Semantic Modelling for the Communication Mechanism of the Production System

Aleksandr E. Karlik, Elena A. Iakovleva, and Vladimir V. Platonov

St. Petersburg State University of Economics, Sadovaya, 21, 191023 St. Petersburg, Russia
karlik1@mail.ru, helen7199@gmail.com, vladimir.platonov@gmail.com

Abstract. The study deals with the application of intelligent management technologies to support communicative mechanisms in the modern production environment based on the analytical tools which apply the cognitive approach, namely, the semantic modelling. It supports the application of the situation analysis for strategic control based on the principle of management metafunctions. The article presents the semantic model of a discrete situational network in the form of a network graph. It is designed to contribute to the implementation of the communicative strategies to facilitate the decision-making under digitalization. The analytical procedure also designed for decision-making on municipal level that is important under tough budget constraints conditioned by the COVID-19 pandemic. The main result of the study is the semantic model of the communicative mechanism of the production system. The proposed intelligent solutions are risk-sensitive because it accounts for the significant exposures. The systematization of the order of interaction under implementation of the cyber-physical systems, production cooperation and communication within the specialization network chain allow to apply the system analysis to the communicative processes that enable information transfer. The article is designed to contribute to the system theory and methodology by application of logical-linguistic analysis and modeling as well as by combining adaptive management and semiotic approach in application to the communicative mechanism of production systems.

Keywords: Semantic modeling · System analysis · Communications · Production

1 Introduction

Digital transformation dictates the need for better communication to support cooperation networks under rapid digitalization [1]. At the same time digitalization makes it possible to implement to apply the tools of the cognitive approach for decision-making in the rapidly changing environment shaped by contradicting influences. There are limits to the digitalization of industry, which include the computability and limitation of many natural resources (water, land, oil, air, human life), on the one hand, and the value of imaginative thinking, mental processes of information transformation among
decision-makers. On the other hand, the boundaries of digitalization are set by the presence of will and emotions, collective and individual value systems (for a control system), processes of transmitting meaning (for example, in hybrid intelligence systems such concepts as peace, conscience, honor), knowledge representation formats (for example, quality life and its dimension in modeling for strategic control in production systems). The impossibility of rigorous formalization and a clear numerical description of these aspects of the functioning of the industry and the industrial production system requires the application of cognitive methods for managing socio-economic complex systems, linguistic-combinatorial modeling, the development of dynamic cognitive scenarios for identifying trends in business and society and implementation in business and non-profit organizations [2].

Risk-sensitive strategic management approaches in the production systems should be integrated via modern intelligent solutions that, as a result of their application, form the rules and relationships to achieve the performance of the enterprise and to provide opportunities for analysis and processing of various data on the exposures to problem situations. Proposed analysis should be carried out in dynamics and in conjunction with changes in the internal and external relevant environments of the production systems operating under conditions of information network society.

2 Literature Review

Structuring the research problem. The main problem of the study is to consider the approach for maintaining the production infrastructure in a stable state or to ensure its homeokinetic (dynamic) equilibrium [3] in the system of strategic control and risk management. The subproblems are: 1) recognition of the meaning in verbal management decisions to objectify the responsibility of the proposed and implemented decisions on strategic management, improving the quality of life, including health care, accessibility and quality of education, improving the demographic situation, finding growth paths for industry, matching a system of budgets at various levels based on methodology of solving strategic problems, meeting the environmental challenges, maintaining the cultural identity; 2) the forecasting systemic trends and contradictions, the emergence of exposures and challenges, identification of risks; 3) distributed processing of large sets of unstructured data (big data); 4) identification of parameters and management methods to resolve conflicts of interest. To further systematize management challenges in order to maintain the production infrastructure in stable equilibrium and as well as to maintain proportions in the industrial production system, there is the urgent need to implement the cognitive approach. Firstly, it is necessary to establish an analysis of the sense making activities of managers [4]. Secondly, it is needed to specify procedures for objectifying the responsibility of put forward and executed decisions on strategic management. Thirdly, the strategic management system should incorporate the semantic prototypes of real perceived and objective information to find system’s distortions, and also predict emerging the system trends and contradictions in the extraction of information to identify risks, exposures and new opportunities in production systems. The latter are sources of formation and large sets of unstructured big data that require further analytics. Such analytics is necessary to
identify the parameters of target standards and develop management methods to resolve conflicts of interest.

The methodological concepts applied for this end are logic, linguistics, mathematics, semiotics, modeling, programming, system analysis, situational approach, cognitive approach, adaptive management, functional approach, risk-sensitive strategic control based on the vital approach to the study of organizational systems. When building the cognitive models, logic, linguistics, mathematics, semiotics, fuzzy logic, programming, system analysis, situational approach, cognitive approach, adaptive management, functional approach, vital approach should be considered. Quantitative and qualitative indicators are applicable, given by the variables described on numerical and linguistic scales.

Maintaining steady-state in the production systems currently depends on coordination and speed of reaction, the personal responsibility of managers and the variability of management parameters, coherence and interaction between subsystems of support for intelligent solutions and the maturity of the production system architecture itself. Such a variety of parameters in real production processes requires coordination of managerial influences at all levels of management and synchronization of approaches to the practice of justification and selection of priority tasks in industry [5, 6]. Proactive recognition of exposures to the emergence of problematic situations requires the implementation of cognitive technologies in the strategic control - from well-known cognitive mapping to the development of the strategic management ontology.

Quantitative and qualitative indicators should be specified within by the system of variables described on numerical and linguistic scales [7] to provide the representation of the real-world systems and improve levels of explanatory power [8].

Criteria for making decisions are to maximize the achievement of target indicators of strategic control with the given resource constraints. The example of the application of this methodology is the maximization or improving the quality of life in the perspective of emerging digital opportunities and new social technologies in the context of specific families in particular regions. The condition for implementation is the creation of a semantic model of a discrete-situational network of problem situations, linguistic-combinatorial modeling, the developing of the intelligent decision support systems for managers taking into account the expected risks [5, 9].

Risk is a characteristic of the exposure. It reflects the composition of the damage and the uncertainty of its occurrence. The risk can be defined in the form of moments of a random amount of damage of one kind or another or in the form of boundary values of this damage, depending on the nature and meaning of this damage within the domain of strategic management. This requires an analysis of sense making processes of decision-makers executed the strategic control, which will identify obstacles and distortions that have impact on the speed of recognition of problem situations. In subsequent iterations, sense making analysis can be used to determine the competence of managers [10], on the one hand, and the formation of management metafunctions, on the other.


3 Research Materials and Methods

The motivation for the implementation of this approach for the identifying the meaning of words is its capacity to produce the independent judgement needed for the supporting the new control systems, since it acts as a necessary link in the development of methodology for the understanding of complex situations and the decision-making process [11, 12]. The need for research based on the methods of cognitive linguistics is due to the limitation of existing methods [13–15] The effective strategic control for the management of complex systems requires the development of a methodology for the implementation of the cognitive approach and tools that would allow decision-makers to implement the reason-based strategic goal setting procedure [16, 17].

Figure 1 is a semantic model of a discrete situational network in the form of a network graph:

Fig. 1. The results on students’ cultural intelligence level

Adaptive process planning facilitates communications and enhance flexibility of production systems [11] Risk-sensitive planning technology is a cognitive technology of building a pool of interconnected solutions to anticipate problem situations at different management tiers, it is built on the identification of the particular growth points by finding the imbalance in the binary pairs “Needs and Opportunities” based on the semantic model of a discrete-situational network (DSN) of problematic situations. It deals with the particular bottlenecks and imbalances, communication disruptions in the production system and brings about the need to implement the new formats of knowledge, transferred between decision-maker and the management subject in the industrial production system. This requires an analysis of the sense of making process
of decision-makers resulted in strategic decisions, which allows to identify hindrances to the speed of recognition of problem situations. In subsequent iterations, sense making analysis can be used to determine the competence of managers, on the one hand, and the building of management metafunctions, on the other. The involvement of the integration, cooperation and specialization mechanisms for effective maintaining the dynamic equilibrium of the production system needs the advanced identification of exposures and risk assessment by the means of modeling for finding solutions for strategic control. Besides it dictates the need to apply in the industrial production

Table 1. Characteristics of symbols in the semantic model

| Name                                               | Name                          |
|----------------------------------------------------|-------------------------------|
| SPS – Strategic problem situation                  | EO – Elementary object        |
| G1 - Discrete situation network (DSN)               | GDS – The goal of the decision center |
| G2 – Decision-maker                                | GDO goal of an elementary object |
| G3 Control object                                  | CLPR – Goal of the decision-maker |
| G4 – Tree of goals of the decision maker            | DRC - Action of the decision center |
| G5 – Tree of goals of the control object            | DC - Decision-makers          |
| G6 - Alternative network schedule of the decision-maker (ANGD) | DEO – Action of elementary object |
| G7-Alternative network schedule of the object, (ANOC) | DLPR – Action of the decision-maker |
| G8 - Resource complex Financial resources          | FRK_FR_G8-Phases of the resource complex Financial resources |
| G9-Resource complex Production facilities and inventories | PRK_PIK_G9-Phases of the resource complex Production facilities and inventories |
| G10-Resource complex Intellectual capital          | FRK_IK_G10-Phases of the resource complex Intellectual capital |
| G11 - Resource complex Human capital, people       | PRK_CPN_G11-Phases of the resource complex Human capital, people |
| G12 - Resource complex Intangible resources        | FRK_NA_G12-Phases of the resource complex Intangible resources |
| G13 - Resource complex Nature, ecology, waste, utilization | PRK_PEOU_G13-Phases of the resource complex Nature, ecology, waste, utilization |
| G14-External environment Suppliers and contractors  | FBS_PIP_G14-external environment Phases Suppliers and contractors |
| G15-External environment Customers, consumers      | FS_ZP_G15-Phases of the external environment Customers and consumers |
| G16-External environment Foreign partners           | FS_ZP_G16-Phases of the external environment Foreign counterparties |
| G17-External environment Banks, insurance companies | FS_BSK_G17-Phases of the external environment Banks, insurance companies |
| G18-External environment Public administration      | FVS.GO_G18 – Phase external environment Public administration |
systems the transfer pricing mechanism to monitor the proper quality, cost control, quantification of the results on the final product in the value chain by tracking the life cycle of products and technologies, adjusted for spatial distribution of production process across the regions (overcoming inequality of incomes, reducing unemployment, ensuring employment). It motivates to build the dynamic cognitive scenario (a “reference” view of the functioning of the management system and the allocation of resources in the chain and objectification of the responsibility of managers) of interaction of all factors, minimizing the exposures and challenges. This approach provides control over the supply chain and tracking the creation of value added in the spatial-temporal aspect, but as well as the waste disposal and recycling (Table 2).

| NN | Connection nodes of the graph | Relationship concepts in the semantic model |
|----|-------------------------------|--------------------------------------------|
| 1  | G2 – G1                       | DC – PS                                    |
| 2  | G2 – G3                       | DC – EO                                    |
| 3  | G2 – G4                       | DC – CLPR                                  |
| 4  | G2 – G5                       | DC – GDO                                   |
| 5  | G2 – G6                       | DC – DLPR                                  |
| 6  | G2 – G7                       | DC – DEO                                   |
| 7  | G2 – G8                       | DC – FRK_G8_ΦP                            |
| 8  | G2 – G9                       | DC – FRK_G9_PIK                           |
| 9  | G2 – G10                      | DC– FRK_G10_IK                            |
| 10 | G2 – G11                      | DC– FRK_G11_CPN                           |
| 11 | G2 – G12                      | DC– FRK_G12_NA                            |
| 12 | G2 – G13                      | DC– FRK_G13_PEUO                          |
| 13 | G2 – G14                      | DC– FVS_G14_PIP                           |
| 14 | G2 – G15                      | DC– FS_g15_ZIP                            |
| 15 | G2 – G16                      | DC– FS_G16_ZIP                            |
| 16 | G2 – G17                      | DC– FS_G17_BSK                            |
| 17 | G3 – G8                       | EO-FRK_G8_FR                              |
| 18 | G3 – G9                       | EO-FRK_G9_PIK                             |
| 19 | G3 – G10                      | EO-FRK_G10_IC                             |
| 20 | G3 – G11                      | EO-FRK_G11_CPN                            |
| 21 | G3 – G12                      | EO-FRK_G12_NA                             |
| 22 | G3 – G13                      | EO-FRK_G13_PEUO                           |
| 23 | G3 – G14                      | EO-FVS_G14_PIP                            |
| 24 | G3 – G15                      | EO-FVS_G15_ZIP                            |
| 25 | G3 – G16                      | EO-FVS_G16_ZP                             |
| 26 | G3 – G17                      | EO – FVS_G17_BSK                          |
| 27 | G4 – G1                       | CLPR – PS                                 |
| 28 | G4 – G6                       | CLPR – DLPR                               |
| 29 | G4 – G7                       | CLPR – DEO                                |
| 30 | G5 – G1                       | GDO – PS                                  |

(continued)
The advantage of the presented semantic model (Fig. 1, Table 1) for the implementation as a method for the support of the intelligent solutions is its capacity to enable the continuum of logical and linguistic variables based on logical-linguistic modeling. The dynamics of the model is described by the control functions and frames of background knowledge about problem situations. It accounts for changes in the resource complexes and allows to update instantly the database of the external environment.

### Table 2. (continued)

| NN | Connection nodes of the graph | Relationship concepts in the semantic model |
|----|--------------------------------|---------------------------------------------|
| 31 | G5 – G3                        | GDO – EO                                    |
| 32 | G5 – G4                        | GDO – CLPR                                  |
| 33 | G5 – G6                        | GDO – DLPR                                  |
| 34 | G5 – G7                        | GDO – DEO                                   |
| 35 | G5 – G8                        | GDO – FRK_G8_FR                             |
| 36 | G5 – G9                        | GDO – FRK_G9_PIK                            |
| 37 | G5 – G10                       | GDO – FRK_G10_IC                            |
| 38 | G5 – G11                       | GDO – FRK_G11_CPN                           |
| 39 | G5 – G12                       | GDO – FRK_G12_NA                            |
| 40 | G5 – G13                       | GDO – FRK_G13_PEUO                          |
| 41 | G5 – G14                       | GDO – FVC_G14_PIP                           |
| 42 | G5 – G15                       | CEOS-FS_G15_ZIP                             |
| 43 | G5 – G16                       | CEOS – FS_G16_ZP                            |
| 44 | G5 – G17                       | CEOS-FS_G17_BSK                             |
| 45 | G6 – G7                        | DLPR-DEO                                    |
| 46 | G7 – G1                        | DEO-PS                                      |
| 47 | G7 – G3                        | DEO-EO                                      |
| 48 | G7 – G8                        | DEO – FRK_G8.FR                             |
| 49 | G7 – G9                        | DEO – FRK_G9_PIK                            |
| 50 | G7 – G10                       | DEO-FRK_G10_IC                              |
| 51 | G7 – G11                       | DEO – FRK_G11_CPN                           |
| 52 | G7 – G12                       | DEO – FRK_G12_NA                            |
| 53 | G7 – G13                       | DEO – FRK_G13_PEUO                          |
| 54 | G7 – G14                       | DEO – FVS_G14_PIP                           |
| 55 | G7 – G15                       | DEO-FS_G15_ZIP                              |
| 56 | G7 – G16                       | DEO-FS_G16_ZIP                              |
| 57 | G7 – G17                       | DEO – FS_G17_BSK                            |
| 58 | G2 – G18                       | DC– FRK_G18.GO                              |
| 59 | G3 – G18                       | EO-FS_G18.GO                                |
| 60 | G5 – G18                       | CEO-FS_G18.GO                               |
| 61 | G7 – G18                       | DEO – FS_G18_GO                             |
Cognitive technology allows to map the world of decision-makers and, finally, to develop the comprehensive ontology for this domain. The meaning of words as the main cognitive unit has recently come into the focus of strategic control from the cognitive linguistics, cognitive psychology, semiotics and related sciences. Among the most important modern approaches to the interpretation of the meaning of the words relevant for application in the strategic management is the situational (event) approach. It focuses on the knowledge and meaning of words in the decision-making, which is realized through its inclusion in some more voluminous unit - a proposition, frame, scene, script, logical-linguistic models, etc.

4 Results

The semantic modeling facilitates the application of the principles of integration, cooperation and specialization to maintain the dynamic balance of the economic system and to identify exposures ahead of time. It supports the risk assessment by modeling a discrete-situational network of problem situations and finding solutions for strategic control. Its implementation needs the following action plan. Firstly, the application of the system control mechanism, monitoring of appropriate quality, regulating the cost, determining the results of the final product in the chain, tracking the life cycle of products and technology, spatial orientation of the production in the regions (overcoming social inequality and unemployment). Secondly, the implementation of a dynamic cognitive scenario that provides a “reference” view of the functioning of the management system and resource allocation in the chain and objectification of the responsibility of managers. Third, it requires the interaction of all factors, including exposures and challenges [11]. This approach provides not only control over the supply chain and tracking the production of value added in the spatio-temporal aspect, but also the disposal of waste after the operation of the product. It creates the conditions for the implementation of not only management metafunctions, such as organization - coordination and control, but also their responsible implementation, including organization, coordination, control, etc. This is necessary to build a new industrial society. New cyber-physical production systems are required, in which products created on the basis of automation of all components of production processes and implementation of the information technologies, where machines of different business entities interact with each other. The creation of digital twin [18].

The application of cyber-physical systems and relevant risk-sensitive strategic control mechanisms based on the principle of management metafunctions will ensure balanced budgets, including at the regional and municipal levels by creating conditions for the implementation of technologies aimed at reducing costs, for the introduction of financial and industrial policies, investment, fiscal transfers, etc. [19, 20] Using metafunctions, typical technologies and DSN allows decomposing the technology among DRC to meet the challenges of ameliorating the problematic situations, elimination of local imbalances, rational allocation of resources and their subsequent consumption in industrial production system with the effective strategic control over input and output parameters.
To model the risk landscape, identify exposures, technologies and methods for monitoring safety, typology and classification of damage factors, multifactor models for predicting the occurrence of exposures and the spread of risks, information models of damage factors, conceptual models of exposure sources are applied [21]. These models are based on the ontology of risk-sensitive control of the industrial production system.

5 Discussion

The formation of the production system with highlighting the relationship between the chains in the spatio-temporal aspect helps to track the dynamics of changes in both existing and future reserves of non-renewable resources (of all types) in each node based on modern computer technologies, in the context of Unified State Register of Legal Entities, TIN, OKVED codes, with the presence of customs, tax returns, VAT invoices, cash register, statistical reports of enterprises, etc. [6, 22] This mechanism helps to determine the types of resources that are used inefficiently but from the point of view of maximizing the cost of the final product, that is, they are “eliminated” at the stage of primary raw processing until a high added value of the final product is obtained. Misuse of resources in the broad sense is a strategic control system vulnerability that must be addressed [23, 24].

Furthermore, the functional diagnosis of mental processes among managers serves to determine the conditions for the implementation of the strategy, assess their level of safety, and early identification of risks and exposures. These methods are used in modern expert systems (Rukovoditel, Miracle). The study uses semiotic approaches to the concept of risk in the risk management [11], where “risk” is understood as the danger arising from incorrect actions and decisions. It consists in identifying problem situations and developing control actions to reduce them: solving problems, diversifying, pooling risks, sharing risks, filtering more information about possible outcomes from structured and unstructured datasets depending on the chosen path. The degree of risk-sensitive control in this context is determined by a state of industrial production system, as well as scientific, technical, environmental and economic opportunities. Communicative mechanism serves the process of formation of the product-natural vertical, where intermediate products are used, “consumed” directly inside the verticals themselves, and only the final products cross its spatial boundary.

This approach serves the goals of greening development, creating the foundation for developing the most intensive and approach to environmental management and conservation, while ensuring the achievement of goals, including overcoming social inequality and poverty. There are also special opportunities for processing a large data sets, the use of artificial intelligence, such as the expert system “Rukovoditel” to solve problematic situations in the industrial production system.

Proposed feedbacks allow to adequately adjust the production schedule on the basis of ongoing control based on the implementation of intellectual solutions based on information technologies with the optimal consumption of resources [25]. The semantic modeling helps to employ the capabilities of situational centers, but the amount of computational procedures, the need for a coordinated solution of particular problems
for the production system, attracting a large amount of expert assessments poses the problem of applying cognitive technologies at current level of development. The future of this approach depends on the development of a new paradigm for the implementation of the cognitive technologies in the production systems and the introduction of the intelligent approaches. What is required is not the development of abstract declarative concepts without analyzing and assessing resource endowment, but the development of management procedures based on the cognitive approach to make consensus decisions within the framework of cooperation networks in production systems. The semantic modeling in this perspective can be considered as one of the key procedures to process the large sets of unstructured big data.

6 Conclusion

The proposed approach to develop the model for the implementation of risk-sensitive strategic control makes it possible to create a methodology and practical management mechanisms for strategic control by integrating rational and cognitive information processing in a fuzzy and incompletely determined environment, a conflict of interest, and taking into account the behavioral characteristics of decision-makers in both management and engineering perspectives. Intelligent solutions for communicative mechanism enables methodological support of strategic control on the production systems via the creation of the pool of interconnected solutions to anticipate problem situations at different management tiers of the system should take into account the interdependence of linguistic and mental structures. This interdependence emphasizes the need for further research in the field of the risk-sensitive management including the cognitive psychology, cognitive linguistics and psycholinguistics coupled with the key concepts of the implementation of management processes, the key activities of managers and developers in industrial production systems.

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