Development of life cycle valuation with priority of national projects and energy efficiency

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Abstract. The paper studies changes in methodology for appraisal activity that pursues effective management of sustainable and breakthrough growth in economy and social sector through ensuring priorities of the National projects and resource efficiency when evaluating cost of life cycles as a result of value-centered management. Gravity to tackle economic problems of need to kick-start innovative high-tech investment cycles for the development of industries, enterprises and investment projects, built upon updated methodological framework for appraisal activity, defines the relevance of this study. In addition, a model to formalize processes of appraisal and management of costs and expenses in economic systems on the basis of life cycles of goods, products and services is proposed to be used as a bedrock of appraising concept. The goal of the study is to develop a set of sound methodological solutions for design of concepts of value appraisal of life cycles in appraisal activity in Russia. It should be done to make its reformation sufficient for cost management of sustainable and breakthrough growth of the country in social and economic fields through effective implementation of the National projects and resource efficiency. The objects of this study are processes of theoretical elaborations and concept-based approaches to the modeling of methodological grounds for value appraisal and management of life cycles of goods within the implementation of national projects by minimizing the cost of their cycles, lifecycle contract, total expenditures and ownership cost of life cycles based on the energy efficient and high-technology products. The applied methods dwell on a comprehensive approach which comprises analysis and synthesis, logical analysis, expert-based approach, methods of economic and mathematical modeling and forecasting.

1 Introduction

Considering the transformation processes of appraisal activity in Russia, the specific development priorities should be emphasized that are related to strategic national goals in the form of finding ways to tackle problems of sustainable socio-economic growth in all

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spheres of national economy. This also covers construction phase of implementation of the National projects with the resource efficiency in the first place. It requires articulation of specified strategies of cost management to meet modern world economic trends.

In this regard, the assessing ideology of cost and expenditures in the systems, which are based on product life cycles, goods and various social and economic, technological and information systems, appears to be a prevailing vector of development of appraisal activity in Russia and global economy.

This shapes a unique research ground that urges to create appropriate methodological aspects in modeling of lifecycle cost estimate of appraisal activity in Russia. They should be aimed at fulfillment of the National projects, prioritizing energy efficiency and cutting-edge products.

President of Russia Vladimir Putin set quite an ambitious goal with the Decree No.204 of May 7, 2018 [1], which provides for rate of economic growth higher than world ones, macroeconomic stability, enhancement of technological development and boost productivity in basic economy sectors.

Current goals are particularly relevant in this turbulent economic times due to global pandemic and oil crisis. Therefore, it demands higher standards of sustainable socio-economic development by practicing highly efficient models of management within capital construction.

Brought up to date methodological appraisal framework should form the basis for planning the pace of sustainable socio-economic growth of industries and enterprises. This framework should kick-start innovative high-end resource efficient investment cycles of development with maximum possible pace of real estate construction.

At the same time the major institutional tool of sustainable growth remains completing of the National projects. Its implementation requires contemporary legislation to be reworked, which dwells on methodological principles that also have not shaped yet.

Improvement of appraisal methodology should be reckoned as the most significant step in the strategy of breakthrough scientific and technological, social and economic and sustainable development of Russia.

Thus, the objects of this study should be processes of theoretical elaborations and concept-based approaches to the modeling of methodological grounds for value appraisal and management of life cycles of goods within the implementation of national projects by minimizing the cost of their cycles, lifecycle contract, total expenditures and ownership cost of life cycles based on the energy efficient and high-technology products. The National development plan on «Safe and High-quality Roads» is of particular interest [3].

The main issue at the implementation of the National projects, when applying cost management indicators, resides in two conflicting tendencies:

firstly, there is a national priority to improve the resource efficiency level of the engineering solutions applied in construction; to increase the use of innovative technologies, materials and R&D products. This requires extra budgeting.

secondly, there is a national priority to save budget resources in state contracting; in optimizing the cost of investment projects and programs, capital construction of all types as well as the ownership cost of goods, works, products and infrastructure facilities by cutting expenses on operation and service, major repairs and other maintenance needs.

The working theory premises on the idea that solution of the stated problem is possible and viable if it is built upon methodology for the value appraisal of life cycles (LC) of goods, products, objects of capital construction and taps into a conceptual approach. This approach is related to lifecycle cost management on the basis of using lifecycle contracts (LC contracts) as an appraising tool. It ensures the concept of resource efficiency and preservation; increases the number of cutting-edge technologies, materials and products

considering the required modeling and management of LC contracts costs as the key parameter of effective sustainable growth.

This economic methodological strategy for the rework of appraisal activity is suggested to be viewed as innovative institutional tool of efficient long-term cost regulation of breakthrough and sustainable economic growth of Russia through effective construction and science and technology advancement in the investment and development sector, including large infrastructure projects.

2 Methods

Methodological principles of the study are based on the theory of life cycles with the use of concept of appraisal activity transformation. This transformation is premised on creating innovative value types in the result of modeling of lifecycle cost of products and services in Russian and foreign economies.

Our previous works [4,5,6,7,8] give a ground to say that a moment has come in theory and practice of appraisal activity in Russia, when, along with the main types of values used, such as market, investment, liquidation and cadastral values, there is a practical need to methodologically lay out its innovative types: value appraisal of life cycles of various kinds of products, cost of lifecycle contracts, maximal initial cost of lifecycle contracts and ownership including assets of capital construction.

Certain methodology for value appraisal requires a new kind of economic thinking and outlook, understanding a product (work) as a life cycle. The latter actively propels the transformation of appraisal activity into an innovative institutional economic mechanism for estimating the value of life cycles, lifecycle contracts and total product ownership expenses in a form of life cycles.

In addition, there is shaping a new kind of cost management of LC, LC contracts and modeling of ownership cost as a special variation of lifecycle value, which is applied to a beneficial owner and user of current LC.

This value methodology also sets an economic vector for the necessity to optimize the performance of state lifecycle product contracts in order to cut the cost of LC contracts through introducing of resource efficient cutting-edge solutions.

The methodology for life cycles, according to our analysis, is used to good advantage in Russian and foreign economies. It stems from macroeconomic life cycles of long economic waves of N.D. Kondratiev, lasting 50-60 years [9], modeling of life cycles of industries, enterprises [10], corporate business systems [11]. Modeling of life cycles is fairly common for: equipment; technical, engineering and informational systems; construction materials; investment projects; state procurements; research and development solutions. A new type of market of state procurements and lifecycle contracts for various products, including capital investment, is being actively shaped now.

For instance, there is a strategy to substitute traditional work-and-labor contracts for lifecycle contracts (LC contracts) in construction sector. This covers large infrastructural and socially important projects. Nowadays, LC contracts must be used in construction of roads and railways, ports, airports, public facilities and other cases. LC contract is actively implemented in military procurements, equipment supply and other sectors of national economy.

Use of lifecycle contracts reorients traditional markets of commodities and investment-and-development ones to new segments. For instance, traditional work-and-labor construction contracts with warranty commitments for certain types of work are transformed into complex lifecycle contracts with additional responsibility of developers for the standardized level of ownership costs of real estate objects introduced during the operational period on the basis of service contracts.

Our previous studies on the theory of lifecycle appraisal prove that growing attention to the value estimate of life cycles as a distinct developing sector in appraisal activity, including capital construction, is related to the global trend to reckon management of products and property in form of life cycles. Thus, value of any product (system) evolves throughout all stages of its life cycle until liquidation as a dynamic parameter. There are different factors that shape lifecycle value, local swings at different LC stages.

Every step of a LC has its own value, its entity and object of the cost ownership, differential and integral accumulation of value as well as various criteria on lifecycle cost management for different entities, objects and terms of ownership.

Initial value for the end-user is a one-time cost to purchase it. This substantiates the initial value of the product life cycle. This also works for assets of capital construction.

Acquisition value is the trade cost in a product market. In construction, it is formed in the primary or secondary markets of diversified real estate. The value types as market, liquidation and other ones are traditionally used in economic relations.

But once the operation phase is added to the initial cost of acquisition, being mandatory for an entity to come into possession for a certain term, then an extra element of the value appears: it is operation value or value in use.

It is the sum of these values in the exchange and operation over a time lag in the life cycle of a product as an economic system from its creation to its use in operation, up to its liquidation, which forms the cost of the life cycle in relation to the product's character, work or system.

Therefore, mutual formalization of two cost components of life cycles, which are exchange and operation values, shape a new type of value appraisal - life cycle cost. Criteria approach is the major feature of such appraisal activity towards life cycles. It requires to minimize lifecycle costing for the end users and life cycle owners. For instance, spending budgetary funds on procurements with the lowest cost may result in significant extra expenditures at the stage of operation. Though, there will be a dubious outcome from cutting the value of acquired products, including investment-type ones. Economy class housing can be built very cheap and affordable, but high operating expenses will bring the low price to naught.

In this case, a goal for theoretical modeling of value effects of ownership and use at certain stages of a life cycle could be set. Such effect is suggested to be defined as the difference between the resale value and life cycle value, which is the lump sum of asset acquisition and the sum of total operating expenses for a certain holding period. The anticipated effects of ownership can be both positive and negative.

Implementation of the National projects as a special institutional, strategic, cutting-edge, socio-economic and sustainable development of Russia is a guideline for prosperity of social sectors and economy of the country.

In this regard, it is apparent that procedures should aim at appraisal methodology for LC and LC contracts with a mandatory precise value estimate of these institutional tools in order to pull off the National projects. The procedures to determine the winner of tenders for state procurement must also be formalized through the starting maximum value of the LC contract, the minimum permissible value of the reduction in this value, and the subsequent monitoring of the performance of these long-term contracts, which are generally long-term and foreseeable.

In general terms, lifecycle cost (LCC) of a product can be defined as a sum of single-time expenditures (E_s) for design, production or construction and total recurring expenditures for operation, measured in annual consumer-based cycles (TOE_{cycle}); for accounting period of ownership (t_{own}) of certain entities of ownership (Ent_{own}):

$$LCC(Ent_{own}) = E_s + \sum TOE_{cyclei}(t_{own}) \rightarrow \min \quad (1)$$

It should be noted, when forming appraisal category «life cycle value», that it is structured as an integral value appraisal procedure, which is the sum of different type of expenses - single-time and recurring (operating). Upon that, the time point at which the value is assembled raises the problem of applying the theory of the cost of money or using discounting to bring different expenses to the single value. If traditional investment estimates accept the discount as an alternative value of capital, then considering only the expenditure flow during the period of consumption, there is a need to further justify the cost of money as a discount device in life cycles, with no income component in the flow of expenditure. Income estimates in current case appear after the ownership stops when the product is sold.

If, after certain justifications, we accept the calculated discount factor (R), then the formula for determining the value of a life cycle (if we bring the expenses to the time of purchase of products or the beginning of the period of ownership) will be the following:

$$LCC(Ent_{own}) = E_s + \sum TOE_{cyclei}(t_{own}) * R \rightarrow \min \quad (2)$$

In some cases, it is permissible to develop the appraisal methodology for the definition of the LCC by introducing additional adjustment factors to the value, which are oriented to the priorities of value formation in state and non-state procurement. For instance, additional adjustments can be introduced to implement highly demanded technologies, materials and research-and-technology solutions and amend their environmental performance, resource efficiency, etc.

In this case, LCC needs to be determined by introducing adjustment factors that offer participants of tenders for lifecycle contracts bonus advantage in comparison to other bidders.

An example of such a conceptual approach is the methodology proposed by the National Association of Designers in 2014, where it is suggested to select projects for government funding based on the lifecycle cost in terms of total expenses. Then, the formula will be the following:

$$LCE = E_s * E_k * R + E_{rec} * G_k * T * K * R \rightarrow \min, \quad (3)$$

where E_s is a sum of single-time expenditures for design, construction, putting into operation and shut down (liquidation); E_{rec} is a sum of recurring expenditures within operation; E_k is a correction index for energy efficiency; G_k is a correction index for «green» technologies in construction; T is a number of times repair works have been held before first capital renovation; K is a correction index for seasonal variances from the standards; R is a discounting factor.

Analysis of the current formula of LCC proves that it is not flawless. It remains unclear why the correction factor E_k to single-time expenses is introduced if it is known that more energy efficient buildings directly reduce the level of operating expenses E_{rec}. Moreover, the «green» factor G_k requires to be additionally studied and well substantiated.

In the Russian economy, the main starting point for the development of the methodology for value appraisal of life cycles was 2013. Federal law 44-FZ on procurement of goods for State and municipal needs was adopted [14]. The main principle of the contractual system to stimulate innovative and high-tech products in state and municipal procurement was laid down. Whereas previously the main criterion was the price of the contract and its minimization, the criterion is now divided into four main structural elements: price; cost of operation and repair; quality and environmental criteria; qualifications of entities, availability of own financial and material resources, work experience, business reputation. The first two components, in terms of price as well as operating expenses, can be identified as the value of a contract for the life cycle of any type of goods and work.

The survey showed [15,16,17] that theory and practice of life cycle assessment in Russia are based on foreign experience in a lot of ways. For instance, the International Valuation Standard IEC 60300-3-3 (2004) [18] was adopted in 2004 in technical systems. A similar standard in Russia on the appraisal of life cycles in technology [19] was adopted only in 2012.

The latest system-wide methodological developments in the field of appraisal of LCC should be considered the methodology of the Ministry of Economic Development of the Russian Federation, issued in December 2017 [20].

They are intended to enhance the procurement of high-technology and innovative products, work and services based on the methodology for value appraisal of life cycles, giving competitive advantages to suppliers of products with higher procurement value, but with a lower value of the LC or the cost of product ownership. The calculation formula takes the following form.

$$\text{LCC} = \text{W}+\text{Q}+\sum_{i=1}^{N} k_i^c X_i+\sum_{i=1}^{N} k_i^d P_i+\sum_{i=1}^{N} k_i^E L_i+\sum_{i=1}^{N} k_i^F S_i+\sum_{i=1}^{N} k_i^G Y_i+\text{Z}^{\text{N}} \rightarrow \min, \quad (4)$$

where N is duration of a product life cycle (years); k_i is a discounting factor; W is acquisition expenditures (of rights for ownership, use, disposition); Q is transportation expenditures; X is storage expenditures; P is preoperational expenditures; L is operating expenses; S is maintenance expenditures; Y is expenditures for operating/scheduled service; Z is disposal expenditures.

Formation of the methodological base of studies in the field of conceptual modeling of value appraisal and cost management of products by its life cycle should be viewed from a perspective of innovative strategies of growth of the national economy under high turbulence conditions.

3 Results

The carried out studies made it possible to propose a classification of the main conceptual directions of the modeling of methodology for appraisal of life cycles of goods, products and works, including investment and development sector; the main strategic directions of valuation are:

1. *Methodological approach to investment valuation of life cycles of projects* This is a classic and the most developed model of appraisal of life cycles of investment projects. They traditionally distinguish the pre-investment, investment and operational phase of project implementation, with the development and modeling of incoming revenue streams, outgoing costs and profit. Performance measures such as payback period, profitability index, net discounted flow and other efficiency indexes are mandatory.
2. *LCC methodological approach (Life Cycle Cost)* [21]. Methodology for life cycle costs (LCC) provides for calculation of integrated total single-time expenditures to buy (create) and maintain operation at entire stages of the LC. It includes acquisition value, operating expenses, maintenance, upgrades and remaining disposal costs at the end of the useful period. A plethora of foreign and Russian standards were built upon this model.
3. *LCCA methodological approach (Life Cycle Cost Analysis).* This is an analytical comparative approach to determine the most cost-effective option among the competing alternatives for life-cycle projects involving the analysis of the total costs of acquisition, ownership, operation and use management, up to the liquidation of the object (process) or sale taking into account the discounting of costs to the zero point of analysis. Current approach can be applied in analysis of pre-investment, investment and operation phases of investment projects, being used as an additional tool to traditional calculation models for efficiency of projects.

4. *TCO methodological approach (Total Cost of Ownership).* The concept of TCO is a systematic valuation approach based on the formation of the target cost of ownership relative to the object of ownership in the form of a commodity, a product or system as a life cycle for certain periods of ownership and fulfillment of the full amount of obligations related to ownership by the owner. There is no one-size-fits-all model for TCO because different types of ownership costs exist for different types of objects (vehicles, equipment, information systems, etc.).

TCO models are widely used in foreign standards, including construction sector. For instance, American National Standards Institute developed a standard «APPA 1000-1» in 2017 [22]. It provides financiers, architects, planners, builders and technicians with a standardized and holistic approach to the implementation of TCO core principles. A second part was added to that standard in 2019 [23]. TCO concept is not exercised for investment-and-development projects and real estate in Russia. Only certain local studies have been introduced [24].

5. *DBFM methodological approach (Design Build Finance Maintain).* This concept refers to investment and construction activity that comprises core phases of life cycles of capital construction objects: design, building, finance and maintenance. This is defined with construction contract, which is rendered as a special complex contract or one for life cycles. A company or consortium assumes responsibility for all phases of the project, including operation periods of up to 20 to 30 years, with additional responsibility for maintenance.

6. *PFI methodological approach (Private Finance Investment).* The concept of private financial initiatives is very broad and multifaceted in the construction of large public infrastructure projects that combines investments of state and private sector. It is premised on establishing public-private partnership and concessions through funding the infrastructural projects with the focus on LC contract-based ones. The world's practice proves that this approach facilitates a faster and cheaper construction.

The analyzed methodological approaches were tested by the authors in terms of methodological application with regard to specific objects of investment and construction activity [5]. For instance, the results of LCC methodological approach to analyzing the structure of life cycle of an object in the Penza region are shown in figure 1.

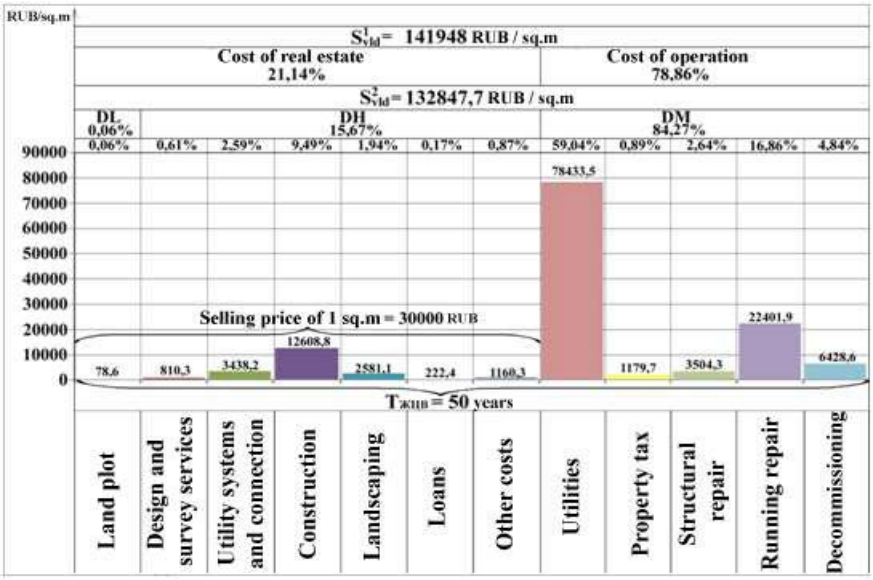

Fig. 1. Analysis of the life cycle structure of construction and operation of investment project by total expenditures when determining the cost of ownership according the LCC methodological approach.

This appraisal was based on a method that involves structuring the life cycle through three sub-systems of development: land (DL); investment and construction (DH); maintenance (DM).

In this case, the ownership cost of real estate (S_{vld}) was calculated by total local expenditures or total life cycle expenditures ($TLCE_i$):

$$\mathbf{S_{vld}}=S_{[DL]}+S_{[DH]}+S_{[DM]}=S\sum_{T1}^{j}\left(\frac{z_{1.j}}{(1+i)^{n1.j}}\right)+S\sum_{T2}^{j}\left(\frac{z_{2.j}}{(1+i)^{n2.j}}\right)+S\sum_{T3}^{j}\left(\frac{z_{3.j}}{(1+i)^{n3.j}}\right) \quad (5)$$

where: T1, T2, T3 are phases of the life cycle within three systems of development; i is a discounting rate; $z_{1.j}$, $z_{2.j}$, $z_{3.j}$ are local expenditures for each system of development.

This methodology makes it possible to model the calculated value S_{vld} as total life cycle expenditures ($TLCE_i$) by its particular phases (technical and economic feasibility (t_1), construction (t_2) and operation/maintenance (t_3)) with regard to the entity of ownership, object of ownership and period of ownership (T_{vld}).

The design period of a life cycle is 50 years, average period for major repairs is 30 years; the considered inflation is 4%.

4 Discussion

Discussion area on in methodology for appraisal activity that pursues effective management of sustainable growth in economy and social sector, through ensuring priorities of the National projects and resource efficiency when evaluating cost of life cycles as a result of value-centered management, is a very broad area of concern. In this context, we will discuss their individual points with regard to the implementation of the National Project «Safe and Quality Roads» through the application of the LC contract concept in road construction.

The project drives a high growing rate for the use of life cycle contracts in terms of the total construction volume. For instance, the share of the LC contract-based road principles in road management (consolidation into one contract not only of construction but also of major maintenance) amounts to: 2019 – 10%; 2020 - 20%; 2022 - 50%; 2024 - 70%.

However, the analysis of implementation of the plans shows that performance of this National project actually failed to meet the intended result.

According to the report of the Accounts Chamber of the Russian Federation on monitoring of performance of the National project «Safe and Quality Roads» for 2020 [25], the constituent entities of the Russian Federation, on average, had concluded contracts on the principles of LC for construction, repair works and further maintenance of roads 3.7 km long in 2019.

There are only few positive examples. Thus, 3 contracts were concluded in the Tver region for the repair and maintenance of 58.3 km, 50.0 km and 30.0 km of roads; 1 contract was concluded in the Chelyabinsk region for the maintenance and repair of 44.4 km of road.

This demonstrates that introduction of these strategies is slow, in spite of the goals to adopt innovative cost-effective mechanisms of life cycle contracts in road construction within the National projects.

The Accounts Chamber also states that, as of August 1, 2019, no register of new and best technologies, materials and technological reuse solutions had been developed in this industry. Though, the deadline was on July 31, 2019.

Further analysis showed that the construction of roads in Russia was based on contracts involving the use of technologies and materials, most of which had been in use since 1970-1980, for example: stone mastic asphalt (SMA), grids, geowebs, recycling methods.

No studies have been carried out in the Russian Federation to appraise the cost of road ownership for certain estimated periods of operation, and no such statistics exist.

Our additional studies in this field, with the help of a number of specialists, made it possible to calculate the average expert indicators of the structure of road ownership in Russia for a calculated period of 50 years, which can be defined as a ratio of 1% to 99%. 99% of the cost of road ownership represents total operating expenses, and only 1% is the capital expenditures for road construction.

This structural ratio of road ownership costs as high as 1 to 99 correlates well with the very expensive mechanism for construction, which is dominated by very important annual cycles, and by current volume of major repair works and their poor quality.

It should be noted that similar indicators of the structure of value of life cycles for residential real estate have been carried out in Russia [26]. The obtained data show that the average cost of ownership for the estimated period of 50 years is 20% - single--time expenditures for the owner to purchase a residential property, and 80% - the total expenditures of the operational stage.

The studies showed the high level of complexity of the problem of transformation of the methodology of appraisal activities and its considerable potential as an innovative State strategy for the sustainable development of the Russian economy based on the application of the estimation procedures of the LC, LC contracts, managing the minimization of the cost of life cycles and the cost of ownership. This will make it possible to carry out the State strategy to prioritize the energy efficiency, energy saving, higher number of applied technologies, materials and cutting-edge research and development products. It is particularly important to apply this methodology in the implementation of national projects as the most important modern institutional mechanism for the country's breakthrough scientific, technical and socio-economic development.

According to our expert data, exercise in the National projects of the concept of formation and management of long-term life cycles of development of industries, enterprises and projects, based on LC contracts, will allow achieving multiplicative indicators of project performance acceleration of at least 10 compared to conventional models of project implementation [28]. Transition to a zone of long-term synergistic effects can be also considered.

The complexity and ambiguity of the development of the LC contracts models for capital construction facilities is indicated by the expert survey data provided by the author on the example of the managers and leading specialists of a number of construction organizations. Only 10% of respondents were found to appreciate the high attractiveness of the legal and institutional models of LC contracts, rather than the use of traditional contractual arrangements. The results indicate both a lack of knowledge in this field and a lack of motivation to apply these models to the construction of roads, social and housing facilities and other types of investment projects.

Many experts also argue that the introduction of LC contract models leads to monopolization in commodity markets and reduced competitiveness. There are other problems that constrain introduction of LC contracts, such as inadequate legislative framework, the unwillingness of the State budget to guarantee long-term co-financing horizons for projects, based on life cycle contracts, and the lack of motivation of the actors to adjust to innovative approaches.

5 Conclusions

The conducted studies have proven the potential of methodology for rework of appraisal activity on the basis of modeling for life cycle cost. Life cycle contracts can be especially effective in terms of implementation of the National projects. This, according to our

opinion, should become a reliable basis for the performance of Russia's national priority to ensure sustainable and breakthrough scientific, technological and socio-economic growth of the country under conditions of external challenges and turbulent economy.

We consider that appraisal concept of modeling for various socio-economic, engineering and informational systems as life cycles, which generate cost and expenditure flows and require unique kinds of valuation and cost management, appears to be an important vector of development of appraisal activity in Russia and the world in general.

Methodology for value appraisal of life cycles requires a new kind of economic thinking and outlook, understanding a product (work) as a life cycle. That is why Russian valuation activity is undergoing active transformation into an economic mechanism for appraising the value of life cycles, life cycle contracts, the initial price of life cycle contracts, total ownership cost of products as life cycles to optimize this type of value.

The active development of methodological approaches to the valuation and management of life cycle cost of products should be viewed from a perspective of innovative strategies of growth of the national economy under high turbulence conditions. This plays a major party in performance of the National projects and programs of capital construction, where it is required to ensure the priority launch of innovative technologies and resource efficient solutions with a long-term view.

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