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INTEGRATED KNOWLEDGE, INNOVATION AND TECHNOLOGY CLUSTER AS A SELF-REGULATING COMPLEX SYSTEM

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Abstract. Current scientific literature aims for adequate understanding of the process for integration of knowledge, innovation and technology in various areas of human activity. This would materialise the hope that integrated knowledge, innovation and technology clusters could become a full-fledged resource in responding to the current and future local and global challenges of sustainable development.

Keywords: knowledge, innovation, technology, integrated knowledge, innovation and technology cluster, sustainable development, its factors and management.

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JEL Classification: O32, Q01, Q55.

1. Introduction

Sustainable development and purposeful integration of science, innovation and technology are the main instruments that would help the world to overcome the current and potential future challenges. The rapidly progressing globalisation and the existing need for national sustainable development are the main drivers for the continuous integration of knowledge, innovation and technology. However, the current analyses of sustainable development lack quantitative measures and accordingly unified concept and expression of sustainability as well as theoretically perfect and pragmatically active perception of knowledge, innovation and technology integration that would foster the sustainability of various systems and processes.

An in-depth analysis of the United Nations post-2015 development agenda suggests that global economic growth and growth potential of an individual region or country as well as solutions to such global problems as food shortage, health and growth of

ecological unsustainability can be successful only through purposeful development of knowledge, innovation and technology (KNIT) cluster. Considering possible global and space disasters, there is no other alternative for the purposeful development of scientific knowledge and space technologies.

The future "Europe for Citizens" programme for 2014–2020 (Europe for Citizens 2007–2013) treats the future challenges and possible ways to avoid the consequences in a rather similar manner. As well as the UN post-2015 development agenda, it strongly speaks for the shift of scientific research from interdisciplinary knowledge to problem-centred researches.

Both aforementioned programmes and a number of other UN and EU documents take a very responsible stock of development policies and priorities, potential problems and their solutions as well as discuss local and global challenges. Almost each of them suggests a a uniform approach to sustainability of development as reasonably most beneficial way forward. Hence, the structure of an integrated KNIT cluster not only appears to be adequate but is also the most effective way to achieve sustainable development.

The following relevant issues, which were carefully touched upon, should be underlined among numerous planned scientific research and pragmatic KNIT structure improvement projects:

- How compatible is boundless economic and demographic growth with limited possibilities of planet Earth?
- What are practically unmanageable or even artificially promoted negative consequences of globalisation? Could they undermine all benefits provided by globalisation?
- What concept and models should be used for quantitative measurement of sustainability or development of processes or systems?
- What mechanisms should be used to form an optimal structure of a KNIT cluster?
- What forms of integration and communication between different countries should dominate during the period of post-globalisation?

There is no doubt that these are the most complex global political issues that could be efficiently addressed designing a KNIT cluster, which would integrate knowledge, innovation and technology considering a variety of internal/external factors (social, cultural, economic, political, innovation and etc.). The design of such cluster concept and alignment of functions pertaining to its components – knowledge, innovation and technology – allows understanding the basic principles behind the sustainable development of a country that fosters intelligent investing. The finalised research on intelligent investing possibilities gives rise to reasonable consideration of the use of KNIT cluster potential for national sustainable development.

2. Integrated knowledge, innovation and technology cluster as a self-regulating complex system

In the scientific literature and pragmatic summaries, it is hardly possible to detect a more detailed interpretation of the progress of interaction between science, knowledge, innovation and technology aimed at sustainable development and the form of interaction between development and integrated KNIT cluster.

As human intellect is the key connective component of the integrated KNIT cluster, it is hardly a surprise that it transforms into a self-organising system. However, it remains unclear how the cluster, which is mainly composed of heterogeneous elements and is focused on implementation of different functions, accumulates the development potential. Additionally, it remains unclear whether the integrated structure of a KNIT cluster, which is adequate in particular situations, has ever been selected in the past for detection and implementation of development possibilities. The existing experience should be investigated for better understanding of the effect made by sustainability of development and possibilities of the integrated KNIT cluster to strengthen this effect.

For basic understanding of the structure of a KNIT cluster, a simplified model of interaction between sub-units of a military unit in a situation when a combat unit is confronted with an unfamiliar opponent. In the model, the role of the intelligence unit is assigned to the knowledge subsystem that employs all efforts to create an adequate picture of the opponent and formulate the vision of the operational unit, i.e. the innovation subsystem, and the setup of strategic factors, i.e. the technology subsystem.

The use of this thinking pattern in less complicated situations could result in selection of a nearly optimal structure for a particular KNIT cluster. However, analysis of more universal situations or attempts to cover the universe of threats requires integrating the scheme for KNIT cluster possibilities and efficiency analysis into the aggregate of concepts, analytical tools, information provision means and decision-making methods of the composite system. Theoretically, a complex system is perceived (Ertmer, Ottenbreit-Leftwich 2010) as a summarised aggregate of assumptions, possible subsystems (components, elements, etc.), their interaction possibilities and methods, general analysis, quantitative knowledge and management methods, which can adequately cover the extremely complicated real situations that contain a virtually unlimited number and variety of objects, ways of interaction, pursued objectives and means.

Fig. 1 attempts to reveal the logics of interaction between the main KNIT cluster components. The scheme suggests that the first encounter with the innovative development code results in the knowledge about trends and techniques as well as the content of innovative development. In turn, the perceived development directions and methods stimulate the interaction between innovation and technology in the context of development. Finally, adaptation knowledge of innovative development and innovation tests bring the development process back to the next step of the development spiral.

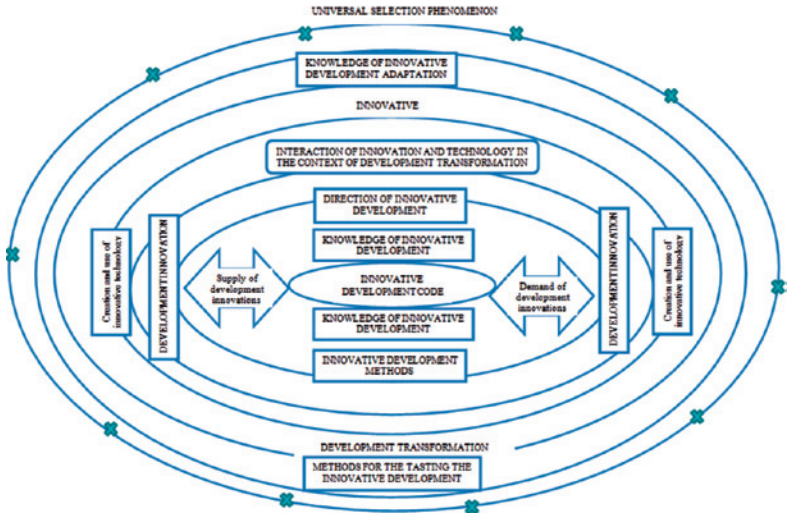


Fig. 1. Use of innovative development code information (Source: created by the authors)

The complexity of integrated KNIT cluster structure and its changes is associated with the complexity of process or system selected for testing. There is no doubt that understanding of the KNIT cluster structure for such sophisticated processes as regional or national development is not only significant but also requires high-level scientific efforts. The object of this research is the analysis of KNIT cluster structure pursuing sustainability of development in a particular country.

3. Purposeful development of knowledge, innovation and technology clusters as the key assumption for integrated KNIT cluster efficiency

As already mentioned, development of knowledge, innovation and technology cluster and, more importantly, prospects of its integrated network or fabric are the most complex and relevant human problems. Once grasped, they might reveal acceptable and realistic development paths as well as survival strategies and success guarantees for the humanity or individual countries. It is understandable as even the generation of fundamental scientific knowledge is associated with the phenomenon of evolution or creation of the universe, for the understanding of which the time of human existence on earth may be insufficient. Codes and management possibilities of physical, biological, cosmic and other regularities can only be considered conditionally.

It may be easier to understand the human origin as well as ways and governing laws applicable to the evolution of human society into the contemporary society, which would reveal applicable management possibilities. However, this is not a reason to be overly optimistic. The ability to intervene into human genetics and social development threatens with destruction of the core value of human nature. Nevertheless, such investigations continue accelerating.

In fact, science is intensively interested in the evolution of human cognition, including the complex physical and cosmic processes and substances. This provides hope for pragmatic understanding.

In this paper, the authors will try to discuss the need to develop knowledge, innovation and technology clusters and assumptions for implementation of possible science-declared guarantees for sustainable development possibilities within the perspective of limited duration (§ 3.1.); as well as intelligent investment strategies for the implementation of universally sustainable development strategy in a particular country (§ 4).

3.1. Integrated KNIT cluster as a self-regulating complex system

Literature is full of pragmatic reflections on a possible make-up of a blog of actions and consequences related to fostering of conditions necessary for sustainability. Next, one of these blogs (Fig. 5) will be used, the implementation of which should be based on the idea of sustainability of development and KNIT cluster as the key instrument of implementation of such blog.

Distinct knowledge, innovation and technology clusters (KNIT) form a real assumption for the formation of an integrated knowledge, innovation and technology cluster. As the world overcomes challenges and countries strive for universally sustainable development possibilities, there is a need for adequate knowledge, which is the main resource facilitating the ability to compete in an uncertain and risky environment (Pacharapha, Ractham 2012). The most important economic commodity – knowledge – constitutes the basis for creation of new products, processes, organisational factors as well as penetration into new markets based on emerging and advancing technologies (Antonelli 2009). Technological development and the national economic, political, environmental and social factors are closely related to the concept of development factors and their effect on sustainability. This section contains description of individual KNIT cluster elements – knowledge, innovation and technology – while referring to the corpus of events and processes listed in the blog.

Knowledge as the base of an integrated cluster

Once knowledge becomes a strategically important resource, this creates a framework for development of competitiveness resulting in an increase of economic value (Sullivan, Marvel 2011). Possession of appropriate knowledge and its appropriate management is a guarantee for development of a business as well as a country. It is hardly surprising there is a universal focus on fostering the integration of knowledge and technology aiming to make knowledge the basis for the development of technology and innovation. Development of the national position should consider the following innovative changes: new sources of revenue as well as provision of new services and supply of innovations to the society (Luke *et al.* 2010). In addition, an essential role is played by the cooperation of science with public and private sectors (Bastalich 2010) as an increase in the number of scientific research projects and development of technologies allows a more efficient use of existing knowledge and creation of principally new knowledge.

Evaluating the adequacy of knowledge in a real situation highlights the need to answer three principal questions on the need to manage knowledge: who, what and how. The answers to these questions generate general knowledge configuration picture, namely, who shares the relevant content knowledge and how (Ertmer, Ottenbreit-Leftwich 2010). Responses reveal the main types of knowledge (Fig. 2).

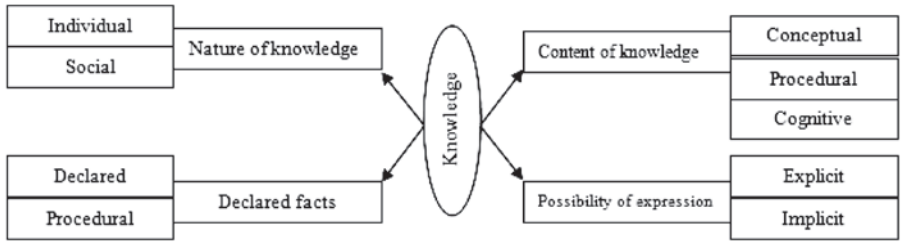


Fig. 2. Main types of knowledge (Source: Camic *et al.* 2012)

Depending on expression possibilities and content, three general knowledge groups can be identified: social, physical and logical-mathematical. A modern man could hardly survive without constant communication and exchange of information; consequently, the acquisition of social knowledge as a way of communication and knowledge sharing is a natural process (Varghese 2013). It is considered that physical knowledge that explains how to act and behave in appropriate situations is no less important. Nevertheless, the basis of all knowledge is logical-mathematical knowledge, the existence of which conditions explanation of logics behind actions and definition of possible consequences. However, an important aspect is the ability to share knowledge and to act purposefully; thus, depending on whether the knowledge is shared or not as well as the form of the knowledge, it is classified into explicit and tacit. Knowledge that has a clear form (often referred to as factual knowledge), is easy to share as it is generally expressed in a certain way, namely, as the standards, rules or regulations; however, scientists are more interested in tacit knowledge as it is regarded as the main human motive to focus on efficient and purposeful work (Shiu-Li, Chia-Wei 2009). In case of the need to use knowledge for development of innovative technologies, the creation of a homogeneous knowledge, innovation and technology cluster would be desirable, as it would serve as the basis for the development of innovative technologies with the use of knowledge. However, analysis of the interaction between knowledge, innovation and technology revealed a certain problem: there is insufficient information about the technological change process, which is caused by social development factors. It is still unclear, how different factors and business processes affect the transformation of knowledge to technology. Technology is often perceived as one of the most important business development factors, but it is not widely considered on the national level when dealing with problems particular to universal sustainability of development. Therefore, the aim of the authors is to identify the technology potential and name naturally occurring problems, in order to achieve universal sustainability of national development.

3.1.1. Technological advancement with improvement of knowledge and implementation of innovations

Usually the process of knowledge transformation to technology is defined as the transfer of technology and understood as the process of existing technological knowledge acquisition, development and utilization, which is generated by individuals. The scientific literature suggests that technology is installed where it does not exist at the time, while technological innovations emerge with properly generated knowledge and developed innovations. This means that with the appropriate knowledge there is a need to implement new technologies that result in national economic development. Graphically, this would look like this (Fig. 3) (Vaz, Nijkamp 2009; Friedrich *et al.* 2009).

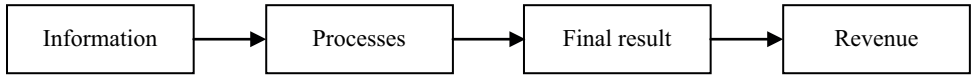


Fig. 3. How information turns into revenue (Source: Vaz, Nijkamp 2009)

Fig. 3 shows that properly managed information generates the final result – knowledge, which gradually turns into technology and innovation, and leads to profit (or improvement trend of certain related factors). For example, possession of information on possible improvements made to the decision-making process provides a possibility to obtain the final result, namely, a timely and efficient solution, the implementation of which would bring the expected income (revenue).

Implementation of technologies alters the following four dimensions: 1) beliefs/ideologies; 2) content knowledge; 3) instructional practices; 4) strategies, methods and approaches of teaching knowledge, instructional resources, technology and material. The change of knowledge leads to improvement of understanding of currently used IT, its diversity and operational efficiency; therefore, as a tool (method), technologies become an integral component. In this case, it is necessary to find methods to be used and goals to be achieved preparing for the proper use of these systems. However, the technology implementation and new knowledge generation will be improved only if it is focused on consumers – innovators who are ready to change their beliefs and give up previously acceptable methods and actions once certain innovations are introduced. In addition, cultural aspects remain extremely important. Cultural differences must be considered to provide information of adequate context indicating how to adapt in a local and global society and select the preferred technology. Consequently, technology integration requires to be focused on: a) technological knowledge and skills, b) pedagogical knowledge and skills, c) technological know-how and management skills. New technologies enhance and improve understanding of new practices, which creates preconditions for testing of new ideas and change of attitudes; however, this requires financial and human resources (Ertmer, Ottenbreit-Leftwich 2010; Noor Al-Jedaiah 2010).

Implementation of technologies starts with selection of the appropriate technology, which depends on available knowledge, current situation (the problem at hand) and other factors, followed by selection of the most reliable supplier. Technology acquisition

possibilities – differences viewpoints of a supplier and customer, level knowledge and technical parameters – should be properly considered because a decision-making technology, which is suitable for one subject may be completely irrelevant to another. Once the technology that conforms to most criteria is selected, it should be implement customized for a particular sector, activity or subject; and in case of deviations, necessary improvements (changes) should be made (Santos Silva *et al.* 2013).

With time, human thinking advances and new knowledge boosts technological development. Certainly, the development of technology is adequate to certain national development phases; thus, it is appropriate to define the main phases of technological development (Boehm, Fredericks 2010; Goel *et al.* 2012):

1) Technology push. There is no connection between national and technology strategies since not all parameters are consistent; there are deviations and significant differences between the existing knowledge, capability to apply innovations and subjects capable of implementing and fostering innovative technologies for national sustainable development;
2) Market pull. Innovations are adapted to market needs since one of the current key national development objectives is to ensure the best possible standard of living, level of economic development, etc.;
3) Portfolio management. Here, the relationship between technology and the country development strategies emerges and innovative processes meet technological possibilities and market/social needs;
4) Integration management. Restructuring of the economy, business strategy formulation and technological management conforms to business/national concept;
5) System integration. Innovations as the core competency helps to improve activity processes, to stabilize the national development process;
6) Network integration comprises coupled public and private sectors and technology strategies, technological development.

New technology is matured over time, gradually destroying old beliefs and methods and replacing them with new ones. There are two factors, which promote change: risks and opportunities (Suh *et al.* 2010). Generally, technological changes lead to technical changes, which accordingly influence operating costs. Technological changes can be understood as structural changes. Unexpected changes necessitate a rapid reaction and change in the current modus operandi or adjustment in the change of specific development factors (Antonelli 2009).

Consequently, application and development of technology is a very important and time-consuming process, which is closely related to national sustainable development and depends on the integration with available knowledge and promoted innovation. The prevailing opinion is that the knowledge economy must be interpreted as the interaction between information and communication technology, innovation, commercialised research and national prosperity. Interaction of these factors leads to the development of economic well-being, development of competitiveness, social welfare, sustainable economic growth, employment and increase of living standards (Bastalich 2010; Bjornson,

Dingsoyr 2008). The relationship between knowledge and technology has already been clarified; thus, about the focus should be placed on the role of innovation.

3.1.2. Innovation as a precondition for a focused integration of knowledge and technology

Innovation is one of the main sources of economic growth and new employment possibilities that makes use of benefits present in the environment. Creation of something new and innovative is aimed at efforts to produce a new product or service required by a customer.

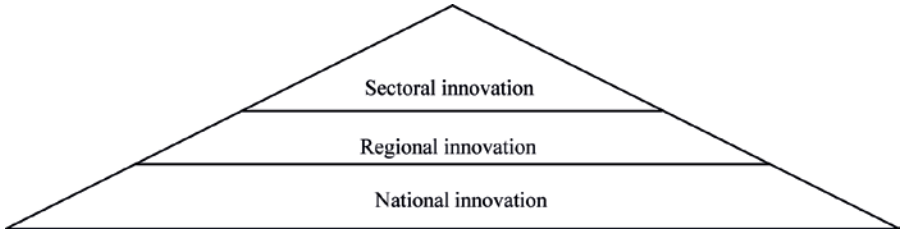


Fig. 4. Main types of innovation (Source: Todtling *et al.* 2009)

The widespread concept of the innovation economy can be understood in two ways: as analysis of meta changes caused by changes in labour costs and technological changes of processes or as analysis of technological knowledge as economic process generation (Antonelli 2009; Naštase 2013).

One of the main characteristics of innovation is risk, which is divided into several categories (Vargas-Hernandez, Garcia-Santillan 2011; Smith *et al.* 2010):

− environment (government policy, culture, exchange rates);
− technical (new methods, technologies, materials);
− resource (human, material, financial);
− integration (new and old systems);
− management (experience, technical data, human resource management);
− marketing and strategies (consumer, competitor).

Continuous integration of knowledge, technologies and innovations encourage futurists to try and create a picture of the world in several decades, after uninterrupted introduction of innovations. It is apparent that innovations would change the world completely within a few decades. The most intense changes await in a number fields: agriculture, economy, mobility, etc. Arrangement of these changes into a number of stages suggests that the world should continue moving toward sustainable development while reducing operating costs and striving for maximum benefit. Innovations would improve lives of people as all activities would be carried out faster and more efficiently; thus, attempts would be made to reduce the number of people living below the poverty threshold, making their lives easier. Continuous communication among inhabitants would foster their sense of unity. Consequently, efforts should be made to gradually transfer from inefficient economic activities sustainable development.

		People's values	Human development	Economy	Agriculture	Forests	Energy and power	Buildings	Mobility	Materials
2050 year	Our vision	One world – people and planet	Basic needs of all are met	True value, costs and profits	Enough food and biofuels through a new Green Revolution	Recovery and regeneration	Secure and sufficient supply of bw-carbon energy	Close to zero net energy buildings	Safe and low-carbon mobility	Not a particle of waste
Transformation period	Measures of success	Sustainable content, integrated to all products, services and lifestyles	Billions of people lifted out of poverty	Internalize D cost of carbon, water and other ecosystem services	Agricultural output doubled by improved land and water productivity	Deforestation halted, carbon stocks in planted forest doubled from 2010	C02 emissions Reduced by 50 % worldwide (based on 2005year level)	AD new buildings Use zero net energy	New universal access to reliable and low-carbon mobility, infrastructue and information sources	Four to tenfold improvement in the eco-efficiency of resources and materials from 2000 year
	Key problems for transformatiom period	Sustainable living becomes the base	Ecosystems and enterprises help create value	True values help drive inclusive markets	Growth in global trade, crop yield and carbon management	Momentum grows for forest protection and efficient production	Greenhouse gas emissions peak and decline	Smarter buildings, wiser users	Intelligence mobility	Closed technobgy

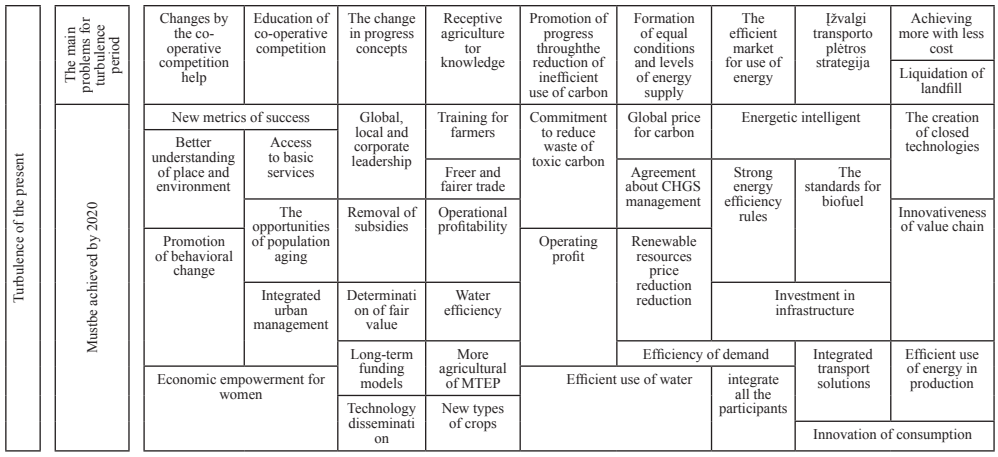


Fig. 5. Bubble of innovations (Source: Vision 2050)

Naturally, Fig. 5 is a digest of possible events. To become mature, integration of a KNIT cluster must be pointed in a required direction. To gain understanding on the dialectics of purposefully managed processes, management of the factor that creates both material and spiritual values – investments – should be explored. The next section is dedicated to the vision of a possible intelligent investment strategy that would create a physical and intellectual basis for universally sustainable development of a small country.

In the event of the need for effective risk management, the available integrated knowledge, innovation and technology cluster should be used. Generally, risk management is considered as a process for understanding unidentified future events, at the same time providing the context, defining the risk, analysing the identified risk, developing responsibility for this risk as well as controlling and monitoring it all the time, even once the project is finalised (Vargas-Hernandez, Garcia-Santillan 2011). This means that

risks can be managed only considering numerous secondary factors. As the complex system of a knowledge, innovation and technology cluster covers risks, it is imperative to take into account the factors affecting this interaction.

4. Management of financial resources for national universally sustainable development and efficient integration of knowledge, innovations and technologies

A period may be called historically significant, provided the advancement of technologies, knowledge and innovations is named as the main factor that increases business efficiency, sustainability and coherence. This is evidenced by various projects and research papers, including Lithuanian publications.

4.1. Principals and possibilities of planning financial resources for national universally sustainable development

In this work, including the sustainability analysis of business development, the authors focused on sustainability development of an economically, politically and territorially autonomous country with scientific knowledge, innovations and technological progress as the main resources, which shape or directly influence the factors of development. Special attention is given to business sustainability; however, at the same time, the authors will attempt to take account of the public sector development, the development of educational systems, and validity of other scientific decisions.

An adequate methodology will have to be employed to achieve these objectives. Additionally, the national sustainable development model will have to be specified, this way explicating links of the knowledge concept with surrounding categories, namely, information, intelligence and wisdom. This text is directly based on previous researches (Rutkauskas 2012; Rutkauskas, Račinskaja 2013); thus, pictorial representation of an intelligent investment strategy that fosters sustainable development will be used next.

Fig. 6 demonstrates the corpus of national universal sustainability components for the feasibility study on management of national universally sustainable development.

Fig. 7 illustrates the scheme for knowledge generation, design of the national universally sustainable development strategy and functional innovation and technology integration into strategy implementation.

Fig. 8 is a short digest of 12 components required for national development with their aggregation into 4 subsystems: PTV, SEE, EKR and FII.

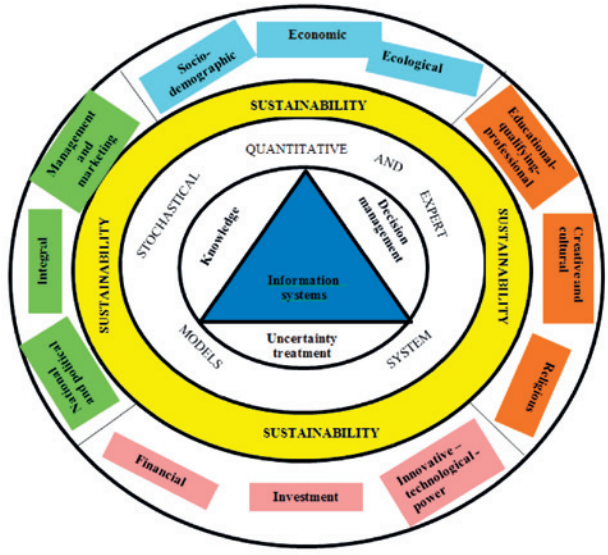


Fig. 6. Digest of national universally sustainable development components and the universe of knowledge and expert evaluations, based on development of universal sustainability management capabilities (Source: Rutkauskas 2012)

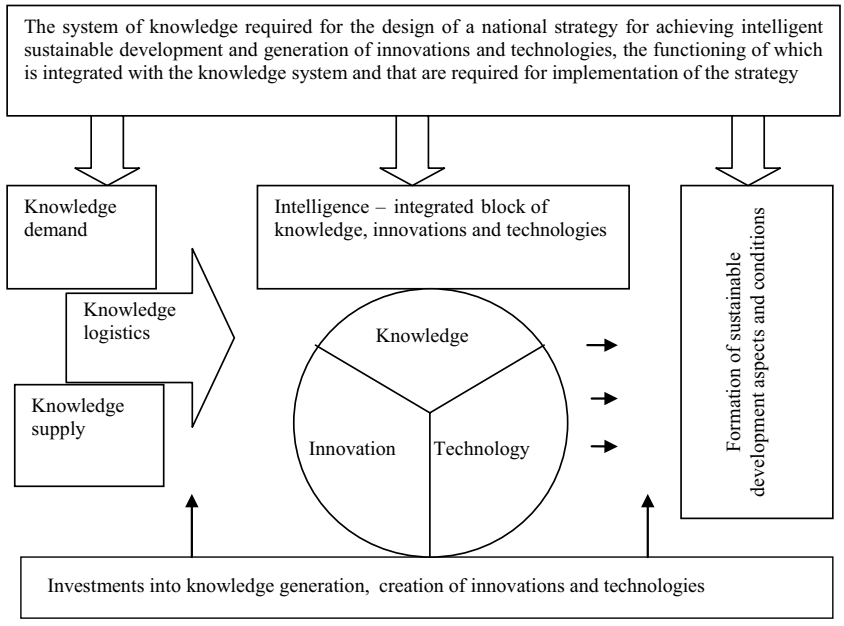


Fig. 7. The system of knowledge required for the design of a national strategy for achieving intelligent sustainable development and generation of innovations and technologies, the functioning of which is integrated with the knowledge system and that are required for implementation of the strategy (Source: Rutkauskas, Račinskaja 2013)

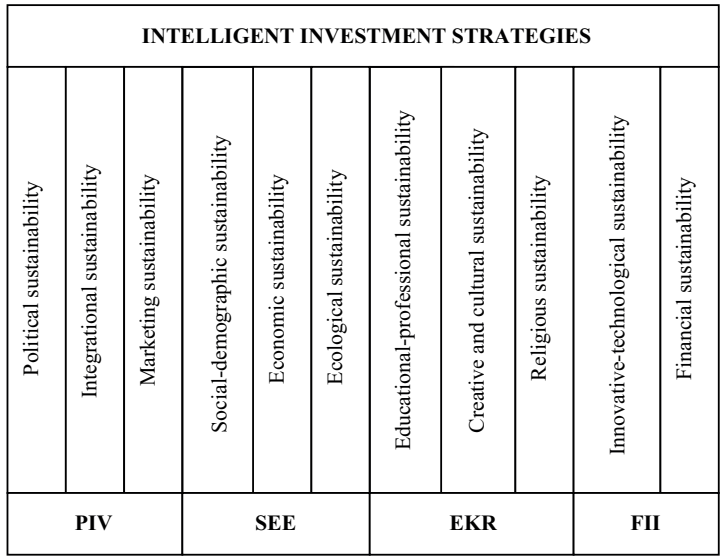


Fig. 8. Subsystems of the national universally sustainable development (Source: Rutkauskas, Račinskaja 2013)

The following brief definitions of each subsystem will be used in the article (Alam, Kabir 2013).

- Religious sustainability – is the ability of humans to accept their temporary existence on earth and indefinite existence beyond this world, recognition of spiritual values, avoidance of hostility toward religion and special focus of individual's attention on problems of a weaker and unhappier member of the society.
- Political sustainability – is a possibility to ensure democratic regeneration of national political institutions, which can guarantee representation of the public interest as well as representation of national interests in international bodies.
- Social–demographic sustainability – the ability to harmoniously reconcile different interests of various social groups, ensuring appropriate human existence conditions in every hierarchical level, and most importantly – the ability to understand the evolution of society, based on scientifically recognised regularities.
- Economic sustainability – is a consequence of the ability to rationally use internal and external resources while ensuring sustainable growth of produced economic results.
- Ecological sustainability – is usually associated with the ability to maintain the diversity of biological systems and effectiveness in the country.
- Educational-professional-creative sustainability – is the ability to combine learning, professional education and creativity in developing business analytics, creative industries and domination of creativity as well as knowledge economy, which ensures the balance between supply and demand in the labour market.
- Creative and cultural sustainability – the ability to use intellect for creation of something new that has value.

- Innovative–technological sustainability – the ability to ensure the use of most advanced technologies, which are based on most efficient innovations, in production of goods and delivery of services.
- Integration sustainability – is an insightful national integration into local, regional or global institutions of general or economic security that guarantee respective security at reasonable costs.
- Marketing sustainability – is utilisation of the national marketing power in a way that ensures sustainable flow of export and import and the development of benefits resulting from economic programmes.
- Financial sustainability – power of the financial system to ensure necessary financial resources for operation of local businesses and the public sector as well as delivery of international obligations.
- Investment sustainability – the ability to generate investment strategies that mobilise local businesses, the public sector and the society as well as offers techniques and methods for investing in a way that would ensure a possibility for future generations to fulfil their objectives (Rutkauskas 2012).

Illustration of the experimental situation with optimised allocation of resources

Based on the assumption that sustainability of national development can be examined using a model of a complex system, we have to admit that the corpus of elements existing in reality would have the following characteristic features:

- A very complex structure;
- High sensitivity to even the smallest changes in dependencies between components;
- Its identification and verification is difficult even with the knowledge of its design or function, or both;
- It is characterised by abundant interactions between different components;
- With time, it may reveal new features or states. There is no doubt that all of these characteristics are particular to the phenomenon of national sustainable development. However, if it needs to remain an open and self-regulating system, the functioning of which required resources, which may not only lead to changes in internal dependencies but also in the effect created by individual subsystems or even the entire system whilst turned into input elements, then, there should be an agreement that the system, the content of which is comprised of above-mentioned features, requires the design of adequate possibilities for its understanding and management.

Fig. 9 presents the conception of the study on interaction between subsystems as well as the universe of instruments for formulation of and search for solutions: the systems of information knowledge, management solutions, uncertainty assessment and the models of stochastic quantitative solutions and expert evaluation. However, assessment of distinct problems should be underlined as exceptional as collected and generated information is used to find interoperability between different aspects of development;

additionally, it employs methods of stochastically informative examination for expert evaluation. Annexes demonstrate differences between Fig. 9 and Fig. 6. They show that the system is focused on opportunities to conduct quantitative interviews during analysis or design of the system for national development.

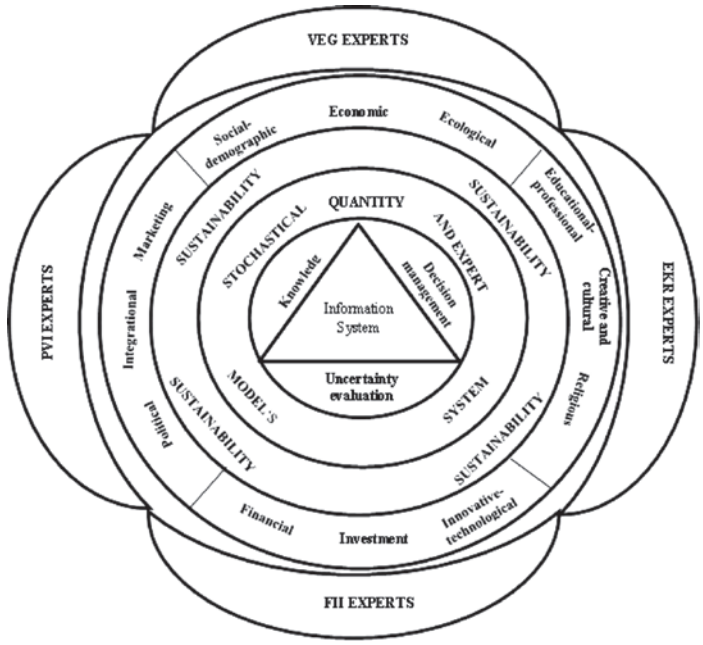


Fig. 9. Scheme depicting the development of universal sustainability components with fragments of knowledge, information and decision management systems (Source: Rutkauskas 2012)

Examining sustainable development problems in the context of methodology for complex systems, a question emerges regarding the alignment of performance measurement dimensions used for separate subsystems and the entire system. It should be reminded that sustainability measurement is two-dimensional, namely, aimed at efficiency and reliability. Reliability has a dimensionless measurement method; however, the measurement of efficiency is impossible without indicators that represent subsystems or the content of the entire system, i.e. developed product, produced crop, etc.

However, in terms of complex systems, it is possible that one subsystem's state may be another subsystem's factor and the final indicator of the entire system may be a complicated function of indicators pertaining to distinct subsystems. However, the most difficult problem arises when dealing with the fundamental economic problem of rational allocation of scarce resources aiming to direct the system toward the optimal state or trajectory.

Next, let us assume that the state of each subsystem can be measured using a dimensionless indicator while informative expert evaluation can determine the marginal efficiency of investment unit, provided it is used to develop the functionality of the i-th subsystem. This allows formulating a task: how to find the optimal allocation of resources among subsystems under conditions of uncertainty.

Let's suppose that the expert evaluation shows possibilities to utilise the marginal investment unit, observing certain investment proportions between isolated subsystems and inside the subsystems, to change the state of each subsystems index (which will be equal to one) and increase (decrease) the following stochastic multipliers:

$$D_1(a_1, S_1), D_2(a_2, S_2), D_3(a_3, S_3), D_4(a_4, S_4), \quad (1)$$

where:

a_i, S_i – are mean and standard deviations of respective random variables.

Let's try to determine the proportion, under which we can divide the marginal investment between the abstracted subsystems, if the system status indicator I is formed as a product of subsystem indicators: $I = I_1 \times I_2 \times I_3 \times I_4$

Let us consider two cases:

1. When the aforementioned multipliers are normal random variables;
2. When the situation is complicated and the aforementioned multipliers take specific forms that are typical for the subsystems.

D_1 becomes lognormal, D_2 – Gumbel distribution, D_3 – Laplace distribution and D_4 – normal.

In both cases, the distributions are governed by the following averages and standard deviations:

$a_1 = 0{,}94$, $s_1 = 0{,}03$; $a_2 = 1{,}22$, $s_2 = 0{,}06$; $a_3 = 0{,}99$, $s_2 = 0{,}05$; $a_4 = 0{,}90$, $s_4 = 0{,}02$.

The results are presented in Fig. 10. They were obtained using the logic and technique of adequate investment portfolio (Rutkauskas *et al.* 2011).

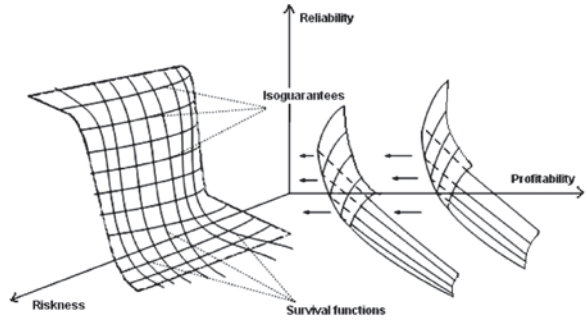
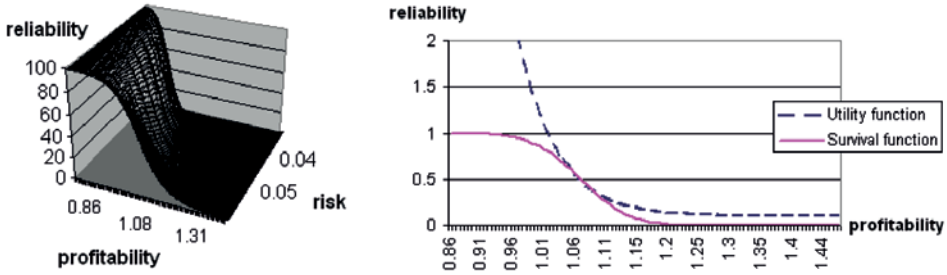
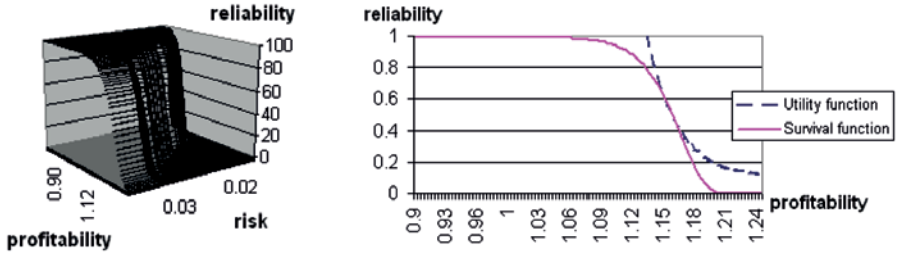


Fig. 10. General view of the three-dimensional efficient surface and respective utility functions (Source: Rutkauskas, Kvietkauskiene 2012)



a section. General scheme depicting the search for solution



b section. On the left – possible solution surfaces,
on the right – finding of a particular decision

1 case				2 case			
1active (PIV)	2 active (SEE)	3 active (EKR)	4 active (FII)	1 active (PIV)	2 active (SEE)	3 active (EKR)	4 active (FII)
The normal probability distribution				Gumbel distribution	La Place distribution	Normal distribution	Lognormal distribution
0.38	0.08	0.28	0.26	0.26	0.32	0.2	0.22
Parameters: e – 1.023116 p – 0.57 r – 0.013701				Parameters: e – 1.151202 p – 0.57 r – 0.029649			

c section. Notes of detailed decisions

Fig. 11. Optimal allocation of resources among four subsystems of universally sustainable development (Source: Rutkauskas *et al.* 2011)

4.2. Allocation of financial resources aimed at effective integration of knowledge, innovations and technologies

Moving from the analysis of possibilities to allocate financial resources aimed at the necessity of the national sustainable development to actual allocation of financial resources in pursuit of an effective integration of knowledge, innovations and technologies, the

following discussion will present the most important functions pertaining to components of the main development factor.

- Knowledge – a resource that emerges naturally, is created by humans and is continuously updated in order to:
  1) develop a full understanding of what is happening in the surrounding environment,
  2) clusterize techniques as operational measures to ensure human survival and continuity of activities,
  3) foster innovations that guarantee sustainability of development.
- The knowledge generation process, as means for complete understanding, seems to be the easiest to understand and least influenced by subjective interests. However, adequate knowledge generation remains the most important prerequisite for the efficiency of an integrated KNIT cluster, considering that inadequate knowledge could generate unperceptive technologies.
- Clusterization of knowledge into activity technologies involves abundant material and financial resources. In turn, technological knowledge clusters combine knowledge of different nature and fields. Besides, different interest groups participate subjectively in the use of technologies. Therefore, the unperceptive development of technologies can result in considerable losses for an individual entity as well as an entire activity, country or region.
- Innovation system is defined as a network of private and public institutions whose activities and interactions initiate, import, modify and insert technologies.

As already mentioned in the introductory part of the article, this section will describe experiments in finding the optimal allocation of resources for an integrated knowledge, innovation and technology cluster designed to achieve universally sustainable development in Lithuania.

Attempts to name knowledge to be generated, technologies to be implemented and innovations to be fostered in a longer perspective would end with a need for an analysis of rather debatable problems since most of already mentioned components of universally sustainable development are of social–economic nature. In this respect, identification of technologies and innovations as well as assessment of costs required for their implementation would provoke an array of problems for discussion.

Therefore, the model structure of innovative functions of the system submitted by Hekkert and Negro (2009) will be used as a rather simplified scheme for solution of the aforementioned problem, which is in this case reformulated for the feasibility study of universally sustainable development with the help of principles for stochastically informative examination used in the previous paragraph and intended for the optimal allocation of financial resources among four integrated components of universally sustainable development. The results for comparison are provided in the form of a figure that demonstrates changes in the results of expert evaluation moving

from allocation of the marginal unit of general resources to the allocation of financial resources for the complex of innovation functions in each of the modular development subsystems (see Fig. 12).

Abbreviation of a subsystem			
PIV	SEE	EKR	FII
Share per unit of subsystem			
0.31	0.19	0.26	0.24
e=1.1007	p=0.56		r= 0.331

Fig. 12. Optimal allocation of financial resources for innovation functions of four universally sustainable development subsystems

The results of Fig. 12 should be compared with the left part of Fig. 11 b. because identical distributions we used for describing the possible effect.

5. Conclusions

1. Problems that emerge while managing the sustainability of systems and processes suggest relevant tasks and tools aimed at improvement of their efficiency.
2. It is regarded that in the complex systems that are focused on creation of value (benefit) using exogenous resources, the concept of the systems' economy adjusts the concept of universally sustainable development.
3. In most cases, the integrated knowledge, innovation and technology cluster is a toolbox used by the examined system (country or region) to utilise the development powers generated by other entities.
4. In relation to the enormous potential of inertia pertaining to complex systems (country, region, the processes of globalisation), the management concept must be replaced with the concept of obedience, i.e. we have to admit the existence of powerful interaction of physical or social laws, the general management of which can only manifest as understanding and non-infringement of those laws.
5. For many small countries that do not have abundant natural resources, a strategy for universally sustainable development and an integrated KNIT cluster, which is used to populate the strategy, is an obvious alternative for the preservation of autonomy.

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