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# Method of estimating the market cost of art objects based on the interpolation model

**Mikhail G. Maltsev** [a]
E-mail: maltsev2000@list.ru

**Sergey I. Baglyuk** [b]
E-mail: b-s-i-1957@yandex.ru

**Irina M. Solntseva** [c]
E-mail: irasolntseva@gmail.com

[a] A.F. Mozhaysky Military-Space Academy
Address: 13, Zhdanovskaja Street, St. Petersburg 197198, Russia

[b] Ltd EFO
Address: 15A, Novolitovskaya Street, St. Petersburg 194100, Russia

[c] KultProekt Gallery
Address: 3, Tverskaya Street, at the Cube Art-Center, Moscow 125009, Russia

**Abstract**

The task of assessing the market cost of an art object (AO) is relevant for artists, art dealers, collectors and museum workers, among others. Experts and appraisers who need appropriate automation tools are involved in its solution. The task is complicated by the inconsistency of the conceptual apparatus of the specialists' various fields of knowledge, the specifics of AO and the art market. Known methods for solving it, especially automated methods, are not numerous and not universal. The purpose of this study was to develop a method for automated valuation of the market value of AO, which defines it as the sum of two components: the prime cost of the AO and added cost – the cost of the asset "value of the AO." To calculate the first component, a cost–based approach and an additive model were used; the second was a comparative approach and an interpolation model. The added value of modern AO is represented by a function of the parameters of each of the four price-forming factors of AO: "the value of the artist," "the artistic value of AO," "the cultural value of AO," "the quality of the state of AO." It is proposed to implement models in the form of a software package integrated into the information systems of modern art institutions, having coordinated the data formats used.

**Keywords:** art object, the cost of the art object, interpolation model, spline interpolation, artistic value, cultural value

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## Introduction

The development of a method for estimating market value of an art object (AO) is a complex task affecting areas of human activity, until recently, still far from each other - art (artistic, cultural values of AO) and science (mathematics, economics, qualimetry). This determined the specifics and complexity of the task.

Property valuation issues are regulated by laws and standards at the state and interstate levels. In the Russian Federation, this is the Federal Law "On Valuation Activities in the Russian Federation" and Federal Valuation Standards (FVS), for example, FVS No. 1, FVS No. 11. At the international level there are International Valuation Standards (IVS) [1–4].

FVS No. 1 offers three assessment approaches: profitable, comparative, and cost-based.

The cost approach was used by appraisers of cultural values and collectibles in a method developed by a team of authors led by Tamoikin, patented by them and proposed in 2010 as a draft of the corresponding standard [5]. This method of valuation is based on the use of the "basic value" of the collectible (the cost of materials and labor spent), which is then refined using more than two dozen coefficients determined by experts.

In addition to the cost of AO, its price is determined by "something" intangible, due to which prices for AO reach hundreds of millions of dollars [6]. An intangible "something" (an intangible asset) that largely determines the value of a joint-stock company is not only its own merits, causing, for example, an emotional response from a viewer, but also the author's name (brand) itself – an effect called "goodwill" [7, 8]. The valuation of an intangible asset is devoted to FVS No. 11 [3] and IVS 210 [4]. Obviously, when evaluating the works of artists with a name, the cost of their work can often be neglected.

In the "three asset model" [8], in addition to tangible and intangible assets, it is proposed to take into account the third asset – "value." The model itself, as the author emphasizes, "... is by no means a practical assessment tool." The paper [7] notes that the asset "value" takes into account "the level of public recognition or the significance of the collectible itself and that it is also intangible."

The market value of cultural values is determined by the corresponding price-forming factors [9]. It is necessary to form a list of price-forming factors that determine the cost of the asset "value of AO".

The art market has brought its own specifics [6, 10] to the AO pricing process: auctions and art fairs have become its main trading platforms, and collectors and branded dealers are the key figures; art objects have become symbols of status and objects of investment, and the market value of AO has become determined primarily by the artist's brand.

It was contemporary art that turned out to be at the epicenter of commercialization [10, 11]. According to a report by the French company Artprice [11], the volume of sales of contemporary art has increased by 2,100% over 20 years and reached $2 billion in 2019.

An extensive list of methods for estimating the cost of AO, considered in [12], is conditionally divided into two groups: those involving automation and others. One of the first software packages for estimating the cost of AO is Investment [7], was developed by the Fine Art Investment Group; they implemented a methodology for valuation of paintings using artists' ratings.

Artist's ratings are used by companies that form analytical reviews, including but not limited to investing in art, for example, InArt Gallery [13].

The Professional Union of Artists of the Russian Federation (PUA of RF) identified classification features and formed a rating of members of the union [14]. They determined price recommendations for AO, taking into account, among other things, the rating of the artist.

There were ideas of using new information technologies in the interests of the art market, so in [15] it is claimed that the blockchain technology will change the art market by solving the issues of transparency, copyright and authenticity of works of art using electronic AO certification [16]. A domain zone of arts ".art" has been created [17]. The creation was announced of a "Digital Twin" on its basis – "an ecosystem of various technological solutions and services in the art world" [18].

Each museum today already has its own information system (IS) [19], for example, KAMIS [20]. Standardization of data presentation formats is relevant for IS art institutions [21]. "Digital Twin" uses the standard for identification of art objects developed by the Getty Trust and accepted by UNESCO, Interpol and ICOM.

The review presented confirms the need for:

- clarification and formalization of the thesaurus of the problem area, first of all – the concepts of "market value of AO," "cultural value of AO," "artistic value of AO," "value of the artist," clarification of the composition of price-forming factors for modern AO and their parameters;
- the review presented confirms the need for an alternative to the well-known method of calculating the value of collectibles [5], using expertly assigned coefficients that refine the "base value" of AO;
- in the method of estimating the cost of AO made in various techniques, spaces and styles;
- in the implementation of the proposed method as a set of models, including an interpolation model for estimating the cost of the asset "value AO" as a function of the set of parameters of pricing factors AO;
- in the implementation of a set of models in the form of a software package and its integration with the IS of modern art institutions [16–18, 20], agreement of the data formats used [19, 21].

The purpose of this study is to develop a method that allows you to advance in the directions listed above.

## 1. Formation of basic concepts and definitions

We believe that market value of an AO consists of two components, "Prime Cost of AO" and value added [22]. Value added or cost asset "Value of AO" is determined by parameter values of the price-forming factors of an AO.

Unlike [7], we believe that the "value of the AO" is not limited to the significance of the AO itself and, unlike [8], we strive for a practically realizable model for assessing the market value of the AO; therefore, the "intangible asset" is not separated into an independent asset from the "value of the AO". Article 5 of the Law No. 4804-1 of the Russian Federation of April 15, 1993 "On the export and import of cultural values" [23] states that "cultural values are movable objects of the material world,

regardless of the time of their creation, having historical, artistic, scientific or cultural significance." Therefore, it is logical to attribute the "private" values of the AO to the price-forming factors of modern AO, namely: artistic and cultural. The concept of "cultural value" has two applications. If we are talking about AO as a collectible or exported "cultural value," then we are talking about "cultural property" with a certain value [24]. The second application of the term "cultural value" is considered as a characteristic of the AO itself, used as one of the four price-forming factors of the AO that determine the cost of the "asset value of the AO." The second factor is the "artistic value of AO. The third – is "the quality of the state of AO" at the time of sale. The fourth in a row, but perhaps the first in importance – the "value of the artist" - determines the level of recognition of his art market or otherwise – the status (brand) of the author of the AO. Each of the four price-forming factors $f = \{1, ..., 4\}$ is not directly measured, but is determined by the corresponding subset of measured parameters ($P_f$).

This corresponds to the essence of factor analysis "... to concentrate the initial information, expressing a large number of considered features through a smaller number of more capacious internal characteristics of the phenomenon (factors), which, however, cannot be directly measured" [25].

The union of $P_f$ subsets forms the set $P$ of all parameters of the price-forming factors of AO:

$$P = Pv_oa \cup Pav \cup Pcv \cup Pcq, \quad (1)$$

where subsets of parameters correspond the following price – forming factors:

$Pv_oa$ – "the value of the artist" ($v_oa$);

$Pav$ – "artistic value AO";

$Pcv$ – "cultural value AO";

$Pcq$ – "condition quality AO".

## 2. The formalization of the task

The expression for calculating the Cost of the $i$-th AO ($Cao_i$) has the following form:

$$Cao_i(P \cup Ppc) = PCao_i(Ppc) + CAVao_i(P). \quad (2)$$

At the same time, $PCao_i$ – is the Prime Cost of AO, calculated using the cost approach as an additive function on a subset of $Ppc$ parameters that determine the prime cost of AO (quantity and cost of materials, etc.), i.e.

$$PCao_i\left(Ppc\right) = \sum\nolimits_{j \in P_{pc}} C_j \cdot Q_{ij}, \quad (3)$$

where $C_j$ is the unit price of the $j$-th resource, and $Q_{ij}$ is its quantity used to create the $i$-th AO;

$CAVao_i(P)$- is the Cost of the Asset "Value of AO", defined as a function using a comparative approach and a multidimensional spline interpolation model [26] on the set of parameters $P$.

Spline interpolation is used in various fields, from medicine [27] to geology [28]. The authors have previously successfully tested the algorithms and programs given in [26] for valuation of the software quality [29]; they are proposed also for calculating the $CAVao_i(P)$ function.

The parameters of the set $P$ in relation to AO (paintings by contemporary artists) are given in *Table 1* ($n\left|P\right| = 21$). For the desired AO, the cost of which is being determined, analogues are selected that form the set $A$ (the procedure for selecting analogues is considered below). If the number of analogues $m = n\left|A\right|$, and $(m+1)$ is the desired AO, then its cost is equal to

$$Cao_{m+1}(P \cup Ppc) = \\ = PCao_{m+1}(Ppc) + CAVao_{m+1}(P). \quad (4)$$

In this case, $CAVao_{m+1}(P)$ is the result of interpolation by a multidimensional spline $S$:

$$CAVao_{m+1}(P) = S^{B_m}_{B'_{m+1}}, \quad (5)$$

which has a T-dimensional (in our case T = 21, according to the number of parameters of the price–forming factors AO) grid ($t_1$, ..., $t_{21}$) with $m$ + 1 nodes, where $B_m$ is the set of coordinates (values of the parameters of the AO-analogs) for $m$ nodes and their values $CAVao_i(P)$ ($i$ = 1, ..., $m$), $B'_{m+1}$ – the set of values of the parameters of the estimated AO, i.e. the coordinates of the corresponding node on the spline, the value of which is $CAVao_{m+1}(P)$ and is the desired one.

The parameters can be both quantitative and qualitative. Qualitative parameters in the model are represented by rank variables that take quantitative relative values. For example, the values of the parameter: "very low," "low," "medium," and "high" are translated into the values of a rank (discrete) variable with the values 0.25, 0.5, 0.75, 1 [30].

A spline with discrete variables is a special case of the spline described in [26] and used, in particular, in [30].

The decision to use the spline interpolation method was made based on several factors, specifically the algorithm's simplicity and good convergence properties of approximation processes. In addition, splines are convenient for approximate description of processes that do not have a regular smoothness property [31]. Finally, the integral and the derivative of the spline are again a spline of greater or lesser dimension, which makes it possible to perform predictive and analytical actions with it regarding trends in estimates. In the future, this will allow us to give the complex new – predictive qualities [32].

### 3. Conditions for the formation and use of the basic software package

In accordance with (2), the software package for estimating the cost of an AO includes two models, respectively: *PCao*(*Ppc*) and *CAVaoi*(*P*). The latter uses analogues of the estimated AO. Therefore, the concept of "class AO" is introduced. To determine the features of the "class AO," the following classification features of the "Unified Art Rating of the PUA RF" are used [14]: the level and category of the artist, which determine, respectively, the professionalism and level of the artist's works; the style of the AO created by him (A – avant-garde, B – "focused on established traditions," etc.); the dimension of the space in which the artist works; the type of artistic technique used by him.

Add the attribute – price range AO. The six AO price ranges are allocated (in US dollars):
1) more than 20 000, 2) 10 000–20 000,
3) 5000–10 000, 4) 3000–5000,
5) 1000–3000, 6) less than 1000.

To test the method and models, a "basic complex" is used, the database (DB) of which contains information about the AO of the following class: paintings by modern professional Russian artists, the rating level of which is from two to six; two-dimensional; technique – easel painting; worth up to $ 20 000.

The database of the complex is formed on the basis of the works of artists of the Russian Federation implemented by the gallery "Kult-Proekt" [33] and data on sales of paintings from open sources, for example, [11]. *Table 2* shows an example of a fragment of such a database. The second line of *Table 2* contains information about the painting being evaluated: Ch (the first letters of its name), TA (the first letters of the last name and first name of the artist). An artist of the second level in the rating of the PUA RF, style of works – avant-garde (A), a two–dimensional painting, easel painting with a relative area of 2.24 (the area of the painting $S$ divided by 2500 (2500 cm$^2$ is the base area of the painting according to [14])).

Accordingly, analogues are selected – this is the AO of its class: paintings by artists of the second rating level, two-dimensional, with technique – easel painting, the area of which differs from the area of the estimated painting by ± 1 base area, and the price of sales to $20 000.

*Table 1.*

**Parameters of price-forming factors AO**

| № | Parameters | Parameter valuation type |
|---|---|---|
| | **Parameters of the artist's value, $Pv_oa$** | |
| 1 | The level of the artist according to the rating of the PUA RF | Integer (1–10) |
| 2 | The number of art unions of which the artist is a member: 1– regional, 2 – and the Russian Federation, 3 – and international | Integer (1–3) |
| 3 | Number of titles, prizes, and awards of the artist | Integer |
| 4 | Of these, international | Integer |
| 5 | The number of the artist's works in the collections of museums, famous galleries or collectors | Integer |
| 6 | Of these, international | Integer |
| 7 | Number of solo exhibitions | Integer |
| 8 | Of them in status institutions | Integer |
| 9 | Of these, international | Integer |
| | **Parameters of cultural value of the painting, *Pcv*** | |
| 10 | Has been in the collections of: museums, status galleries or collectors (number of times) | Integer |
| 11 | Of these, international | Integer |
| 12 | Participated in status projects (exhibitions, competitions) (number of times) | Integer |
| 13 | Of these, international | Integer |
| 14 | The author is recognized as a laureate or diploma holder of status projects (number of times) | Integer |
| 15 | Of these, international | Integer |
| | **Parameters of the artistic value of the painting, *Pav*** | |
| 16 | Novelty of the artist's vision (absent 0; elements of originality – 0.25; mostly original – 0.5; original – 0.75; paradoxical – 1) | One of the values: 0.25, 0.5, 0.75, 1 |

| № | Parameters | Parameter valuation type |
|---|---|---|
| 17 | Originality of content – ideas (absent; elements present; mostly original; original) | One of the values: 0.25, 0.5, 0.75, 1 |
| 18 | The originality of the form (composition, coloristic solution, chiaroscuro solution, geometry of lines and spots, texture of the paint layer). The assessment is made for each element measured in relative units 0, 0.25, 0.5, 0.75, 1. The total score is summed up. (Minimum – 0, maximum – 5). | Numbers varying in the range from 0 to 5 in increments of 0.25 |
| 19 | The originality of this work among other works of the artist (absent, there are elements; mostly original; original) | One of the values: 0.25, 0.5, 0.75, 1 |
| 20 | Professionalism of painting execution (low, medium, high, very high) | One of the values: 0.25, 0.5, 0.75, 1 |
| **Picture condition quality parameters, *Pcq*** | | |
| 21 | Quality and condition: the basics of painting, paints, stretcher. The assessment is made for each element measured by relative values 0, 0.25, 0.5, 0.75, 1. The total score is summed up (minimum – 0, maximum – 3) | Numbers varying in the range from 0 to 3 in increments of 0.25 |

*Table 2.*

**Selection of AO-analogues**

| Artist | PUA RF level | The name of the painting | Relative area | Price, USD |
|---|---|---|---|---|
| SA | 2A | Bve | 2.89 | 16284 |
| TA | 2A | Ch | 2.24 | * |
| TA | 2A | M | 1.40 | 1316 |
| PN | 2A | Lx | 1.68 | 750 |
| PN | 2A | K | 1.40 | 680 |
| ZhN | 2A | Le | 1.92 | 900 |
| ZhN | 2A | ZmV | 3.20 | 2100 |
| RI | 2B | VtP | 1.40 | 1700 |
| RI | 2B | Lg | 1.40 | 1400 |

* The price of this AO is the desired one

*Table 3.*

**Estimates of parameters of price-forming factors AO**

| No | Ch, TA | Bve, SA | Lx, PN | Lg, RI |
|---|---|---|---|---|
| | | ***$Pv_o a$*** | | |
| 1 | 2 | 2 | 2 | 2 |
| 2 | 1 | 2 | 2 | 1 |
| 3 | 0 | 7 | 1 | 1 |
| 4 | 0 | 3 | 0 | 1 |
| 5 | 0 | 24 | 0 | 0 |
| 6 | 0 | 11 | 0 | 7 |
| 7 | 27 | 24 | 7 | 0 |
| 8 | 8 | 7 | 3 | 4 |
| 9 | 10 | 6 | 3 | 0 |
| | | ***Pcv*** | | |
| 10 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 1 | 0 |
| 15 | 0 | 0 | 1 | 0 |
| | | ***Pav*** | | |
| 16 | 0.75 | 1 | 0.75 | 0.25 |
| 17 | 0 | 0.75 | 0 | 0 |
| 18 | 2 | 3 | 3 | 0 |
| 19 | 0.75 | 0 | 0.50 | 0 |
| 20 | 1 | 1 | 1 | 1 |
| | | ***Pcq*** | | |
| 21 | 3 | 3 | 3 | 3 |

*Table 3* shows the values of all parameters for the estimated AO (paintings by Ch, artist TA) and AO analogues (paintings by Bve, Lx and Lg artists SA, PN and RI, respectively) (*Table 1*).

Due to the similarity of the values of the parameters (the level of the artist, size, technique) of the evaluated painting and its analogues, it can be assumed that the prime cost of their creation is approximately the same, and the difference in price is determined by *CAVao*. Therefore, *Table 2* shows the price of their sale directly, and according to the results of spline interpolation, we get the value of the desired AO (paintings by the artist) equal to $ 2540.

Of course, when it comes to estimating AO like Hirst's "Diamond Skull," then the assumption of equality of the prime cost of analogues will be unacceptable.

The appraiser works directly with the complex, among other things, entering into the database a complex of estimates of the AO parameters provided by the corresponding experts. The undoubted advantage of the complex can be the functionality that will allow the presentation of the photo of the assessed JSC and complete information (provenance, etc.) on its analogues, which will allow us to demonstrate to the buyer the "reasonableness of the price" [6] of the AO.

## 4. Directions of development of the basic software package

The complex is built on the principles of modular organization and consistent expansion of functionality. Directions of development of the basic complex:

- expanding the range of classes of assessed AO, increasing the accuracy of the assessment, both by increasing the number of AO-analogues in it database, and expanding (clarifying) the list of price-forming factors and/or their parameters;
- specialization for specific art institutions: auction houses (AO estimate definition [6]), art fairs, branded dealer using additional price-forming factors and/or AO valuation parameters or their own experts;
- the use of AO in the secondary market, which requires a corresponding expansion of functionality through the development of extrapolation models, additional consideration of the price-forming factor "historical value of AO," the dynamics of art prices;
- consideration of the task of assessing the market value of AO as part of a complex task – creating an "ecosystem of various technological solutions and services in the art world" [18], i.e. integrating the proposed complex with the information systems of modern art institutions [16, 18, 20];
- coordination of data formats with the IS standards of art institutions [19, 21], including in them the information used to estimate the value of AO.

## Conclusion

A method is proposed for estimating the market value of AO as the sum of two components: the prime cost of AO and the added cost – the cost of the asset "value of AO." To evaluate the first component, a cost-based approach and an additive calculation model were used; the second is a comparative approach and a spline interpolation model. The thesaurus of the problem area has been clarified. The price-forming factors that determine the value of modern AO are highlighted: "the value of the artist," "the cultural value of AO," "the artistic value of AO," "the quality of the state of AO." For each of them, subsets of the parameters defining them are formed estimated by experts for the desired AO and its analogues. The obtained estimates and the sales price of analogues are used to construct an interpolation spline – a tool for calculating the value added of the estimated AO.

The method is universal. It is applicable for valuation of the AO of different levels of artistic and/or cultural value created by artists of different professional levels working in various styles and techniques, up to digital art, which is achieved by the openness of models to corresponding changes in the composition of pricing factors and/or their parameters. An example of using the method is given.

Mathematical models are implemented programmatically. An example of initial data for the basic software package and the directions of its development are presented. The implementation options of the complex can take into account the spe-cifics of various users or art institutions and can be integrated with their information systems.

Special mathematical knowledge from the users of the complex will not be required. ■

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## About the authors

**Mikhail G. Maltsev**

Cand. Sci. (Tech.), associate professor;

Associate Professor of the Mozhaisky Military Space Academy, 13, Zhdanovskaja Street, St. Petersburg 197198, Russia;

E-mail: maltsev2000@list.ru

ORCID: 0000-0001-6921-251X

**Sergey I. Baglyuk**

Cand. Sci. (Tech.), associate professor;

Head of the Department for Information Systems & Technologies of the EFO Ltd., 15A, Novolitovskaya Street, St. Petersburg 194100, Russia;

E-mail: b-s-i-1957@yandex.ru

ORCID: 0000-0002-2328-6158

**Irina M. Solntseva**

MBA (Art-management);

Founder and curator of the "KultProekt" Gallery (member of the Association of Galleries), at the Cube Moscow Art-Center, 3, Tverskaya Street, Moscow 125009, Russia;

E-mail: irasolntseva@gmail.com

ORCID: 0000-0003-4272-6013