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Article

Using Sustainability Engineering to Gain Universal Sustainability Efficiency

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Abstract: The present article is an attempt to perceive the universal sustainability observable in an individual country or region, where the religious, political, social-demographic, economic, environmental, creative, technological and investment subsystems are revealed not only through the vitality of spiritual and material existence media, but rather through the signs of the development of these subsystems as self-assembled units through the erosion of their interaction. The problem of optimal allocation of investment resources among the separate sustainability's subsystems was addressed by means of expert methods and techniques of portfolio methodology which will enable the achievement of the enshrined universal sustainability standards. A country-specific index composition of sustainability subsystems' indices was chosen as the universal sustainability index for the specific country. The index in its dynamics is perceived as a random process. While projecting its state and evaluating its power, *i.e.*, the impact of the subsystem efficiency in a particular moment, this power is measured by the level of the index and the reliability or guarantee of an appropriate level. To solve the problem of investment resources allocation, the idea of Markowitz Random Field was invoked in order to reach the maximum power of sustainability index while applying the technical solution—the so-called "GoldSim" system. Engineering is a methodology that aspires to reveal the core attributes of complex systems and instruments in order to manage the possibility to influence these properties for the systems. Experimental expert evaluation and case study is performed on Lithuanian data.

Keywords: sustainability concept; sustainability intelligence; universal sustainability; sustainability engineering

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1. Introduction. Where Should the Sustainability System Evolve?

Sustainability, an activity seeking to satisfy today's current needs and also leave future generations the possibility to satisfy their needs, is the main concept of science capable of finding the solution for the relevant problem [1–5]. The concept should match its prototype in every subsystem of sustainability. Today, the category of sustainability is highly demanding, requiring the adequate appreciation and engagement in science, as well as in practice [6–12]. The credo of sustainability should be disseminated in the micro level as well. There is a need for sustainability analysis and management in protozoa germination, as well as in the evolution of the universe.

The concept and methodology of sustainable development which has provided us with a new viewpoint towards the cognition of the genetic code and a creative application of physical, biological, technological and socio-economical evolution of the system forming the strategies of its development was properly appreciated and applied in almost every area of human life: from the state of mind to the projects of saving life on the Earth and individual activity to global behavior of the world [13–18].

Sustainable development retained the knowledge of management and economic science which has endured the tests of the reality, and revealed the created credo of thought and activity—*to sustain ability for that which leads us to the future*. The concept of sustainability largely prevails in the management of scientific cognition and the universal knowledge formation.

2. The Principal Scheme for the Analysis and Management of the Development Sustainability of the Country (Region)

In the present paper, the authors have opted to use the universal concept of sustainability proposed by the authors for the 1st World Sustainability Forum [19], intended to investigate development sustainability. Figure 1 presents a slightly modified scheme disclosing the content of the concept.

Figure 1. The scheme of country (region) development sustainability analysis.

According to Figure 1, the cognition of universal sustainability is oriented towards a largely self-sufficient combination of functional components or subsystems.

Four of the earlier mentioned subsystems—the subsystem of ecological sustainability, subsystem of social-demographic sustainability, subsystem of economic sustainability and subsystem of political sustainability—are actually included into every comprehensive research case of development sustainability. The subsystems of energetic sustainability, educational-professional-creative sustainability, as well as innovative-technological and financial sustainability have been scarcely analyzed as separate subsystems of the sustainability development. For an extended period of time, the subsystem of religious development sustainability was officially recognized but the experience of the past decades has shown that this is an especially important component of development sustainability.

The specific, rarely mentioned subsystem of investment development sustainability requires a separate presentation. In this respect it should be noticed that this is the core subsystem searching for efficient sustainable development strategies. Its mission is to develop an investment structure, investment science and investment means measured up with the country's current opportunities and its future needs which would guarantee the return on the capital invested today and forming a base for the development of all functional sustainability subsystems and the guarantee for the universal sustainability of development.

2.1. Universal Sustainability as a Halo of Sustainability Subsystems

In addressing the issues related to the evaluation and management of sustainability a set of sustainabilities or a structure of universal (from the Lat. *universalis*) sustainability has been chosen revealing the possibilities to formulate and solve the specific sustainability problems. As mentioned above, usually the social, economic, ecological and political sustainability subsystems are distinguished, often—technological and religious sustainability subsystems, however, the investment sustainability subsystems are mentioned quite rarely.

Further specific characters and objectives are raised in respect of each subsystem:

- *Religious sustainability* is the possibility for the humankind to face up its temporariness of existence on Earth and interminable existence in the other world, to recognize each other's spiritual values, avoid a contraposition of religious gospel and focus everybody's exceptional attention on the weaker and the more unfortunate members of society.
- *Political sustainability* enables the citizens to ensure the democratic regeneration of a country's political institutions that what would guarantee the representation of public interests and also represent a country's interests in international institutions.
- *Social-demographic sustainability* is the possibility to harmoniously combine the different interests of all social groups, ensuring proper conditions of human existence on the ground level of hierarchy and, what is most important—the ability to develop the society evolution under a number of scientifically recognized consistent patterns.
- *Innovative-technological sustainability* is the ability to ensure the renewal of technologies used to produce products and services with the help of the most efficient innovations.
- *Educational-professional-creative sustainability* is the ability to combine learning, professional education and creativity to nurture business intelligence, development of creative industries,

and the dominance of creativity and knowledge economy, as well as to ensure the balance of supply and demand in the labor market.

- *Ecological sustainability* is most often referred to as a possibility to sustain bio-system diversity and efficiency.
- *Economic sustainability* is the ability to satisfy the needs of country maximizing the use of its resources at the same time invoking international communication and support opportunities.
- *Energy sustainability* is the primary base for sustainability and efficiency of economic and social processes.
- *Financial sustainability* is the power of financial system to supply the country with financial resources, form economic interests of the economy and social subjects, and guarantee a rational use of material resources.
- *Investment sustainability* is the ability to generate the investment strategies that would mobilize the country's business, its public sector and society at large, while proposing the ways and methods for the capital invested in the past to ensure the possibilities for future generations to reach their objectives.

The main objective of each universal sustainability subsystem could be understood as a subsystem's ability to robustly maintain the core system parameter's level above the critical threshold; if it fell below this level, the subsystem would start losing its resilience. However, undoubtedly the main question remains outstanding, *i.e.*, what kind of ability the universal sustainability should foster, *i.e.*, the resultant of all sustainability subsystems. Searching for the answer to this question unambiguously brings about the idea that this feature conceptually should be understood as the preservation of the subsystems' ability to interact. Actually, the necessity of such a feature is being explored by analyzing the environmental sustainability individually, as well as other sustainability subsystems. However, for individual subsystems the interaction of their elements or subsystems is conceptually more perceivable and unfolding for management. In the case of universal sustainability there is a need for the formation of the perfect concept of interaction, as well as for the preparation of engineering foundations of interaction.

The key tasks here are to understand the content, methods and consequences of universal sustainability and be able to adequately simulate those processes in order to create the assumptions for the specialists of various subsystems to consider them on the basis of the available quantitative information.

Considerations about the universal sustainability apprehension and fostering are not abundant and one-directional, furthermore, they are not practically constructive. The ESI (Environmental Sustainability Index) was published in 1999–2005 [20]. However, it was rather a measurement of environmental parameters of the State or estimates which are more suitable for comparing the environmental condition of different countries. Later, it was substituted by the EPI (Environmental Performance Index) [21–24], and as the name asserts it seeks to become an instrument for the research of sustainability's anatomy.

2.2. Investment as a Constructive Discussion with the Future

The investment subsystem which gained an exceptional position on the mentioned scheme also performs an exceptional function—to mobilize the resources necessary for maintaining the main functions of the mentioned subsystems, and to strengthen their interaction. Here, the focus should not be placed on exceptionality, however, inopportune attention to the saving of sustainability powers renders an account for expenses which can become crippling for mankind.

Investment can and must be perceived as a discussion of the present with the future, when the past and the present leave the created assets, as well as the inevitably growing liabilities for the future. Moreover, the investment scope and structure is concurrent to the evaluation of powers accumulated in the past and to the amount of liabilities included into the country or region development balance.

The condition of the investment sustainability subsystem is related to the condition of all development subsystems. In addition, the nurturance of every sustainability subsystem is based on the ability of the investment subsystem to enhance the power of the currently invested capital in every sustainability subsystem distinguished. It is further worth noticing that the investment subsystem reveals the essence of the sustainability concept in the most natural way.

Is the capital invested today capable of giving the required return in the future, will we be able to bear the growing burden of liabilities?

A deeper analysis of financial and economic crises, including today's processes shows that investment is losing its ability to efficiently use the accumulated and natural resources.

Indeed, what kind of balance of liabilities and assets we have today and what will be left for the future? What should be done in order to retain the power of invested capital and make it grow in every sustainability subsystem? It is almost clear that even global investment strategies and policies increasingly approach the inability to settle the assumed liabilities. The trend concerns virtually every subsystem. The elementary accounting allows us to make a conclusion that insolvency, and, further, bankruptcy is approaching.

It is not difficult to understand that the constructive dialogue with the future, or a rational investment strategy, is a prerequisite to assure the development sustainability for every country or region.

3. The Essence, Nature and Anatomy of the Concept of Sustainability

Losing the sustainability power in any universal sustainability subsystem creates a threat of catastrophic losses for any country or region; however, the possibility or even realization does not provide sufficient information about how the sustainability power should be fostered.

In order to use the adequate methodology to formulate the decisions of system analysis and management it is necessary:

- to understand the essence, nature and anatomy of the sustainability concept;
- to be able to quantitatively measure the power of sustainability;
- to be able to relate the positive changes of sustainability power with the required volume and structure of the resources;
- to be able to understand the link of universal sustainability power with sustainability subsystems' powers and the possibilities of interaction of these subsystems;

- to be able to disclose the optimal resource allocation among separate subsystems in order to reach the maximum power of universal sustainability.

An analysis of such issues may turn into a quite risky task as they are widely covered in research literature and the number of unanswered or even unanswerable questions is not decreasing. However, some major issues have to be addressed in order to take the five steps referred to earlier.

3.1. Theoretical Background for Sustainability Development Research

First, the principal question that arises is whether sustainability is a category of evolution or development, *i.e.*, are there any objectively existing characteristics of naturally composed processes and systems, including social, and consistent patterns displayed in the evolution of processes and systems, or is it just a personal understanding? Of course, it may be concluded that categorizing sustainability has brought about an evolution of thinking for mankind, and that a category of sustainability should be accepted as a category of development.

Second, is sustainability an attribute of power, *i.e.*, does a higher degree of sustainability stipulate higher productivity? Thus, this characteristic can disappear as a consequence of the system or process development or evolution. Still, it is especially important to perceive if sustainability is only the informational characteristic, which informs environment about its presence, or it is a feature of power, the degree of which informs about the usefulness of a system or process. This information is important in relation to any attempt to measure sustainability.

The theoretical conclusions of thinking, stating that: "sustainability assessment has recently emerged as policy tool, whose fundamental purpose is to direct planning and decision making towards sustainability", along with practical selection of sustainability index models ensures that for sustainability, as a characteristic of a state, the feature of power is also assigned.

However, when the past or the present moment is considered, the power, as well as other features, can be measured with a certain adequately determined indicator. But when it comes to the future, the indicator of real power should be supplemented by the probability of its achievement, or simply it should be expressed as a probability distribution of the indicator of the power of the possibilities of sustainability.

The research attempts to analyze the situation analogical to our formulated problem apply the logics of the so-called survival function which organically combines the magnitude of power and the probability of that magnitude. For every population, its quantity is a natural characteristic of the population's vitality, along with the biology and environment, where the existing population generates the quantity k critical for the population. Where the population falls below this value it loses its ability to reproduce.

If the mentioned universal sustainability subsystem possesses the indicator of its efficiency power S^i, and it drops to level S_k^i, critical for the subsystem, the subsystem loses its main characteristic—the ability to remain renewable. This means that the logics of fostering of the population's evolution sustainability could be shifted to the universal sustainability subsystems management.

If the critical level of indicator, describing the power of subsystem, equals Ski, and it is assumed that the possibilities of indicator in the future can be perceived as the realization of a random process, then our aim could be perceived as actions guaranteeing that:

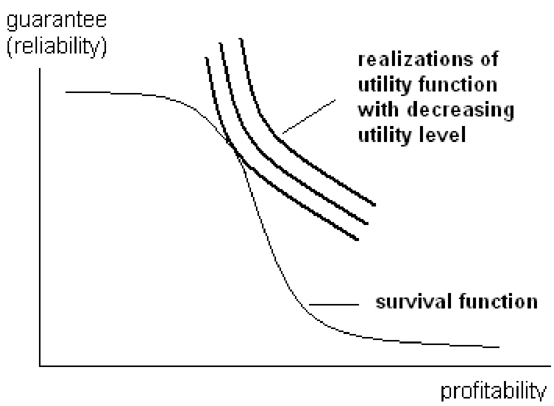
$$P\{\xi^i \geq S_k^i\} = \beta_k^i \quad (1)$$

where:

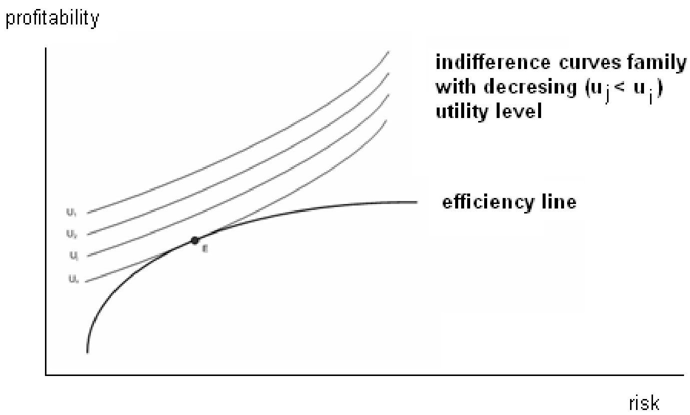
ξ^i —current quantity of population members;
S_k^i—critical index value;
β—guarantee level.

It follows that the guarantee that a subsystem's sustainability index that will not drop below the critical threshold is of a desired level. Geometrically (Figure 2 (**a**)) this logic is fully disclosed by the graphical view of the so-called survival function. Here, the abscissa shows the possible sustainability index values S^i, and in the ordinate axis—the values of probabilities $P\{\xi^i \geq S_k^i\}$, where S_k^i is the critical index value.

Figure 2. The main moments of the optimization on the efficient surface [25]. (**a**) selection of an optimal ratio between profitability and reliability; (**b**) selection of an optimal ratio between profitability and risk.



(**a**)



(**b**)

The geometrical view of the survival function leads to further contemplation. Let the sustainability index level influence the efficiency of the subsystem and demand certain expenses after having reached the desired guarantee level. Then naturally a problem arises—what level of sustainability index is the most useful for the subsystem? And, more generally, what universal level of sustainability index in the most useful for the entire sustainability system?

The problems of profitability, reliability and risk management can be coherently investigated using the concept and technique of the adequate portfolio [22–24]. The issue will be addressed in the following section of the paper.

3.2. Uncertainty as a Permanent State of Systems and Processes

Uncertainty is a natural state of many systems and processes. However, often such expressions as optimal decisions with regard to uncertainty or stochastic optimization, *etc*. need additional explanation or special consideration.

First of all, it is the matching of the determined state of the present and the past with the uncertainty of the future. It seems that while switching to the perspective we simply wade into the reality of uncertainty. Suppose we know that today a roll costs 1 LTL and feeling the tendencies of price increase, we do not decide and we would not succeed to evaluate unambiguously the price of the roll one year later.

Probably the most popular, but not a unique method for constructive analysis of the future price possibilities one year later is the probability theory that involves the analysis of the possibilities of the forecasted prices by evaluating their realization probability. These assumptions seems to be elementary with regard to reality, however, they need completely new thinking. In effect, when we have a preconceived assumption that we are interested in a possibility of particular value, then the objective, and often even the means of its attainment become clear—there is a need to minimize any possible risk. Almost the same way of problem solving is in case we are already limited by the level of risk—then we readily choose the biggest possibility of not exceeding the particular level of risk.

But where we have to consider the selection of the pair of best possibility and its riskiness, there is a need for completely new assumptions. There is no doubt that rationality of the choice depends on the subject performing selection. However, often in taking decisions or formulating decision-making strategies riskiness is identified with risk, and the abilities of a subject to respond to risk are not taken into account.

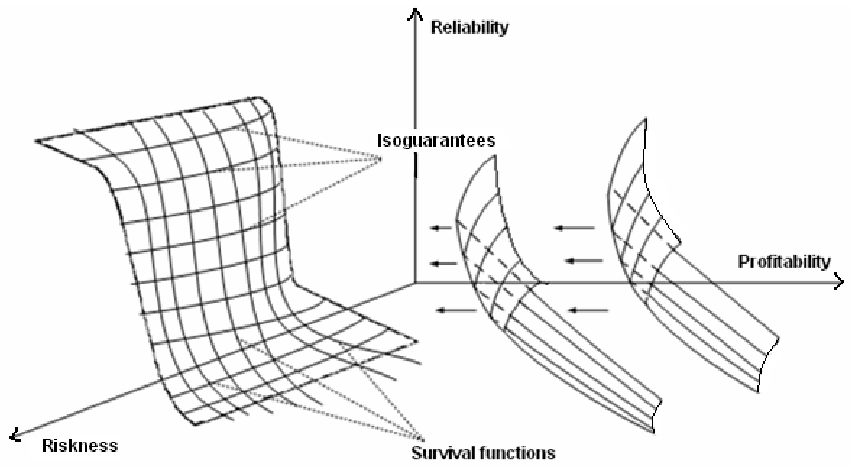
In many cases at least partly related to investment portfolio management the resulting situation is as shown in Figure 3.

On this three-dimensional surface we can analyze all existing dependencies among profitability, guarantee and the risk when the survival functions react to investors' possibilities to respond to the risk.

The exceptional dependencies are the selection of optimal ratio between profitability and reliability (Figure 2(**a**)) and determination of an optimal ratio between the profitability and riskiness (Figure 2(**b**)).

On the spatial utility function (Figure 2) these moments are integrated and optimization is performed according three criteria: profitability, reliability (guarantee) and riskiness (risk). Given that the portfolio actually is a multifactor function, Figure 3 presents the multi-criteria optimization case of a multi-factoral stochastic function.

Figure 3 The general view of three-dimensional efficient surface and respective utility functions [22].



4. The Problems of the Assessment of the Universal Sustainability

Interaction or the ability to interact—is there a difference? The question often arises when analyzing the development of the interaction between separate subsystems of sustainability. In previous chapters of the paper an attempt was made to perceive if the content of universal sustainability and interaction of sustainability subsystems are the encoded principles of evolution, or rather a subjective target desire. Until recently the content of sustainability definition was illustrated by consequences accompanying the results of human activity. Meeting the growing needs of mankind in view of the population increase and the irrational exploitation of resources is indicative of possible catastrophic results in the future. It mostly happens because the conservators of the content of the sustainability category were not claiming to turn it into scientific category. As has been earlier noted [26,27] there is an emerging area called sustainability science. Though sustainability is not yet an autonomous discipline in its perception field or knowledge extension it has been perceived to be problem-driven and seen as a network of aims, oriented towards guiding the decision-making. There is still hope and necessity that the knowledge about the interaction of the individual subsystems of sustainability will become the first and most important problem of this science.

Measuring, analysis and management of the individual subsystems, and especially the powers of sustainability is not limited to the mechanical changing of indicators. Assuming a country's volume of National Product (NP) per capita does not decrease—this does not mean that its social sustainability power does not change if in that period 10% of the most qualified workforce has left the country.

The sources of the subsystems' sustainability powers mainly lie in their interaction. Thus, in assessing resources needed for subsystems', e.g., for natural environment sustainability power maintenance, it is often necessary to take from other subsystems, for example, economic subsystems. Probably because of this even having detailed enough and functionally adequate description of country economic, social, political, religious, ecological and investment processes, one should apply experts or even expert systems that are able to form an additional feeling for determining and solving complex sustainability problems. Also, the expert examination results often have to be thoroughly assessed.

The author of the present paper, probably like many others analyzing the situation in a country or certain issues related to the country's development sustainability does not seek to leave the ambition that this is an especially important scientific problem. Of course, this is a complex problem, but discussing whether this is a classic scientific problem, it is also worth recalling other reality cognition means that are applied for complex systems' analysis,—namely, engineering. The delicate comparison of these two systems can lead to a conclusion that science explores the reality as it is, while engineering—as we want it to be. Probably, the authors ready to analyze the possibilities of the country or its certain structures' development sustainability will not change if it appears to be the object of engineering research. In addition, it is worth noticing that this is not engineering in the sense of competences of a particular engineer profession, but it is engineering in the sense of the application of science to the optimum conversion of natural resources to the use of the mankind.

Probably the "archimportant" problem is the formation of the model of a subject, process or system. Subchapter 2.1 stated that the mentioned index must adequately reflect the real power of the subject, process or system to implement its functions while rationally using required resources. There should be an indicator adequately reacting to the marginal efforts to increase the system's power and first of all to ensure the efficient interaction between the individual subsystems. Thus, a universal sustainability index should be the adequate composition of indices of the subsystems determining universal sustainability.

Assuming that there is a place for engineering philosophy and methods in cognition of sustainability, it may be assumed that for sustainability of religious, political, social, economical, ecological and investment subsystems as for natural purposes of these systems' management, integrating public, the EU support and business funds, the particular fund for each EU member is formed, which can be disposed by the country distributing it among the mentioned subsystems and thus reaching the desired changes in the universal sustainability index. With the help of specific measurements obtained from lower level subsystems and based on expert evaluation, we can assess how the usage of the marginal financial unit impacts the changes in the indices of every sustainability subsystem. The science of economics has been generating a set of indexes, describing the power of each subsystem and the subsystems' dependence on the main factors which in most cases are being formed in other subsystems. The primary task of the author is to identify those indexes that would allow adequately describe the power of functions of each subsystem. This impact is estimated as a stochastic variable in the indices of subsystems. The index of universal sustainability is embraced as a production of the sustainability indices of all subsystems which supports the presumption that universal sustainability accumulates changes of all systems.

Note 1. In this case the coefficient c is the bearer of changes; and is used as a multiplier of the existing index value.

$$C = \prod_{i=1}^{n} D(a_{si}, \sigma_{si})^{w_i} \tag{2}$$

where:

D—is the form of probability distribution adequate to the index marginal change in the i^{-th} subsystem under the description of state *s*;

σ_{si}—the standard deviation of the mentioned distribution;
m_{si}—the mean value of the mentioned distribution;
s—the state where the marginal change is analysed;
i—the number of subsystem.

The expert valuations for Lithuanian case determined the following values of the coefficients:

D_1 (0.99; 0.13)—for social-demographic subsystem;
D_2 (1.02; 0.04)—for ecological subsystem;
D_3 (0.96; 0.12)—for economic subsystem;
D_4 (0.93; 0.11)—for political subsystem;
D_5 (0.9; 0.1)—for creative subsystem;
D_6 (1.05; 0.5)—for technological subsystem;
D_7 (0.8; 0.1)—for energy subsystem;
D_8 (0.75; 0.15)—for financial subsystem;
D_9 (0.85; 0.12)—for investment subsystem.

Note 2. It was presumed that for the initial situation, *i.e.*, for the mentioned situation s, the indices of subsystems equal 1. Also, concerning the religious sustainability expert opinions diverged therefore it was excluded.

The possibilities of universal index are characterized by the extent in the index change, as well as by the reliability of the change and by the riskiness. It is obvious that we have to know how to select the possibility which guarantees the maximum increase of index powers. The power of index is calculated with the help of the utility function analogue:

$$U = u(e, p, r) = \frac{ep_e}{r_e} \quad (3)$$

where:

e—value of index change possibility;
p—guarantee of the possibility;
r—riskiness of possibilities' set.

5. Engineering as a Suitable Instrument for the Promotion of Sustainability

Recalling the discussion commenced earlier, when questioning if sustainability is the main attribute of development, or it is a subjective conviction of development agents, it is worth refering to the idea of Theodore Van Karman [28] that "Scientists study the world as it is; engineers the world that has never been". May be, this idea could be corrected in the same time not offending nor Theodore Van Karman, nor the engineers in such a manner: "Science studies the world as it is, while engineers—the world that they can create".

In his research paper, Vincent Walter [29] has stated that the world of engineering research differs from scientific research. First, engineering usually considers situations where the basic knowledge of physics or chemistry is well-perceived, but problems are too complex for accurate decision finding.

Theodore Van Karman claims the existence of an overlap between the research and engineering practices; in engineering one can apply science. Both areas endeavor to rely on accurate observations of materials and phenomena, both use mathematics and classification criteria to analyze and commensurate observations.

By its nature engineering is bound up with society and human behavior. Engineering is a subject that ranges from large-scale collaboration to limited coverage individual projects. Almost all engineering projects are dependent on some sort of a financing agency: a company, a set of investors or a government. The few types of engineering that are minimally constrained by such issues are pro bono engineering and open design engineering.

To resume the above, it should be noted that engineering is the discipline, art, skill and profession of acquiring and applying scientific, mathematical, economic, social and practical knowledge in order to design and build structures, machines, systems, materials, devices and processes that safely realize the improvements to the lives of people.

Sustainability is the state of systems and processes that could serve for safety and efficiency and should be gained with the help of engineering.

5.1. Has the Problem of Sustainability Management Already Solved

Keith Campbell [30] in his paper "Sustainability—Engineering for the rest of us" resumes that sustainability is about the same things as engineering—achieving the targets in responsible ways. A capital project is about achieving a specified objective in a way that produces maximum return on investment. This requires minimizing the consumption of resources, basically matter and energy, over the lifetime of the product or process. This is what engineers are trained to do, and this is why many of them are having difficulties coming to terms with the concept of sustainability—to them that is no news.

Further, Keith Campbell supposes that engineers are naturally trained to perform in a sustainable way. Their education is steeped in an understanding of conservation laws and equations involving matter and energy. Differential calculus is about evaluating and finding minimums. Give engineers a challenge to find solutions that utilize minimum resources and they will jump right on it. But sometimes they find their efforts thwarted.

To point out the oneness of engineering thinking Keith Campbell claims that "During my career in project engineering, we were encouraged or expected to take courses with titles such as "Marketing for non-Marketers" or "Finance for the non-Financial". I don't ever remember a course on "Engineering for the non-Engineer". Perhaps had such courses been required sustainability would have been easier for many to embrace. Is sustainability really about engineering for all of us? Maybe sustainability gives us all a chance to dabble a bit in engineering principles without looking nerdy."

Apparently, since sustainability is the way of existence, *i.e.*, system or process state category and engineering is the way of action these ways ought to go side by side. However, they both need additional attention.

The state of universal sustainability requires its full-rate subsystem interaction recognition, engineering practically does not exploit the formation of concerns and their usage in pursuance of the management strategy preparation of the desired system or process.

5.2. Step-by-Step to Sustainability Management

In the previous chapter, the preparation of principles for system's sustainability power management was discussed assuming that the index is a real indicator of subsystem sustainability power, but its projection for the future can be accepted as a preparation for a random process management. For every universal sustainability subsystem out of the six influencing the power of universal sustainability, the concept and application principles of survival function were formed with regard to fostering sustainability powers of the subsystem.

How should the selection of sequence of steps for universal sustainability power fostering start? Probably, the first step should be the assigning of universal sustainability index Su to a certain function of universal sustainability—the index of subsystem. The universal sustainability index S_u will be treated as a product of the subsystem's sustainability indices:

$$S_u = \prod_{r=1}^{6} S_i^{ai} \quad (4)$$

where:

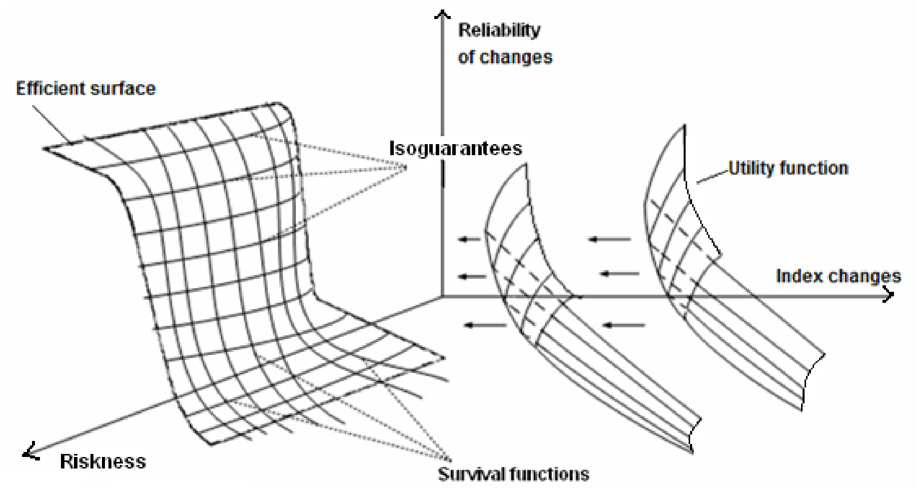
$$\sum_{i=1}^{6} a_i = 1 .$$

Actually this is quite a reasonable step, because the index S_u, as well as the index S_i is treated here as probability distributions of index possibilities. Therefore, the product serves as a certification that S_u is the result of S_i, i = 1, 2,…, 6 subsystems' combined operation.

Following the example of the stochastic optimization for investment portfolio formation and application, we will construct an efficient surface and respective utility functions in the three-dimensional space for our case.

However, if in the case of investment portfolio efficient surface is composed out of profitability possibilities, measured with the magnitude, reliability and riskiness of this possibility, in the analyzed case the surface is composed of the sustainability subsystems' portfolio or, simply, universal sustainability index changes which are raised by additional marginal unit of expenses for sustainability index maintenance (Figure 4).

Figure 4. The idealized view (scheme) of the efficient surface and utility functions of universal sustainability index changes.

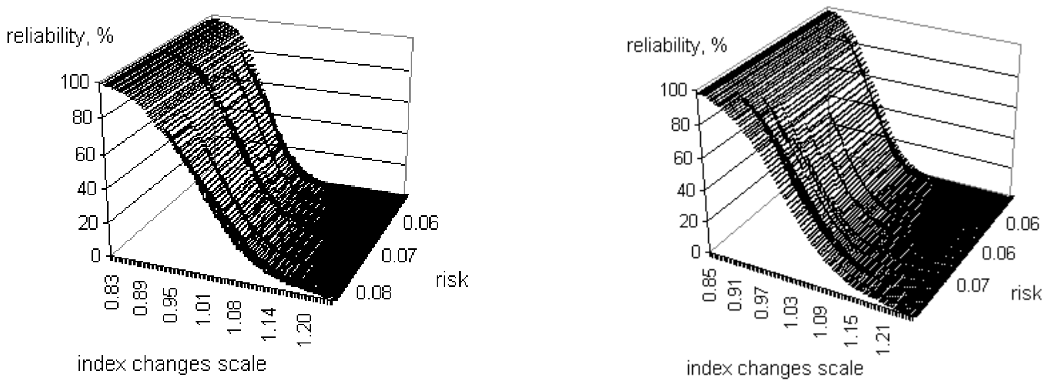


Thus the projecting of these changes is performed according to the same three measurements as in the case of investment portfolio profitability.

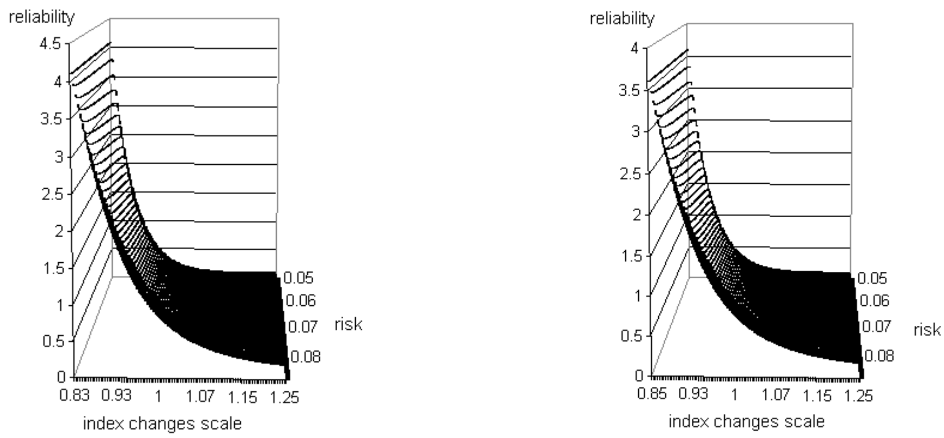
5.3. Case Study

We will come back to the analysis of the particular data which was presented in Subchapter 4.1. The Lithuanian case is analyzed. Using the data we will present the efficient surface (Figure 5 (**a**)), utility functions (Figure 5 (**b**)), the general view of utility functions and efficient surface (Figure 5 (**c**)), and, finally, the finding of the intersection of efficient surface with utility function, *i.e.*, the optimal decision (Figure 5 (**d**)). On the left side the graphs are presented when the coefficients set by the experts in Subchapter 4.1 conform to the Normal probability distribution of possibilities, and on the right side—when these coefficients conform to the Lognormal probability distribution of possibilities. In both cases the mean value and standard deviation of possibility are the same values. This allows us to observe the extent to which the decisions taken are sensitive to the nature of the probability distribution of possibilities.

Figure 5. (**a**) Efficient surfaces. (**b**) Dimensional view of utility functions. (**c**) The intersection moments of possibilities' set and utility functions. (**d**) Particular points of intersection. (**e**) Intersection points in Normal and Lognormal case including the risk coefficient 2 in the utility function. *Note:* on the left side—Normal probability distribution, on the right side—Lognormal probability distribution.

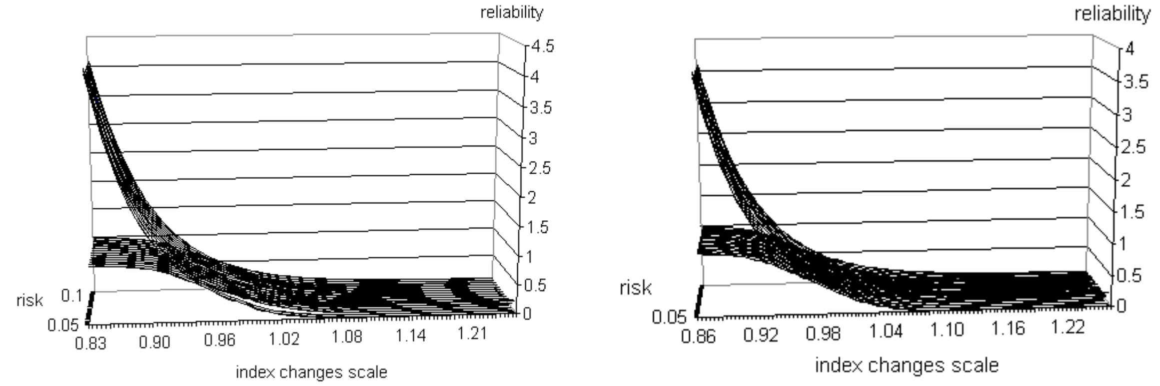


(**a**)

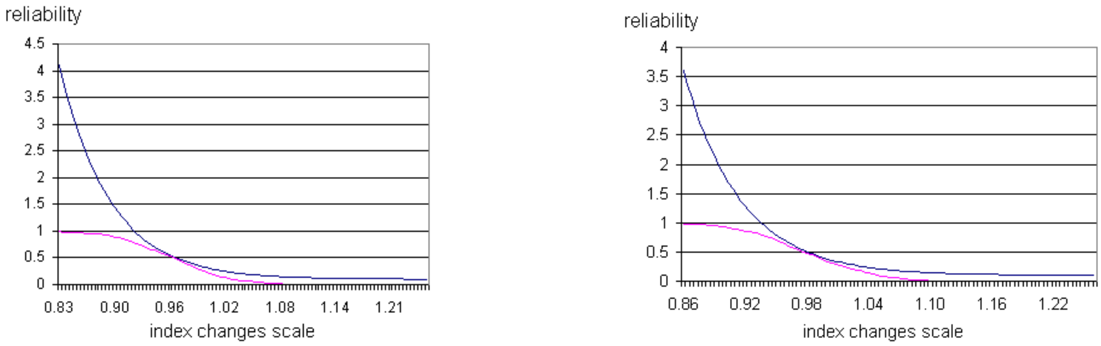


(**b**)

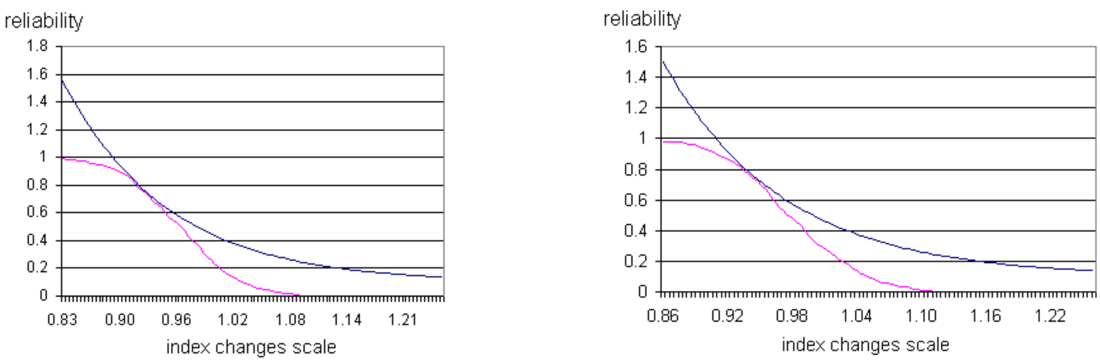
Figure 5. *Cont.*



(**c**)



(**d**)



(**e**)

Figure 5 (**e**) shows the moment of optimal decision finding for both analyzed cases when the risk coefficient in the utility function is set 2.

According to their analytical form, random efficient surfaces and utility functions are convex surfaces with regard to each other. Since for the existence of a decision and its finding this is the principal moment, we admit that the situation presented in Figure 6 can also be an alternative to the surfaces convex with regard to each other.

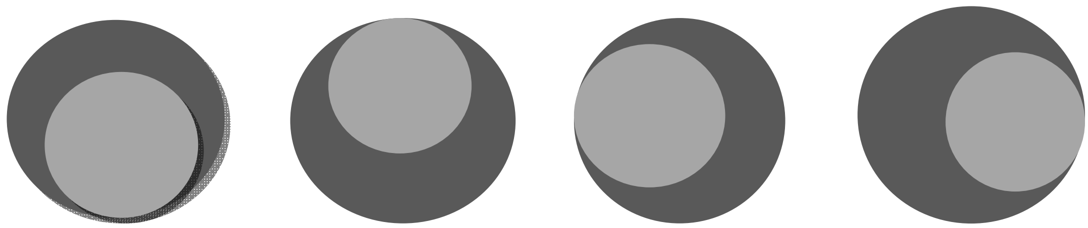
From Figure 5 we can see that coordinates of optimal decision in the case when risk is identified with riskiness differs only slightly and in completely explicit direction, according Figure 3 (**a**).

Furthermore, we have presented the values of the main parameters of every case out of four intersection points analyzed (Table 1). It is clear that by increasing the impact of riskiness in utility function, the maximum utility value decreases.

Table 1. The values of parameters of the intersection points (optimal decisions) of possibilities' set and utility function.

Parameter	Normal probability distribution	Lognormal probability distribution
Usual impact of risk		
Index value	0.96	0.98
Riskiness	0.056	0.056
Reliability	0.48	0.47
Impact of risk doubled		
Index value	0.91	0.93
Riskiness	0.056	0.056
Reliability	0.85	0.83

Figure 6. Non-typical geometric view of mutually convex surfaces.



However, to assume that the argument of utility function becomes a function of riskiness (in the analyzed case it is assumed that risk equals the riskiness multiplied by 2), allows us to see significant changes in the situation of coordinates of optimal point on the efficient surface. We see that the value of utility function decreased in Normal and Lognormal distribution case.

In fact, the intersection of possibilities' set (surface) with utility surface is apparently not perceived. There are possible cases when the surface of possibilities—the external ring, and the utility surface—the internal ring, and their intersection resembles the situation depicted in Figure 6. However, obviously, even in this case, the intersection of these surfaces results in a unique possible solution.

6. Conclusions

1. The concept of sustainability, which brings the credo "to sustain ability for that which leads us to the future", fosters the formation of scientific knowledge field named the development sustainability.
2. The universal scheme of country (region) development sustainability distinguishes the following subsystems: social-demographic, economic, ecological, political, technological, religious and creative sustainability, the synergized operation of which makes it possible to retain and improve the general sustainability power.

3. Sustainability can be explained as the state of systems and processes that could serve for safety and efficiency and should be gained with the help of engineering philosophy and methodology.
4. Expert systems and simulation technologies are capable means of solving the tasks of optimal allocation of resources, in particular, for determining the coefficients and parameters of the probability distribution of sustainability effect and their function.
5. To address the problem of financial resources allocation among different sustainability subsystems the idea, concept and technique of adequate portfolio was invoked in order to reach the maximum power of the sustainability index.

Conflict of Interest

The author declares no conflict of interest.

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