Transdisciplinary Science Methodology as a Necessary Condition in Research and Education

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Traditional methods are not sufficient to deal with highly complex questions of modern world. Transdisciplinarity is mandatory to understand and solve those problems, which exist within the domain of multiple disciplines. Subsets' optimal does not always equal to the optimal of the general system set structure. Transdisciplinary approach is mainly focuses on a process of synthesis and aims to reach set optimal. The amount of data produced and distributed through modern communication channels is huge and remarkable percentage of this data is not genuine. That leads to a phenomena which is called information distortion. To minimize information distortion and maximize information security principles of hermeneutics must be embraced. A transdisciplinary approach in education is required to educate future generations to deal with complex problems of the world. The dominant system of the world is System 2, which is driven by power and money. The dominance of System 2 causes serious problems at world level like conflicts, wars, human traffic, drug traffic and degradation of natural resources use. To prevent such problems and to solve the existing ones System 1, which is based on science, technology, innovation and uses ethics as a constant, should be embraced as the dominant world system.

Keywords: A-STEM-H, transdisciplinary domain, trans-sector, transdisciplinary curriculum.

1 Introduction

The scope of science and its structure is constantly changing and evolving. As the science progresses over the time, it has to deal with more complicated issues and manage to come up with minimum error margin to scientific explanations and solutions. Due to the iterative and evolutionary nature of science, in time dynamics, more complex ones emerge. Most of the complex scientific issues exist in the domain of multi scientific disciplines.

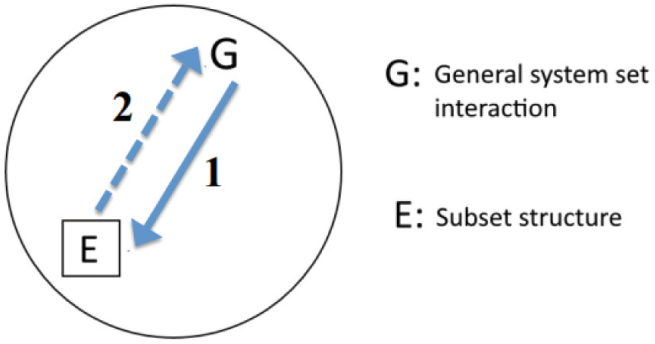

Figure 1: General system set interaction and subset structure (Güvenen, 2000).

To deal with sophisticated questions with high degree of complexity, requires the cooperation of multiple scientific disciplines. It needs to be targeted to the problem, analyse, interpret, converge to solutions with an iterative transdisciplinary approach which endogenize various disciplines.

The complex scientific issues that deals with multiple disciplines used in general the following approaches:

- Intradisciplinary Science Metholodgy
- Interdisciplinary Science Methodology
- Multidisciplinary Science Methodology
- Transdisciplinary Science Methodology

Intradisciplinary Science Methodology: Science methodology which concentrates on research and education systems within the same scientific discipline.

Interdisciplinary Science Methodology: Researchers interact with the goal of transferring knowledge from one discipline to another. Allows researchers to inform each others work and compare individual findings.

Multidisciplinary (Pluridisciplinary) Science Methodology: Researchers from a variety of disciplines work together at some point during a project, but have separate questions, separate conclusions, and disseminate in different journals. It is dominantly a synthesis approach.

Transdisciplinary Science Methodology: It can be defined by following points:

- Being targeted to complex phenomena
- Working in an iterative approach
- Continuous cooperation of various sciences and disciplines converging to the solution of determined problem.

Figure 1 [1] shows the interactions between set structure and subset structures. As it is well known, the sum of the subsets' optimal is not equal to the set optimal. This theorem can be summarized with the formula below:

$$\sum \text{subset}' \text{ optimal} \neq \text{Set Optimal}$$

In the light of the information provided by the theorem it is possible to estimate that both approaches, interdisciplinarity and multidisciplinarity (pluridisciplinarity), leads to solutions which are under optimal and cannot use the full potential of the scientific disciplines which are used in research and education. To converge to the optimal solution, the transdisciplinary science methodology can be considered as a necessary condition.

In Arise 2 report by American Academy of Arts and Sciences there is an important observation which is : "Efforts to take advantage of these opportunities, however, have met significant barriers. The current organization of the research sector complicates communication and collaboration across disciplines. Furthermore, fundamental advances are not being translated efficiently into new products and services." [2] This observation clearly states that lack of proper communication and low level cooperation between different sciences and disciplines causes serious problems to converge to optimal solutions. Joseph E. Brenner describes transdisciplinarity as being supported by three major conceptual "pillars" which are complexity, levels of reality and logic of the included middle or third [3]. He asserts that

the general methodology of the transdisciplinarity is based on those three conceptual pillars and the roots of those pillars lie within the domain of modern science.

2 Transdisciplinary Science Methodology , Information Systems, Big Data and Information Distortion Interactions

As it has been previously mentioned above both interdisciplinary and pluridisciplinary methodologies obtain general scientific data from each discipline as the first step in research. They combine the obtained data, make a synthesis and come up with a final result. The limited interaction of these approaches causes under optimal result; because the sum of subsets' optima usually isn't equal into being set optimal. Interdisciplinary and multidisciplinary (pluridisciplinary) approach focus on the subset and partial analysis which lead to quasi systematic and under optimal end solutions in social sciences because of not comprehending the properties of social phenomena.

There are three main structural properties of social phenomena. These are:

- Mathematical complexity
- Mathematical chaos
- Low predictability

To understand the true nature and essence of systems that social sciences deal with, it is important to consider all these factors together.

It is important to develop an exterior point of view to see the set structure and create an optimal solution in the light of the factors mentioned above. It is not possible to solve a problem of a specific discipline by using only the data and methods of that scientific discipline. Input from various other scientific disciplines and contribution of scientists with different sets of skills are required to come up with an optimal solution.

Transdisciplinary research includes the key components of interdisciplinarity, along with the incorporation of external nonacademic knowledge, applied to solve practical problems. Transdisciplinary research leads to a creation of new paradigms and provides pathways to new frontiers. Atilla Ertas states that transdisciplinary research includes key components of interdisciplinarity with the support of non-academic knowledge which forms an application to solve practical problems; thus trandisciplinary research changes paradigms and forms new frontiers [4].

The structures involved with science, society and especially individual are known for being mathematically complex, chaotic and low predictability. If we consider these structures as functions of "n" variables tends to the infinity. A change in one or few variables, can cause serious changes in end results.

One of the most important contemporary key concept in modern world is called big data. Big data is a term which is used to describe the exponential growth and availability of data in both structured and unstructured ways. Big data maybe as important to business and to the society, as much as Internet has become [5].

Big data creates an extreme volume of data.100 terabytes of data are uploaded daily to Facebook; Akamai analyses 75 million events a day to target online ads; Walmart handles 1 million customer transactions every single hour. 90% of all data ever created was generated in the past 2 years. "90% of data generated is 'unstructured', coming in all shapes and forms- from geo-spatial data, to tweets which can be analyzed for content and sentiment, to visual data such as photos and videos" [6].

In recent research by The Academy of Transdisciplinary Learning & Advanced Studies, information has been defined as: "conjunction of the energetic processes involved in the transmission and receptionof meaning and that meaning, such that information cannot be separated from the underlying physical processes of its generation" [7]. The article concludes that information is something that lies within, between and beyond all disciplines, which carries strong similarities with Brenner's transdisciplinarity describtion mentioned in the earlier parts of this article.

As it can be seen from the information provided above, big data opens a new era for social sciences by providing a huge amount of cumulative data as never seen before. However the increase in quantity of the information available to access does not automatically guarantee the increase in quality and authenticity of the information. While some of these information are genuine, some of them might be

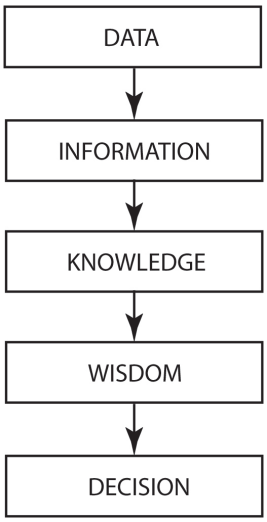

Figure 2: The linkage between data and decision (Güvenen, 2014).

wrong or simply affected by a phenomena called "information distortion".

It can be safely mentioned that the information can be distorted, manipulated, distracted or influenced in order to mislead the user of the information for a specific purpose. There are various examples to these phenomena from all disciplines which all of them created very high social and economic alternative costs which are:

- Distortion of probabilities and outcome information in the direction of preferred decision alternative
- Information distortion can occur where the number of distinct pieces of information on the network increases

"Hermeneutics" is a fundamental rule in science methodology. The initial source, the initial signals may avoid in the time and space dynamics, high negative impacts and alternative costs that may occur [8].

Figure 2 [9] represents the path data takes and nodes it passes while transforming into the decision in the end. It clearly shows that distortion at any part of the linkage will affect the end result, in this case decision, in a negative manner. So it is really vital to start with reliable and distortion free data to come up with right decisions by using value added decision analysis and transdisciplinary science methodology.

Mathematical complexity and chaos models can be examined within the scope of non-lineer mathematic. Error margins and information distortion in complex and chaotic systems cause serious problems for science and application areas. Due to that reason, the use of specific analysis and evaluation methods, which decreases the error margins and information distortion,increases the quality of the research and strength of the decision system. Figure 3 [10] illustrates the importance of transdisciplinary science methodology in minimizing error margins and information distortion.

"Information pollution" is an important challenge as environmental pollution, and it has to be considered and resolved sensibly.

3 Anticipative Analysis and Transdisciplinary Science Methodology

Anticipative analysis is endogeneous to trandisciplinary science methodology, especially in highly complex structures of social sciences would converge the decision systems to optimality and minimize alternative costs.

Anticipative analysis examines the solution of problem "P_1" in time interval "t_1" [11]:

- In analysis and research if the decision maker decides to solve the problem "P_1" in time interval "t_1" and use the estimated and required solution approach, analysis and research, the probability is relatively high that problem can be solved as an example with "1 unit cost".

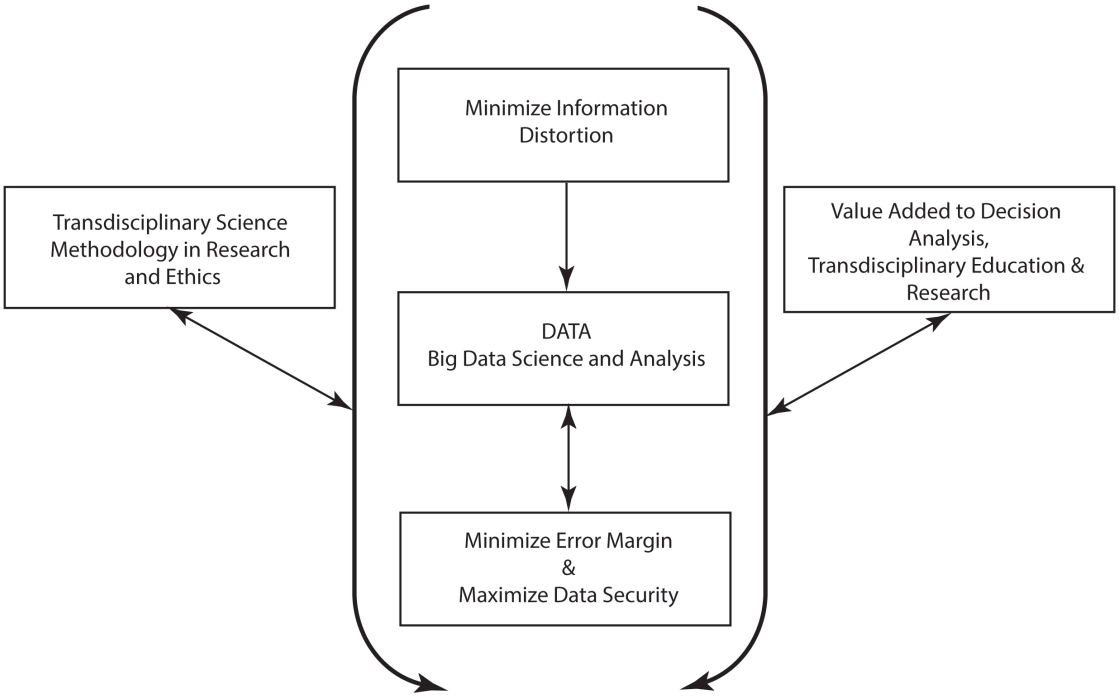

Figure 3: Minimizing information distortion and transdisciplinary science methodology (Güvenen, 2014).

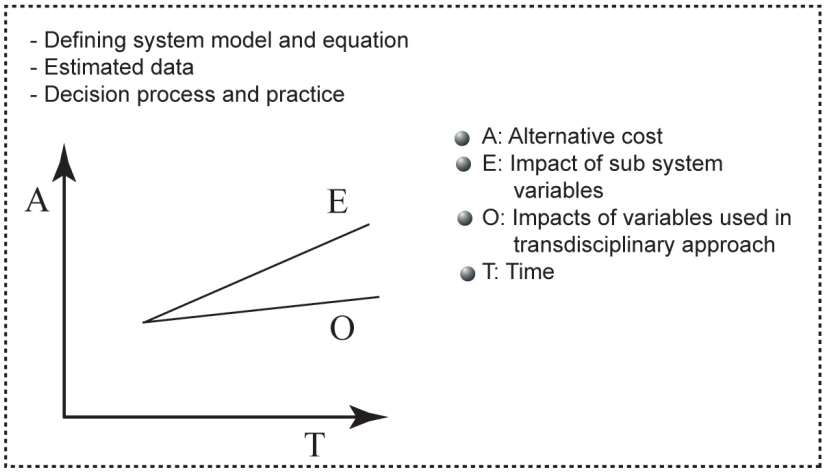

Figure 4: Importance of strategic anticipation in research (Güvenen, 2015).

- If the solution in time "t_1" is postponed for a definite amount of time, like five years, the structure of the problem might change. This might increase the alternative costs and the cost of solving the problem "P_1" , and it may be 8, 10 or more units.
- If the problem p1 is ignored in time much longer, the important changes in system dynamics, structures and problem environment might turn the problem into being unsolvable due to public, private decisions, environmental, sustainability, e.g. constraints.

Obtaining data, making observations and anticipating the future trends carries significant importance in scientific progress. Figure 4 [12] visualizes the strict relation between science methodologies and strategic anticipation. As it can be recognized from the figure the particular scientific approach has serious impact on the end result. Choosing an suboptimal scientific approach can end up with serious

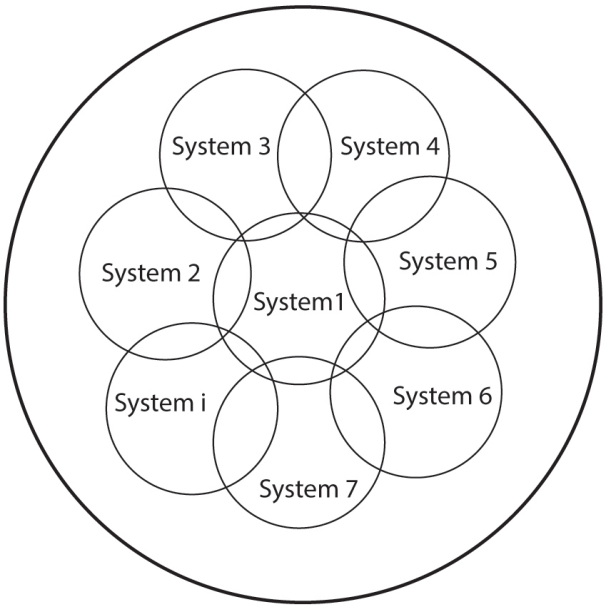

Figure 5: Complex structure of social sciences and anticipative analysis (Güvenen, 2013).

alternative costs in researches.

Figure 5 [13] represents the complex, intricated and interrelated nature of social science systems. Due to complex nature of these systems, anticipative analysis should be made by using transdisciplinary methods to converge to optimal result.

The collaborative and cooperative nature and problem targeted approach of Transdisciplinary science methodology can minimize the common problems and shortcomings of both pluridisciplinary and interdisciplinary science methodologies.

Transdisciplinary implies an integration-driven emergence of new disciplines, not just ad hoc collaborations. The transdisciplinary nature of current scientific and societal challenges–and the powerful new approaches enabled by the combination of traditionally separate disciplines–can be fully addressed only by a rethinking of current academic and government funding structures, as well as the traditional relationships among academia, the private sector, and government.

4 Transdisciplinary science methodology in education

One of the most important areas which transdisciplinary approach should be applied is the education system. The structural changes in science and society caused important changes in education system too. In 13th century when the first universities has been founded, the number of disciplines were only 7, however now there is more than 8000 scientific disciplines [14]. This paradigm shift shows why it is impossible to educate the future generations with the education system of the past.

The existing education structure generally is based on "department" system. "Department" dominantly transmits an education of subset and partial analysis. It does not provide the methodology of linking subsets within an iterative set approach of transdisciplinarity. Figure 6 [15] illustrates the relation between department system and complete system in education.

The department system neglects to dominantly the impact of science and knowledge elaborated by other disciplines which should be considered as complimentary to a given department teaching in a continous iterative approach. It tends to create an impact in the medium-long term; mechanistic, short-termist approaches in the society. The alternative costs of this subset and partial analysis approach are dominantly observed in the 20th century. 21st century science, research, analysis requires transdisciplinary methodology in order to deal with high complexities and provide feasible solutions. Students' needs, characteristics, interests and personal learning processes occupy the core of transdisciplinary educational model.

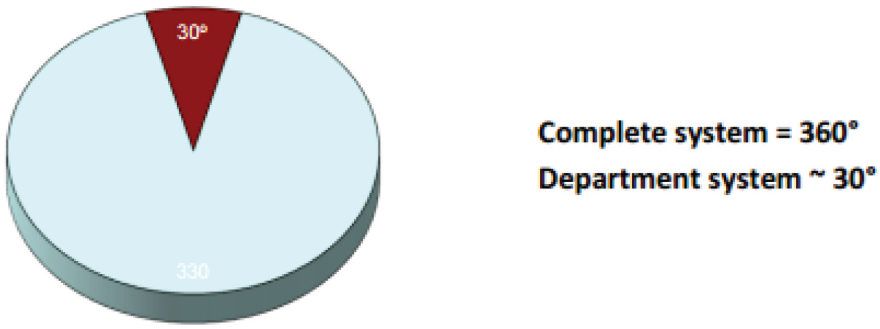

Figure 6: Transdisciplinary science methodology in education (Güvenen, 2013).

It is important that the transdisciplinary skills to be taught to students during education include knowledge and skills required to identify, frame and address important scientific and practical problems that cut across disciplinary boundaries. Such problems are complex and they require such skills as [16]:

1. Integration of problem framing and problem solving
2. Communication and collaboration among people from different disciplines and educational levels
3. Intelligent use of technologies and resources that support collective knowledge construction and extend human problem-solving capability.

Educational institutes are evolving to answer the demand for education of transdisciplinary skills. Actually universities are going through significant changes which they evolve from science-based , government funded institutions into international know-how hubs which is called third generation universities [17].

The concept of Transdisciplinarity and its practices which endogenize not only research, education but also daily life, decisions at the individual, corporate, institutional, nation state, international sphere must be a part of teaching, learning methodology for the earliest ages in school programmes.

Figure 7 [18] illustrates the basic traits of third generation universities. One of those traits and probably one of the most important, is transdisciplinary research. The fundemental research core of third generation universities are based upon the principles of transdisciplinary science methodology to ensure a competitive and modern university education.

Third generation universities through fundamental research, education, business and corporations continuous cooperation, complementary endogenize transdisciplinarity to universities. Their contribution increase the value added to research and education.

5 Transdisciplinary science methodology and ethics

Figure 8 [19] above represents the relationship between the System 1 (S1) and System 2 (S2). S1 can be described as the structure of world dynamics targeting "humanity optimality". S1 is the normative approach. System 2 (S2) represents the structure of world dynamics in 2016.

The dominance of S2 causes crisis and serious socio-economic problems. 2008 economic crisis is one of them. In the context of the 2008 world crisis, we observe that the world GDP was $60 trillion at that time. However, the amount of financial operations in investment banking and markets were over $600 trillion. Concerning this huge amount, we observe that there was not, and today there is not any legal, economic and regulatory framework concerning these operations and markets. It can be considered that it is appropriate to call it : a "crisis of ethics".

As long as we live in a world which S2 is dominant, such crises, world level conflicts, wars, human traffic, drug traffic, degradation of natural resources use, nature, environmental problems are unavoidable. We need to transform system into a brand new one which relies on human optimal; in other words we should focus on the values which S1 built on. Science, technology and transdisciplinarity are among the most important of those values. Ethics is a necessary condition for the set optimal [20, 21].

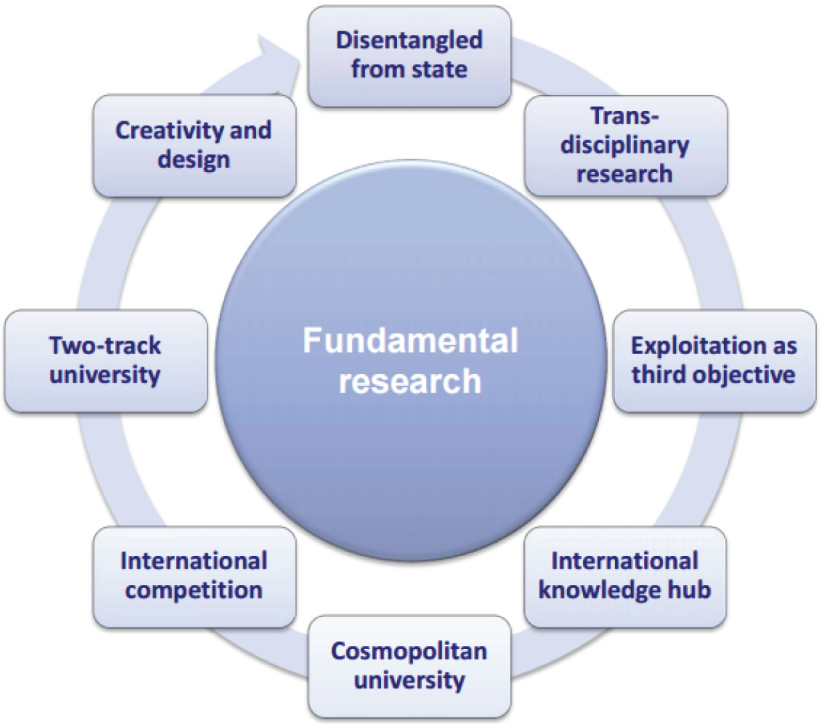

Figure 7: Third generation universities (Aarts, 2014).

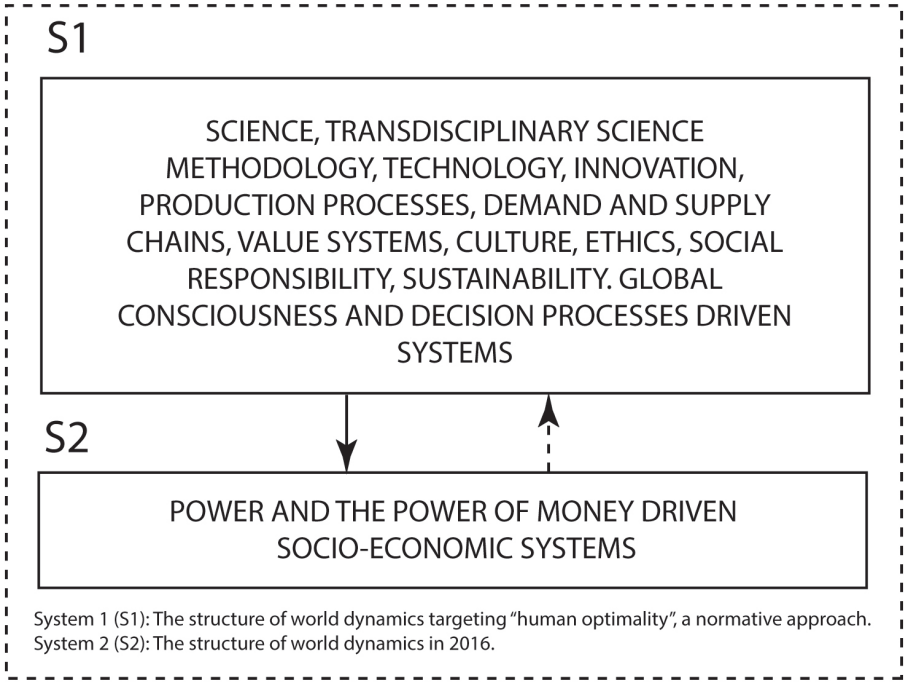

Figure 8: World dynamics and some comments on socio-economic systems (Güvenen, 2013).

$$\textbf{Set Optimal} = \alpha 0 + \alpha 1x1 + \alpha 2x2 + \alpha 3x3... + \varepsilon$$

"$\alpha 0$" is necessary condition, which represents ethics whether at individual, corporate, institutional, nation state, transnational corporations, international organizations and international sphere levels.

6 Conclusions

Any search for a system optimal requires that ethics must remain constant in the dynamics of time and space at the individuals, institutions, corporations, nation states and international level. In preventing information distortion; the starting point, the initiator, the igniter constant should be ethics for the regulators and for the information system security practice.

This approach should include the other explanatory variables in order to understand and minimize the error margins of the complex structures and decision systems which endogenize transdisciplinary science methodology.

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