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APPLICATION OF THE MODELING METHOD IN

When researching objects, in some cases there are certain difficulties when obtaining a categorical opinion on an expert task is not always possible. One of the problems that hinders the intention of a forensic expert in ensuring the completeness of the study is the inability to directly study the object of study. The solution of the theoretical and practical aspects of this problem is very important, but so far this problem has been solved on an applied plane, that is, in different types of studies in the relevant types of forensic examinations, special research methods have been developed based on certain developments that, in one or other degrees apply the modeling method.

The purpose of the article is to systematize the theoretical foundations of applying the method of scientific modeling in forensic research, determining the requirements for building models in forensic research and creating a modeling method in forensic examination by stages of research.

The article examines the historical formation of the modeling method, describes the content, terminology and essence of the modeling method as an effective general scientific tool for cognition. The main feature of modeling is fixed as a method of indirect cognition of objects of research through substitute objects, when the model serves as a cognitive tool that the researcher puts between himself and the object, and with the help of which he studies the object of interest to him. The classification of the types of models is presented. Cases have been outlined where modeling when carrying out research in forensic science is desirable, and cases are presented separately when applying scientific modeling when conducting research in forensic science is the only possible method for obtaining a definitive conclusion. The general scientific theoretical foundations of applying the similarity criteria and similarity theorems in modeling when carrying out research in forensic science are systematized, the requirements for building models are identified, and similarity signs are formulated in forensic expert research.

A method for applying modeling at different stages of conducting research in forensics has been developed.

Keywords: forensic science, object of study, model, similarity, similarity criteria, simplification, adequacy, uniqueness.

Formulation of Research Problem. The tasks decided by forensic science are based on advanced scientific advances, and since the forensic expert is involved in the process of proving the case, he or she must have different scientific methods to provide an objective conclusion in forensic examination. Modeling is one of the most common in the application of scientific methods. The application of the simulation method in forensics requires the forensic expert to operate certain philosophical categories,

conceptual apparatus, appropriate terminology and scientific knowledge in constructing models of research objects. Some peculiarities of forensic expert examination are that sometimes an expert examining the object given to him may not always be able to reach a conclusion, because the objects of the study may be damaged, certain properties and characteristics may be lost. In addition, there are other cases where, for example, expert study may be performed in fragments, and expert conclusions must be given in the fragments under research. Therefore, scientific modeling is often the only method that can be used by a forensic expert in object research.The principles of simplification and preservation of similarity are crucial when creating a forensic model of the object under research.

Because the need for modeling is due to the complexity, and sometimes the inability to directly study a real object; it is much more accessible to create and explore prototypes of real objects (processes, phenomena) that means models. But these models must reflect the essential properties of the real object (process, phenomenon).

Important is the information that determines a complete list of all the essential properties of a real object (process, phenomenon) when building a forensic model of the research object. Finally, to conclude on the adequacy of the model of the research object is possible only if the data (content of information) about the characteristics (parameters, properties) of the object determined by the expert, which in turn allows to establish the suitability of the model for use in the implemented forensic methodology for a specific forensic specialty, or as it may be described, embodied (implemented) in a particular field of scientific knowledge.

Analysis of recent research and publications. In the relevant types of forensics from different types of studies, special research methods (register of forensic techniques[1]) have been created that is used in one way or another a modeling method that allows to carry out the study of the object indirectly in the light of some experience. Usually, the problem of modeling is solved in forensic practice separately in each type of research in the applied plane, even though the scientific method of modeling is generally studied in detail. The application of scientific knowledge on these issues of scientific modeling in the modeling of objects of research in forensic examination should ensure a clear determination of the fit of the model to the investigated object (process, phenomenon) that should fully determine the adequacy of the model used in the while research on the object. The adequacy of the model to the specific real phenomenon (object, process) for which it is created can only be achieved by applying certain requirements, the criteria of similarity. The theory of this question provides three similarity theorems. One of the developers and researchers of this issue is academician M. V. Kirpichov.One of the developers and

[1] Ofitsiinyi sait Ministerstva yustytsii [Officers of the Ministry of Justice website]. URL : http://rmpse.minjust.gov.ua/ (data zvernennia 24.04.2019 [in Ukrainian].

researchers of this issue is academician M. V. Kirpichov Application of similarity theorems in forensic research allows to establish general requirements for the construction of models in forensic research and on their basis to determine methodological recommendations for the stages of research in the application of modeling in forensic research.

The **Article Purpose** is systematization of theoretical bases of application of the method of scientific modeling in forensic research, determination of requirements for construction of models in forensic research and development of a method of application of modeling in forensic examination by stages of research.

Main content presentation. While performing his activity, forensic expert is guided by normative legal acts, among which among others are, first of all, the Law of Ukraine: *On Judicial Examination, On Scientific and Scientific and Technical Activities, On Scientific and scientific and technical evaluation, Instruction on appointing and conducting forensic examinations and researches*etc.According to the tasks of forensic analysis, expert research relies on advanced scientific advances, and since the forensic expert is involved in the process of proving the case, he must have different scientific methods to provide an objective conclusion in forensic science. Modeling is one of the most common in the application of scientific methods as an effective scientific tool of cognition.Applying philosophical categories, the scientific method, which has a general scientific application, can be called epistemological.Understanding the epistemological meaning of modeling can be achieved by applying definitions, that is, when the meaning of the concept of the model used in science is clearly defined. In other words, understanding of all kinds of modeling should begin by figuring out the exact meaning or meaning of the term model.

Analysis of the scientific literature, which uses the term model, gives the structure of different scientific theories, their experimental verification, description and explanation of the phenomena being studied, shows that this term is used primarily in two completely different, directly opposite meanings. Firstly: in the sense of something to which the theory applies, that is, that it describes or reflects.

The specified dualism of definition of the term model is also cited by A. A Gritsanov in [6]: «Model (Latin modulus: measure, sample) is an object-substitute, which in certain conditions can replace the object-original, reproducing the interesting properties and characteristics of the original.

Reproduction is carried out both in the subject (layout, device, sample) and in sign forms (graph, diagram, program, theory). There are two ways to build a model. If the first goes from the empirically revealed properties and dependencies of an object to its model, the second already

at the starting point involves the experimental reconstruction of the object into the model, and, since the model is known, the object is known»[1].

The dualism of the term definition of the model can be traced to the well-known from the school bench example of the construction of the universe by Ptolemy and N. Copernicus. The model of the geocentric and heliocentric structure is a drawing (layout) and outlook (theory). We can say that modeling in various scientific studies was used in ancient times.

Gradually, it captured completely new branches of scientific knowledge, namely: construction and architecture, engineering, astronomy, physics and chemistry, biology and others. The great successes of the modeling method, as well as the recognition in many fields of science, have brought about the 20th and 21st centuries. The Great Interpretive Dictionary of Modern Ukrainian provides eight interpretations of the Model meaning from everyday used in everyday ordinary use to values that reflect worldview, scientific categories.

1. Example of some new product, a model example of something.

2. Type, brand of construction. *New car model.*

3. The reproducing sample emulates the structure and action of any object used to gain new knowledge about the object.

Item reproduced in a reduced, sometimes enlarged or in kind.

Scale model: a model of aircraft, car, rail, etc., made in one of the international standard scales.

4. What is material, nature for artistic image, reproduction. A person posing in front of a painter or sculptor; *sitter*.

5. Sample from which a mold for casting or reproducing in another material is removed.

6. An imaginary or conditional (image, description, diagram, etc.) image of any object, process, or phenomenon used as its *representative*.

7. Design, structure, pattern by which a certain unit of language is constructed from lower-level units.

8. A mathematical dependency system or program that displays the essential properties of the object, process, or phenomenon under research.[2]

In general, the following types of models are used by researchers in widespread use in science and technology.

Systematics of modeling is presented in this article in a comprehensive way.

1. Imaginary or perfect modeling includes different representations in the form of imaginary models. This is where idealization is inextricably

[1] *Gricanov A. A.* Novejshij filosofskij slovar [The latest philosophical dictionary] Mn. : izd. V. M. Skakun, 1999. 896 s. URL : https://www.e-reading.club/book.php?book=149350 (data zvernennia 23.03.2019) [in Russian].

[2] Velykyi tlumachnyi slovnyk suchasnoi ukrainskoi movy (z dod. i dopov.) [A great explanatory dictionary of modern Ukrainian (with additions and supplements)] Uklad. i holov. red. V. T. Busel. K. ; irpin : Perun, 2005. S. 683 [in Ukrainian].

linked to modeling – imaginary construction of concepts, concepts of objects that do not really exist. For them, there is only a close analogue in the real world. Examples of ideal objects are geometric concepts: points, lines, planes; perfect gas; black body; etc.

2. Information modeling is a collection of information that characterizes the essential properties and states of the object of study (process, phenomena), as well as the relationship with the outside world.

Essence of information modeling is to create a database of parameters, characteristics, properties of the object of study (process, phenomena).

Information that contains data about a research object is selected by certain criteria. 3. Physical (material) modeling characterized by the fact that studies are conducted on models that have a physical similarity and preserve in whole or in part the nature of the object of study (process, phenomena) under research.

4. Symbolic (character) modeling is associated with the symbolic representation of some of the properties of the original. Symbolic (character) models are the various topological, graphic and symbolic images (in the form of maps, graphs, diagrams, chemical formulas, etc.) of the objects under research.

5. Kind of symbolic (sign) modeling is mathematical modeling is a way of studying phenomena that have different physical content but are described by the same mathematical expressions.Mathematical models include algorithms and programs designed for computers that model certain procedures. Numerical simulation on computer is based on the mathematical model of the object under study and is applied to the large amount of computations that are required to research on.

Measure of the completeness of the model is one of the main features in the classification of modeling types. n this basis, all models can be divided into: full, incomplete, approximate. Depending on the nature of the processes under study, all types of modeling are divided into: deterministic and stochastic. Classification over time divides models into dynamic, static, continuous, discrete, discrete-continuous. While performing certain types of expert studies, the definitions of the model can be applied to the preceding values of the term and the classification given, and for some expert studies (such as engineering), the given interpretations of the term model need to be specified, supplemented and specified.

Historically, in the mathematical sciences, after Descartes and Fermat's creation of analytic geometry, based on which the idea of coherence between different parts of mathematics was strengthened, the concept of the model was used to develop an ideological idea. This model becomes a theory that has a structural similarity to another theory. Two such theories are called isomorphic, and one of them acts as a model of the other, and vice versa. V. A. Stoff says that «Such models represent a significant moment of any historically transient scientific picture of the world, and the question may be how scientifically valid these models are,

what are their functions, purpose, goal. However, the model always acts in this sense as some idealization, simplification of reality although the very nature and degree of simplification of reality introduced by the model may change over time. The model, as an integral element of the scientific picture of the world, also contains an element of fantasy being a product of creative imagination and this element of fantasy in one way or another must always be limited by facts, observations, measurements. In this sense, the models were discussed by G. Hertz, M. Planck, N. A. Umov and other physicists In this source, the author cites significant factors that, when using the same conceptual apparatus, link the model and the object of study – this is the simplicity and similarity of the model created to obtain the result of scientific modeling while performing research on the object. The peculiarities of forensic research are that sometimes an expert examining an object given to him may not always be able to conclude that Article 5 of the Law requires the forensic expert to ensure the maximum conservation of research objects. During forensics, research objects may be damaged or expended only to the extent necessary for research. It is not always possible to achieve this even with a full-scale inspection because of the limitations, when the objects of study provided, for example, have damage with loss of form, properties and so on. In such cases, carrying out research by a forensic expert applying the instrumental methods to the object does not always produce the expected result. In addition, there may be some complications and limitations, since the objects of study provided in the damaged state may have an irreversible loss of some of their properties and characteristics, and the data on the existence of these properties in the object of research in the damaged state do not contain. In addition, expert research can be performed on fragments (the objects of study are parts or components of the whole), and conclusions on the expert need to be given on the fragments under research. There are frequent cases of forensic practice where the conclusions regarding the material objects of the study require the investigation of the use of data from material sources of information, or the expert task has the opposite task. Therefore, scientific modeling is often the only method that can be used by a forensic expert in object research.

During modeling, the forensic expert considers the peculiarities of the modeling method and determines its specific features. In addition to that the expert resorts to the use of abstractions, analogies, hypotheses or versions, other categories and other methods of cognition, which in turn requires the forensic expert to professionally apply this and other scientific methods. For the forensic expert it is essential to study the object that if the creation of a physical object model, for example (see the classification of species above) for further research is carried out using the principle of full reflection of the structure, structure, properties (and such other) of this object, that is, when the model and the object are isomorphic, the study of such a model requires a considerable amount of work. When a forensic expert creates a model that displays only certain characteristics that are

relevant to the object, obtaining the result, namely, the conclusion of the expert in the study, can be achieved because the model reflects the object.

In addition, the study can be performed in a shorter time. In this regard, it is advisable to cite the statement of A. I. Bochkin, quoted by P. Yu. Kononyuk: «By model, we will mean a system indistinguishable from a modeled object in respect of some properties assumed to be essential and distinguishable by all other properties that are considered unimportant; at the same time, the absence of insignificant elements in the model is no less important than the presence of essential elements in«[1].

The same conclusion is reached by P. Yu. Kononyuk in the *Generalized Modeling Theory* monograph:

«1. Models are more convenient to study than the original objects. In addition, some objects can only be studied on models.

2. Modeling allows you to identify the most significant factors of the object or phenomenon being studied, so it is a tool for a deeper study of reality»[2].

Consequently, principles of simplification and preservation of similarity are crucial when creating a forensic model of the object under research. Because the need for modeling is due to the complexity, and sometimes the inability to directly study a real object; it is much more accessible to create and explore prototypes of real objects (processes, phenomena) that means models. But these models must reflect the essential properties of the real object (process, phenomenon). Important is the information that determines a complete list of all the essential properties of a real object (process, phenomenon) when building a forensic model of the research object. Only in this case can it be considered that adequacy, as a measure of conformity of the model to the specific real phenomenon (object, process) for which it is created (under construction) can be achieved. Finally, to conclude on the adequacy of the model of the research object is possible only if the data (content of information) about the characteristics (parameters, properties) of the object determined by the expert, which in turn allows to establish the suitability of the model for use in the implemented forensic methodology for a specific forensic specialty, or as it may be described, embodied (implemented) in a particular field of scientific knowledge.

That is why it is important to define the adequacy criteria. In scientific sources, the definition of *similarity criteria* is more common.

One of the developers and researchers on this issue is Academician M. V. Kirpichov Proof of these theorems is performed using sections of Further Mathematics. Formulations of similarity theorems and explanations of their understanding are given in brief.

[1] Kononiuk A. E. Obobshhennaia teoriia modelirovanija [Generalized theory of modeling]. K. : Osvita Ukraïni, 2012. S. 16 [in Russian].

[2] Ibidem.

First theorem. «*Such phenomena are described by literally the same equations, which are conditionally or unconditionally invariant with respect to such transformations of their magnitudes*«[1].

This means that the data obtained in the study of an object (process, phenomenon) can be transferred only to objects (processes, phenomena) that are like it, that is, objects described by one and the same by the equations themselves.

Second theorem. *For obtained data from experience to be directly applicable to such phenomena, they must be processed in the form of a relationship between the criteria of similarity.» In other words, it is necessary to try not to establish the dependence not between the individual quantities (parameters) that characterize the object of study (process, phenomenon), but between their complexes, which represent the criteria of similarity*.

When applying the method of relative units, the formulation of the second theorem is further reduced to the next formulation. In similar phenomena, the criteria are the same. An exemplary example is the application of similarity criteria in the theory of heat-mass transfer, when the similarity criteria established by Nusselt, Reynolds, and Prandtlem are used for different objects subjected to heating (cooling) when determining by the researcher the actual data on reaching a certain temperature as the number Nu, Re, Pr, in the mathematical expressions used in the calculations. First two theorems proceed from the existence of similarity as a consciously known fact, which is predetermined, the third theorem, on the contrary, establishes signs by which it is possible to find out whether two objects (processes, phenomena) are like each other.

Third theorem. «Similar phenomena occurring in geometrically similar systems are subject to the same coupling equations, in which the monovalents are in a numerically constant relation and the criteria made of them are equal. Since the property of such phenomena is that in nature there are only those whose criteria of similarity are equal, then it is possible to understand both the constancy of relations between them and the equality of the criteria made up of these quantities by the similitude of monovalents. Similarity of monovalents can also include the geometric similarity of systems. With such an expanded interpretation of the word «similarity« of quantities, the third theorem is formulated as follows: *Similar are phenomena whose monovalents are similar*. Since the theorem is proved by mathematical techniques, mathematical formulation is more concise, namely: similar objects (processes, phenomena), which are described by the same system of differential equations, and in which the similarity of uniqueness conditions is observed. Conditions of uniqueness are called boundary and initial conditions, which allow one to infinitely many solutions of the system of differential equations to distinguish one

[1] *Kirpichev M. V.* Teorija podobija [Similarity theory]. Moskva: Akademija nauk, 1953. S. 35 [in Russian].

that meets the conditions of this problem. Criteria containing at least one non-uniqueness value are called non-determinants. After the formulation of the original source, it is possible to construct a non-mathematical formulation of the third similarity theorem, which is widely available. For similarities of objects (processes, phenomena), the defining criteria of similarity and similar conditions of uniqueness should be the same. In other words third similarity theorem determines the necessary and sufficient conditions for the similarity of objects (processes, phenomena).

As an example of the application of the third similarity theorem, it is possible to cite an expert study in which the influence of a magnetic field on the indicator of a magnetic field installed on a metering device is investigated. While solving a system of differential equations in the research problem of a magnetic field to determine the magnitude of the magnetic induction on a magnetic field indicator, which is solved by applying the finite element method, the area in which the solution of differential equations is sought is broken down into a finite number of sub-regions (elements). Boundary conditions under which an unambiguous solution of the whole problem is possible, provided that the approximating function at the nodes of the grid of adjacent elements is the same[1].

Summarizing the similarity theorems provided for their practical application in forensic research, the following formulations are given in this paper as signs of similarity:

First sign of similarity. Characteristic properties (parameters) of the model and the characteristic properties (parameters) of the study object are described by the same formulations, physical regularities, mathematical dependencies and expressions. The same definitions and conclusions can be applied to.

Second sign of similarity. Model is like a research object in case the general or determinative list of the characteristic properties (parameters) of the model and the research object coincides.

Third sign of similarity. Model is identical (identical) to the object of study in the case of simultaneous coincidence of the general or definitive list of characteristic properties (parameters) of the model and

[1] *Rohalin S. V.* Matematychne modeliuvannia vykhrovoho polia ta vyznachennia yoho kharakterystyk metodom kintsevykh elementiv prohramnymy zasobamy obchyslennia u doslidzhenni indykatoriv mahnitnoho polia pry vyrishenni diahnostychnykh zavdan sudovoi ekspertyzy rozrakhunkovykh pryladiv obliku, shcho zaznaly vtruchannia vid vplyvu postiinoho abo povilno zminnoho mahnitnoho polia [Mathematical modeling of a vortex field and determination of its characteristics by a finite element method by software calculators in the study of magnetic field indicators in solving diagnostic problems of forensic examination of accounting devices that have been interfered with by the influence of a constant or slowly varying magnetic field] // Aktualni pytannia sudovoi ekspertyzy i kryminalistyky : zbirnyk materialiv mizhnar. nauk.-prakt. konf., prysviach. 150-richchiu z dnia narodzhennia Zasl. prof. M. S. Bokariusa (Kharkiv, 18–19 kvitnia 2019 roku) Kharkiv : KhNDiSE. 2019. S. 346–348 [in Ukrainian].

object of study and coincidence of conditions and circumstances in which their characteristic properties (parameters) are clearly manifested.

Application of scientific knowledge on these issues of scientific modeling in the modeling of objects of research in forensic examination should ensure a clear determination of the fit of the model to the investigated object (process, phenomenon) that should fully determine the adequacy of the model used in the while research on the object.

Thus, models are classified according to their attribution to the first, second, and third signs of similarity and, therefore, their appropriate use in certain forensic researches, namely:

1) models that are identified by forensic expert as being like objects (processes, phenomena) by the first sign of similarity are models that can be classified as a generalized set of expert studies and belong to a forensic examinations;

2) models that are identified by forensic expert as similar to objects (processes, phenomena) by the second sign of similarity are models that can be classified as a subset of expert studies and determine their belonging to a particular group of forensic studies (directions) in determined by the first sign of similarity to the type of forensic examinations;

3) models that are identified by the forensic expert as like objects (processes, phenomena) by the third sign of similarity are models that can be classified as one that is specific to that object in the expert study, which establishes individual conformity in the conditions unambiguous circumstances.

Conclusions. Summarizing, it can be stated that in modeling, the principle of simplification and similarity should be supplemented with completeness (enough completeness) and adequacy.

Observance of these limitations and specific requirements specified in the study allows the forensic expert to apply the forensic research methods and / or scientific developments in the relevant scientific directions, to build a model for further research.

Thus, it is possible to distinguish the following steps in the expert study, which the forensic expert must overcome when applying the method of scientific modeling in forensic examination:

1. Awareness of the problem of studying the research object (original) in the factual circumstances and circumstances recorded in the case materials;

2. Defining the task and fixing all characteristics (parameters, properties) of the research object;

3. Defining essential characteristics (parameters, properties) of the research object;

4. Defining insignificant characteristics (parameters, properties) of the research object;

5. Minimizing the list of essential characteristics (parameters, properties) of the study object and maximize the list of non-essential

parameters, properties) of the study object by successive step-by-step reduction for significant and non-essential lists.

Reducing the list of significant characteristics and increasing the list of irrelevant characteristics of the study object can be done in groups or in pairs.

It is necessary to monitor the presence or absence of dependency in groups or in pairs;

6. Preliminary establishment of adequacy of the list of material and non-essential characteristics (parameters, properties) of the research object;

7. Optimization of the study by limiting the number of significant and insignificant characteristics (parameters, properties) of the research object. If necessary, a limit (increase or decrease) in the number of significant characteristics (parameters, properties) of the original should be introduced to obtain quantitative results in the expert's opinion on the results of the study, including to determine the accuracy of calculations when obtaining numerical results for models that are planned for use;

8. Use of similarity features in the construction (model) of a model that adequately describes the specific characteristics (parameters, properties) of the object of study (original), conditions and circumstances in which the characteristic properties (parameters) of the original clearly manifest. Final determination of the list of essential and insignificant characteristics (parameters, properties) of the original. Model construction is performed with the use of forensic research methods and / or scientific developments in the relevant scientific fields;

9. Studying of the model according to the expert task;

10. Transferring the model study results to the research object (original);

11. Delivering a reasoned conclusion.

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ЗАСТОСУВАННЯ МЕТОДУ МОДЕЛЮВАННЯ В ДОСЛІДНИЦЬКІЙ ПРАКТИЦІ СУДОВИХ ЕКСПЕРТИЗ

У статті досліджено історичне становлення методу моделювання, наведено термінологію, зміст і суть методу моделювання. Надано класифікацію видів моделей. Систематизовано загальнонаукові теоретичні засади застосування критеріїв подібності та теорем подібності у моделюванні при виконанні дослідження в судовій експертизі, визначено вимоги до побудови моделей та сформульовано ознаки подібності у судовому експертному дослідженні, розроблено метод застосування моделювання у судовій експертизі по етапах дослідження.

Ключові слова: судова експертиза, об'єкт дослідження, модель, подібність, критерії подібності, спрощення, адекватність, однозначність.

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