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Formalization of Impact of Information on the Human Behaviour for Automatization of Calculation of the Marketing Influence

Michael Vladimirovich Samosudov,

D.Sc. Economics, Head of Expert and Methodological Department, Group of Companies "Delicate Moving" and Associate Professor of the Department of Theory and Organization of Management, State University of Management

E-mail: samosudov@Mail.Ru

Abstract:

Using the comprehensive mathematical model of the social system functioning in active environment, the task of formalization of the impact of the company disseminated information on the human behaviour has been solved. This is necessary to organize the interaction of the company with the participants of relations, particularly, with customers.

The objective of the work is, firstly, to develop approaches to calculation of the company marketing activity; secondly, to determine what kind of information should be recorded in the digital twin of the company to calculate the future incoming cash flow.

There have been determined the mathematical dependences demonstrating the impact of informational flows formed by the company to involve the participants on their behaviour. The dependences provide for considering the company activeness and the competitors' activeness and the information content in the calculation of the expected marketing activity results.

The mathematical apparatus makes it possible to solve the tasks of calculation of the marketing and managerial decisions using the standard packages to ensure working with matrices, solve differential and integral equations. The results obtained make it possible to solve the applied tasks of management automation in the social systems, to specify the data list to be recorded in the digital twin of the company to ensure simulation of the social systems of different purpose, spheres and scales of activity.

Keywords: comprehensive mathematical model of the social system; marketing; management; business automation; digital twin of the company; company simulation model.

INTRODUCTION

Approaches to design or assessment of involvement of customers (marketing), as well as employees, partners and so on, often do not suppose using the calculation methods. But to ensure accuracy of management, not only the resulting indicators but also the forecast ones should be calculated, it is important to be able to calculate the forecast result and compare the actual trajectory of situation development with the design, identify deviations and properly correct the company actions.

This is rather significant if taking into account the trends towards the company activity automation. Using the digital twins of the company and simulation models for calculations in the course of management is of particular interest.

Digital twin is a computer model imitating the behaviour of a real object or, in other words, a simulation model [1; 10; 11; 12]. It can be used in the management system as the "active advisor" that makes it possible to compare the effect of the decision of the management entity with the computer offered decision [2]. And for the parts, units, equipment and processes, the simulation models contained in the "digital twins" are often rather detailed and built at the low abstraction level [10]. But this is not true for attempts to form the digital twins of the social systems. In many aspects, this is due to that the conventional theoretical basis used to describe the social systems does not assume the description of such systems and their operation processes at the parametric level.

PROBLEM STATEMENT

The literature discussing the topic of calculation in marketing, mainly, considers the efficiency assessment of the advertising activity already implemented. The efficiency assessment of the marketing activity is often performed by means of division of the effect into expenses in the form of the customer involvement or incoming cash flow. Sometimes, the ROI and similar indicators are assessed. But to organise the activity, it is required not only to assess the results but also to calculate what the marketing activeness should be for getting the necessary result. In addition, as a rule, the impact of advertising is considered and comprehensive marketing effect is rarely considered that distorts the general picture.

In the literature devoted to mathematical modelling of the economic systems, there are the attempts to calculate the future impact of the marketing effect (see, for example, [3, 6]). Thus, the work [3, p. 150-154] considers a model providing for assessment of the expected effect of advertising:

$$\frac{dN}{dt} = [\alpha_1(t) + \alpha_2(t)N(t)](N_0 - N)$$

t	–	the time period that has elapsed since the start of the advertising campaign;
$N(t)$	–	the number of the already informed customers;
N_0	–	the total number of the potential solvent purchasers;
$\alpha_1(t)$	–	the coefficient reflecting the advertising campaign intensity that is actually

determined by the advertising campaign costs at the time;

$\alpha_2(t)$ – the coefficient reflecting the contribution of the consumers that have already known about the product into the information dissemination.

Such models certainly give the information for management but have their disadvantages.

Firstly, they, as a rule, require statistical data based on the past experience that in principle diminishes their features when it comes to a new product launch.

Secondly, they traditionally do not take into account the information content, but only the advertising intensity that comes down to costs. This is a fundamental problem of traditional models; yet in 1961, the Noble-prize winner 1982, G. J. Stigler, noted the following in his work "The Economics of Information": "... the information is a valuable resource... And yet it occupies a slum dwelling in the town of economics. Mostly it is ignored... And one of the information-producing industries, advertising, is treated with a hostility that economists normally reserve for tariffs and monopolists" [9, p. 213].

Thirdly, the assumptions the reasoning is based on often significantly limit the use of the models, lead to their inadequacy for overwhelming majority of situations.

To control the informational flow oriented to the potential participants, the control method with the feedback by violating impact is mostly suitable, that is the effect on the potential participants formed by the competitors, as well as the effect of the institutional environment that is often deterministic today. But implementing this method requires formalisation and consideration of such effect, and taking into account the task of business automation, it is desirable to have strict common factors suitable for formation of the computational algorithms.

The necessary information can be recorded in the digital twin of the company, and the simulation models to calculate the effect from the actions of the company specialists can be used. For this, the models considering all material system parameters are required.

As the work [5] shows, one of the material groups of the system parameters are the parameters of the activeness of the economic agents that is reflected in the informational and resource flows they create in the socio-economic space (SES). That is why it is important to record the changing activeness of the agents and calculate the consequences of such change.

STUDY METHOD

To solve the task, the mathematical modelling and comprehensive mathematical model of the social system functioning in active environment [5] are used. The concept of the vector of behaviour has been based on the works in neurophysiology, mainly, those of the school of thought of Ukhtomsky-Simonov (see, for example, [7; 8]), but also the works in sociology, psychology, human ethology, biological cybernetics, etc. have been considered (for details, see [4]).

SUBJECT MATTER

There is $\Omega(R(Q), g_0, t)$ the social system designed for the target function implementation g_0 and formed by a set of participants Q that have transferred the resources to the system $R(Q)$.

The system exists in the SES Θ formed by a set of participants Q_Θ capable of interacting (exchanging the information and resources).

There is the space point (the *j*-th participant), which state at any time point *t* is described by the vector:

$$\langle B_j(O_j),\ R_{av.j},\ R_{jrec.}(Q_{\Theta act.}),\ I_{rec.\,j}(Q_{\Theta act.}),\ R_{trans.j}(a_j, Q_{rec.res.j}),\ I_{trans.\,j}(R_j(a_j), Q_{rec.inf.})\rangle$$

$B_j(O_j)$	–	the vector of behaviour of the participant in the basis of the conditioned actions known to him O_j;
$R_{av.j}$	–	a set of resources available for the participant;
$R_{jrec.}(Q_{\Theta act.})$	–	a set of resources received by the *j*-th participant from the active SES participants $Q_{\Theta act.}$ at the time point *t* (incoming resource flow);
$R_{trans.j}(a_j, Q_{rec.res.j})$	–	the resources transferred by the *j*-th participant to the other participants from the set $Q_{rec.res.j}$;
$I_{\text{rec.}\,j}(Q_{\text{act.}})$	–	the information received by the *j*-th participant from the active SES participants $Q_{\Theta act.}$;
$I_{trans.\,j}(R_j(a_j), Q_{rec.inf.})$	–	the information outcoming from the participant and transferred to the participants of the set $Q_{rec.inf.}$ by spending the resources for implementation of its activeness $R_j(a_j)$;
a_j	–	the momentum of the participant's activeness.

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The resources available for the participant constitute a set of resources that are directly available (controlled by him) and resources he can involve from the other participants. For example, this is not only money a man has but also that he could receive from the bank, acquaintances, etc. At this, the resources are considered in the wide sense – material, informational, intellectual, spatial, social, time.

Behaviour is a character reference of a human demonstrating the probability of performance of certain conditioned actions. Any action o_k is formalised by the dependency: $R_{init.} \xrightarrow{o_k} R_{result.}$, where $R_{init.}$ and $R_{result.}$ are the initial and resulting sets of resources [5]. And the activity as a complex of actions is characterized by a resource trace, that is the sequence of transformations of the resource base, and its recording in the digital twin provides for recording of the state of activity.

Vector of behaviour is a value providing for considering the human behaviour and actions in the model; this is the 1×k matrix which elements define the probability of performance of the k-th action:

$$B(O) = (p(o_1) \quad \dots \quad p(o_k)), o_k \in O$$

Based on the analysis of the information about human behaviour [4, p. 422-432] determined the factors influencing the probability of performance of action and demonstrates that it is equal to the probability of choosing the action on the basis of assessment of significance of the action-related stimuli and limitations [4, p. 133-154]. It also determines the approaches to calculation of the probability of performance of action. Stimuli are the resources received from the performance of action; and limitations are the resources lost during the performance of action. It is also demonstrated that it is of critical importance to take into account the dualism of action - a human not only decides what action to perform but also chooses between "to do" and "not to do". Besides, the "not to do" can have own stimuli and limitations not related to the stimuli and limitations for action.

For applied tasks, the component of the vector of behaviour can be calculated according to the simplified formula:

$$p(o_k) = \frac{S(o_k) + L(\neg o_k)}{S(\neg o_k) + L(o_k)} - 1$$

$p(o_k)$	–	the probability of performance of action by a human o_k;
$S(o_k), S(\neg o_k)$	–	total stimulus for action o_k and inaction $\neg o_k$;
$L(o_k), L(\neg o_k)$	–	total limitation for action o_k and inaction $\neg o_k$;

The total stimuli and limitations are calculated as follows:

$$S(o_k) = \sum_m s_m(o_k), \qquad L(o_k) = \sum_n l_n(o_k)$$

$$s_m(o_k) = \left(\frac{r_{m\ av.j} + r_{m\ rec.j}\, p(r_{m\ rec.j}, o_k)}{r_{m\ need\ j}}\right)^{\gamma_j}, \qquad l_n(o_k) = \left(\frac{r_{n\ need\ j}}{r_{n\ av.j} - r_{n\ lost.j}\, p(r_{n\ lost.j}, o_k)}\right)^{\gamma_j}$$

$$p(r_{m\ rec.j}, o_k) = \frac{v_{rec.j}}{v_{rec.j} + v_{not\ rec..j}}, \qquad p(r_{n\ lost.j}, o_k) = \frac{v_{lost.j}}{v_{lost.j} + v_{not\ lost.j}}$$

$s_m(o_k), l_n(o_k)$	–	the stimulus-motive and limitation-motive for action o_k;
$r_{av.j}, r_{rec.j}, r_{lost.j}, r_{need\ j}$	–	resources available, received, lost, and needed by the participant;
$p(r_{m\ rec.j}, o_k), p(r_{n\ lost.j}, o_k)$	–	the probability of receipt and loss of resources due to the performance of action;
$v_{rec.j}, v_{lost.j}, v_{not\ rec.j}, v_{not\ lost.j}$	–	the number of cases of receipt, loss, non-receipt and non-loss of resources due to the performance of action that are known to a human o_k.
γ_j	–	the non-linearity coefficient that depends on individual characteristics of a human;

The probability of performance of action is influenced by the informational flows, including those received by a human from the economic agents in the form of advertising. We will consider the mechanism of the information impact on the behaviour in details.

The information received from different sources $I_{rec.j}(t)$ is transformed by the human conscience into a set of signals $\{i_n\}$that determine the change in assessment of stimuli, limitations and probability of these consequences related to performance of certain actions that leads to changing behaviour [5]:

$$I_{rec.j}(t) \xrightarrow{B_j(O_j)} \{i_1 \quad \cdots \quad i_n\} \xrightarrow{B_j(O_j)} \Delta B_j(O_j, t+1)$$

At this, the vector of behaviour of a human impacts the receipt and perception of the information - the behaviour partially determines the choice of channels for information receipt, interpretation actions, that is the signal identification and interpretation.

The information effecting on a human at the time point t is a sum of information received from the institutional environment, active agents, and autoinformation:

$$I_{rec.j}(t) = I^{H}_{rec.j}(t) + \sum_n I^{Q_{act.}}_{rec.jn}(t) + I^{auto}_{rec.j}(t)$$

$I_{rec.j}$	–	the total information received by the *j*-th participant;
$I^{H}_{rec.j}$	–	the information received from the institutional environment;
$I^{Q_{act.}}_{rec.jn}$	–	the information received from the active SES participants $Q_{act.}$ via *n*-th channel;
$I^{auto}_{rec.j}$	–	autoinformation.

Let's consider each component of the informational flow.

Social institute is the information about actions and consequences of such actions a man receives when observing the human behaviour or from the documents [4, p. 187]. Institutional environment H_Ω of the social system Ω is a set of elemental social institutes of this system: $H_\Omega = \bigcup_k h_k$. This is similar for the institutional environment H_Θ of the SES Θ.

As it is shown in [4], the elemental institute is determined by the following components:

$$h_k = \langle o_k \quad s^k_1, \dots, s^k_n \quad p(s^k_1), \dots p(s^k_n) \quad l^k_1, \dots, l^k_m \quad p(l^k_1), \dots p(l^k_m) \rangle$$

h_k	–	*k*-th elemental social institute;
o_k	–	*k*-th conditioned action;
s^k_n	–	stimuli for performance of action o_k, that is the *n*-resources received when performing the action;
l^k_m	–	limitations for performance of the *k*-th action - the *m*-resources lost when performing the action;
$p(s^k_n)$, $p(l^k_m)$	–	probability, respectively, of receipt of the *n*-resources and loss of the *m*-resources when performing the action o_k.

The institutional environment of the social system Ω is formalized by a matrix dimension of *k*×[2(*n*+*m*)+1] – the institutional matrix:

$$H_\Omega = \begin{pmatrix} o_1 & s^1_1 & \cdots & s^1_n & p(s^1_1) & \cdots & p(s^1_n) & l^1_1 & \cdots & l^1_m & p(l^1_1) & \cdots & p(l^1_m) \\ \vdots & & & \vdots & & & \vdots & & & \vdots & & & \vdots \\ o_k & s^k_1 & \cdots & s^k_n & p(s^k_1) & \cdots & p(s^k_n) & l^k_1 & \cdots & l^k_m & p(l^k_1) & \cdots & p(l^k_m) \end{pmatrix}$$

The matrix dimension is, of course large, but the full analysis of the institutional environment is not always required, it is often sufficient to analyse the subsystem environment and only for a small number of actions. In addition, it is possible to record the institutional environment in the digital twin of the company, and use the necessary "fragment" for calculation of the management action.

Therefore, the information a man receives from the institutional environment is a function of the institutional environment, quantity of contacts $\nu_{cont.}$ with the participants:

$$I^{H}_{rec.j}(t) = \varphi(H_\Omega(t), H_\Theta(t), \nu_{cont.})$$

The autoinformation depends on the resources available for a man, the needed resources and the resources received from the other participants of the set $Q_{trans.res.}$:

$$I^{auto}_{rec.j}(t) = \varphi\big(R_{need.j}, R_{av.j}, R_{rec.j}(Q_{trans.res.})\big)$$

At this, the information received by the *j*-th participant via the *k*-th channel is a sum of messages transmitted by the active SES participants via this channel considering the transfer function of the channel δ_k that defines the signal distortions and noises:

$$I_{rec.jk} = \delta_k \left(\sum_n^{Q_{\Theta act.}} I_{trans.n} \right)$$

k	–	number of the information transfer channel;
n	–	number of the active agent using the *k*-th transfer channel;
δ_k	–	transfer function of the channel;
$Q_{\Theta act.}$	–	a set of active SES participants.

Under the effect of the information, $I_{rec.j}(t)$ the vector of behaviour changes due to the divergence determined in the *j*-th point of the *k*-th scalar plane of the SES that corresponds to action o_k:

$$divB_j^k\left(O_j, I_{rec.j}(t)\right) = \\ = \left(\frac{\partial B_j(o_k)}{\partial s_1(o_k)} + \cdots + \frac{\partial B_j(o_k)}{\partial s_m(o_k)} + \frac{\partial B_j(o_k)}{\partial l_1(o_k)} + \cdots \\ + \frac{\partial B_j(o_k)}{\partial l_n(o_k)} + \frac{\partial B_j(o_k)}{\partial s_1(\neg o_k)} + \cdots + \frac{\partial B_j(o_k)}{\partial s_m(\neg o_k)} \\ + \frac{\partial B_j}{\partial l_1(\neg o_k)} + \cdots + \frac{\partial B_j}{\partial l_n(\neg o_k)}\right), \qquad o_k \in O_j$$

Respectively, the instant change of the vector of behaviour $\Delta B_j\left(O_j, I_{rec.}(t)\right)$ at the time point t under the effect of the information $I_{rec.j}(t)$ represents the matrix dimension of 1×*k*, with each element showing the divergence in the *j*-th point of the scalar plane of the space that corresponds to action o_k:

$$\Delta B_j\left(O_j, I_{rec.j}(t)\right) \\ = \left(divB_j^1\left(O_j, I_{rec.j}(t)\right), divB_j^2\left(O_j, I_{rec.j}(t)\right), \dots, divB_j^k\left(O_j, I_{rec.j}(t)\right)\right)$$

And the vector of behaviour of a human at any time point is determined as follows:

$$B_j(O_j, t) \\ = B_j(O_j, t_0) \\ + \left(\int_{t_0}^{t_{exp.}} divB_j^1\left(O_j, I_{rec.j}(t)\right)dt\,, \quad \cdots, \quad \int_{t_0}^{t_{exp.}} divB_j^k\left(O_j, I_{rec.j}(t)\right)dt\right)$$

$t_{exp.}$ – the time of exposition (the time during which a human was effected by the informational flow);

Let's introduce the axiom: *at any time point, there is a non-empty set of actions performed by a human:* $\forall t\ \exists O_j(t) = \emptyset$ – a human always does something. This is more obvious if to take into account the dualism of action ("action" or "inaction").

Then, considering the above, there are such divergence and such change in the vector of behaviour at any time point that provide for the value of its certain components being equal to 1. That is the total effect of the informational flows leads to the performance of conditioned actions by a human that correspond to this effect:

$$B_j(O_j, t) + \Delta B_j\left(O_j, I_{rec.j}(t)\right) \to O_j(t)$$

As it is shown in [5], the actions performed by a human in combination with the available resources determine the outcoming informational and resource flows:

$$O_j(t) + R_{av.j}(t) = \begin{cases} R_{trans.j}(Q_{rec.res.}, t) \\ I_{trans.j}(Q_{rec.inf.}, t) \end{cases}$$

If the company informs a human in a certain way considering the other effecting informational flows, he will perform necessary actions and, respectively, the necessary informational and resource flows will appear that leads to appearance of the necessary resource flow incoming into the system.

CONCLUSIONS

Based on the above, the main business task can be formulated: considering the excitements made by the competitors' information and the institutional environment, to create such informational flow effecting on the *j*-th participant so that the divergence of the vector of behaviour will lead to the performance of necessary actions.

To do this, it is necessary to choose the transfer channels informing the necessary participants, consider the information a human will receive from them, in addition to the information from the company, and compute the process of informing to ensure the required change in the human behaviour.

The work carried out, in addition to the condition the incoming informational flow of the company should meet, makes it possible to determine a required set of data to computation the marketing activity of the company:

- Vector of behaviour of the potential participant in the basis of the conditioned actions related to the information receipt and interpretation.
- Benefits expected by the participants.
- Direction, intensity, content (a set of signals in messages) and context (a set of stimuli and limitations for certain actions) of the informational flows effecting on the potential participant.
- Resources available for a human and involved in the process of interaction.
- Direction, intensity, content and context of the informational flows transmitted by the company via the chosen transfer channels.
- Resources the company transfer to the participants, the extent to which they compensate for the undesirable activeness.

Recording of this information in the digital twin of the company will allow for simulating the system behaviour in the SES, calculating the necessary effect to receive the specified incoming resource flows.

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