TRANSDISCIPLINARITY OF LOGIC'S HISTORY

Gheorghe Săvoiu[1], Sandra Matei[2]

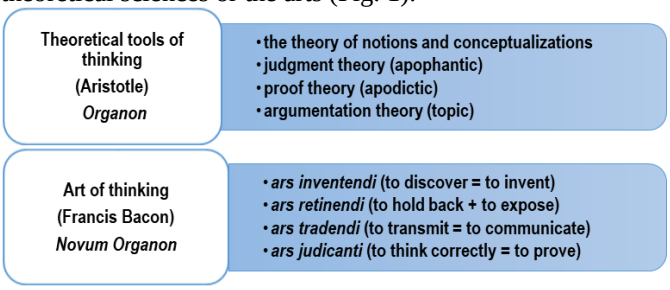
[1]*Romanian Statistical Association, Bucharest, Romania, e-mail: gsavoiu@yahoo.com*
[2]*"Regina Maria" School, Bucharest, Romania, e-mail: sandra.savoiui@yahoo.com*

Abstract. *This article developes an associative approach between transdisciplinarity and the history of logic or the history of the first science and probably of the most adaptive scientific way of thinking from the ancient world to modern investigation. The article is also a succinct discourse in favor of the transdisciplinarity of logic, in an ever-expanding multiverse of modern science, capitalizing on the arguments of syllogistics (as the first essence of deduction or scientifically correct reasoning), but also based on the historical transition from bivalent logic as the existence of only the truth and false solutions (error) to polivalent logic. At the end of a synthetic investigation, a few final remarks redefine the need for modern transdisciplinarity as a way of thinking more appropriate to the increasingly complex reality.*

Keywords: *transdisciplinarity, logic, multipurpose logic, fuzzy logic, neutrosophic logic, history of logic*

1. INTRODUCTION

Logic is unanimously considered the oldest of the world's sciences, because it has never abandoned its instrumental ability to think about thinking and reason specifically to the "*beginning of all science*" (Aristotle), being recognized as the "*discipline of disciplines*" (Augustine), but also as "*art of the arts*" (Thomas d'Aquino), without omitting the qualities of "theory of theories" (Edmund Husserl) or "research of researches" (John Dewey) and even the whole "principles of all methods' applied"(Albertus Magnus) in the abstract body of modern science [1] In his treatise entitled *History of Logic*, Anton Dumitriu defines the science of logic as the unique "*Aristotelian intellectual act: to think about thinking*". The classical period of logic, also known as traditional logic, is already essentialized in the "*Organon*" of Aristotle, the founder of the first complex and fully defined logical theory. Aristotle's contribution is thus defining in the formation of scientific deductive reasoning and especially in the further development of all sciences. The post-Aristotelian period of the same traditional logic is balanced by the conceptualization of logic as art, outlining the end of its classical period, in Francis Bacon in "*Novum Organon*", both works demonstrating the qualities of integration specific to the indisputable transdisciplinarity of logic, in a completely different way. emphasizing either the integration of the theoretical sciences or the arts (Fig. 1).



Source: Realised by the author from [1] (extended table, pp. 26-27).

Fig. 1. Essence of the logic's transdisciplinarity between *Organon* and *Novum Organon*

Traditional or classical logic was born and lived in the blinding light of the search for truth, as the goal of the millennial thinking of humanity and the fundamental issues of the human individual. The scientist's desperate attempt to avoid falsehood or error, often due to the inadequacy of his unidisciplinary, isolated and fragmented approach to traditional education and classical research, naturally gave birth to elements of the transdisciplinarity of logic as a necessary reaction to the complexity of reality. in a perpetual change, but especially as a possibility to understand the meaning and evolution of the world. The transdisciplinary accents of logic have multiplied in the logic of the modern age and especially in contemporary logic. If only the example of the Port-Royal logicians, Antoine Arnauld and Pierre Nicole, is capitalized, as well as their transdisciplinary emphasis on notion, judgment, reasoning and methodology, there is a further integration of gnoseological and psychological influences apparently external to classical logic. also tested by the mathematical contributions of René Descartes and Gottfried Wilhelm Leibniz. Another exemplary paradigm of modern logic and of its specific transdisciplinarity outlines the first axiomatic system of propositional calculus and precise definition or conceptualization of symbolic logic (Gottlob Frege), but also a mathematization of reasoning, giving birth to the new mathematical logic, consecrated by *Principia Mathematica* of Bertrand Russell and Alfred North Whitehead [2, 3, 4].

2. AN ANALOGY BETWEEN LOGIC' S HISTORY AND LOGIC' S TRANSDISCIPLINARITY

A classic answer, one argued unidisciplinary or exclusively on the basis of logic, even purely mathematical logic, has gradually become impossible to offer in practice, both to education and research. The framework of a new quantum logic [5], revealed to academic education and scientific research as a result of the emergence of quantum physics, brings back the hope of a new understanding of complexity in reality and offers transdisciplinary solutions of quantification and experimental validation, made with the support of new methodological thinking, specific to statistical physics. Logic, either Aristotelian or modern (symbolic or mathematical) uses essential methods:

i. *standardization* (transformation of natural language utterances into expressions with a detachable logical structure without altering the content);
ii. *symbolization* (the use of special symbols logically fixed in specific formulas);
iii. *formalization* (generalization of symbols in logical calculation) but also to some universal methods.

A lot of mathematical methods (arithmetic, set theory, mathematical structures, Cantor diagonals, mathematical induction, recursive methods, etc.) are included together to understand symbolic languages, from algorithmic methods to

axiomatic methods, from precise methods of definition or conceptualization to classification or grouping methods, from division methods to graphical methods, etc. Many of the methods of mathematical statistics brought by logic in their most abstract and synthetic form are easily recognized here, too. The role of logic is mainly practical, even active, capitalizing on rules of definition, classification and argumentation, emphasizing the validation or invalidation of theories and thought processes, pursuing clarity and ambiguity, precision and inaccuracy, hierarchy and structural chaos, order and disorder, consistency and inconsistency, coherence and incoherence, argued and unargued, etc. Modern logic emphasizes the importance of replacing variation with a system of constants in its reasoning as well as a proper interpretation of formalisms in parallel with modeling its own processes or logical phenomena:

[1] *the principle of identity*, according to which each thing is identical with it only with itself (the act of thinking maintaining the meaningful identity of words in the science of logic);

[2] *the principle of non-contradiction*, in relation to which one thing cannot be and will not be at the same time (two logical judgments one affirming and another denying the same thing cannot both be true);

[3] *the principle of "no third [possibility] is given"* (*tertium non datur*) which necessarily selects one of the two previous judgments (other possibility not existing or being excluded);

[4] *the principle of sufficient reason*, according to which everything will have a basis (there is nothing without a basis (cause), consisting of evidence or arguments.

Axiomatic logic systems must also benefit from consistency, completeness and independence, and logical operations must use the definition of notions to simplify, classify and divide, both for judgments of immediate (direct) inference and for reasoning in mediated inference. All this together gives an obvious transdisciplinarity to the logic and history of this science. The logic's history has an essential advantage over the vast majority of other sciences, because it integrates in an exemplary way everything that has been done since antiquity and until now in its specific field or, more simply, in the specific way of thinking in all the other sciences. The history of logic is something more than a seemingly trivial "*summation of all the moments in the history of this science itself*" [6].

All the logic disciplines types can be added to investigation in any heterogeneous transdisciplinarity approach. Neither *dialectical logic* (the theory of the composition, structure and functioning of logical operations), *nor pure/formal logic* (research of thought forms*), nor applied logic* (the approach of pure logic, undertaken by determining the forms of sentences, terms, operations and relations with or without the restriction of the number of formulas that are logically-true), *nor the logic of science* (the study of the way in which logical processes and schemes manifest in one field or another of scientific knowledge), *nor mathematical logic* (rational exposition using formalized languages anywhere by applying mathematics to the study of formal logic) *nor the many detailed logics of other mathematical disciplines*. The detailed logic applied in mathematical sciences includes *inductive logic* (whose reasoning evolves from individual to general judgments), *transductive logic* (the logic of inferences of some generality judgments), *deductive logic* (where conclusions are obtained from judgments, from the universal to the most general ones, then to the particular ones or finally to the very individual ones).

The history of logic means much more, however, beyond a simple yet difficult historical aggregation, a credible explanation that must be permanent to the function of thinking in all fields, which makes it a limit of human knowledge, just as difficult to be attained as the truth itself. Thus the supreme Hegelian argument remains "*the history of logic can never be written definitively, this being the history of all knowledge in all its magnitude*" [7].

Any historical research of logic comes to a natural conclusion, according to which thought will not be able to omit anything of what it has previously done in the specific field of the way of thinking itself, thus being obliged to constantly reveal one or another facet of past logics. In any ancient logics either Socratic, peripatetic, Stoic, Epicurean, or ven scholastic, logicians are rediscovered or reinterpreted, either from the methodological point of view or even from the purely mathematical one, etc.

"*The unity of logic with history is more and more obvious*", being directly and non-contradictory delimited by certain "*ever-changing variables*". This unique science of thought is neither eternal nor circumstantial, but has evolved historically, more complex and more intense than all the other sciences, through a continuous redefinition focused on the multidimensional expansion of human knowledge or as a "*science of the historical development of human thought*" [8-11]. The transdisciplinarity of logic is proved even by the history of this science, placed simultaneously "*both within and within the disciplines it appeals to*", creatively, taking original aspects from the specificity of their thinking and focusing on "*concomitant actions of several levels*" of reality "*with the intention of knowing the thought's complexity*" [12].

The diversity of attempts to write a history of logic makes it increasingly difficult to identify in practice the first major treatise in this field. There are still differing opinions even today, ranging from choosing the correctness of information from Johannes Georgius Walchius's *History Logicae* (Leipzig, 1721) and the overly detailed, but also subjective *Geschichte der Logik im Abendlande* [*History of Logic in West*] by Cari Prantl (Leipzig, 1870), as well as supporters of the scholastic treatise of Paul Janet and Gabriel Seailles, entitled *Histoire de la Philosophie* [*History of Philosophy*], which also contains a relative exposition of the history of logic (Paris 1887) to Friedrich Harms's *Geschichte der Logik* [History of Logic] (Berlin, 1881), in fact the second volume of a larger work *Die Philosophie în ihrer Geschichte* [*Philosophy in its History*] (Berlin, 1881). Admirers of international synthetic works still oscillate between Robert Adamson's *A Short History of Logic* (Edinburgh, 1911) and *Lehrbuch der Logik auf positivistischer Grundlage mit Beriicksichtigung der Geschichte der Logik* [*Treatise on logic based on positivism considering the history of logic]*, Theodor Ziehen's treatise (Bonn, 1920) [6].

The first major international treatise on the history of logic was *Formal Logik*, a treatise by Józef Maria Bocheński (Freiburg - Munich, 1956), followed by The Development of Logic by William and Martha. Kneale (Oxford, 1962), as well as Tadeusz Kotarbinski's De Lecons sur l'Histoire de la Logique (Lessons on the History of Logic) (Paris, 1964), in a

summary list of the great treatises on the history of logic compiled on pure criteria chronological [6, 13-14].

The first comprehensive treatise on the History of Logic appeared in Romania, in 1966, under the signature of Professor Anton Dumitriu, who gave the second course in logic, in the academic year 1947-1948, in the first department of logic in our country, also at the University of Bucharest, updating and finally managing to recover a significant time interval from the time lag of the perception of the history of "*thinking about the way of thinking*", in the Romanian academic space. The history of logic of Anton Dumitriu was added and revised later in several editions, but even today it is placed internationally in the small family of the most complete and profound treatises on the history of logic, attesting to the transdisciplinarity of this science. Initially, the young and enthusiastic researcher Anton Dumitriu deepened mathematics in an original way, emphasizing the importance of conceptualizations and definitions, but also capitalizing creatively on the language, which he borrowed from reasoning with a naturalness hard to match, and finally offering specific contours in mathematical logic. In the fascinating journey of the history of logic, Anton Dumitriu's lucid thinking becomes essence and implicit landmark, as an extract from the ephemerality of the evolution of thought, similar to light importance in Spinoza way of thinking, both for his thought and for understanding human error [12]. The logic's history, written by Anton Dumitriu, simultaneously reveals not only the typology of the reasoning of all specific schools and, especially, the reunion of all of them to rationally and promptly reflect an increasingly diverse reality, but also the inherent tendencies of *transdisciplinarity* of logic able to facilitate and solve complex and pressing problems. This creative treatise and its inside attitude together with the influence of Stephane Lupasco original ideas were probably considered one of the best inspirations for Basarab Nicolescu in redefining the modern transdisciplinarity [15-19].

A preliminary conceptualization of the logic's history is a difficult attempt to make, because there is no other science that has as many meanings as logic. Logic has often been assimilated into philosophy or knowledge in general, bringing together "*from metaphysics in Hegelian philosophy to aesthetics or the logic of beauty, from psychology to epistemology, from transcendental logic to ontology*" [12], and capitalizing on the most abstract notions from the general mathematical language, to that of mathematical logic [6], statistics, quantum physics, etc. with the most specific and diverse meanings or signs.

3.FROM CLASSIC SYLLOGISTICS TO MODERN POLI-VALENT LOGICS

Simplifying and transforming logic into commonplace synthesis of sentences or into minimal set of essential or central principles or concepts is equally useless and perhaps even impossible process. A good exemple of such unadequate approach can start with the seemingly simple example of the syllogism, as it is defined by successive sentences or classic premises in which something is said initially, being followed with rational necessity or necessarily by something else to the end.

By logical formalization, various logos were treated as formulas to describe variables placed beyond the appearance of the actual use of words, etc. Hence, Joseph Bochenski, both in his famous work *A History of Formal Logic* and in *Logic and Ontology*, finds it questionable that both the central concepts and the derived sentences that contain or explain them become multiple or multi-meaningful subjects in the science of logic. explained to the uninitiated: "*What prescribed formulas, when their variables are replaced by constants, allow conditional statements, so that when the previous wording is accepted, the consequence must be admitted*?" [12, 13].

The history and transdisciplinarity of logic reveals models reflecting the multifaceted nature of reality and identifying structured trends of the systems that compose it, holistically providing increasing amounts of information, explaining the layers and substrates of statistical similarities or connections, and even more statistical correlations. The transdisciplinary approach transforms the way decisions are made in almost any field, seemingly disparate contexts sharing a lot of common transdisciplinary ideas, which are unsuspectedly useful in practical activities. Logic' s education and research differ from the evolution of psychology, which studies psychic phenomena that include what is right and wrong and not truth or false in the way of thinking. Psychology describes the way of thinking, including the logical one as a complex psychic process of normal investigation, totally different from the pathological, correlated with factors and conditions of thought itself (neurophysiological states, memory or imagination). Similarly, there are significant differences between logic and epistemology, as science dimensioned as a set of ways of understanding or as the philosophical study of the nature, origin, and limits of human knowledge, and between logic and ontology as a philosophical theory of its existence, essences and ultimate principles.

Sequential or particular truths, including those deduced from the stratification of the differentiated levels of unidisciplinary reality or resulting from the slicing of isolated reality, are reunited or reassembled on the trajectory of the continuity of transdisciplinarity. This finding does not exclude but obviously includes logic and the history of logic. Therefore, the transdisciplinarity of logic has become a "*realistic, value-based, context-sensitive, open, interesting, and patient approach to the logic's history, and the ontology of the transdisciplinary context of logic, as science that can be seen as an ontology of connectivity*" [20].

Any selection of the main moments in logic's history describes and simultaneously synthesizes the main ways of education and scientific research during the logic's evolution as one of the major transdisciplinary sciences. This long phenomenon of delimiting major processes, in which the historical research of logical thinking materializes in a profound description of the succession of correct ways of thinking, constantly searching for the truth or *aletheia*, using the famous Greek term [21]. Any selection of the main moments in logic's history describes and simultaneously synthesizes the main ways of education and scientific research during the logic's evolution as one of the major transdisciplinary sciences. The extensive investigation simultaneously reveals the transdisciplinarity of any similar approach, and for the natural understanding of the investigation' s magnitude is always necessary to re-establish a family of concepts and methods including elements like "*conception of the human condition, human cycle theory,*

mythos as method and idea, specific etymology (i.e. orthótes tõn onomáton), philosophy' s purpose, idea of logos." [21]

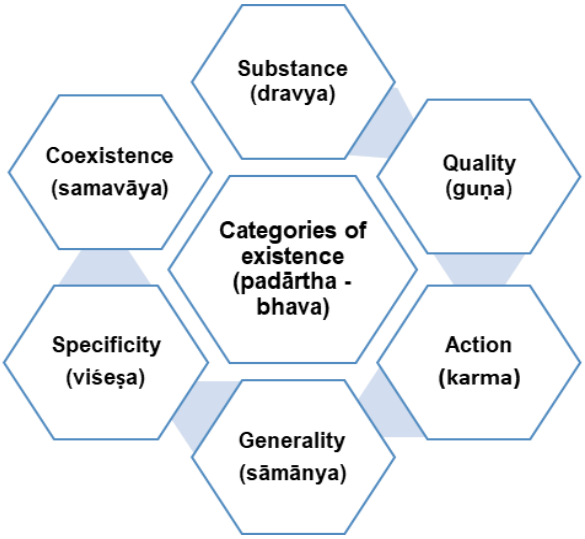
Logic originated and developed in antiquity, in various geographical and cultural areas, from China and India to Greece. Ancient Chinese logic was not a logic of extension, but a logic of order and effectiveness, starting from the Chinese philosophy, in which it was born and which remained a philosophy of existence, focused on a synthetic spirit revealed in a spiritual whole, according with some important texts such as the philosophy of Confucius. The discovery of this whole, as a concept, consisted in the knowledge of its parts, and any causality which might have implied a whole abstract has been practically ignored in ancient China. The effect concept was not an implied as analytical part of the question, but together with the cause formed a real couple, made up of the two complementary forces that describe the phenomena of life or existence, through a generalized whole of Yin-Yang type (feminine - masculine, even - odd, passive - active) [22]. Through the play of this couple of complex concepts, ancient Chinese logic tried to explain the whole order and rhythmic development of nature and society. The supreme and most difficult principle to reproduce, through its complexity, was and remained Tao, which seems to be the principle of all principles in its most general sense, from order, to totality, from responsibility, to effectiveness [5]. Also, Tao acquired the meaning of reason, close in meaning to the Platonic logos [22].

Regarding the beginnings of logic in ancient India, Surendranath Dasgupta notes that even there everything was under the cloak of philosophy, this time of traditional Hindu philosophy, in transcendent dominant context, where "*philosophical systems did not simply start from speculative questions on which puts the human mind to them due to a natural inclination towards abstract ideas, but they tended to achieve a transcendent state*" [23]. Indian philosophy has its sources in the Indian "scriptures" whose generic name was that of "*veda*" or *science*, in translation, and their texts were considered revealed. A *Vedic Samhita* also contained three annexes:

i. *brahmana* (texts intended to instruct the brahmins on the origin and meaning of rituals);
ii. *aranyaka* (the symbolism of ceremonial rituals known as the forest texts, from the aranya = forest);
iii. *upanishad* (the esoteric doctrinal texts).

The Hindu philosophical systems were divided on the basis of the existential criterion (*asti* = is or *na asti* = is not) into the categories of *nastica* (including Buddhism, Jainism, and Carvaka) and *astica* (including the six *darshana* or points of view that complement each other: *Mimansa* and *Vedanta*, *Samkya* and *Yoga*, *Nyaya* and *Vaiseshika*).

As forerunners of logicians, Indian philosophers did not generate or did not develop a formal logic, but a logical theory of knowledge and the beginnings of the deductive thinking based on a first form of syllogism, which would be constructed much simpler in Aristotelian form as a valid deductive argument based on two premises and a conclusion. The original purpose of Indian philosophy and, implicitly, of Indian logic, was rather that of complete relief from pain, together with salvation by general knowledge, accomplished with the support of 16 categories (pramana) or only six categories of corrective knowledge in the particular case of existence (padārtha–bhava) according to figure no. 2



Source: Graphic synthesis realized by author after [5] pp. 56-58.

Fig. no. 2. Restricted knowledge's categories of existence with major impact on epistemology of ancient Indian logic

With the appearance of the category *abhava* (*non-existence*), as an antinomy to existence, the conceptualization of false (error) is also certified, along with a first nuanced typology of it through the next subcategories [5]:

a. previous non-existence or error (*prag-abhava*);
b. non-existence or posterior error (*pradhavamsa-abhava*);
c. absolute non-existence or error (*atyanta-abhava*);
d. non-existence or error (*anyonya-abhava*).

The valorization of logical notion of false (error) through the category of non-existence gave birth to pure knowledge through negativity. In this context the *advaita vedanta* theory is considered the first attempt at modal logic, also belonging to Indian philosophers, more precisely to Jain logicians who described the coexistence of three distinct states: real, unreal and indescribable, defining a *tritya bhanga* where the indescribable represents the third possibility, without to accept the excluded third of ancient logic. Some traditionalist Indian logicians have not constructed their logical system with the exclusive use of affirmation (*truth*) and negation (*false*) as values of sentences, but have accepted a contrary relationship and not a strictly contradictory one [24], and thus have promoted other states and implicitly the *uniqueness through multiplicity*.

Indian logic has developed more intensely in perspective or *Nyaya darshana*, facilitating the art of debate, valid means of knowledge, begginings of syllogism and analysis of opposing views or divergent opinions. The temptation of the Indian logicians called *naiyayika*, who capitalized on the certain *anumana* or inference, considered to be of Indian origin, also raised some questions about the unique Greek origin of the syllogism in logic (*avayava*). The existence of evidence for theorizing syllogisms focused on exemplifying Indian logicians, their specific attempts to construct the syllogism with the help of several sentences (5 or 10) could justify an original Indian debut, but not a deductive supremacy if one try to compare in fact with the clarity of the Aristotelian syllogism [25], as shown in figure no. 3:

Indian syllogism (Pararthanumana)	Aristotelian syllogism (with minor premise snd affirmative or negative conclusion)
Socrates is mortal. Because he's human. All people have been mortal in the past, like Thales, Zeno, etc. Socrates is a man of the same type. Therefore he is mortal.	Major premise: All men are mortal. Minor premise: Socrates is a man. Conclusion: So Socrates is mortal. Major premise: All Greeks are human. Minor premise: Human beings are not immortal. Conclusion: Therefore, the Greeks are not immortal.

Source: Realised by author after [25] p. 83

Fig. no 3: Specificity and non-similarity in syllogism's constructions (Indian versus Aristotelian syllogisms)

The traditional Indian syllogism, although considered relatively valid from a deductive point of view, remained a redundant construction from the clasical logic point of view, becoming in fact a seemingly natural form of rhetoric and less a completely logical form, especially one benefiting from the maximal purity of logical deduction, from which had not yet disappeared all unnecessary elements.Any traditional syllogism demonstated the utility both of some main notions of classical (Aristotelian) logic, and of the pillars of traditional scientific thought, intensely capitalized on in classical and modern education and research. Nearly two and a half millennia after its appearance, Aristotle's *Organon*, according to the sections *Analitica prima* and *Analitica secunda*, in the second and the third volumes, is still the best introduction to traditional logic and to the laws that govern correct reasoning.

Aristotelian syllogism, benefiting from an almost perfect simplicity of argument, started from two premises recognized as truths and essentially offered a deductive reasoning by which the conclusion became the immediate consequence of its premises, thus essentializing the whole ancient Greek theory of proof. A rigorously developed syllogism is an incipient study of scientific proof, and a proof of deductive completeness, in parallel with a demonstration of constructive simplicity, being focused on firm structural laws, beyond the mandatory three-dimensional content of reasoning, developed by the two premises, one major and one minor, as well as an absolutely necessary conclusion.

Inside classical syllogism of the Greek, Aristotelian and post-Aristotelian philosophers, an affirmative premise was necessarily present, two negative premises not being able to lead to a necessary conclusion. A *major premise*, so named from the major term included in its body, contained the logical predicate of the conclusion, while the logical subject was found in a *minor premise*, which included the minor term. In any traditional syllogism, a *conclusion* included both a subject and a predicate. The so called *structural triad* of the syllogism permanently generated two opposite final states, in relation to the fact that the syllogism illustrated a valid or an invalid argument, starting from the two true premises and reaching either a true or a false conclusion.

A valid Aristotelian argument possessed a form that made it impossible to pass from true premises to a false conclusion. Aristotle's syllogism was and remains the most important systematic formulation of classical logic, and this in the conditions of a double conditioning in which at least one premise had to be universal and another premise had to be affirmative. A single negative premise also gave rise to an automatically negative conclusion. The apparent simplicity and constructive perfection of Aristotelian syllogism forcibly identified itself with demonstration and, to the limit, even assimilated itself with classical logic as a whole. This type of approach clearly omitted the fact that the syllogism was and remains in the history of logic a mere fragment of a debut, even if it has long been admired by any public during over the next two milenia and even more. Such an opinion of biased assimilation of classical logic in a manner restricted exclusively to Aristotelian syllogism dominated scholastic and even pre-Renaissance culture, going much further in time to the beginning of the nineteenth century.

The structure of the syllogism seemed to be extracted from the balance or constructive perfection of the triangle in geometry, the sides becoming terms of major, medium and minor type, in relation to the size of their sphere of logical significance. Like the geometric continuity of the area or perimeter of the triangle, the middle term was distributed at least in one premise to ensure the connection with the major and minor term, considered the extreme terms, which appeared both distinctly in a premise and together in conclusion. The modal value (mode) is conferred by the three judgments (*n*) that make it up, the two premises and the conclusion, but also by the four combinations of quality and quantity (*M*). As a simple example, a categorical syllogism has the ability to generate or differentiate, in the end, no less than 64 distinct modes (M^n where $M = 4$ and $n = 3$). Aristotle recognized in a reductionist way two modes considered perfect in syllogism or which required nothing else to be valid, namely the universal affirmative mode and the universal negative mode, while all other syllogisms had to be converted into these two types. The existence of the three terms or acronyms [major (*meizon akron*), minor (*elatton akron*) and middle (*meson akron*)] in the perfectly constructed Aristotelian syllogism depended decisively not on the extremes that formed the predicate and the subject of the conclusion, but on of the *meson* term, which united the two syllogistic premises. The laws or rules of the syllogism were fully applied to the categorical syllogism, because it had all the standard components, they gave classical logic stronger and more precise arguments.

In fig no. 4, their statement is summarized in a structured manner, based on the three different colors and each group of three lines coincides with the laws of terms, laws of premises' quality and laws of premises' quantity:

I.A syllogism contains 3 terms: major & minor premise, and conclusion
II.The average term will be distributed in at least one premise.
III.A term distributed in conclusion will appear in a relevant premise, too.
IV.Both premises can never be negative, at least one will be affirmative.
V. If a premise is negative, the conclusion will still be negative.
VI. If two premises are affirmative, the conclusion will still be affirmative
VII. At least one of the premises will be universal
VIII. If a premise is particular, the conclusion will still be particular
IX. Necessary and sufficient general laws give rise to necessary particular conditions

Source: Realized by author after [5, 26]

Fig. no 4: Syllogism's laws of terms, laws of premises' quality and laws of premises' quantity

In this narrow approach to the history of logic, the syllogism was first selected as an example of the natural existence and persistence of cultural differences, which have left a clear mark on traditional logic, but also as a gradation of clarity of reasoning and the complexity of the concept of deduction, with a major impact on the transdisciplinary validity of its logic and history. From syllogism' s example one can more easily deduce the huge leap made by Greek logic and philosophy, the power of crystallization and symbolization of logic and implicitly the history of logic in Greek antiquity as well as its first signs of transdisciplinarity and pragmatism. The syllogism defined both a main notion of classical (Aristotelian) logic and one of the pillars of scientific thought, in classical and modern education and research with the first clear accents of transdisciplinarity. The Aristotelian syllogism clearly emphasizes the major role of deduction in the logic of the ancient Greek philosophers, delimiting it more and more clearly from the dominant role of experience (intuition) in Chinese and Indian logic and made possible the emergence of a deductive system at the same time. Aristotelian syllogism offered also a maximum level of completeness, able to rigorously establish the axioms and the logical apparatus necessary for any scientiic approaches that had claims of accuracy.

An incredible constructive premeditation of truth (alétheia) is identified in Aristotelian syllogism [27-30], even if the work of the Greek philosopher is reduced to only two explanatory findings (apophantikos):

i. *truth and false (error) imply union and separation*;
ii. *every truth has as much truth as its existence*, emphasizing the deeper roots of Greek logic arising from the particularly deep philosophical layers of Chinese and Indian culture) [21].

The syllogism's diversification became obsessive in the medieval history of logic, and many scholastic logicians have been intensely and unusually preoccupied with enumerating, exemplifying, and hypologizing syllogisms as logical expressions, without creatively generating other forms. Henrik Lagerlund summarized the main evolutionary moments of medieval syllogistics, selecting several personalities who had defining contributions in the rebirth and development of the syllogism "*from Boethius to Abelard and beyond him, to the new logic of at the end of the 12th century or even until the Renaissance*" [31]. The early medieval logicians, starting from the example of Boethius, did not add many new aspects to the syllogism, but tried to convey the legacy of Aristotelian logic in a clear or unambiguous manner. Between 750 and 1258, the syllogistic contributions of Arab logicians justified the consideration of the entire Abbasid caliphate as a "*golden age*". The restitution through remarkable interpretations of Aristotelian logic in the space of Arab culture made Al-Farabi to stand out, nicknamed the second master (mentor) after Aristotle, and the syllogistic creativity of Ibn-Sina, whose Latinized name was Avicenna. Avicena divided syllogisms into *conjunctive* and *repetitive*, in a similar way to the distinction of classical logic between categorical and hypothetical syllogisms. No minimalist synthesis of Arab logicians can be concluded without mentioning Ibn-Ruschd or Averroes, nicknamed the third Aristotle, to whom the extensive teaching of the duality of truth was connected[32]. Peter Abelard creatively condensed the syllogism, including the hypothetical one, without mixing the logic of the terms with the propositional logic, but sophisticatedly developing the latter [31]. Other personalities in the history of medieval syllogistic logic were Richard Rufus of Campsall, William of Ockham, and John Buridan. Richard Rufus of Campsall identified and creatively developed the asymmetry between affirmative and negative modal sentences. Although he made original contributions to the theory of assertive syllogism, Jean Buridan regarded syllogistics as a formal consequence and thus modified its image by practically subsuming it into the theory of formal consequence or the logic of extended and complex consequences. Known as a professor of Martin Luther and a staunch supporter of Ockham and Buridan, Jodocus Trutfetter and his treatise on logic (*Summulae totius logicae*) theoretically ended the medieval period of syllogistics.

With *Novum Organon*, Francis Bacon originally developed inductive logic based on scientific induction, as opposed to the scholastic distortions of medieval scholasticism. This extensive approach was followed by Rene Descartes who practically changed the approach in education and research, according to Discours de la méthode, reconsidering as true only verified and proven works and ideas, breaking down complex processes into simpler subprocesses. Rene Descartes investigated from the obvious in the direction of the less obvious and studied the ensembles in more and more detailed way. As a result, although important schools of logic appeared in the post-medieval period whose intentions were to purify Aristotelian logic from scholastic distortions, listing here *Port Royal school*, run by Cartesianists Antoine Arnauld and Pierre Nicole, or the *Hamburg school* of Joachim Jungius, they proved to be poorer or less significant by their syllogistic contributions, in fact only deeper interpretations of classic ideas. The case of Joachim Jungius and his paternity on *oblique syllogism*, in which the argument was not made directly but indirectly (obliquely), is a proof of an excess, not creative but interpretive, because examples of such syllogisms were present in medieval logic even Wilhelm de Occam [5]. The *Port-Royal school* took the initiative to analyze the sentences more as a combination of ideas and less as terms. During the Renaissance, syllogism retained conventionalism for some time, but gradually gave way to the logic of terms and then to the development of mathematics. The essence of the classical syllogism, which was also dependent on words (implicitly letters), but also on the meanings of words (implicitly letters), was increasingly clearly seeking a valid general support

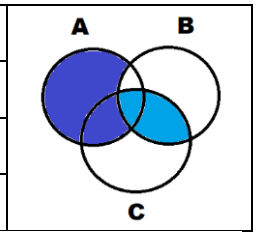
A critical support of the classical syllogism has been received from the mathematician Gottfried Wilhelm von Leibniz, who has constructed new deductive theories structured in the form of mathematical calculus, or from an idealistic philosopher like Immanuel Kant, who has reconsidered the truth-false concordances or inconsistencies as excerpted from both ideas and reality. Even a dialectician like Georg Wilhelm Friedrich Hegel, who has been interested rather in the impact of the laws of logic and less in syllogistics and who have shaped to syllogism an image relatively incompatible with scientific evolution, generated a support for the clasic syllogism, renamed by John Stuart Mill only a verbal inferential vision, and therefore apparent or at best a "disguise" of a real inference [33].

A System of Logic as John Stuart Mill's new interpretation of syllogistics has subordinated the syllogism to other aspects of

logic, his previously eminent status turning into an auxiliary one, and has connected any syllogism at the same time to simple processes of inference.

Since the nineteenth century, classical logic has changed completely under the creative impact of mathematics, benefiting in a very short time not only from many congruent names given to it, from formal logic, to the algebra of logic or to symbolic logic. but also by new logical theories constructed with the help of specific notations and more rigorous deductive methods. All of these intense changes translated not only transdisciplinary tendency, but a pragmatic attitude and a dominant wish for adequacy. In *Formal Logic* Augustus De Morgan, with the support of set theory provides the solution to the mathematical generalization of syllogism validation, and in *The Laws of Thought*, George Boole constructed a new computational logic, based on binary values of truth {1} and false {0}, and John Venn in *Symbolic Logic*, radically simplified the validation of syllogisms with the help of his diagrams (fig. no. 5).

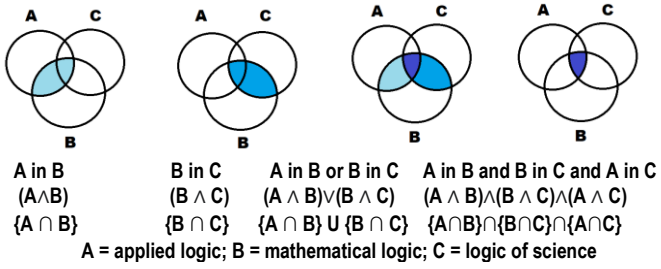
Classic syllogism with negative minor premise and conclusion
Major premise: ***A=All Greeks are human.***
Minor premise: ***B=Human beings are not immortal.***
Conclusion: ***C=Therefore, the Greeks are not immortal***



Source: A syllogism exemplified, visualizated, validated by author.

Fig. no. 5: Venn diagram for a better visualization and validation of classic syllogism

Venn diagrams could be used extensively in syllogisms with more than two premises, intersected or logically reunited, also benefiting from the implicit logic of set theory or Boolean logic (fig. no. 6).



Source: Realized by the author as a simple example of visualization and prompt validation

Fig. no. 6: Syllogisms validation based on Venn diagram and on Boolean support of set theory language

Through his entire work, Charles Sanders Peirce developed a logical system for relations and quantifiers and contributed to the almost total change of logic, which would occur from 1879, with the book *Conceptography*, written by Friedrich Ludwig Gottlob Frege, an Aristotelian personality. Gottlob Frege's logical system and, in particular, his contributions to propositional calculus and formal language were ignored for a period, due to the relatively complicated notation created by him, but succed in forming later the theoretical basis for the emergence and development of computer science and computers. The first logician to unify all the previous names of mathematical developments in logic into one, namely *mathematical logic*, was Giuseppe Peano, who recognized himself also as an Aristotelian descent. His evolution in logic was based on a system, with new algebraic notations, much more abstract, a truly unique system of mathematical signs. In the twentieth century, the evolution of mathematical logic became exponential, especially after 1910, the year of the publication of *Principia mathematica* by Bertrand Russell and Alfred North Whitehead, a book that intuits and avoids paradoxes, and capitalizes on specific notation from Frege's logic and Peano's logic, which is still valid today. Clarence Irving Lewis creates among the latest syllogistic echoes in the much more advanced subject of mathematical logic and brings back the classic conditional "*if/then*" in the analysis of *A Survey of Symbolic Logic*, published in 1918, to solve definitively the syllogistics problems, as a strict implication, which to be true, requires a stronger relationship between the antecedent and its aftermath, compared to the classical conditional. Remarkable logicians outline new directions in mathematical logic:

i) metamathematics, proposed in 1920 by David Hilbert;

ii) fuzzy logic, the 1920s nuance of the space between truth and falsehood (untruth), through an endless number of intermediate degrees by Jan Łukasiewicz;

iii) modeling abstract calculus, a vast process from 1930, undertaken by an almost endless suite of great logicians: Kurt Gödel, Alan Turing, Stephen Kleene, Emil Leon Post, Haskell Curry, Alonzo Church, etc;

iv) natural deduction, in 1935, according to the works of Gerhard Gentzen;

v) relational algebra, outlined in 1940, by Alfred Tarski and his disciples;

vi) the hierarchical classification of the different grammars that generate formal languages, in 1956, by Noam Chomsky;

vii) the logic's history, from 1956, when the first great treatises of Józef Maria Bocheński, William and Martha Kneale, Tadeusz Kotarbinski and Anton Dumitriu began to appear successively.

The second important aspect in the narrow structure of this chapter is the relationship between the logical concepts of truth and falsehood (error). The logic initially synthesized as a reasoning of ideas in a rigorous order structured by words, from the meanings of the Greek logos, generated not only the desire to know the truth as accurately as possible, but also as an increasingly accurate identification of false or error. From the Hellenic times, logic as a science of human thought about different way of thinking has tried to multiply the specific ways to delineate an error or untruth, beginning with *doubt* or *uncertainty*, continuing with *confusion* or *ambiguity*, to complete the process with *aberration* or *absurdity*.

In dual Aristotelian analysis, which loses nothing of its purely existential naturalness, truth has been defined as the statement that *it is not what it is not*, and that *it is what it is*, while the false has been described as the statement in which it is found that *it is not what it is* and that *it is what it is not* [30]. The dogmatic approach to the truth-false duality, however, appeared in Chrysippus, later renamed Chrysippian, even against his Stoic school, which recognized the neutral, in addition to truth and false, redefining logic itself as "the science of true, false, or ***neither true***, ***nor false***" (none of

those) [34]. Classical logic was born and developed as pure or formal logic, comprising laws strictly dependent on the values of truth and false, and the study of its operations and relations was done exclusively through the formal properties of relations and through the true and false values. After more than two millennia, Jan Łukasiewicz, returning to Chrysippos' name and ideas of truth-false duality or of bivalent logic, gave rise to a poly- or multi-valent mathematical logic, which he named *non-Chrysippian logic*. Jan Łukasiewicz used this because the Chrysippos' formulation about *tertium non datur*, the memorable Stoic being considered the most rigid and dogmatic philosopher in the entire logic's history. Jan Łukasiewicz's new approach, which introduced a third state called "*possible*", transformed truth-false duality into an initial three-dimensionality, that would later evolve in the direction of advanced poly- or multi-valent attitude, starting from the mere fact of admitting the existence between the true and false states of an endless number of intermediate degrees.

Since 1920, when Jan Łukasiewicz's created a poly- or multi-valent mathematical logic from the classic bivalent one, many researcher, but especially mathematicians and logicians have tried to give it important practical use. Lotfi Zadeh fully succeeded in this desire, being considered the father of a new applied mathematical logic, which he called fuzzy or nuanced logic. [35]. As a responsible father of fuzzy theoretical and applied logic, Lotfi Zadeh noted since 1965 that as an analysis (including logic or statistics) "*increases complexity, precise formulations lose meaning and meaningful formulations I lose my precision.*" Lotfi Zadeh applied his fuzzy logic in terms of approximate reasoning, characterized by the use of inaccurate inputs or approximate values to give rise to significantly improved outputs as understood, through a completely new interpolation reasoning, focused on the fuzzy paradigm. Since 1972, after the detailed theorizing of the linguistic variable (a qualitative variable, expressed in linguistic terms), the applicability of fuzzy logic have expanded unexpectedly in all complex processes and systems, generating a process of fuzzyfication in almost all applied mathematical disciplines and in early research focused on artificial intelligence (AI).

Classical bivalent logic, described by the set of values {0;1}, where the alternative variable admits the duality false (0) - true (1), is naturally nuanced in a trivalent logic {0; ½; 1}, where (½) represents the "possible" state of doubt between true and false, then in tetravalent logic {0; ⅓; ⅔; 1}, where (⅓) and (⅔) translate into false, but not necessarily false and true, but not necessarily true, then into pentavalent logic {0; 1/4; 2/4; 3/4; 1}, between (0) and (1) appearing the three intermediate degrees already described etc. Thus, in a natural generalization of the n - valence logic the set of values is of the form [36]:

$$\{0; 1/(n-1); ...; (n-2)/(n-1); 1\} \quad (1)$$

As originally described by Jan Łukasiewicz, the new concept of "possible" changed the truth-false duality of classical logic and allowed a sentence to be interpreted in three ways as true, gradually true, or false, infinitely multiplying not only theoretical and applied possibilities of modern mathematical logic.

This logical nuance is easily assimilated to the statistical distribution of the quantile's family, detailed by modal segmentation (trivalent logic), quartiles (tetravalent logic), quintiles (pentavalent logic), etc. Finally, Jan Łukasiewicz was named as the author of polyvalent logic, and Lotfi Zadeh the father of fuzzy logic, more appropriately translated as nuanced logic in Romanian in the books and papers of Grigore Moisil, in a culture where the negative impact of complexity and excess of precision are perfectly outlined in the well-known wisdom of a proverb: the forest is not visible because of the trees. A first attempt to generalize nuanced or fuzzy logic did not take long to appear, and in 1995, the logic paradigm was to be practically enriched with the contribution of neutrosophy focusing on neutralities and their interactions, Florentin Smarandache introducing and delimiting a new scientific theory. Neutrosophy reconsidered any notion or idea "A" only together with their distinctive opposition or negation, represented by "Anti-A", as well as their specific spectrum of neutralities "Neut-A". All of these notions became the real support of neutrosophic logic, neutrosophic sets, neutrosophic probability and even neutrosophic statistics which were subsequently increasingly used together in software-based applications or computer fusion.

Neutrosophical logic as a first generalization of nuanced or fuzzy intuitionistic logic characterized each sentence with the help of a three-dimensional neutrosophical space, valuing its specificity and quality through truth (A), false (F) and indeterminacy (I) [37-39]. In this way A, F and I are considered incomplete information when their sum is less than 1 or complete when they reach the value of aggregates 1. From a static point of view A, I and F are subsets of the neutrosophic set {A + I + F}, and dynamically A, I and F become functions or operators that depend on known or unknown parameters. In both situations A, I and F are transformed into real standard or non-standard neutrosophic subsets outside the standard range [0,1], but belonging to the non-standard range] +0, 1+ [.

The dogmatism of the truth-false duality that characterizes classical logic was indeed gradually replaced by the versatility of these final logical forms, the realism and flexibility brought by such mathematical logics can be considerred thus permanently detached from the Aristotelian tradition and syllogistics.

4. SOME FINAL REMARKS

This paper mainly focused on trandisciplinarity impact of logics's history underlying some major moments in the history of the scientific way of thinking, from Aristotelian syllogistics to modern nuanced logics.

Organon and *Novum Organon* underlines an eternal scientific truth. Logics and not concepts are the tool (*organon*) with which teachers and researchers manage to creatively identify solutions to complex phenomena. Logics, especially mathematical and polyvalent ones, are practically a starting point for the future defined as something else, they enter the transdisciplinary processes, ie all modern logics have their own assimilated and assimilable history which is a lesson of pure, unique or sui generis transdisciplinarity.

5. REFERENCES

[1] Ioan, P. (coord.), 1994. *Logică şi Educaţie*, Iaşi: Editura Junimea.

[2] Whitehead, A. N., 1898. *A Treatise on Universal Algebra*, Cambridge: Cambridge University Press

[3] Russell, B. 1903. *The Principles of Mathematics*, Cambridge: Cambridge University Press.

[4] Russell, B. and Whitehead, A. N. 1963. *Principia mathematica*, 2nd Edition, vol. 1-4, Cambridge: Cambridge University Press, Available online at: https://lesharmoniesdelesprit.files.wordpress.com/2015/11/whiteheadrussell-principiamathematica volumei.pdf Accessed on the 1st February 2022.

[5] Dumitriu, A. 1977. *History of Logic*, 4 vol. Kent Wells: Editions Abacus Press.

[6] Hegel, G. W. F. 1966. *Ştiinţa logicii* (*Wissenschaft de Logik*). Bucuresti: Editura Academiei.

[7] Dumitriu, A. 1993. *Istoria logicii*, ed III, vol. 1, Bucuresti: Editura Tehnică.

[8] Dumitriu, A. 1995. *Istoria logicii*, ed III, vol. 2, Bucuresti: Editura Tehnică.

[9] Dumitriu, A. 1997. *Istoria logicii*, ed III, vol. 3, Bucuresti: Editura Tehnică.

[10] Dumitriu, A. 1998. *Istoria logicii*, ed III, vol. 4, Bucuresti: Editura Tehnică

[11] Dumitriu, A. 1990. *Homo universalis. Încercare asupra naturii realităţii umane* Bucuresti: Editura Eminescu.

[12] Bochenski, J.M. 1956. *Formale logic*, Freiburg y Munchen: Verlag Karl Alber.

[13] Bochenski, J. M. 1951. *Ancient Formal Logic*, Amsterdam: North - Holland Publishing Company.

[14] Bertrand, R. 1945. *A History of Western Philosophy*. New York: Simon and Schuster

[15] Nicolescu, B. 2002. *Manifesto of transdisciplinarity* (K. C. Voss, Trans.). Albany, NY: State University of New York Press.

[16] Nicolescu, B. 2009. *Ce este Realitatea? Reflecţii în jurul operei lui Stephane Lupasco*, Iaşi: Editura Junimea.

[17] Nicolescu, B. 2010. Methodology of transdisciplinarity: Levels of reality, logic of the included middle and complexity. *Transdisciplinary Journal of Engineering & Science*, vol. 1, pp. 17-32.

[18] Nicolescu, B. 2012. Transdisciplinarity: The hidden third, between the subject and the object. *Human and Social Studies*, vol. 1(2), pp. 13-28.

[19] Nicolescu, B. 1996. *La Transdisciplinarité,* (English translation Lexington: Watersign Press), Paris: Rocher.

[20] Boulton, J., Allen, P., & Bowman, C. 2015. *Embracing complexity: Strategic perspectives for an age of turbulence.* London: Oxford University Press.

[21] Dumitriu, A. 1984. *Alétheia. Încercare asupra ideii de adevăr în Grecia antică*, Bucuresti: Editura Eminescu.

[22] Kia-Hway, L. 1961. *L'esprit synthétique de la Chine: étude de la mentalité chinoise selon les textes philosophique de l'antiquité*, Paris: Presses Universitaires de France.

[23] Dasgupta, S. 1963. *A History of Indian Philosophy*. Cambridge: Cambridge University Press.

[24] Barlingay, S.S. 1965. *The teory of Negation, Non-existence and Contradiction*, in *A Modern Introduction to Indian Logic*. Delhi: National Publishing House.

[25] Atreya, B. L. 1962. *The Elements of Indian Logic*. Moradabad: Darshana Printers.

[26] Shorey, P. 1924. The Origin of the Syllogism. *Classical Philology*, vol. 19 (1), pp. 1–19.

[27] Aristotel, 1958. *Organon*, vol.2. *Analitica prima*, Bucureşti: Editura Ştiinţifică şi Enciclopedică.

[28] Aristotel, 1961. *Organon*, vol.3. *Analitica secunda*, Bucureşti: Editura Ştiinţifică şi Enciclopedică.

[29] Aristotel, 1963. *Organon*, vol. 4. *Topica, Respingerile sofistice*, Bucureşti: Editura Ştiinţifică şi Enciclopedică.

[30] Aristotel, 1965. *Metafizica*, traducere de Şt. Bezdechi, studiu introductiv şi note de Dan Bădărău, Bucureşti: Editura Academiei.

[31] Lagerlund, H. 2021. *Medieval Theories of the Syllogism*, *The Stanford Encyclopedia of Philosophy* (Summer 2021 Edition), Edward N. Zalta (editor), Available online at: https://plato.stanford.edu/archives/sum2021/entries/medieval-syllogism/, Accessed on the 10th of February 2022

[32] Street, T., Germann, N. 2021. Arabic and Islamic Philosophy of Language and Logic, *The Stanford Encyclopedia of Philosophy* (Spring 2021 Ed.), Edward N. Zalta (ed.), Available online at: https://plato.stanford.edu/archives/spr2021/entries/arabic-islamic-language/. Accesed on 15th of February, 2022.

[33] Stoianovici, D. 2008. J.S. Mill şi filosofia silogismului, *Revista de Filosofie Analitică* Volu II (2), pp. 27-36

[34] Joja, A. 1958. *About Tertium non datur*, Bucuresti: Ed tehnică.

[35] Zadeh, L. A. 1965. Fuzzy sets, *Inform. Contr.*, vol. 8, pp. 338-353.

[36] Moisil, G. 1975. *Lecţii despre logica raţionamentului nuanţat*, Bucureşti: Editura ştiinţifică şi enciclopedică.

[37] Săvoiu, G. 2007. *O definiţie a statisticii conform logicii fuzzy*, Sesiune de comunicări internaţionale, în cadrul Zilelor Academice Ieşene, Ediţia a XXII-a, intitulată „*Progrese in teoria deciziilor economice in condiţii de risc şi incertitudine*", Ed. Performantica Iaşi, Vol II, 2007, pag. 111-126.

[38] Săvoiu, G. 2012. *Statistică generală cu aplicaţii în contabilitate*, Bucureşti: Editura universitară.

[39] Săvoiu, G. 2013. *Modelarea economică – financiară. Gândirea economică aplicată în domeniul financiar,* Bucureşti: Editura universitară.