Management and Information Support Issues in the Implementation of Innovation Projects in Production Systems

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Abstract: The article investigates tasks and approaches related to the management of innovation projects, the current state of production and project management in production environment. The article gives a review of main approaches for the management of project implementation in production systems. It suggests the task of management and selection of project development paths on all the stages of project implementation. The article surveys possibilities and drawbacks of existing theories and approaches regarding planning and management tasks in project implementation. It examines general characteristics of building project management models in production-and-economic systems and their practical application. The main goal of the article is to determine gaps in the development of methods and approaches related to the management of project implementation paths as a study object based on the information about projects and their implementation environment, i.e. systems. The practical significance consists in the possibility to increase the amount of successfully implemented projects, to reduce the time period of project development stages, and to cut expenses for the implementation of project stages.

1 INTRODUCTION

Currently, production systems operate in open market where the markets of innovation products have greatest potential. This situation demands fast decision-making and high quality of decisions as there is a necessity to consider a growing number of factors, multicoupled parameters and criteria of production system and implemented projects. Production systems need to be flexible since innovation products have a short life cycle, a great number of modifications (we can even observe a trend towards short-run and single piece production specifically for customer's needs), have high technology and are highly engineered. At the same time, production systems are accelerative and cannot readjust the ongoing processes in a single step. That is why, in order for the desired outcome to be achieved, it is necessary to make such changes greatly in advance, i.e. make planning and embed changes in production systems beforehand. So, there are attempts to develop methods for the management of projects and their production system environments by taking into consideration the whole project life cycle: idea, the transformation of idea into an innovation project, developing the project for the implementation in production system, its production, and sales.

In practice, it turns out to be complicated to manage this consecutive process as the process is not sufficiently formalized at all the stages. Hence, the application of formalized, theoretically sound approaches is limited in such conditions. Besides at seed stages, project implementation risks are very high and are beyond quantitative estimation. Such risks get much higher if we consider management tasks for long-term perspectives. Today, even sophisticated methods and approaches for production system management are considerably limited in application as they do not allow to make time planning of how innovation projects will be implemented in production systems. For instance, the theory of production functions [1] allows to consider only the implementation principles of projects and production systems on the base of well-known principles of their interaction; the theory of multi-agent systems [2] considers projects as independent elements that compete for resources and production system is taken as their environment, rather than an interaction element, that greatly affects the principles of project competitiveness; the theory of active systems [3] is focused on studying the principles of production system operation, operation risks, interaction with external environment without distinguishing multiple markets and projects as independent systems; approaches which are based on project portfolio risk management [4] do not consider production systems as an object of management.

When we consider the external environment as multiple markets and projects, it is reasonable to take into account a high level of variability and dynamics of ongoing processes together with the accelerative nature of production systems. This imposes limitations on the application of methods which are used as a basis for the theories and conceptual foundations of production system management. For instance, the application of such approaches as actual data-based management, reflexive management, target management (that does not take into consideration the dynamics of production system environment changing) leads to delayed decisions and actions and shows up in management failures. Such failures trigger incoherent actions of subsystems and disorder production cycles in time.

Decision makers can use different behaviour strategies for their management principles. By the interaction of production systems with market and innovation projects it is possible to choose most optimal strategies based on the existing or unfolding (according to forecast values) situation. Otherwise, there is a possibility to work out effective measures for the external environment that will provide the desired performance of a production system.

Hence, there is a task to determine the application areas of existing theories, approaches and methods by taking into account production system requirements and their operation conditions.

2 PROJECT IMPLEMENTATION TASK SETTING AND THE PLACE OF MODERN APPROACHES AND THEORIES IN THE SOLUTION OF THIS TASK

In project implementation management, it is necessary to consider management processes of project development on different stages and take into account the change from one stage to another one (see the Figure 1) which can be formulated as a set of changes $G_i^{(D)} \cup J_i^{(C)}\ \exists i$:

$$\begin{array}{l} S_{i-3}^{(A)} \cup S_{i-3}^{(B)} \xrightarrow{I_{i-3}^{(B)} \cup I_{i-3}^{(AB)}, P_i^{(B)}, R_{i-3}^{(B)}} \\ S_{i-2}^{(B)} \cup S_{i-2}^{(C)} \xrightarrow{I_i^{(C)} \cup I_{i-2}^{(BC)}, P_{i-2}^{(C)}, R_{i-2}^{(C)}} \\ S_{i-1}^{(C)} \cup S_{i-1}^{(D)} \xrightarrow{I_{i-1}^{(D)} \cup I_{i-1}^{(CD)}, P_{i-1}^{(D)}, R_{i-1}^{(D)}} \\ S_i^{(D)} \cup S_i^{(E)} \xrightarrow{I_i^{(E)} \cup I_i^{(DE)}, P_i^{(E)}, R_i^{(E)}} \\ S_{i+1}^{(E)} \cup S_{i+1}^{(F)} \xrightarrow{I_{i+1}^{(F)} \cup I_{i+1}^{(EF)}, P_{i+1}^{(F)}, R_{i+1}^{(F)}} S_{i+2}^{(F)} \end{array}, \qquad (1)$$

where i – the number of planning step ($n - 1 > i > 2$), – the planning horizon, I – the set of resources (investments) necessary to make a change, R – the risk evaluation of making a change, P – the potential profit (benefits) expected from making a change, S – the set of possible states.

In the suggested setting, task solution requires an active element, i.e. management subject. More than that, different project stages have different formalization levels. That is why, by tackling the task we cannot apply only one single method or approach, yet we need to think about applying a group of methods or approaches within one theory or strategy.

Currently, scientists consider changes within one stage generally. The most developed stage is project implementation stage in the existing production system environment ($S_{i-1}^{(D)} \xrightarrow{I_{i-1}^{(D)}, P_{i-1}^{(D)}, R_{i-1}^{(D)}} S_i^{(D)}$).

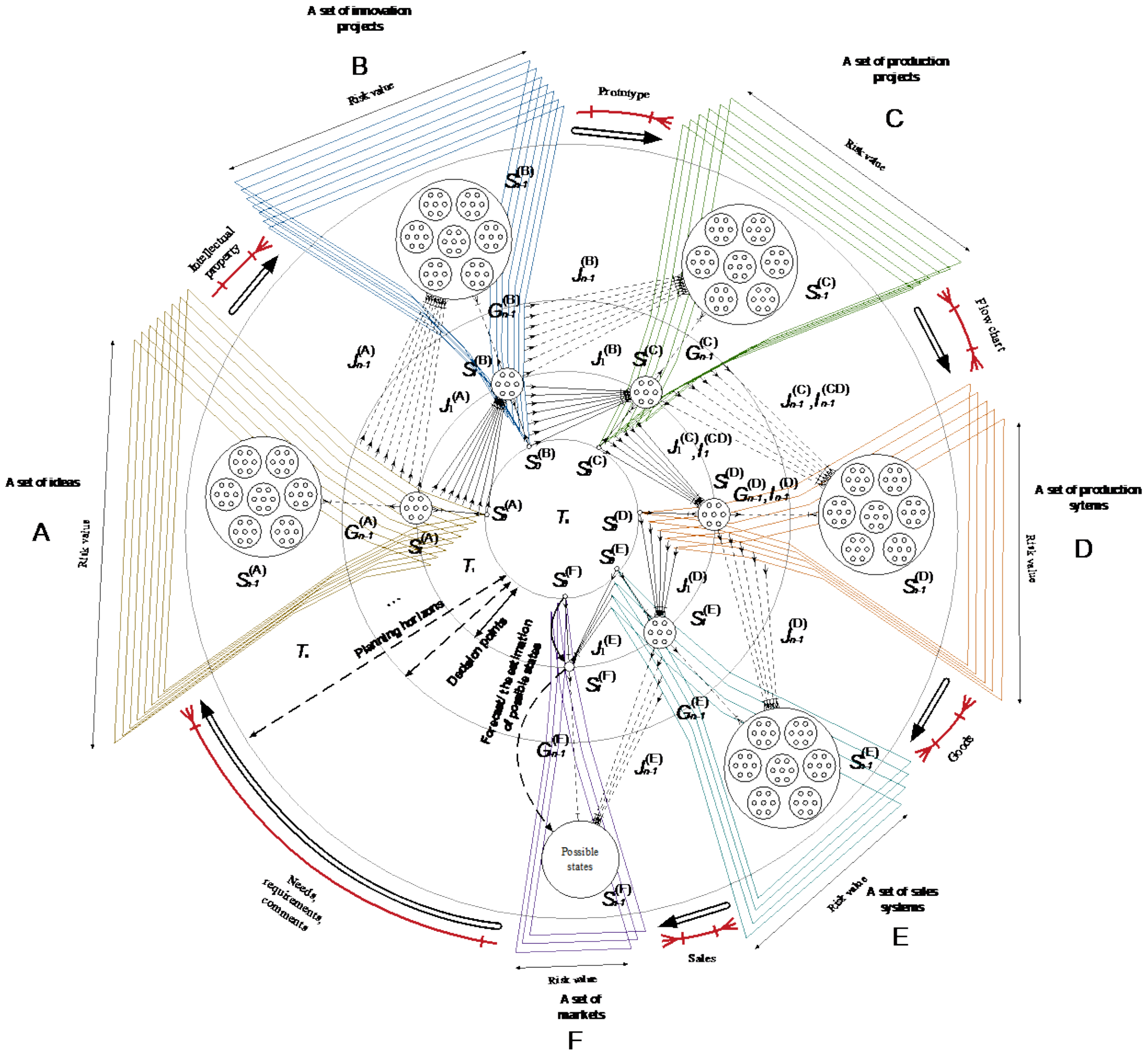

Figure 1: The structural interaction breakdown between innovation project implementation stages by solving the task of their implementation and planning management.

Popular theories which are widely used in the management of production systems and their project activities are given in the Table 1) with their characteristics:

T1) The theory of active systems which is focused on the term «active element» introduced by V.N. Burkov and open management principle [3], as well as the theory of organizational systems (see the works of D.A. Novikov) that developed the idea of cybernetic solution path application for the management of social and economic systems; according to this theory, the ongoing processes in social-and-economic and production environments are also considered in their interaction, including uncertainty conditions of external and internal environments (the set of states $S_i^{(D)}$ and changes $S_{i-1}^{(D)} \xrightarrow{I_{i-1}^{(D)},P_{i-1}^{(D)},R_{i-1}^{(D)}} S_i^{(D)}$ by a limited set of production systems D), and multiple management aspects are considered (i.e. financial management, organizational project management, institutional management, information management, etc. (see [5], [6] and [7]). A group of models was implemented under the specified theories: the financial model of innovation projects (see [8] and [9]); the decision making model that is based on rational behaviour and determinism hypotheses (by probabilistic indeterminacy) [10]; the basic model of organizational (active) system (OS) and its extension (dynamic OS model, multidimensional OS model, multiple-level OS model, OS model with distributed control, OS model with uncertainties, OS model with limited joint activities, OS model with information support) [10] [11]; reflexive model [9] [12]; the basic models of single- and multidimensional active systems (AS) (which also include distributed control) on the basis of the following incentive systems: compensatory, uneven, proportional, unified proportional, and in multidimensional AS by taking into account uncertainty [11] [10]; the models of rational behaviour and bounded rationality [9]; the model of fuzzy control in social-and-economic systems [13], the model that takes into consideration the preferences of decision makers [14], etc.

T2) Related to project management (C), the theory of multi-agent systems became popular after L. Peppal had proposed to use the theory of games for describing backup and improving innovations in 1997 [15] where projects are considered as information agents within the theory of multi-agent systems (see [16] and [17]) that compete for resources ($I_i^{(D)}$ and $I_i^{(CD)}$). In the specified theory, there is a traditional classification of different types of models: deliberative models (as an example see [18] and [19]), reactive models [20], hybrid models [21].

T3) The theory of production functions deals with the investigation and the functional interaction description of production systems (D) and projects (E) that are being implemented in production environment (the set of changes $G_i^{(D)}$ in the Figure 1) by taking into account different factors and, as a rule, in one or a limited set of production systems. In this theory, mathematical model is used as a formula of production output dependence (revenue) from the vector of spent or utilized resources in production (purchased resources) [1]. Here is the list of most popular functions that were developed according to this theory: the function with fixed factor proportions (the Leontief production function), the Cobb-Douglas production function, linear production function, the Allen production function, the CES production function, the production function with a linear factor change elasticity, the Solow and Hilhorst production function, bounded function, multimode function, the production function in linear programming [22], [23], [1].

T4) The results of theoretical and practical efforts in the previous years introduced a vast number of approaches which are based on structuring management processes in production systems, and namely [23]: the methodology of structured analysis and design (SADT (D. Ross), DFD (E. Yourdon), DFD (K. Gane — T. Sarson, DeMarca), object-oriented methods (OOD (Booch/Jacobson/Rumbaugh) [24], OOAD (P. Coad — E. Yourdon) [25] and [26], OODLE (Shlaer — Mellor), Demeter, Henderson-Sellers); information engineering methods (Martin-Finkelstein, Porter, Goldkuhl); project management standards (ISO/IEC 15288; DIN 69901; GOST P54869-2011, etc.).

T5) Machine learning methods related to project management in production systems. There is a steady trend of applying machine learning methods by handling management tasks in production-and-economic systems (see, for instance, [27]). At the same time, the significant role of machine learning methods in production management tasks will be only increasing [28]. Today, machine learning methods are used for solving a group of management and planning tasks (for instance, forecasting machinery breakdown, building empirical models by taking into consideration the changes of machinery characteristics in time, predictive management of accelerative systems (such as head supply systems and processing units), the development of market pricing and planning principles in production [29]).

By counterclockwise movement from the stage C to the stages B and A (see the Figure 1) the formalization level is decreasing. Currently, expert communities examine projects and determine goals for the projects on the stages B and A as a part of competitions. However, different information is collected about projects (analogues, market demand, investment, project team, the presence of prototype, project characteristics compared with analogous versions, etc.), attempts are made to analyze the collected statistical information (see, for instance, [30]). Available statistical data and expert community create a good background for analyzing innovation projects with help of machine learning methods (also on the basis of a new approach, i.e. reinforcement learning techniques (semi-learning methods) [31]).

Table 1: Change management and decision-making support by project implementation in production environment.

	T1	T2	T3	T4	T5
Goal orientation	Searching the ways how to affect the system for achieving its desired behaviour	There is no clear goal definition or the goal is determined only with help of logical means.	Management goal is not formulated in the methodology of production function.	Goal is determined by a decision maker.	Goal is determined on the stage of model design by management subject.
The system of relationships between production system and projects	Performed on the basis of rules, laws and procedures that regulate the interaction of participants.	Each participant operates independently in accordance with own regulations.	Established as interaction between production function parameters.	Established by the regulated structure and principles of interaction.	Laid down during model learning process based on specified goals.
Risk management	Considers different uncertainty types (internal, external, mixed) and uses interval, fuzzy, probabilistic approaches.	The probability of this or that behaviour is determined on the base of simulation modeling by the Monte Carlo method or the Bayes' theorem.	Not performed.	Not performed.	Risk evaluation and the use of any techniques for work with uncertainties.
Time orientation	Models in both statistical and dynamic setting.	Time is discrete and is defined by the emergence of events.	In the classical theory of production function, the time factor is not considered.	Considered as a continuous process.	All models are adjusted in time and are dynamic.
Interaction with management subject	For management subjects, models can be presented as decision-making support systems.	Modeling results are considered as information that is taken into consideration by management subject in decision-making.	Management subject uses the methodology of production function for decision-making based on production function studies with help of only mathematical methods.	Information support of management subject.	Ready decisions are produced which can be used by decision makers.
External environment orientation	Market is considered as a general term that can include other production systems.	The connection of agent and environmental area is not precisely defined. Historical data are not considered. It is not clear what agents the goal will and will not be dependent on.	Bounded by production function factors.	In accordance with the specified principles and rules.	Within a restricted set of observed parameters.
Change management	Recommendations for making changes in system performance.	Not considered.	The study results are used for defining the amount of required resources and production capacity on the basis of production elasticity and maximum capacity determination.	Performed by decision makers by structuring production system activities.	All the decisions are suggestions for the selection of parameters or performance algorithms.
Basic idea	The use of cybernetic approach for managing systems with uncertainty.	System element is considered as an independent active element that operates due to its own internal rules.	Conformity search among the parameters of production system and released products with help of heuristic methods.	There is a possibility to describe system activity with help of a limited set of elements and their interaction rules.	The automated process of building and adjusting empirical models on the basis of empirical and actual data.

3 ADDITIONAL REQUIREMENTS TO THE IMPLEMENTATION OF PROJECT MANAGEMENT MODELS IN PRODUCTION SYSTEMS

The description and analysis of paths (1) sets up a grading problem and, hence, one of the existing management approaches can be used for defining their estimate criteria: project management, management and planning by objective, resource management, information and reflexive management, predictive management, adaptive management. The management mechanism is chosen on the basis of management goals that are set by management subject. In production-and-economic systems, economic efficiency and feasibility of project implementation is considered as a general criterion. In this case, each state S_i and entering this state from the state S_{i-1} can be estimated as follows:

$$(1 - R)(P - I) \rightarrow \max, \qquad (2)$$

where R – the risk evaluation on making a change, P – the potential profit, I – the required investment (resources) for making a change.

In the planning and management of projects and production systems, it is also possible to use other criteria and consider the consistency of goals in production subsystems and their projects, invariant states in decision points, the complementarity of projects in production environment, irreversibility of managerial decisions. Besides, the information has to be reliable.

The step size $\Delta t_i(t)$ (it depends on decision points and is considered as a discrete variate with a variable step) and the planning horizons T_n. determine the set of possible states (S_i). Such time position narrows a group of techniques that can be used before applying special state principle and case management. However, we encounter the problem of choosing planning horizons. This action is based on the expected project portfolio. The probability of portfolio criteria efficiency is described by a binomial distribution (the planned state S_i), and the Bayes' theorem defines the probability of a successful change into a new state that is dependent on the previous state (the state that we are in) [32]. Invariance in project development path selection will show up as a set of equally obtainable optimal and Pareto states. In this case, the solution of task will be a set of development paths and states that can be conditionally presented as a tree.

Hence, the key problem is the generation of a set of possible states. For this purpose, we need to build a model that includes estimate criteria parameters (2). For the examined stage, the surrounding elements of the stage (see the Figure 1, the set of sales systems E is not marked out in some settings and is considered as a production system element) form the external environment. The management object interacts with the external environment through its variables and the way these variables are used in management model. In order for planning tasks to be solved and accelerative processes to be considered in production environment, the values of these variables [33] and project parameters [34] have to be predicted. The predictions have a certain degree of reliability which is determined on the basis of adequacy evaluation and the range of possible deviations. The latter ones can be calculated into risk estimates for the expected forecast-based states to be obtained [35]. The model parameters can be presented by different types of data (time series, single characteristic values that all together characterize the project, some of them are described by known principles and can be built upon several values [36]). Therefore, another important task is to determine the significance of parameters, certain characteristic values and their combinations for project implementation [37]. Taking into account the differences in implementation stages and data-dependent model characteristics, empirical techniques should be applied in order to build the model.

The model of each project implementation stage has to be designed individually as stages have different implementation environment (as shown in the Figure 1). Besides, it is important to take into consideration the specifics of project itself or its environment system. At the same time, this will be a complex model with a required system optimization [38], that triggers a group of problems, i.e. the problems of selecting behaviour strategy (for instance, the behaviour for the common benefit or for the purposes of certain elements) not only in the interaction of production systems but also in the interaction of production system elements; the problems of model elements' compromising which handle different tasks within one general management and planning task in production environment (for instance, see the breakdown in the Figure 2) on the base of complex modeling and possible states' search by determining the constraints in the area of possible solutions. More than that, the model has to consider technical and economic tasks jointly (i.e. heterogeneous model) by taking into account the time factor; besides, it should be a computable model that connects different management parameters in one system (the paradigm C^5) [39].

The model should be built on the principles that allow its changes (teaching, adjusting) along with the changes in its external and internal environment operation conditions and different degree of experience that was obtained in different model operation time period. Hence, in order for a complex model to be implemented, we need to use different approaches and methods for its elements by taking into consideration additional requirements of management subject, developer preferences, and statistical data.

4 INSTRUMENTAL CHARACTERISTICS OF COMPLEX MODEL IMPLEMENTATION IN MANAGEMENT

Implemented as information product, the model tackles several DSS tasks: *a)* tool implementation for «searching solutions», that is based on using models as a series of procedures for data and statement processing in decision making [40]; *b)* the implementation of interactive computer-based systems that help use data and models for tackling unstructured problems; *c)* the implementation of computer information systems for the support of diverse activities by making decisions in the

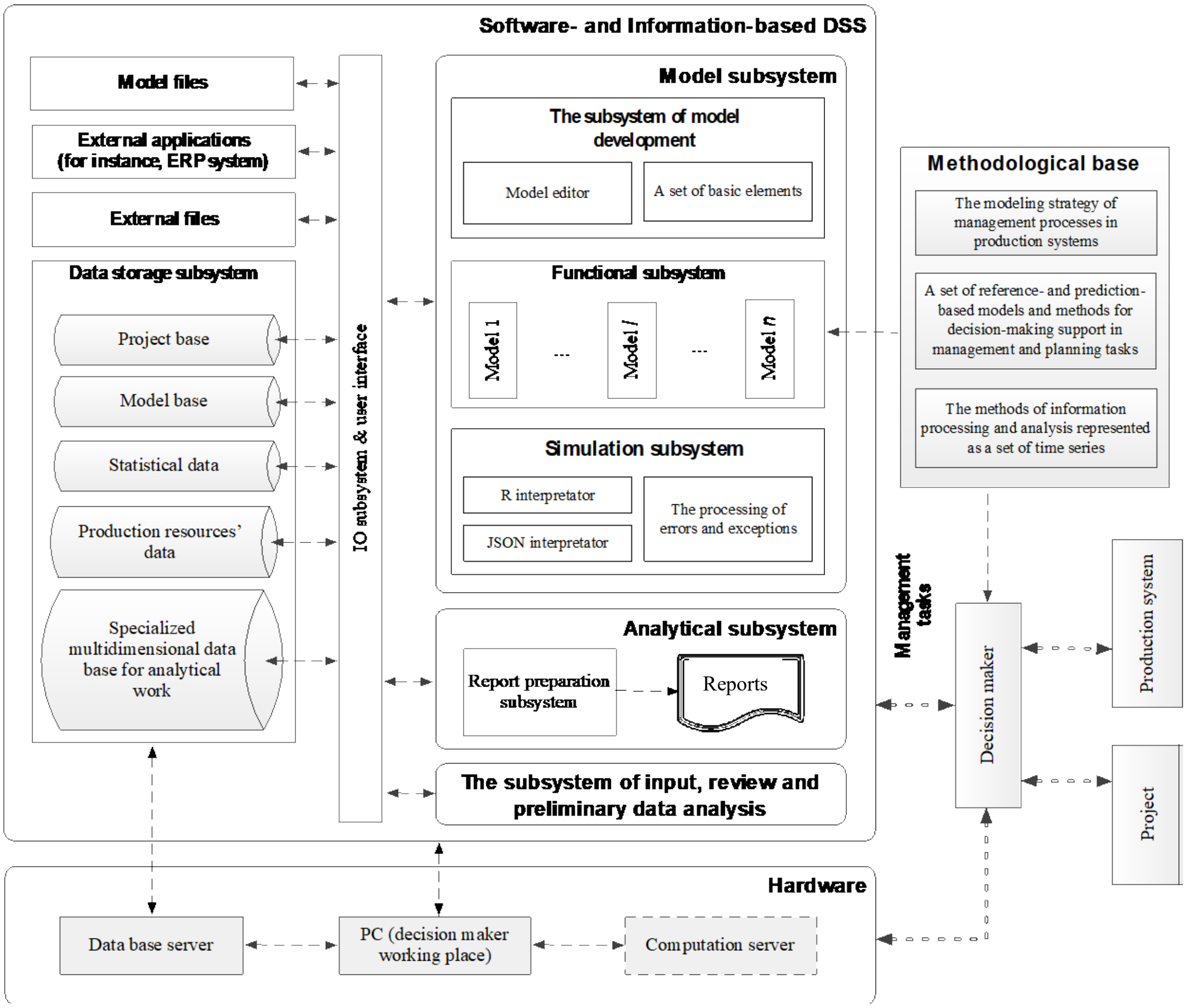

Figure 2: The structural information interaction breakdown for the implementation of models and methods in order to support managerial decision-making process in production systems.

situations where the use of automated systems for the whole decision making process is infeasible or troublesome [41].

The application of one toolset (even the most sophisticated one) is not enough for building heterogeneous systems. That is why, by the development of information system we need to consider the mechanisms of work with data and the ways how model components can be integrated in the consolidated information area [42].

The structure of information area that satisfies the specified requirements is shown in the Figure 2.

5 CONCLUSIONS

Despite a big amount of studies dedicated to different management aspects, the analysis of production and project activities, the issues of studying ongoing processes and the impact of managerial decisions on examined systems, the modern planning and management methods do not allow to consider all factors related to available resources required for production systems as well as technical, economic and financial project criteria and parameters. Today, when production competitiveness is strongly focused on innovations and continual release of new goods, management and planning becomes challenging in production environment, since the level of process automation is increasing due to fast decision-making requirements and human factor deregulation (at the same time, despite a vast number of negative factors, the integration of human workforce into production process allows to provide additional control and handle exceptions).

To summarize, we can say, that today there are interesting theories and approaches that allow to solve management tasks in projects and production systems by taking into consideration certain groups of tasks or specified conditions. However, we encounter a shortage in methodological approaches in marketing management, innovation projects' selection and management formalization.

When we solve individual tasks, it is impossible to solve the task of innovation project management on all the stages of its life cycle even with specific suppositions. Today, there are no approaches which are not bound to singe task characteristics. Moreover, the existing models do not allow to work with several innovation projects simultaneously [43].

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