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A FUZZY MODEL FOR TEAM CONTROL AND ITS APPLICATION

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Abstract
An original fuzzy team control model is presented in this article. The model is based on a non-traditional combination of classical and contemporary achievements of management and mathematical theories of fuzzy logic and fuzzy sets. In methodological terms, the article also offers a set of tools for measuring and evaluating both team performance and the effectiveness of the team control system in the organization. Fuzzy tools and techniques for decision-making, studying of hidden effects and joint influences, and quantification of evaluations are employed in this set of tools. The suggested fuzzy model contributes to overcoming theoretical deficits on the issues of team control, and the methodology of team control fills a gap in the toolkit of team management. The results from verification of the fuzzy team control model at a small-sized Bulgarian enterprise are also discussed in this article. They indicate that it is possible to develop a fuzzy model for team control, increasing the effectiveness of the team control system in the enterprise.

Keywords
team, fuzzy control, management model, performance evaluation, Bulgarian enterprise.

Introduction

The application of team approach is of great significance to the successful management of modern organizations. Nowadays, this view is taken with one voice by management theory and practice. First, a special emphasis is placed in the scientific literature on the synergy effect achieved by teams. This effect is considered to be "the contribution of teams to the organizations' success" [1]. This contribution is "of vital importance to the organization in times of crisis" [2]. Second, "a number of contemporary organizational structures, incl. organizational democracy, adhocracy, and etc., are based on the team approach" [3]. Third, management theory determines the team approach as a key organizational strategy [4] and management has recently introduced it into practice as such [5].

Despite the importance of team approach, only partially developed problems of team control could now be found in the scientific literature. Widespread team concepts and models, which are closest to the author's ideas, are taken into account in this article. Their main deficiencies could be defined as follows:

- Theory of the adaptive team performance by Kozlovsky, Gully, Nasson and Smith [6] – 1) This theory ignores team formation features. 2) It is not very logical to distinguish the combination of tasks, roles and team members as separate stages of team development.
- Concepts of McIntyre, Dickinson, and Salas [5, 7] – They focus on behaviour aspects of teamwork but ignore team formation and results.
- Team performance model of Zigon [8] – It: 1) does not provide feedback on the evaluation process; 2) is only focused on team results; 3) ignores team process and formation;
- Team effectiveness model of Burns, Bradley, and Weiner [9] – The systematization of indicators of team process and activity is not fully perceived by the author of the article.
- Team effectiveness model of Tannenbaum, Beard, and Salas [10] – The author of this article does not perceive: 1) classifications of input and out-

put factors of the team system; 2) the idea of team performance as a team result.

It is evident from this review that the research on the topic of team control is limited and focused mainly to measurement theory in management and performance management. Neglecting the links between team control and the other areas of management science as well as partial concepts of that issue do not allow matching scientific achievements not only of various management areas but also of other sciences.

Then again, there exist opportunities in the era of knowledge to develop a team control model at an up-to-date scientific level thanks to the development of mathematics. The fuzzy model of team control presented here is an attempt to contribute to this aim.

Research framework

The *research objective* of this article is to suggest an original fuzzy model for team control.

A non-traditional combination of classical and contemporary achievements of management and fuzzy mathematical theories provides the methodological basis for the team control model. *The originality of the model* lies in this unconventional combination of theories and their tools.

The *significance of the team control model* could be found in a few directions. First, the model is viewed as a step forward towards replenishing conceptual and methodological shortage in the field of team control. Second, a state-of-art methodology using fuzzy logic and fuzzy sets tools is at the heart of the model. Third, due to the conceptual and methodological contributions of the model, it is relevant to both management theory and practice.

The key *research restrictions* of the model are:

1. The information used in the model is predominantly of qualitative nature.
2. The implementation of a set of managerial decisions for improving teams' features must be considered to be the only reason for the better performance achieved by teams.

Two *research tasks* are defined in this article:

- Clarifying the fuzzy team control model and its methodological bases;
- Demonstrating the model's ability to work.

The *research thesis* of this study is: It is possible to increase the effectiveness of team control process by implementing a team control model based on achievements of management and fuzzy theories.

The state of scientific literature in the field of team control and the contemporary level of fuzzy theories provide the basis for this opportunity. The great significance of team approach to the successful management of contemporary organizations is the main reason for the need to develop an effective and modern team control model.

Methodological framework

Theories of general management, management control, performance management, human resource management, organizational behaviour, stakeholders, fuzzy logic and fuzzy sets lay the methodological foundations of the suggested team control model.

Conceptual framework

As a type of management model, the proposed team control model is based on approaches and principles of general management theory. The most important for this research are: the motivational approach of the controlled object involvement in the management reactions formulation, the function approach [11], the management by exception approach [12], the management by objectives approach [13], the principle of effectiveness of managerial activities [14], and others.

The team nature and features are defined in this article on the basis of the *theories of human resource management and organizational behaviour*. The team definition proposed here combines views of several authors. The team is perceived by Aubert, Gruere, Jabes, Laroche, and Michel as a social community [15]. Kandula focuses on the team effectiveness and common objectives of team members [16]. Cohen and Bailey define the team as "a set of individuals who share values and responsibilities" [17]. Team features are classified here on the basis of Margerison and McCann's idea about factors of the work group effectiveness. They assort these factors in three sets: system input factors, factors related to the system performance and system output factors [18].

Theories of human resource management and organizational behaviour are also the basis for the choice of input variables used in this model.

The theory of stakeholders [19] is considered here as relevant for determining the subject of team control. In accordance with this theory, parties concerned (stakeholders) with teams' performance are viewed as the subject of control.

From a management point of view, theories of management control and performance management are of great importance for the team control model.

In theoretical terms, the author's concept of team control is based on the *theory of management control*. The theoretical control model by Simeonov is the theoretical foundation of this team control model. Simeonov defines six elements of the control function [20]. The essence and the lower number of elements of the team control model are the main differences with Simeonov's model (Fig. 1). The need to modify Simeonov's model has arisen mainly for the "dropout of the action planning system" [3] "from a number of contemporary organizational structures based on team approach" [21].

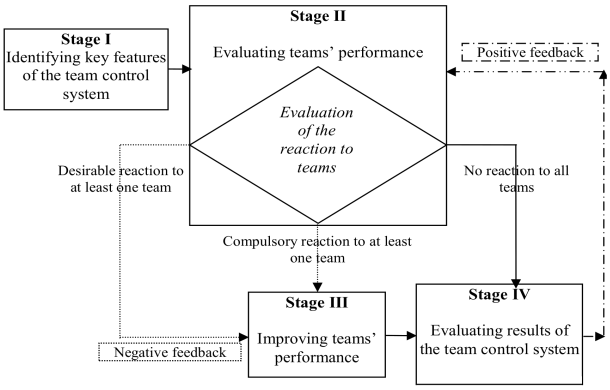

Fig. 1. Author's model of the team control process.

The essence and elements of the team control system are also defined on the basis of management control theory [22]. Understanding effectiveness by achieving objectives [23] underlies the concept of the team control system effectiveness. It is evaluated here by indicators based on Performance Audit Standards of the International Organization of Supreme Audit Institutions (INTOSAI) [24].

The significance of the *performance management theory* for this model stems from its application in several directions. First of all, basic approaches of this theory provide the conceptual foundation for the model's procedures. Two approaches are of great importance for the model: multidimensional evaluation and management by objectives.

Secondly, these approaches form the ground for defining and choosing output variables of the team control model. Management by objectives approach [13] is the conceptual basis for choosing indicators of team output evaluation (team performance) and effectiveness of the team control system (average deviation in teams' performance progress). The effectiveness of the team control system is also defined here in terms of management by objectives approach. Multidimensional evaluation approach is based on the perception that results are not the only indicator of evaluation [25]. In the context of the multidimensional approach, the author's definition of team performance is formulated here.

Thirdly, some basic concepts of the team control model are defined in the context of performance management incl. team control, team performance measurement and evaluation, team performance improvement, and so on. Ilgen and Schneider's ideas [26] underlie the definitions of team performance measurement and evaluation suggested here. The Caldwell's concept of improvement [27] is applied to circumscribe the team performance improvement. The team control process is also defined here from the point of view of performance management. This definition is closest to Cardy and Leonard's view of the performance management process [28]. Elements of the team control process reflect to the greatest extent McAfee and Champagne [29], Ainsworth and Smith's [30] ideas on the stages of performance management process.

Instrumental framework

In instrumental terms, the team control model is based on theories of fuzzy logic and fuzzy sets.

The *fuzzy logic theory* ensures "a methodology for dealing with linguistic variables that serves as a basis for decision analysis and control actions" [31]. Fuzzy logic models employ fuzzy sets to describe imprecise and complex phenomena and uses logic operations to arrive to conclusion [31].

Linguistic variables and logical decision rules of type 'if ..., then ...' are the fuzzy logic tools. Variables are characterized by possible states described both qualitatively (linguistically) and quantitatively (by fuzzy sets/numbers [31]). Logical rules consist of a precondition ('if . . . ,') and a conclusion (', then. . . '). In this model, Mamdani's system (a conjunction-based system, [32]) is applied to define rules. According to it, the precondition is formed as an intersection of sets ('if ... and ...,') by the logical operation 'and' (min function). The sets represent the input variables and are described by fuzzy numbers. The conclusion expresses the truth of preconditions [31] and is described by fuzzy set. Depending on the number of input/output variables, there are different types of fuzzy control models [31]. The MISO (many input variables and one output variable) model is used here.

Fuzzy logic and fuzzy sets (in particular fuzzy numbers) applied to control problems form a field of knowledge called "fuzzy logic control" [33].

The fuzzy logic control process covers the following activities [31]: defining linguistic variables and logical rules of the control process, encoding the input variables, developing decision table and induced decision table, determining active cells of the induced decision table, defining active control rules, developing table of fuzzy decision, aggregating fuzzy results, and defuzzifying the aggregated fuzzy result. Encoding an input variable means to match the specific evaluations (called "readings") of that input variable with fuzzy membership functions representing the possible states of its scale. The results of encoding are called "fuzzy reading inputs" [32]. In Mamdani's system, variables are fuzzy but readings used for encoding input variables are discrete real numbers [32]. The logical rules with possible fuzzy outputs, presented symbolically on a rectangular, form the decision table [31]. The induced decision table is made by replacing the rules in the decision table with the corresponding membership functions of the fuzzy reading inputs [31]. The active cells of the induced decision table are those with a value other than zero. The active control rules are located in the active cells of the induced decision table. The table of fuzzy decision is an analogue of the induced decision table that systematises the outputs resulting from the application of the min function to the fuzzy reading inputs of the active rules. The fuzzy outputs are generated by aggregating all the non-zero results described in the table of fuzzy decision. This aggregation is done by max function ('or'). The defuzzification is defined in the scientific literature as a representation of fuzzy sets by discrete values [31]. There is no unique way to perform it. The most commonly used methods are described in [31].

The evaluations of team performance and the necessity to react to teams are generated in this team control model by fuzzy logic control.

The *fuzzy sets theory* is defined to be "an analogue of the probability theory applied to the processing of information based on subjective, qualitative evaluations under uncertainty" [34].

Fuzzy sets and numbers, fuzzy influence matrices and expertons are tools of the fuzzy sets theory. The fuzzy set is defined [35] as a subset of the universal final set, where the belonging of elements to this subset is described by the so-called "characteristic (membership) function" that takes values within the interval [0; 1]. Fuzzy number is a special case of the fuzzy set [31]. The fuzzy number is a subset of the set of real numbers, which has a normalized and convex characteristic function [31]. Fuzzy matrices [36] are matrices which elements are represented by fuzzy numbers. Fuzzy influence matrices are fuzzy matrices representing relationships of influence. The fuzzy experton is a function that is considered as a generalization of fuzzy matrices where its elements are described by confidence intervals [37].

In this team control model, the fuzzy sets tools are used as follows: fuzzy sets – to quantify team evaluations on output variables; fuzzy numbers (triangular and trapezoidal) – to quantify team evaluations on input variables; fuzzy matrices and fuzzy expertons – to diagnose hidden effects, study mutual and joint influences between managerial decisions and team evaluations on input variables, and develop scales of the linguistic variables.

Fuzzy team control model

Basic concepts of the model

- *Team* – A social entity where individuals are united on the basis of common values and objectives. Teams are characterized by their features. Team features are systematized in this model in three groups: team formation, team activities, and team results (Fig. 2).
- *Team management* – Team performance management.
- *Control on teams*:
- In the context of the management control theory – A management process ensuring achievement of planned level of teams' performance where the process is based on the feedback principle.
- In the context of the performance management theory – A process aimed at improving performance of teams by measuring and evaluating their performance.
- *Team performance* – An integral indicator for the team state. It is defined here as an aggregate evaluation of the team state. This evaluation is made by parties concerned with the team state. It reflects in total views of parties concerned about team formation, team activities and team results.
- *Team performance measurement* – An activity of quantifying team performance.
- *Team performance evaluation* – An activity of attributing an evaluation of the value or quality regarding the quantified team performance.
- *Team performance improvement* – Achieving an aggregate evaluation of "a new state [of the team in this context] which exceeds the previous actual evaluation" [27].
- *Input variables of the team control model* – The three groups of team features: team formation, team activity and team results (Fig. 2).
- *Output variables of the team control model* – Team performance and necessity to react to the team (Fig. 2).
- *Controllable indicators of the team control process* – The entire range of team features employed to evaluate the team (Fig. 2).
- *Team control system* – "A set of mechanisms designed to increase the probability of achieving objectives [to improve teams' performance in this

context] by appropriate behaviour of individuals in it" [22].

- *Effectiveness of the team control system* – "The extent to which the objective [of improving teams' performance in this context] has been achieved" [23, 24]. According to the control theory, "an effective control system [team control system in this context] allows zero or, at worst, minimal deviation" [20] from the planned performance [teams' performance forecast in this context]. In this model, the average deviation in teams' performance progress is employed as an indicator for evaluating the effectiveness of the team control system.
- *Average deviation in teams' performance progress* – A mean of differences between actual and forecast progress in the performance of all teams controlled in the organization.
- *Actual progress in team performance* – A difference between the second and the first actual evaluation of the team performance.
- *Forecast progress in team performance* – A difference between the forecast and the first actual evaluation of the team performance.

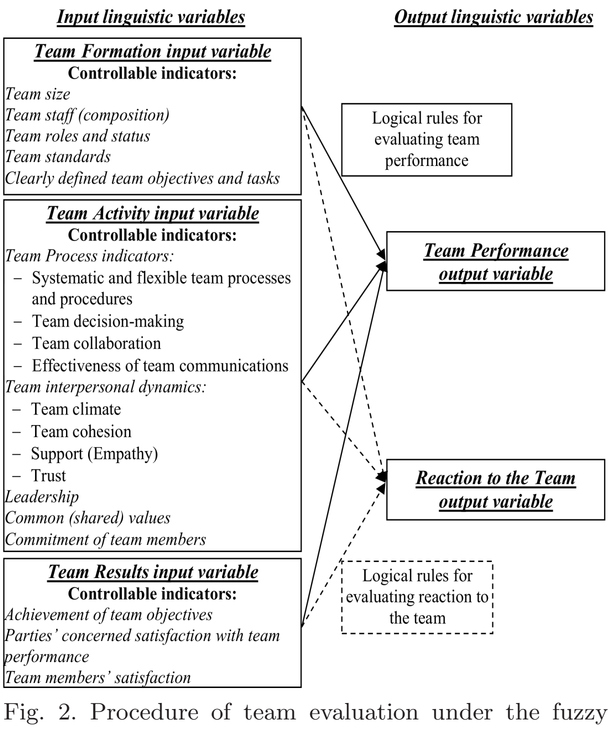

Fig. 2. Procedure of team evaluation under the fuzzy team control model.

Description of the model

Specificity of the team control model suggested here (Fig. 1) mainly concerns the author's vision of team performance and the way it is evaluated. Fuzzy logic tools are employed in evaluating process. It is carried out through the application of fuzzy logic rules to the team's evaluations on input variables. As a result, a transformation (Fig. 2) of the input team evaluations (quantitative/qualitative) into output evaluations (quantitative/qualitative) of team performance and the necessity to react to the team is accomplished. *Another specificity* of the model is the combination of fuzzy techniques and tools used for quantification of evaluations, studying of hidden effects, mutual and joint influences.

The team control process consists of four *stages* (Fig. 1):

- Stage I - Identifying key features of the team control system;
- Stage II - Evaluating teams' performance;
- Stage III – Improving teams' performance;
- Stage IV – Evaluating results of the team control system.

Key features of the team control system are identified in the *first stage* of the team control process incl. the elements of the team control process and the initialization features of the fuzzy logic tools.

The *tools* used in the first stage are focus groups, fuzzy logic tools, operations with fuzzy numbers.

The *procedures* of the first stage are five:

- Identifying the object of control;
- Identifying the subject of control;
- Defining the team control subject-matter;
- Defining linguistic variables of the model;
- Defining logical rules of the model.

The elements of the team control process are the object, subject, and subject-matter of control. The role of the object of control is played here by teams. The subject of control is identified in the model in the context of the stakeholder theory. Parties concerned with teams' performance are considered to be subject of control. These are group actors in the team control process: the controlled teams, the team control committee of the organization, and the other parties concerned. Each party concerned participates in the control process through a focus group. In this model, all team features are viewed as subject-matter of control (Fig. 2).

The initialization features of the fuzzy logic tools are the number, essence and possible qualitative states of linguistic variables and logical rules. The linguistic variables of the model are five - three input variables (team formation, team activity and team results) and two output variables (team performance and reaction to the team). Three possible states of the input variables "team formation" and "team activity" are established here: weak, good, and excellent evaluation. The possible states of the input variable "team results" are five: low, average, good, very good, and excellent evaluation. The output variable "team performance" is described by seven possible states: very weak, weak, unsatisfactory, satisfactory, good, very good, and excellent evaluation. The defined possible states of the output variable "reaction to the team" are three: compulsory reaction, desirable reaction, no reaction to the team. The fuzzy logic rules used in the model are 90. They have three main features: 1) The preconditions are formed of three sets ('if ... and ... and ...,') described by fuzzy numbers; 2) The rules are defined separately for each output variable; 3) The preconditions of rules are the same for both output variables but their conclusions are different.

At the *second stage*, the first actual monitoring of the teams is carried out. As a result, the first actual evaluations of the teams on both output variables are generated.

The *tools* used in the second stage are survey method, focus groups, fuzzy logic tools, operations with confidence intervals and fuzzy numbers, fuzzy influence matrices, and fuzzy expertons.

The *procedures* of the second stage are four:

- Developing scales of the linguistic variables;
- Evaluating teams on input variables;
- Generating first actual output evaluations of teams;
- Decision-making on corrective actions to teams.

Fuzzy numbers (triangular and trapezoidal) are used to quantify team evaluations on input variables and the possible states of scales. Team evaluations on output variables are described by fuzzy sets.

The scales of linguistic variables are developed by team control committee through the survey method in three activities: primary evaluation, secondary evaluation, and scales definition. Evaluations are generated for each possible state of each scale of the model's variables. Primary evaluations are described by fuzzy numbers. The secondary evaluations refer to the primary evaluations of a given state of the particular scale. They are described by confidence intervals with four evaluations (confidence fours) and are aggregated in fuzzy influence matrices and expertons. The definition of a given scale consists of two activities applied separately to each state: an aggregation of the primary and secondary evaluations of the state and a subsequent weighting of the results with their subjective possibilities of realization.

The first actual evaluations of the teams on input variables are generated in the third procedure by the following activities: questioning the parties concerned for their team evaluations on input variables and the significance of these evaluations, aggregating the evaluations by focus groups and controllable indicators, weighting the aggregated team evaluations with their significance, and summing the weighted team evaluations by controllable indicators and input variables.

The first actual evaluations of teams on output variables are the main product of the second stage. They are generated separately for each output variable (MISO model – Fig. 2) by applying the corresponding logical rules to the possible states of the input variables. Unlike Mamdani's system, fuzzy variables and fuzzy readings of input variables are used in the model.

A decision on corrective actions to the corresponding teams must be taken when the first actual evaluation of reaction to at least one team is a compulsory reaction or a desired reaction to the team (Fig. 1). Then, the third stage of the process must be carried out. If the first actual evaluations of reaction to all teams are "no reaction", the third procedure of the fourth stage must be followed.

Improving team performance is the objective of *the third stage* of the team control process.

The same *tools* are used in the third stage as those of the second one. In addition, a max-min function applied to fuzzy expertons is also used.

The *procedures* of the third stage are four:

- Generation of a set of managerial decisions to improve teams' performance;
- Evaluating the forecast effect of managerial decisions on input variables;
- Evaluating joint and mutual influences between managerial decisions and teams' evaluations on input variables;
- Generation of forecasts for teams' evaluations on output variables.

At the third stage, a set of managerial decisions is generated by the teams and the team control committee. It is aimed at raising the minimal first actual evaluations of the teams on the controllable indicators of input variables. These evaluations are lower than a fixed constant. According to the restriction 2 of the model, the implementation of that set of decisions must be considered to be the only reason for the better performance of teams.

In the second procedure of the stage, the team control committee makes three types of forecasts for each team: forecasts for the effect of each managerial decision on the minimal first actual evaluations on input variables, forecasts for mutual influences between managerial decisions and forecasts for mutual influences between minimal evaluations. The forecasts are aggregated by parties concerned, controllable indicators, and input variables.

The joint and mutual influences between managerial decisions and minimal teams' evaluations on input variables are evaluated by fuzzy sets tools [37] incl. operations with confidence fours and fuzzy numbers, fuzzy influence matrices and expertons, and max-min functions applied to fuzzy expertons.

The forecasts for output teams' evaluations are the main product of the third stage. They are generated in the fourth procedure by fuzzy logic.

At the *fourth stage* of the process, the results of the team control system are evaluated and analysed. They cover the actual effect of managerial decisions on team performance, the hidden effects of these decisions on teams' evaluations by input variables, the effectiveness of the team control system, conclusions and recommendations to the team control system and teams.

The same *tools* are used in the fourth stage as those of the second and third ones.

The *procedures* of the fourth stage are four:

- Evaluating the actual effect of the implementation of managerial decisions;
- Diagnostics of hidden effects of managerial decisions on teams' evaluations by input variables;
- Evaluating the effectiveness of the team control system in the organization;
- Drawing conclusions and formulating recommendations.

The second actual evaluations of teams on output variables reflect the actual effect of the implemented managerial decisions. They are generated in the first procedure of this stage by fuzzy logic tools.

The hidden effects of managerial decisions on teams' evaluations by input variables are diagnosed by fuzzy sets tools [37] incl. operations with confidence fours, fuzzy matrices and expertons.

The effectiveness of the team control system is evaluated here by three activities: determining the average deviation in teams' performance progress, development of the scale of team control system effectiveness, and determining the effectiveness of the team control system. The first activity is done by calculating the mean of differences between the actual and forecast progress in the performance of all controlled teams. In this model, the scale for evaluating effectiveness of the team control system consists of three possible states: effective team control system, ineffective team control system with a negative deviation and ineffective team control system with a positive deviation. The scale is developed by the team control committee by using confidence intervals with two evaluations. The evaluation of the effectiveness is determined by a comparison between the average deviation in teams' performance progress and the evaluations of possible states of the effectiveness scale.

In the final procedure, the conclusions are drawn and the recommendations are formulated to the team control system and teams of the organization. When evaluating standards are found to be outdated, the first procedure of second stage ("Developing scales of the linguistic variables") must be carried out (Fig. 1).

The fuzzy model verification

Results

The team control model suggested here was verified by six production teams at Twins Design Ltd. (TD) for the period May – June 2018. It is a small-sized Bulgarian enterprise for manufacturing unique wooden furniture. Questionnaires for testing were developed based on the TD's quality control system and scientific literature [1, 38, 39].

Each controlled team was formed by six persons – a team manager and five members. The team manager role was assigned to a manufacturing technologist. Members of each team were employed at TD in the following positions: machine operator for wood products, carpenter furniture maker, machine operator (priming, painting, polishing), woodcarver, assembler.

All six teams were classified into two groups formed according to the product type criterion. Each group consisted of three teams. Group 1 was formed by the teams producing unique coffers (team 1, 2, and 3) and group 2 – by the teams producing unique settees (team 4, 5, and 6). Teams in each group were ranked in decreasing order by their performance results. Teams with the best performance results in group 1 and group 2 were team 1 and team 4 respectively (Table 2).

The subjects viewed as *parties concerned* in this practical study were: the team control committee at TD, the customers and the controlled teams.

The specificity of the team control system at TD is referred to the input variable "team results" (Fig. 2) mainly to the controllable indicators of specific features "achievement of teams' objectives" and "satisfaction of the parties concerned". *Controllable indicators of* the feature *"achievement of production teams' objectives"* were: compliance with the term for the order execution; meeting the product quality requirements for: accuracy of the shape of pieces, accuracy of the pieces' dimensions, strength of the furniture assembly units, originality and precision of the woodcarving objects, smoothness and colouring of the product surfaces, quality of the product coatings (paint, varnish); product compliance with the technical project; product awards at exhibitions. *The controllable indicators of* the feature *"satisfaction of the parties concerned (customers and team control committee at TD)"* were: product compliance with the customer's technical requirements, aesthetics of the product, precision of workmanship, term for making the product, meeting expectations about the product.

In order to improve teams' performance, the following *managerial decisions* were implemented at TD in May – June 2018: detailed clarification of team members' tasks in the product making process, change of procedures of interaction between team members in the work process, daily operational meetings to discuss issues and results, public recognition of the team members' contributions.

The following *main results* of verifying the team control model at Twins Design Ltd. in May – June 2018 were established:

- For the teams with the best performance results:
- For team 1 – in Table 1, Table 2, and Fig. 3;
- For team 4 – in Table 1, Table 2, and Fig. 4;
- For the team control system of TD: – in Table 2.

Tables and figures shown here cover defuzzified quantitative evaluations. Three methods were used for defuzzification: the centre of area (CA) method, the height defuzzification method (HD), and the mean of maximum (MM) method. They are described in detail in [31]. In this study, the results by the CA method are based on a maximum number of evaluations compared to the other two methods. That why, results by the CA method are considered to be the most precise and are only discussed here.

Table 1
Results of production teams 1 and 4 at Twins Design Ltd. for the period May – June 2018 (own source).

Team	Evaluation of team performance			Evaluation of reaction to the team		
	1st actual	Forecast	2nd actual	1st actual	Forecast	2nd actual
Evaluations defuzzified by the mean of maximum (MM) method						
1	0.7885	0.8532	0.9093	0.7176	0.8285	0.9173
	very good	excellent		desirable	no reaction	
4	0.7049	0.7184	0.7393	0.5729	0.5846	0.6043
	very good			desirable		
Evaluations defuzzified by the height defuzzification (HD) method						
1	0.7641	0.7758	0.7814	0.6872	0.6939	0.7756
	very good			desirable		desirable – no reaction
4	0.5826	0.6501	0.6698	0.4039	0.4893	0.5353
	good	good – very good		compulsory – desirable	desirable	
Evaluations defuzzified by the centre of area (CA) method						
1	0.7532	0.7765	0.8076	0.6513	0.7088	0.7535
	very good		very good – excellent	desirable		desirable – no reaction
4	0.6305	0.6822	0.6828	0.5006	0.5227	0.5373
	good – very good			desirable		

Table 2
Results (defuzzified by the centre of area method) of the team control system at Twins Design Ltd.
for the period May – June 2018 (own source).

Team	Team performance evaluation			Team performance progress		Deviation in team performance progress
	1st actual	2nd actual	Forecast	Actual	Forecast	
	1	2	3	4=2-1	5=3-1	6=4-5
Group 1 (Teams producing coffers)						
1	0.7532	0.8076	0.7765	0.0544	0.0233	0.0311
2	0.6927	0.7994	0.7681	0.1067	0.0754	0.0313
3	0.7314	0.8012	0.7694	0.0698	0.038	0.0318
Average deviation in performance progress of teams in group 1						*0.0314*
Group 2 (Teams producing settees)						
4	0.6305	0.6828	0.6822	0.0523	0.0517	0.0006
5	0.5911	0.6252	0.6897	0.0341	0.0986	−0.0645
6	0.6593	0.6926	0.7088	0.0333	0.0495	−0.0162
Average deviation in performance progress of teams in group 2						*−0.0267*
Average deviation in teams' performance progress at TD ltd.						**0.0047**

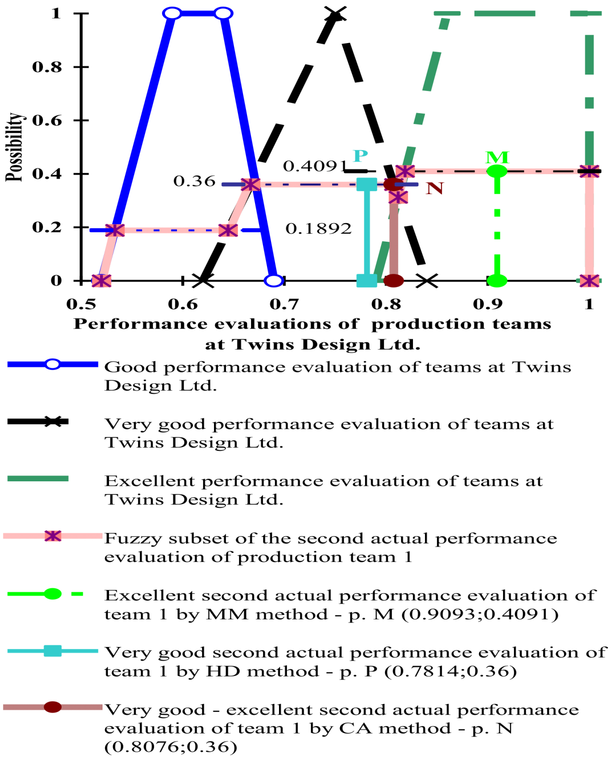

Fig. 3. Second actual performance evaluation of team 1 at Twins Design Ltd. for the period May – June 2018 (own source).

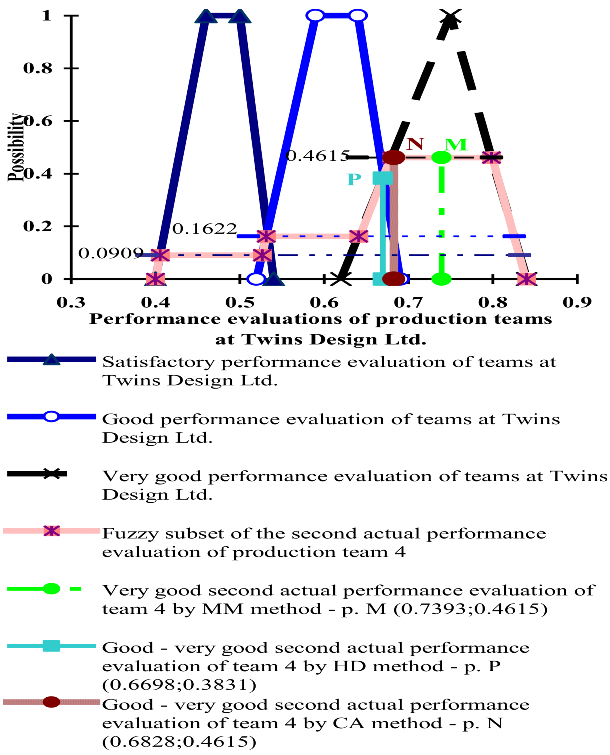

Fig. 4. Second actual performance evaluation of team 4 at Twins Design Ltd. for the period May – June 2018 (own source).

Discussion

The *comparison of team results* gives good reasons to highlight the following key performance features of teams at Twins Design Ltd. for May – June 2018:

- The performance of all production teams at TD was improved for May – June 2018 due to the implementation of a set of managerial decisions. The positive values of actual performance progress for all teams are considered as a proof of this conclusion (Table 2). These results proved the correct selection of managerial decisions to improve performance of TD's teams for May – June 2018.
- Four production teams (team 1, 2, 3, and 4) achieved their objectives. This finding could be argued by positive values of deviation in performance progress of these teams (Table 2). The results mean that teams 1, 2, 3, and 4 not only achieved, but also exceeded their objectives. Two teams (team 5 and 6) did not achieve their objectives. They had negative deviations in performance progress: −0.0645 for team 5 and −0.0162 for team 6.
- The performance results of the groups in which teams had been classified: The results of group 1 were better than those of group 2. The average deviation in teams' performance progress of group 1 had a positive value (0.0314, Table 2) while the same indicator of group 2 had a negative value (−0.0267, Table 2). Consequently, group 1 achieved its objectives, but group 2 did not achieve them.

The comparative performance analysis of teams with the best results in both groups (team 1 and 4) at Twins Design Ltd. for May – June 2018 provides the basis for the following findings:

- The performance of teams 1 and 4 at TD was improved for May – June 2018. The actual performance progress of both teams (Table 2) was commensurate: 0.0544 for team 1 and 0.0523 for team 4.
- The objectives of both teams were achieved and exceeded. This conclusion is based on (see Table 2) their positive deviations in team performance progress: 0.0311 for team 1 and 0.0006 for team 4.
- The second actual evaluations of both teams on the output variable "team performance" were quite different (Table 1, Fig. 3, and Fig. 4). Under the CA method, the variation range was 0.1248 (team 1 – 0.8076, team 4 – 0.6828). The qualitative evaluations of both teams were: team 1 – "very good – excellent" and team 4 – "good – very good".

- The second actual evaluations of both teams on the output variable "reaction to the team" were also different (Table 1). Under the CA method, the variation range was 0.2162 (team 1 – 0.7535, team 4 – 0.5373). The qualitative evaluations of both teams were: team 1 – "desirable reaction – no reaction", and team 4 – "desirable reaction". The teams' results on the output variable "reaction to the team" could be determined as a logical consequence of their evaluations' dynamic on the output variable "team performance".
- Team 1 had about 52 times higher deviation in performance progress than team 4 by the CA method (0.0311 and 0.0006 respectively, Table 2). *Possible reasons* for such a large difference could be the following: Firstly, this difference was a result of the lower actual performance progress of team 4 compared to team 1 (0.0523 versus 0.0544 respectively). In this context, *the first reason* could be explained by the inability of team 4 to compensate, ceteris paribus, its lower first actual performance evaluation. *The second reason* could be the nonlinear effect of the progress in evaluations on input variables to the progress in evaluation on the output variable "team performance". Secondly, that difference came from the lower forecast performance progress of team 1 compared to team 4 (0.0233 versus 0.0517 respectively). In this context, *the third reason* could be formulated as imprecise forecasting of the team control committee for team 1. *The fourth reason* is referred to the relevance of standards (scales) by which teams were evaluated. The lower deviation in performance progress of team 4 has indicated that standards were better suited to evaluate performance of TD's teams producing settee (teams in group 2, like team 4) than TD's teams producing coffers (teams in group 1, like team 1).

The results and special characteristics of the team control system tested *at Twins Design Ltd.* for May – June 2018 (Table 2) are the following:

- First, the scale for evaluating the effectiveness of the TD's team control system was the same as that in the model's description. The evaluations were within the range [−1; 1]. The possible states of the scale were evaluated by the TD's team control committee as follows: "effective team control system" – in the range [−0.02; 0.05], "ineffective system with a negative deviation" – in the range [−1; −0.02), and "ineffective system with a positive deviation" – in the range (0.05; 1]). The ranges of ineffectiveness were referred to a failure and an overachievement of teams' objectives respectively.
- Second, the team control system tested at TD functioned successfully. The conclusion is based on the average deviation in teams' performance progress at TD for May – June 2018. It had a positive value (0.0047, Table 2). This result indicates that teams' objectives were achieved on the whole (for all six teams).
- Third, the team control system tested at TD was effective. As a proof, the average deviation in teams' performance progress could be considered. Its value (0.0047) was positive and fell within the range [−0.02; 0.05] of the evaluation "effective team control system".
- Fourth, although the experimental team control system of TD was evaluated as effective, the effectiveness evaluations of both groups of production teams were quite different. According to the results (Table 2), the control system applied to the teams of group 1 was effective. This qualification is due to the fact that the average deviation in teams' performance progress (0.0314, Table 2) of group 1 fell within the range [−0.02; 0.05] of the evaluation "effective team control system". Simultaneously, the same control system applied to the teams of group 2 was ineffective because its average deviation in teams' performance progress (−0.0267, Table 2) fell within the range [−1; −0.02) of the evaluation "ineffective team control system with a negative deviation". According to the author of this article, the main reason for these dissimilar results, ceteris paribus, was the imprecise forecasting for the effect of managerial decision on the teams' performance. Performance expectations for the teams of group 1 were underestimated (deviation of 0.0314, Table 2) and performance expectations for teams 5 and 6 from group 2 were overestimated (deviations of −0.0645 and −0.0162 respectively, Table 2). The most precise forecast is for the performance of team 4 (deviations of 0.0006, Table 2).
- Fifth, the TD's team control system was not evaluated to be as effective as possible for May – June 2018. Its evaluation of effectiveness (0.0047) was very close to zero average deviation in teams' performance progress, but did not match zero. This result indicated that the effectiveness of the TD's team control system could be increased. The author of this article believes that the team control system could become more effective by actions in the following directions: improving the TD's planning system (incl. forecasting) of team performance, and increasing teams' evaluations on input variables by implementing a set of managerial decisions which is consistent with the pro-

duction process specifics of various unique products.

It could be drawn the following *main conclusions from the practical study* at Twins Design Ltd.:

- The performance of teams was improved as a result of the implementation of the fuzzy team control model in the TD's managerial practice for the period May – June 2018. The positive values of actual team performance progress for all teams are the main indicator for this effect.
- Improvement in the TD teams' performance for May – June 2018 was achieved by implementing a proper set of managerial decisions.
- The implementation of the team control model at TD was successful. The operation of the system for May – June 2018 was effective. This conclusion is based on the positive value of the average deviation in teams' performance progress at TD (0.0047).
- Three major recommendations could be made to the TD's management to increase the effectiveness of its team control system. First, different standards for measuring and evaluating the performance of TD's teams producing various unique products should be applied. Second, the same recommendation could also be made on the managerial decisions aimed at increasing performance evaluations of TD's production teams. They must be tailored to the specifics of TD's products and processes. Third, the forecasting precision of the team control committee at TD should be increased.

Conclusions

The major finding from the research presented in this article is as follows: *It could be concluded that the thesis of this article is confirmed*. This conclusion is based on the scientific evidence found in the research results. The results indicate that it is possible to increase the effectiveness of team control by implementing a team control model based on achievements of management and fuzzy theories. As a proof, an original contemporary fuzzy team control model and a toolkit for measuring and evaluating team performance and the effectiveness of the team control system are suggested here. In conceptual and methodological terms, the model and the toolkit are viewed as contributions to the management science in the field of team control. The fuzzy team control model has been verified in the managerial practice of a small Bulgarian enterprise. The empirical results demonstrate the model's ability to operate.

The author of this article believes that the implementation of the proposed team control model will contribute to a more effective team management and thus to the success of organizations.

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