UDC 351**DOI: 10.31110/2789-6536/2021-2/002****MODELING THE EMOTIONAL INTELLIGENCE IMPACT
ON DECISION-MAKING IN PROBLEM SITUATIONS****Olena Sergienko***National Technical University "Kharkiv Polytechnic Institute", Ukraine**ORCID : 0000-0002-9796-9218***Valeria Baranova***V.N. Karazin Kharkiv National University, Ukraine**ORCID : 0000-0002-8163-881X***Natalia Yakimenko-Tereschenko***National Technical University "Kharkiv Polytechnic Institute", Ukraine**ORCID : 0000-0003-2927-7989***Nataliia Volosnikova***National Technical University "Kharkiv Polytechnic Institute", Ukraine**ORCID : 0000-0001-9076-5231*

Annotation. The article is devoted to the research of the problem of subjective factors influence in making individual and group decisions. Subjective factor is considered in terms of the emotional intelligence impact on the decision-making process. In this case, the methods of analysis and influence of emotional intelligence on the decision-making process were applied. Through the implementation of the test for emotional intelligence, a hypothesis was proposed and proved. The hypothesis essence is that the higher the emotional intelligence level, the more objective a person makes decisions. For assessment the influence of emotional intelligence level on the outcome of the decision using neural network, the model of individual decision makers' emotional intelligence classification was proposed and built. The obtained

research results made possible to model the subjective factors influence in the decision-making process.

The problem of group decision-making by modeling the behavior of decision makers under the influence of advertising, information from other agents and internal factors influencing the decision of decision makers is considered. For modeling the behavior of group decision makers in the market the agent simulation in the AnyLogic environment was used, which made possible to simulate the changes in the decision makers state depending on the impact of the environment and emotional intelligence. The received results showed that with the necessary information about the consumer and knowledge of the behavioral economics mechanisms, it is possible to predict and control his behavior, which is a great competitive advantage in certain segment market.

Keywords: subjectivism, emotional intelligence, model, decision making, influence, analysis, hypothesis, neural networks, simulation, agent, behavior, forecast.

Introduction. Decision-making is defined as a mental process and a volitional act that covers all activities to address the problem of determining the best or acceptable action mode to achieve one or more goals. The subject of any decision is the person making the decision (decision maker). It can be one person – an individual decision maker or a group of decision makers who make individual or collective decisions. Decision maker often has to deal with poorly structured tasks. Most often, the poorly structured tasks include tasks that have a formal model of problem, but the tasks are multi-criteria because there are several mismatched goals. Weakly structured solutions are typical for non-standard problems, for situations of novelty, uncertainty that require a creative approach. For a poorly structured problem, the concept of "wrong decision" becomes fuzzy, as the existence of many criteria for evaluating alternatives deprives to some extent the procedure of choosing a single objective solution. Such tasks arise in the political and administrative spheres. Mistakes in decision-making in modern conditions are often expensive and the more expensive, the higher the management level at which these decisions are made.

The human factor has many forms of manifestation that affect the achievement

of decision maker goals. When analyzing the system functioning and development decision maker can't get high results reliability without taking into account the human factor. According to the classical theory of decision makers' behavior, decision maker chooses the alternative with the greatest benefit for him. But there are psychological factors that set up managers, responsible persons to show subjectivity in the process of selecting problems and establishing their importance level. Therefore, subjectivism is an integral part of human decision-making.

Subjectivism has different assessments, which together make decision maker possibility to make decisions. In this paper, subjectivism will be considered in terms of emotions impact on decision-making. Emotions are an integral part of human life. The emotions importance in decision-making is manifested in the fact that the decision-making process is often emotional. Previously, emotions did not take into account in research because they were considered unstable, unpredictable, and not objectively measurable. However, now understanding what emotions are needed for can help explain human behavior.

Thus, this research object is the decision-making process and the influence of subjective factors on it. The research subject is the construction of models that reflect the subjective characteristics influence in the decision-making process.

Research review. The growing amount of information that modern person has to deal with has led to the fact that decision-making activities are becoming more complex and responsible. It is no coincidence that decision theory, certain aspects of which have now taken a formalized form, is in focus of representatives of such various knowledge fields as mathematics, cybernetics, systems research, logic, psychology, policy, sociology, economy and others.

In the last two decades, the movement associated with the feedback ideas application has arisen among cyberneticists and systems theorists in a wide range of scientific fields from mathematics to sociology: in analyzing the system functioning and development we can't obtain high reliability without human factor. The study of the human factor and its role in management mechanisms requires serious development. That is why a classical economy with completely rational agents cannot

explain many social and economic phenomena related to human economic behavior, both on a macroeconomic and microeconomic scale. Thanks to this, as well as the assertion that human psychology can influence the economy, and systematically and predictably, a new science emerges, called behavioral economics.

The problem of people economic behavior is present in the papers of the classics of economic thought such as A. Smith, K. Marx, M. Weber, J. M. Keynes and others. Their theories were developed from new positions by G. Becker, H. Simon, O. Williamson, A. Marshall, P. Samuelson, S. Fisher, F. Hayek, M. Friedman etc. [2].

In addition, the issues of economic behavior were studied by representatives of sociological and psychological sciences (R. Darendorf, T. Parsons, A. Maslow, D. Kahneman, A. Tversky etc.) [6].

In the field of economics, research on individual choice and decision-making at the micro level, with the rules set at the macro level, performed by J. Buchanan and G. Brennan [12].

However, unfortunately, it can be stated that the approaches and methods involved in the study of individual or group decision-making by modeling the decision makers' behavior under the external factors influence are extremely limited. That is why the paper offers a study of decision makers' emotions impact on the decision-making process, as well as modeling the process of individual and collective decision-making taking into account emotional intelligence.

So the main research purpose is modeling the subjective factors influence in the decision-making process for further possibility to predict and control behavior of individual decision maker emotional intelligence, which will be an advantage on certain market segment.

In our opinion, further research can be aimed at studying the features of the emotions impact on decision-making processes.

Main part. In the most general form, the content of the decision-making task, as well as any task, can be expressed in the form of "given ...", "need to determine ...". Concretizing this form of presentation, we describe the decision-making model for

individual and group decision makers in the following form [5-8, 16, 18].

For individual decision maker, the task of decision-making takes the form:

$$\langle S_0, T, Q \mid S, A, B, Y, f, K, Y^* \rangle,$$

where before the vertical line are symbols describing known task elements, and on the right unknown elements:

S_0 is problem situation;

T is time for a decision;

Q is the resources needed for a decision;

$S = (S_1, \dots, S_n)$ is a set of alternative situations that determine the problem situation S_0 ;

$A = (A_1, \dots, A_k)$ is a set of goals pursued in decision-making;

$B = (B_1, \dots, B_l)$ is a set of restrictions;

$Y = (Y_1, \dots, Y_m)$ is a set of alternative solutions;

f is the function of the decision maker advantage;

K is criterion for choosing the best solution;

Y^* is the optimal solution.

In some cases, the time and resources for decision-making may be unknown and will be determined by decision maker. Then you need to place the symbols T and Q in the formula to the right of the vertical line.

The decision-making task of individual decision maker can be summarized as follows. In the conditions of problem situation S_0 , available time T and resources Q it is necessary to determine also the situation S_0 by the set of alternative situations S , to formulate sets of goals A , restrictions B , alternative solutions Y , to evaluate the advantages of solutions and to find the optimal solution Y^* from set of Y , guided by the formulated criterion choice K .

Now consider the decision-making model of group decision makers. For group decision makers, the decision task is:

$$\langle S_0, T, Q \mid S, A, B, Y, F(f), L, Y^* \rangle,$$

where $S_0, T, Q, S, A, B, Y, Y^*$ are the same symbols as in the task for individual decision makers, but

$F(f)$ is a group preference function that depends on the vector of individual advantages of group members $f = (f_1, \dots, f_d)$;

d is the number of members in the group;

L is the principle of coordination of individual advantages for the formation of group advantages. The choice of one or another principle determines the concept of the best agreement. The well-known principle of reconciling individual advantages, which creates group advantage, is, for example, the principle of a majority vote. There are other principles of coordination too [8].

Thus, the decision-making tasks of group decision makers are formed as follows. In the problem situation S_0 , available time T and resources Q it is necessary also to determine the situation S_0 by a set of alternative situations S , to formulate sets of goals A , restrictions B , alternative solutions Y , to conduct an individual assessment of solution advantages, to construct a group advantage function $F(f)$ on the bases of the chosen principle of coordination L and to find the optimal solution Y^* that satisfies the criterion of group advantage.

The content of the decision-making task makes possible to formulate a number of statements that characterize the management decisions features, emphasize the difference between the task of management decision from the mathematical problem of finding optimal solution [7-8, 15], and also prove the need for consideration emotional component [6] (Fig. 1).

Fig. 1. Features of management decisions in terms of the decision makers emotions usage

So, considering the task of decision-making for individual and group decision makers, we need to take into account the decision makers emotions, as one of the subjective factors, because every human action is related to emotion. Emotions are included in the work for the reason that the capabilities of the rational brain are severely limited. Some scientists, such as Ap Dijksterhuis, argue that any problem with more than four variables throws the rational brain out of balance. And when a person lacks "random access memory", the emotional brain comes to the rescue, which makes decisions. That is, a person feels that it should be done this way and not otherwise.

That is, one of the important subjective factors of the decision-making process is a person's emotional intelligence. One of the most popular models of decision making that takes into account emotional intelligence are BDI and EBDI models [5, 18]. The basic idea of BDI (desire-intention-belief) is that a person's reasoning is based on his "mental state". The BDI model is centered around three mental attitudes: intentions, desires and beliefs (Fig. 2).

Fig. 2. BDI model

Fig. 3. EBDI model

Beliefs are information about the environment that may not be true. Desires are all possible states that an object can or wants to achieve, they represent options that could affect the actions of the object. At the same time desires and beliefs can be changed. At each step of reasoning, the BDI beliefs of the object are updated on the bases of perception. Intentions to be achieved move into plans [5, 18].

Emotional BDI (EBDI) model is extended relative to BDI by including emotions as one of the decision criteria. EBDI is based on the idea that in order to model human behavior properly, you need to consider the emotions impact. EBDI is the first model to view emotions as a decision control mechanism. EBDI includes an internal representation of the object resources and capabilities, which makes possible to allocate resources in a highly dynamic environment more efficiently. It is presented in Fig. 3.

EBDI takes into account the possibilities, abstract action plans that an object can use to influence its environment. In order to become concrete, abstract plans must be consistent with object ideas, abilities and capabilities. This is done through resources that can be either physical or virtual. An object in EBDI has information only about a limited part of its environment and itself. This means that the object

can't be aware of all resources and capabilities. In order for an object to become aware of these capabilities and resources, it must first become effective through the viewing function "Effective Resources" which is based on the object perception, as well as the various components derived from the BDI model. In addition to possibilities and resources, two new components have been added: module of sensors perception and emotional state. The first filters information from all representations and other stimuli. The emotional state is responsible for managing the resources and possibilities used in the information processing stages of the model.

Analysis of the above models makes possible to conclude that emotions are a fundamental catalyst and inducer of energy for a person, which encourages the individual to make decisions of varying degrees of usefulness and polarity.

Thus, it can be hypothesized that people with a high level of emotional intelligence have a good understanding of their emotions and the feelings of others, can control their emotional sphere, and therefore in society their behavior is more adaptive and the decisions they make are more objective.

On the bases of the above theories and models, the hypothesis was put forward that the higher the emotional intelligence (EI), the more objectively a person makes decisions. For studying the influence of decision makers' emotional intelligence on the decision-making process it is proposed the following conceptual model in this research (Fig. 4).

Let's consider the first research stage: modeling the impact of EI on the decision-making process of individual decision maker.

Fig. 4. Conceptual research model of the influence of decision maker emotional intelligence on the decision-making process

For an experimental research of the emotional intelligence detection in different areas of work and in different cities of the country, 18 people were involved, which included managers, subordinates in different areas of work and students. The test for emotional intelligence according to the method of N. Hall [3] was used in research. The test shows how people use emotions in their lives, and takes into account different aspects of emotional intelligence: attitudes toward themselves and others, the ability to communicate; attitude to life and the search for harmony.

The test consists of statements that in one way or another reflect different aspects of life. The test consists of five scales, which are given in Tab. 1.

Table 1

Scales for assessing emotional intelligence according to the method of N. Hall

Scale name	Evaluation content
"Emotional awareness"	it is the awareness and understanding of one's emotions, and for this purpose the constant replenishment of own emotions vocabulary. People with high emotional awareness are more aware than others of their inner state.
"Management of your emotions"	it is emotional detachment, emotional flexibility, etc., in other words, arbitrary control of one's emotions.
"Self-motivation"	managing your behavior by managing your emotions

"Empathy"	it is an understanding of other people's emotions, the ability to empathize with another person's current emotional state, as well as a willingness to provide support. This is the ability to understand a person's condition by facial expressions, gestures, shades of speech, posture.
"Management of other people's emotions"	the ability to influence the other people emotional state

It was necessary to make an assessment that best reflects the agreement degree with the statement. At the output the general assessment of emotional intelligence and the separate assessment on each scale were received. The results interpretation was performed as follows (Tab. 2).

Table 2

Correspondence of scores and qualitative characteristics of the emotional intelligence components according to the N. Hall method

Levels of partial (separately on each scale) emotional intelligence		Integrative (sum on all scales) level of emotional intelligence	
14 and more	high	70 and more	high
8-13	average	40–69	average
7 and less	low	39 and less	low

The research results of EI in 18 people are shown in Tab. 3.

Table 3

The results of the assessment of emotional intelligence according to the N. Hall method

Subject	Emotional awareness	Management of your emotions	Self-motivation	Empathy	Management of other people's emotions	Level of emotional intelligence
1	15	12	10	9	14	60 (average)
2	7	9	14	16	14	60 (average)
3	10	6	12	9	13	50 (average)
4	5	-2	2	8	-2	11 (low)
5	3	15	13	5	2	38 (low)
6	9	14	14	11	7	55 (average)
7	8	-3	10	15	8	38 (low)
8	8	8	12	6	8	42 (average)
9	14	-2	12	18	17	59 (average)
10	11	5	11	10	12	49 (average)
11	17	6	7	7	11	48 (average)
12	8	1	3	8	9	29 (low)
13	11	10	14	15	14	64 (average)
14	14	2	5	10	8	39 (low)
15	5	-7	12	11	8	29 (low)
16	5	11	13	2	9	40 (average)

17	9	-3	5	-1	10	20 (low)
18	14	15	13	17	15	74 (high)

On the bases of people observations and the obtained results, it was found that the higher the emotional intelligence, the more objective decisions are made. Also, people with higher emotional intelligence hold a leadership position, which requires objectivity in decision-making. There is also a tendency to depend on generations, the older the generation, the lower the emotional intelligence.

Let's move on to the next task: building a model for recognizing and classifying the decision maker emotional intelligence. The obtained results of N. Hall's test for emotional intelligence became the initial data for building a neural network model as a task of classification and recognition of the emotional intelligence influence on the decision-making process of individual decision maker.

The module Neural networks of application package STATISTICA was used for building the model. The components of EI assessment were used as initial data: x1 – emotional awareness, x2 – management of your emotions, x3 – self-motivation, x4 – empathy and x5 – management of other people's emotions, x6 – level of emotional intelligence as a separate variable with qualitative components. "Level of emotional intelligence" (x6) is set by the values: "high", "average", "low", according to the values of Tab. 3. For building the neural network, we set the dependent and independent variables: the dependent variable is the level of emotional intelligence x6, and the independent variables include x1-x5. We carry out all necessary settings of parameters in the corresponding module of the STATISTICA program: we set activation functions (logistic and hyperbolic on the hidden and initial layers), we will use attenuation for hidden layers, we will increase the number of hidden neurons, which will help to calculate a larger number of errors for which we activate the attenuation function [10-11, 14]. We train the system and get the best productivity (percentage of correct classification) in the fifth model. Thus, the closer the value is to 100, the better the model classifies the data. The results of the model implementation are presented in Fig. 5.

Summary of active networks (Spreadsheet1)								
Index	Net. name	Training perf.	Test perf.	Validation perf.	Training algorithm	Error function	Hidden activation	Output activation
1	MLP 5-19-3	92,8571	100,0000	50,00000	BFGS 7	Entropy	Logistic	Softmax
2	MLP 5-19-3	85,7143	100,0000	50,00000	BFGS 7	Entropy	Logistic	Softmax
3	MLP 5-3-3	92,8571	100,0000	50,00000	BFGS 0	Entropy	Logistic	Softmax
4	MLP 5-12-3	92,8571	50,0000	50,00000	BFGS 7	Entropy	Logistic	Softmax
5	MLP 5-10-3	100,0000	100,0000	50,00000	BFGS 0	Entropy	Tanh	Softmax

Fig. 5. The results of the neural network model implementation of decision maker emotional intelligence classification

Let's display the sensitivity analysis, i.e. the analysis of model variables importance in Fig. 6.

Sensitivity analysis (Spreadsheet1)					
Samples: Train, Test, Validation					
Networks	x2	x3	x4	x1	x5
5.MLP 5-10-3	2,428504	1,820817	1,418041	1,285161	1,079156

Fig. 6. Sensitivity analysis of the neural network model implementation of decision maker emotional intelligence classification

From the above simulation results, we conclude that each emotional intelligence component has an impact on the overall level of EI, and none of them we can't exclude. To carry out the classification, we test the model on specific values of input variables (Fig. 7), and obtain the result of assignment to a specific class at the level of EI, namely to the class "average".

Fig. 7. Testing the model of decision maker emotional intelligence recognition and classification

Thus, at this stage, the model of recognition and classification of decision maker emotional intelligence using a neural network was built and implemented.

Let's consider the second stage of the conceptual model: modeling the impact of EI on the decision-making process of group decision maker (see Fig. 4).

When it comes to modeling the behavior of a large number of people, almost always the best method is multi-agent modeling [12-13, 17]. With it, we can create a huge number of decision makers and track their behavior in a given environment with prescribed characteristics and complex relationships. One of the biggest and most important benefits of agent modeling is the emerging behavior. This is a behavior that is very difficult to detect and predict without the means of agent modeling. We can also check how the decision makers will behave depending on the change in input data and parameter values. That is why the model of the consumer market on the bases of the model of Bass innovations diffusion was used to reproduce the behavior of group decision makers [2].

To solve the problem of decision makers behavior modeling (assuming buyers) without taking into account their EI (under the advertising influence), create a model that will demonstrate the advertising impact on the product initial sales.

The model is implemented using the AnyLogic for simulation [1]. The following settings were made for simulation:

- the population of 10000 agents such as Consumer were set, which simulate individual consumers (decision makers).
- the AdEff parameter (advertising effectiveness) was added to specify the percentage of potential consumers who will want to buy the product during the day due to the advertising impact. We assume that during the day an average of 0.5% of potential consumers make a decision of purchasing the product.
- consumers behavior is specified using a state diagram. State diagrams are the most convenient way to specify the agent behavior, contain the state itself and the transitions. The states of the diagram are mutually exclusive, i.e. at any given time the agent can be in only one state. Triggering a transition changes the state and activation of new transitions. We set the behavior of the consumer agent as two consecutive states (PotentialUser – in this state the agent is a potential buyer and may be interested in buying; User – a consumer who has already bought the product).
- the transition was created from the PotentialUser state to the User state in order to model the decision-making of purchasing a product under the advertising influence, called Advert. The transition property was set to intensity equal to the AdEff parameter per day.

The modeling purpose is determination the decision makers that purchased a product at a given point in time. To do this, we introduce functions that will count the number of consumers and potential consumers of the product, respectively.

We will also consider the impact on decision makers of positive reviews about the product from its owners. To do this, we simulate the communication of agents with each other, namely conversations about the product, which motivate people to purchase it. In the model, messages will be sent only by those agents that are in the User state. A special WOM transition was created to implement the impact.

For the model realism, it was taken into account that the product may have a limited shelf life (or service life). When the consumer can no longer use the product, it'll need a replacement. Therefore, there is an assumption that after the expiration date of the product, the agents go from the User state back to the PotentialUser state, which describes the transition to Discard.

So the model takes into account the impact on decision makers of advertising, positive customers reviews and limitation of the product service life, which leads to changes in the state of decision makers from PotentialUser to the User state and vice versa. Having launched the model, we will analyze the dynamics of product sales: after a certain time, the growth of market saturation will be replaced by a local decline (Fig. 8).

Fig. 8. The results of modeling the decision makers' behavior under the advertising influence

Let's consider the last task: modeling the decision makers' behavior taking into account EI. In the previous model, it was assumed that the product is always available, and therefore the transition from the PotentialUser state to the User state is

instantaneous, impulsive, without giving time to make an informed and prudent decision.

At the last research stage, it is proposed to improve the proposed model by adding the decision makers state, which will correspond to the time elapsed from the moment of the decision to purchase the product until the product goes on sale and delivery to the buyer. During this period EI of decision makers is connected to the decision-making process: before making a purchase, a person will adequately assess the situation, discuss decision with relatives, and make a balanced, responsible decision to avoid stress, impulsivity, inadequacy of perception. So in this case all components of decision makers EI interfere in the decision-making process.

To simulate the delay between the decision to purchase and the purchase itself, the WannaBuy state was introduced into the model and the transition from it to the User state called Purchase (Fig. 9). Assuming that the average product delivery takes two days, the simulation results are shown in Fig. 10.

Fig. 9. Adding the state of decision makers "Want to buy"

Fig. 10. Graph of the dynamics of decision makers states

Next, the fact was taken into account that the time that consumers agree to spend waiting for the goods delivery is limited. If the delivery time exceeds the maximum allowable waiting time, the consumer will cancel the purchase. To

implement this assumption, the model was introduced two parameters that specify the maximum goods delivery time (21 days) and the maximum waiting time for delivery (5 days) respectively (in average delivery takes two days). The value of delivery time through stochastic expressions is also set.

For simulation the decision makers refusal to purchase the product due to its long absence, a transition called CantWait was created, which exits the WannaBuy state and leads to the PotentialUser state. As a result, the diagram of decision makers states will look like as in Fig. 11.

Having launched the model, let's analyze the decision makers' states dynamics taking into account EI. By changing the maximum waiting time and the maximum delivery time, it is possible to assess the impact of these changes on decision makers' behavior and market conditions.

Fig. 11. The results of modeling the decision makers' behavior taking into account EI

As a modeling result we can see that the decision makers' behavior in given conditions is subject to a certain pattern. On the bases of the built model, it is possible to predict the consumers' behavior at different stages of product distribution and on the bases of the dissemination of information about it, which is a very competitive advantage of any organization. The constructed model is completely adaptive, i.e. it can be adapted to different market situations and modernized in parallel with the development of scientific knowledge about the decision maker behavior and the EI state.

Conclusions. On the bases of the research results, the influence of subjective factors in the decision-making process was simulated in the paper. Through the implementation of the test for emotional intelligence, a hypothesis was proposed and proved that the higher the level of emotional intelligence, the more objective a person makes decisions. With the help of the neural network, the problem of classification was proposed and a model of emotional intelligence classification of individual decision maker was built. For modeling the group decision maker behavior in the market agent simulation modeling was used, which helped to simulate changes in the decision maker state depending on the influence of the external environment and emotional intellectual. The results showed that with the necessary information about the consumer and knowledge of the mechanisms of behavioral economics, it is possible to predict and control his behavior, which is a great competitive advantage in a particular market segment.

Thus, the research emphasizes the relevance of the existence and consideration of the decision-making theory in the modern world. In particular, the cost of making individual or group decisions is increasing, and it is not always possible to find a better strategy for making such decisions. That is why further research will be aimed at studying the features of the emotions influence on decision-making processes at the micro and macro level in interdisciplinarity: economics, finance, insurance, politics and so on.

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