Principles for Modeling Information Flows in Open Socio-Economic Systems

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Abstract Modern socio-economic systems exist and function being inevitably immersed into the information space. When modeling management in such systems there is a need for a formalized representation of the information flows providing the interaction of the system with its environment. The chapter discusses the principles of modeling information flows in open socio-economic systems considered as determining the impact of the environment on socio-economic systems and the impact of the systems on the environment, and, thus, form the state of the socio-economic system. The resources transferred by the environment to the system for the execution of its mission are considered input information flows, the output flows are formed as the transfer of the results of the system's activities demanded by the environment. The ways of correlating the influence of information flow on the state of the system, chosen by people, and, thus, not reducible to functional dependencies, are modeled as "thinking" functions. An open socio-economic system is considered as a form of interaction of the environment with itself, and the proposed principles for modeling information flows reflect the dualism of the relationship between the system and the environment.

Keywords Open socio-economic system · Management in socio-economic systems · Model of an open socio-economic system · Information flow · Information flows modeling

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1 Introduction

Modern socio-economic systems exist and function being inevitably immersed into the information space. The successful functioning of any socio-economic system (SES) requires constant monitoring and analysis of information flows that ensure the influence of the environment on the system and the influence of the system on the environment [1–3].

When modeling management in socio-economic systems immersed in the information environment there is a need for a formalized representation of the information flows for modeling the interaction of the system with its environment.

2 Approaches to Modeling Information Flows in Socio-Economic Systems

In a number of studies information flows are distinguished by the types of information sources that generate these flows (e.g. financial flows [4, 5], cash flows [6, 7], sales management flows [8], logistics flows [9–11]). In [12] the authors consider information flow as "a key variable in system safety" and underline the role of information in causing or preventing technological accidents [13]. In [12], the optimal informational flow model is introduced and its applicability to assess predictive causality by extracting predictive causal networks of complex ecosystems is considered. Information flow study related to the problems of SES safety is presented in [14], modeling causal interactions for predictability of ecosystem management [15].

But for modeling the behavior of SES operating in the information environment, there is a need for a formalized representation of information flows, abstracted from information sources [16]. Information flow models are proposed in a number of studies [17]. In [18], an input information flow model is proposed, represented by a set of elementary information fragments, which are considered as a pertinent part of various information documents. Information flows are represented as Poisson processes; the information processing planning task is modeled within the queuing theory. The model is proposed to be applied to reduce the influence of information noise on the quality of the information processing process.

In [19] information flows are considered as a set of semantically related elements (documents) that form an information space in the dynamics of their evolution. Information flows are modeled as time series, for the analysis of which correlation analysis, variance analysis, fractal analysis, wavelet analysis are used. To represent semantic properties, the concept of a thematic information flow is introduced as a sequence of messages corresponding to a specific topic. The developed model is proposed for solving problems related to automatic text processing.

The model of information flows of logistics processes at the enterprise, proposed in [20], is represented by a set of project documents. The model is based on formalized descriptions of text, tabular and graphic documents describing information flow

schemes, information about external objects, data stores, and other characteristics of logistics processes. As information flows, both information flows within the system and flows between the system and its environment are considered [21].

In [22], methods of modeling information flows in the context of the organization of management in SES are considered. An information flow model distinguishes the discrete processing stages within the process, describes how information flows through that system, characterizes the kinds of data items that flow through the process, and captures the type or method of data access. Depending on the formalization approach, two categories of models of information flows are distinguished—diagrammatical and mathematical models. Pictorial, matrix, and graph models are considered as diagrammatical models, agent-based models, system dynamics models, discrete-event models are referred to as mathematical models. Depending on the level of accessibility and use of information, information flows are considered as belonging to the macro-, meso- and micro-levels. Information flows at the macro-level model the environment of the system.

3 Model of an Open Socio-Economic System

In the considered models the information flows inside the system (the internal flows) are considered as the main flows determining the functioning of SES regardless of the method and degree of formalization. The external flows, representing the SES interaction with the environment are modeled as factors somehow influencing the internal flows. Thus, the SES environment is considered as an external resource for the SES itself. This modeling principle, based on the primacy of SES in relation to the environment, does not reflect the very essence of the existence of SES as an open system, created by the environment to fulfill the mission determined by the environment. In terms of openness, the functioning of any SES is determined precisely by the external information flows that form the state of the system [23].

The interaction of SES with the environment is a structured set of signs, texts—contracts, agreements, executive documents, i.e. a set of information about a legal entity and environment, which is constantly growing, forming a flow of information. It is natural to divide such a flow into two: the input flow is the information that represents what the SES is for the environment, and the output flow is what the environment is for the SES.

The concept of a flow is always associated with time, respectively, each state of the SES is associated with the current time of the system's life:

$$SES\_State_t = F(InputStream_t, OutputStream_t), \tag{1}$$

where SES_State_t—the system state at current time t; $InputStream_t$—input information flow (influence of the environment on the system); $OutputStream_t$—output

information flow (system impact on the environment); F—way of correlating input and output information flows that form the current state of the system.

The input flow represents the resources that the environment transfers to the system for the execution of its mission (tangible and intangible objects). The output stream is formed as a transfer of the results of the system's activity, demanded by the environment (these can also be tangible and intangible objects).

SES itself is not a material object, it is an artifact created by the activities of people, providing the conditions for their existence [24]. In terms of artifacts categorizing, the SES is an informational phenomenon, since the state of any SES and any input and output flows in the SES are always identified with the flows of information.

Any change in the input and output flows over time ($t + \Delta t$) leads to a change in the state of the system:

$$SES_{State_{t+\Delta t}} = F(InputStream_{t+\Delta t}, OutputStream_{t+\Delta t}). \tag{2}$$

The SES functioning, i.e. the execution of the SES its mission consists in creating a new input stream, leading to an acceptable system state that ensures the existence of the system itself at a time ($t + \Delta t$), i.e.:

$$InputStream_{t+\Delta t} = \Phi(SES\_State_t, OutputStream_t), \tag{3}$$

where Φ—a way of correlating the influence of the state of the system and the output flow formed by it on the reaction of the environment in the form of the input flow.

The influence of the output flow on the formation of the input flow of the system in the classical control theory is called feedback. However, in the context of SES management, the representation of such an influence by any functional dependency is not possible due to the uncertainty of the reaction of the environment to the system.

The formation of a new output flow is carried out as a result of actions performed by the system, determined by the input flow:

$$OutputStream_{t+\Delta t} = \Psi(InputStream_t \oplus OutputStream_t), \tag{4}$$

where Ψ—a way of correlating the results of actions performed by the system and the new output flow generated by it; «$\oplus$»—pseudo-mathematical operation reflecting the way the output flow is generated.

The ways of correlation indicated in formulas (1–3) as F, Φ and Ψ, respectively, are chosen by people, and due to the non-numerical nature of the thinking process, they are not reducible to any functional dependencies. Therefore, in the general case, F, Φ and Ψ symbolize so-called "thinking" functions inherent in people.

Thus, the system of equations:

$$\begin{gathered} SES_{State_t} = F(InputStream_t, OutputStream_t), \\ SES_{State_{t+\Delta t}} = F(InputStream_{t+\Delta t}, OutputStream_{t+\Delta t}), \\ InputStream_{t+\Delta t} = \Phi\left(SES_{State_t}, OutputStream_{t+\Delta t}\right), \\ OutputStream_{t+\Delta t} = (InputStream_t) \oplus (\Delta OutputStream). \end{gathered} \tag{5}$$

is a pseudo-mathematical model of an open SES, reflecting the dynamics of the system's existence and the fulfillment of its mission. Any SES exists, interacting with the environment through information flows. On the other hand, the environment, interacting with the SES, provides an opportunity for self-realization.

4 Principles for Modeling Information Flows in Open Socio-Economic Systems

Thus, the authors propose the following principles for modeling information flows in open socio-economic systems:

1. Openness is a key property of any SES, which ensures its functioning in interaction with the environment.
2. The functioning of the SES is determined by external (input and output) information flows that form its state.
3. The input information flow is formed by the resources that the environment transfers to the SES for the execution of its mission, the output flow is formed as the transfer of the results of the SES activities demanded by the environment.
4. The state of the SES is determined by the "balance" of input and output information flows.
5. The dynamics of input and output information flow leads to a change in the state of the SES.
6. The input and output flows are interconnected and interdependent by the fulfillment of the SES mission, which determines the system's existence.

Any SES, as an open system created by the environment for the execution of its mission determined by the environment, can be considered as a form of interaction of the environment with itself, and proposed principles of modeling information flows reflect the dualism of the relationship between the system and the environment (as shown in Fig. 1).

5 Conclusion

The proposed principles of modeling information flow make it possible to model SES as an information fragment of the network information space. The information flows themselves are a form of the information network functioning. The network

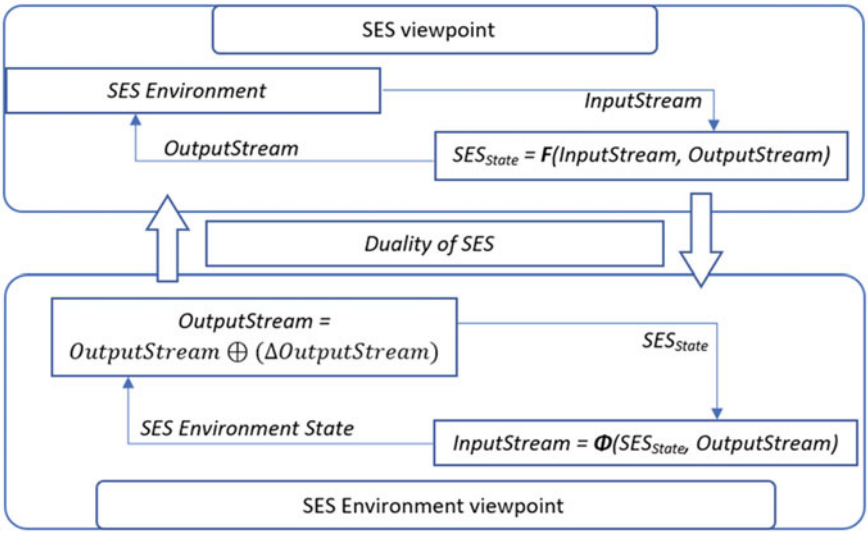

Fig. 1 Relationship between the system and the environment through information flows

controls the SES through information flows that reflect the impact of the network on the system, and identify the SES as belonging to the network.

Thus, socio-economic systems form a network of relations with each other, which ultimately determines the existence of the society itself. The functioning of each SES in the network is a process of continuous formation of the society as integrity, which disintegrates into a plurality of socio-economic systems, but again restores the global network of life as itself. At the same time, the interactions, contradictions, and even conflicts arising between information flow in the network are the sources of the "power" that allows the SES to carry out its activities called the SES mission in the network.

Modeling SES as an information fragment of the network information space justifies the possibility of digitalization of the society formed by a plurality of open interacting SES (organizations).

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