Conceptual Foundations of Modelling of Innovative Production Projects

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***Abstract*—At the moment there is a lack of methodological approaches to formalization of management of innovative projects relating to production systems, as well as to adaptation and practical use of the existing approaches. This article is about one potential approach to the management of innovative projects, which makes the building of innovative process models possible based on objective approach. It outlines the frameworks for the building of innovative project models, and describes the method of transition from conceptual modelling to innovative project management. In this case, the model alone and together with parameters used for evaluation of the project may be unique and depends on the special features of the project, preferences of decision-making person, and production and economic system in which it is to be implemented. Unlike existing approaches, this concept does not place any restrictions on types of models and makes it possible to take into account the specificities of economic and production systems. Principles embodied in the model allow its usage as a basis for simulation model to be used in one of specialized simulation systems, as well as for information system providing information support of decision-making process in production and economic systems both newly developed by the company (enterprise) and designed on the basis of available information systems that interact through the exchange of data. In addition, this article shows that the development of conceptual foundations of innovative project management in the economic and production systems is inseparable from the development of the theory of industrial control systems, and their comprehensive study may be reduced to a set of elements represented as certain algorithms, models and evaluations. Thus, the study of innovative process may be conducted in both directions: from general to particular, and vice versa.**

***Keywords:* innovative project, management, decision-making, algorithm, analysis, concept, search for optimal solution innovative project, management, decision-making, algorithm, analysis, concept, search for optimal solution.**

I. Introduction

The existence of fresh results that can be used in the products has become a resource which gives strategic advantages. However, it is essential to use such resource properly.

In large production systems time and budget for implementing any changes are strictly limited. Each of these projects requires key competencies some of which a company may not have. In such a situation, execution of the project gives the company new competencies and skills, as well as new impetus for its development.

Effect of innovations may take the form of improved consumer properties and higher level of standardization and automation of production, which in turn leads to reduced costs.

High rates of economic growth become an additional factor under a free market economy. According to data from the Federal State Statistics Service in the period from 2009 to 2013, the product output in the Russian Federation (in million rubles) grew by 181,92%; and the output of innovative products grew by 350% which demonstrates economic expediency of innovative products.

System manufacturing innovative products had to be in a process of transformation manifested as the need to increase the number of product modifications, relationship links with other enterprises, and proprietary sub-systems as compared to traditional products. This makes higher demands for quick administrative decisions and high-quality innovation management, therefore the quality of management, as a rule, becomes a critical factor in the success of projects aimed at development and manufacture of innovative products and technologies, and addressing the problem of efficient management of innovative projects becomes more and more important.

Theory and practice of the management were developed through addressing local problems because it was hard to manage innovation as a single system [15] which created a lack of methodological approaches to formalization [formal characterization] of the management of innovative projects as a single system.

Because of this, while noting all benefits of holistic consideration of the problem of innovative project management, modern publications do not describe any models of innovative projects as complicated systems, which allows no effective solution of the issues of management, expertise and rationale. Such issues are often viewed as separate not interconnected challenges rather than a single process [12][15].

There are some special approaches to certain types of innovations. They depend largely on the sector of economy and sphere they are related to (organizational innovations, innovations in the field of service, technological innovations, innovations applicable to the products which affect their consumer properties, etc.).

Methods of solving management tasks and decision making used in product innovative projects are based on analysis of the project properties. Scientific and technical literature relating to innovative programs and processes contains description of several stages and functions of manager at each stage. A common feature is that all his decisions must be informed and reasoned [11].

The rationale needs the use of model. The way and method of modelling must solve the problem of increasing the efficiency of administrative decisions.

A model allows the manager to rule out the prospect that only some of available methods were used during project execution, determine the dynamics of its progress and set its parameters reasoning from the current and desirable dynamics.

II. Modelling of Innovative Projects

Development of methods of mathematic formalization of innovative project management has been reflected in several approaches.

In the context of this approach volumetric production planning and procurement (acquisition) planning are the most studied. The principal research in this area focuses on support of administrative decisions in nonlinear-cost or combined-structure systems, and most studies focuses on cost minimization and demand forecasting. Only little research deals with training and promotion of decision-making skills with due regard for requirements of production systems [10]. Important problem arising from the above challenges is concurrent consideration of challenges of pricing (price formation), volumetric production planning and procurement planning. Solving of this problem raises the issues of market selection and internal structural organization of economic and production systems, and is defined "Wagner-Whitin's problem" [9].

Formalization of concurrent consideration of challenges (tasks) relating to market selection and volumetric production planning was first mentioned in [1], and continued to be a challenge. It has been shown that this is a NP-full task, and can be tackled only when certain factors are determined[1] [10].

The perception of single innovations as constants is a very rough assumption. In 1995 Peppal suggested the use of game theory [8] in description of duplicating and improving innovations so that to take account of interaction and reciprocal influence between projects. This approach has generated new developments related to the issues of change management. Its promotion in the field of innovation management is currently connected with agent-based modelling and the use of forecasts. In early 2000s this approach was furthered by object-oriented modelling, and, when applied to economic and production systems, is known as multi-agent systems [4] taking into account such factors as independence, exposure to external shocks (influences), flexibility, pro-activities, and availability of intellectual control [3][7]. The most complex issue is to coordinate interaction between different parts of economic and production system [5].

Another approach is management model oriented at such event as innovation diffusion (Eric von Hippel) [1], namely, adoption and study of best practices of similar product manufacturing used in various production systems in an effort to find common features. This approach helps to uncover common features and to provide guidance based on the same type of products and similar production systems.

Approach to innovation management in production systems is often based on some pattern of events that make up the process concerned (Jordan's modelling, Hein's logical modelling), through it does not take into account the relationship between different sub-systems and their interference.

Present-day development of methods of statistics-based management is establishment of databases of actual status of process, event and object. This approach presupposes that all facts within the framework of innovative process paradigm are true, and involves the use of interdependent and agreed databases, their relationship and processing rules [13]. This method may serve as a good base for designing information infrastructures in systems with well-established processes, but is not efficient for creating information infrastructures in dynamic systems, that is, introduction of innovations (novelties) entails a lot of changes in production systems.

There is a great number of practically developed methods and techniques of formalizing individual solutions that can be used in different special cases irrespective of management levels and types of innovation.

By knowing the peculiarities of innovative project to be executed, and the relevant economic and production system (its identification), one can reduce the modelling of its management to application of a number of standard or author's models and methods to each component of innovative project. This approach is justified by the high level of some challenges. So it would be reasonable to give due consideration for the decisive results which can be received from solving local tasks, especially in connection with the fact that evolution of technical and economic systems becomes more complicated both in number of elements and quality of their relations, and hence structuring of models allows changes of this type to be easily incorporated [17].

The challenge of choosing right methods and models to be used can be addressed by a decision-making person. To simplify the process, existing and known methods can be presented in a convenient form based on classification characteristics of innovative projects (refer to Fig. 1).

The application of this scheme is only to choose the classification characteristics[2] as shown in Fig. 1 [2]. In this case, to present methods and models means to indentify their location by reference to the chosen characteristics.

The next challenge is to combine them in an effort to make general assessments at decision-making points. Thus, it is essential to establish relationship between methods when they are combined.

On the one hand, interrelation of methods will depend on interrelation of sub-systems, their elements and tasks they help to address (structural scheme of economic and production system, sequence of management tasks to be solved, etc.). On the other hand, successive (application of some methods to determine internal parameters of others) or parallel (general assessments) application of some methods can be used to determine coefficients of others.

[1] For instance, Jean Tirole has successfully addressed the issue of management in sector markets.

[2] Only characteristics having common angles (Fig. 2) may be chosen.

If there are known structural interrelations a model of innovative project (innovative process) introduction can be presented as a matrix [16]:

$$[M] = \left([A][K]^T \begin{bmatrix} M_1 \\ \cdots \\ M_l \end{bmatrix} \right),$$

where

$[A]$- incidence matrix (demonstrates interrelations between sub-systems, methods and project parameters);

$[M]$ - vector of summative assessments for each methods employed;

$[K]$ - diagonal matrix of corrective coefficients;

M_i – assessment of method employed;

l - number of combined methods employed.

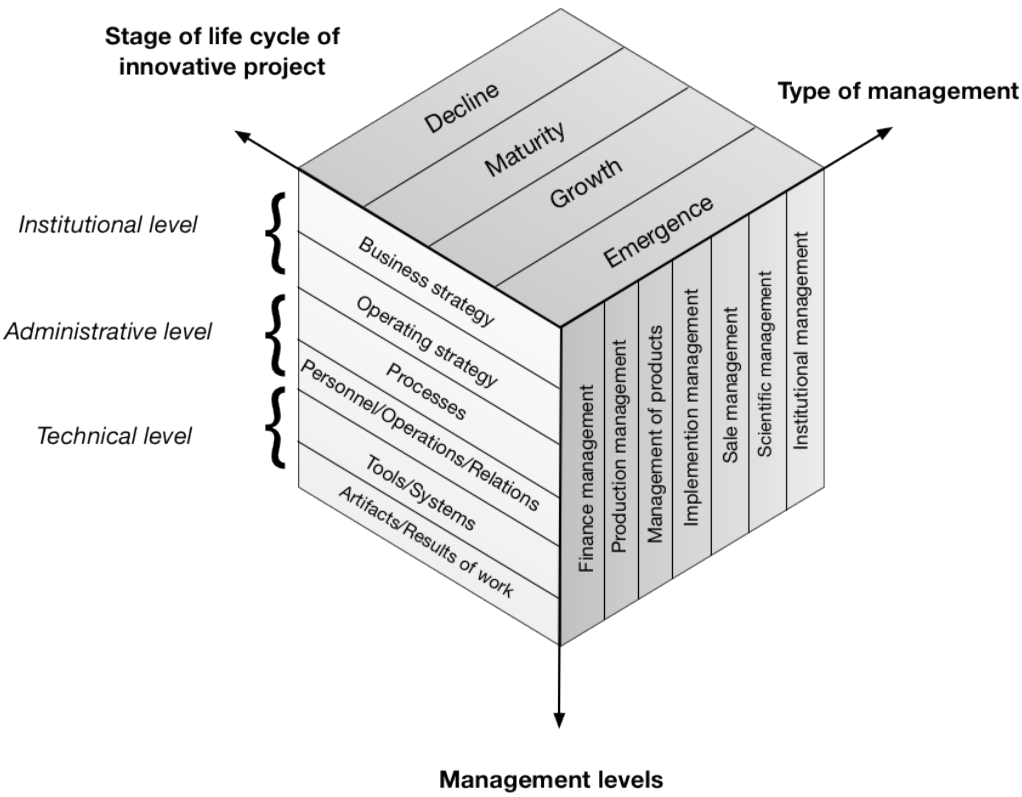

Fig. 1. The Way of Combining Management Presentations to Choose the Right Methods and Techniques Suitable for Assessment of Outcome of Administrative Influences in Execution of Project

For the purpose of addressing economic challenges, results enabling to take optimal or admissible decisions are particularly important. Thus, there is the need for generic criterion which can be obtained by adding or deducting assessments made with the methods described herein [16].

In other cases, method interrelation can also be represented through adding, deducting, multiplying and dividing assessments obtained with these methods.

Thus, implementation of this approach reduces the modelling to a number of operations with mathematical descriptions of methods, techniques and models relating to certain tasks.

In this regard, it could be concluded that implementation of innovations and manufacturing of innovative products have “nucleus” - “generic production function” in the form of non-linear multi-factor dependence between output figures and vector of generic production factors.

III. Functional Approach to Administrative Decision Making in the Execution of Innovative Project

The modelling theory outlines a few tasks that can be addressed with the use of models depending on the unknown. If we look at a model of innovative project implementation, we can highlight two objectives:

1) to establish internal setpoint of project parameters aimed at ensuring the achievement of given targets (goals) of the projects;

2) to determine production parameter values (settings) at the decision-making points.

If we look at examples of formalized objectives, then in the first case production function will dictate general criterial function as follows (refer to more detailed information [16]):

$$\sum_{j=1}^{l_1} u_j k_j (h_j - M_j)^2 + \sum_{j=l_1+1}^{l_2} u_j k_j M_j - \sum_{j=l_2+1}^{l} u_j k_j M_j \rightarrow min$$

where

h_j - desirable value;

k_j - elements of vector of corrective coefficients $[K]$ which, in turn, is calculated by the above formula:

$$k_j = \frac{k_{\text{в}j} - k_{\text{н}j}}{k},$$

where

$k_{\text{в}j}$ - upper edge of the range of parameter variations in j-method;

$k_{\text{н}j}$ - lower edge of the range of parameter variations in j-method);

u_j - assessment of importance of chosen methods (can be made with the use of both expert approach and assessment methods);

l_1, l_2 - boundaries of groups depending on the criterial function ($l \geq l_2 \geq l_1$),

M_j - summative assessment of each method employed.

Search for optimal solution may restrict the targets of methods employed m_{ij} (components of summative assessments of methods M_j):

$$m_{ij} \in G_{ij};\ j = \overline{1, l};\ i = \overline{1, n_l},$$

where

G_{ij} – multitude of alternative parameter values (settings) for j – method;

i - parameter.

This objective can be reduced to a class of discrete multi-parameter optimization tasks with certain restrictions, and achieved by using Bellman-Ford algorithm which is adapted method of dynamic programming for graphs.

As an example of second-type formalization, we will consider a volumetric scheduling task based on discrete volumetric production targets.

$$\sum_i \sum_h K_{ih} \sum_t (C_h(t)x_h(t) + C_h(t)x_h(t)) \to max$$

$$\sum_i \sum_t R_{ij} x_i(t) \leq P_j(t),\ j = \overline{1, M}$$

$$\sum_i \sum_t S_{ki} x_i(t) \leq T_k(t),\ k = \overline{1, K}$$

$$\sum_i \sum_t \alpha_i^q x_i(t) \leq G^q(t),\ k = \overline{1, Q}$$

$$\sum_h \sum_t R_{hj} x_h(t) \leq P_j(t),\ j = \overline{1, M}$$

$$\sum_h \sum_t S_{kh} x_h(t) \leq T_k(t),\ k = \overline{1, K}$$

$$\sum_h \sum_t \alpha_h^q x_h(t) \leq G^q(t),\ k = \overline{1, Q}$$

where

x_i, $i = \overline{1, N}$ – vector unknown;

i type, C_i, $i = \overline{1, N}$ - net revenue from production of i - goods (estimated);

R_{ij}, $j = \overline{1, M}$, $i = \overline{1, M}$ - required capacity of each type of equipment per finished product;

P_j, $j = \overline{1, M}$ - total capacity resources for each type of equipment in terms of average production rate of all equipment of that type;

S_{ki}, $k = \overline{1, K}$, $i = \overline{1, N}$ - required volume of key materials per finished product;

T_k, $k = \overline{1, K}$ - volume of available key materials based on inventory in stock and procurement plan;

$$\alpha_i^q = \begin{cases} 1 - \text{if } i - \text{goods belong to } q \text{ category} \\ 0 - \text{if } i - \text{goods does not belong } q \text{ category} \end{cases}$$

G^q, $q = \overline{1, Q}$ - restriction on sales market (marketing area) (estimated);

K_{ih} - coefficient of correspondence between i and h goods, which shows economic feasibility of joint manufacturing of goods or group of goods within one production (as evaluated by one of methods of Slope One group on the basis of sales statistic data).

The use of forecasts in second-type tasks, even if they are very adequate, may result in variations (especially if there are crisis phenomena in the economy). If we include accidental variations in our model, we will get Markovsky process, which requires further research on the basis repeated modelling and statistic data – refer to Fig 2.

Thus, the designed models and production functions can be considered, as a set of "black boxes" of a sort, each with the relevant functional description [18]. This approach was first proposed by an American economist J.B. Clark.

In addition to the above models which take into account production functions, there are many models of certain units (production department, warehouse, etc.); models of types of activities (production, sales); and models of personnel, product, finance and other models.

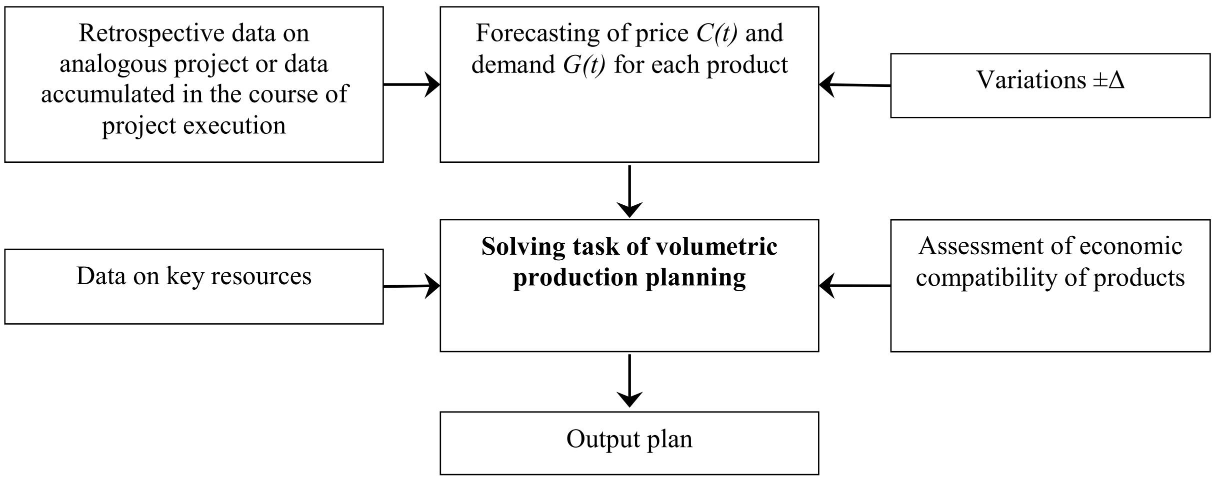

Fig. 2. Hierarchy of Selection of school based on analytical hierarchy process [6].

IV. CONCLUSION

Based on the above, we can conclude that at present there is no uniform concept of project management that would allow us to perform focused search for administrative decisions instead of their analysis and sorting out. Development of conceptual business tends to focus either on separate management sub-systems (such as enterprise management information system [14]) or on separate sub-tasks (such as management of warehouse, sales, deliveries, etc. [18]).

Thus, development of the conceptual foundations of the theory of innovative project management is as topic as ever. It is precisely the understanding of conceptual foundations that facilitates the use of methods and approaches in this field of study as a tool of practical task solving.

It is shown, that development of conceptual foundations of management of product innovative projects is inseparable from development of theory of production system management. Their comprehensive study can be reduced to a number of elements embodied with specific algorithms, models and assessments, which makes it possible not only to take administrative decisions, but to design information system to manage economic and production systems as well.

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