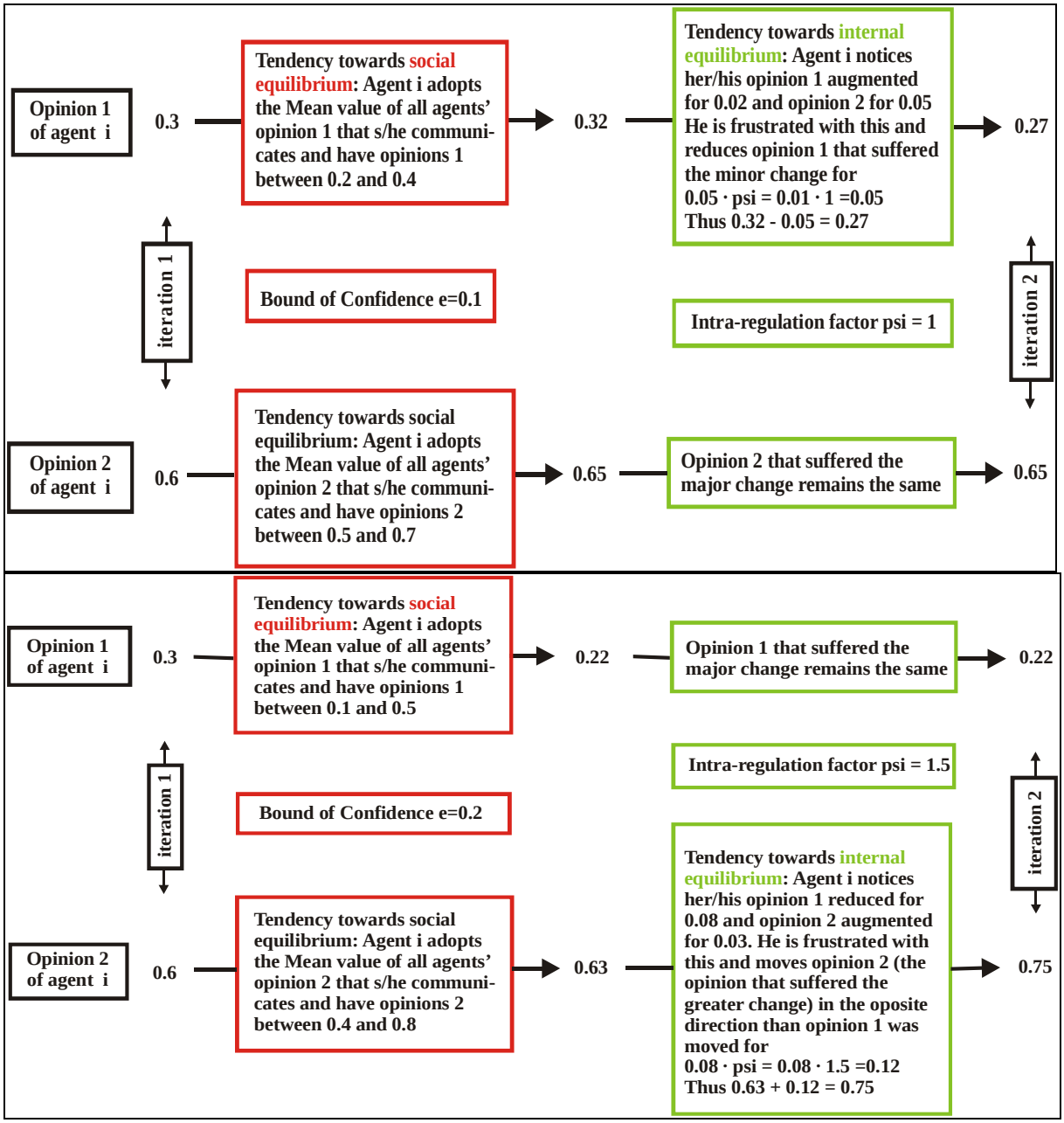

Figure 1. An example of the MER algorithm: a) $\varepsilon = 0{,}1$ and $\psi = 1$ for updating agent's opinions #1 and #2; opinion #2 is subject to the largest change due to the social influence imposed by other agents; b) $\varepsilon = 0{,}2$ and $\psi = 1{,}5$ for updating agent's opinions #1 and #2; opinion #1 is subject to the largest change due to the social influence imposed by other agents.

The opinions are normalized between 0 and 1 and may receive all possible values in this interval. The initial state, as defined by the set of initial values of opinions #1 and #2, can be empirically estimated through a random utility maximization framework, e.g., using a logit-type econometric model, on the basis of a specified utility function $U_i = f(Z_i)$ [23, 24][4].

Due to lack of empirical data, the initial state is produced here by randomly assigning to all agents with two numbers belonging to the interval [0, 1]. These $2 \times 100 = 200$ numbers are produced by a random number generator, namely, a random initial profile is adopted. If an agent's opinion #1 equals 0, then he/she is totally not in favor of the no-toll regime; the opposite holds if his/her opinion #1 equals 1, which means that he/she is a fervent supporter of the no-toll regime.

Let us assume that agent i has opinion #1 equal to 0,3 and opinion #2 equal to 0,6. That means he/she is in loosely favor of the toll regime, but he/she does not reject completely the no-toll regime. Agent i is influenced by all other agents whose opinions is aware of and belong to his/her own proximity and geographic locality (depending on the social and spatial topology of the network, respectively, as will be analyzed later). The proximity/closeness of agents' opinions is regulated by the bound of confidence ε, as suggested in the model of Hegselmann and Krause [16]. It is noted that such continuous opinion dynamics models as the BoC, which are related to negotiation problems or fuzzy attitudes that do not actually match with a yes or no decision, have also been suggested in different versions in the existing literature [25, 26]. In the latter case, the concept of repeated averaging under bounded confidence can involve multidimensional opinions and heterogeneous bounds which may drift the average opinion to extremal opinions.

In the current example, one agent is influenced by those agents with opinion #1 between 0,2 and 0,4 (if $\varepsilon = 0{,}1$) and with opinion #2 between 0,5 and 0,7. Therefore, the confidence interval ε for opinion #1 is [0,2; 0,4] and for opinion #2 is [0,5, 0,7]. Due to the social influence, the agent i temporarily changes/updates his/her opinion #1 to 0,32 and opinion #2 to 0,65, by calculating the mean values of the same and local others for opinions #1 and #2, respectively. After that, the agent feels frustrated, since he/she believes that both the no-toll regime and the toll regime are better policy options than they were before. The frustration is attributed to the structure (yes or no) of opinions, i.e. opinion #1 goes the other direction than opinion #2. In order to address this frustration, the agent chooses to keep opinion #2, which experienced the largest change (by 0,05), and updates opinion #1 at the opposite direction, by a magnitude equal to the product between the change of opinion #2 and the intra-regulation factor (here, $\psi = 1$), i.e., $0{,}05 \cdot \psi = 0{,}05 \cdot 1 = 0{,}05$; thus, opinion #1 becomes $0{,}32 - 0{,}05 = 0{,}27$. In other words, this opinion-making process gradually makes agent i to weaken the support for the no-toll regime and strengthen the support for the toll regime.

The whole algorithm is described in Figure 1a, while Figure 1b shows a corresponding example where opinion #1 experiences the largest change. In the latter case, where $\psi = 1{,}5$, the dissonant opinion (i.e., opinion #2) is adjusted by multiplying the maximal difference (of opinion #1), i.e. 0,08, with 1,5, and adding this product to its value, i.e., $0{,}63 + 0{,}08\ 1{,}5 = 0{,}75$. The addition is due to the move of opinion #1 to the opposite direction. As a result, in the latter example (Figure 1b), the opinion-making process makes agent i to even more weaken the support for the no-toll regime and even more strengthen the support for the toll regime, compared to the former example (Figure 1a). The parameter ψ can take values between zero (where the tendency to intra-individual equilibrium is absent) and infinity. Nevertheless, ψ is considered to be limited theoretically, since values above 2 would be rather 'unrealistic'. This is because by adding or subtracting the double of the maximal difference found in one opinion to the other can be characterized as 'over-reaction'. In order to prevent opinions escaping from the predefined interval [0, 1] and, at the same time, retain the dynamical behavior of the system, a procedure called *rescaling* is applied (for details, see [12]).

DESCRIPTION OF ALTERNATIVE TOPOLOGIES

The MER model is implemented through the use of five typical network structures, which depict alternative topologies of communication between agents. In each case, the agents lie on the nodes of the graph and the edges (links) denote communication. These topologies, which are illustrated in Figure 2, are as follows:

(i) The complete graph topology (CGT), where every agent communicates with and is aware of the opinions of all the others, Fig. 2a). However, the agent is influenced only by those that have opinion included in his/her own proximity, based on confidence interval ε.

(ii) The star (or one-to-all) graph topology, where the central agent has a 'global' view of the system (knowledge of the opinions of all other agents). He/she affects and is influenced by all of them, conditional upon their proximity (Fig. 2b)), while the other agents are (explicitly) influenced only by him/her.

(iii) The Cellular Automata (CA) topology [27, 28], where each agent is posed on a different cell and communicates only with those agents located within a 3×3 locality pattern (also known as Moore neighbourhood). This CA topology is shown in Figure 2c), where the larger size indicates nodes with more connections.

(iv) The small-world network topology [29], where most agents are not neighbors, but they can be reached from every other through a small number of hops or steps (denoted as L). Figs. 2d) and 2e) depict two small-world networks with $L = 3$ and $L = 6$, respectively[5].

(v) The random graph topology results from randomly assigning links to various nodes (agents). Figures 2f) and 2g) illustrate two random graphs which have been generated by assuming that every possible link occurs independently with (uniform) wiring probability $wp = 0{,}10$ and $wp = 0{,}50$, respectively[6].

The CGT, star and CA networks can be generally regarded as theoretically extreme cases of real-life social networks. In practice, two (or more) individuals may never communicate just because they will never meet each other. Even with the advent of high-technology communication devices and internet/software, such as the web 2.0, the ubiquitous interaction of all agents in a society (as reflects in CGT) can be considered as practically impossible. Besides, agents are not typically isolated and forced to communicate with just a 'leader' agent. Such an extreme case (as reflects in star topology) would possibly happen in the presence of a powerful central leader (e.g., a 'dictator') who prohibits any physical (face-to-face) contact and cuts every possible distant communication among individuals. Lastly, geographic locality cannot completely constrain the interactions among agents within a community (as implied in CA), since the information and communication technologies have reduced the role of spatial friction on social networking. In contrast with these three types of networks (which are undirected graphs), the small-world and random topologies (which are directed graphs) constitute closer representations of social networks in real-life communities. This is because they consider both geographically close as well as distant interactions between agents with varying degrees of connectivity. Especially the small-world network, through parameter L, can properly take into account the relative influence of geographic proximity (neighborhood) on the formation of network-level interactions among agents. For demonstration purposes, a set of 100 agents is assumed in each network setting. A relatively moderate value of $\varepsilon = 0{,}2$ is adopted for the confidence bound, and a value of $\psi = 1$ is set for the intra-regulation factor.

THE EFFECT OF TOPOLOGIES ON OPINION DYNAMICS

EXPERIMENTAL SETUP

This section investigates the opinion grouping, dynamics and macro-behavior resulting from running the MER model with the alternative communication topologies (as described in the previous section). Figure 3 shows a three-dimensional representation of the dynamics of opinion 1 and opinion 2 with respect to the number of iterations. In the current context, each iteration can be viewed as a time interval lasting several hours (e.g., day period). In addition to the three undirected graph topologies, i.e. the CGT (Fig. 3a)), the star topology (Fig. 3b))

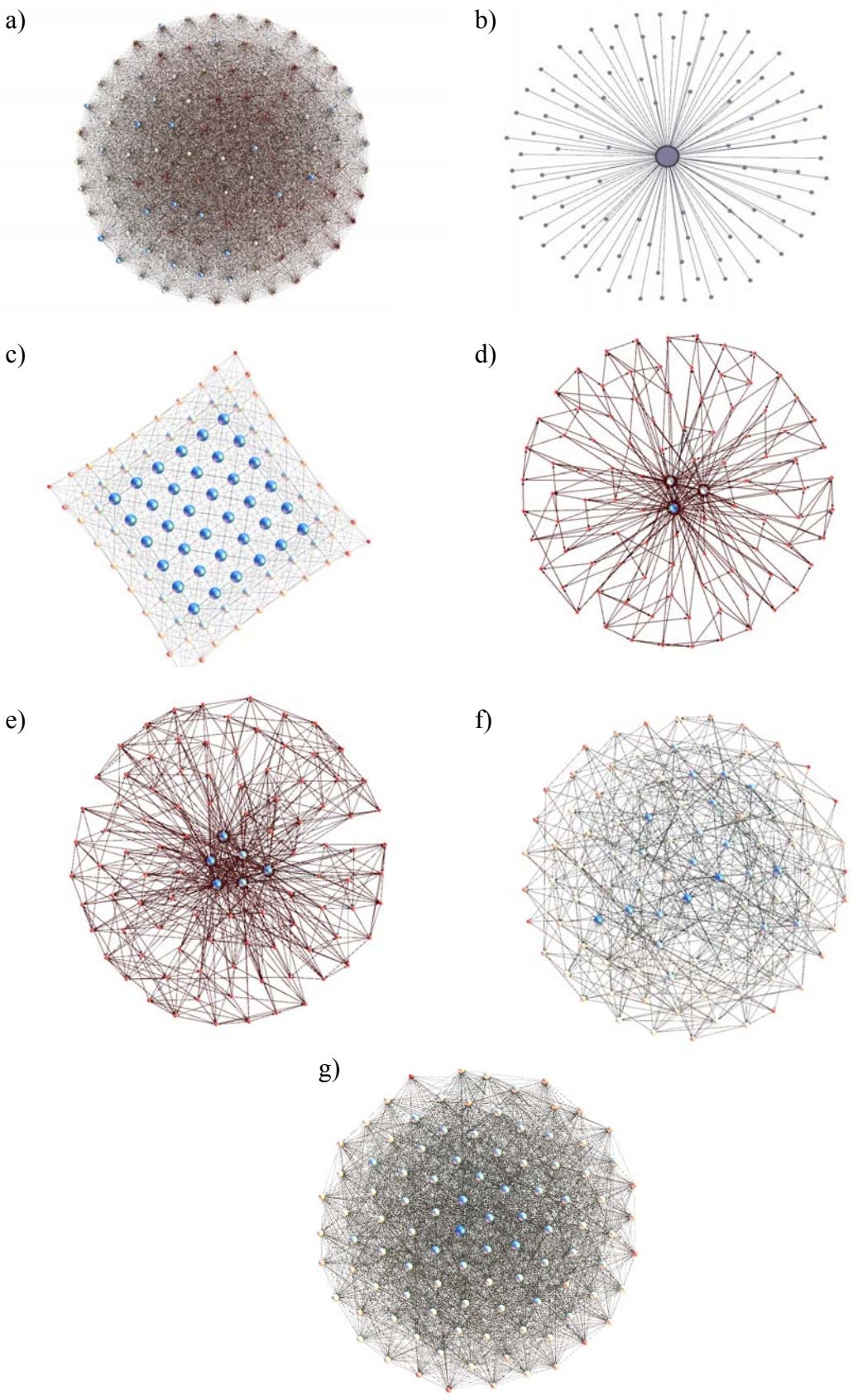

Figure 2. Alternative topologies of communication between agents: a) Complete Graph Topology (CGT); b) Star (one-to-all) topology; c) Cellular Automation (CA) topology; d) Small-world topology (L = 3); e) Small-world topology (L = 6); f) Random graph topology (wp = 0,10) and g) Random topology (wp = 0,50).

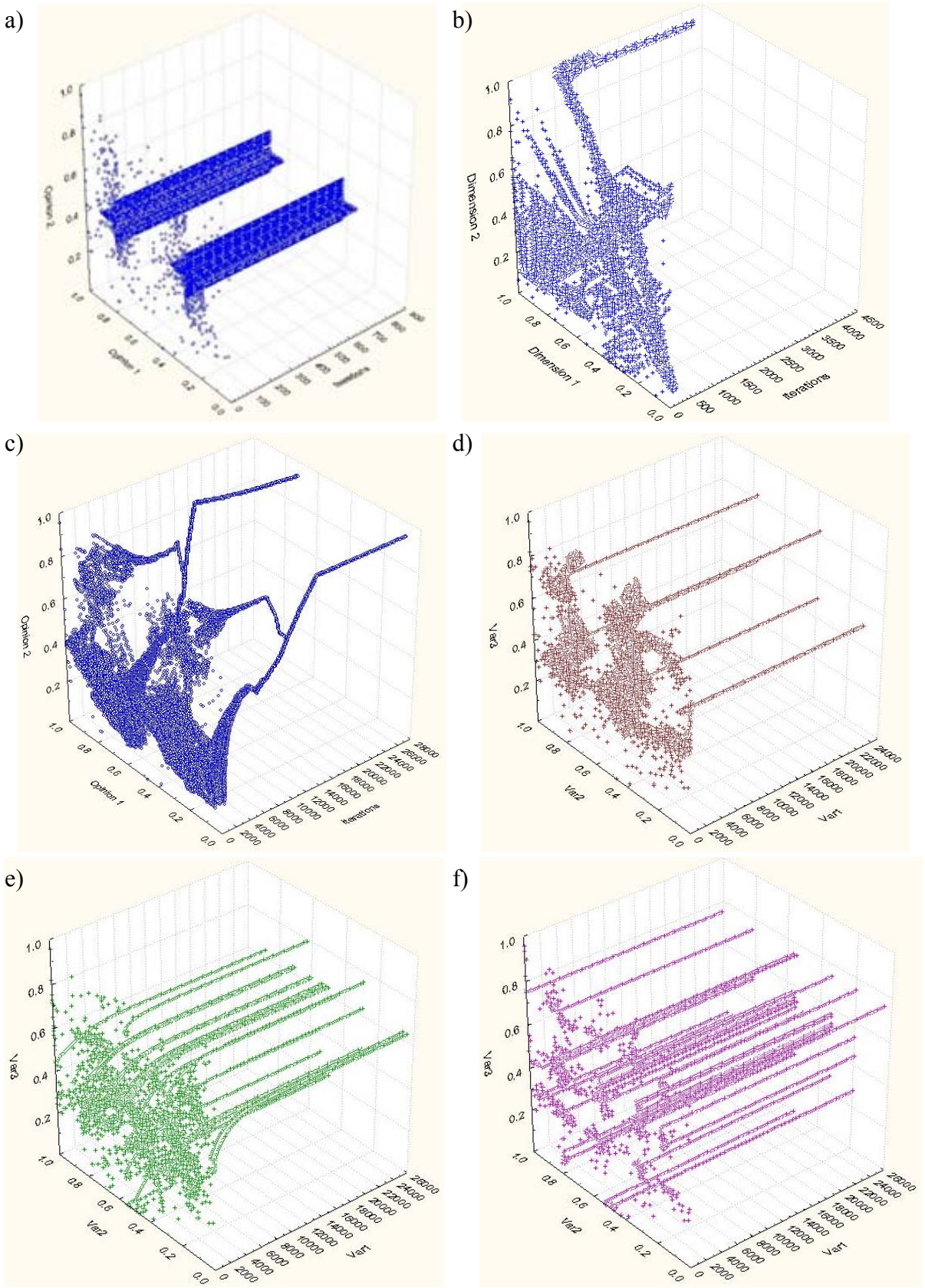

Figure 3. Full dynamics and macro-behavior of the MER model for: a) Complete Graph Topology (CGT); b) Star (one-to-all) topology; c) Cellular Automation (CA) topology; d) Small-world topology (L=3); e) Small-world topology (L = 6); f) Random graph topology (wp = 0,10); g) Random topology (wp = 0,50).

and the CA topology (Fig. 3c)), the small-world graph topology is depicted for the cases of $L = 3$ and $L = 6$ (Figs. 3d) and 3e), respectively), and the random graph topology is represented by adopting wiring probabilities $wp = 0{,}10$ and $wp = 0{,}50$ (Figs. 3f) and 3g), respectively).Table 2 presents several calculated statistical measures which suggest underlying properties of these network topologies. These measures refer to: (i) *Average in-degree* (or *row degree*), i.e., the average of the connections leading to a node from other nodes, (ii) *average out-degree* (or *column degree*), i.e., the average of the connections leading out from a node to other nodes, which denotes how influential the node may be, (iii) *network diameter*, that is the longest graph distance between any two nodes in the network and indicates how far apart the two most distant nodes are, (iv) *network density*, which measures how close the network is to complete (the CGT has all possible edges and density equal to one), (v) *average clustering coefficient*, which provides an overall indication of the clustering in the network by measuring the probability that nodes are embedded in their neighborhood (typically used to determine whether or not a 'small-world' effect exists in the network), (vi) *average path length*, that is the average graph distance between all pairs of nodes, and (vii) *modularity*, which provides a community detection measure. A better decomposition of the network yields a higher modularity score (although it increases the computational time of processing).

Furthermore, two statistical measures, i.e., the *Lyapunov exponent* and *Information Entropy*, are calculated to determine the sensitivity to initial conditions[7] and chaotic behavior of the model. The Lyapunov exponent denotes the average exponential growth of the error at each iteration and it shows under what conditions the model is sensitive to initial conditions and thus becomes unpredictable. A positive Lyapunov exponent means that even slight perturbations in the system grow over time (nearby opinion trajectories move away), predictability diminishes and chaotic conditions arise. A negative exponent implies a fixed point (nearby opinion trajectories are attracted) or periodic cycle, and a zero exponent indicates a marginally or neutrally stable orbit [30]. The information entropy, whose calculation is based on the Shannon's entropy measure, denotes the extent of possible alternative patterns of organization of the system: as entropy increases, the system becomes less uniform and more disorganized, and vice verse [31].

RESULTS AND DISCUSSION

By and large, the DoC, DSIT and BoC models have been found to result in systems that are self-organized into opinion clusters with a rather predictable behavior. In other words, after a certain number of interactions, the agents' society splits into separated 'cultural worlds' or 'opinion worlds' that do no longer interact; this is a reason that all these models finalize in a steady final state. The resulting configurations are – although emergent – stable and unchanging. On the contrary, the MER model presents a more complex set of results, which vary from a typical steady final state to an ever-changing pure chaos, heavily depending on the social network structure.

In the CGT, the opinion trajectories are polarized in a stable final state (periodical), within the first few hundred iterations, by forming two major opinion clusters (probably due to $\varepsilon = 0{,}2$; see also the BoC model). The CGT creates a single community (i.e., a global common neighborhood) with the highest density and average clustering coefficient, and the shortest average path length (all equal to one), compared to the other topologies. It also yields the lowest level of organization (or the most increased disorganization), together with the random graph topology with $wp = 0{,}1$, as reflects the measure of information entropy (equal to 4,05 and 5,30, respectively). Besides, the CGT is the least sensitive to changes in the initial conditions (hence, the most predictable), in relation to the other two undirected graph

Table 2. Statistical measures of alternative communication topologies of the model.

Character	**Undirected**			**Directed**			
Model	CGT	CA Square, Radius 2, Moore neigh.	Star	Small world, $L = 3$	Small world, $L = 6$	Random network, wp = 0,10	Random network, wp = 0,50
Implemented Social Network Characteristics[8]							
Average In-degree	49,5	9,18	1,98	3,0	6,0	4,92	24,38
Average Out-degree	49,5	9,18	1,98	3,0	6,0	4,92	24,38
Diameter	1	5	2	44	20	7	4
Density	1	0,185	0,02	0,03	0,061	0,049	0,24
Average Clustering Coefficient	1	0,638	0	0,24	0,236	0,048	0,248
Average Path Length	1	2,598	1,98	15,40	7,287	2,522	1,498
Modularity coeff. /communities	0/1	0,45/5	0/1	0,40/11	0,36/8	0,24/13	0,0/1
System Dynamics[10]							
Lyapunov Exponent[9]	$\approx 0^-$	+0,197	$\approx 0^+$	$\approx 0^+$	$\approx 0^+$	–0,11	–0,027
Information Entropy[11]	4,05	1,34	1.08	2,36	2,01	5,30	2,95
Dynamical Assessment	Stable	Pure Chaos	Transient chaos[12]			Stable	

structures (the CA and star topologies). This is because all the agents communicate with each other and have knowledge of the moves of the others, although they are unaware of the number of opinion clusters formed and how each cluster departs from their own.

The CA topology is found to yield a system that is the most unstable or sensitive to initial conditions (Lyapunov exponent is equal to 0,197), but the most organized one, together with that produced by the star topology (with entropy values equal to 1,34 and 1,08, respectively). Thus, a policy planner would possibly prefer to control the network (hence, the outcome of a referendum), through imposing a central agent[13] that communicates with and influences all the others who rest communicate only with him/her, to maximize the system's organization and make it more predictable, compared to establishing only local communication between (neighboring) agents (the case of CA). The current finding is consistent with the notion of a 'dictatorship' that ends up with a heteropolar (bipolar) equilibrium [32], as generated by a process of social influence, which was explicitly neglected in the fundamental result of social choice theory [33].

The random graph topology is found to be the least sensitive to initial conditions (Lyapunov exponent is equal to –0,11, for $wp = 0,10$, and –0,027, for $wp = 0,50$). Particularly for $wp = 0,10$, the results (Table 2) suggest that the system reaches a stable but highly disorganized final state with multiple small opinion clusters, where 13 neighborhoods are formed. Therefore, for

the given parameter settings, assuming a random communication topology would move the system far away from a socio-economic consensus of consumers/voters to fiscal measures (such as the congestion tax). On the other hand, the small-world networks (both with $L = 3$ and $L = 6$) are found to produce systems that are relatively stable (predictable, with transient chaos, having Lyapunov exponent very close to 0), and considerably more organized (less fragmented) than the random networks.

Compared to the random graph (for $wp = 0{,}10$), the small-world networks are composed of fewer communities (i.e., 11 for $L = 3$ and 8 for $L = 6$), but they have a considerably higher average clustering coefficient and path length. These results suggest that a small-world organization of the social network, through creating highly clustered groups of agents that are a few steps away from each other, would enhance both its predictability and stability towards a less fragmented (and hence more manageable) grouping of opinions. Such a type of organization is typically met in several real-life social and artificial networks [29, 34], particularly those of sites extracted from the web [35], since they can arguably depict more realistic aspects of them, with regard to common social relationships among individuals.

CONCLUSIONS

This article aims at offering some new insights regarding the dynamics of complex societies: stability is the word of the day in the middle of a fierce economic (and social) crisis. Several economic and social policies are designed to treat the impact of crisis and diminish their adverse effects, including opinion conflicts, to achieve the widest possible acceptance. The MER model relies on a logic of simplicity, that of formalizing two psycho-social principles in terms of a methodological individualism[14]. Simple micro-specifications, including the tendency of deterministic rational agents towards intra-individual equilibrium and their bound of confidence, as well as the topology of communication, are sufficient to generate macro-structures of interest. Equilibrium is a motive: all agents are searching to attain synchronously a state of stability, whether it is social (inter-individual) or intra-individual. However, because of this quest for two equilibria, unpredictability is generated: everything seems to be negotiated on the edge between social and individual.

On the one hand, based on the proposed methodology for simulating complex systems, different communication topologies (regarding capital flow, voting behavior or even 'simple' opinion change) can produce *radically different* dynamical social behavior patterns. The society of agents is self-organized into clusters (opinion groups in this particular case) that *emerge* at the macro level through properties and interactions from the micro level. Namely, both the agents' properties and social network structure influence the dynamics of the system, which, under certain conditions, may be chaotic, i.e., sensitive to the initial state, unpredictable and ever-changing without resulting in a steady final state.

On the other hand, given that specific topologies ('small world', 'scale free'[15]) are frequently met in real-world conditions, it can be hypothesized that the 'naturally' prevailing occurrence of these types of networks may be due to their dynamical characteristics[16]. Hence, the current findings, in conjunction with others of recent empirical studies concerning the impact of social network structures, can contribute to 'guiding' the behavior and overall stability (or instability) of such systems towards a desired state. Social networks are generally considered as being more difficult (or resistant) to be manipulated or controlled, compared to the physical and technological systems, and control attempts may lead to outcomes very different from the intended or predicted ones. Nonetheless, some topological characteristics that affect their stability and natural tendencies and (self-organizing) behavior, such as density, number of neighbourhoods and critical agents ('driver nodes') can be identified and appropriately treated [36, 37].

The MER model aspires to offer knowledge of the least prerequisites to make the system more robust and predictable. The treatment of unpredictability can be useful for horizons where a specific course of policy actions or design options may be deployed and bring about expected outcomes. It has been shown that unpredictability itself cannot be predicted for complex social systems, at least not in a traditional sense, namely, by comparing successive snapshots of a system's trajectory in the course of time [13]. This is because the esoteric interactions of a chaotic system do usually prevail upon external control or management attempts. But the present model enables the identification of the path dependency and possible occurrence of outcomes which may deviate from a single steady-state equilibrium point in the prediction horizon, in contrast with other relevant models. In the context of a congestion pricing strategy, policy planners and decision makers should organize the information diffusion and learning in the community so that enhance the predictability and stability of the desired outcome (in a final steady state), as well as the management of possible conflicts. Such a macro-level organization may involve the formation of larger-size localities-neighbourhoods and use of web-based technologies to increase the density of communication. The resulting network structure can promote acceptability (or diminish opinion fragmentation) towards the desirable pricing regime, without compromising the democratization of the voting process (e.g., through trying to impose a star communication topology).

At the micro-level, the MER model can help to design targeted policy interventions, through social media campaigning, advertising and public consultation processes, to influence personality traits and relevant parameters of most critical agents in the community. In addition, such processes can affect the agents' perceptions about factors that are (positively or negatively) related to the acceptability of congestion taxation, including time savings, environmental benefits, equity concerns and political aspects. More empirical research in the field could enrich real-life knowledge on the initial opinion formation of consumers/voters, through specifying and validating a general-form utility function, and the structural parameters of the small-world network and distribution of their values.

Specifically, a top-down decision-making approach may be required to deal with practical aspects of the realistic behavior of agents, compared to the present bottom-up mechanisms. Such an approach refers to the catastrophe theory [41], which can be used to determine the set of conditions wherein the agents would finally choose one among the two (or more) competitive options (e.g., no or yes on congestion pricing). This approach can adequately explain and classify abrupt conflict phenomena when a dynamical system reaches or exceeds a bifurcation point. These phenomena are characterized by sudden and dramatic shifts in system dynamics arising from small changes in certain parameters of the agents' behavior and network structure. After the bifurcation, it can help to define multiple dynamical states in which the agents' choices are no longer superimposed and the system can reach stable equilibria or possibly enter into unstable and chaotic conditions.

Last, it is noted that there are essentially numerous potential areas of further research and practical implementation of the proposed modeling framework. In methodological terms, the model can simulate all systems composed of agents (humans, cells, neurons, facilities, institutions, etc.) who exchange information and seek both an internal and external-social equilibrium. By adopting the laws pertaining to the operation of each system, it can simulate, for instance, gene mutation and organism stability in biology, spread of diseases in epidemiology, and synchronization of neurons in memory processes. Especially useful insights can be obtained from simulating social systems operating in highly volatile environments and which relate to self-organization processes and behaviors where determinism and randomness co-exist. Such systems encompass the financial agents' transactions in national economies and stock markets, online trading and auctioning in electronic markets,

the rise and fall of political parties, urban formation dynamics guided by household and firm location choices, and the transport and inventory management in logistics networks.

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REMARKS

[1]The effect of the number of agents on the cultures formed has been investigated in the Axelrod's model; it seems that it does not play a significant role in the Latané and Nowak and the Bounded Confidence models, while this effect has not yet been examined in the MER Model, due to its heavy computational burden.

[2]For some parameters' settings and locality in communication.

[3]Although this statement has not been published, it is easy to observe when running a program with the algorithm of Bounded Confidence model for a CA topology.

[4]It is noted that existing economic models used to assess the acceptability of congestion tax or other pricing measures in transport and other network industries are typically based solely on the maximization of some measure of the utility of consumer agents, ignoring the effects of interaction topologies (social network structures) and personality characteristics at the individual and social level.

[5]Made with Gephi 0.7a© (Watts-Strogatz Small World model A).

[6]Made with Gephi 0.7a© (Random Graph).

[7]he sensitivity to initial conditions also relates to the fact that there is no error-free measurement data and it constitutes a characteristic of the system itself, not a characteristic of the measurement tool (data collection method) applied.

[8]All measurements result from Gephi 0.7a©, http://gephi.org.

[9]Zero implies a value smaller than | 0,01 |; the sign is shown in the parenthesis.

[10]100 agents (nodes), $\psi = 1$, bound of confidence $\varepsilon = 0{,}2$ and run up to 25 000 iterations.

[11]Initial value (random initial profile): 6,246.

[12]A system presents transient chaos when initially the Lyapunov exponents are positive but, after a number of iterations, they tend to zero [38]. This means that the system originally exhibits (even high) sensitivity to initial conditions but, gradually, after a tight self-organization process, it becomes stable and predictable.

[13]For instance, this may be some kind of Mass Media Communication system.

[14]The simplest way of defining methodological individualism is the thesis in which every proposition about a group is, implicitly or explicitly, formulated in terms of the behavior or interaction of the individuals constituting the group [39].

[15]In scale-free networks, some nodes-agents act as highly connected hubs (high degree), although most nodes are of low degree. Their structure and dynamics are independent of the system size. Namely, it has the same properties no matter what the number of nodes is.

[16]For instance, the prevalence of small-world networks in biological systems and the Internet may reflect an evolutionary advantage of such an architecture. One possibility is that small-world networks are more robust to perturbations (due to damage by mutation or viral infection, and random breakdowns, respectively) than other network architectures [40].

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SIMULACIJA DINAMIKE STAVOVA U DRUŠTVENIM MREŽAMA POMOĆU REGULACIJSKIH MODELA S VIŠE RAVNOTEŽNIH STANJA, TEMELJENIH NA AGENTIMA

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SAŽETAK

Rad istražuje modele regulacije s više ravnotežnih stanja, tj. simulacijske modele temeljene na agentima, za prikazivanje dinamike stavova u društvenim mrežama. Model polazi od malog broja mikro-zahtjeva (omeđena uravnoteženost i povjerenje individue) i pokazuje emergenciju (ne)stacionarnih makro-karakteristika. Ti ishodi se mogu odnositi na konsenzus, polarizaciju ili fragmentaciju stavova o oporezivanju (npr. zakrčenost cijenama) ili o drugim mjerama javnih politika već prema načinu na koji je komunikacija strukturirana. U suprotnsoti s drugim modelima dinamike stavova, model omogućuje i regulaciju diskrepancije individue kao i utjecaj varijabilnosti stavova između individua na društveno učenje i dinamiku mreže. Nekoliko je simulacijskih eksperimenata prezentirano radi pokazivanja, kroz model s više ravnotežnih stanja, uloge različitih struktura mreže (potpune mreže, mreže zvijezde, stanični automati, mreže malog svijeta i nasumične mreže) na dinamiku stvaranja stavova i cjelokupnu evoluciju sustava. Rezultati mogu pomoći identificiranju specifičnih značajki topologije (poput gustoće, broja susjeda i kritičnih čvorova-agenata) koje utječu na stabilnost i dinamiku sustava. To znanje može biti upotrijebljeno za bolju organizaciju difuzije informacija i učenja u zajednici, povećanje predvidivosti ishoda te upravljanje mogućim sukobima. Pokazano je kako organizacija malog svijeta,

koja realistično predstavlja neke vidove stvarnog života i virtualnih društvenih sustava, omogućava povećanu predvidivost i stabilnost manje fragmentiranih i više upravljivih grupiranja stavova, u usporedbi s nasumičnom mrežom. Takva organiziranja na makro-razini mogu biti pojačana uporabom mrežnih tehnologija, za povećanje gustoće komunikacije i javnog prihvaćanja mjera javne politike.

KLJUČNE RIJEČI

modeli temeljeni na agentima, društvene mreže, dinamika stavova, topologija komunikacije, nepredvidivost

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CONTRIBUTION TO RESEARCH OF MATHEMATICAL PROPERTIES OF PRE-CHRISTIAN SLAVIC SACRED LANDSCAPE STRUCTURES

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ABSTRACT

Considerable amount of interpreted data indicates that the ancient Slavs positioned their sacred sites in a way which refers to characteristic Sun angles. The article addresses the question whether distances among such sites are based on a common unit of length. In particular, this article tackles that question applying the mathematical formalism on the following two assumptions: (i) the absolute value of a distance between sacred sites was significant to the pre-Christian Slavic priests, along with the angles between lines connecting pairs of sites; (ii) the distances were prevalently measured utilising the projections of isosceles right triangle on the horizontal plane, with the exceptions of flat grounds for which the distances were measured by walk. That assumption follows from the frequent occurrence of ratio $1:\sqrt{2}$ in the analysed sacred sites. Based on the two stated assumptions the attempts are done to find the best possible length modules by using the probability distribution method of arithmetic sequences. The main property of length modules which are the least probable to appear by mere chance is that they account for as many as possible of distances from the analysed set of distances. The stated method is applied on numerous sacred systems described in literature. The result is that several common modules are extracted. The modules are subsequently correlated with the modules extracted in my recent article using the novel method which extracts the optimal common sub-module. Value of the length module thereby obtained is 30,9 m. It has 60 sub-units 0,515 m long (a cubit) and 100 sub-units 0.309 m long (a foot). Multiples of 100 or 365 sub-units, respectively, are regularly encountered in the analysed set of sacred sites in the form of sub-harmonics of the observed distances. One may argue that results of the analysis of the distances contributed to the fact that the ancient Slavs were giving a lot of attention to a solar calendar and accurate determination of the time of a year.

KEY WORDS

myth in space, metrology, archeoastronomy, spatial analysis, probability distribution

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INTRODUCTION

The pre-Christian Slavs positioned their sacred places in a tripartite structures [1]. Such structures were related to the central Slavic myth of a divine battle between Perun and Veles [2-4]. Measuring the angles which the Sun takes through the annual cycle and comparing them with the angles between sacred sites, the pre-Christian priests could accurately determine the days of religious festivals. The number of sacred triangles have already been described in Croatia, Slovenia, Austria and Germany [5-15]. These triangles probably give enough evidence that the ancient Slavs positioned their sacred places in spatial constellations which formed the sun angles. This paper as a start point takes the assumption that besides the angles also the distances between sacred sites were important to the pre-Christian Slavic priests and then questions was that distancing done by using some common units of length. The problem is approached by relying on the mathematical theory of probability.

In my recent article [15] it is described a mathematical method which helps to find out the possible common modules of length between some set of sacred sites. The method relies on the mathematical properties of arithmetic and geometric sequences. If for some of the initial parameters of the sequences the probability function for a given distribution of sacred sites in some area shows to be significantly smaller than the average, then it is an indication that the respective distribution is not random. The parameters in such case may point to a system of measures used during creation of the structure. Method tests have shown that any arithmetic or geometric sequence which is not a result of randomness and which is part of some intended system, will appear with its sub-harmonics and harmonics in the histogram of the probability function despite any reasonable number of added points which are not part of the system. But, on the other side, some moderately improbable arithmetic or geometric sequences can appear as a result of completely random distribution of points. It means that if a real distribution of sacred points in some area really is a result of intention, we surely will detect the used modules, but we will not be sure if they are a result of coincidence. But comparing the resulting modules from various Slavic regions it should be possible to determine if among them there is a correlation which can significantly minimize the accidental results. Results form my recent article were indicative, but made on insufficient number of sacred landscape structures. In this article the modified proposed method is applied to a several sacred systems discovered by the other recognized researchers.

This paper is divided into three main sections. In section one the mathematical methods used to calculate the common modules of distances between sacred sites are described along with the explanation how the pre-Christian priests were able to measure them. In section two the least probable modules of arithmetic sequences separately for Župa Dubrovačka and 10 sacred triangles from different regions are computed. Then the modules obtained modules from different regions are taken as input into the common module method with the aim of finding out the ultimate metric module common to the majority of analyzed sacred landscape systems. In section three I give the interpretation of the obtained ultimate metric module.

MATHEMATICAL METHODS

In this article the two main methods for calculating the common modules are used. Probability distribution method uses the properties of arithmetic sequences and is more appropriate for situations when every distance from some set of distances does not necessarily belong to the same system.

Common sub-module method calculates the best common sub-module among several distances and is suitable for situations when all of them are surely part of the same system.

PROBABILITY DISTRIBUTION OF ARITHMETIC SEQUENCE

Arithmetic sequence is a sequence of numbers such that the difference between the consecutive terms is constant. The probability distribution of points around some central position is calculated depending on the value of difference and the value of tolerance.

If for some of the difference values the probability function for a given distribution of sacred sites in some landscape shows to be significantly smaller than the average, then it is an indication that the respective distribution is not random.

The general case [15; pp.129-131] was defined in a two-dimensional plane as a sequence of distances (D_1, D_2, D_3, ... D_k) measured from the central point (S_0) with the associated limits of tolerance (t_1, t_2, t_3, ... t_k). But, practically the same results are given by the simplified formula in which all the input lengths are projected on one-dimension. Since in [15] the tolerance depended on the difference value D, the smaller differences had the absolute values of tolerance too small compared to the value of uncertainty with which the sacred sites were determined. Moreover, the larger differences had the absolute values of tolerance too large in comparison with that uncertainty. Here, the absolute value of tolerance for the arithmetic sequences is taken to be a constant.

In the case of an arithmetic sequence with the difference D and the absolute value of tolerance T (Fig. 1) the probability p, that a sacred site satisfies the conditions to be considered as a member of a sequence, equals the ratio of thickened segments length to the total length. On average, that can be expressed by the following expression:

$$p = \frac{2T}{D}. \tag{1}$$

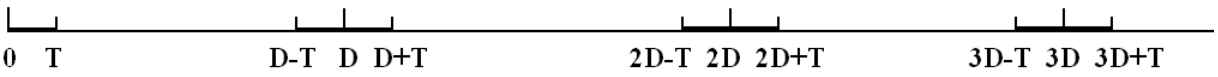


Figure 1. Arithmetic sequence with the difference D and the absolute value of tolerance T. Points satisfying conditions stated in the text are within the thickened segments.

The likelihood P of any distribution of sacred sites in respect to such sequence is expressed using the formula for the binomial distribution:

$$P = q^{N-n} p^n \cdot \frac{N!}{n!(N-n)!}, . \tag{2}$$

with N the total number of sacred points, n being the total number of sacred points which meet the conditions, p the probability that a sacred point satisfies the conditions of any member of sequence and $q = 1 - p$ the probability that a sacred point does not satisfy the conditions.

PROBABILITY HISTOGRAM

The results which gives the formula (2) for every arithmetic sequence from D = 100 m to D = 1500 m with the resolution of 1 m are presented in a form of histogram in which on the ordinate are plotted the logarithms of the reciprocal values of probability for every difference value D of the abscissa. The logarithms of the reciprocal values of probability are the most practical way for representing the probabilities, because the less probable sequences result with the higher values and the relative difference among any of them is not very big. The span from 100 m to 1500 m shows to be optimal for the usual size of tolerance with which the sacred sites can be located (approximately ±10 m to ±20 m) and how they are usually distanced (500 m to 30 000 m).

AGGREGATED PROBABILITY HISTOGRAM

This is a method in which the probability distribution of arithmetic sequences around every sacred point in some area is calculated separately. Subsequently the obtained results are aggregated in a single histogram. That means that the reciprocal values of probability for a certain value D for every point are summed and plotted on the histogram with the logarithmic scale. Such a histogram represents the overall probability distribution for all points. If there is any common module around any of the sacred points in the area, such graph will reveal it with a significantly large confidence.

COMMON SUB-MODULE METHOD

Among several distances (A_1, A_2, A_3, ... A_n) the method tries to find a common sub-module x in such a way that its harmonics (a_1, a_2, a_3, … a_n) give the lengths as close as possible to the measured distances:

$$x \approx A_1/a_1 \approx A_2/a_2 \approx A_3/a_3 \approx ... \approx A_n/a_n.$$

The harmonics are either integers or integers multiplied by $\sqrt{2}$.

The possible set of harmonics is searched dividing the minimal distance value A_{min} by every integer and integer multiplied by $\sqrt{2}$ within a range from 1 to 100 and from $\sqrt{2}$ to $100\sqrt{2}$, respectively, giving the test sub-module values x_i. The values of harmonics are then calculated dividing every distance (A_1, A_2, A_3, ... A_n) with the test sub-modules x_i and rounding up the result to the nearest integer:

$$a_i = [A_i/x_i],\ i = 1, ..., n.$$

The candidate sub-module x which is a real number very close to the value of test sub-module x_i is determined using the function:

$$f(x) = \min_x \sum_{i=1}^{n} \left| a_i x - A_i \right|. \tag{3}$$

At its minimum, the first derivation of function $f(x)$ its sign, which occurs only at the one of the following, non-differentiable points:

$$a_i x - A_i = 0 \rightarrow x_i = A_i/a_i,\ i = 1, ..., n.$$

The candidate sub-module is determined by testing which of the values x_1, x_2, … x_n gives the minimal value for $f(\cdot)$ in (3). Within a given set of candidate sub-modules, the optimal module is the one which gives the minimal value of total error. The fact is that the sub-modules which have the smaller harmonic numbers will more probably appear by intention than the ones which have the larger harmonic numbers.

DISTANCE MEASUREMENT

This article is based on the assumption that the absolute values of distances between sacred sites were important to the pre-Christian Slavic priests, so here I conjecture how they measured these distances. The simplest way to measure some distance is with the help of a measuring rope and stakes for maintaining the direction.

In the plain areas the distance between sacred sites has been measured simply by walk, but in the mountainous and hilly areas or the areas filled with lakes or some other bodies of water it surely has not always been possible. There is also a dilemma as to whether the pre-Christian priests in hilly areas measured the walk distances or the horizontal plane distances.

The pre-Christian priest had the simple means to measure the horizontal plane distances using the rules of the isosceles right triangle (Fig. 2). In this case only one side of the triangle has to lie on the the plain area.

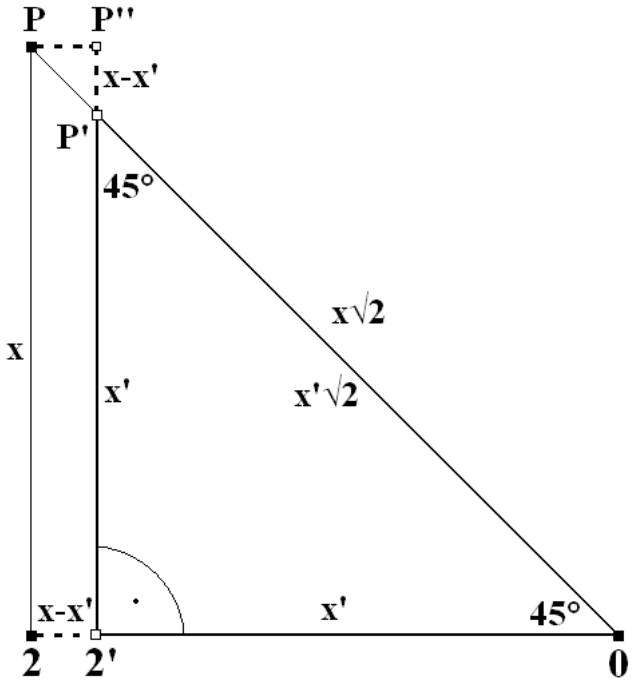


Figure 2. Locating the point 2 using the characteristics of the isosceles right triangle.

If the wish of priest was that the distance 0-2 has the length of *x*, he could have estimated the position of point 2 by locating it temporarily at the point 2'. Then, using the rules of the isosceles right triangle he could walk from point 2' in the one or the other direction perpendicular to the side 0-2' until the point 0 was seen at the angle of 45°, which he achieved at the point P'. If the distance *x*' which he traveled was smaller than *x*, he knew that the point 2' must be moved away from point 0 for the value of *x* –*x*'. If the distance *x*' which he traveled was bigger than x, then he knew that the point 2' must be moved towards point 0 for the value of *x* –*x*'. After that the distances 0-2 and 2-P were equal to *x*, and the distance 0-P equals $x\sqrt{2}$. This method naturally accounts for frequent appearance of ratio $1:\sqrt{2}$ among distances.

RESULTS

ŽUPA DUBROVAČKA

The structure of sacred sites at Župa Dubrovačka[1] southeast of Dubrovnik in Croatia, described by I. Kipre [6; p.130], indicates that pre-Christian priests had really measured distances between sacred sites and that they had frequently used relation $1:\sqrt{2}$. The system has a number of points so the probability distribution method of arithmetic sequences demonstrates its real strength and reveals what otherwise would not be easily detectable. The method brings about the aggregated probability histogram of arithmetic sequences with an exceptionally improbable length of 432 m and an additional slightly more probable length of 610 m (Fig. 4a and Table 1). These lengths are mutually related by $\sqrt{2}$: $610 = 432 \times \sqrt{2}$ which is rather indicative. Graphical representation of lengths which are multiples of 432 m (Fig. 3b) reveals that the lengths which are related by $\sqrt{2}$ prevalently appear at point 7 which is a mountain peak of height 880 m. This indicates that these lengths were measured using the isosceles right triangles.

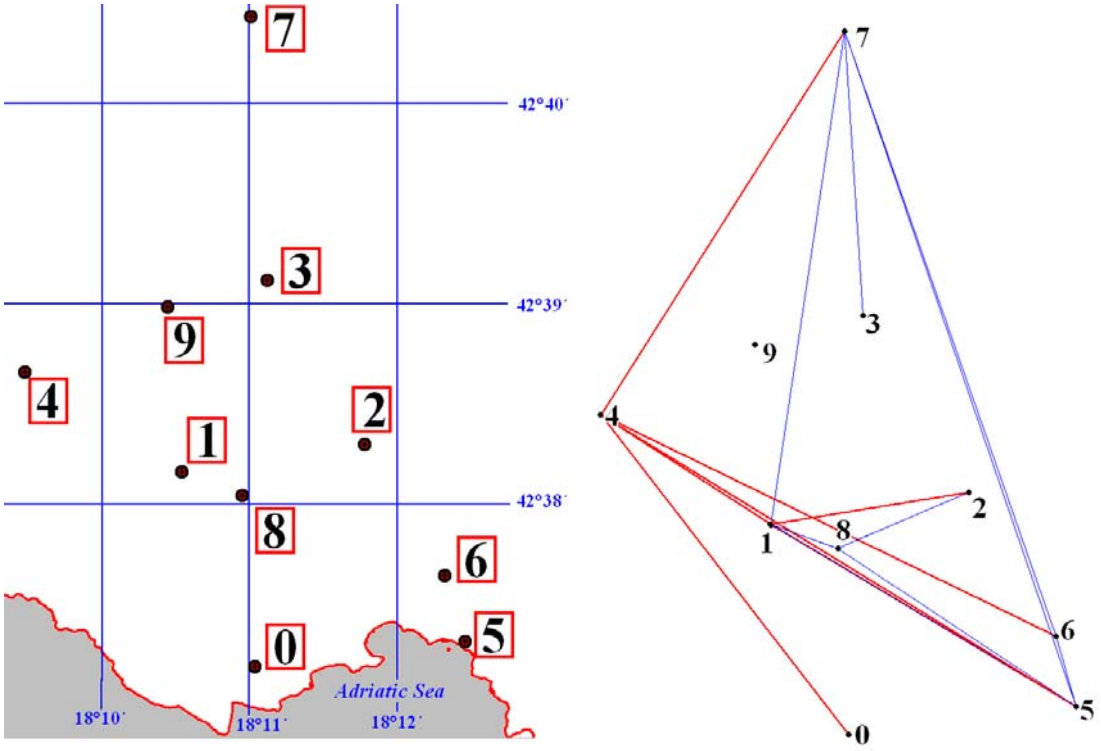


Figure 3. The spatial distribution of sacred sites at Župa Dubrovačka: a) sketch of the map of the area, b) presented distances which are multiples of 432 m (red lines) and $432\sqrt{2} = 611$ m (blue lines), with the tolerance 20 m. Sites are denoted as: 0 – St. Peter in Prenj, 1 – St. Vincent Ferrer in Rovanj, 2 – St. George in Sućurađ, 3 – The Church of the Assumption in Martinovići, 4 – St. Anne (St. Petka or St. Parascheva) in Brgat Gornji, 5 – St. Hilarion in Mlini, 6 – The Church of the Holy Salvation in Krstac, 7 – Peak of Elijah, 8 – St. Mary Magdalene in Mandaljena and 9 – Gradac.

Results indicate the lengths of 648 m and 775 m to be the least probable to appear by chance in a given set of 10 sacred triangles.

THE SET OF TEN SACRED TRIANGLES

In [15], in the area northwest of Zagreb in Croatia, the module of 620 m was detected in the probability diagrams of geometric sequences around Babožnica and St. Vitus in Javorje, and also in the probability diagram of arithmetic sequences around Gradna. The modules of 677 m, 873 m and 1234 m are detected among important archeological sites on the island of Rügen in Germany.

The literature about Slavic pre-Christian sacred tripartite landscape structures describes the number of other sacred triangles in Croatia, Slovenia and Austria. The most of these are shown[2] in Figure 5. It is not very practical to plot the probability histogram of the probability distribution method of arithmetic sequences for every sacred triangle separately, because in every one of them there are only three distances. Better results are obtained if all the distances[3] between the sacred sites which appear in the maps in Figure 5 are taken to be the input into the algorithm which calculates the probability histogram of arithmetic sequences upon such distribution of lengths. Even if some of the triangles are falsely identified as sacred, it will not prevent the algorithm to detect the common modules if they really exist among the remaining triangles or at least among several of them. Falsely identified triangles should not affect the algorithm if their distribution of lengths is random.

The results given by the probability distribution method of arithmetic sequences are presented in Figure 4b and Table 2.

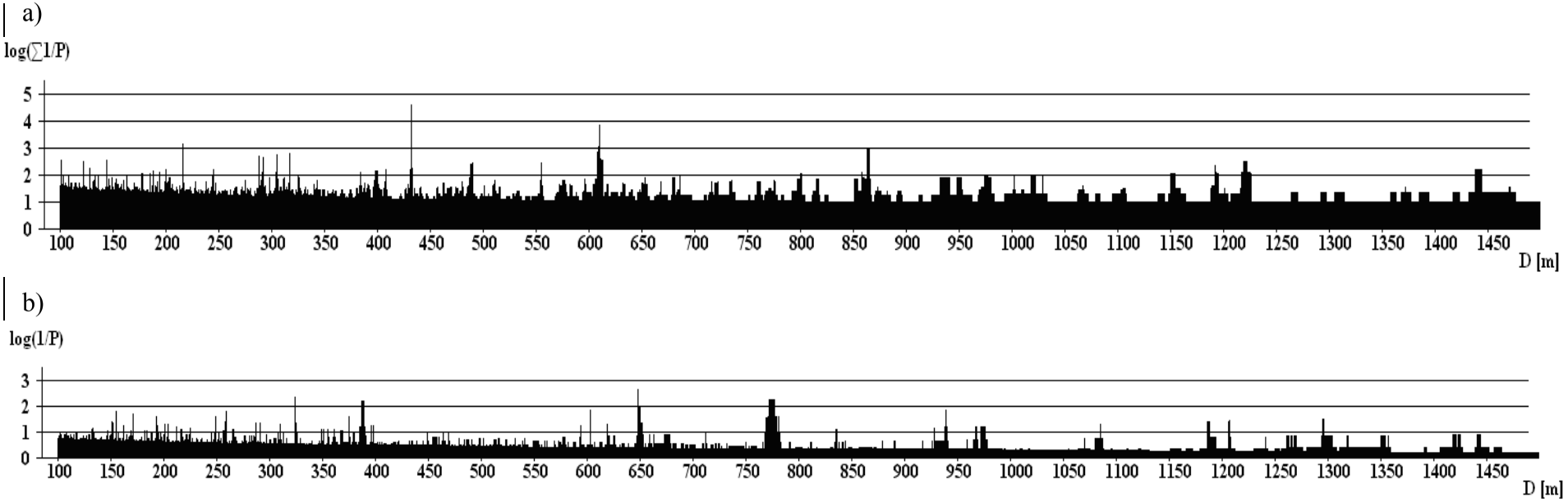


Figure 4. Aggregated histogram of the logarithm of the reciprocal values of probability of arithmetic sequences for: a) all the points in Figure 3, $T = 10$ m, b) all distances in Figure 5, $T = 15$ m.

Table 3. Computed candidate common sub-modules from the list of detected modules. The harmonics with error larger than 6 m are hatched because the calculated error is too large.

Modules, m / Sub-modules, m	432	610	620	648	677	775	873	877	1234	Total error, m
154,326	$2\sqrt{2}$ (–4,5)	~~4 (–7,3)~~	4 (2,7)	~~$3\sqrt{2}$ (–6,8)~~	~~$3\sqrt{2}$ (22,3)~~	5 (3,4)	$4\sqrt{2}$ (0,0)	$4\sqrt{2}$ (4,0)	8 (–0,6)	51,5
109,125	4 (–4,5)	~~$4\sqrt{2}$ (–7,3)~~	$4\sqrt{2}$ (2,7)	~~6 (–6,8)~~	~~6 (22,3)~~	$5\sqrt{2}$ (3,4)	8 (0,0)	8 (4,0)	$8\sqrt{2}$ (–0,6)	51,5
77,125	$4\sqrt{2}$ (–4,3)	~~8 (–7,0)~~	8 (3,0)	~~$6\sqrt{2}$ (–6,4)~~	9 (–17,1)	10 (3,8)	$8\sqrt{2}$ (0,4)	$8\sqrt{2}$ (4,4)	16 (0,0)	46,4
43,628	$7\sqrt{2}$ (0,1)	14 (–0,8)	$10\sqrt{2}$ (3,0)	~~15 (–6,4)~~	$11\sqrt{2}$ (–1,7)	~~18 (–10,3)~~	20 (0,4)	20 (4,4)	$20\sqrt{2}$ (0,0)	27,2
30,857	**14 (0,0)**	**$14\sqrt{2}$ (–0,9)**	**20 (2,9)**	**21 (0,0)**	**22 (–1,9)**	**25 (3,6)**	**$20\sqrt{2}$ (0,2)**	**$20\sqrt{2}$ (4,2)**	**40 (–0,3)**	**14,0**

Table 1. Minimal values of probability of arithmetic sequences aggregated for all points in Fig. 3.

Arithmetic module, m	$\log(\sum p^{-1})$	Relation
432	**4,654**	**432**
610	**3,935**	≈ 432√2
216	3,244	432/2
864	3,053	432 × 2

Table 2. Minimal values of probability of arithmetic sequences for all distances in Figure 5.

Arithmetic module, m	$\log(\sum p^{-1})$	Relation
648	**2,727**	**648**
324	**2,428**	≈ 648/2
775	2,336	775
388	2,277	775/2

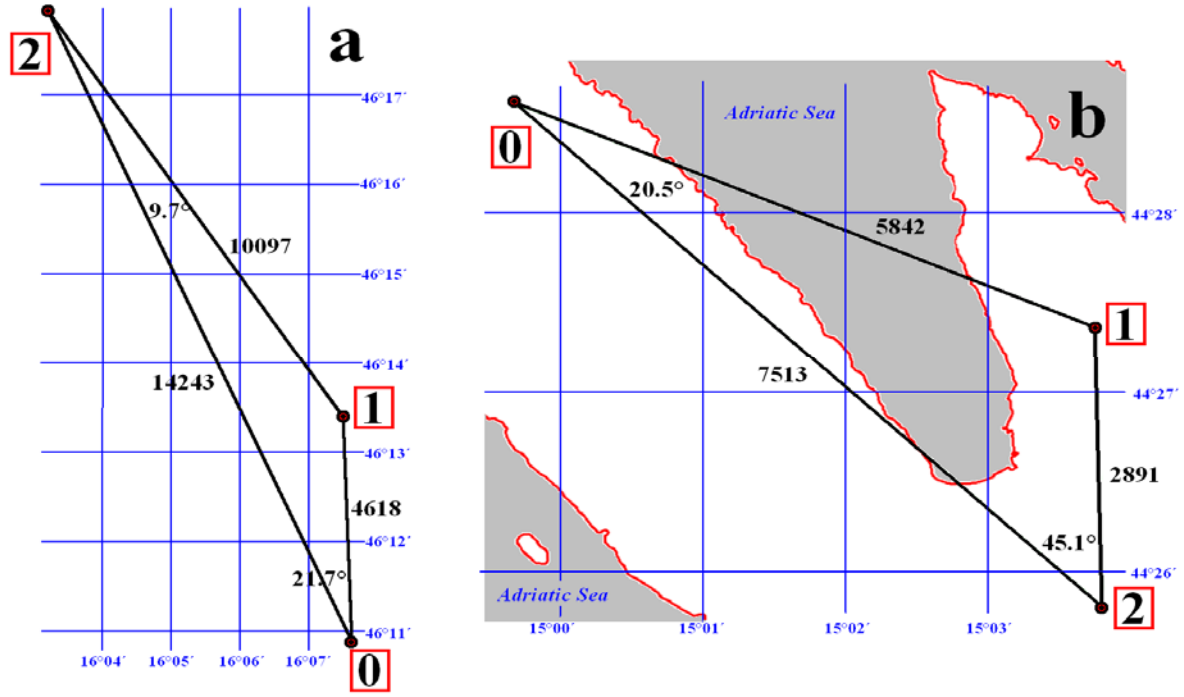
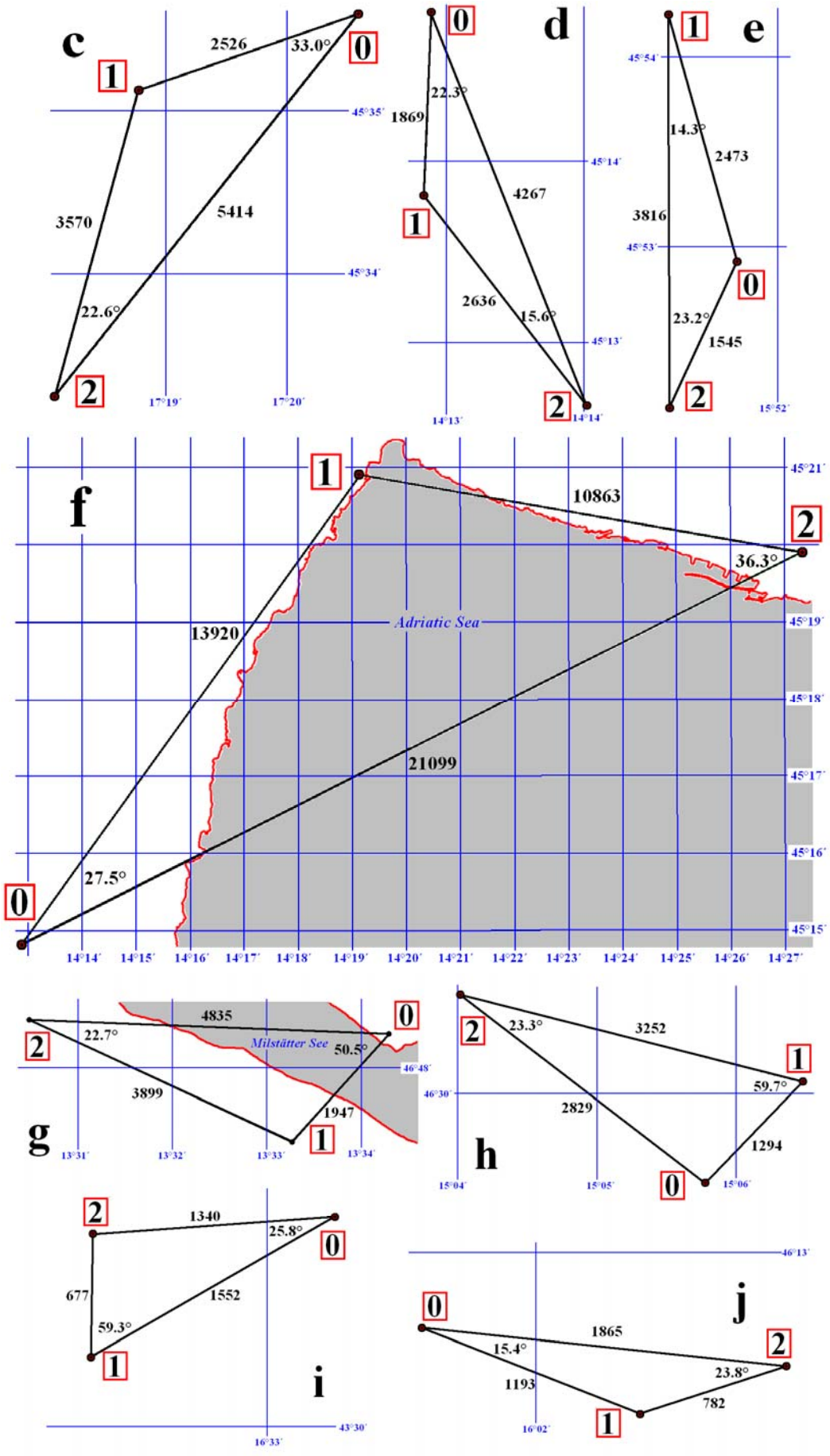


Figure 5. (This page and p.79) Ten sacred triangles, a) Ivanec in Croatia (0 – Ivančica, 1 – St. Mary in Ivanec, 2 – St. Wolfgang in Vukovoj[4]) [5; pp.426-433, 14; p.193], b) Pag in Croatia (0 – St. Vitus, 1 – St. George, 2 – St. Mary[5]) [5; pp.445-449, 10, 11, 14; p.193] and [15; pp.151-152], c) Papuk in Croatia [9; p.54, 14; p.193] (0 – Pogani vrh, 1 – Petrov vrh, 2 – Bijela (St. Margaret)[6]), d) Mošćenice in Croatia [5; pp.437-439, 14; p.194] (0 – Perun in Mošćenice, 1 – Gradac, 2 – St. Helen in Jelena[7]), e) Kameni svati in Croatia (0 – The former Puzjak's mill at Lončar in Novaki, 1 – St. Venedelin in Donja Bistra, 2 – Kameni svati[8]) [13; p.77], f) Rijeka in Croatia [5; p.439, 14; p.193] (0 – Perun in Mošćenice, 1 – At. Anne in Volosko, 2 – St. George Trsat9), g) Millstatt in Austria [1; pp.165-166] (0 – St. Salvator in Millstatt, 1 – Hochgosch, 2 – St. Wolfgang[10]), h) Slovenj Gradec in Slovenia [1; pp.167-168] (0 – St. Mary in Homec, 1 – St. George in Legen, 2 – St. Pancras in Puščava[11]), i) Žminjača in Croatia (0 – St. George in Perunsko, 1 – The Lady of Sita in Strožanac[12], 2 – The Snake's stone in Žminjača[13]) [5; pp.441-443, 7, 8, 14; p.194], j) Lepoglava in Croatia [5; pp.443-444, 14; p.194] (0 – St.George in Purga Lepoglavska, 1 – St. Mary in Lepoglava, 2 – St. John (Vitus) in Gorica Lepoglavska[14]).


c
2526
33.0°
3570
5414
22.6°
d
22.3°
1869
4267
2636
15.6°
e
14.3°
2473
3816
23.2°
1545
f
10863
36.3°
Adriatic Sea
13920
21099
27.5°
g
4835
22.7°
Milstätter See
50.5°
3899
1947
h
23.3°
3252
59.7°
2829
1294
i
1340
25.8°
677
1552
59.3°
j
1865
15.4°
23.8°
1193
782

COMMON SUB-MODULE

So far we detected the next modules as the least probable to appear by mere chance:

- Babožnica, Gradna: 620 m; 877 m [15; p.142, p.154].
- Rügen: 677 m; 873 m; 1234 m [15; p.142, p.154].
- Župa Dubrovačka: 432 m; 610 m.
- set of 10 sacred triangles in Croatia, Slovenia and Austria: 648 m; 775 m.

If these modules are taken as the input values $A_1 = 432$, $A_2 = 610$, $A_3 = 620$, $A_4 = 648$, $A_5 = 677$, $A_6 = 775$, $A_7 = 873$, $A_8 = 877$ and $A_) = 1234$, for the common sub-module method, then it results with several candidate common sub-modules, listed in Table 3.

The optimal common sub-module with the minimal total error is the candidate common sub-module with length 30,857 m.

DISCUSSION

From Table 3 it can be seen that the module of 432 m has 14 sub-modules of (30,857 ± 0.15) m, 610 m has 14√2 of them, the module 620 m have 20 detected sub-modules, the module of 648 m 21 of them, the module of 677 m 22 of them, the module of 775 m has them 25, the modules of 873 m and 877 m have 20√2 of them and the module of 1234 m has 40 of them.

The other detected candidate modules in Table 3 are the value of 43,628 m which is equal to 30,857 × 1,414 and the members of a geometric sequence which is nearly identical to the geometric sequence detected at Babožnica: 77,2 ↔ 109,2 ↔ 154,4 ↔ 218,4 ↔ 308,8 ↔ 436,7 ↔ 617,6 ↔ 873,4 ↔ 1235,2 m [15; p.138; p.142].

In addition, the length of 0,517 m, a cubit was proposed to be a basic unit behind 620 m [15; p.154]. The detected sub-module of 30,865 m has about 60 such anthropomorphic sub-units.

It is possible to propose also the sub-unit of 0,3086 m (a foot) because in the detected sub-module there is a hundred of such sub-units. Behind both of these sub-units could be the length of 0,1029 m which is equal to 0,3086/3 m or 0,5143/5 m, which is their first common sub-harmonic. The above mentioned geometric sequence has a member with the length of 154,3 m which is the first common harmonic of 30,86 m and 51,43 m.

The largest number of sacred triangles in Figure 5 have sides which can be decomposed into the subharmonics equal to the sub-module values of approximately 30,9 m and 51,43 m.

In this way, few of them have sides which are some multiple of 7 detected sub-modules or 700 detected sub-units. These are the Papuk's triangle which can be factorized into[15] 0,5155 m × 700 × (7, 7√2, 15), the Slovenj Gradec's triangle which can be factorized into 0,3097 m × 700 × (6, 13, 15) and the Rijeka's triangle which can be factorized into 0.3107 m × 700 × (50, 64, 97).

The Kameni svati's triangle and Žminjača's triangle can be factorized into the multiples of 2 sub-modules or 200 sub-units: the first one has sides 0,5152 m × 200 × (15, 24, 37) and the other 0,3090 m × 200 × (11, 22, 25).

The Millstatt's triangle and the Pag's triangle can be factorized into multiples of 3 sub-modules or 300 feet: the first one into 0,3094m × 300 × (21, 42, 52) and the other into 0,3092 m × 300 × (22√2, 63, 81).

Other triangles deviate from the above mentioned rule. The two triangles from Ivanec's area have sides which are multiples of 120 feet: the Ivanec's triangle can be factorized into 0,3092 m × 8 × 120 × (11√2, 34, 48) and the Lepoglava's triangle into 0.3107 m × 120 × (21, 32, 50).

The Mošćenice's triangle cannot be simply factorized into any multiples of 100 or 120 sub-units. But the possible common module factorization of all 3 sides of this triangle is with a factor of 365 cubits: 0,5166 m × 365 × (7√2, 14, 16√2).

If the mentioned module of 1234 m from Rügen has 40 sub-modules of 30,85 m or 4000 feet of 0,3085 m, then the module of 677 m can be factorized into 0,3085 m × 6 × 365,75, which is very close to 0,3085 m × 2200 (678,7 m).

However, it is not clear whether the Rügen's north triangle (Arkona-Venzer Burgwall--Rugard) [12; p.242, 13; p.81, 15; pp.147-148] should be factorized into 0,3085 m × 365 × 6 × (18, 31, 42) or 0,3078 m × 2200 × (18, 31, 42). That dilemma may be resolved looking at the distance between Wanda mound and Krakus mound in Krakow which has 8629 m [16], as given in Fig. 6 and Table 5. That length is almost exactly for the factor of √2 less than the length between Rugard and Venzer Burgwall on the island of Rügen [15; p.149]: 12 188 m = 1,41245 × 8629 m.

The distance between Wanda mound and Krakus mound can be decomposed into 28 000 feet or 16 800 cubits: 0,3082 m × 28 000 = 0,3082 m × (40 × 700) = 0,3082 m × (14 × 2000) = 0,5136 m × 16 800 = 0,5136 m × (14 × 1200) = 0,5136 m × 46 × 365,217.

It means that this distance is at the same time the multiple of 700 and 1000 feet, and simultaneously the multiple of 1200 cubits and 365,22 cubits.

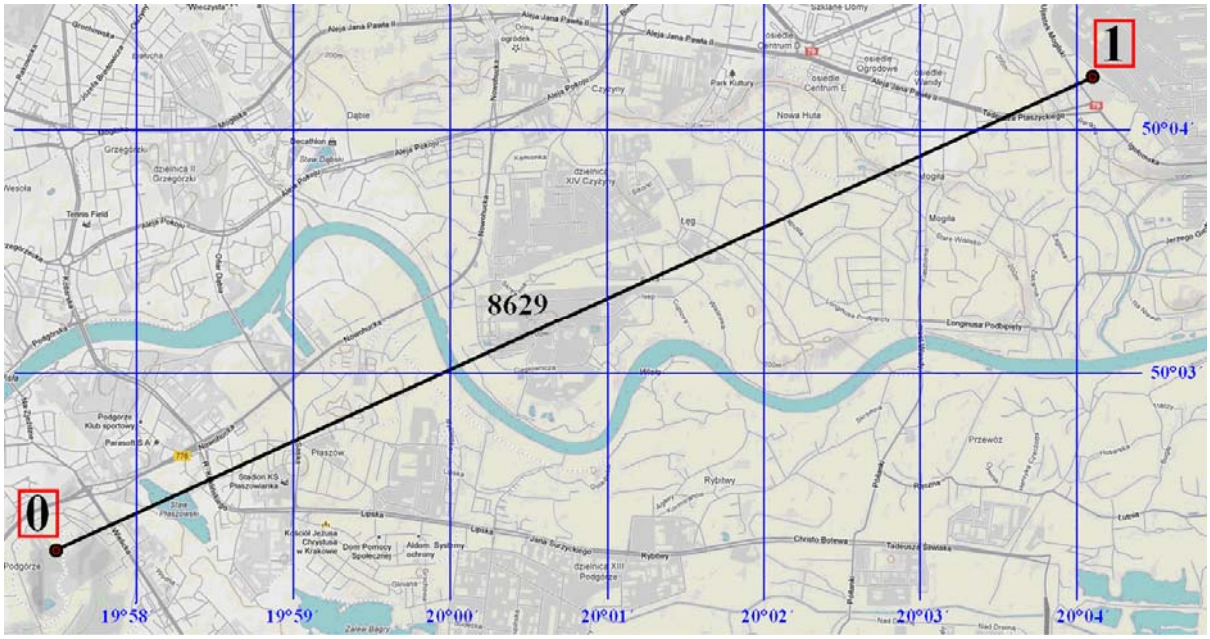


Figure 6. Geographic location of Krakus mound and Wanda mound in Krakow, Poland[16], 0 – Krakus mound and 1 – Wanda mound.

Table 5. Geographic location of Wanda mound and Krakus mound in Krakow Poland [16].

Point	**ϕ**		**λ**		***h* (*H*), m**		**Point name**	
KR	50°02'17"		19°57'30"		309,2 (269,4)		Krakus Mound	
KW	50°04'13"		20°04'05"		277,9 (238,5)		Wanda Mound	
Direction	**Distance *d*, m**	**A1-2**	**A2-1**	***δ***	**Date Sunrise**		**Date Sunset**	
KR-KW	8629	65°29' 38"	245°34' 41"	15°28'	2. V	10. VIII	6. II	4. XI

The fact that 16 800 days equal exactly 46 years, or that 8400 days or 1200 weeks equal exactly 23 solar years accounting also the leap-year days is a well known fact since ancient times. The number 8400 is the lowest common harmonic of 100 and 365,2. In reality one solar year duration is 365,242 days. The observed accuracy is rather indicative.

If one cinsiders that the length of 12 188 m between Rugard and Venzer Burgwall equals 16 800√2 cubits with a cubit of 0,513 m and a feet of 0,3078 m (0,513 × 3/5), then the module of 677 m actually equals 2200 feet which is only approximately equal to the number of days in 6 years, 2191,5 days.

After performing that correction, it appears that the Rügen's north triangle can be factorized into 0,513 m × 2400 × (7√2, 17, 23) and also into 0,3078 m × 2200 × (18, 31, 42). The Rügen's south triangle (Zudar-Venzer Burgwall-Rugard) [13; p.81, 15; pp.147-148] can be factorized into 0,3078 m × 4400 × (9, 14, 20).

It can also be observed that in the area of Župa Dubrovačka the distance between Ilijin vrh (Peak of Elijah) and the Church of St. Hilarion in Mlini amounts to 6105 m, which is 8629/1,4134 m. According to the perfect ratio observed in the case of Krakow this length has exactly 8400√2 cubits or 14 000√2 feet. The modules of 432 m and 611 m which we detected there amount to 1400 and 1400√2 feet. The triangle Ilijin vrh – St. Anne in Brgat Gornji – St. Hilarion in Mlini is almost right angled (Fig. 3). Its angles are 89,2°, 51,2° and 39,5° and sides 432 m × (9, 11, 10√2)), but it is not the isosceles triangle. One may argue whether the constructor used the approximation that the right angled triangle with the legs in a ratio 9:11 has the hypotenuse almost equal to 10√2.

In the area of Babožnica the length which could encode the number of days in 46 solar years is the distance between Kameni svati and the Church of St. Catharine in Hrebine [15; p.144]. This line crosses exactly above Babožnica and amounts to 8685 m giving a cubit of 8685/16800 m = 0,517 m. This is the same value which gives the module of 620 m when divided by 1200. Just to the south, the triangle St. Anthony in Gradna – St. Nicholas in Strmec – St. Anastasia in Samobor has the characteristic sun angles of 23,5° and 34,2° [15; p.145]. The length between St. Anthony in Gradna and St. Nicholas in Strmec amounts to 4342 m which is 8685/2 m, so it contains exactly 8400 cubits and codes the number of days in 23 solar years.

That analysis points to the fact that not only the angles, as previously shown, but also the distances between the sacred sites could refer to a some form of a solar calendar (the number of days in a year, 365). Indeed, the identification of the common sub-module relied upon the property that the distances concentrate around the values which are both the multiple of 100 sub-units and the multiple of 365 sub-units.

Rather important confirmation of the sub-unit which equals 0,309 m (a foot) is a fact that the length of 3,00 m to 3,13 m was as a basic measuring unit of burial sites and sacral objects detected by A. Pleterski in his key article about three-partite Slavic pre-Christian landscape structures [1; p.182].

If the detected modules are intentionally formed, which means that they did not appear by pure chance, then one can assume that the basic unit of length had sacred meanings. That brings about the further thought that it was probably represented in some form inside the Slavic pre-Christian temples[17].

CONCLUSIONS

Despite that it is not possible to prove beyond absolute doubt that the discovered length of approximately 30,9 m belongs to the common system of measures of pre-Christian Slavs, it is possible to assume that if distances between sacred sites were important to the pre-Christian Slavic priests and if they possessed some common system of units then the discovered common sub-module is the most probable candidate for such system. The fact that the units of 30,9/60 m and 30,9/100 m multiplied by 100 and 365 are often the common sub-harmonics of the observed distances is an additional confirmation of the correctness of the theory. The appearance of the distances which contain some multiple of 8400 cubits referencing in this way 8400 days, 1200 weeks and exactly 23 solar years accounting also the leap-year days is also indicative.

We can surmise that the performed analysis of the distances indicates the same which was already known from the observed angles between sacred places: the ancient Slavs were giving a lot of attention to solar calendar and accurate determination of the time of year.

ACKNOWLEDGMENTS

The author acknowledges contribution of two anonymous referees to the final form of this article.

REMARKS

[1]Geographic coordinates of sacred sites are: 0 (423711,50 181101,93), 1 (423809,70 181032,70), 2 (423818,55 181146,86), 3 (423907,31 181107,34), 4 (423839,93 180929,06), 5 (423719,06 181226,94), 6 (423738,57 181219,60), 7 (424026,28 181100,20), 8 (423803,07 181057,78) and 9 (423859,47 181027,48). These, as well as geographic coordinates in remarks 2-9, 13 and 14, were determined using www.arkod.hr.

[2]Some triangles are excluded from the analysis because the available sources did not make possible to accurately locate the sacred sites. These are the triangles at Wechsel in Austria, Paški Kozjak in Slovenia, Dejlovce in Macedonia [1], Mrdakovica near Vodice in Croatia [18] and some others. The triangle northeast of Perun at Žrnovnica is excluded because it is not clear whether the third point of this triangle is the Church of St. Michael or the peak of Gračić [5, 6, 18] and for the Zagreb's triangle it is not clear where to precisely locate Županići.

[3]The lengths in meters are: 1340, 677, 1552, 3252, 2829, 1294, 2526, 3570, 5414, 4835, 3899, 1947, 1865, 1193, 782, 1869, 4267, 2636, 2473, 3816, 1545, 10 097, 14 243, 4618, 5842, 7513, 2891, 10 863, 13 920 and 21 099.

[4]Geographic coordinates of sacred sites are: 0 (461053,14 160737,91), 1 (461322,53 160730,40) and 2 (461755,75 160311,83).

[5]Geographic coordinates of sacred sites are: 0 (442836,27 145941,73), 1 (442721,70 150344,65) and 2 (442548,08 150347,34).

[6]Geographic coordinates of sacred sites are: 0 (453535,47 172035,59), 1 (453507,60 171846,02) and 2 (453315,60 171804,93).

[7]Geographic coordinates of sacred sites are: 0 (451449,32 141253,23), 1 (451348,82 141250,06) and 2 (451239,60 141400,83).

[8]Geographic coordinates of sacred sites are: 0 (455255,58 155142,77), 1 (455413,11 155113,98) and 2 (455209,53 155114,82).

[9]Geographic coordinates of sacred sites are: 0 (451449,32 141253,23), 1 (452054,59 141907,76) and 2 (451954,72 142719,39).

[10]The coordinates of sacred sites are determined using GoogleEarth: 0 (464814,58 133417,32), 1 (464727,63 133316,08) and 2 (464821,01 133029,49).

[11]Cartesian coordinates of sacred sites are determined using gis.arso.gov.si/atlasokolja: 0 (507744 149856), 1 (508651 150779) and 2 (505498 151576).
[12]The position of sacred site according to some researchers is not located at The Lady of Sita, but rather in the close vicinity (at 'Krug' in Strožanac). This article uses the older positioning.
[13]The coordinates of sacred sites are: 0 (433037,61 163316,51), 1 (433012,53 163216,62) and 2 (433034,47 163217,04).
[14]The coordinates of sacred sites are: 0 (461247,66 160132,91), 1 (461233,54 160224,71) and 2 (461241,27 160259,47).
[15]The sides of triangles are written in a form: a measuring unit *x* a number of units *x* (a factor for the first side, a factor for the second side, a factor for the third side).
[16]Map adapted from maps.google.com.
[17]This could be the height of some statue. For example, the idol of Zbruch is 2,57 m tall, which is equal to 0,514 m × 5. The height of the Plomin tablet is 0,52 m. It is symptomatic that this Late Antique Roman plastic with carved glagolitic letters has a figure with unnaturally shortened legs, perhaps to accommodate the length of one cubit.

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DOPRINOS ISTRAŽIVANJU MATEMATIČKIH SVOJSTAVA SVETIH KRAJOBRAZNIH STRUKTURA PREDKRŠĆANSKIH SLAVENA

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SAŽETAK

Znatna količina interpretiranih podataka upućuje na to kako su stari Slaveni postavljali svoja posvećena mjesta na način koji povezan s karakterističnim Sunčevim kutovima. Ovaj članak razmatra jesu li udaljenosti između takvih svetih mjesta višekratnik zajedničke mjerne jedinice za duljinu. Razmatranje se provodi sa striktno matematičkog stajališta polazeći od sljedećih pretpostavki: (i) pretkršćanskim slavenskim svećenicima bile su važne apsolutne vrijednosti udaljenosti među posvećenim mjestima, zajedno s kutovima između pravaca koji ih povezuju, (ii) predkršćanski svećenici često su mjerili udaljenosti metodom koja koristi svojstva istorkačnog pravokutnog trokuta, osim kad su mjerili udaljenosti po ravnome tlu. Ta pretpostavka posljedica je relativno česte pojave omjera $1:\sqrt{2}$. Na temelju navedenih pretpostavki, primjenom metode raspodjele vjerojatnosti u aritmetičkim nizovima, tražen je optimalni modul duljine. Moduli duljine najmanje nasumične vjerojatnosti pojavljivanja predstavljaju subharmonike što većeg broja stvarnih udaljenosti između posvećenih mjesta. Navedena metoda primijenjena je na brojna posvećena mjesta opisana u literaturi. Kao rezultat, izdvojeno je nekoliko modula duljine koji su zatim korelirani s modulima izdvojenim u prethodnom radu novom metodom kojom se izdvaja optimalni zajednički submodul. Tako je dobiven iznos 30,9 m. Ta duljina sadrži 60 duljina 0,5143 m (lakat) i 100 duljina 0,309 m (stopa). Spomenute jedinice pomnožene sa 100 i 365 su često zajednički subharmonici promatranih udaljenosti. U radu se raspravlja o doprinosu analize duljine prethodnom stavu da su stari Slaveni mnogo pažnje poklanjali solarnom kalendaru i točnom određivanju doba godine.

KLJUČNE RIJEČI

mitovi u prostoru, mjeriteljstvo, arheoastronomija, prostorna analiza, raspodjela vjerojatnosti

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SOCIO-CULTURAL CONTEXT OF DRUG USE WITH REFLECTIONS TO CANNABIS USE IN CROATIA*

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ABSTRACT

Socio-cultural context of drug use is reflected as the constitutive part of interpretation of its effects and corresponding meanings, both at macro and micro-societal level of sociological analysis. In the first part of the article some more influential social-theoretical approaches to drug use are considered. Most of them consider drug use in terms of sociology of subculture and deviance. In second part, Croatian socio-cultural context is analysed, with reflections on questioning key terms that are addressed in the first part of the article. The concluding part indicates the ability for critical reflection of part of theories with regard to specificities of Croatian socio-cultural context. Furthermore, it is indicated that is necessary to overcome existing focus on the war, transition and after-war period as still dominant interpretative model in actual Croatian social research on drug use.

KEY WORDS

socio-cultural context, drug use, cannabis, subcultures

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INTRODUCTION

Drug use is considered here with respect to the assumptions that social and cultural context is the indispensable element of understanding the causes, forms, meanings and consequences of drug use. The detailed social theoretical approaches indicated a need to overcome those explanations that are based solely on the supposed "pharmacological reality" of legal and illegal substances and which are embedded in the dominant notions and social norms of the greater, lesser or none acceptance of any drugs. Social-theoretical analyzes that are considered here have shown this context is a complex phenomenon which tends to change and diversity, and that it can be studied at different levels of social reality.

With regard to macro-sociological analysis, socio-cultural context as an important element is incorporated in an attempt to answer the question about the nature of drug use at the societal level, and it is usually sketched using concepts that suggest basic social processes: immediate or enduring characteristics of a society – like frequently applied Merton's anomic approach [1, 2], or Young's definition of productivity ethos as an important mark of the dominant culture in industrial society [3], and suggestions of British society, defined as a post-modern one, made by Parker, Aldridge and Measham in the mid-nineties [4]. On the other hand, the socio-cultural context of drug use is outlined at micro-social level as the immediate context in which the use occurs. Ways, forms and consequences of drug use that are recognizable in actual life experience of users, are often affected by concepts of groups, learning, subcultures, etc. at the micro-level [5-7]. At both levels the socio-cultural context is the constitutive factor (with the personality of the user and pharmacological properties of drugs) in the function of drugs and their effect on the human psyche. Similarly, at both levels, drug users and their identities are being formed in their manifestations, sometimes more, sometimes less, determined by elements of the societal reaction that accompanies drug use and reflects the interests of social groups which play a crucial role in defining the core values in the dominant culture. Societal reaction mainly manifests itself by carrying out the principles of legality: allowing the use of legal drugs in the socially standardized forms and condemning both drug use when it takes place in the improper way and the use of illicit drugs in general.

The levels of socio-cultural context are not always strictly separated, but rather simultaneously integrated into the structure of concepts or models. Mostly, it is a literature that examines the use of drugs in the development of theoretical generalizations within the sociology of deviance and subcultures. Focus on research from these two fields in sociology is not surprising, considering that the use of illegal drugs clearly implies exceeding the norms as a common element in the social and cultural contexts which can be considerably different.

FROM SUBCULTURES TO COUNTERCULTURE

Concepts of subculture and deviance were already implied in the studies by authors from Chicago school of sociology [8, 9]. Referring to the normative conflict as understandable in terms of cultural transmission and the diversity of American society, Sutherland's concept of "social learning" as a socio-psychological framework for understanding deviance (crime) has proved to be incentive for future surveys of cannabis users [10]. While those surveys almost always confirmed significance of (friendly) group in accepting the aspects that approve drug tasting and longer smoking, the space left for questioning the scope of the initial concept was opened in the absence of interest in the issue of the conflicting nature of society and the problem of social causes of deviance [9] as well as an actor's implicit "drowning" in the context and being subject to the group "pressure" [11]. However, the context of the (friendly,

peer) group, including exceeding the norms and the various conceptual modifications, will wriggle later as one of inevitable level of studies about drug use.

Theoretical developments that followed the Second World War have insisted emphatically upon the interaction between subculture and deviance. How much and in what ways these concepts, particularly in the study of the use of cannabis and other drugs, were brought in relation to each other, mediated by the very socio-cultural context in which the surveys were conducted. If it's kept in mind that it is mostly on theoretical approaches that generally observed use of drugs in general within societies of high capitalist modernization, especially in the U.S. [5-7, 12, 13], it is evident that the key changes in the socio-cultural context of drug use surrounded with the "spirit of the sixties" and the counterculture of the young people, which will be the very fertile ground to form new concepts, as well as to further develop and modify the terms of subculture and deviance, as the actual terms within the current studies of drugs and their users today. The approaches preceding the counterculture were fewer and their achievements were more often analyzed in performing through recent decades and even today, than at the time of their development. Those are: the delinquent anomic subculture by Cloward and Ohlin [14], Alfred Lindesmith's review of their model [15] that questioned anomic perspective in general, and Becker's sequential model of deviance [5] that will anticipate counterculture and future social-theoretical developments at the plane of drugs. They are important for several reasons.

The extending of Merton anomic matrix [1] enabled the Cloward and Ohlin [14] to specify a delinquent subculture of retreatment, which means collective (group) rejection of cultural goals of society along with the already unavailable legitimate and illegitimate means to achieve them. Cloward and Ohlin have situated such withdrawal at subculture level in the context of disorganization and disintegration of communities in urban centres, referring to drugs as a central preoccupation in terms of self-orientation of actors determined with failure. This approach has proven to be inspirational many times. However, its critical examination primarily allowed disclosure of theoretical reserves towards anomic paradigm as a comprehensive model for explaining drug use. Taking into account the multiplicity of motives for drug use, the variability in the effect of the same drug in various stages of an individual user's career, the diversity of culturally shaped patterns of drug use in different contexts, and, finally, the diversity of patterns of use of the same drug in the same context, but at different periods (such as the use of opiates in American society during the nineteenth and twentieth centuries), Lindesmith and Gagnon [15] have disputed the scope of understanding of the focus on drugs as individual or collective withdrawal, confirming their insights using complex historical material. Their observations suggest that the scientific explanation coincides with the official one too much, and that an element of illegality as a direct expression of social policy on drugs can significantly shape the modalities of their use and the elements of their appearance. In other words, illegality and social policies should be included in sociological analysis because they can - rather than withdrawal as a socio-structurally determined reaction to anomie – imply the problem of marginalization of users. These remarks are implicitly evident in the remarks addressed to Cloward and Ohlin because of their excessive insistence on socio-structural factors and street crime which has left too much room for the assumptions of predisposed risk markers of lower and marginalized social strata and groups in the field of crime [11, 16]. But regardless of this justified criticism, the concept of delinquent subcultures anticipated the importance of some concepts in the context of various forms of subcultural association [17]. Finally, the concept of withdrawal subculture has inspired researches of the role of structural factors in chronic and uncontrolled use of certain drugs (e.g., crack) in the context of the disintegration of local communities in poor and minority enclaves of American cities during the eighties and nineties [18].

The interaction of subculture and deviance in sociology of 1950s has been considerably nuanced in the works of authors dealing with interaction. Howard Becker [5] has determined subcultures only in principle, through examination of the character of the possible outcome of the plurality of society and social groups, and keeping a distance from notions of society and culture as a homogeneous entity. On the other hand, the socio-demographic characteristics of the actors in the context of the problem of deviance are relativised here by reference to the problem of the power structure and the key role that social status groups (depending on age, gender, ethnicity and class) allows making and enforcing the rules, i. e. labelling only one part of the lawbreakers. Using the analysis of phases in the career of marijuana smokers Becker has developed a model for the study of deviance in which discontinuities in the behaviour reflected the characteristic motivations that are shaped incidentally, not prior to the initial transgression, and thus reaffirm the (deviant) actor as a subject that can overcome inevitable determinism of the group (subculture) visible in the social learning theory.

Counterculture of youth, the forthcoming period of psychedelics and significantly expanding drug use during 1960s allowed further examination of the approaches that focused only to the lower social strata and marginalized world of immigrants and coloured people. Mass drug tasting and occasional drug taking was simultaneously the starting point for the development of new approaches and concepts. The epidemic model was significantly stabilized at the level of official definitions, confirming the indications of far-reaching Becker's "hierarchy of credibility" and social theory has met the need of redefining socio-structural components in the study of drugs. In this sense, cannabis (often with LSD) was observed as a drug to which young people from predominantly middle strata of society were devoted to [6, 19], and the mentioned terms of subculture and deviance have actualized Becker's clues to the "loosening" of socio-demographically determined motives for use. This is already evident in Goode's studies [6]. He implies a subculture as a sub community, and this fact would be even more recognizable in research by Zinberg [7]. Subculture has been implicated as sub community [6], or simply, in the research by Zinberg [7], as a peer group that approves the drug use, makes it controlled and gives it meaning using internal sanctions and rituals (as opposed to official sanctions of rejection and punishment). Although the Young's [3] apostrophizing of the bohemian youth culture (as the subculture of hippies and black people) was a reminder that the different positions in the social structure form the different attitudes towards the productivity ethos as the dominant value of the industrial capitalism, and might have the use of associated drugs as a kind of outcome, the drug use abruptly jumped from a margin into the centre of society. The turning point is, if we ignore the other elements in the discussion about the achievements of the counterculture, at least in the case of cannabis referred to the cultural assimilation of knowledge among users (and to some extent even among non-users): it will be manifested primarily in notion that it is a light drug and its use will become noticeably less ritualized, including the decline of earlier stricter forms of neutralizing external control [7]. One can discern that cultural assimilation of knowledge mentioned emerged on the waves of counterculture, as well as Young's prediction about youth as a social category in which - due to their specific position in the context of questioning contradictory impulses of free time and productivity ethos - drugs retain an important role in subsequent periods, corresponding to cultural accommodation of forbidden and modalities of recreational drug use among young people, as key concepts indicated in the studies of British authors from the mid-nineties [4].

FROM COUNTERCULTURE TO NORMALIZATION

But the social and cultural context of the use of cannabis and other drugs is not a one way street. Grinspoon and Bakalar [20] warned that a society only partially "becomes what it

consumes". Inspecting the deviant paradigm in the study of cannabis use to the "normalization thesis" will be developed gradually, along with the concept of moral panic [21, 22] repeatedly showing that analyzing the societal reactions we could be convinced that the capacity of society to accept the drug use as a normal human choice is still narrow. The approaches that inspect the deviance as a starting point, without accepting the pathological premises, individual or social, have been developed till 1990s in different conditions: from emphatically prohibitive, like those in the U.S. in 1980s, to the Dutch, which will not only anticipate, but now for nearly three decades, serve as an example of how the assumption of normal cannabis use can be integrated into socially acceptable patterns. Also, cultural accumulation of knowledge among users of different drugs enabled the creation and development of approaches that were yet to establish themselves in 1990s as a desirable and acceptable official policy. Harm reduction is a typical example of a legitimate approach subject to the attempts of science and politics, preoccupied with prohibition and abstinence, to adapt it to their own premises [23].

Multiplication and the increasing complexity of young people's micro worlds now affected by the different and new concepts in subculture sociology with wider social changes that implied speech about post-modern society, have allowed the wider use of drugs that fit into the form of recreational drugs (where cannabis cannot be forgotten), and an apparent increase of user knowledge in relation to "public knowledge" issued in the terms of "normalization thesis" [4, 24], with obviously marked distance from the subcultural-deviant paradigm. The authors have portrayed the social and cultural context in which substances like cannabis and amphetamine drugs are not a "phenomenon" reserved for a hidden, unknown, delinquent and subcultural world, that their use does not necessarily result in deterioration of the user, although the use of some drugs is associated with obvious risks, but also that the entire, complex world of socializing forms itself no longer depending on whether drugs are used or not. There are indicated movements that reflect reduction of socio-demographic differences in tasting drugs, where – considering the implicit focus of sociological research of the world of drugs as a male world – gender redistribution has the greatest importance and follows the well-known changes in the belonging to a class, a race or an ethnicity. The apparent adaptation, the integration of drug use into the context of everyday obligations indicates the social and cultural context in which drugs are just one of the hazards of growing up and living in highly modernized societies, and often one of the ways in which young people somewhat neutralize the difficulties of everyday life [24].

CANNABIS IN CROATIA

Considering the use of cannabis in the Croatian context, it is necessary to question the usefulness of theoretical approaches in outlining its specifics and associated elements which we could regard universal. They clearly indicate the existence of both kinds of elements.

Cannabis, like most other illegal drugs in the Croatian context, perhaps generally points to the kind of "historical concentration". As sociological literature on youth subcultures shows that the process of their fragmentation intensifies during the 1980s [17], not lagging behind those in developed industrial societies, so the spread of cannabis use may be observed as a process that directly corresponds to it. Youth subculture is also the birthplace of use of other illegal drugs in Croatia. However, the use of cannabis occurs during the 1970s primarily as smoking hashish, simultaneously being undifferentiated compared to other illegal drugs (except heroin – its significant use started later, when the process of differentiation among drug users advanced). This usage can be interpreted in terms of subculture because it was a small number of young people whose preoccupation with drug experimentation would soon grow into recognizable shapes of focusing on drug-mediated activity and isolation apart from the

whole emerging youth culture, but also because drugs were inevitable area of experimentation and interest within fragments of the subcultures in the process of their formation.

At that time cannabis appeared in the society as something new – without the traditional long-term use, as it was the case with alcohol, deeply rooted in the culture of the wider society in which widespread use among young people often reproduced already existing patterns. The spread of cannabis was not preceded with the long-term presence or the use among certain social groups on whose repression, discrimination and marginalization the societal reaction focused to the criminalization of cannabis use in some developed industrial and other societies was based. In other words, there was no drug use in neglected urban quarters like those typical for the Latin American population in the United States, and no Rastafarians in the hills near major Croatian cities. Cannabis was present only in the form of industrially grown hemp. Unlike hashish smoking, marijuana smoking, planting and spreading started among young people on the turn of 1980s, when it was already sung about and celebrated in rock-music-mediated youth culture in the world for numerous times. Knowledge and perceptions of its effects were more or less mediated by reception of foreign rock culture and preceded the process of expansion. As already mentioned, although marijuana appears simultaneously with heroin, the area of their differentiation among users was already prepared for some time, either in the development of positive and negative symbolic notions, or literally in the form of at least occasional and sporadic separation of consumer scenes [17].

Marijuana quickly established itself among the various youth subcultures, where its use constantly raised in relation to other illegal drugs, and alongside socio-demographic strictly confining boundaries. To some extent this is true for the use of other illegal drugs. They appear and become established in the social system which – despite of stratification elements that are generated from its single-party system embedded in traditional marks of the dominant culture, or the contradiction between the planned and the commercial economy, and finally, the split between the official self-management project and its performance, often observed in literature in terms of half-modernisation [25, 26] – did legitimize itself, at least with the illusion of social security and social equality, passing through phases of prosperity and economic and political crisis until the final collapse and the war. If socio-theoretical approaches to the cannabis and other drugs use issue outlined broader socio-cultural context in advanced industrial societies as a shift from the margins of adolescence and youth, from ethnically and racially bounded world, to the massing in its centre during 1960s, with emphasis on young people from the middle classes, and later on crossing over socio-demographic framework (at least for cannabis), here it all starts right from the fragments of the centre – a wide range of young people who were in the mixture of compulsory education and open way to the university as a medium of social mobility entered the transition period with cannabis as a drug that represents something familiar and even fairly accepted: the grass which was tasted, smoked for some time, or is still consumed occasionally or frequently. Dispersion among subcultures and social strata can leave space for identifying the different modalities of drug use in numerous groups based on socializing, from those from certain neighbourhoods or benches in parks to those from the student rooms or toilets, or from some other, more or less conspicuous place in a club or disco. However, through twenty years, cannabis established itself as a drug the use of which can not be fully grasped by the socio-economic categories - as witnessed in the literature [17], that described changes in the subculture of bullies, recognized in 1970s at the “poor entry” of children from segments of labour families that were not accepting any drugs other than alcohol, and in the second half of 1980s were somewhat integrated into an entirely new world of football fans, not so much determined by classes, with both heroin and marijuana present in its fragments.

If the modalities considering this or that subculture are somewhat different, the prevailing patterns of drug use from the beginnings, more than twenty years ago, may be aggregated in the term recreational use – mostly smoking marijuana for pleasure, without the individual's decay, which is smoking more periodically or more often integrated into individual existence not in the form of escape from the pressures that come from certain life, but rather as something not directly related to these pressures. Smoking marijuana does not manifest as a disorienting response of young people to swinging and evident social crisis in 1980s or the difficulties of transition in 1990s, it is neither escape, and mostly not even symbolic resistance, it is rather continually incorporated into pluralisation of youth styles as clearly recognizable modernizing indication of the social development as something to be decorated with sometimes and to invent different "niches" in the multiplicity of individual and group orientations some other times. In so far smoking is often a sort of companion to "shaving" as a term (symbolically processed several times in subcultures) that shows different forms of expression, from the primarily hedonistic to those creative, sometimes equally indigestible for the dominant culture. Finally, over the period mentioned, which was recorded in Croatian sociological literature [2, 17], smoking cannabis has gradually, but clearly without doubt, lost the belonging clear sense of exceeding the norm that it once had. But it remained prohibited, punishable and subject to rejecting as harmful and dangerous in the notions and the fears of illegal drugs in the dominant culture.

This also indicated the socio-cultural context of cannabis use with respect to the terms in which it is outlined here: as a gradual and differentiated normalization that takes place from the beginning of drug use in conditions of societal reaction focused on abstinence. As such, the socio-cultural context is constant, regardless to the diversity of actors/users and the diversity of socio-economic stages in the development of Croatian society. At the same time, in contradiction of fundamental efforts it is not compact and consistent – the spreading of predominantly recreational marijuana smoking over the last quarter of 20C in Croatia took place in conditions in which the refusal from the side of the dominant culture was often presented as diffuse, allowing us to recall Cohen's [21] warnings that the spreading of normative interest in deviance is neither always politically and economically determined, nor it is always substitutable in its outcomes. As the refusal of societal reaction remains constant, and a kind of "quotient of tolerance" of the dominant culture in an effort to reintegrate is today tested through its talking to itself during the campaign of moral panic, and tomorrow it will be manifested through circumvention of formal and informal sanctions, so the normalization is expressed as differential – leaving opportunities to appreciate the heterogeneity of youth attitudes and behaviour with regard to drug use, i. e. for the recognition of different motives and forms of existence in various forms of drug use within the differentiated segments of young population. In addition, in the meantime, the world of users focused to cannabis has articulated among generations, searching for approaching of their own beliefs, knowledge, rationalizations and action strategies within the current possibilities for actualizing different motives and patterns of cannabis use.

When the ambivalence of a socio-cultural context is outlined following the research insights that have pointed to the complexity of social dynamics and cultural impacts in Croatia over the past ten years in a similar way, but within slightly different issues, there is the intention to draw attention to the richness and "elaboration" of space between assumed extremes to which the context may more or less incline in certain periods. This indicates the dynamics of context in time, which allows us to observe the intertwining fragments of normalization and the societal reaction without succumbing to linear determinism, where the actors would be just passive observers whose focus on the cannabis and other drug use appears only as a reaction to the "social and economic crisis", war and transition, as it has been interpreted in some

Croatian contemporary drug research [2, 27, 28]. The increase in cannabis use among young people in the early 1990s was recorded in post-industrial societies, and existed in Croatia before it. Therefore, the effects of war and transition to the cannabis use do not appear as a completely unambiguous or consistent (from the variability of accessibility which can drastically vary at different periods of transition, to the types of legal and illegal drugs, increased use of which was mediated by the horrors of war), and do not form the base for users' disoriented focusing to the drug use. Drug use shapes in its diversity, mostly through questioning accents in the societal reaction with respect to its actual effects – the accumulation of knowledge and the multiplicity of users' options takes place in the ambient of more or less certain, but actual "sweat" and it can sometimes produce similar or identical marginalization outcomes, regardless of whether it is the first or the hundredth smoked joint in one's life.

The mediation of societal reaction in drug use manifests itself in a way that approaches the Croatian context in terms of internal heterogeneity with regard to the fact one can talk about the diversity of supply, patterns of use, its visibility, but also of the refusal or sanctions and moral concerns in terms of interest not only from region to region or depending on the degree of urbanization, but also among the major urban centres. Most of the concepts developed in the theoretical approaches – from focusing on subculture and generating of moral panic to cultural accommodations of the forbidden – will prove adequate in varying degrees in different parts of Croatia. Somewhere it would be impossible to buy joint rolling papers as basic equipment for smoking marijuana, or the drug would just be brought around occasionally, and such circumstances would be unimaginable elsewhere. In some cities, at the level of micromedia, there would be developed acquaintance with elementary and impartial facts about cannabis with the help of school teachers, and at other places one would witness activities to mobilize the local population focused on "purifying" the neighbourhood of drug addicts, with the online campaign to testify not only the IT education of the interested parties, but also the total disqualifications of the shyest mention of the need for differentiation of illegal drugs. However, in the third location for "indefinite time" there would be "comics reading club" working as a kind of Croatian version of Amsterdam's coffee-shop. At the same time, in different locations. But the question is in what extent such diversity can be seen as a pronounced specificity of Croatian socio-cultural context, and in what extent as something that essentially refers to its universalizing characteristics with regard to significant internal differentiation that can be seen elsewhere, where perhaps would be enough to state that – in terms of enhanced continuity of tolerant policies towards the cannabis use – the example of Amsterdam is often stereotypically taken as typical of the whole context of the Netherlands.

While the dynamics of the socio-cultural context at the macro level refers to the opportunity to speak about differentiated and gradual normalization in terms of subtractive societal response, with appreciation of the fluctuations and occasional upheavals in its shaping and recreativity as the dominant feature, at the micro-level the context shapes through the group. It remains a necessary and pervasive element in the immediate context of use - allowing us to simultaneously apply and question nearly all of the concepts and models developed in socio-theoretical approaches. This means that we will be able to inspect the usefulness of escapist elements in Cloward's and Ohlin's [12] model of withdrawal subculture, but also embrace their indications of the importance of the reference group. Alternatively, the part of drug users from different parts of Croatia, using their own experience, could convince us of the existence of certain stages in Becker's concept of marijuana smokers' career [5], recognizing the "labelling drama" as close, while some others would also show that the whole world of drug use, from its beginnings at the individual level to continuous smoking, has developed in its diversity in Croatia. Similarly, today, the group as a predominant feature of the immediate

context of drug use stands as the only entity in understanding of meaning and use and rebuttal of stereotypes associated with cannabis in the context of a wider society – it is the stimulus, the impulse to smoke it for pleasure, or for smoking as a catalyst in companionship, and, finally, as something casual. At the same time, the group is an occasional shelter, i. e. almost the only mediator in the forming of drug use that might just wave its hand responding to the warning messages and moralizing of societal reaction, and perhaps seek for some sort of alternative socio-pharmacology and question adverse effects of cannabis use in its own terms. In its own organization today, such a group leaves plenty of room for the actor/user as an individual, as well as for the recognition and acceptance of non-users. It can be defined as a subculture, as a subcommunity or as an affective affiliation – of peers, adolescents, or some other members. Groups as a kind of focal points in organizing of various symbolic structures, along with the intertwining of people, meanings and contents, have resulted in a certain way by extending the concept of subculture in social theory. Research contributions that have enabled overcoming focus exclusively on withdrawal and isolation in relation to the wider society, symbolic accept of values of the dominant culture or class defining of symbolic rejection, today are the heritage of several decades of theoretical sociology of subculture. The need for similar progress is implicitly marked in literature that has a basic interest in the drug use as a subject. Smoking marijuana and hashish is present in different fragments of the youth culture, even when it follows to some extent the formation of various more or less complex micro-worlds. In those in which the affection to smoking will be expressed more, the complex world of interactions, symbols, identities and beliefs that revolve around the use of cannabis would be formed. In so far as the subculture term which expresses the general characteristics of cannabis use in Croatia, with indications of the extent of the elementary and intergenerational establishing, they will be somewhat questioned, but at any attempt of ethnographic or similar insight into the formation and the possible existence of "grain tribe" – also confirmed.

CONCLUSIONS

Croatian society has changed in relation to the society of 1970s or early 1980s, when cannabis and other illicit drugs appeared in it [25, 29, 30]. Throughout this period, and even today, it shows a pronounced fear of unknown forms psychoactivity, whether mediated by drug use or not. In the case of drugs it's primary principle relating to psychoactivity is based on the principle of legality. Croatian society is not extraordinary in this at all. Different societies and cultures express aversion to substances that are new, unfamiliar, and their use may allow the questioning of the prevailing patterns of reality and, perhaps, the values that the dominant social groups present as an integrative framework of society and culture, most often in their existing forms: from rejection of alcohol in countries where Islam is the dominant religion, to a range of psychoactive substances that European colonists attributed to "lower" and "primitive" forms of human existence and attempted to eradicate them along with cultures and peoples that used those substances or integrated them in social and cultural terms [31, 32]. In a similar way, along with the warnings of non-motivating syndrome as a result of smoking cannabis, one could recall Young's indications [3] which show that the dominant culture of industrial society refuses hedonistic and expressive drug use that symbolically structures the inspecting the productivity ethos by developing alternate realities. Despite everything, the alternative forms of reality have not disappeared: in some areas they were an integral part of resistance to the culture of invaders, and have almost everywhere survived on the margins of society, often being labelled as dangerous in efforts for the purpose of reintegration of the wider society and culture on the lines of detachment toward deviance, crime and obvious discriminative labelling of the whole racial and ethnic groups, usually minority groups. It was perhaps also a key form of controlling the unknown and various forms of psychoactivity, until 1950s. When questioning of the predominant existence

forms in 1960s appeared from within, or in the very centre of a developed industrial society, in the form of youthful massive and radical rejection of the culture of industrial capitalism, it was mediated by the use of various psychoactive substances. It was rather shocking in its appearance, and "dangerous" in its visions of a new world and therefore continually criminalized, parallel with putting new substances beyond the possibilities of legal use, and it was just that much widely recognized as a challenge and a new space in the world, the consumption-oriented industrial capitalism. From that point on, a complex interplay of rejection and absorption has taken place. Drugs continued to be presented purely in terms of rejection, harm, damage, danger, disease, etc., i.e. the topics by which societal reactions have often tried to patch holes in the dominant culture and to restore the society on the lines of long forms of domination, from those based on age and gender, to those fundamental in the system of capitalist production, emphasizing the youth as highly sensitive and weak, but important link in maintaining its own continuity. At the same time, the illegal drugs as once more and sometimes less present, but certainly a lasting element in youth culture, were indirectly integrated into the new, growing and propulsive parts of the capitalist economy, finding their place, more implicitly and in the form of the intriguing association within rock culture industry, and later within the rave culture and the entertainment industry in general. Psychoactivity will be built into the budgets of usability, if it can not be accepted any more. In other words, in the actual conditions the drugs will become a dynamic element of the cultural logic of late capitalism in which "drug economy" continues to be illegal, but its commercial cultural support will be legitimate and profitable [33, 34]. As it appears that the society ultimately may not be so interested in a particular difficult problems which drug use can result in, as commonly spoken, so it can be discerned that even the original culture is not entirely immune to psychoactivity if it can sustain it within its own endurable framework and patterns. So, shifts of perception and experience are no longer reserved for the interpretation of the use of stroboscope and lasers in night clubs, or in the context of rave culture labelled as "drug use", but they are installed along with all associated technology into the conventional notion of the average football matches or the opening of the Olympic Games, where the magic and psychedelic moments will be the basis of the event organization itself.

During 1990s and 2000s, the social theory draws attention to the ambiguity of "social preoccupation with drugs" and is using certain terms, such as "normalization" and "persistence of drug use" to comprehend the main features of the certain illegal drugs recreational use in the socio-cultural contexts of highly modernized societies. Cannabis will be often pronounced as the paradigmatic example. This allows us to notice that most of the contents in recent studies dealing with cannabis in the past decade concerns the possibilities of formal social control of its use, with emphasis on the structuring of norms which would allow the cannabis use not to be punished no longer. The decriminalization and non-penalisation of drug use, as the actual issues that deserve proper attention also in Croatia, depending on the understanding of the concepts themselves, will be the inevitable question in the social policy towards the use of cannabis in forthcoming years. A socio-cultural context of its use in Croatia, along with all of the pertinent specifics in the social and cultural dynamics, the difficulties mediated by the war and the transition, as well as the manifestation of use and societal responses, will warn of the existence of substantial universalizing marks – especially those that the actors of drug use and the actors of societal responses share with associated actors in numerous countries in the world.

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SOCIOKULTURNI KONTEKST UPOTREBE DROGA S OSVRTOM NA UPOTREBU KANABISA U HRVATSKOJ

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SAŽETAK

Sociokulturni kontekst upotrebe droga ovdje se razmatra kao konstitutivni čimbenik u interpretaciji njihova učinka i pripadajućeg značenja na makro i mikro socijetalnoj razini sociološke analize. U prvom dijelu razmotreni su važniji socijalno teorijski pristupi koji upotrebi droga pristupaju u terminima sociologije devijantnosti i subkultura. U drugom dijelu, razmatra se sociokulturni kontekst upotrebe kanabisa u Hrvatskoj i mogućnosti propitivanja osnovnih termina navedenih u teorijskom dijelu rada. U zaključnom dijelu naznačuje se mogućnost kritičke refleksije pojedinih teorija s obzirom na specifičnosti hrvatskog sociokulturnog konteksta, kao i potreba za prevladavanjem fokusa na ratu, tranziciji i poraću prisutnih u pojedinim hrvatskim društvenim istraživanjima upotrebe droga.

KLJUČNE RIJEČI

sociokulturni kontekst, upotreba droga, kanabis, subkulture

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EXPLORATION OF THE FUTURE – A KEY TO SUSTAINABLE DEVELOPMENT

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ABSTRACT

Throughout the history people were fascinated and curious about the future. The future was, and still is seen as a key for prosperous development in all aspects of the society. As such, new discipline is developed – future studies.

This paper discusses the discipline of future studies and its role in the society and science. Future studies are analyzed in the context of sustainable development. It is argued that future studies and sustainable development are complementary in nature. Based on analysis of most developed countries in the world, that spend the greatest portion of their budget on research, development and science in comparison to the rest of the world, there is a conclusive link between investments in research, development and science, and the recognition of the importance of thinking about the future. Those countries started to formalize their future orientation in many respected research centres and universities through their educational programs and research. That situation poses the need for other, less well off countries, to follow up.

KEY WORDS

future studies, strategic foresight, sustainable development, economic growth, universities

CLASSIFICATION

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INTRODUCTION

Rapid production of new knowledge and, consequently, high innovation rate that results in new technologies fundamentally changes the way we live. The impression is that most societies are surprised by these changes. In other words, we were not prepared for yesterday's future that caught us today. Countries that are more conscious about the future better cope with change and make easier transition to the new circumstances in the global socio economic environment which results, among other things in their superior economic position.

FUTURE STUDIES

People were always interested in the future and accordingly they tried to plan their activities in all aspects of life and society. There are myriad examples of prediction efforts thorough the history; from ancient Egypt to present times. Through prediction, people tried to diminish uncertainty and to prepare themselves for the coming times. Although the main concern of the art of prediction is the future, it cannot be used as a synonym for future studies. Prediction comes from the word to predict which is defined as an act "to declare or indicate in advance ... foretell on a basis of observation, experience, or scientific reason" [1]. Therefore, the word prediction refers to "a statement that says what you think will happen; the act of making such a statement" [2]. Therefore, prediction is concerned with upcoming events not necessarily explaining the context or other consequences that would lead to other upcoming events. Prediction is focused, often missing holistic view. In other words, prediction is concerned with future facts not the meaning or the context because it is "path dependent: it matters how we got there" [3; p.13]. In other words, prediction relies primarily on our past experiences (history). Things that are not seen as path dependent are often regarded as illusionary, as science fiction, as a figment of imagination, not based on reality and our previous experiences. So, that is the point where future studies come in.

Future studies can generally be defined as "an empirical and scientifically based approach to understanding the future" [4; p.109]. They are concerned with investigation of possible futures – what can actually happen, probable futures – which are most likely to happen, and preferable futures – what should happen [5]. Future studies are often taken as a synonym for technology assessment, as analysis of past, present and future technologies represent standard approach to future research [6; p.8]. Most of people under the term technology consider only an object or a tool for a specific purpose and that clearly is not the subject of the future studies research. One of the main concerns of future studies is technology but not as "a system of machines with certain functions; but rather as an expression of a social world" [7; p.47]. Basically, main aim of the futurologists is to improve human well being and the whole world, often making future world scenarios self fulfilling prophecies.

First futurologists were science fiction writers. The beginning of futurology many authors trace back to 1901 when H.G. Wells published his book *Anticipations of the Reactions of Mechanical and Scientific Progress upon Human Life and Thought* [8; p.185, 9; p.552], in which he made predictions for the next 100 years where some of them proved to be accurate [10, 11]. There are many other notable fiction and nonfiction writers that largely contributed to development of future studies in the last century, such as: Arthur C. Clarke with his book *Profiles of the Future: An Inquiry into the Limits of the Possible* where he made predictions about the future with a firm grounding in the laws of science, of which some already became true (i.e. global TV and radio & cellular phones) [12], Alvin Tofler with his work *The Future Shock* where he predicts environmental change and points out major challenges which will individuals and societies face in the future [13], Carl Sagan with his work *The Dragons of*

Eden: Speculations on the Evolution of Human Intelligence where he speculates about artificial and extraterrestrial intelligence based on human evolution [14] and Ray Kurzwiel with his book *The Age of Spiritual Machines: When Computers Exceed human Intelligence* where he foresees that artificial intelligence will surpass human intelligence by the year 2020 and anticipates amalgamation of human and artificial intelligence [15]. Apart from nonfictional work mentioned above, it is also important to mention Isaac Asimov's novel *Foundation* written in 1951, where he envisioned the rise of psychohistory which he has defined "...to be that branch of mathematics which deals with the reactions of human conglomerates to fixed social and economic stimuli..." [16; p.16], or in other words, psychohistory deals with development of future scenarios of actions of large human groups (populations) which can be referred to as one of the first definitions of future studies.

First institution that systematically approached future issues (mainly related to military) is RAND Corporation that was established in 1945 [17]. Today, they are intensively working on exploration of future beyond military issues in their Frederick S. Pardee Center for Longer Range Global Policy and the Future Human Condition [18]. In 1966, in Washington DC, a group of individuals founded a World Future Society [19], that is publishing bimonthly journal *The Futurist* and peer-reviewed journal *World Future Review*. In 1974, University of Houston initiated first masters program in Future studies in the world that is still operational today [20]. Today, there are a total of 22 future studies (or strategic foresight) programs as a major programs of study in different countries [21] promising to establish future studies as widely accepted and recognized scientific discipline.

SUSTAINABLE DEVELOPMENT

Sustainable development represents an answer to the problems posed by traditional development that is focused exclusively on economic growth while the changes in other parts of society are just a consequence. Today, the term sustainable development is closely linked with the term sustainability that refers primarily to ecological issues (relationship between biological organisms and their environment) while in its roots, as Baker argues, "the chief focus of sustainable development is on society". She further explains that sustainable development is refers to coordination of societal change between social, economic and ecological aspects of society that represent three pillars of sustainable development [22; p.7]. The whole concept of sustainable development is future oriented as the United Nations definition of the concept states: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [23]. Or, as Baker states, sustainable development is about visioning alternative futures and embracing one that is sustainable [22; p.8]. In other words, sustainable development deals with development of different sets of future scenarios and putting all the efforts to realize the most preferable one. To make sustainable development concept (or a style of life) widely accepted people need a common understanding of the future, the good and the bad version of it. The path to understanding is through visualisation of abstract concepts and their communication not just to scientific community, but to the entire society.

OVERVIEW OF MOST DEVELOPED COUNTRIES IN THE WORLD

Most developed countries in the world are predominately knowledge oriented with largely diversified economies, where high percentage of their gross domestic product (GDP) goes to research and development activities in both private and public sectors. According to World Bank data [24] (Table 1) country with the highest gross national income (GNI) per capita[1] is Qatar whose success is contributed mainly by their natural (oil and gas) reserves which account for more than 85 % of their exports, and for more than 50 % of GDP [24]. That data

Table 1. Top 25 countries per GNI per capita in 2011.

Rank	Country	GNI per capita, $
1.	Qatar	86 440,00
2.	Luxembourg	64 260,00
3.	Norway	61 460,00
4.	Singapore	59 380,00
5.	Switzerland	52 570,00
6.	Hong Kong SAR, China	52 350,00
7.	United States	48 820,00
8.	United Arab Emirates	47 890,00
9.	Netherlands	43 140,00
10.	Sweden	42 200,00
11.	Austria	42 050,00
12.	Denmark	41 900,00
13.	Germany	40 230,00
14.	Canada	39 660,00
15.	Belgium	39 190,00
16.	Australia	38 110,00
17.	Finland	37 670,00
18.	United Kingdom	36 010,00
19.	France	35 910,00
20.	Japan	35 330,00
21.	Ireland	34 180,00
22.	Italy	32 400,00
23.	Spain	31 400,00
24.	Iceland	31 020,00
25.	Korea, Rep.	30 370,00

is consistent with their research and development (R&D) potential as petroleum refining is considered medium-low technology sector [25]; if we use as an indicator of R&D potential the number of published scientific journal articles, according to World Bank data [26], in year 2009 Qatar published only 64 articles what in comparison to top ranked United States with total of 208 601 articles, is fairly low. Similar is the case of Luxembourg with 137 published articles and United Arab Emirates with 265 published articles respectively. Singapore, as a fairly small country, in year 2009 published 4187 articles what ranks him on high 28th place.

The World Bank data on expenditure for R&D as a percentage of Gross Domestic Product (GDP) slightly changes the picture [27] (14 years average). Neither Qatar nor the United Arab Emirates are among top 25 countries in spending on R&D. As related to other countries, top 25 list is similar to that of GNI per capita (Table 2). Only serious newcomer to the top 25 list is Israel that on average spends more than 4 % of its GDP on R&D (which is consistent with their production of 6304 scientific articles in year 2009).

To elaborate things further, we should look at the Academic Ranking of World Universities (ARWU), or popularly called the Shanghai List that is updated annually since year 2003. Universities are ranked by following indicators: “number of alumni and staff winning Nobel Prizes and Fields Medals, number of highly cited researchers selected by Thomson Scientific, number of articles published in journals of Nature and Science, number of articles indexed in Science Citation Index – Expanded and Social Sciences Citation Index, and per capita

Table 2. 14 years average spending on research and development as a percentage of GDP.

Rank	Country	14 year average R&D spending, % of GDP
1.	Israel	4,08
2.	Sweden	3,65
3.	Finland	3,31
4.	Japan	3,15
5.	Switzerland	2,77
6.	Korea, Rep.	2,63
7.	United States	2,63
8.	Iceland	2,60
9.	Germany	2,47
10.	Denmark	2,41
11.	Austria	2,18
12.	France	2,17
13.	Singapore	2,00
14.	Canada	1,91
15.	Belgium	1,90
16.	Netherlands	1,87
17.	Australia	1,83
18.	United Kingdom	1,78
19.	Norway	1,63
20.	Luxembourg	1,62
21.	Slovenia	1,45
22.	Czech Republic	1,28
23.	Ireland	1,27
24.	New Zealand	1,11
25.	Italy	1,10

performance with respect to the size of an institution“ [28]. List includes top 500 universities around the globe. For the year 2012 first 100 positions are held by universities from 16 countries [29]. The dominant country is United States with total of 53 universities, followed by United Kingdom with 9 universities (Table 3).

Other important thing to mention is that all countries that are represented in the first 100 positions, apart from Russia, are also present in the list of top 25 countries by GNI per capita and 14 years average spending on R&D as a percentage of GDP.

CONSCIOUSNESS ABOUT THE FUTURE – COMMON DENOMINATOR OF MOST DEVELOPED COUNTRIES

Previous section gives an overview of most developed countries together with R&D potential. Vision of the future that is usually formally presented as a strategic plan (or strategy paper) represents major guiding point for R&D efforts. That is recognized in all advanced economies. In example, UK Department for Business, Innovation & Skills states that “... if we are to realise our vision for the UK’s future we need to strengthen our innovative capability and encourage investment in innovation” [30]. The importance of exploration of the future and future orientation for national economies and sustainable development is slowly becoming recognized by universities throughout the world, especially among most

Table 3. Ranking of countries by the number of universities in the first 100 positions on the ARWU for the year 2012.

Rank	Country	Number of universities
1.	United States	53
2.	United Kingdom	9
3.	Australia	5
4.	Canada	4
5.	Switzerland	4
6.	Germany	4
7.	Japan	4
8.	France	3
9.	Israel	3
10.	Sweden	3
11.	Denmark	2
12.	Netherlands	2
13.	Belgium	1
14.	Finland	1
15.	Norway	1
16.	Russia	1

developed countries. Acceleration Studies Foundation, a non profit organization dedicated to promotion of education about the future, comprised a list of graduate programs that offer degrees and courses in future studies (or, as they state, foresight programs) [20]. The list is divided in three parts: list of universities (and programs) that offer primary Master of Science and Doctorate degrees in future studies – a total of 22 universities; list of universities with secondary future studies programs that put a notable emphasis on any of the primary foresight subjects or have on-campus futures research centres which may be used for potential affiliations during graduate study – a total of 83 universities and a list of universities with program potentials but that do not offer a degree study or an option of potential affiliation during graduate study – a total of 13 universities. When analyzed in the context of top 25 GNI per capita ranking, top 25 R&D spending as a percentage of GDP ranking and the top 100 ranking on the ARWU, all countries apart from Norway and Switzerland have some form of university level education in future studies (Table 4) or future studies research centres.

The surprising fact is that only 18, out of top 100 universities in the world offer some kind of education in future studies. But, nevertheless, it is evident that academic community is becoming aware of the importance of future studies; first four universities on the ARWU offer future studies as secondary programs:

- Harvard University has founded Berkman Center for Internet & Society that is dedicated to exploration of cyber space and as such is involved into doctorate degree program in law,
- Stanford University offers MBA study and doctorate degree program that is oriented toward future studies and is supported by the Foresight and Innovation program, by The Center for Internet and Society, and by the Center for Social Innovation,
- Massachusetts Institute of Technology offers a graduate, doctorate program in Science, technology and society at the School of Humanities, Arts, and Social Sciences,
- University of California Berkley offers graduate degree programs at three schools: at the Institute of Transportation Studies, at the Haas School of Business and at the School of Information.

Table 4. Number of universities per country offering some kind of education in future studies.

Country	No. of universities with primary program	No. of universities with secondary program	No. of universities with potential programs
United States	4	39	4
United Kingdom	0	12	2
Australia	1	3	0
Canada	1	3	0
Switzerland	0	0	0
Germany	2	1	0
Japan	0	1	1
France	1	3	1
Israel	0	2	1
Sweden	0	2	0
Denmark	1	0	0
Netherlands	0	2	0
Belgium	0	1	0
Finland	1	0	0
Norway	0	0	0
Russia	0	1	0

CONCLUSIONS

Sustainable development is clearly defined by our perception of the future. To have clear perception of the future, societies need to develop think tanks of future oriented experts that would support R&D efforts towards prosperous future. In that manner, future thinking cannot be reserved only for technology experts. The approach to future thinking is interdisciplinary in its nature. It should include experts from all areas of human work. As such, these experts should work on viable future scenarios that would lead to consensus about what kind of future we want. Although most developed countries are already in early stages of future studies development, sustainable development needs inclusion of all countries because social, economic and ecological problems in today's world represent global issues that need global consensus on common future.

Only the most powerful economies invest in future studies research, therefore this scientific discipline represents an upgrade in research efforts aimed at driving society towards sustainable development based on all three pillars. As above mentioned countries that are leaders in future studies have not only economic, but also human potential means for conducting research of all aspects of the future, it is expected that exactly these countries will become leaders in future development of a true global society. Academic community is becoming aware of the importance of future studies, and therefore, apart from above mentioned countries; it is important that other countries are included in the development of this scientific discipline so that the future scenarios include local differences and preferences aimed at the ultimate goal of fulfilment of global progress and sustainability.

REMARK

[1]GNI is preferred indicator of countries performance because GDP can be misleading. For detailed explanation refer to article *GDP and GNI*, OECD Observer, No. 246-247, December 2004-January 2005, http://bit.ly/WrxZQO, accessed 26 December 2012.

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ISTRAŽIVANJE BUDUĆNOSTI – KLJUČ ODRŽIVOG RAZVOJA

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SAŽETAK

Tijekom povijesti ljudi su iskazivali svoju znatiželju i interes za budućnost. Orijentacija budućnosti se oduvijek smatrala ključem prosperitetnog razvoja svih segmenata suvremenog društva. U tom kontekstu se i razvija nova disciplina – futurologija.

Članak u uvodnom dijelu daje osvrt na futurologiju i njenu ulogu u društvu i znanosti. Futurologija je predstavljena iz perspektive održivog razvoja čime se argumentira kako su futurologija i održivi razvoj komplementarne discipline. Temeljem analize najrazvijenijih država svijeta koje imaju i najvišu stopu izdvajanja iz bruto društvenog proizvoda za istraživanje i razvoj uspostavlja se korelacija između investicija u istraživanje, razvoj i znanost te percepcije važnosti promišljanja o budućnosti na nacionalnoj razini. Najrazvijenije države svijeta počeli su i službeno uvažavati futurologiju kroz osnivanje istraživačkih centara te

pokretanjem niza sveučilišnih programa koji u svojim temeljima sadrže futurologiju. Ovakva situacija nameće potrebu da se i manje razvijene države priključe trendu istraživanja budućnosti.

KLJUČNE RIJEČI

futurologija, strateško predviđanje, održivi razvoj, ekonomski rast, sveučilišta

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WHY DO STUDENTS USE VIRTUAL SOCIAL NETWORKS IN IRAN: A SYSTEM APPROACH

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ABSTRACT

Rise of Social Network Sites, such as Facebook, significantly influences the behaviour of students around the world nowadays. Different studies have been done up till now to investigate different stimuli on using Facebook. In this study, as one of the first attempts to investigate dynamic influencing factors, systems approach is used to consider such factors' effects and their feedback simultaneously. After finding major factors and estimating the behaviours, in order to verify effects of them, an online questionnaire was prepared to gather Iranian Facebook users' attitudes toward these factors. After interpreting answers, we ran a dynamic simulation model and made some discussions about the effects of different factors on the time which users spend in Facebook. The results show that negative impact of filtering causes decrease on time users spend in Facebook. Under current situation, although filtering on internet has its effects on users in Iran, tendency toward using different facilities of Facebook is strong enough to overcome these negative effects.

KEY WORDS

social networks, students, Iran, system dynamics

CLASSIFICATION

JEL: M39, P46

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INTRODUCTION

Social network sites (SNS) are web based services that allow individuals to construct a profile within a bounded system, interacting with a list of other users and passing through their list of connections and those made by the others. The nature of these connections may vary from site to site [1].

Social network sites were started by Sixdegree.com, launched in 1997. Then, Ryze.com was launched in 2001. In 2002, Friendster was launched as a social complement to Ryze. From 2003 onward, many SNSs were launched that caused users pay less attention to them, even projects of Major Corporation like Google's Orkut (Orkut failed to make a sustainable U.S user base). MySpace.com was begun in 2003 and gradually attracted users, especially teenagers. Furthermore, MySpace differentiate itself by regularly adding features based on users demand and allowing users to personalize their pages. A detailed study of SNSs' history and scholarship can be found in [1].

In 2004, an undergraduate student of Harvard University designed Facebook to only support distinct college. In the beginning, a user had to have a harvard.edu email address to join Facebook. By September 2005, Facebook expanded to include high school students, professionals inside corporate network and eventually everyone. At first, unlike other SNSs, Facebook users were unable to make their full profiles public to all users. Possibility for outside users to make different application which allows users to personalize their profiles and perform other tasks was another specific feature of Facebook. Figure1 depicts the growth of Facebook across global regions.

The more users a network attracts, the more influential it would be on different issues like social, political, economic, and other social related issues. It was believed that there is a relationship between growth of Facebook and unemployment as indicated by comscore research in June 2007. Facebook can also be used as a place for transferring knowledge, for example the communication between diabetes in Facebook [2]. Virtual social networks (VSN) like Facebook change the way of noticing people's voice by governors or other administrators. In a study, it was reported that how students used Facebook to influence negotiation process between administrations of university and faculty when faculties were on strike [3].

A complex system is the system that we cannot simply find out its behavior by looking through the system. According to characteristics for a complex system, continuing changes, interactions, nonlinear relations, feedbacks, history dependency, self-organizing, adaptivity, which are mentioned in Business Dynamics [4], and different aspects of Facebook were mentioned above, it can be perceived that using VSNs is a complex system. So, to perform any kind of analysis, a tool which has the ability to overcome this complexity is needed.

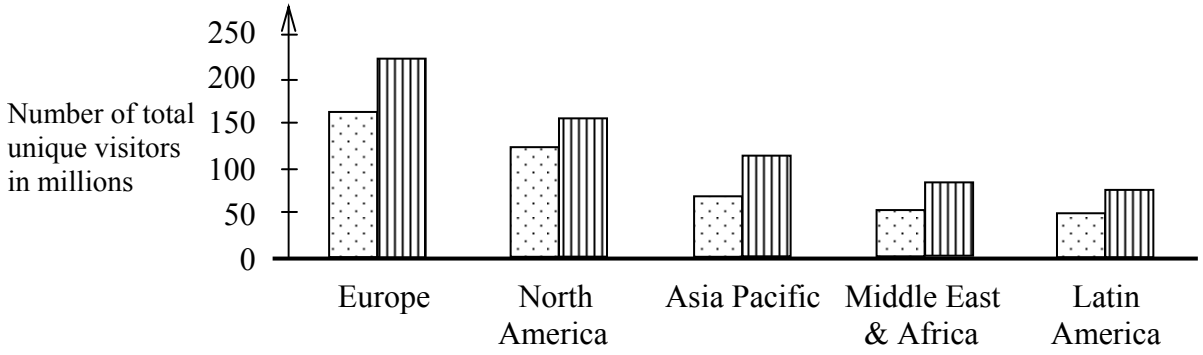

Figure 1. Growth of Facebook across global regions. Data: March 2010 (doted bars) and March 2011 (bars with lines). Adapted from http://www.comscore.com.

System Dynamics (SD) is a tool which gives the ability to do various kinds of analysis through this complexity. System dynamics approach considers all factors in the system's boundary and their effects besides feedbacks simultaneously and shows us the behavior of system by simulation [4]. As the considered problem has a lot of complexities with different kinds of cause and effect relations and feedbacks, it is very suitable to use System Dynamics (SD) approach here. Not only SD was listed as a powerful social simulation tool [5], but also it was applied in different social studies before [6-8].

Different studies have been done up to now about Facebook, generally, all kind of SNSs [9-12]. Most of the students have Facebook account, that's why different studied have been dedicated to using of Facebook among students [10-15]. For instance, the impact of Facebook in the peer relation and the adaption of students with social emotional and behavioral difficulties within school are examined in [16]. The questions like why college students use SNSs, how they use this sites and how this sites influence the development of individuals identity is the subject of a study that is referred in [17]. For the target of this paper, students are selected as a target group for some reasons: 1) basically Facebook was a place for students. Therefore, its characteristics are more fitted to students. Therefore, interpreting of students' behavior in Facebook is more meaningful, 2) they were more accessible than other people for authors because we are in same academic environment, and 3) moreover, in Iran, students were first groups who were attracted by Facebook.

An investigation has been done on Facebook and Orkut in India and Pakistan to show what features of Facebook and Orkut are more important for users [11]. But the discussion of how Facebook and Orkut meet users' needs was not presented. Some researchers studied in their work to find out the possibility that people with certain characteristics were more likely to be Facebook users and to determine whether these characteristics were related to different usage of the site [18]. Some studies explored how personality characteristics influenced the ways in which university students utilized Facebook [9]. They investigated very well in their work the relationship between scores of Big Five and the usage of Facebook, but then again, they did not consider the feedback of using Facebook on these characteristics.

As VSN is a kind of media, gratification theory [19] can be well applied to describe consumer behavior. Gratification Theory (GT) assumed to be one of the "most influential theories in media research" [20]. GT tries to clarify the gratification which consumers are looking for in specific media and their sensitivity for that medium [21]. It explains that how different people can use same media for different purposes [20]. Some researchers in this area argue that, while at first people are attracted to the media accidentally, they will not keep on using the media unless they are provided with explicit benefits.

Unwillingness-to-communicate is defined as a tendency to avoid oral communication and to view the communication situation relatively unrewarding. Considering gratification theory, some authors used it to examine how the unwillingness-to-communication influences gratification obtained from Facebook use [10]. The relationship between unwillingness-to-communication and the behavioral outcome of Facebook use was investigated too, but it was not discussed that people keep on using Facebook only for same primitive reasons or not, they will being gradually changed.

Expectation Disconfirmation Theory (EDT) describes an individual's behavioral process from the initial pre-use expectations of a product to the post-use perceptions of the product. There are proposed research model that investigate the factors influencing user's continuance intention to use Facebook based on EDT and the motivation of using Facebook [22]. They considered the feedbacks correctly by EDT but not simultaneously considering all factors.

Like other countries, Facebook found its way in Iran too. First group of Iranian internet users that walk in to Facebook were students that have the memory of Orkut in their minds[1]. The new innovations, good look environment, professional designing, being international and more importantly birth place of Facebook (that was a university) were primary factors that could encourage Iranian students to welcome Facebook.

The point that is more considered in this study is "what happens to Iranian Facebook users after a while of being a member?" We want to investigate how feedback from Facebook's facilities affect users attitude toward using Facebook. Do users spend the same amount of time in this VSN after being satisfied or not, their courage will be damped? All previous studies only discussed the need of people to use such systems but they did not talk about how they will behavior after a while.

Based on concepts were presented in some previous studies [17, 22], which argue about how student use Facebook and what are the influential parameters, we analyze effects of some factors on the amount of time which Iranian students spend in Facebook daily. In fact we consider the factors that are more influencing on Iranian students that encourage them spend more time in Facebook. Unlike previous works which did not consider effects of feedbacks on users or did not consider these feedbacks simultaneously, we consider this issue in our work through a System Dynamics (SD) simulation model. In other word, our model has the ability to interpret the intra-relation of parameters and their simultaneous effect on the final consumer desire for Facebook. Simulation models give us a useful insight about the system under study by showing us the evolution of system and also we can have some guesses about the behavior of the system in future. Although a previous work [23] applied a dynamic model of using Facebook, it was limited to online games in Facebook. Hence, this paper is the first study of dynamic effects of online social networks, i.e. VSNs, through a system dynamics model that considers most of aspects in using VSNs.

This study is organized as follows. First the research methodology is described and system dynamics approach is explained briefly. Next, a systemic view of the problem is developed through causal loop diagrams which depicts different factors and their effects into the system; moreover, system dynamics model of the problem is presented. Then, results of simulation and discussions are presented. Finally, a conclusion completes the paper.

MATERIALS AND METHODS

First concentration was on finding the factors and their effects in our model. Then the causal relations between these factors are considered. To find the relationships among these variables, we need to use users' attitudes toward their use of Facebook to establish these relations. Hence, we made an online questionnaire and ask students to fill it. Here, System Dynamics is briefly introduced at first and then, the way questionnaire is used.

SYSTEM DYNAMICS

System Dynamics (SD) is an approach which is used to analyze a system's behavior and to overcome the complexities of problems and it was primarily introduced by J. W. Forester in 1960s at Massachusetts Institute of Technology (MIT). The basics of SD are acquired from the area of electric circuits, servo-mechanism theory and feedback control theory. As a result, SD considers the system as a complex of feedback processes. In the book *Industrial Dynamic* [25] it was shown that how modeling of human behaviors together with policies that govern it in a human system could help to make better perception of the system and its behavior in future. It is not so rough to say that SD consists of four main concepts: system, feedback, level, and rate.

Causality and Feedback

The causal relation presents that an element has impact on others. To model these impacts, Causal Loop Diagram has been developed. Every feedbacks of different elements has a polarity either positive (+) or negative (–). For example, if element B move in the same direction of element A when it is affected by A, the polarity of relation from A to B is positive (i.e. $\partial A/\partial B > 0$), while negative polarity means move in the inverse direction.

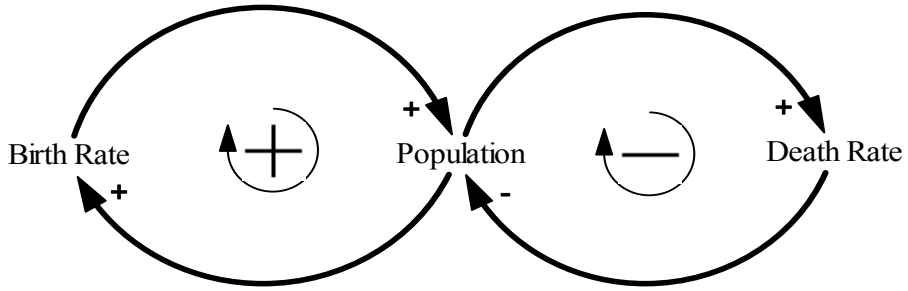

Figure 2. The diagram of causal relationship.

Feedback loops are main reason for complexity in the dynamic behavior of a system. There are two kinds of feedback: Reinforcing (R) and Balancing (B). As it is presented in Figure 2, rising of population would increase the number of birth which in result population would be increased. It is an example of R loops. In contrast, increasing population would raise the number of deaths and consequently the population would be reduced. It is an example of B loops.

Level and Rate

To form a differential equation which is needed to simulate a system, two variables are used: level and rate. Current condition of a system is called level; for instance, the level of an inventory in any time point. Rate measures the change of level during time passage; for instance the rate of production (units per hour) in a factory. Time factor is a distinguishing factor in realizing levels and rates. Net rate (a summation of all positive and negative rates that affect a specific level) is required to calculate the value of level. Stock and Flow Diagram (SFD) is applied to formulate the levels and rates for simulation. SFD formulas, which are infact differential relations, are illustrated as follows:

$$Stock_t = Stock_{t-\mathrm{d}t} + \mathrm{d}t\cdot(\mathrm{Inflow}_{t-\mathrm{d}t} - Outflow_{t-\mathrm{d}t}),.$$

$$\frac{\mathrm{d}(Stock_t)}{\mathrm{d}t} = Inflow_t - Outflow_t .$$

where $Stock_t$ is value of stock in time t. Every CLD has a corresponding SFD. For example, Figure 3 shows the SFD concerning CLD in Figure2.

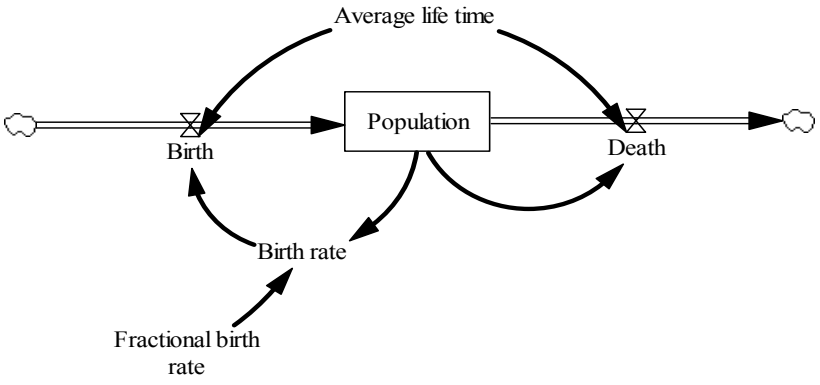

Figure 3. Stock-flow diagram.

In this example, “Population” is assumed to be a stock, while “Birth” and “Death” are both rates. One additional variable is used here “Fractional birth rate”. It is an expectation of birth rate per person and is dimensionless. So, the value of “Birthrate” would be “Population” multiplied by “Fractional birth rate”. Since the process is not happening in one moment and at least it takes average lifetime of people in “Population” to add their children to “Population”, “Birth” can be the value of “Birthrate” divided by average lifetime of people in “Population”. The same is true about “Death”. While the birth directly increases the population, indirectly increases the deaths and causes decrease in population and subsequently it decrease the birth. Hence, it is evident that a nonlinear relation exists and the system’s variables cannot be determined by linear equations [4].

DATA GATHERING

A total of 44 Iranian students participated in the study. We asked students of different majors (Engineering, Management, Economy, ...) from different universities in Iran to fill a five-point Likert questionnaire. The link of questionnaire was shared in Facebook so every student could fill it. Most of them were in the age between 22 and 26. From total number of filled questionnaire, only 40 numbers of them were usable. Average age of participants was 24,02. Participant answers the questions that reflect their views about:

- how much time in average they spend daily in Facebook
- how they divide this time to different aspects (reading news, having fun, talking to friends …)
- how much does Facebook influence their habits in real life
- how much negative factors (i.e. filtering, inefficient internet, etc) affect the users

Finally, the answers are normalized between 0 and 1 (very low to very high) and the final parameters are determined based on average answers to the related questions.

It should be noted that the questionnaire is not used to build the model’s structure, rather it is used to estimate the required parameters of the simulation model in order to produce more real behavior by the simulation of the model. Hence, the few numbers of filled questionnaires does not affect the model seriously.

CAUSAL LOOP DIAGRAMS (CLDs) OF MAJOR FACTORS IN USING FACEBOOK

Here, the factors and their effects that we considered in our model are introduced. Four of them are incentives for Facebook users that keep them using Facebook and one of them has negative effect and it is kind of barrier in front of Iranian users. For each factor we draw the causal loop that shows their effects. The first four factors that are listed below are based on previous studies with a few changes:

- Information Seeking
- Fun and aimless activities
- Lectern to present yourself (writing Status, establishing a special interest groups, comment on others’ beliefs…)
- Keep Offline Contact (finding old friends)
- Filtering and Deficiency of internet in Iran

INFORMATION SEEKING

Many of Facebook users replaced reading newspapers and watching news on TV, by reading news in Facebook. Thus, it can be a good incentive that keeps them online in Facebook, for

the fact that as doing other activity there, you can read the latest news, too.

Before being a member of Facebook, those who would read every day newspaper or watch TV news, has a determined amount of time during the day assigned to stuff like this. This time is represented in our model by "Assigned Time in Life for news reading and information seeking". But after being a member of Facebook, some parameters like, "quality of news pages in Facebook", "Usefulness of what others share in the Facebook", "Presence of Journalists in Facebook", make Facebook so attractive for them to get latest news, this attractiveness is represented by "Facebook Attractiveness in Information Seeking and News". It is obvious that, the more attractiveness, the more time you spend in Facebook for news and information seeking (time for information seeking and news in Facebook) and in result the less "Assigned time in life for news reading and information seeking" cause the more "average amount of time in Facebook".

Now that "Average amount of time in Facebook" is increasing, in a feedback, you would assign a larger part of this time to the "Time for Information Seeking and News in Facebook)". We should mention here that the "Assigned Time in Life for News Reading and Information seeking" means the specific amount of time you read newspaper or watched news in TV before being a member of Facebook. Figure 4 is the CLD that we consider for this factor.

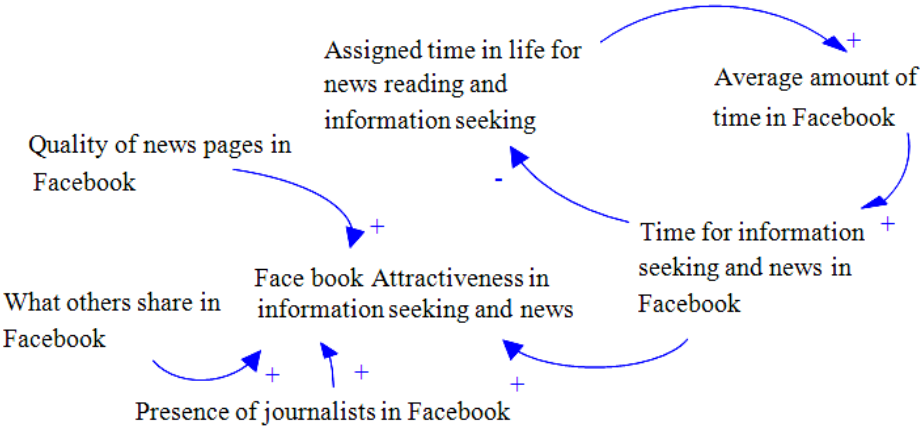

Figure 4. Information seeking causal-loop diagram.

FUN AND AIMLESS

Some users use Facebook aimless and only for fun as it appears the easiest way to spend time and rest. When they come home after a hard day, they sit in front of the computer and start to check friends comment, talk to them, make laugh, play games.

Like the previous loop, stuff like "Quality of chat facility in Facebook", the "Quality of applications in Facebook" and "Excitement of different games in Facebook" are parameters that causes "Facebook Attractiveness for Having Fun". This attractiveness cause you spend more "Time for Having Fun in Facebook" and cut off some amount of time from your leisure time outside the Facebook, "Have Fun and Aimless Activities Outside the Facebook". The result of this cutting and adding is the growth in level of "Average Amount of Time in Facebook". The effect of this growth will be an increase in "Time for Having Fun in Facebook" again, Figure 5.

You can write all of your feelings, beliefs and anything else, share them with others and start discussions about them. of course blogs give you this chance, but, wide spreading beliefs by

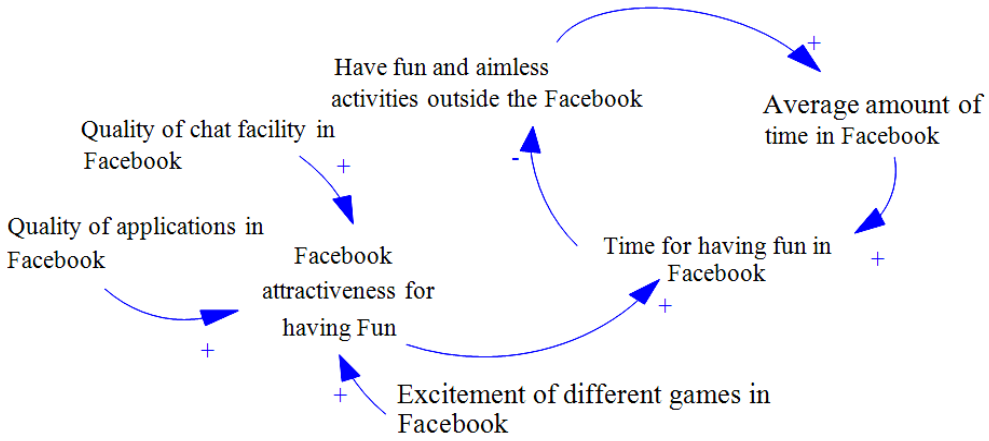

Figure 5. Fun and aimless causal loop diagram.

Facebook is too easy. At the same time that you push "Submit" button to share an idea, all of your friends (and even strangers) can read it in Facebook.

LECTERN

You can write all of your feelings, beliefs and anything else, share them with others and start to discuss about them. of course blogs give you this chance, but, wide spreading beliefs by Facebook is too easy. At the same time that you push "Submit" button to share an idea, all of your friends (and even strangers) can read it in Facebook. The most prominent feature that makes us to give the Lectern attribute to Facebook is its two ways communication. For example, in billboard, newspapers and other similar stuffs, one has the chance to share his/her ideas, but there is no feedbacks or it is very difficult to have feedbacks in Facebook, exactly like lectern, it is very easy for all people to comment on an idea and challenge everything very easily. Moreover, having multimedia capabilities, Facebook is more similar to a lectern relative to billboard, newspaper, etc.

In social interactions, people are naturally inclined to present themselves and gain information about each other [24]. Before Facebook, people use other tool to present themselves to their friends, their colleagues, and to whoever may have some similarities and are interested to same issues, like blogging. But different aspects of stuff like blogging are gathered in one place in Facebook. "Applicability of discussion tools in Facebook" and "frequency of status updating" are sample facilities in Facebook applied for self-presentation. These facilities cause "Facebook Attractiveness of Being a Lectern". This attractiveness makes you replace other thing for self-representation by Facebook. In this way your "Time for presenting yourself in Facebook" increases and "Time for presenting yourself elsewhere" decreases. This increase in "time for presenting yourself in Facebook" will add more time to "average amount of time in Facebook" and as a result again the "time for presenting yourself in Facebook" will increase. This mechanism is represented in Figure 6.

KEEP OFFLINE CONTACT (FINDING OLD FRIENDS)

Though it is not specifically for Iranian, but is a good incentive. All students are very interested to figure out what happen to their college classmates. "Where are they now?" "What are they doing now? And they do this by checking photos, profiles and status regularly. The majority of students want to be together as it is an emotionally factor. For the memories they have during college, for the friendship they make.

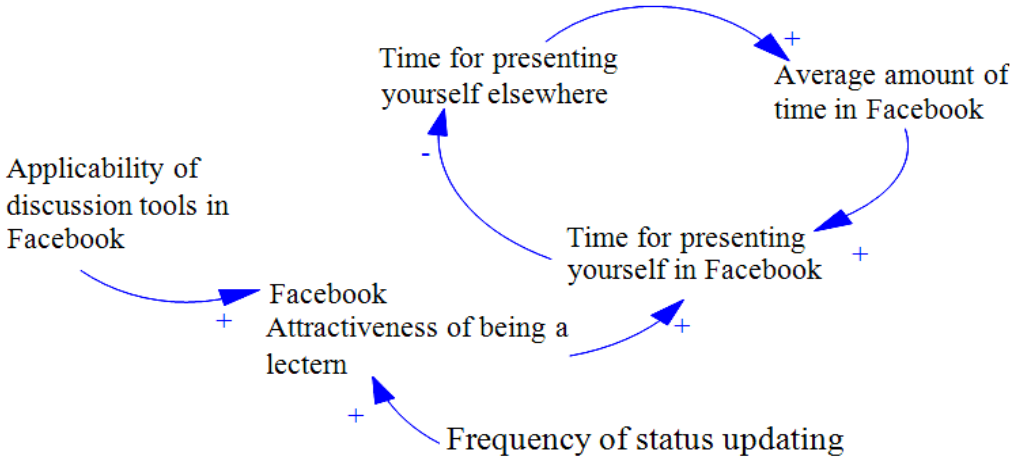

Figure 6. Lectern causal loop diagram.

What do we do when we are with our friends? What do we do when we see an old friend? How do we understand what happened to our old friends? We have special time for things like these. The "Effect of commenting on friends photos and status", the "Effect of making or joining peer groups", the "Effect of sharing photos by yourself" are parameters that make attractiveness toward using Facebook for this target that is represented by "Facebook Attractiveness in Keeping Offline Contacts" in our model. This attractiveness causes you spend more time on Facebook, "Time for Keeping Offline contacts in Facebook", because now you prefer to add more time on "Average amount of time in Facebook and decrease the "time you assign for your offline contacts in real world"; see Figure 7.

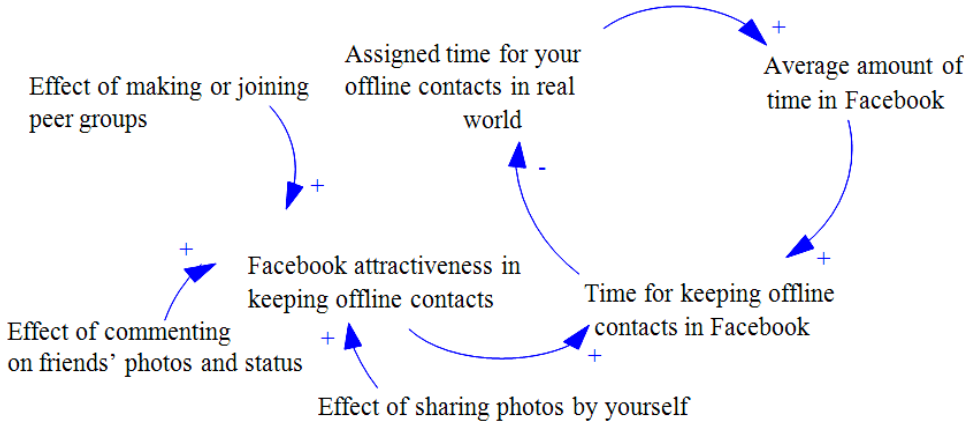

Figure 7. Keep offline contact.

FILTERING AND DEFICIENCY OF THE INTERNET

As we can see in Figure 8, "Effect of Filtering in Iran" and "Effect of Low Speed of Internet in Iran" are two parameters that make negative effects on the "Average Amount of Time in Facebook". It means that we prefer keep our old fashion for the "Time you assign for your offline contact in real world", the "time you assign in your life for reading news and seeming information", "time for present yourself elsewhere", "have fun and aimless activities outside the Facebook".

All of the above mentioned relations are modeled in vensim as it is shown in Figure 8 as a stock-flow diagram.

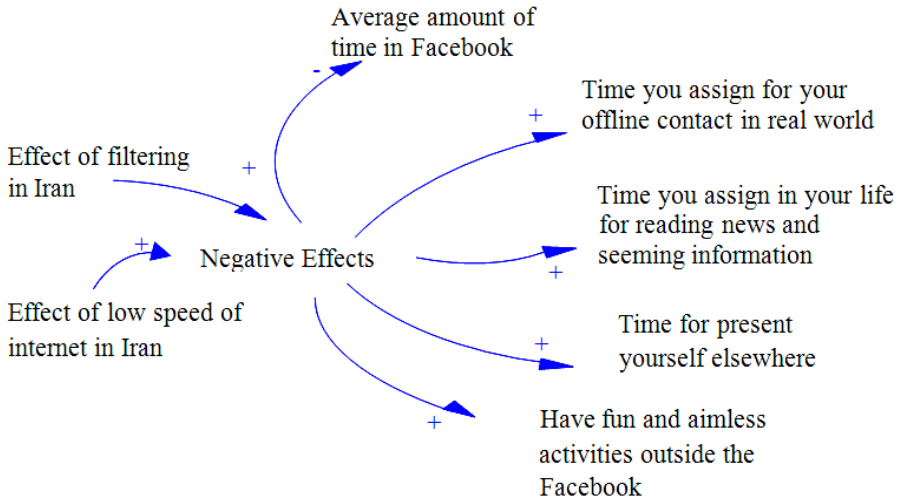

Figure 8. Filtering and deficiency of internet in Iran, causal loop diagram.

SIMULATION RESULTS AND DISCUSSION

We developed our proposed SFD (Stock-Flow Diagram) according to the introduced causal loops and variables. After evaluating questionnaire results; the relationships among variables, units of parameters and variables, were specified and at last the SFD was simulated in Vensim software (Figure 9). Values for parameters are listed in Table 1 (parameters are normalized

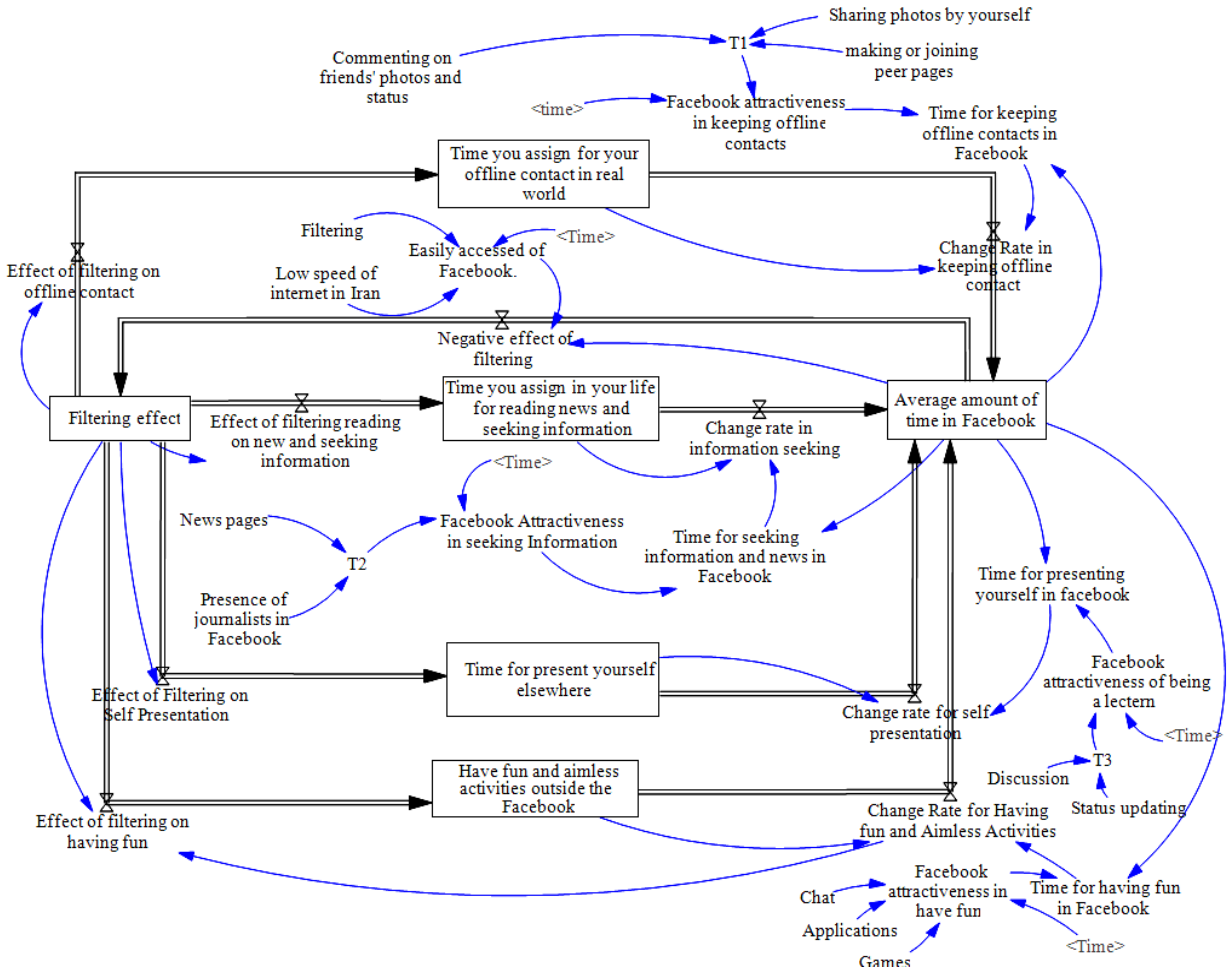

Figure 9. SD model proposed to study dynamics of "Average Amount of Time in Facebook.

Table 1. Values of parameters as obtained from the questionnaire.

Keeping offline contacts		
Commenting on friends' photos and status: 0,3	Sharing photos by yourself: 0,3	Making or joining peer pages: 0,15
Reading news and information seeking		
News pages: 0,3	Presence of journalists in Facebook: 0,2	
Self presentation		
Discussion: 0,15	Status updating: 0,3	
Have fun		
Chat: 0,1	Applications: 0,1	Games: 0,01

between 0 and 1 that is zero means very low and one means very high). The result of questionnaire was interesting ing in two cases: first, students claimed that filtering has less effect on their desire and so does deficient internet, it can be for good internet services (good internet for Iranian internet users is something like 512 Kbps, obviously, it is a very low quality internet speed for many other countries) within universities unlike out of universities or for powerful anti-filtering software that are used; second, the results showed that students are very less interested in using fun tools in Facebook and prefer to use other facilities such as news pages. More attraction is for "Comment" and adaption period is about 30 days. Under these assumptions, we run the model for 300 days (about 1 year).

Let us first consider the effect of filtering and deficient internet in Iran at first and see the behavior of the model. Figure10 shows that in absence of filtering and deficient internet effect "Average amount of time in Facebook", is rising rapidly and after about two months, the rising of halts, which was expected at first, because the desires of users is fulfilled somehow and in return, they do not need to add more time in their daily usage in Facebook. On the other hand, we can see a rapid drop of time users assigned for different stuff in their real life (reading newspaper, talking to friends).

As the parameters are based on users' attitudes and the questionnaire was filled by a sample of students, it is possible that their values change through the time for different reasons. Because different samples of students may give different scores, so to have a suitable analysis, we need to evaluate model for different changes in parameters' values. For this reason, some sensitivity analysis is done on parameters to see what happens to system:

A1: more influenced by filtering and low quality of internet, less interested for using news pages, discussion and status updating,

A2: more influenced by filtering and low internet quality, more interested for using news pages, discussion and status updating,

A3: less influenced by filtering and low quality of the internet, less interested to use news pages, discussion tools, updating photos.

Figure 11 gives an insight about the behavior of model. Both A1 and A2 are influenced by filtering and deficient internet, but A2 is more interested for same facilities that are less interested in A1. So we expect that line A2 locate in upper side of line A1. As it is observed, the behavior of simulated model under this assumption is verifying our expected behavior. It is obvious that line for A1 is under line for A3. Although we have less interest for news pages and discussion in A3, we have less effective filtering too. This means that other facilities of Facebook are accessed easily and for this reason users spend more time; however, in A1, accessibility of other facilities that users keep their interest, is now more difficult, because of more filtering pressure. In comparison of A2 with A3, we see that, at first A2 is upper than A3, because of more interests for facilities, but after a while, being more influenced by filtering in

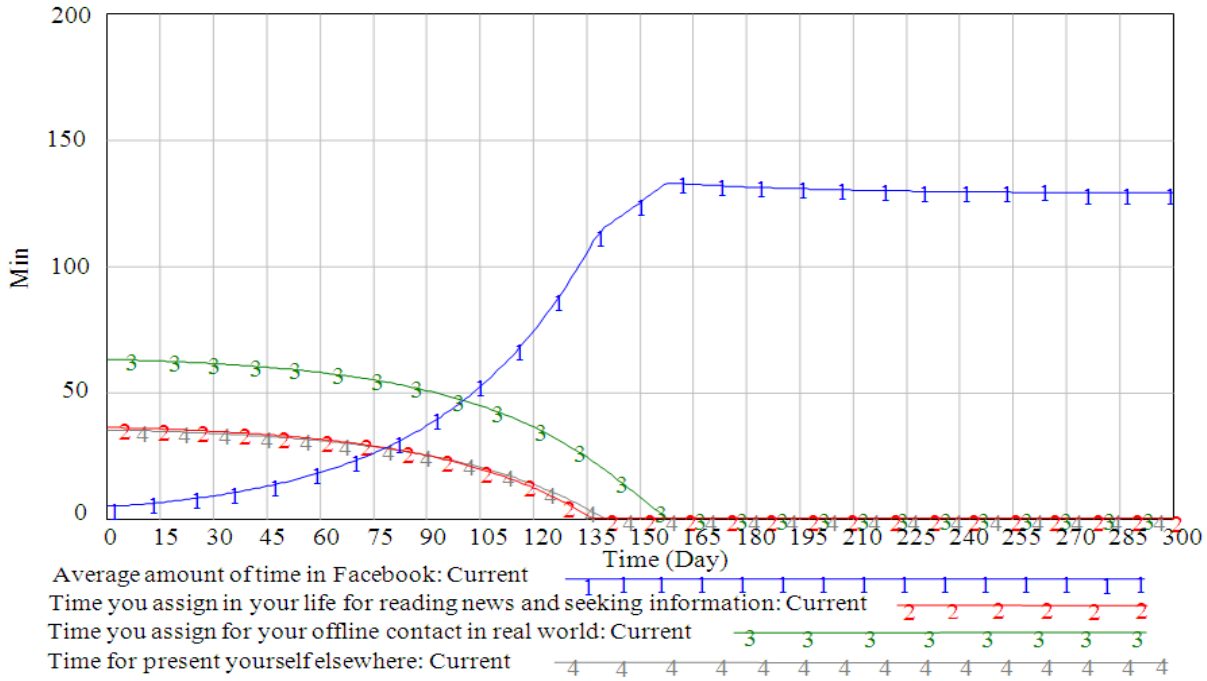

Figure 10. Average amount of time in Facebook (without filtering).

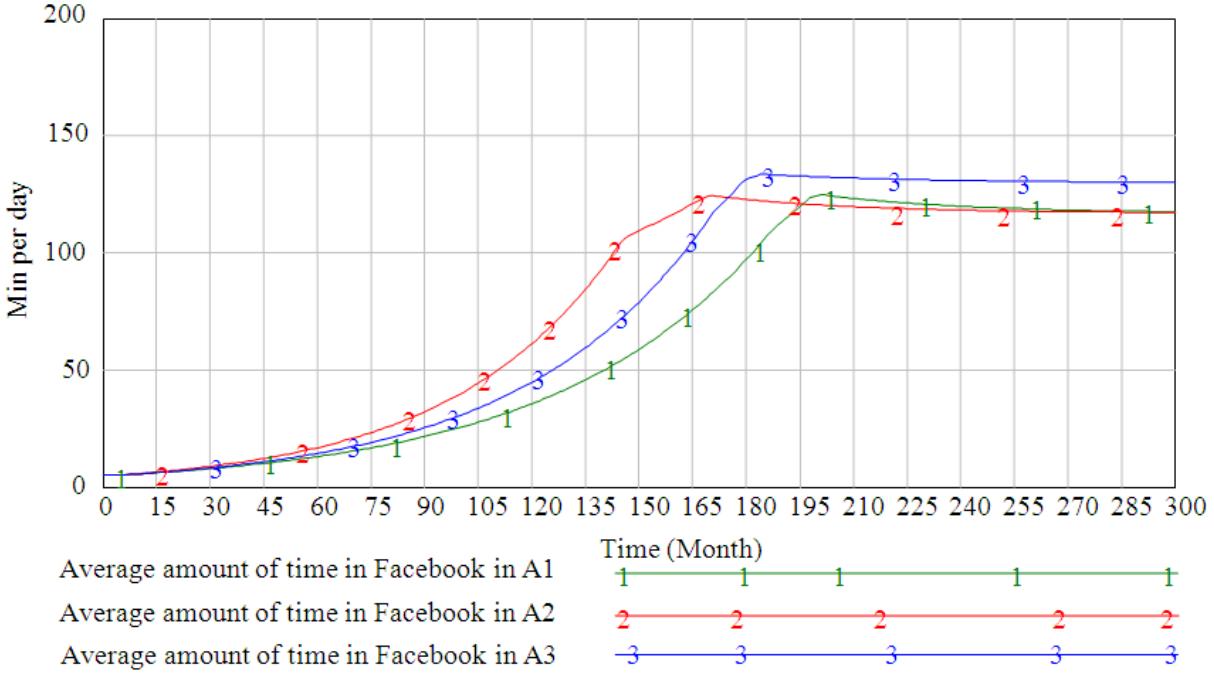

Figure 11. Result of changes in parameters.

A2 shows itself and causes a fall in diagram, but A3 keep on its raise, because the filtering effect is defeated by users' interest, though less interests.

CONCLUSIONS

As one the first attempts to make a system dynamics model of SNSs' dynamics, this study investigated different factors and their different effects in a simulation model that shows the overall behavior of system and variables, simultaneously. After building model's structure based on the related literature, a questionnaire was designed to estimate model's parameters in order that the model produces more real behavior. Simulation of the model makes it

prominent that filtering has its effect even less than other influencing factors, but can be a powerful negative factor. The behavior of system in the case of new improvement of Facebook that is highly dependent to internet speed is considered too and according to model's behavior, users will be more suffered from filtering.

All in all, simulation results are representative of the fact that inappropriate interventions like filtering and inefficient internet speed, are not very successful to prevent users from using Facebook although they can control the rate of participation to Facebook in short-term.

In this study the dynamics of influencing factors on the time that an Iranian student spends in Facebook is investigated; further research could be done on the dynamics of user's population (dynamics of their entrance/exit rate) and effect of other rival social networks (i.e. Google+, Twitter, Orkut, MySpace, etc).

It is worthy to mention that the paper aims just the whole behavior of the system, so the results should be admitted by more precisely callibration of the coefficients based on much more data collected through questionnaires.

ACKNOWLEDGMENT

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REMARK

[1]In fact, there is no official (national or international) statistics of Iranian Facebook users since the website is filtered and users utilize different kind of anti-filters; therefore, their statistics are counted for other countries. Hence, most of information about Iranian Facebook users (i.e. being a student, overall average age, gender, etc) are based on the authors experiences and interactions with users.

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ZAŠTO STUDENTI KORISTE VIRTUALNE DRUŠTVENE MREŽE U IRANU: PRISTUP ZNANOSTI O SUSTAVIMA

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SAŽETAK

Širenje društvenih mreža, poput društvene mreže Facebook, u današnje vrijeme značajno utječe na ponašanje studenata širom svijeta. Različite su studije provedene za istraživanje različitih poticaja korištenja društvene mreže Facebook. U ovom radu, kao jednom od početnih pokušaja za istraživanje dinamike utjecajnih faktora, pristup znanosti o sustavima odabran je za istovremeno razmatranje utjecaja tih faktora i pripadnih povratnih veza. Nakon izdvajanja glavnih faktora i procjene njihovog ponašanja, zbog verifikacije njihovih učinaka, pripremljen je *online* upitnik. Njime su prikupljeni stavovi korisnika društvene mreže Facebook u Iranu o izdvojenim faktorima. Nakon interpretiranja odgovora, numerički je simuliran model te su diskutirani različiti faktori koji utječu na vrijeme što ga korisnici provedu na društvenoj mreži Facebook. Rezultati pokazuju da utjecaj filtriranja smanjuje to vrijeme. Iako u trenutnoj situaciji filtriranje interneta negativno utječe na korisnike u Iranu, uporaba dostupnih opcija na društvenoj mreži Facebook omogućava uklanjanje tih negativnih učinaka.

KLJUČNE RIJEČI

društvene mreže, studenti, Iran, dinamika sustava

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PERCEIVED BARRIERS TO E-COMMERCE: EMPIRICAL EVIDENCE FROM EU COUNTRIES*

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ABSTRACT

Internet usage is growing rapidly among the world. Furthermore, Internet usage is widely accepted among EU countries' citizens. In this paper intend is to research to what extent Internet sales by individuals is influenced by the barriers people perceive to buying/ordering over the Internet, using of Internet, and level of computer/Internet skills them posses. A data source for that research Eurostat database will be used. For investigating the research question the multiple linear regression models will be applied. As dependent variable percentage of individuals who used Internet for buying goods and/or services within last 3 months will be used. As independent variables following will be used: (1) perceived barriers are used for analysis, (2) level of computer skills, (3) level of Internet skills, and (4) level of Internet usage. The percentage of the individuals who bought goods/services over the Internet within last 3 months and factors: giving personal details over the Internet, level of necessary computer usage skills, and lack of necessary computer usage skills have been found to be statistically significant. In this research both hypotheses can be accepted, thus confirming that buying over the Internet in EU countries is influenced both by the level of individuals' skills and the level of perceived barriers.

KEY WORDS

e-commerce, online sale, internet, European Union, regression analysis

CLASSIFICATION

JEL: D83, L81, L86, M15, O33

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INTRODUCTION

The Internet is causing significant changes in the business models in all of the industry sectors and all of the business aspects. Although at the beginning of Internet usage (middle 90s), firms were less likely to implement Internet as a sales channel [1, 2], and customers were less likely to buy goods over the Internet. Within the last decade Internet sales have become widely accepted business model in many fields [3, 4]. Many researches have investigated the barriers to buying over the Internet [5, 6]. The aim of this paper is to research to what extent Internet sales by individuals from EU countries is influenced by the perceived barriers, computer skills, Internet skills and level of Internet usage.

In first part of the paper literature overview will be shown, stating the main research topics on information and communication technology, as well on e-commerce. After that the research methodology will be described. Main part of this paper is the paragraph which describes the research results. And finally, there will be brief discussion and conclusion.

LITERATURE OVERVIEW

Role of information and communication technology in business and society increased every day, especially with development of e-commerce. Continuity of technological changes as well as the constant and fast improvement of the quality of ICT products stimulates further development and diffusion of ICT [7]. ICT adoption will further facilitate service quality, service delivery and cost reduction [8]. Furthermore, information and communication technology (ICT) has had an effect on instructional activities in the teaching process, changed the way students learn and had an impact on school as a physical learning environment [9]. It is indisputable that information and communication technology (ICT) has an enormous effect on contemporary business [10].

Li and Xie developed a framework that incorporates factors determining firms' adoption of e-commerce. In their paper they summarized ten factors which determine firms' adoption of e-commerce. Four significant factors were especially highlighted, including managerial attitudes, corporate strategies, external pressures and firms' technology strengths [11]. Doherty and Ellis-Chadwick study's endings suggest that the scope of the retailers' e-commerce strategies is strongly associated with the strength of management support behind the strategy and its perceived strategic fit. The perceived success of their strategies is most strongly associated with the degree to which the retailer has deployed a portfolio of appropriate resources and capabilities, in support of its online operations [12].

Abbad et al. in their paper try to clarify the status of e-commerce in terms of limitations, problems and barriers facing the application and use of e-commerce in Jordan. They found six main limitations of e-commerce: security and trust; Internet experience; enjoyment; language; legal issues; and technology acceptance (ease of use and usefulness).The results of their research showed that the main limitations of e-commerce in Jordan appeared to be related to non-technical limitations. The reason behind this result could be related to the lack of students' awareness of technical issues, in that they might not have known about the technical issues that could face e-commerce [13].

Ghobakhloo et al. examine the factors within the technology-organization-environment (TOE) framework that affect the decision to adopt electronic commerce (EC) and extent of EC adoption, as well as adoption and non-adoption of different EC applications within small- and medium-sized enterprises (SMEs). They find out that e-commerce adoption within SMEs is affected by perceived relative advantage, perceived compatibility, CEO's innovativeness,

information intensity, buyer/supplier pressure, support from technology vendors, and competition [14]. Technological competence has a positive effect on performance. Firms perceive enhanced performance if they are well equipped in IT, when they have available infrastructure, and when they employ professionals with the necessary knowledge and skills to conduct the activities required [15]. Perceived usefulness related to the online price policies and online product policies, the perceived safety and, therefore, the trust in online commerce sites, seems to correlate with a higher purchase intention than the elements of usability or ease of use in the development of an e-commerce marketing project and web design [16]. Online purchase intention and repeat purchase intention depend on such factors as perceived risk, a risk which in an online context might be due to the purchaser's inability to directly value product quality, the lack of personal contact with sellers, the cost of learning how to use the internet and change of channel, or the absence of any personal interaction with other buyers [17].

Weisberg et al. in their study investigate the relationship between past online purchases and purchasing intentions, representing the social context by the notions of social presence and trust. They find out that past purchasing predicts intentions to purchase and that trust and social presence act as partial mediators [18].

Oh et al. in their paper try to establish the obstacles and the perceived barriers to the continuing use of e-trade technologies by small Korean firms. They found that information risk and business risk negatively affect adoption and use. They also tested the relationship between the environment of the organization and adoption of e-trade. The results show that the maturity of information technology and the innovation characteristics of the firm have positive influences on the adoption of e-trade [19].

On the base of this founding we define expectations related with results of this research: (1) Hypothesis 1: Buying over the Internet is influenced by the level of individuals' skills; (2) Hypothesis 2: Buying over the Internet is influenced by the level of perceived barriers to buying/ordering over the Internet.

METHODOLOGY

Eurostat database is used as a source for information for the research within the chapter of Information-Communication Technology. Data is collected according to the Eurostat model for the Community Survey on ICT usage in households and by individuals 2009 [10]. Multiple linear regression model is used for testing the hypothesis of this work. As dependent variable percentage of individuals who used Internet for buying goods and/or services within last 3 months is used. As independent variables following are used: (1) perceived barriers are used for analysis (No need; Relevant information about goods and services difficult to find on website; Lack the necessary skills; It's too expensive; Too long delivery times; Problematic to receive the ordered goods at home; Worried about giving personal details over the Internet; Worried about giving credit card or personal details over the Internet; Speed of the Internet connection is too low); (2) level of computer skills (Individuals who have used a mouse to launch programs such as an Internet browser or word processor); (3) level of Internet skills (Individuals who have used a search engine to find information), and (4) level of Internet usage (Individuals who used Internet within last 12 months).

RESULTS

Number of On-line shoppers is increasing constantly. The reasons are in the increase of Internet users, the rich offer of wide range of products and services over the high-quality designed web-sites and increasing percentage of females shopping on-line. The habits of

using Internet and related skills were investigated by the calculating descriptive statistics (mean and standard deviation). The same analysis was conducted for perceived barriers to buying/ordering over the Internet and made their last online purchase within last three months. The average percentage of individuals who bought over the Internet over the last 3 months, with basic computer skills, with basic Internet skills, and who used Internet over the last 12 months are presented in Table 1. Table 2. presents average percentage of individuals who perceive barriers for buying/ordering goods over the Internet. The largest perceived barriers to buying/ordering over the Internet are worries about giving personal details over the Internet (22,8 %) and lack of the necessary skills (21,7 %).

Pearson correlation coefficients between buying over the Internet over the last 3 months and other factors examined are presented in Table 3.

As expected, perceived barriers influence percentage of individuals that bought goods/services over the Internet over the last 3 months in negative manner, but only three of the barriers have found to be statistically significant (No need, Lack of the necessary skills, Worried about giving personal details over the Internet).

According to the results of correlation analysis there is a positive correlation between percentage of individuals that bought goods/services over the Internet over the last 3 months and level of computer skills, level of Internet skills and Internet usage over the last 12 months.

In order to explain buying over the Internet by the perceived barriers and level of knowledge (computer and Internet skills), and Internet usage, multiple regression model was designed with the percentage of employees that bought goods over the Internet over the last 3 months as dependent variable. Results are presented in the Table 4. where estimated values for regression parameters are presented with p-values in the parenthesis.

The data fit the model rather well (Adjusted R-Squared = 0,936), what indicates highly representative regression model and two parameter estimates for the perceived barriers to buying/ordering over the Internet (Worried about giving personal details over the Internet,

Table 1. Habits of using internet and related skills.

Habits of Using Internet and Related Skills	Mean	Stand. dev.
Percentage of individuals who bought over the Internet over the last 3 months	25,0	18,4
Percentage of individuals with basic computer skills	64,0	18,4
Percentage of individuals with basic Internet skills	58,0	16,7
Percentage of individuals who used Internet over the last 12 months	64,6	17,2

Source: Authors' research

Table 2. Perceived barriers to buying/ordering over the internet.

Perceived barriers to buying/ordering over the Internet	Mean	Stand. dev.
No need	5,0	3,4
Relevant information about goods and services difficult to find on website	3,2	3,2
Lack the necessary skills	21,7	11,0
It is too expensive	3,9	2,8
Too long delivery times	10,3	6,8
Problematic to receive the ordered goods at home	11,6	7,0
Worried about giving personal details over the Internet	22,8	9,7
Worried about giving credit card or personal details over the Internet	5,6	2,9
Speed of the Internet connection is too low	3,7	3,5

Source: Authors' research

Table 3. Pearson correlation coefficients between variables buying over the internet over the last months months and other factors examined.

Variables	Pearson correlation	Significance (two-tailed)
No need	–0,540**	0,003
Relevant information about goods and services difficult to find on website	–0,121	0,549
Lack the necessary skills	–0,610**	0,000
It is too expensive	0,028	0,887
Too long delivery times	–0,182	0,336
Problematic to receive the ordered goods at home	–0,107	0,574
Worried about giving personal details over the Internet	–0,532**	0,002
Worried about giving credit card or personal details over the Internet	–0,120	0,537
Speed of the Internet connection is too low	–0,223	0,264
Percentage of individuals with basic computer skills	0,865**	0,000
Percentage of individuals with basic Internet skills	0,835**	0,000
Percentage of individuals who used Internet over the last 12 months	0,881**	0,000

**Correlation is significant at the* 0,05 *level* (2-*tailed*)
***Correlation is significant at the* 0,01 *level* (2-*tailed*)
Source: Authors' research

Lack the necessary skills) are statistically significant at 1 % level. Level of computer skills is also found to be statistically significant at 1 % level.

Impact of the perceived barriers that are found to be statistically significant is negative, while the impact of the computer skills is found to be positive. Those results confirm the research of the [5] that stress the influence of the perceived risk and the consumer buying process of Internet airline reservations. Similar conclusions have been found by [3]. Trust is a factor that is significantly more important to adoption of the e-commerce [21].

Table 4. Results of linear regression model.

Variable	Regression coefficients
Constant	2,048
No need	–0,381
Relevant information about goods and services difficult to find on website	0,289
Lack the necessary skills	–0,382**
It is too expensive	0,000
Too long delivery times	–0,485
Problematic to receive the ordered goods at home	0,741
Worried about giving personal details over the Internet	–0,667**
Worried about giving credit card or personal details over the Internet	0,686
Speed of the Internet connection is too low	0,373
Percentage of individuals with basic computer skills	0,092
Percentage of individuals with basic Internet skills	–0,431
Percentage of indivduals who used Internet over the last 12 monhts	1,119**
Adjusted R-square	0,936

**Statistically significant at 1 % level
Source: Authors' research

DISCUSSION AND CONCLUSIONS

The analysis of e-customer behavior is a key issue for the development of e-retailing. Better knowledge about the evolution of consumer behavior allows a better management of the e-customer – firm relationship (e-business). Firms should bear in mind the relevant perceptions of e-customers for each decision [22].

In this paper we investigate individuals who used Internet for buying goods and/or services within last 3 months is used and perceived barriers, computer skills, Internet skills and level of Internet usage. According to the results of correlation analysis there is a positive correlation between percentage of individuals that bought goods/services over the Internet over the last 3 months and level of computer skills, level of Internet skills and Internet usage over the last 12 months.

Government agencies and public bodies of EU countries should encourage all forms of education, especially the development of various computer and Internet skills. Legislation and regulations should allow access to ICT infrastructure at the lowest possible prices to all residents. Furthermore, they should encourage and educate residents how to use all resources that ICT infrastructure provides in order to increase the strength of the Internet as sales channel.

Limitation of the study is limited number of barriers. In future analysis new barriers should be investigated as well different type of c-commerce models and Internet buyers should be taken in analysis. Impact of culture could be one of it. There are complex interactions between project environmental cultural traits leading to different trajectories impacting on ICT implementation [23]. Contextual factors have been largely ignored, therefore little is known about the effects of specific types of ICT under different circumstances [10].

E-commerce is growing rapidly, and number of new buyers on Internet is increasing every day. There is still significant influence of the perceived barriers for the e-commerce, and the level of computer/Internet skills. Multiple linear regression model was used for the analysis and relationships have been found to be statistically significant for the percentage of the individuals who bought goods/services over the Internet within last 3 months: Worried about giving personal details over the Internet, Lack the necessary skills, Level of computer skills. Results show that usage of Internet did not have statistically significant influence, reason for that probably is wide use of Internet. In this research both hypotheses can be accepted, thus confirming that buying over the Internet in EU countries is influenced both by the level of individuals' skills and the level of perceived barriers.

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PREPREKE ELEKTRONIČKE TRGOVINE: EMPIRIJSKI DOKAZ NA ZEMLJAMA EUROPSKE UNIJE

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SAŽETAK

Gledajući svjetsku razinu korištenje Interneta raste razmjerno brzo. Između ostalih, upotreba Interneta raširena je i među građanima Europske unije. U ovom znanstvenom radu istražuje se u kojoj je mjeri prodaja putem Interneta pojedinaca uvjetovana preprekama koje kupci opažaju prilikom kupnje ili naručivanja putem Interneta, prilikom korištenja Interneta i računalnim i internetskim vještinama koje posjeduju. Kao temelj za istraživanje korištena je Eurostat baza podataka. Nadalje, u istraživanju koriste se model višestruke linearne regresije. Kao zavisna varijabla koristi se postotak pojedinaca koji su koristili Internet za kupovinu proizvoda i/ili usluga u posljednja tri mjeseca. Nezavisne varijable su: (1) opažene prepreke (2) računalne vještine, (3) internetske vještine i (4) razina korištenja Interneta. Utvrđeno je da postotak pojedinaca koji su koristili Internet za kupovinu proizvoda i/ili usluga u posljednja tri mjeseca i čimbenici: objava osobnih podataka na Internetu, razina potrebnih računalnih vještina i nedostatak potrebnih računalnih vještina statistički su značajni uz definiranu razinu signifikantnosti. U ovom radu obje hipoteze mogu se prihvatiti potvrđujući da je kupovina putem Interneta u zemljama Europske unije pod utjecajem razine vještina pojedinaca i razine opaženih prepreka elektroničke trgovine.

KLJUČNE RIJEČI

elektronička trgovina, internetska prodaja, internet, Europska unija, regresijska analiza

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CROATIAN TELECOMMUNICATION MARKET: CONCENTRATION TRENDS IN THE PERIOD FROM 2003 TO 2008*

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ABSTRACT

Telecommunication markets are a valuable factor that contributes to the economic growth and development. The development of the telecommunication markets and services was slower in the countries in transition than in developed European countries, altough after the fall of communism countries in transition implemented a big progress in spreading and modernizing of their telecommunication network.

The paper analysis the level of concentration of telecommunication industry in Croatia from 2003 to 2008. The data used in the analysis consider 50 Croatian largest IT firms that are operating on telecommunication market and specific telecommunication sectors: producers of telecommunication equipment, distributers of telecommunication services and implementers of telecommunication solutions. The main two conclusions of this article are: (1) degree of concentration on the telecommunication market in Croatia changed differently in different market shares, (2) degree of concentration on the telecommunication market in Croatia is influenced by different barriers to enter the market.

The analysis finds that Croatian telecommunication industry is in a good position even a few steps ahead of some other transition countries.

KEY WORDS

telecommunication market, concentration, Croatia, transition countries

CLASSIFICATION

JEL: L96, L43

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INTRODUCTION

Telecommunication markets are a valuable factor that contributes to the economic growth [1], especially when there are a great number of competitors [2]. The development of the telecommunication markets and services was slower in the countries in transition than in developed European countries. After the fall of communism, transition countries saw a big progress in spreading and modernizing of their telecommunication network.

Telecommunication markets in transition countries were highly concentrated at the beginning of the 21st century with only one or few telecommunication companies [3]. In most of the central and eastern European countries, there weren't more than two competitors in the telecommunication market at the end of the 20th century. The exceptions were Slovenia and Bulgaria with one operator and Estonia with three operators [1]. At the same time, the process of deregulation started in transition countries, which lead to an increase of private national and multinational companies on the telecommunication markets [4].

The beginning of the 21st century saw many changes. Most of the countries started with the liberalization of the market. United Kingdom liberalized the telecommunication market in 1980s [5]. Liberalization of the telecommunication market led to the competition between telecommunication companies, development and application of new technologies and services, lower prices, that eventually led to the increase of end users [6]. The processes of liberalization, privatization and deregulation led to the significant growth in the telecommunication market [5]. Apart from this, new investors appeared on the markets; market shares changed, and the importance of numerous telecommunication services that did not exist up to then. This confirms a significant dynamics of the telecommunications market that led to the need to analyze the concentration on the telecommunication market in Croatia. At the beginning of the 21st century, Croatian telecommunication market shows a high concentration as well as the lack of efficient regulation of access to essential network resources [7]. There is a monopoly on the market of the fixed telecommunication system, and a duopoly on the market of the mobile telecommunication. Broadband does not appear on the market until 2005. Besides this, legal regulation and administration were another barrier to the new competition. However, from 2003, the situation started changing. A new legal framework was put in place when the new Telecommunication Act was passed and in 2005, a third mobile operator entered the market of mobile services that lead to competition increase [7]. The new companies increased the competition and lower the market share of the existing operator who had a monopoly on the market [5]. This development had a positive influence on the services offered to end users.

The purpose of the paper is to research on the degree of concentration on the telecommunication market in Croatia. The research will enclose the period from 2003 to 2008, applying the method of corresponding concentration measures. The main two objectives of this article are: (1) degree of concentration on the telecommunication market in Croatia changed differently in different market shares, (2) degree of concentration on the telecommunication market in Croatia is influenced by different barriers to enter the market. To prove these goals, correspondent research methods will be used. Correspondent statistical-mathematical measures will be applied to measure the concentration; concentration ratios, Herfindahl-Hirschman (HH) index, Entropy Index, as well as Gini Coefficient and Lorenz Curve.

The paper is organized as follows; at the beginning, there is an introduction part. Section two defines concentration in transition countries. Section three presents data, research methodology and statistical analysis. Discussion part explains our findings and results. Section five concludes the paper.

INDUSTRIAL CONCENTRATION IN TRANSITION COUNTRIES

In the past 15 years, the industrial concentration has been the subject matter of many studies conducted in European transition countries.

Newbery and Kattuman conducted a research [8] on concentration and competition in selected Eastern European countries (Eastern Germany, Czechoslovakia and Poland). Centralized economies of the mentioned countries were characterized by big dominant companies within specific industrial sectors whereas medium-scale and small-scale enterprises had a marginal impact as a group. The collapse of the Soviet Union in 1989 started a process of privatization and restructuring of big companies [9]. The process of restructuring was the outcome of external pressure, in other words, competition, and was supervised by the state. Restructuring often led to discontent among workers who feared to lose their jobs. All the above led to a decrease of concentration and increase of competitiveness in EasternEuropean countries accompanied by the development of distribution of firms according to size corresponding to the free-market economy.

Furthermore, research conducted by Uncovsky [10] brought interesting results. According to the author, there are tendencies in deconcentration connected with the transition to the market economy in Slovakia. High concentration of the Slovak industry is a result of adaptation of the company to the demands of the Czech economy.

It is important to underline the work of Maryanchyk [11] that researched the influence of the concentration of competitiveness on the company profits in Ukraine during the transition period.

There are several other studies on concentration within selected industries in certain countries in transition. Sadowski [12] researched the influence of competitors from Western European countries on the telecommunication market in Poland, Hungary and the Czech Republic. Grandys [13] analyzed the characteristics of the textile industry in Poland. Their research and results discovered the decrease within the industrial concentration. Furthermore, the concentration of the bank sector is the subject matter of the research that underlined the liaison between competition, concentration and efficiency of banks [14, 15].

Gruber analysed differences of telecommunication markets between Central and Eastern Europe and Western Europe [1]. The telecommunication sector developed less in centralized economies, because it was not recognized as productive, hence production sectors were supported and the development of services neglected. This is the reason why the economic significance of the telecommunication sector in central and eastern European countries is a lot lower than in the countries of the Western Europe. In the Czech Republic and Hungary, the share of the telecommunication sector in the overall GDP is a little above 1 %, while in the OECD countries it is significantly above the 2 %. Several negative characteristics influence the telecommunication sector in countries of central and Eastern Europe; prices determined according to political goals, bad connections and long waiting lists for subscriptions, bad service quality, and recurrent connection loss and long waiting time for customer service. The fact that the telecommunication services have a positive influence on the development and growth of economies contributes to further progress of the telecommunication market.

The structure of the mobile telecommunication market differs among the countries of the EU. There are monopolized markets with a handful of subscribers and markets with several operators and a high number of subscribers [6]. The number of countries that open up to new mobile operators on their markets is growing. The number of mobile network operators increased for two reasons. The first reason is the liberalization of mobile and landline telephony that started in the 1980s. The other reason is connected to the privatization of the former incumbent public telecom operators during 1980s and 1990s. There are several

advantages to using and developing the mobile telephony within the overall telecommunication market. That is the reason why the mobile telephony is more and more used as the alternative to the inefficient fixed lines. A conclusion can be drawn that mobile telephony has a significant influence on the development of the telecommunication market as a whole. One of the reasons why telecommunication markets of countries in transition are less developed is the eight-year delay with which these countries started using mobile devices and developing the mobile telephony [1].

The competition that exists for quite some years now has brought the decrease in prices and increase in usage, especially in Luxemburg, Finland and Denmark, and somewhat less in the Czech Republic, Portugal, Austria and Greece. Mobile telephony market in the EU was liberalized until the year 2000; this brought to higher competition [5]. Besides, to further development and progress of the telecommunication sector – digital technologies, more competition and decrease of state monopoly contributed to create the sector of mobile telephony [2]. It is also important to mention that comparing fixed and mobile telecommunication industry, mobile telecommunication can provide competitive telecommunication services and can provide private capital [1].

To enter a highly concentrated telecommunication market is difficult for companies, as it is difficult to keep the first-mover advantages. Even if the companies that entered the market first have more advantages that the other [6]. The advantages that come when companies are first into the market are: ability of one company to acquire scarce assets before other competitors, targeting the most profitable parts of the market, brand loyalty, switching costs and buyer uncertainty. There are different strategies of keeping first position on the market, such as: highlighting product development, product and service quality and technology. There are also some ways for improving their position for companies that enter the highly concentrated telecommunication market [2]. Sometimes they have employed similar actions to their competitors or have totally different strategies such as: price focused strategies, innovation and new products. In their research, Fernandez and Usero [4] suggest that the best strategy for pioneers is differentiation and for followers is price.

It is also important to mention that the market share of incumbents within mobile markets has fallen when the liberalization of telecommunication markets has started. Whalley and Curwen in their research [6] stated that in some countries, the loss of market share for some incumbents within mobile markets has been sharp (Ukraine) and in some other countries have been slow (UK). Some incumbents within mobile markets are trying to regain market share, for example, Telekom Austria in Austria, T-Mobile in Croatia and C&W in Guernsey.

In Croatia, the process of liberalization started a bit later. High concentration can be noticed in the Croatian market only in the first years of the 21st century. In the market of fixed telephony, there was a monopole held by only one company up to then, and on the market of mobile telephony, there was a duopoly and no broadband until 2005. At the beginning of 2005, things change; one new operator comes into the fixed telecommunications market, and one in the mobile market [7]. Looking at the fixed and the mobile telephony a conclusion can be drawn that liberalization of fixed telephony is weak and that the company that held the monopole on the market is still too dominant compared to other operators. There are 10 fixed telephony operators on the market Amis, B.net, H1, HT, Iskon, Metronet, Optima, Primatel, VIPnet, Vodatel. Out of these 10 HT had the most subscribers and the highest profit. The telecommunication market of mobile telephony is characterized by positive liberalization and three operators: T-Mobile, VIPnet, and Tele2. It is important to underline that the growth of mobile telecommunication services draws foreign investments [1], because of faster access,

simpler infrastructure, and fewer barriers to enter the market that ensures the growth of the competition.

Whalley and Curwen (2012) conducted a research on telecommunication operators in European countries in 2010 and had interesting results. One of these results is that the competition is present in 45 out of 49 analysed countries. Four countries with only one mobile operator and where there is no competition are: Greenland, Gibraltar, Andora and Monaco. Within the 45 countries, there is more than one operator, 32 countries have two or more operators, and 14 countries have four or more mobile operators on the market. Germany, a country with a population of 80 million and Lichtenstein with a population of 35 000 have the same number of mobile operators – four. In the markets of Ukraine and UK, there were five mobile operators by the end of 2009, as well as in the Netherlands. Furthermore, they also concluded that mobile markets are highly concentrated, with the two largest mobile operators often controlling between them more than half of the market. On the basis of given results, we can draw a conclusion that next to the incumbent operator within mobile markets, there are mostly two more operators in the transition countries. The exceptions are Poland with all together 6 operators and Rumania with four.

RESEARCH METHODOLOGY AND RESULTS

This section will focus on data selection, research methodology and results. The analysis gives a short overview of the telecommunication market. Data on all the 50 biggest telecommunication companies were used, as well as data on specific sectors; producers of telecommunication equipment distributors, service providers and implementers of telecommunication solutions [6]. Publications on the biggest telecommunication companies on the Croatian market published in the Infotrend magazine in 2003, and 2008 were used as the data source for concentration trends in telecommunication markets.

Table 1 shows values of market concentration for all the 50 biggest telecommunication companies together. Data for specific sectors are also outlined; telecommunication equipment producers, distributors, service providers and solution implementers.

Comparing the given results, similarities can be noticed, and mostly in the same movement of concentration ratios. All the considered sectors, as well as all the 50 biggest telecommunication companies together there is the same direction of concentration change, regardless of which concentration measures are used, with two exceptions; Gini's coefficient moves in the opposite direction compared to the other concentration measures, but with a low intensity of the opposite movement.

LEADER'S MARKET SHARE

According to the data in the Table 1, the share of 50 biggest telecommunication companies as well as other telecommunications service providers decreased in the period from 2003 to 2008. The share of the telecommunications equipment producers increased in 2006 compared to 2005. Further increase is measured in 2007, whereas the market share of telecommunications equipment producers in 2006 and in 2008 is the same. Leader's market share of telecommunication solution's implementers increased in 2005 and in 2007. Relevant differences were not measured in the given period in leaders' market share of telecommunication solution's implementers.

Concentration ratio C2

Value of the concentration ratio C2 is an indicator of the share of the two biggest companies in the telecommunication industry. Value of the concentration ratio C2 is almost the same

within the six-year period for the 50 biggest telecommunication companies. We can mostly see the decrease in value compared to previous years, besides for the 2007 where an increase was measured compared to 2006.

Decrease of value of the concentration ratio C2 can be noticed also for the telecommunication equipment producers, besides in 2006 that measured a growth compared to 2005. In the past three years, a greater value of the concentration ratio C2 can be noticed, above 90 %, which indicates a greater degree of competition, since a smaller number of companies participated in a bigger market share. In 2006, value of the concentration ratio C2 (97,36 %) indicates that two biggest companies have 97,36 % share in the market.

In the six-year period, the value of the concentration ratio C2 for telecommunication equipment distributors had a continuous decrease, besides in 2005 and 2008 where it grew compared to the previous years. The highest value of the concentration ratio C2 (93,24 %) is measured in 2008. This means that the two biggest companies have 93,24 % of market share. There is an increase in the value of the concentration ratio C2 for telecommunication service providers in the first three years and a decrease in the last three.

Telecommunication solution's implementers have the smallest values of the concentration ratio C2. The values of the concentration ratio C2 span from 25 % to 35 %. The growth of value of the concentration ratio C2 above 30% was measured in 2005 and 2007.

Considering that the value of the concentration ratio C2 for all the above companies, mostly spans between 40 % and 99 %, it is obvious that we are dealing with a telecommunications market with one dominant company.

The value of the concentration ratio C2 in the given period of six years for all the above company types shows that the most significant difference was measured for the telecommunication equipment distributors; in 2003 the value of the concentration ratio C2 was 54,84 % compared to 93,24 % in 2008.

Concentration ratio C4

Value of the concentration ratio C4 is the indicator of the share of the biggest four companies in the telecommunication industry. Value of the concentration ratio C4 is almost the same within the given period of six years for the 50 biggest telecommunication companies. We mostly notice a decrease in value compared to the previous years, besides for the years 2006 and 2007 where there was a continuous growth.

The growth in value of the concentration ratio C4 can be noticed for telecommunication equipment producers, besides in 2008 where a minor decrease was measured compared to 2007. In 2007 and 2008 the value of the concentration ratio C4 equalled 100 % which represents a complete monopoly in the telecommunications market. Other values of the concentration ratio C4 is significantly high, which indicates a big degree of competition. It can be concluded that four of the biggest companies in telecommunications equipment producers have 90 % market share throughout the given period.

In the period of six years the value of the concentration ratio C4 for the telecommunication equipment distributors continuously decreased, besides in 2005 and 2008 where growth was measured compared to previous years. The highest value of the concentration ratio C4 (99,32 %) was measured in 2008, which means that the four biggest companies have 99,32 % share in the market.

For telecommunication service providers, growth is measured only in the first year and in all other years the value decreases. Value of the concentration ratio C4 is very high, above 90 %,

which means that throughout the whole period four of the biggest companies had more than 90 % of the telecommunication market.

The lowest value of the concentration ratio C4 is measured in telecommunication solution's implementers. The value of the concentration ratio C4 spans from 45 % and 55 %. The growth above 50 % value of the concentration ratio C4 was measured in 2005 and 2008.

HH index

HH index shows the market share distribution for the 50 biggest telecommunication companies.

The value of the HH index decreases in all the given years besides in 2007 for the mentioned companies. The HH value spans from 1800 and 2500, meaning that we are dealing with a highly concentrated market.

Decrease of the value of the HH index can also be noticed for telecommunication equipment producers, besides in 2006 where a growth is measured compared to 2005. A value above 4000 can be noticed in the HH index in the past three years. This indicated a higher degree of competition.

In the period of six years the value of HH index for the telecommunication equipment distributors continuously decreased besides in 2005 and 2008, where growth was measured compared to previous years. The highest value of HH index (6,195%) was measured in 2008, indicating a highly concentrated market.

For the telecommunication service providers, a decrease can be notices throughout all the given years, besides 2005. The HH index values are, nevertheless, high (2790 - 3873), hence above 1800. This indicates a highly concentrated market.

The lowest values of HH index are measured in telecommunication solution's implementers. These span from 800 to 1100, indicating a low concentrated market. The decrease in the HH index value was also measured in 2006 and 2008, whilst the other years indicated growth.

Comparing the HH index values throughout the given period for all the above company

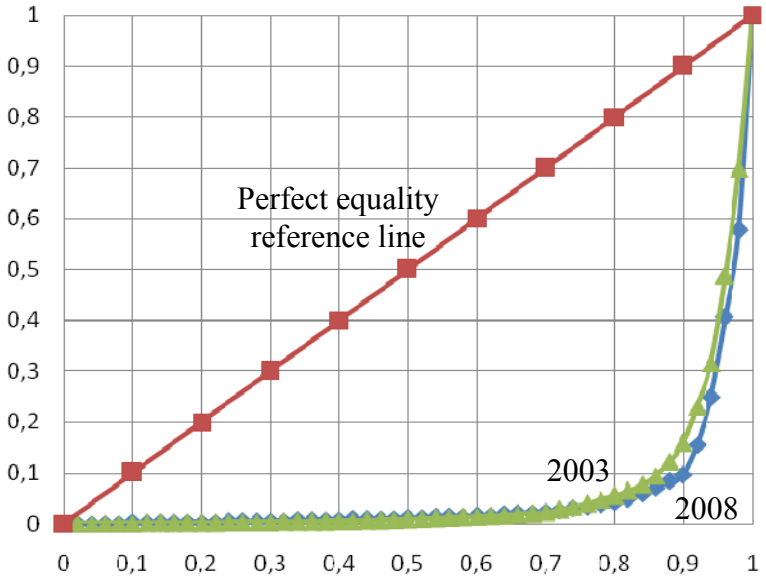

Figure 1. Lorenz curve for 50 biggest telecommunication companies in Croatia in 2003 and 2008 (adapted from [4]).

Table 1. Value of indicators of market concentration in 2003 and 2008.

Indicator of market concentration	Year	50 biggest telecommunication companies, %	Telecommunication equipment producers, %	Telecommunication equipment distributors, %	Telecommunication service providers, %	Telecommunication solutions implementers, %
Leader's market share, %	2003	42,27	53,88	29,90	54,50	14,46
	2004	39,52 ↓	48,11 ↓	25,31 ↓	52,56 ↓	13,58 ↓
	2005	36,08 ↓	42,36 ↓	75,25 ↑	52,90 ↓	17,40 ↑
	2006	33,69 ↓	50,15 ↑	57,84 ↓	44,20 ↓	12,61 ↓
	2007	33,64 ↓	52,60 ↑	48,05 ↓	42,72 ↓	16,89 ↑
	2008	30,15 ↓	50,70 ↓	76,83 ↑	39,05 ↓	15,86 ↓
Concentration ratio C2, %	2003	59,43	88,53	54,84	76,64	25,30
	2004	58,39 ↓	87,82 ↓	45,12 ↓	77,67 ↑	24,83 ↓
	2005	55,95 ↑	78,95 ↓	82,61 ↑	82,03 ↑	33,33 ↑
	2006	53,95 ↓	97,36 ↑	68,88 ↓	70,78 ↓	23,45 ↓
	2007	54,36 ↑	96,82 ↓	63,20 ↓	69,05 ↓	33,30 ↑
	2008	51,15 ↓	93,49 ↓	93,24 ↑	66,25 ↓	28,49 ↓
Concentration ratio C4, %	2003	84,41	98,41	74,94	98,55	46,89
	2004	82,31 ↓	99,20 ↑	71,12 ↓	98,16 ↑	45,11 ↓
	2005	74,63 ↓	99,15 ↑	91,62 ↑	97,62 ↓	56,45 ↑
	2006	79,58 ↑	100,00 ↑	87,48 ↓	94,49 ↓	42,94 ↓
	2007	80,81 ↑	100,00	84,29 ↓	92,46 ↓	55,98 ↑
	2008	76,89 ↓	99,21 ↓	99,32 ↑	92,20 ↓	49,59 ↓
HH index	2003	456	4158	1903	3873	842
	2004	2285 ↓	3976 ↓	1566 ↓	3756 ↓	849 ↑
	2005	1999 ↓	3483 ↓	5775 ↑	3842 ↑	1159 ↑
	2006	1989 ↓	4748 ↑	3688 ↓	3156 ↓	785 ↓
	2007	2014 ↑	4729 ↓	2809 ↓	3027 ↓	1076 ↑
	2008	1801 ↓	4425 ↓	6195 ↑	2790 ↓	999 ↓
Entropy index	2003	0,8084	0,4682	0,8072	0,4993	1,1215
	2004	0,8292 ↑	0,4638 ↑	0,8869 ↑	0,5116 ↑	1,1159 ↓
	2005	0,8842 ↑	0,5015 ↑	0,4491 ↓	0,5149 ↑	1,0760 ↓
	2006	0,8808 ↑	0,3530 ↓	0,6247 ↑	0,6054 ↑	1,1496 ↑
	2007	0,8774 ↑	0,3583 ↓	0,7372 ↑	0,6365 ↑	1,0317 ↓
	2008	0,9139 ↑	0,4069 ↑	0,3223 ↓	0,6579 ↑	1,0524 ↑
Gini coefficient	2003	0,9331	0,7110	0,8403	0,8403	0,2793
	2004	0,8873 ↓	0,6056 ↓	0,5085 ↓	0,8369 ↓	0,2961 ↑
	2005	0,8748 ↑	0,5595 ↓	0,7694 ↑	0,8629 ↑	0,4069 ↑
	2006	0,8731 ↓	0,4835 ↓	0,5044 ↓	0,8358 ↓	0,1515 ↓
	2007	0,8741 ↑	0,4937 ↑	0,6414 ↑	0,8280 ↓	0,3409 ↑
	2008	0,8687 ↓	0,5662 ↑	0,8378 ↑	0,8378 ↑	0,3543 ↓

Source: Infotrend (2004-2009). TOP50 in Croatian telecommunication industry; adapted from [4].

types, we can conclude that the biggest difference in value was measured for telecommunication equipment distributors; in 2003, the HH index value was equal to 1903, whereas in 2008 it was equal to 6195.

Considering data in Table 1 clearly the concentration movement measures by the entropy index and the Gini coefficient mostly follow the movement of the HH index.

Lorenz's curve for the 50 biggest telecommunication companies in Croatia in 2003 and 2008 (Fig. 1) confirms the results regarding high level of concentration in the telecommunication market. However, slow progress is visible to the shift in Lorenz's curve in 2008 from 2003 towards the perfect equality reference line.

DISCUSSION

We have analysed the indicators of telecommunication market in the period from 2003 to 2008. During the examined period, we have investigated the oscillations on the year-to-year basis. However, in order to discuss changes in concentration during the examined period it is necessary to compare the base period (2003) with the final period (2008).

Leader's market share indicated the higher level of control of the leading companies in the telecommunication markets. The highest leader market share in 2003 was that of the telecommunication services' provider (54,50 %), and telecommunication equipment producer (53,88 %). The lowest leader market share is that of the telecommunication solutions' implementers (14,46 %). The highest market share belongs to the telecommunication equipment distributors (76,83 %).

Concentration ratio C2 in 2003 shows a significantly higher figure compared to the leader's market share. The highest value of the concentration ratio C2 was reached by the sector of telecommunication equipment producers in 2003 (88,53 %) and in 2008 (93,49 %). Comparing the data it can be concluded that the highest growth is present in the sector of the telecommunication equipment distributors.

The concentration ratio C4 showed significantly higher figures compared to the leader's market share and concentration ratio C2 in 2003. The highest value of the concentration ratio C2 was reached by the sector of telecommunications equipment producers in 2003 (98,41 %) and in 2008 (99,32 %). It is the same situation as for the concentration ratio C2, the highest growth can be seen in the sector of the telecommunication equipment distributors.

HH index shows higher values in 2008 than in 2003. In the sector of telecommunication equipment distributors, the concentration increases. Concentration decreases in the sector of telecommunication service providers. In the sectors of telecommunication equipment producers and telecommunication solution implementers the HH index measures a slight increase in concentration.

From the data from the Table 1 it can be concluded that the values of the Entropy index, and the Gini coefficient are very similar to the values of the HH index, approximately the same decreases and increases as the values.

CONCLUSIONS

The telecommunication industry is relatively new but have a strong influence on all segments of work and life [4]. At the beginning of the 21st century, telecommunication industry started growing rapidly and competition, innovations and entering of new companies bring positive steps in liberalization and concentration of telecommunication market [6].

The paper analysis the level of concentration of telecommunication industry in Croatia. In this research, the concentration was measured by the leader's market share with concentration ratios C2 and C4, HH index, concentration index and Gini's coefficient. Concentration of all the 50 biggest telecommunication companies was analysed, and the data are gathered from the Infotrend magazine. Telecommunication companies are divided into four groups: telecommunication equipment producers, telecommunication equipment distributors, telecommunication service providers and telecommunication solution's implementers.

The paper sets two goals. The first goal assumes that the concentration degree on the telecommunication market in Croatia changed differently in different shares in the telecommunication market (producers and distributors of the telecommunication equipment, providers of telecommunication services and telecommunication solution's implementers) in the period from 2003 to 2008. Using analysis of concentration indicators the first goal was confirmed, and it was also shown that the concentration varied differently in specific sectors. The other goal assumes that the degree of concentration on the telecommunication market is influenced by barriers to enter the market. Based on the characteristics of individual sectors of the telecommunication market, it can be concluded that the barriers shrank in the observed period in the sector of telecommunication service providers but in the other sectors, there were no changes.

The telecommunication industry was under the strong influence of regulation and at the end of the 1990s private subjects were enabled to enter the market. With the growing number of the telecommunication companies, the market became more and more oligopoly. This will lead towards further deregulation and liberalization of the telecommunication market [4].

Further growth and development of the telecommunication industry will depend on liberalization, privatization and deregulation of the telecommunication market on the global level [5]. The application of brand new technologies and market competition will also have a positive influence on even better services provided to the end users in the telecommunication industry [1]. New and dynamic issues in telecommunication industry will enable new opportunities and challenges for the operators. There has been positive steps on the Croatian telecommunication market, especially for digital network, high standards for universal services and the current situation in the mobile market, comparing with some other eastern and southeastern European countries [4]. It can be concluded that Croatia is on its way to liberalize the market, and that big progress has been made within the telecommunication industry.

Further research should involve some additional variables into the research and newer data. One such variable should be the financial performance of the subjects of telecommunication markets. Data should include variables about some European countries and situation on their telecommunication markets. There is a broad range of issues to be tackled in the future work.

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TELEKOMUNIKACIJSKO TRŽIŠTE U HRVATSKOJ: KONCENTRACIJSKI TRENDOVI OD 2003.-2008. GODINE

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SAŽETAK

Telekomunikacijska tržišta su značajan čimbenik ekonomskog rasta. Dosadašnji razvoj telekomunikacijskih tržišta i usluga bio je sporiji je u zemljama u tranziciji u odnosu na razvijene europske zemlje, iako su nakon promjene društvenog uređenja, zemlje u tranzicij uvidjele prednosti razvoja i modernizacije telekomunikacijske mreže i tržišta.

Članak analizira stupanj koncentracije telekomunikacijske industrije od 2003. do 2008. godine. U analizi su korišteni podaci o 50 najvećih hrvatskih informatičkih kompanija na telekomunikacijskom tržitštu, ali i o specifičnim sektorima telekomunikacijskog tržišta kao što su: proizvođači telekomunikacijske opreme, distributeri telekomunikacijske opreme i implementatori telekomunikacijskih rješenja. Dva glavna zaključka koja proizlaze iz rezultata članka su: (1) stupanj koncentracije unutar telekomunikacijskog sektora u Hrvatskoj se mijenja različito u različitim sektorima telekomunikacijskog tržišta, (2) stupanj koncentracije unutar telekomunikacijskog sektora pod utjecajem je različitih preprekama ulaska na tržište.

KLJUČNE RIJEČI

telekomunikacijsko tržište, koncentracija, Hrvatska, zemlje u tranziciji

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INTERPRETING DEVELOPMENT OF UNMANNED AERIAL VEHICLES USING SYSTEMS THINKING

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ABSTRACT

Rapid present development of unmanned aerial vehicles is rather unstructured. Starting from general systems theory we formulate classification of unmanned aerial vehicles (UAVs) that properly groups diverse produced unmanned aerial vehicles, along with their currently unproduced, yet possible types. First we structure the context of applications of UAVs using systems thinking. Secondly, we divide UAVs according to their function in environment: transfer of mass, energy and information. Thirdly, we further divide UAVs following with exchanges between them and environment which do not perform UAVs main predicted function. Fourthly, we analyse possible types of UAVs and divide them based on the structure of their lift-creating element, on their regulating programmes, and on the type of their power-plant.

We deduce guidelines for researchers and practitioners regarding prospective focuses in the field of unmanned aerial vehicles.

KEY WORDS

unmanned aerial vehicles, UAV, transfer of mass, transfer of energy, transfer of information, system, classification

CLASSIFICATION

JEL: L84, R41
PACS: 88.85.J-, 89.40.Dd

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INTRODUCTION

Unmanned Aerial Vehicle (UAV) is an object capable of flying without carrying a human pilot during flight. We consider that UAVs include Unmanned Aircrafts [1] as well as other flying bodies. Nowadays, UAVs usually form a part of Unmanned Aerial Systems (UAS) [1, 2].

In recent years and, according to predictions, in near perspective, their development is of considerable proportions both in quantity and quality. Their applications cover a broad range of tasks which were previously conducted by aircrafts carrying human pilots, which have been conducted with simpler aerial devices, or which were previously conducted without flying objects. Examples of types of UAVs that we refer to in this article range from semi-autonomous and guided aircrafts or balloons, to guided rockets, to unguided balloons, to unguided rockets and projectiles.

It may come as no surprise that underlying development of UAVs is rather stochastic, occurring independently in many institutions, in many areas of application, accompanied with research and development covering a large number of disciplines.

Attempts to develop classification of UAVs have been undertaken since some time ago. As a rule, these attempts have resulted in the classification based presumably on mass of UAVs [2-7]. Mass serves as a scalar criterion for classification and is certainly an important UAVs parameter. UAV's mass is partially influenced by number of devices and instruments that UAVs carry, by its construction, by type of lift-creating elements and by targeted flight endurance. Furthermore, overall UAV's mass is connected with costs for manipulation and maintenance of UAVs, etc. In that way it is a parameter that aggregates many influences and that is sensitive to changes in all of them.

However, classification based presumably on UAVs mass does not make possible distinction of various functions of UAVs, does not enable one to infer about UAVs further characteristics. Moreover, it does not provides one with a solid basis for analysing influence of a particular UAVs sub-system, or attributed function onto the overall efficiency of UAV and it does not contribute to simplifying conduction of efficiency and other technological analyses of UAVs. To illustrate of these points, Figs 1 and 2 relate two UAVs flight characteristics (flight duration and flight velocity) with their mass (corresponding numerical values are given in the Appendix). Finally, from the system point of view, classification based on mass is unrelated to some general technical principles. Before proceeding, let us note that classification base on mass does not end on it, but further introduces sub-groups of UAVs based on the character of their function: (i) tactical UAVs, (ii) strategic UAVs, (iii) special task UAVs and (iv) other UAVs [2, 7], as well as further sub-sub-groups.

Classification of UAVs that as a starting point takes into account several of UAVs' characteristics would, therefore, contribute to clearer overall view of UAVs research and development, to more efficient isolation of inefficient phases in development, to ranking of different types of UAV applications based on their prospectiveness, and generally to improved understanding of trends and perspectives of development which are most important parts of UAVs for non-technical sectors such as are commercial use, legislation, etc. To state that differently, better adaptation of UAV's production to the context of their use would benefit from the UAV classification which utilises more than one classifying parameter [8, 9].

Second section elaborates structure of UAV-classification scheme. Third section presents the compact graphical representation of the formulated classification. Perspectives for the UAV's development, as inferred from the formulated classification, are given in the fourth, concluding section.

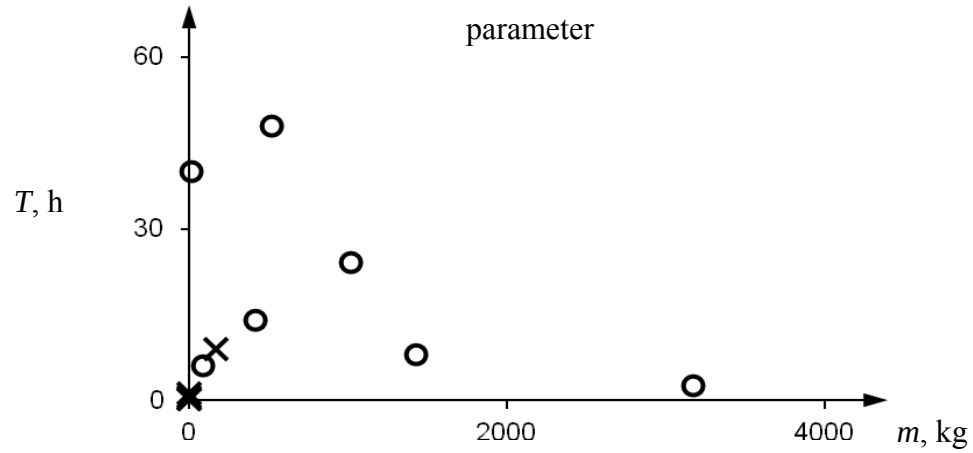

Figure 1. Relation of UAV's flight duration (*T*) to their mass (*m*) for two types of power-plants: crosses denote electric motors as power-plants and circles fossil-fuel engines.

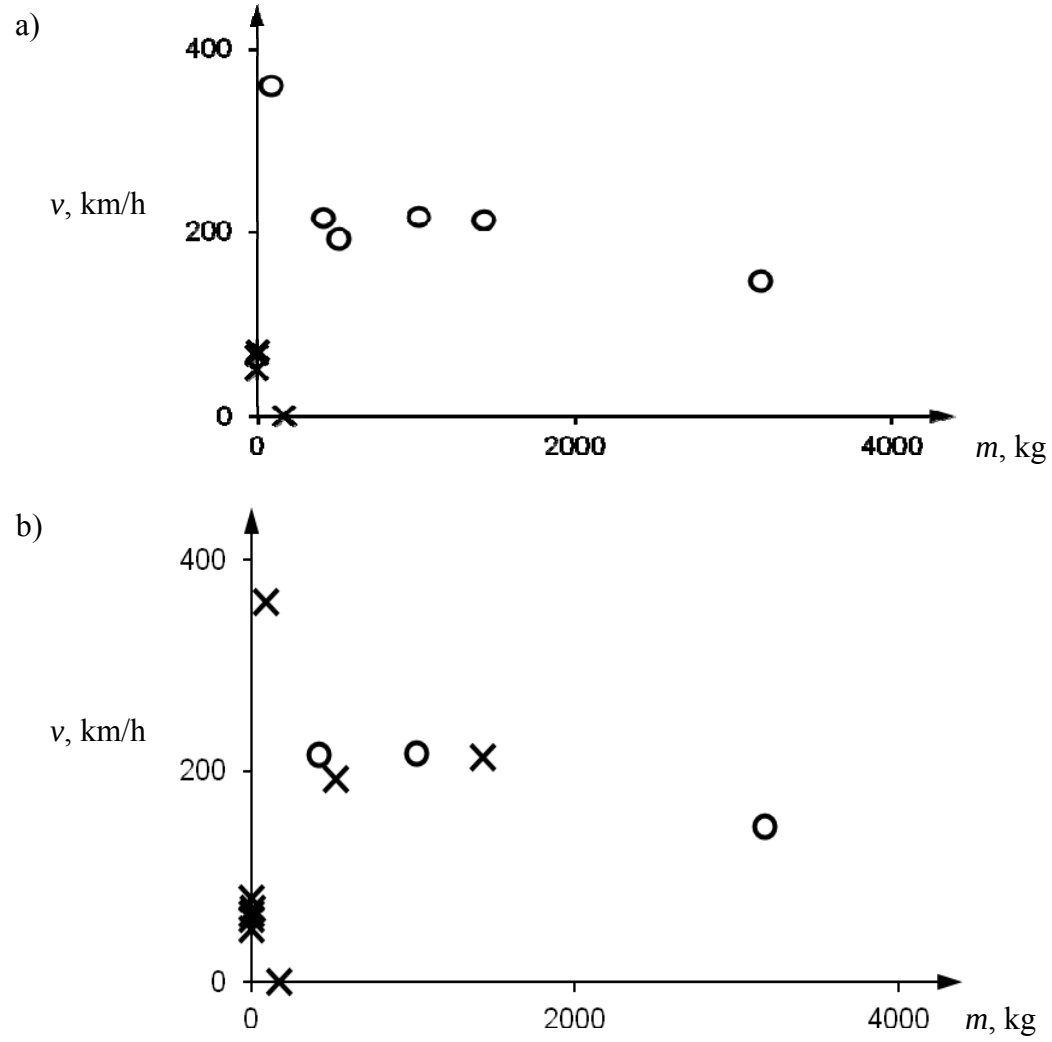

Figure 2. Relation of UAV's maximal velocity relatively to atmosphere during horizontal flight (*v*) and their mass (*m*), a) for two types of power-plants: crosses denote electric motors as power-plants and circles fossil-fuel engines, b) for two types of transfer: crosses denote primary transfer of information and circles primary transfer of mass (described further in the text).

UNMANNED AERIAL VEHICLES CLASSIFICATION BASED ON SYSTEMS-THINKING

CONTEXT OF UNMANNED AERIAL VEHICLES' FUNCTIONING

Starting point of the classification is that any single UAV is a system. That fact may look as a trivial one, or can be misinterpreted having in mind the existing notion of UAS. Despite its appearance, that fact has profound consequences.

For if an UAV is a system, one may argue that it is opportune to apply onto it the systems thinking, or other methodologies from General Systems Theory. In particular, any system is functioning in a given environment with which it has transfers. Transfers are divided into transfer of mass, energy and information [10]. The system has its function in a given environment and we relate fulfilment of that function with realisation of transfers. Such transfers are further in the text denoted as primary transfers. There can be additional transfers of mass, energy and information between system and its environment, which are not closely related to fulfilment of its function. We treat such transfers separately from the transfer related closely to the system's function, and denote them as secondary transfers. To summarise, the primary transfer is conducted via UAV between different parts of UAV's environment, while secondary transfers occur between UAV and its environment. In other words, primary transfer is the one in which the UAV figures as a subsystem of a broader, larger-scale system while secondary transfer is the one in which the UAV is a system in a given environments. Taking explicitly into account the further level, the sub-systems of an UAV, is of interest for aiming to completeness of the classification.

Mentioning of the environment is by no means sufficient, as for a useful classification further dividing the environment is needed. Here we treat environment as consisting of host, target, obstacles and atmosphere, Fig. 3. Host consists of launching facilities, system for tracking and guiding an UAV, as well as of further elements needed to enable the UAV its predicted functioning. Element target is any part of environment onto which an UAV performs a given function. Elements obstacles are any artificial, human-made elements or systems which influences in a negative way capability of UAV's functioning. Finally, element atmosphere is physical space with its weather, including other natural influences onto UAV's performance. Generally, stated elements are mutually different elements. However, in some cases it may happen that one element performs more than one function. Examples are when an UAV collects some data from the atmosphere in case of which target and atmosphere coincide. In many defensive applications target is enemy or hostile location the facilities of which include diverse obstacles to UAV's functioning.

Before proceeding, let us remark that a system consists of elements mutually connected with relations because of what in the case of UAVs we consider the elements to be lift-creating elements, power-plant, energy source and governing algorithm (programme). Relations are again considered as transfers of mass, energy and information, but this time as internal transfers.

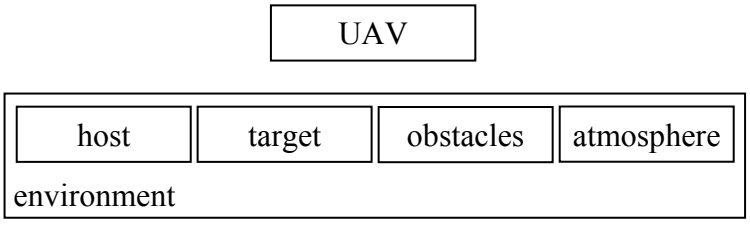

Figure 3. Context of functioning of an UAV.

UNMANNED AERIAL VEHICLES' PRIMARY TRANSFERS

The first criterion for UAV classification is: primary transfer conducted during regular UAV's performance. Possibilities are that primary transfer is transfer of mass, transfer of energy or transfer of information, all between UAV and target. That criterion relates the UAV to their function in environment.

Transfer of mass is realised, e.g. when an UAV carries materials that target needs from host, e.g. medicines, food, construction materials, ammunition, etc. Along with the other defensive applications, transfer of mass includes carrying of explosive ordnances which are predicted to destroy a target, but without simultaneous destroying the UAV. Mentioned examples cover net input of mass from host to target. Examples of transfer of mass with net input of mass from target to host cover possible collecting of materials for diverse purpose such as research, etc. The aerial applications cover collecting the air samples during flight. In all applications insofar listed, all elements from Fig. 2 are separate elements. Other cases are also possible. For example, let us assume a possible situation that first a host sends and UAV with food and medicine to target, and secondly that UAV returns to host carrying further objects, and some mass in general. Then that second action is not a net transfer of mass from target to host but again a transfer of mass from host to target with the peculiarity that control facilities of a host are identical as target. Overall, transfer of mass here means a single transfer, to be contrasted with multiple transfers of a mass which in fact falls into other types of transfer. A particular example of use of UAVs as aerial bombs, the use that was prevalent in early development of UAVs, falls into primary transfer of mass in which host, target and obstacle coincide.

Transfer of energy includes both directions of net input of energy: from host to target and the other way around. There is no prescribed type of energy transferred so in general it can be chemical, mechanical, heat energy, etc., with single, double of multiple types of energy transferred during one application. Projectiles and bombs are examples of UAVs that transfer energy from host to target. Possible application in which UAV carries tools and conducts some work at the target falls in this category. Corresponding examples include drilling rocks at high altitudes, limbing or cutting trees, etc. The other type of transfer of energy includes collecting the energy from atmosphere. So, UAVs with solar panels, either with fixed-wings of significant span, or balloons and airships, fall in this category. Additional applications of this kind are UAVs that collect wind-energy, or use energy of thermals. In such applications the atmosphere is the target. Collected energy is transferred to ground host. Let us remark that to this category does not belong the case of an UAV that utilises the collected energy for its own endurance. Such a case refers to details of energy source as an UAV's element, and not to its primary transfer.

Transfer of information is the prevalent primary transfer of diverse UAV's applications. It includes collecting of information from target for defence, scientific and other purposes. That is the net input of information from target to host. Depending on the application, the secondary transfer of information to the target may need to be suppressed, in applications like are defence applications, eco-system applications, etc. In such applications, along with the predicted information flow from target to host, there can be restrictions for other simultaneously occurring transfers. Since other transfers are covered by secondary transfers, that topic will be covered in the next section.

Use of UAVs for transferring information from host to target includes applications for telecommunication purposes. An UAV may serve as an aerial access point, making possible communication among several locations, in principle of non-determined number. The collection of such locations serve as distributed element figuring simultaneously as host and

target, since their pervading is too intense, during usually rather small time intervals, to make possible separation of the locations into either the hosts or the targets.

SECONDARY TRANSFERS RELATED TO UNMANNED AERIAL VEHICLES

These are transfers that accompany primary transfer, or that occur independently to it. Presumably, to that category belongs the transfer between the UAV and host.

Secondary transfer of mass is rather an exception than a regular case of UAV's use. It is so because the mass restrictions for UAVs are rather stringent, so a lot of efforts in construction phase and during exploitation is involved in order to suppress the unwanted wasting of rather scarce UAV's energy onto transfer of ballast.

Similarly, secondary transfer of energy is rather rare compared to primary transfers of energy. On the one hand, regularly encountered losses of energy (e.g. waste heat and noise) are usually accompanied with the omnidirectional fluxes. Their suppression or channelling is the important task during the UAV's construction. We will not include these transfers explicitly in further considerations, but will consider them implicitly as a separate characteristic of a particular UAV's subsystem, presumably of UAV's power-plant. Another type of secondary energy transfer includes cases in which UAVs collect energy from environment. These cases may be absorbing the solar energy, utilisation of horizontal air streams such as winds or jet streams, or utilisation of vertical air stream as is thermal convections, all for enhancing the UAV's flight endurance. Currently, examples of UAVs which collect total or significant portion of working energy from environment are rather scarce. Along with the fact that R&D in that area will possibly bring about significant achievements in near future, let us note that it is the first step in developing the use of UAV for primary transfer of energy.

Information transfer is the prevalent secondary transfer. For guided UAVs it is constant during their flight. We will cover some possible situations regarding other possibilities of secondary information transfer. For example, in many defence applications an UAV should not be detected by the target, or any other group which does not belong to the host. That imposes restrictions onto the visibility of the UAV, height of its flying during the mission, radar cross section minimisation, etc. On the other hand, an UAV exploited in a defence missions can be of minimal achievable dimensions, if that suits the need for the UAV to penetrate geometrically confined regions such as buildings' interiors. Such UAVs are visibly and auditory detectable, so their perseverance depends on their manoeuvrability. Information transfer can be, in diverse applications, of restricted access to all parties but the host. That imposes additional restrictions. On the one hand these fall into the detectability problem for an UAV, while on the other hand it may happen that the very detectability of an UAV is not a problem, but that intercepting of the transferred information should be restricted. We consider the question of intercepting to be a software problem, not related to primary or secondary transfer of UAV and its sub systems.

UAV SUB-SYSTEMS

As was listed previously, the sub-systems of UAVs that we cover explicitly are lift-creating elements, power-plant, energy source and governing algorithm (programme).

Lift-creating elements are divided, in accordance with the aircrafts with human crew, into static buoyancy elements and dynamic buoyancy elements. Static buoyancy elements are volumes of balloons and airships. In the context of creation of lift, we do not further differentiate balloons from airships, as their difference is caused by guidance and manoeuvrability. Elements of dynamics buoyancy are wings, and we further differentiated UAVs with wings fixed for other parts and UAVs with wings that can move regarding to

other parts. Into the former group falls airplane-like UAVs and in the later the rotorcraft-like UAVs, such as helicopters and quadrotors. In principle, hybrid construction is possible that combines volume for static lift and wings for dynamics lift.

While most of the types of UAVs have power-plant, some types still do not have separate power-plant but their motion is obtained in other ways. Ballistic projectiles use inertia for motion, gliders and launch-and-forget meteorological balloons use dynamic and static lift, respectively, etc. Non-ballistic projectiles exploit rocket motors as a degradable power plant. Its degradation because of use is well adapted to its guidance and overall flying capabilities. Rocket motors are further divided, but that is out of the scope of this classification. Other types of power plant include internal combustion engines, turbo-engines, electric motors, etc. A particular case of sport leisure and toy UAVs, in particular the small flying models, include intermittent, small-power power sources, such as is rubber tape.

Energy source sub-system is important because of the overall importance of energy efficiency. We differentiate autonomously powered UAVs from environmentally supported UAVs. In the former class belong all UAVs that carry their own fuel, whether that be fossil fuel or source of electric energy. Examples of the later case, environmentally supported UAVs, are UAVs that partially or completely obtain energy for flight endurance from the environment, like are previously mentioned solar-powered UAVs, gliders or balloons.

Governing algorithm's characteristics important for this classification are first whether it exists. If it exists, second characteristic is whether it works autonomously during UAVs flight or not.

COMPACT CLASSIFICATION

Previously elaborated aspects of UAVs are grouped as shown in Table 1. Classification is utilised as follows. First letter, a capital one, denotes the UAV's primary transfer. Second and possibly other letters, all small, denote secondary transfers if they exist, with more important additional letter being more to the left in the sequence. Slashes separate sub-system characteristics, in the following order from left to right: lift-creating elements, power-plant, energy source and governing algorithm. Letters after slash denote main characteristics of subsystems. Slashes are written only to the last non-blank notation.

Table 1. Notations for primary and secondary transfers of UAVs.

Transfer	Mass	Energy	Information
Primary	M	E	I
Secondary	m	e	i

Table 2. Notations for UAV's sub-systems.

Sub-system	Lift-creating element	Power-plant	Energy source	Governing algorithm
Notation	F – fixed wings R – rotating wings B – balloon (blank) – none	(blank) – none D – fossil fuel engine E – electric motor O – other types	I – inertia E – electric energy A – environment (atmosphere) K – fossil fuel	A – autonomous flight G – guided flight (blank) – none

To illustrate notation in Tables 1 and 2, a solar-powered controlled balloon serving as aerial access point is denoted as I/B/E/A/G, a ballistic projectile is denoted as M, etc. In particular, more examples of realised UAVs are given in Table 3.

Table 3. Examples of classifying some of the existing UAVs.

UAV	Source	Classification
Wasp block III	http://www.avinc.com	Im/F/E/E/A
GNAT-750	http://www.designation-systems.net/dusrm/app4/gnat.html	Im/F/D/K/G
MQ-1 Predator	http://www.af.mil/information/factsheets/factsheet.asp?fsID=122	MI/F/D/K/G
RQ-4 Global Hawk	http://en.wikipedia.org/wiki/Northrop_Grumman_RQ-4_Global_Hawk	I/F/D/K/G
RQ-7 Shadow	http://olive-drab.com/idphoto/id_photos_uav_rq7.php	I/F/E//A
MQ-8 Fire Scout	http://www.as.northropgrumman.com/index.html	I/R/D//A
Bell Eagle Eye	http://www.naval-technology.com/projects/belleagleeyeuav	I/FR/D/K/G
Draganflyer X8	http://www.draganfly.com/uav-helicopter/draganflyer-x8	I/R/E/E/G
Dassault nEUROn	http://www.dassault-aviation.com/en/aviation/press/press-kits/2012/the-neuron-makes-its-maiden-flight.html?L=1	IM/F/D/K/G
Lehmann Aviation LM450	http://www.lehmannaviation.com	I/F//I/A
FR SWAN X1	http://www.flying-robots.com/en/company/profil-de-mission.html	IM/R/D/K/G
SELEX Galileo Falco	http://selex-es.com/~/media/Files/S/Selex-Galileo/products/air/unmanned-systems/FALCO.pdf	IM/F/D/K/G
Bayraktar Mini UAV	http://www.baykarmakina.com/en/MiniUAV	I/F/E/E/G
MicroPilot MP-Vision UAV Glider	http://www.micropilot.com/products-mp-visione.htm	I/F//I/A
Kaman K-MAX	http://www.kaman.com/aerospace/helicopters	M/R/D/K/G
Parrot AR.Drone	http://ardrone2.parrot.com	I/R/E/E/G

CONCLUSIONS AND PERSPECTIVES

Presented classification aims to group from the functional point of view all possible aspects of UAVs. The classification is based on the systems thinking. That being the case, from the

point of view of perspectives, we can only analyse diversifying the number of existing types (i.e. functions or applications) of UAVs in near future. Based on the search through available literature, we extract the primary energy transfer of the UAVs to be the qualitatively most prospective field of UAVs R&D in the near future.

APPENDIX

Table 4. Numerical values of UAV's characteristics shown in graphs in Figs 1 and 2.

UAV	Maximal velocity*, km/h	Mass, kg	Power-plant power, kW	Flight duration, h
Wasp block III	65	0,43		0,75
GNAT-750	192	520	64	48
MQ-1 Predator	217	1020	86	24
RQ-7 Shadow	204	170	28	9
MQ-8 Fire Scout	213	1430	313	8
Bell Eagle Eye	360	91	478	6
Draganflyer X8	50	2,7		0,3
Lehmann Aviation LM450	80	0,95		0,55
FR SWAN X1		17		40
SELEX Galileo Falco	216	420	48	14
Bayraktar Mini UAV	70	3,5		1,3
MicroPilot MP-Vision UAV Glider	60	2,72		0,9
Kaman K-MAX	148,2	3175	1341	2,7
Parrot AR.Drone		0,42	15	0,2

*relative to the atmosphere during horizontal flight

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INTERPRETACIJA RAZVOJA BESPILOTNIH LETJELICA PRIMJENOM PRISTUPA SUSTAVA

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SAŽETAK

Brzi sadašnji razvoj bespilotnih letjelica vrlo je nestrukturiran. Polazeći od opće teorije sustava postavljamo klasifikaciju bespilotnih letjelica koja pravilno grupira različite proizvedene bespilotne letjelice, kao i one vrste koje trenutno nisu proizvedene ali su moguće. Kao prvo strukturiramo kontekst primjene bespilotnih letjelica primjenjujući pristup sustava. Kao drugo, dijelimo bespilotne letjelice prema njihovoj funkciji u okolini: prijenos mase, energije ili informacije. Kao treće, dodatno dijelimo bespilotne letjelice obzirom na njihove izmjene s okolinom koje ne ulaze u njihove glavne predviđene funkcije. Kao četvrto, analiziramo moguće vrste bespilotnih letjelica i dijelimo ih prema njihovim uzgonskim elementima, regulacijskim programima i vrsti pogona.

Izveli smo nekoliko smjernica za istraživače i korisnike obzirom na perspektivne smjerove razvoja bespilotnih letjelica.

KLJUČNE RIJEČI

bespilotna letjelica, UAV, prijenos mase, prijenos energije, prijenos informacije, sustav, klasifikacija

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ADAPTIVE NOISE REDUCTION SYSTEM

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"*The day will come when man will have to fight noise as inexorably as cholera and plague*." - Robert Koch, 1905.

ABSTRACT

Noise is an all-present environment pollutant, considered to be one of the greatest contemporary pollutants. World-wide, co-ordinated actions are conducted in order to develop systems which minimise the noise influence onto society.

In this article we argue that novel approach to suppression of influence of noise is useful. Furthermore, we argue that the efficient approach is formulation of the efficient, broadly applicable, ubiquituous, adaptive noise-protection system. The approach combines the natural noise-protection form based on plants with the artificially formed coatings.

Elements of the system are discussed, its formation and maintenance analysed and perspectives conjectured.

KEY WORDS

noise, sound damping, adaptation, nanotechnology

CLASSIFICATION

JEL: A55, Q53
PACS: 43.40.+s, 43.50.+y

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INTRODUCTION

Noise is defined as any undesirable sound in the place where people live and work, which causes annoyment or can be even harmfull for health [1]. World Health Organization in its reports refer noise, by water and air, as one of three main pollutant of human enviroment [2]. Thus the statement of the Nobel prize-winning bacteriologist Robert Koch, writen previously, became a reality. Noise manifests complexity of modern world. There is rarely a particular source of noise that can be modified, but prevalently noise is aggregated consequence of a large number of aspects of modern life: machines, vehicles, processes, human themselves, etc. There seems to be a certain level of noise accompanying some technical level of a civilisation, yet stringent efforts should be involved in research and development of noise reduction in order to preserve that level within acceptable limit for humans. In that way, regarding noise, civilisation should achieve sustainable development in which noise is limited within a certain limit.

Noise pollution increases every day. Estimated 20 % of EU population, approximatelly 80 million people, suffers from noise levels that scientists and health experts consider to be unacceptable. Because of that, life conditions of a lot of people has changed, with consequences ranging from e.g. their sleep being disturbed to e.g. permanent health problem of some of them, such as is hear loss. Furthermore, approximatelly 170 million citizens live in so called *grey areas* where the noise levels are such to cause serious annoyance during the daytime. The problem of too intense noise is treated implicitly by the EU Directive 2002/49 which refers to the assessment and management of environmental noise [3]. In particular, that statement addresses the need to monitor the environmental problem (along with drawing "strategic noise maps"), to inform and consult the public about noise exposure and its effects, to address the local noise issues by requiring competent authorities to draw up action plans to reduce noise where necessary and maintain environmental noise quality where it is good, and finally to develop the long-term EU strategy [4].

There exists a significant number of types of noise sources. Many times people exposed to these sources are not aware what is a source of observed noise. The prevalent noise sources are traffic noise, working devices and activities conducted.

Since a long-time ago, globally a part of noise protection of workers has been a workplace safety. As a consequence, many countries have their Workplace safety laws and related regulations. The corresponding EU-level regulations are the Control of Noise at Work Regulations from 2005. The aim of the Noise Regulations is to ensure that workers' hearing is protected from excessive noise at their place of work, which could cause them to lose their hearing and/or to suffer from tinnitus (permanent ringing in the ears) [4].

While on the one hand listed regulations and other legislatory measures clearly demonstrate the large efforts that society involves to solve or reduce the problem of too intense noise, on the other hand the problem is stil far from being solved on a satisfactory level. One approach to contributing to the noise-level suppression in urban regions is to enhance the efficiency of noise barriers by approapriate, innovative constructions.

In this article, we combine the two existing sets of noise barriers, the natural and the artificial barriers and treat them as a system with variable amount of artificial character (or, conversely of natural character). We argue that such a system, with variable amount being the adaptive parameter, enables people to reduce existing noise levels in a larger amount than if the sets of noise barriers are not combined in an adaptive manner.

The second section presents facts about the noise and its impact onto humans, third section discusses in some details existing sets of noise barriers along with the description of their adaptive combination. Fourth section presents conclusions and provides the readers with perspectives of the described approach.

THE NOISE AND ITS IMPACT ON THE HUMAN HEALTH

Noise in an internal working space (or, generally for indoor locations) occurs from few basic sources: internal disturbances, external noise and structural noise which is carried out by the infrastructure such as is a building. Consequently, there are three approaches to noise reduction: noise reduction directly at the location of the noise source, noise reduction between the source and the observer and noise reduction directly at the location of the observer.

Let us concentrate onto the indoor protection from external noise. These external noises include noise originating in external space or noise originating in neighbouring rooms and pursued by sound insulation. For efficient sound insulation it is important (i) to decrease sound pressure emited from the sound source, (ii) to decrease surface area connecting two rooms, (iii) to increase absorption in receiving room, and (iv) to increase sound insulation of existing barrier [5]. Further in the text we will focus on the effects of sound insulation onto the noise reduction.

Along with the noise-protetion of working place, it is important to protect people from envirometal noise pollution in their living places. Somewhat poetically, current status of the living place pollution by noise is that *silence does not live in our enviroment anymore*.

Noise exposure has a cumulative effect. Harmful impact of noise is observable after longer time and manifests itself as changes of mood, being tired, insomnia, headaches, concentration loss (e.g. loss of work capability) and eventually as the permanent hearing loss. Quantitatively, longer exposures to noise of 80 dB can bring about the temporary or permanent threshold shift. It is considered that relaxation period of duration of 16 h is necessary to rehabilitate a person who was exposed to noise at 85 dB for 8 hours. At the sound pressure of 140 dB it is possible to lose balance [6]. During verbal communication persons surrounded with noise unconsciously talk louder and longer exposures to noise cause voice disorders.

NOISE BARRIERS

NOISE PROTECTION BY NATURAL STRUCTURES

One of the noise protection ways is the use of plants.

In large urban areas, because of a heavy traffic, noise significantly degrades the quality of living. Transportation capacity and average speed cause visual and auditory pollution in urban areas.

Different barriers are utilised to block or reduce the noise in urban areas. For example, in researches about the noise levels in Ankara [7] the authors concluded that plants reduce the environmental noise, with different types of plants differing in sound insulation characteristics. In particular, *Hedera helix, Rubus fruticosus, Polygonum auberti, Parthenocissus quinquefolia* revealed efficient noise reduction [7]. Furthermore, that study extracted 16 deciduous plant species that can be used as noise curtain for Ankara, as well as 14 coniferous species that can be used both to absorb the noise and to block the wind effect in Ankara. According to the results of the research conducted, with a noise curtaining of three rows, the amount of noise has been reduced by 5 dB, which means that the perception of noise by people was halved [7].

Reducing the environmental noise by plants is more complete if a tree or a bush curtain is closer to the noise source, further to the region to be protected. The reason is that in such cases larger portion of acoustical energy is absorbed and scattered in diverse directions including the directions to the atmosphere.

Plant *Viburnum rhytidophyllum* protects from a noise throughout the year. Its evergreen leaves are wrinkled, with their length ranging from 18 cm to 25 cm. Their shape and dimensions are causes of the capability of that plant to reduce noise. That plant is known as "bush of donkey ears" [2]. Figure 1 sketches the general influence of that and other similar plants onto environmental noise. In Figure 1a, spectrum, a frequency dependence, of noise level is shown. In the absence of a plant it is assumed that noise level spectrum is horizontal line through most of the frequency region, except the high frequency region as it is attenuated even in the air. The lower the value of noise level, correspondingly, the larger the reduction of noise caused by plants. The complex frequency dependence of the plant's influence is related to non-trivial frequency dependence of scattering of acoustical waves on the collection of geometrically highly irregular objects, leaves and branches. Before proceeding, let us note that plant's influence is significant both in the high- and the low-frequency region, the regions in which the least part of the human speech is conducted, and at the same time the regions the sounds within which annoy humans above average. The minimal influence of plants on the noise level, what in Fig. 1a means the local maxima of the noise level, occurrs at frequencies of approximately 1 kHz [8]. Figure 1b sketches the difference in noise level, and correspondingly in the noise level reduction, because of the seasonal variations of some general plant. For constant intensity of noise source, the noise level is lower in summer because of the larger density of vegetation of plants, andthus of the denser collection of scatterers.

While influence of diverse plant species onto noise level mutually differs, general trend of that, natural barrier to noise is as shown in Fig. 1.

NOISE PROTECTION BY COATINGS

Coatings are ony type of artificial noise reduction. Among large variety of ways in which materials in different geometries and different textures reduces the ambient noise, let us use an illustratory case study to discuss in some detail the noise reduction related characteristics of a water-based coatings. In experimental study by Fan et al. [9] it was determined that damping

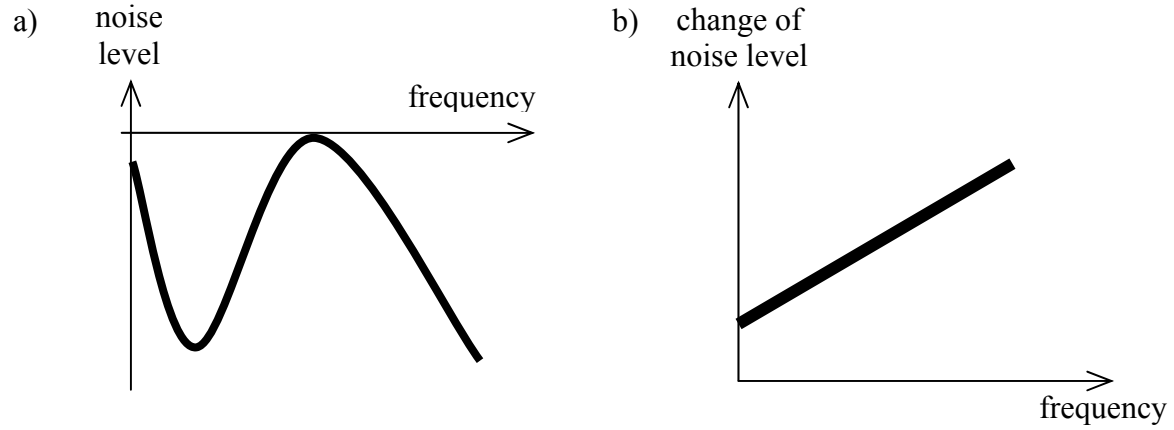


Figure 1. Impact of plants onto enviromental noise: a) noise level spectrum in vicinity of plants. Zero value of the ordinate corresponds to the absence of noise reduction and negative values generaly represents reduced noise, b) difference of noise level in summer and in winter (adapted from [8]).

material with water-based coating decreases the unweighted rms acceleration of the fundament. Since the vibrations causes acoustical disturbance in neighbouring atmosphere, i.e. the noise, their suppression is a significant contribution to noise level reduction by the previously listed approach, noise reduction directly at the location of the noise source. Without coating, that acceleration was typically in the range from 0,08 m/s^2 to 0,79 m/s^2. With the described coating the corresponding range was from 0,06 m/s^2 to 0,49 m/s^2. It was further discovered that vibrations can be reduced in considerably broader frequency bandwith by utilising the bitumen-based damping material than by utilising the butyl rubber damping material. The damping treatment of coated objects can reduce the dominant components of noise spectrum in the frequency region from 25 Hz to 160 Hz.

One may argue that the rapid development of new materials (foams, composites, coatings...) and of nanotechnology (and consequently of nanotechnologically treated) coatings for noise protection brings about the additional potential for further improvement of the acoustically damping coatings and innovative production of new types.

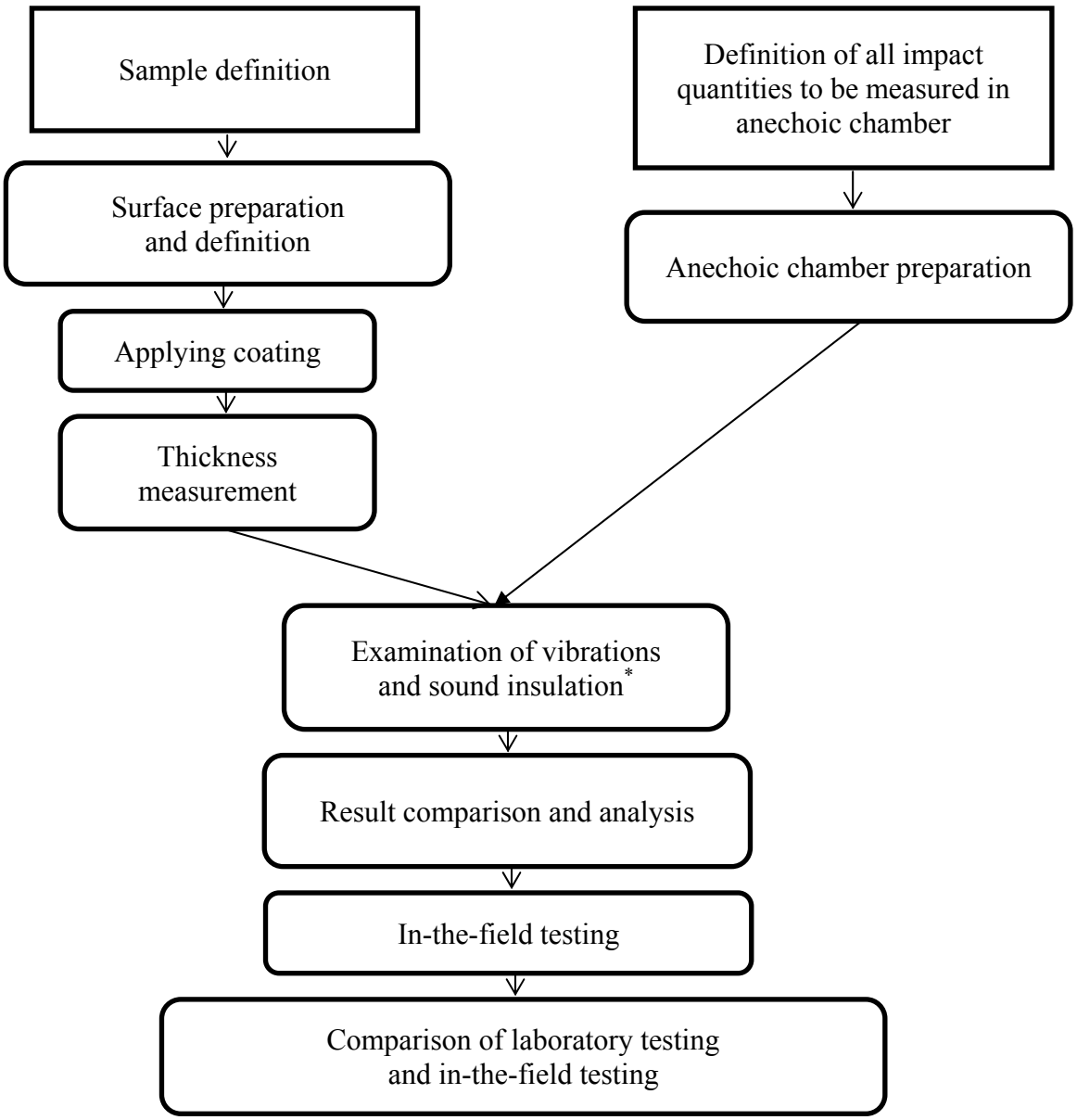
Let us consider in more detail representative exmaples of that development.

Research of Verdejo et al. [10] revealed that acoustic waves can be scattered by interfacial sliding and stick-slip behaviour even in the presence of some covalent bonds. It was also defined that damping effects are attributed to the large surface area at the polymer-carbon nanotube interface. In the experimental study, Rajoria and Jalili [11] found that multi-walled carbon nanotubes present good reinforcement choice for damping enhancement. As a particular result, let us emphasise that up to 700 % enlargening of the damping by epoxy-based coating was observed when weight ratio of multi-walled carbon nanotubes in epoxy was 5,0 %. In their research Ruijgrok et al. [12] studied damping of vibrations in the acoustic region, by the homogeneous water suspension of gold nanospheres (80 nm diameter) and nanorods (25 nm diameter and 60 nm length). Their results indicate that vibrational damping occurs by dissipation of acoustical energy in the liquid and by intrinsic damping of a particle.

In the context of reducing enviromental noise, in particular of the noise emitted by machines such as compressors, vehicle engines etc., it is important to examine vibration and noise damping properties of coatings developed purposefully for listed noise sources. Noise generated by a machine can be reduced by supression of its surface vibrations, covering of wall by acoustically absorbing materials, by shielding (encapsulation) of noise sources, or by a combination of these measures [13]. Generally, examination such as the one presented in Fig. 2 is needed in order to determine the damping characteriscs of a coating.

First, it is important to characterise the sample regarding its shape, dimensions and material characteristics [14]. In accordance with the desired level of noise and vibration damping, the coating material should be determined. Then, the surface preparation takes place, according to sample material and coating to be applied. After surface preparation it is important to define surface by measuring its waviness and roughness in order to make conclusions about properties of e.g. new materials application. The prepared surface are coated with the choosen coating material. Subsequently, thickness of the coating material layer is determined, as it represents a possible factor influencing the coating noise damping characteristics [14]. Prepared sample should be examined in adequately prepared anechoic chamber. In one part of it is the source, in the other the receivers, while the prepared sample is put between them.

Testing of the vibrations and sound insulation in the anechoic chamber is conducted on the samples with coatings as well as on the samples without coating which functions as a referent sample. One expects that in this phase some results are obtaiend that can be utilised in formulating the improvements in coatings, their compositions and textures. In-the-field testing



*measuring surface waviness and roughness

Figure 2. Structure of the testing of the damping characteristics of a coating.

of noise damping system is influenced by many different factors such as is a resonant characteristics of the interior in which the machine is placed. Because of that, in-the-field testing is unavoidable.

ADAPTIVE NOISE PROTECTION

As inferred from Fig 1a, there exists a frequency bandwidth in which the noise reduction by plants is rather small. It is then opportune to purposefully develop coatings which are maximally efficient in vibration reduction in that frequency region. Having in mind that frequency dependence of vibration supression is rather non-trivial, i.e. nonlinear, parameters describing the optimal coating may differ in cases that different frequency bandwidth is used for optimising average noise reduction.

CONCLUSIONS

Noise is a significant contemporary pollutant, in the focus of relevant international and national authorities. Two noise reduction approaches, one based on natural and the other on artificial noise barriers, are discussed, compared, and used as components of novel, adaptive, noise reduction system. The artificial part is realised as nano-level treated materials since they have revealed a significant potential in noise reduction.

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ADAPTIVNI SUSTAV SMANJENJA BUKE

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SAŽETAK

Buka je sveprisutni izvor zagađenja okoline, kojeg se smatra jednim od najvećih današnjih zagađivača. Po cijelom svijetu provode se koordinirane akcije s ciljem razvoja sustava koji minimizira utjecaj buke na društvo.

U ovom članku razmatramo novi pristup potiskivanju utjecaja buke. Nadalje, razmatramo je li učinkovit pristup postavljanju široko primjenjivog, neprimjetnog, adaptivnog sustava zaštite od buke. Ovaj pristup objedinjuje prirodne strukture zaštite od buke temeljene na drveću i umjetno ostvarene prevlake.

Razmatrani su elementi sustava, njegovo postavljanje, održavanje i perspektive primjene.

KLJUČNE RIJEČI

buka, zvuk, gušenje, adaptacija, nanotehnologija

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ABOUT DEFINING THE REFERENT THERMAL SCALE POINTS

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ABSTRACT

The absolute temperature T has a recognized physical meaning in equilibrium thermodynamics. The scale realized by the closely related Lagrange coefficient β usually figures as an auxiliary scale. In this article, the scale spanned by β is a proper intensive thermal quantity for equilibrium and, suitably generalized, for stationary non-equilibrium state description. The coefficient β measures a relative deviation of a system state from the state of uniform distribution function. The cause of deviation is coupling to environment, which is realized as a net energy transfer and which ceases in the $\beta = 0$ state. A canonical ensemble of two level atoms coupled to electromagnetic quasi-continuum is considered as an example. The proposed and the usual interpretations of β are applied to stationary states of the same system, in which case the notion of the generalized absolute temperature is introduced. The generalized absolute temperature is a measure of a deviation of a system state from a state of infinitely intense external influence.

KEY WORDS

non-equilibrium thermodynamics, equilibrium, Lagrange coefficient

CLASSIFICATION

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INTRODUCTION

The absolute temperature, T, connects the differential changes of system energy and its entropy in isochoric processes. In description of a system of classical particles with translational degrees of freedom, it is a measure of the difference between the average and the minimal system energy. Within statistical physics it is introduced trough a distribution function determination. In that determination the auxiliary quantities, the Lagrange coefficients, occur [1] and are, for the sake of simplicity, often used throughout the calculations. In the case of a system with known spectrum and energy, the Lagrange coefficient β is a quantity sufficient to determine the equilibrium distribution. Coefficient β is related to the absolute temperature usually as $\beta = T^{-1}$.

In cases of stationary non-equilibrium states, β is not sufficient to determine the distribution function [2, 3] as it does not include the effects of the fluxes between the system and its environment. One of the quantities encountered in stationary non-equilibrium state description is the non-equilibrium absolute temperature θ [2-5]. Its limit when the system approaches equilibrium is the absolute temperature T. in cases of relatively small non-equilibrium effects θ is expressible as the absolute temperature modified by a flux-dependent part [2, 4, 6, 7]. A number of thermally related quantities have been introduced in order to provide an intensive quantity for description of out of equilibrium states [5]. However, at the present moment, there is no such generally applicable quantity recognized.

Exchange of energy with the environment is an environment influence, realized with the opening of channels for delocalization of system energy. The system state obtained asymptotically the alignment of the environment and the system state occurs [8]. Cases of environments parameterized trough several influences with the corresponding limiting, stationary system states, are straightforwardly included. Regarding the system state evolution, the referent state is introduced. It is the origin of a scale spanned by the system state variable. Generally, when the system state is close to some limiting state, the limiting and referent state coincide. The absolute temperature T is an example of a state variable the zero of which is both a referent state and a limiting state of system coupled with environment in the minimal energy state. However, there are several objections to equating the limiting and referent state. Operationally, the thermodynamic description based on one limiting state becomes rather complex when states close to another limiting state are considered. Substantially, such a reference emphasizes one particular environment influence, and that may screen some of the underlying system evolutionary characteristics (one example is discussed in the last paragraph of Section 3). Furthermore, in stationary non-equilibrium states the influence of the environment on the system is not fully developed, hence a reference to some intrinsically system quantity is more aligned with that fact. This is emphasized in systems with slow relaxation or with intensive environment dynamics. Regarding that, the intrinsic system state is introduced as the state with the uniform level population function.

In this article the referent state is the system's intrinsic state, unlike the case in which the referent state is one of its limiting states.

The central point of this article is to contribute to the recognition of the intrinsic state. The specific cases are considered for illustration purposes. Because in equilibrium statistical mechanics the approaches based on T and β are formally equivalent, the article largely deals with the case of stationary non-equilibrium.

The first case considered is an ensemble of two level atoms in equilibrium with an electromagnetic field, the state of which is described using β. As the second case, stationary

states of the system having finite energy and finite heat flux are considered. The deviation of the system state and intrinsic system state is measured using a set of Lagrange coefficients. Within that a notion of a generalized absolute temperature (GAT) is introduced. GAT is a measure of the deviation of a system state from the corresponding limiting state. Besides absolute temperature, a quantity which refers to the zero energy state, two additional quantities are used in description: a GAT which refers to the maximal heat flux state, and the Lagrange coefficient γ. The similarities between different temperatures used are described, and their relation to Lagrange coefficients discussed.

The article is organized as follows. In the Section 2, after a preliminary recognition of the parameters, a system of two level atoms without fluxes is considered. Following the proposed centering of thermal properties around β, the standard statistical mechanics expression for average energy is obtained. In the Section 3 the consequences of the heat flux in the system are elaborated. Discussion of the results is given in the Section 4, while main results are summarized in the Section 5.

SYSTEM OF TWO LEVEL ATOMS EXCHANGING ENERGY WITH ELECTROMAGNETIC FIELD

In the information theory approach to statistical physics [2], one maximizes the expression for entropy S as a sum over the available states with energies ε_i, i = 1, ..., N. If f_i is the distribution function, and $A^{(a)}$ relevant constraints, which are assumed expressible using one-particle quantities $A^{(a)}_\mathrm{i}$, then for fermions one has

$$S \sim \sum_\mathrm{i} \left[(1 - f_\mathrm{i}) \ln(1 - f_\mathrm{i}) + f_\mathrm{i} \ln f_\mathrm{i} \right], \tag{1}$$

$$A^{(a)} \sim \sum_\mathrm{i} A^{(a)}_\mathrm{i} f_\mathrm{i} , \tag{2}$$

thus obtaining

$$f_\mathrm{i} = \left[\sum_a A^{(a)}_\mathrm{i} \alpha^{(a)} + 1 \right]^{-1} . \tag{3}$$

In (3), quantities $\alpha^{(a)}$ are Lagrange coefficients, trough which the constraints (2) are taken into account. Lagrange coefficients are considered to be auxiliary quantities which are, using (2), related to macroscopic, measurable quantities.

In the case of a constant number of fermions of average energy E, (2) and (3) become

$$E = \sum_\mathrm{i} f_\mathrm{i} \varepsilon_\mathrm{i} , \tag{4}$$

$$f_\mathrm{i} = (\mathrm{e}^{\beta \varepsilon_\mathrm{i}} + 1)^{-1} , \tag{5}$$

respectively. For simplicity, $\hbar = 1$ and $k_\mathrm{B} = 1$ is taken throughout the article. Alternatively to the information theory approach, energy E and other macroscopic quantities are derivable from the partition function.

In this section another way of deriving macroscopic quantities of a system is described. It is applied to a collection of mutually independent two level atoms, with energy levels ε_1 and ε_2 and level populations n_1 and n_2, respectively. In the initial state, the system is in equilibrium with the environment, assumed to be a quasi-continuous bosonic heat bath and represented as a collection of electromagnetic (EM) modes, i.e., photons. The heat bath temperature is taken to be high enough so that the average number of photons is constant in the region of frequencies of the order of $|\varepsilon_2 - \varepsilon_1|$. In that case the equilibrium spectral density of EM field, given by the Planck formula,

$$u(\omega) = \frac{\omega^3}{\pi^2 c^3} \frac{1}{\mathrm{e}^{\beta\omega} - 1}, \tag{6}$$

is well approximated by the classical, Rayleigh-Jeans expression

$$u(\omega) \approx \frac{\omega^2}{\pi^2 c^3} \frac{1}{\beta}. \tag{7}$$

In the initial state, therefore, the system has approximately equally populated levels, $n_1 = n_2$, and its average energy per atom, E_0, satisfies

$$(n_1 + n_2)E_0 = n_1\varepsilon_1 + n_2\varepsilon_2 \Rightarrow E_0 = \frac{\varepsilon_1 + \varepsilon_2}{2}. \tag{8}$$

Let the heat bath subsequently cool infinitesimally. In the new state of equilibrium between the system and the EM field, the absolute temperature is slightly lees then infinity, its Lagrange coefficient $\mathrm{d}\beta$ is infinitesimal and positive. Furthermore, level populations satisfy Einstein's relation

$$n_1 u(|\varepsilon_2 - \varepsilon_1|)B = n_2\left[u(|\varepsilon_2 - \varepsilon_1|)B + A\right], \tag{9}$$

with $A/B = \omega^3/(\pi^2 c^3)$. Combination of (7) and (9) gives

$$\frac{n_1}{n_2} = 1 + (\varepsilon_2 - \varepsilon_1)\mathrm{d}\beta. \tag{10}$$

Because of the infinitesimalities encountered, the following substitution is applicable

$$n_\mathrm{i} = C_\mathrm{i} + D_\mathrm{i}\mathrm{d}\beta, \tag{11}$$

in which C_i and D_i are constants independent of EM field characteristics. Relations (10) and (11) are combined into

$$1 + (\varepsilon_2 - \varepsilon_1)\mathrm{d}\beta = \frac{C_1}{C_2} + \left(\frac{D_2}{D_1} - \frac{C_1 D_2}{C_2^2}\right)\mathrm{d}\beta, \tag{12}$$

with factors proportional to $(\mathrm{d}\beta)^2$ neglected. It is seen that $C_1 = C_2 = 1/2$, where the equalities follow from (12) and (11), respectively. From $n_1 + n_2 = 1$ the $D_1 = -D_2$ follows, and from (12) one has

$$D_\mathrm{i} = \frac{\varepsilon_\mathrm{j} - \varepsilon_\mathrm{i}}{4},\ i \neq j. \tag{13}$$

Expression (13) is equivalently written as $D_\mathrm{i} = \varepsilon_\mathrm{j} - \varepsilon_\mathrm{i}/4 - \varepsilon_\mathrm{i}/2 = (E_0 - \varepsilon_\mathrm{i})/2$. The last form is also valid in the case of three- or more-level atoms. Finally, (11) is written as

$$n_\mathrm{i}(\mathrm{d}\beta) = \left[1 - (\varepsilon_\mathrm{i} - E_0)\mathrm{d}\beta\right]n_\mathrm{i}(0). \tag{14}$$

A special form of expression (14) will be discussed in detail in Section 4.

The infinitesimal change $\mathrm{d}\beta$ can be considered as β/M for some finite β and a large enough number M. Than level populations after M applications of infinitesimal cooling, i.e., after cooling of environment from $\beta = 0$ to $\beta > 0$, satisfy

$$n_\mathrm{i} = \left[1 - (\varepsilon_\mathrm{i} - E_0)\mathrm{d}\beta\right] \cdot \ldots \cdot \left[1 - (\varepsilon_\mathrm{i} - E_0)\mathrm{d}\beta\right] \cdot \frac{1}{2} = \frac{1}{2}\left[1 - \frac{(\varepsilon_\mathrm{i} - E_0)\mathrm{d}\beta}{M}\right]^M \xrightarrow{M\to\infty} \frac{\mathrm{e}^{-(\varepsilon_\mathrm{i} - E_0)\beta}}{2}, \tag{15}$$

with $n_1(0) = 1/2$ used. While $\{n_\mathrm{i}(0)\}$ is properly normalized, level population in (15) are not, which will be discussed in more detail later. Using (15), the average energy becomes

$$E = \frac{\mathrm{e}^{-\varepsilon_1\beta}\varepsilon_1 + \mathrm{e}^{-\varepsilon_2\beta}\varepsilon_2}{\mathrm{e}^{-\varepsilon_1\beta} + \mathrm{e}^{-\varepsilon_2\beta}}, \tag{16}$$

Which is the well-known statistical physics expression. In the derivation of (16), the cooling of the environment was considered, i.e., $\beta > 0$, because of what the equation (6) was applicable. Formally, the expression (16) is also obtainable for $\beta < 0$, if one does not invoke

(6) and (7), but starts from some other expression, e.g. (10). From the foregoing expressions it follows that the change in sign of β brings about inversion of the level population function.

In the present derivation of (16), the notion of partition function was not exploited. Moreover, the distribution function was not needed in order to obtain (16). Instead, the consequences of the change of environment were analyzed. Formally, the simplified, classical formula (7) is recognized as an elementary transformation of the system which, after a sequence of repetitions, brings about (16).this contributes to the recognition of the importance of coefficient β. In particular, it is interpreted here as a measure of the influence of the environment on the system. Let us elaborate that connection in more detail. The coupling to environment, linked before to energy transfer, generally is asymmetric, which induces asymmetry in the level population (the effects of particle statistics and suppressions caused by symmetry are not considered here). A system of mutually non-interacting particles, which is isolated from environment, has neither stimulated nor spontaneous channels for energy transfer. In case of a system coupled to the environment in a minimal energy state, the allowed channel for particle transfers is a spontaneous emission. In the case of a system coupled to the environment in a non-minimal energy state, i.e., the colored environment, the allowed channels additionally include stimulated processes. The stimulated processes preserve the symmetry of the level population function. Similarly, the lower the EM field intensity, the smaller the branch of stimulated processes, thus bringing about the prevalence of spontaneous emission, as well as the asymmetry in level population function thereby induced. In the case of $\beta < 0$ the asymmetry in energy transfer is realized through the diminishing of number of photons radiated from the system to environment. That is possible as suppression of spontaneous emission. The degree of asymmetry in the particle transfer is taken as the measure of environment influence. Then the influence is stronger for larger β. The influence's limit is the diverging β state, or the $T = 0$ state. The interpretation presented belongs to the equilibrium state description, in which β and T are formally equivalent quantities. However, one specific characteristic of β-centered interpretation is seen – the larger the β, the larger the environment influence.

Some of the expressions used in obtaining (15) and (16) are related to the high-temperature approximation of the EM field spectral density function (7). However, this expression was merely an auxiliary quantity, which served in formulation of the first change. For repetitive changes, the expression (15) is sufficient. The derivation before (15) was needed in order to show that the standard, equilibrium statistical mechanics expression for system quantities are obtainable following the assumed gradual intensification of the environment influence.

Until now, the only parameter representing the EM field spectral density has been β. Because of the equilibrium between the system and its environment, the same is valid for the system. Hence, the absolute temperature introduced through the relation

$$T^{-1} = \beta, \tag{17}$$

represents the value of the system's absolute temperature. But, despite the simple function relation between T and β, they differ substantially. The coefficient β is zero when there is no induced asymmetry in the level population, and its value gradually changes as the environment induces larger and larger changes in level population. Therefore, β represents a deviation of the system state from the state of uniform level population, termed here the intrinsic system state. On the contrary, absolute temperature is zero for maximally asymmetric level populations, whether approached from the side of positive or negative values. Then the influence of the environment is maximal. The value of the absolute temperature is maximal and equal to infinity for a system with a spectrum bounded from above, when the environment influence is minimal, i.e., when the level population is symmetric. Parameter β measures the deviation of an equilibrium system state from the

intrinsic system state. In the same line of thought the absolute temperature measures the deviation of the system state from the particular state of maximal level population asymmetry, i.e., from the state in which only the lowest energy level is populated. The symmetry (maximal asymmetry) of the level population is related to the maximal (minimal) entropy of the state. Hence, β measures deviation of a system state from the state of maximal entropy.

In the case analyzed, there are two limiting states – states with the lowest and largest possible energy. Regarding that, the absolute temperature measures deviation of a state from the one particular limiting state, the lower energy level. The negative absolute temperature measures deviation of a state from the other limiting state, which is here the other level, i.e., the higher energy level. In the sense, the absolute temperature and negative absolute temperature are two completely independent notions. Because of the simplicity of a canonical ensemble of two level atoms, these two temperatures are related through only a sign change. Generally, it is therefore opportune to think about two different absolute temperatures; one related to a deviation from the minimal energy state, and other related to a deviation from the maximal energy state.

It is a consequence of the physical space that the absolute temperature of the average EM field is relatively small, so that lowering the temperature, i.e., making β larger, is the asymptotic change. In addition, for a large enough class of systems, the environment EM field temperature is not high enough to bring about a level symmetry, even if it is the only energy exchange channel.

SYSTEM OF TWO LEVEL ATOMS WITH FINITE HEAT FLUX AND ENERGY CONTENT

In this section a special configuration of two level atoms is considered. Geometrically, the system resembles a well-analyzed system of harmonic oscillators [2]. In the system, N equidistant, two level atoms form a ring. The interaction between the atoms is a direct energy exchange between the nearest neighbors, with the interaction integral J. Dispersion relation of normal modes, excitons, is

$$\varepsilon_{\mathrm{n}} = \varepsilon_0 - 2J\cos\frac{n\pi}{N}, \tag{18}$$

with $\varepsilon_0 = \varepsilon_2 - \varepsilon_1$, and $n = -N, ..., -1, 0, 1, ..., N-1$. Along with (18), the following auxiliary quantity is introduced,

$$q_{\mathrm{n}} = \varepsilon_{\mathrm{n}}\frac{\varepsilon_{\mathrm{n}+1} - \varepsilon_{\mathrm{n}}}{(\pi/N)} = 2J\left(\varepsilon_0 - 2J\cos\frac{n\pi}{N}\right)\sin\frac{n\pi}{N}, \tag{19}$$

with the last equation valid for $N >> 1$. Thermodynamically, the stationary states of the system are analyzed, which are characterized by the energy content and heat flux. In the way one speaks about the "superconductor of thermal energy" [7], as the heat flux lasts indefinitely. The average energy per atom, E, and the heat flux divided by number of atoms, Q, satisfy

$$E = \sum_{\mathrm{n}} \varepsilon_{\mathrm{n}} f_{\mathrm{n}}, \tag{20}$$

$$Q = \sum_{\mathrm{n}} q_{\mathrm{n}} f_{\mathrm{n}}, \tag{21}$$

with the following expression for the exciton distribution function,

$$f_{\mathrm{n}} = (\mathrm{e}^{\beta\varepsilon_{\mathrm{n}} + \gamma q_{\mathrm{n}}} + 1)^{-1}, \tag{22}$$

in which β and γ are Lagrange coefficients, real scalars. Expressions (18-22) are discretized versions of expressions found in the literature [6]. Dependence of system energy E, determined using (18), (20) and (22), on Lagrange coefficients is shown in Figure 1 for two

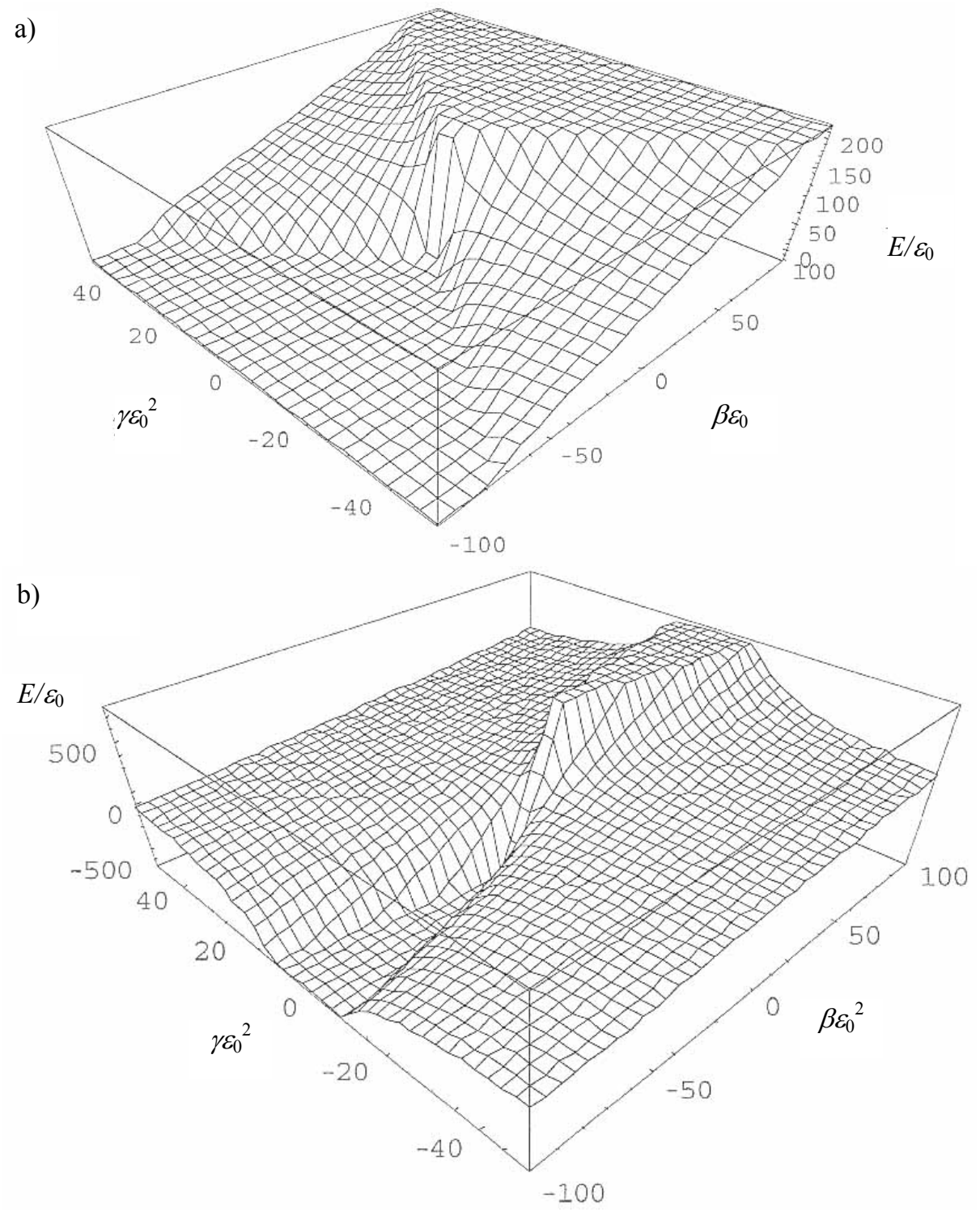

Figure 1. Energy E as a non-normalised function of β and γ for $N = 100$. Parameter $\alpha = 2J/\varepsilon_0$ equals a) 1, b) 10.

cases of coupling strength $\alpha = 2J/\varepsilon_0$. In the case of negligible coupling strength, energy does not depend on γ. Conversely, the larger the α, the more pronounced the dependence of energy on γ. In the following discussion the value $\alpha = 1$ is taken. In the graph relating Q and E (Fig. 2), curves of constant β and γ form two families of mutually intersecting curves. Graphs relevant for the inverse case are shown in Figure 3. In these graphs, the Lagrange coefficients are related, with explicitly shown curves of constant E and Q. While in the classical region of $\beta \to \infty$ the

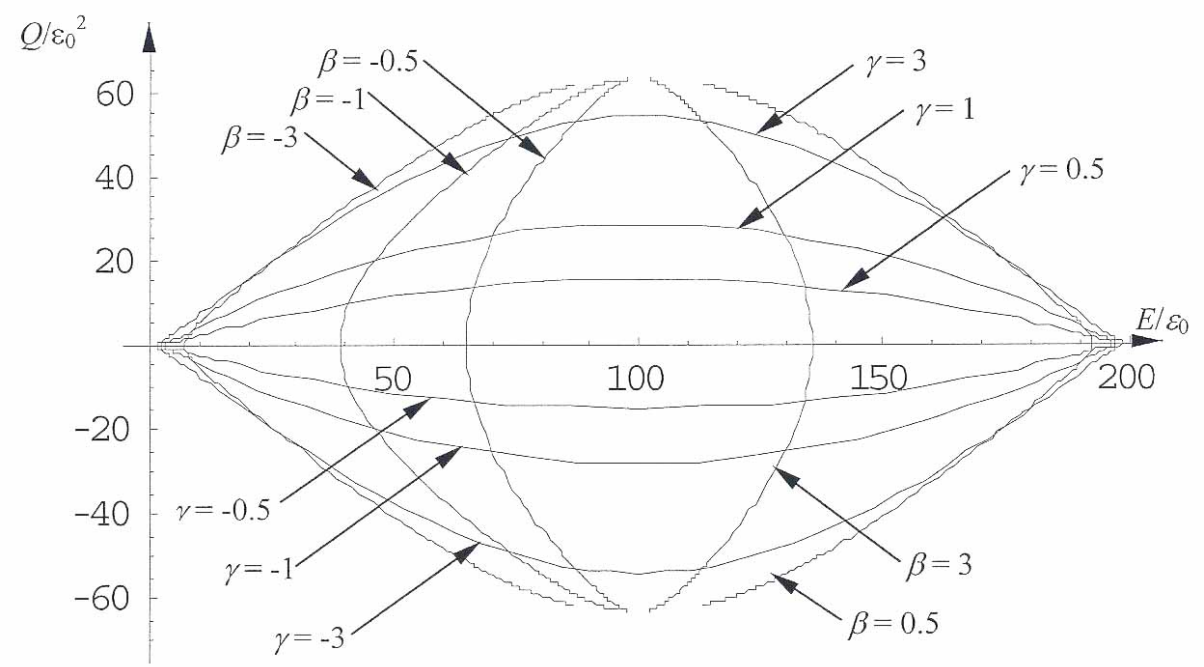

Figure 2. Curves of constant β and γ on the graph relating non-normalised heat flux Q and system energy E for $N = 100$. Units on axis are arbitrary. Curves for $\beta = 0$ and $\gamma = 0$ are parallel to vertical and horizontal axis, respectivelly. Convergence of curves to points of extremal Q is not shown because of numerical reasons.

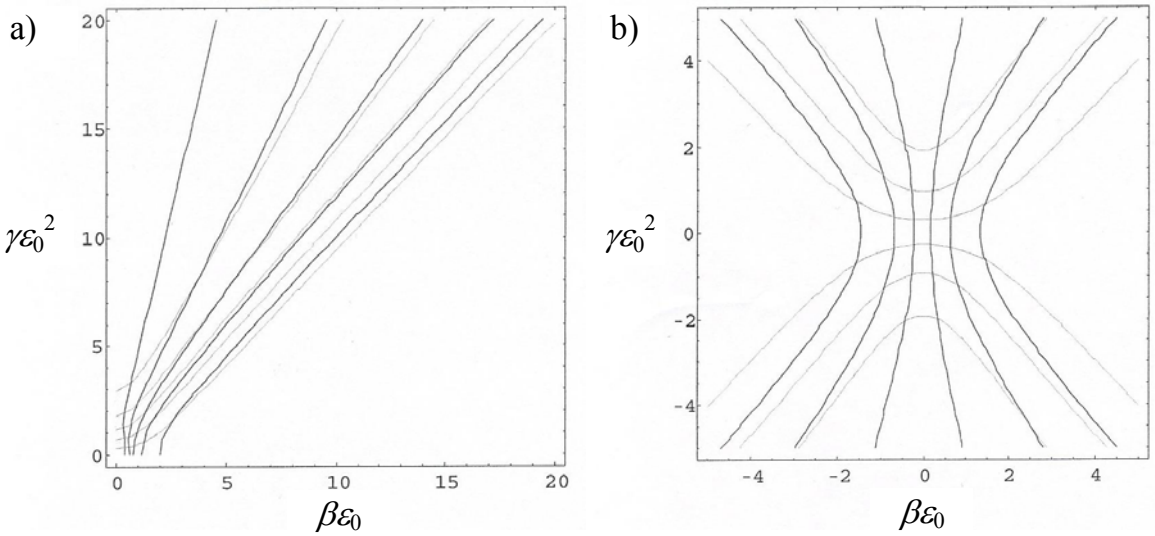

Figure 3. Curves of constant E (solid) and Q (dashed) on the graph relating Lagrange coefficients β and γ, a) global character and b) neighbourhood of the intrinsic state $\beta = \gamma = 0$.

curves of constant β and constant γ tend to be parallel, in the neighborhood of the intrinsic state they become perpendicular one to another. Therefore, in the classical region, a change of, e.g., system energy E, is accompanied by the change in the system heat flux Q. On the contrary, near the intrinsic state the change in E is considerably larger than the change in Q, thus it is possible to change E with almost negligibly changing Q.

From Eq. (22) some special cases can be inferred. First, if γ is negligible compared to β, one has periodic analogy of collection of two level atoms considered in the previous section. There are then two limiting states, with co-ordinates

$$(\varepsilon_0 \pm 2J, 0), \tag{23}$$

in the (*E, Q*) plane. In (23), the minus (plus) sign refers to states with minimal (maximal) energy. In the case when the system state is close enough to one of limiting states, the distribution function (22) becomes approximately

$$f_{\mathrm{n}} \approx \mathrm{e}^{-\beta\varepsilon_{\mathrm{n}}} . \tag{24}$$

In the second special case, β is negligible to γ, and furthermore the system in the neighborhood of one of the limiting states is considered. Then (22) simplifies to

$$f_{\mathrm{n}} \approx \mathrm{e}^{-\gamma q_{\mathrm{n}}} , \tag{25}$$

and it is clear that relevant contribution of the n-th state is q_{n} and not the energy ε_{n}. Expression (25) is interpretable as a classical distribution function of a system which has (19) as the dispersion relation. One could further introduce the equivalent absolute temperatures, $T_{\mathrm{eq}\pm}$, measuring deviations of system states from the states with extremal heat flux values,

$$T_{\mathrm{eq}\pm} = \pm\frac{1}{\gamma} . \tag{26}$$

From (19) it can be determined that the states with maximal contribution to the heat flux Q, having indices $n_{\pm}$, satisfy

$$\cos\frac{n_{\pm}\pi}{N} = \frac{1 \pm \sqrt{1+8\alpha^2}}{\alpha} , \tag{27}$$

with valid solution(s) satisfying $(1 - 4\alpha)\cdot\sin(n\pi/N) > 0$. Generally, this gives the two values of (19) for the limiting states

$$q_{\pm}. \tag{28}$$

Comparison of (24) and (25) on one hand, and (23) and (28) on the other hand implies that the two sets of limiting states are relatable through exchange

$$\begin{Bmatrix} \beta \\ \varepsilon_0 \pm 2J \end{Bmatrix} \leftrightarrow \begin{Bmatrix} \gamma \\ q_{\pm} \end{Bmatrix} . \tag{29}$$

Projected onto the whole system, the state without heat flux and with relatively low energy is similar to the state with maximal heat flux, because in both cases a few particles are not in states characterized by (23) or (28). For thermodynamics of states close to the limiting states, one has to take into consideration that there is a parabolic dispersion relation when γ is negligible to β, while (19) depends linearly on the index n in the case of a relatively small β and relatively large γ.

In approaching limiting states, quantities β and γ diverge. In the case of $\beta \to +\infty$ and $\gamma = 0$, the usual description invokes the limit $\beta = +\infty$, i.e., the zero energy state, as a referent state in terms of the absolute temperature, $T = 1/\beta$. In the case of $\beta \to -\infty$ and $\gamma = 0$, the limit $\beta \to -\infty$, the state of maximal energy, if expressed in terms of quantity $-T$, serves as the referent state. Cases with $\beta = 0$ and $\gamma \to \pm\infty$ have not been thoroughly examined in the literature. Such states are encountered, e.g., during intensive particle motion. Then $\gamma \to \pm\infty$ means large enough drift motion in which diffusive motion in negligible. States with diverging β and states with diverging γ, share the relatively large asymmetry of the level population function.

The plane spanned by Lagrange coefficients β and γ, contains all possible stationary states of the described system (Fig. 4). Along with the axis of β and γ, the axis for the absolute temperature and for the negative absolute temperature are shown in order to emphasize their relationship with β. States far from axis β are not easily described using the non-equilibrium absolute temperature θ as a GAT, as is seen from the corresponding distribution function (25), which is valid approximately in that case. The temperature related part is negligible then, and the reference to $\beta \to \infty$ state is not solid. From the foregoing expressions it follows that the

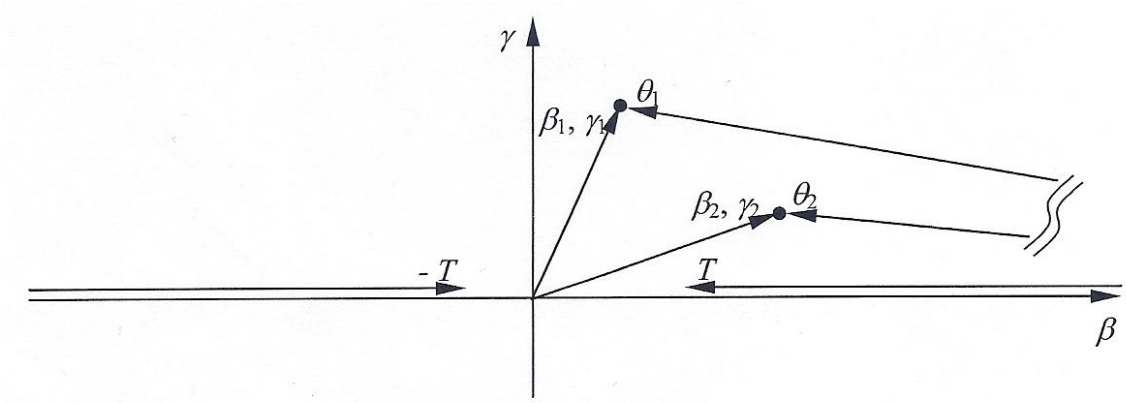

Figure 4. Comparison of different systems states as performed in the absolute temperature T, negative absolute temperature $-T$ and the Lagrange coefficient centred approach. States are denoted using non-equilibrium absolute temperature θ and a pair of Lagrange coefficients α and β.

relevant quantities are the β and γ, which are on one hand connected to T, and on the other hand to different GATs.

DISCUSSION

Expressions (14) and (15) resemble the expressions connected with generators of infinitesimal changes [9]. In particular, when there is time-homogeneity, Hamiltonian is the generator of infinitesimal translations in tame. If $|\psi(t)\rangle$ is some time-dependent state vector in time t, then its value in infinitesimally later time $t + \mathrm{d}t$ is

$$\left|\psi(t+\mathrm{d}t)\right\rangle = (1-\mathrm{i}H t)\left|\psi(t)\right\rangle \tag{30}$$

While its value in Δt later moment is

$$\left|\psi(t+\Delta t)\right\rangle = e^{\mathrm{i}H\Delta t}\left|\psi(t)\right\rangle . \tag{31}$$

The expressions (14) and (15) are obtained within the classical approach to statistical physic, in such a way that c-numbers figure in them. In the quantum mechanics, from which (30) and (31) are taken, operators are state vectors figure. A manifest difference between two groups of expressions in an imaginary unit, which is missing in previous expressions. All that is aligned with the existing recognition that β may be considered as imaginary time. In that sense, (14) is the averaged value of infinitesimal imaginary time translation,

$$\left\langle i\left|\mathrm{e}^{-H\mathrm{d}\beta}\rho(0)\right|i\right\rangle = \left\langle i\left|(1-H\mathrm{d}\beta)\rho(0)\right|i\right\rangle = \frac{1-\varepsilon_i \mathrm{d}\beta}{2}, \tag{32}$$

with the initial density matrix of the canonical ensemble $\rho(0) = \mathbf{E}/2$, where $\mathbf{E}$ is 2×2 identity matrix. In (32) it was assumed that $|i\rangle \in \{|1\rangle, |2\rangle\}$ are eigenstates of the system Hamiltonian H. Overall, the repetition of imaginary time translations brings about (15). However, the similarity between (30) and (14) is not fully manifested in the derivation presented here, as (30) is a unitary transformation for hermitian H, while (14) is not. In addition, in (32) the form of time translation valid for functions is used, which is not appropriate for a density matrix. In other words, additional care should be taken in derivation of (14) if one wants to interpret it as an imaginary time translation (32). Still, one more non-manifest similarity between the real time and imaginary time translations should be mentioned: admissible values of time parameter cover the set of real numbers.

For each limiting state one can introduce a generalized absolute temperature (GAT). GAT is the quantity measuring the deviation of a system's state from some limiting state. In that way, when the scale spanned by the GAT is used, the corresponding limiting state is the referent state. The GAT is a generalization of the absolute temperature T. The absolute temperature is one realization of the GAT introduced for only one limiting state. The GAT has different realizations, each referring to different among the possible limiting states. Further examples of GATs mentioned in this article are listed in Table 1. Each GAT is introduced for a particular limiting state. In that way, as seen from Table 1, generally there are several GATs applicable for diverging $(\beta^2 + \gamma^2)^{1/2}$. In measuring GAT one encounters the similar problem as in measuring nonequilibrium temperature θ – when using a thermometer the absolute temperature is measured. Hence, there is the indirect way of measuring GATs, i.e., through determination of the exciton population function f_n, fitting it to the form (22) and using definitions in Table 1 to determine a particular GAT.

Depending on the dynamics and initial conditions, a system will evolve through regions close to different limiting states, hence the different GATs will be suitable for the description of such dynamics. While in the simpler cases this does not cause problems, in more complex cases, in which there are many limiting states as the described ones, this may bring about tedious, non-tractable calculations. In the later case it is opportune to refer to the intrinsic system state in description of system dynamics. Such a determination of a referent state of a system generally changes somewhat a written from of the relevant expressions. In Figure 4 the coordinate system defined through β and γ is shown. Two states shown have the appropriate values of Lagrange coefficients, and the values of non-equilibrium absolute temperature. It is seen that the non-equilibrium absolute temperature measures combined effects of β and γ, i.e., energy and heat flux, on the system state. The non-equilibrium absolute temperature is useful for system states close to the axis abscissa. The β and γ are useful in describing a general system state. In addition, a deviation of a system state from the intrinsic, i.e., $\beta = \gamma = 0$ state points to strength of an environment influence: states closer to the origin are less influenced by environment. In case of the usual environment with $T \approx 0$, a system in states with higher β is more aligned with the environment. A system in a state with strong fluxes, i.e., rather large value of γ, is subjected to an intense environment influence, hence is more similar to a system in low temperature states in that the variations in the level population are less pronounced. From (24) and (25) it is clear that a different approach is needed for the general description of system state instead of quantities related to a single limiting state.

Finally, from (10), (19) and (22) it is seen that the following substitution is possible

$$\frac{g_n}{\theta} = \beta\varepsilon_n + \gamma q_n, \tag{33}$$

Table 1. Temperatures encountered in the description of system's states.

Temperature	**Absolute temperature**	**Non-equilibrium absolute temperature**	**Negative absolute temperature**	**Equivalent temperatures**	
				$1/\gamma$	**$-1/\gamma$**
Notation	T	θ	$-T$	T_{eq+}	T_{eq-}
Nearest limiting state	$E = 0$, $Q = 0$	$E = 0$, $Q = 0$	max E, $Q = 0$	max Q	min Q
Region of suitability	$\beta \to \infty$, $\gamma = 0$	$\beta \to \infty$, $\gamma \approx 0$	$\beta \to -\infty$, $\gamma = 0$	$\beta \to 0$, $\gamma \to \infty$	$\beta \to 0$, $\gamma \to -\infty$

for a small enough neighborhood of some limiting state, in order for the dependence of g_n on changes of β and γ to be negligible. Quantity g_n is a generalised dispersion relation which combines effects of the dispersion relation and the heat flux.

SUMMARY AND CONCLUSIONS

In this article, the Lagrange coefficient β is proposed as a referent, intensive thermal quantity, for which it may be argued that it is particularly useful in broadening the notion of temperature-like quantity out of equilibrium thermodynamics. It is argued that there is a relation between β and environment influence. The absolute temperature T is recognized as a particular realization of the GAT, which refers to the deviation of the system state from a minimal energy state. The consequences of the propulsion are discussed in the case of the ensemble of two level atoms interacting with an electromagnetic field. In cases where heat flux is considered, similar results are obtained.

The results serve as a starting point for the alternative treatment of stationary non-equilibrium states in which system states are described using β and other Lagrange coefficients instead of trying to use a temperature-related quantity. In such a treatment the emphasis of a particular limiting state is overcome, hence the asymmetry of a treatment of flux- and temperature-related variables does not exist. Furthermore, the fact that a system, in a stationary state, is not coupled to the environment in an intense enough way to establish solid relations to some environment referent point is emphasized in the formalism.

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O DEFINIRANJU REFERENTNIH TOČAKA TEMPERATURNE SKALE

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SAŽETAK

Apsolutna tempperatura T raspoznatog je fizikalnog značenja u ravnotežnoj termodinamici. Skala razapeta Lagrangeovim koeficijentom β uobičajeno je pomoćna skala. U ovom radu, skala razapeta koeficijentom β je primjerena intenzivna termalna veličina za opis ravnotežnog i, primjereno poopćena, stacionarnog neravnotežnog stanja. Koeficijent β mjeri relativno odstupanje stanja sustava od stanja opisanog uniformnom distribucijskom funkcijom. Razlog odstupanja je vezanje za okolinu, koje je ostavreno izmjenom energije i koje išćezava u stanju $\beta = 0$. Kao primjer razmotren je kanonski ansambl atomā s dvije razine vezan za elektromagnetski kvazikontinuum. Predložena i uobičajena interpretacija koeficijenta β primijenjene su na stacionarna stanja tog sustava u kom slučaju se uvodi pojam poopćene apsolutne temperature. Poopćena apsolutna temperatura mjera je odstupanja stanja sustava od stanja s beskonačno intenzivnim vanjskim utjecajem.

KLJUČNE RIJEČI

neravnotežna termodinamika, ravnoteža, Lagrangeov koeficijent

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