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New Fuzzy Model for quality evaluation of E-Training of CNC Operators

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Abstract: *The quality of e-learning is a very important issue, especially when production technologies are concerned. This paper introduces a new fuzzy model for e-learning quality evaluation. All uncertainties and consequent imprecision are modeled by triangular fuzzy numbers. The quality of CNC e-learning process is determined by using the fuzzy logic IF-THEN rules. The proposed method derives an aggregated satisfaction value both for the participants as well as the trainers.The authors introduce a genuine metric interval for the objective evaluation of E-learning effect. The OLS regression model estimates the magnitude and polarity of E-learning effect on participants` perception of the training quality. The predicted coefficient of E-learning effect on the overall quality of CNC training is estimated to be14.88 measurement points with a negative impact on overall satisfaction. These novel findings shed a new light on the quantitative effect of E-learning on CNC machine training and contribute to the contemporary scientific literature within the research area.The developed model is illustrated by real-life data from secondary technological schools from central Serbia.*

Keywords: *CNC technologies, E-learning effect, E-training process, Evaluation, Fuzzy sets, Production technologies,*

I. Introduction

Education and creation of human resources is an important part of national strategies of developed countries, especially having in mind the fact that knowledge productivity has a direct influence upon economic growth of a country. Continual social and economic changes and an increased scientific and technological development, especially IT development, place a demand for highly educated workforce that would be able to efficiently solve various problems. In such a way, developed societies become learning societies; apart from a well-structured formal educational system, they have an opportunity for continual education and training due to a suitable system of institutions, organizational forms and programs which are not a part of formal education.

The issue of permanent education in the field of modern production technologies, such as CNC technologies whose application in production processes is immense with an ever growing tendency, is of utmost importance in developing countries. Venture costs rise dramatically unless there is a suitable number of educated people with specific knowledge who can promptly enter production processes. Otherwise, the whole venture becomes rather expensive and risky. Thus, for developing countries, and Serbia as one of these, it becomes of utmost importance to reform and advance the educational system as far as this field is concerned.

The quality of CNC education has a direct influence upon productivity of workers participating in processes.A number of papers presented in literature deal with the considered problem. Multimedia technology and Internet applications are important tools for teaching and learning in engineering education. Nowadays online simulative environments are indispensable tools for teaching computer numerical control (CNC) course in mechanical engineering. Previous studies were seldom designed in such a way to consider new emerging innovations and applications when CNC technologies are concerned.

Some authors [1], [2], [3], are engaged in engineering education and use the concept of Web services and clarify the advantages of implementing simulation in testing written programs for the CNC machine with the use of computers which certainly helps trainers/ lecturers to efficiently implement the process of learning to improve skills of participants.Forinstance, M.Exel et al. [4] write about two web-based training approaches forremote control.In [5], the author attempts to propose a virtual operating system applied to operation training of manufacturing facility and manufacturing process simulation.

Virtual reality (VR) technology has many advantages such as excellent interaction, high precision in 3D display and offers opportunities to manufacturing firms to meet the above challenges. VR technology has been widely used in manufacture simulation, especially, the web-based virtual machining simulation system that has become popular due to its cooperation facility and good platform independence [6-10].Discussion regarding training within the field of mechanical engineering (especially training conducted on CNC machines), with the emphasis on the application of Internet, E-learning andWeb-based training, and including manners to overcome the difficulties in implementation of new technologies (CNC, ICT, Internet, E-learning, Web) is presented in [11].

E-learning education quality is a complex notion which could be estimated according to multiple criteria.The authors hypothesize that identified criteria do not have relative importance and values. The relative importance of identified criteria and their values are difficult or rather impropriate to quantify, and as such have to be thoroughly assessed by decision makers.

A multi-criteria methodology defined from the perspective of learner satisfaction to support evaluation-based activities taking place at the pre- and post-adoption phases of the web-based e-learning education system (WELS) life cycle is proposed in [12]. Theassessment of relative importance of identified criteria is performed by investigated learners' perceptions. This investigation carried out a survey of college students, and the data obtained is then analyzed by analytic hierarchy process in order to derive an integrated preference structure of learners as a ground for evaluation. It isfound that learners regarded the learner interface as being the most important dimension of decision criteria. This allows a higher level of e-learner satisfaction to be reached, and in the process increases the level of system acceptance and continued use.

Decision makers express their judgments far better by using linguistic expressions than by representing them in terms of precise numbers.The Fuzzy Set Theory should be employed in the case of scarce evidence data or if the data values are rapidly modified due to the changes in the environment, according to Zimmermann, 1978. On the other side, the decision makers define their estimations faster and easier when applying linguistic expressions compared to exact numbers. Taking this into account it could be said that the Fuzzy Set Theory represents an adequate tool for handling with uncertainty and imprecision of any kind while simultaneously offering a possibility to overcome the obstacles regarding imprecision, number of data and the uncertainty among the decision makers.

In this paper all subjective assessments are described by linguistic expressions which are then modeled by fuzzy sets, as it has been used in[13-14]. Fuzzy set theory can provide a valuable framework for handling imprecise and ambiguous data, and provides reasoning and decision making methods based on such data. It can be said that by applying the fuzzy approach in the modeling of linguistic expressions, all uncertainties and imprecision which emerged due to lack of good evidence are eliminated.

In [15] a fuzzy multi-criteria method for e-E-learning quality evaluation has been developed. E-learning training process is decomposed into sub-processes. The existing uncertainties in the relative importance of sub-processes and their corresponding values are displayed by discrete fuzzy numbers. However, the values of identified sub-processes can be crisp and uncertain. The normalization of values of identified crisp sub-processes is given by using linear normalization procedure [16]. The transformation of all the uncertain sub-processes into degrees of belief is performed by applying a fuzzy set comparison method [17]. Determining the weighted normalized values of sub-processes is represented as a group decision making problem. The aggregation of individual opinions into group consensus is performed by usingthe averaging method. The overall value of e-learning process quality is calculated by using the method proposed in [15].

An assessment of E-learning laboratory objectives for control engineering education is considered in [18]. The relative importance of laboratory objectives is described by triangular fuzzy numbers(TFNs) and calculated by the proposed fuzzy Delphi method. The values of treated objectives are modeled by trapezoidal fuzzynumbers (TrFNs). The elements of fuzzy decision matrix can be computed as product of the relative importance of laboratory objectives and their normalized values. The best laboratory with respect to all objectives is found by applyingthe comparison method, i.e.TFNs[19].

In this paper, the relative importance of identified criteria is defined according to AHP framework, as presented in[20-22]. It is easier and closer to human reasoning to evaluate the relative importance of each pair of attributes instead of making a direct evaluation. The assessment of the relative importance is denoted as a fuzzy group decision making problem. In general, the aggregation of individual opinions into group consensus may be determined by applying different operators. Another point of view would be that trainers have the equal relevance, so that consensus may be given by fuzzy logic method (by analogy [23]). The weights of the considered criteria are computed by using the concept of extent analysis [24] which is extensively implemented approach in the literature. The obtained criteria weights, in this case however, are not the fuzzy numbers.

Within the approach suggested in paper, the estimation of criteria values is based on the subjective assessment of a trainer who conducts an e-learning training, and of trainees, separately. Furthermore, the isolated effect of e-learning based CNC machine training is calculated by employing a multivariate regression model.

Contribution of this paper compared with other cited works, mirrors itself in a new method definition that undoubtedly allows for possibility to determine the values of particular described criteria and sub-criteria. In addition, it allows for an influence on those (sub)criteria that have the minimal values so that we reach the improvement of total quality assessment of the CNC training both in classical approach and the e-learning approach.

A new fuzzy model for assessing CNC e-learningtraining is therefore proposed.All existing uncertainties are described by pre-defined linguistic expressions which are modeled by triangular fuzzy numbers (TFNs). The scope of the treated problem is as follows: (1) modeling of the assessments of trainersandparticipants is performed by using triangular fuzzy numbers (TFNs);(2) the weights vector of criteria are obtained by fuzzy Analytic Hierarchical Process (FAHP); (3) a new fuzzy model for assessing CNC e-learning training is proposed;(4) based on the obtained resultstrainers can define priority of management initiativesthat should lead to the improvement of the e-learning education quality. This may be seen as crucial in a time of economic crisis because the level of e-learning quality has to absorb the magnitude of the undesirable event and enhance long term sustainability of the education systems. It can be recognized as the main advantage of the proposed fuzzy model.

The paper is organized as follows: the basis of the considered problem is given in Section 2, including a new fuzzy set based approach to model the uncertainty in criteria weights and criteria values according to which the evaluation of e-learning education is performed. Section 3 describes a new fuzzy multi-criteria method for calculating e-learning education estimation. The proposed algorithm is illustrated by an example in section 4. Section 5 provides an interpretation of the generated results followed by an OLS regression model. The conclusions are presented in Section 6.

II. Modeling Of Uncertainties

In this Section, modeling of uncertainties in the relative importance of criteria is described. Uncertainties are described by the linguistic expression modeled by fuzzy sets, as discussed in[14]. A fuzzy set is represented by its membership function. The parameters of a membership function are the shape, granularity and location in the universe of discourse. Determining of the membership function can be defined as a task by itself. The membership function of a fuzzy set can be obtained based on one'sexperience, subjective belief of decision makers, intuition and contextual knowledge about the concept modeled [25]. Pedrycz and Gomide [26] defined six ways for determining the membership functions. However, subjectivity in determining the membership function has been considered as the weakest point in the fuzzy sets theory.

The triangular fuzzy numbers (TFNs) are widely used since they offer a good compromise between descriptive power and computational simplicity. Triangular function is less tolerant because the range of maximum membership has to be around the crisp point of the triangle. Fuzzy sets of higher types and levels have not as yet played a significant role in the applications of the fuzzy sets theory [27].

Granularity is defined as the number of fuzzy numbers assigned to the relative importance and values of identified criteria. Lootsma [28] suggests that human being can have only seven categories at the most. In this paper, respecting the type and size of the considered problem and Lootsma's suggestion authors used five linguistic expressions assigned to the existing linguistic variables.

In the related literature there is no strict guideline how to determine domain of any TFN. In general, domains of TFNs are defined on the real sets into different interval (for an instance:[0-1], [1-5], [1-9], etc.). Also, the way how to determine lower bound, upper bound and modal value of any TFN is not defined in the literature [29-30]. TFNs may be presented symmetrically on the proposed scale or they may be presented in compliance with decision makers' experience and knowledge.

This paper offers a problem setup for CNC (Computer Numerical Control) training quality evaluation. A training conducted by using e-learning approach based on multi-criteria; and a method of CNC training quality evaluation based on e-learning. The uncertainties detected in the proposed model can be expressed as: 1) the relative importance of sub-criteria of training evaluation, 2) the values of sub-criteria prescribed by Fuzzy Sets Theory.

2.1 Basic assumptions

The paper further explains the problem of defining CNC e-learning education quality. Solution of the considered problem directly influences the effectiveness of management in manufacturing and production system, with special focus on productivity improvement.

Relative importance of the considered criteria and their values are described by different linguistic variables which are afterwards modeled by triangular fuzzy numbers.

The following are the assumptions that underline a model of the considered problem:

- Trainers define the criteria that are used for the evaluation of CNC e-learning education. Trainers define the number and types of criteria based on their knowledge, skills and experience. To each defined criterion an organized pair (relative importance, value joined) is associated.
- Relative importance of treated criteria is hardly changed over time. Generally, the relative importance of criteria is different and determined according to knowledge and experience of trainers. It can be stated as fuzzy group decision making problem.
- Values of defined criteria are determined for each participant, separately, by trainers. In the considered problem, these values are uncertain.
- All uncertain values are modeled by applying the fuzzy set theory.

2.2Criteria weights modeling

All criteria for evaluating quality of e-learning education are usually not of the same relative importance. Also, they can be taken as unchangeable during the considered period of time. They involve a high degree of subjective judgments and individual preferences of trainers. The judgment of each pair of treated criteria suits a human-decision nature (by analogy with AHP method) the best. In conventional AHP, the pairwise comparison is established using a standard integer scale. The use of discrete scale of AHP is simple and easy, but it is not sufficient to take into account the uncertainty associated with the mapping of one's perception to a number. Trainers express their judgments far better by using linguistic expressions than by representing them in terms of precise numbers.

The following notation is used in the paper:

T- number of considered trainers

t- index of trainer

P- number of treated participants

p- index of participant

K number of the identified criteria

k- index of criterion

$W_{kk'}^t$-triangular fuzzy number describing the local importance of criterion k over a criterion k', $k, k' = 1, .., K; k \neq k'$which is given by trainer t, t=1,..,T

$W_{kk'}$-triangular fuzzy number describing the aggregated relative importance of criterion k over a criterion k', $k, k' = 1, .., K; k \neq k'$

w_k -crisp value describing the criterion weight k, k=1,..,K

$\tilde{v}_{kp}^t$ -triangular fuzzy number describing the criterion value k, k=1,..,K at the level trainer t, t=1,..T, which is estimated by participant p, p=1,..,P

$\tilde{d}_k$ -triangular fuzzy number describing the weighted value of criterion k, k=1,..,K respecting the all participants

$\tilde{c}$-fuzzy number describing the satisfaction level of participants with respect to all criteria and their weights

c-the representative scalar of the fuzzy number$\tilde{c}$

In this paper, the trainers' fuzzy rating for each pair of treated criteria is described by linguistic expressions which can be represented as in Equation (1):

$$\text{TFN}\,\tilde{W}_{kk'}^{t} = \left(x; l_{kk'}^{t}, m_{kk'}^{t}, u_{kk'}^{t}\right) \tag{1}$$

with the lower and upper bounds $l_{kk'}^t$, $u_{kk'}^t$ and modal value $m_{kk'}^t$, respectively. Values in the domain of these TFNs belong to a real set within the interval from 1 to 5.

If strong relative importance of criterion k' over criterion k holds, then pair-wise comparison scale can be represented by Equation (2):

$$\text{TFN}\tilde{W}_{kk'}^{t} = \left(\tilde{W}_{k'k}^{t}\right)^{-1} = \left(\frac{1}{u_{kk'}^{t}}, \frac{1}{m_{kk'}^{t}}, \frac{1}{l_{kk'}^{t}}\right). \tag{2}$$

If $k = k'$ ($k, k' = 1,.., K$), then relative importance of criterion k over criterion k' is represented by single point 1 which is TFN (1,1,1).

In this paper, the fuzzy rating of each decision maker can be described by using three linguistic expressionsas following:

low importance- $\tilde{R}_1 = (x; 1, 1, 5)$

medium importance- $\tilde{R}_2 = (x; 1, 3, 5)$

most importance- $\tilde{R}_3 = (x; 1, 5, 5)$

Calculation of the Criteria Priority Weights is presented as follows.

The value of fuzzy synthetic extent with respect to the i-th object is defined as in Equation (3):

$$\tilde{S}_k = \sum_{k=1}^{K} N_k^k \cdot \left[\sum_{k=1}^{K}\sum_{k=1}^{K} N_k^k\right]^{-1} \tag{3}$$

where:

$$\sum_{k=1}^{K} N_k^k = \left(\sum_{k'=1}^{K} l_{kk'}, \sum_{k'=1}^{K} m_{kk'}, \sum_{k'=1}^{K} u_{kk'} \right) \tag{4}$$

$$\sum_{k=1}^{K} \sum_{k=1}^{K} N_k^k = \left(\sum_{k=1}^{K} \sum_{k'=1}^{K} l_{kk'}, \sum_{k=1}^{K} \sum_{k'=1}^{K} m_{kk'}, \sum_{k=1}^{K} \sum_{k'=1}^{K} u_{kk'} \right) \tag{5}$$

$$\left[\sum_{k=1}^{K} \sum_{k=1}^{K} N_k^k\right]^{-1} = \left(\frac{1}{\sum_{k=1}^{K} \sum_{k=1}^{K} u_{kk'}}, \frac{1}{\sum_{k=1}^{K} \sum_{k=1}^{K} m_{kk'}}, \frac{1}{\sum_{k=1}^{K} \sum_{k=1}^{K} l_{kk'}}\right) \tag{6}$$

The value of fuzzy synthetic extent with respect to the k-th criterion is defined by Equation (7):

$$\tilde{S}_k = \left(\sum_{k=1}^{K} l_{kk'}, \sum_{k=1}^{K} m_{kk'}, \sum_{k=1}^{K} u_{kk'}\right) \cdot \left(\frac{1}{\sum_{k=1}^{K} \sum_{k=1}^{K} u_{kk'}}, \frac{1}{\sum_{k=1}^{K} \sum_{k=1}^{K} m_{kk'}}, \frac{1}{\sum_{k=1}^{K} \sum_{k=1}^{K} l_{kk'}}, \right) \tag{7}$$

The weights vector is represented as in Equation (8):

$$W_p = \left(\left(Bel\left(\tilde{S}_1 \right) \right), \ldots, \left(Bel\left(\tilde{S}_k \right) \right), \ldots, \left(Bel\left(\tilde{S}_K \right) \right) \right) \tag{8}$$

Where $Bel\left(\tilde{S}_k\right)$ is measure of belief according to which TFB $\tilde{S}_k$ is bigger than all other TFBs $\tilde{S}_{k'}$, $(k, k' = 1,.., K; k \neq k')$. This value is obtained by applying the method for fuzzy numbers comparison [31-32]. After normalizing w_p, we get the normalized weights vector W as in Equation (9):

$$W = \left(w_1,.., w_k,..., w_K\right) \tag{9}$$

W is a non-fuzzy number and this gives the priority weights of one criterion over the other.

2.3Modeling of uncertain criteria

Values of all defined criteria underlying the estimation of e-learning education quality cannot be stated quantitatively, as both trainers and trainees most often base their estimates on evidence data, knowledge, experiences, etc. In such cases, their values are adequately described by five linguistic expressions: *verylow value, low value, moderate value, high value,* and *very high value*. These linguistic expressions are modeled by TFNswhich domains belong to a real set within the interval from 1 to 9 (by analogy with the Saaty's measurement scale). These TFNs are given in the following way:

very low value - $\tilde{V}_1 = (y; 0, 0, 0.2)$

low value- $\tilde{V}_2 = (y; 0.15, 0.3, 0.45)$

moderate value - $\tilde{V}_3 = (y; 0.35, 0.5, 0.65)$

high value - $\tilde{V}_4 = (y; .0.55, 0.7, 0.85)$

very high value - $\tilde{V}_5 = (y; 0.75, 1, 1)$

2.4 Modeling of the regions of education satisfaction

Trainer and participant may have different levels of education satisfaction.This paper proposes, three different state regions of education satisfaction:*low education satisfaction region*, *mid-point education satisfaction region*, and *high education satisfaction region*. The proposed regions represent the baseline for education satisfaction assessment. The regions of education satisfactioncan be modeled by one of the three predetermined linguistic terms. These linguistic expressions are modeled by TFNs.

The TFNs for modeling the regions of education satisfaction are:

- *low education satisfaction region* - $\tilde{S}_1 = (x; 0, 0, 0.55)$
- *mid-point education satisfaction region* - $\tilde{S}_2 = (x; 0.15, 0.5, 0.85)$
- *high education satisfaction region* - $\tilde{S}_3 = (x; 0.45, 1, 1)$

The proposed domains of the defined regionsare given with respect to pre-defined values of considered uncertainties. These values may be changed and adjusted according to the specific needs of the treated education organizations.

III. The Proposedfuzzy Modelfor Quality Evaluation Of E-Training Of Cnc Operators

In this paper, e-learning education quality is determined in an exact way by applying the proposed fuzzy model which is realized in several stages.
The proposed procedure can be accomplished through the following steps. A general design of the quality assessment is given in Fig. 1.

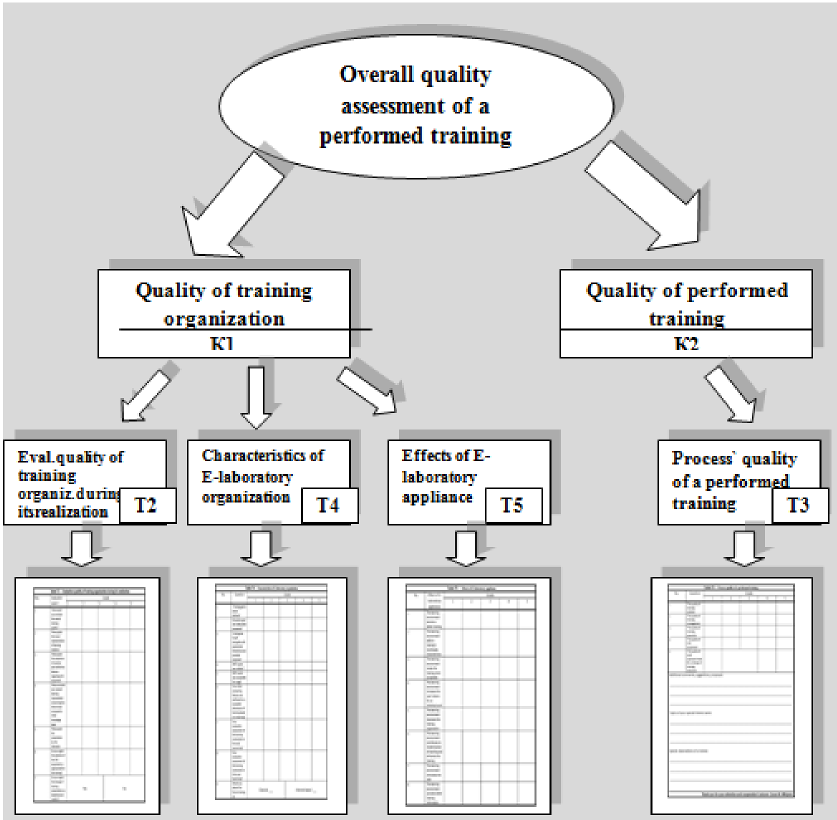

Figure 1-Overall quality assessment of a performed training

Step 1. The fuzzy pair-wise comparison matrix of the relative importance of evaluation criteria is stated:

$$\left[\tilde{W}^{t}_{kk'}\right]_{KxK} \qquad k, k' = 1,\dots, K; k \neq k'; t = 1,\dots, T$$

Step 2. Calculate the aggregated assessments of trainers, $\tilde{W}_{kk'} = (l_{kk'}, m_{kk'}, u_{kk'}), k, k' = 1,\dots, K; k \neq k'$ by using the procedure proposedin [23], such that we have Equation (10):

$$l_{kk'} = \min_{t=1,\dots,T} l^{t}_{kk'}, \; m_{kk'} = \frac{1}{T} \cdot \sum_{t=1}^{T} m^{t}_{kk'}, \text{ and } u_{kk'} = \max_{t=1,\dots,T} u^{t}_{kk'} \tag{10}$$

The aggregated fuzzy pair-wise comparison matrix of the relative importance of the treated criteria can be presented as:

$$\left[\tilde{W}_{kk'}\right]_{KxK} \quad k, k' = 1,..., K; k \neq k'$$

Step 3. Calculate the criteria priority weights, $W = (w_1,.., w_k,..., w_K)$ by using the concept of extent analysis [24].

Step 4. Assessment of participant p, p=1,..,P by trainer t, t=1,..,T under criterion k, k=1,..,K is described by linguistic expressions which are modeled by TFNs, $\tilde{v}_{kp}^{t}$.

Step 5. Construction of weighted aggregated fuzzy decision matrices is shown as:

$$\left[\tilde{d}_k\right]_{1xK}$$

Where in Equation (11):

$$\tilde{d}_k = \frac{1}{T} \cdot \frac{1}{P} \cdot w_k \cdot \sum_{p=1}^{P} \sum_{t=1}^{T} \tilde{V}_{kp}^{t} \tag{11}$$

Step 6. Calculate the overall satisfaction of participants, $\tilde{c}$ as in Equation (12):

$$\tilde{c} = \bigcup_{k=1,..,K} \tilde{d}_k \tag{12}$$

Step 7. Find the representative scalar of the fuzzy numbers $\tilde{c}$ by using the moment method used in[14].

Step 8. The region of education satisfaction in the observed trainers and participants can be defined according to the rule:

IF the value of "overall education satisfaction" equals c, THEN the region of education satisfaction is described by the linguistic expression where the level of education of participants is given in Equation (13):

$$\max_{q=1,2,3} \mu_{\tilde{S}_q}(x = c) = \mu_{\tilde{S}_{q^*}} . \tag{13}$$

IV. Case Study

The participants' satisfaction with the CNC e-learning education for secondary technical school teachers is realized as a part of continual education, which is one of requirements of Total Quality Management principles. A series of the same content trainings were organized during one year, including two major processes: process of programming and handling process.The considered education process includes 32 participants (High school lecturers that teach withinthe CNC field and engineers from industrial enterprises). The descriptive statistics of the aggregate sample – 91 participant is presented in Table 1. Average education level among the participants is almost 16 years[1], i.e. the majority has a B. Sc. degree. The experience on average is 10.5 years, where some have only 6 years of professional employment. Itis realized by two trainers. The quality of the treated education process is evaluated by using satisfaction of the participants. The satisfaction level of the participants is calculated by using the proposed fuzzy model. Three criteria are considered: quality of the training content (k=1); quality of training execution (k=2) and equipment quality (k=3).

Table I: Descriptive statistics of the total sample (original sample values given in parentheses)

	E-learning	Education	Experience	Grade
Mean	0.13747 (0.13448)	15.84 (15.98)	9.83 (10.27)	4.05 (3. 93103)
Maximum	0.2	18	22	5
Minimum	0.1	14.5	6	1
Range	0.1	3.5	16	4
Stand.	0.02869 (0.02934)	0.60411	3.455314	1.03669

[1]Described values in this paragraph relate to the original sample size, excluding those candidates assigned to the area "unsuccessful".

Deviation		(0.72558)	(3.43195)	(1.22273)
Variance	0.00082 (0.00086)	0.36495 (0.52647)	11.93919 (11.7783)	1.074725 (1.49507)

The proposed fuzzy model for the quality evaluation is applied in following steps:
Step 1
The relative importance of criteria values estimated by two trainers is presented in the followingfuzzy pair-wise matrix:

$$\begin{bmatrix} \tilde{1} & 1/\tilde{R}_2, 1/\tilde{R}_1 & 1/\tilde{R}_3, 1/\tilde{R}_2 \\ \tilde{R}_2, \tilde{R}_1 & \tilde{1} & 1/\tilde{R}_2, \tilde{R}_1 \\ \tilde{R}_3, \tilde{R}_2 & \tilde{R}_2, 1/\tilde{R}_1 & \tilde{1} \end{bmatrix}$$

Step 2
The aggregated fuzzy pair-wise matrix of the relative importance of treated criteria is:

$$\begin{bmatrix} (1,1,1) & (0.2, 0.67, 1) & (0.2, 0.27, 1) \\ (1,2,5) & (1,1,1) & (0.2, 0.67, 5) \\ (1,4,5) & (0.2, 2, 5) & (1,1,1) \end{bmatrix}$$

Step 3
The value of fuzzy synthetic extent with respects to the k-th criterion is calculated as follows:

$$\tilde{S}_1 = (1.4, 1.94, 3) \cdot \left(\frac{1}{25}, \frac{1}{12.61}, \frac{1}{5.8}\right) = (0.056, 0.154, 0.517)$$

$$\tilde{S}_2 = (2.2, 3.67, 11) \cdot \left(\frac{1}{25}, \frac{1}{12.61}, \frac{1}{5.8}\right) = (0.088, 0.291, 1.897)$$

$$\tilde{S}_3 = (2.2, 7, 11) \cdot \left(\frac{1}{25}, \frac{1}{12.61}, \frac{1}{5.8}\right) = (0.088, 0.555, 1.897)$$

The weights vector is:

$$W_p = (0.517, 0.873, 1)$$

The normalized weights vector of criteria is:

$$w = (0.216, 0.365, 0.418)$$

The assessment of participants for each trainer under each treated criterion is presented in Table 2:

Table II: The assessment of the criteria values

	k=1	k=2	k=3
t=1	$\widetilde{V}_4, \widetilde{V}_5 x31$	$\widetilde{V}_4 x4, \widetilde{V}_5 x28$	$\widetilde{V}_2 x4, \widetilde{V}_3 x4\ \widetilde{V}_4 x4, \widetilde{V}_5 x20$
t=2	$\widetilde{V}_3, \widetilde{V}_4 x5,\ \widetilde{V}_5 x26$	$\widetilde{V}_3, \widetilde{V}_4,\ \widetilde{V}_5 x30$	$\widetilde{V}_2 x4, \widetilde{V}_3 x4\ \widetilde{V}_4 x4, \widetilde{V}_5 x20$

Steps 4 and 5
The weighted aggregated values of the participants'satisfaction are calculated as:

$$\tilde{d}_1 = \frac{1}{2} \cdot \frac{1}{32} \cdot 0.216 \cdot \left(\tilde{V}_3 + \tilde{V}_4\, x6 + \tilde{V}_5\, x57 \right) = (y; 0.16, 0.21, 0.21)$$

$$\tilde{d}_2 = \frac{1}{2} \cdot \frac{1}{32} \cdot 0.365 \cdot \left(\tilde{V}_3 + \tilde{V}_4\, x5 + \tilde{V}_5\, x58 \right) = (y; 0.27, 0.35, 0.36)$$

$$\tilde{d}_3 = \frac{1}{2} \cdot \frac{1}{32} \cdot 0.418 \cdot \left(\tilde{V}_2\, x8 + \tilde{V}_3\, x8 + \tilde{V}_4\, x8 + \tilde{V}_5\, x40 \right) = (y; 0.25, 0.32, 0.36)$$

Steps 6 and 7: The calculated satisfaction of participants and the representative scalars:

The satisfaction of participants, $\tilde{c}$ as well as the representative scalars are calculated, so that:
c=0.277
Steps 8
The region of education satisfaction for trainers is calculated as follows:

$\mu_{\tilde{S}_2}(x = 0.277) = 0.386$, $\mu_{\tilde{S}_3}(x = 0.277) = 0.088$

max (0.386, 0.088)=0.386

V. Results And Discussion

Implementation of web-based training, dependent on contemporary Information Technologies (IT) literacy and actual development of multimedia technology as well as internet applications, could also include the usage of non-licensed software accompanied with appropriate internet connection stability.

The computed values should be located within the real numbers interval [0-1], where zero represents the maximal level of satisfaction and one stands for the minimum level of satisfaction (Dubois and Prade, 1980). However, the boundaries of the interval are supposed not to be reached in reality. The authors` research experience shows that the good performances of participants within the e-learning framework are to be expected even though the overall satisfaction degree falls into the third sub-interval with the corresponding value of 0.75. These arguments of rather positive acceptance of the empirical results are expressed in the end of previous section. According to previously conducted research experiments, the authors decompose the upper interval into three sub-intervals: *high satisfaction* [0-0.3], *relative satisfaction* [0.31-0.6], *low satisfaction* [0.61-1]. The empirical satisfaction of the participants (c=0.277) informs about relatively higher degree of satisfaction among them, since the value is within the first third of the interval. This could be interpreted in the sense of relatively higher level of concentration achieved during the training and therefore an increased effort investment and therefore higher satisfaction with conducted work. We explain this phenomenon as a situation where a participant is self-content simply due to the effort invested in the actual task.

The mentioned higher concentration level is related to permanent concern over possible damage on the machine due to exogenous factors, i.e. internet connectivity, lower video coverage. On the other hand, overall satisfaction among the two trainers is slightly lower, μ_S=0.386, which informs about the awareness of the risks present among the lecturers, *a priori.* This diminishes their degree of satisfaction since they are aware that an absolute precision will not be reached. Additionally, the relatively insufficient video coverage and ever present connection buffering increased their skepticism and decreased satisfaction. Therefore the final value is being located within the second sub-interval.The source of the skepticism among the trainers is depicted on Fig.2.

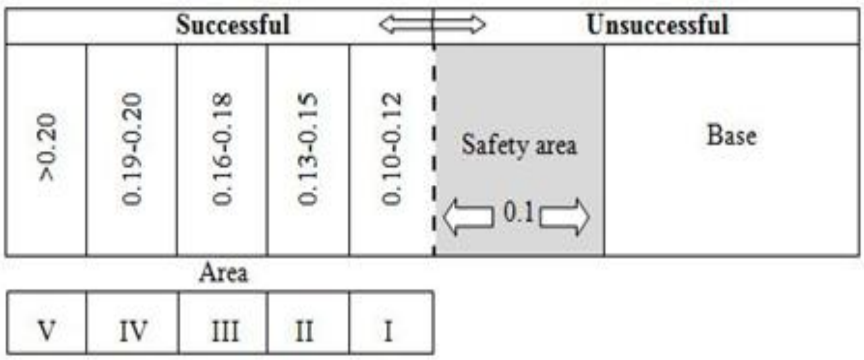

Figure 2 – Introduction of Safety area during CNC machine manipulation

The genuine contribution of the research article reflects on the introduction of „safety area" during the direct training on CNC machines. This area was defined according the authors previous experiences. The proposed value is 0.1. Unsuccessful is considered to be any value that enters the safety area, i.e. lower than 0.1. Otherwise the damage would be made on the tool and machine itself. The substantial argument for proposing the safety area is inability to prevent the accidence beforehand is such an area would not exist. This strongly relates to the dynamics of the real-time CNC training process. The Basis represents an initial set up for the machine. Successful is considered to be any value achieved within the suggested sub-zones (grade areas) where each zone prevents the risk of accidence to occur. This is the first task for the trainer in the process of successful knowledge transfer. The proposed values of the sub-zones are defined according to previous experience of the authors. However, of the corresponding grade areas only I-IV are accepted as successful. We have detected 3 (three) candidates that penetrated into the safety area (see Table 3). This validates the initial hypothesis of correlation between accidence risk and online navigated handling of the machine. The necessity of safety area is therefore obvious.

Area / Values		Grade	Participants (cum.number)
I	0.10-0.12	5	12
II	0.13-0.15	4	10
III	0.16-0.18	3	4
IV	0.19- 0.20	2	3
V	> 0.21	1	0
Unsuccessful < 0.1			3

Table III: The results of the CNC machine manipulation

By applying the proposed fuzzy model, it could be seen that the equipment quality(k=3) was assigned the highest weights.This is advantageous for both trainers and trainees, as it defines high quality of the chosen equipment used in the process of training, which is one of important preconditions for the training quality. In other hands, it directly connected with the finances supporting such a project. Selection of CNC equipment must be done in cautious and qualified manner. It should be handed over to a special team of skillful or licensed instructors.The development and planning of training process is necessary, especially in the case of CNC technologies and web-based training process. The lowest satisfaction level among participants is given under the criterion which is denoted as training content (k=1). This refers to alignment of a designed CNC programming content and the manipulation of CNC equipment in terms of contemporary scientific and industrial developments; the need of the total economy for a new technological solutions (i.e. to offer these new solutions to total economy); to offer an approach to the implementation of these solutions. Additionally, the designed CNC programming training and the manipulation of CNC machines has to be flexible towards the new market demands and present time. It can be concluded thatevaluation should be continuously conducted, during and after training process, with permanent readiness for eventual modifications in the way how training process is being fulfilled; gained experiences and skills have to be published and used for later trainings.

The main research idea of the article is to precisely define the impact of "e-learning effect" during the training part related to CNC machine manipulation. The focus is intentionally put on this section due to ever occurring technicalobstacles. The consequences of this effect are mirrored in the aggregate satisfaction of the participants. To reach the research goal, we construct an OLS model analogue to the Mincer earning equation[2]. The estimatedmodel is as follows:

$$\widehat{GRADE}=\widehat{\beta 0}+\beta\widehat{1ELRN}+\beta\widehat{2EDU}+\beta\widehat{3EXP}+\beta 4\widehat{EXPSQ}+\widehat{ui} \qquad (1)$$

Where,*GRADE* – is a dependent variable,
β_i – estimation coefficient ,
ELRN – E-learning effect,
EDU – Education in years
EXP – Tenure in years,
EXPSQ – Tenure squared (log),
u_i – error term.

The sample is augmented by applying the theorem of random sampling, where the main moments are extrapolated from the original sample (n=32). The number of observations is henceforth 100 instead of 32. The unsuccessful attempts, see page 12, are excluded from the analysis, which defines the final sample of 91 participants (3 on 32 and 9 on 100). As a proxy for the aggregate satisfaction level of the participants we use the final marks of each participant during the online CNC manipulation training[3].Here, we deal only with participants` satisfaction and its causal relation with e-learning effect (see Fig. 3).

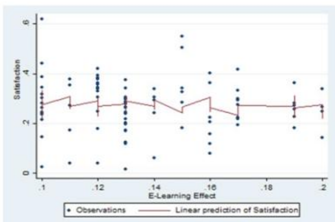

Figure 3 – Causal relationship between satisfaction and e-learning effect

[2]To capture the effect of e-learning, individual education level and tenure on dependent variable, we find appropriate to express our model as a modified Mincer equation function.

[3]Here we use the final grades obtained during the part of training related to CNC machine manipulation. This however differs from the final grades obtained after the programming training part conducted on CNC machines.

The authors suppose a high degree of correlation between overall satisfaction of a participant and his grade by the rule of thumb. Estimation results provide a genuine assessment of how the e-learning affects the participants` quality assessment of a conducted training. We find a negative correlation between e-learning and grade with a magnitude of 14.88 (see Table 4).
Consequently, the impact of e-learning is accurately described through uncertainties which it generates. The lack of preciseness, or put in slightly another way, the variations within the precision levels of participants are its obvious manifestations. This estimation of e-learning effect during the CNC training represents the main contribution of this research paper. On the other hand, remaining regressors do have a positive influence on regressand, with significantly lower estimated coefficients. Furthermore, in proposed model only e-learning effect regressor is significant. Although the explanatory power of the OLS model is relatively low ($R^2 = 0.20$), the findings point out to a negative effect of the CNC training conducted online. This finding is a novel contribution to the mostly scarce scientific research within the field. Additionally, education is positively related to the grade. Interestingly, not significant when e-learning variable is included in the model. This can be explained by the existence of the uncertainties during the product processing in a real time on the CNC machine. The video technology and internet connection buffering hinder the concentration of the participant and objectively diminish the chances of reaching the absolute precision required in serial production heavily related to CNC machines.

Table IV: OLS regression model results

Source	SS	df	MS		Number of obs. = 91
Model	20.2311645	4	5.05779114		F (4,86) = 5.69
Residual	76.4941102	86	0.889466397		Prob. > F = 0.0004 R-squared = 0.2092
Total	96.7252747	90	1.07472527		Adj. R-squared = 0.1724
					Root MSE = 0.94312
Grade	Coefficient	Stand. Err.	t	P > | t |	[95% Conf. Interval]
E-learning	-14.87932	3.580344	-4.16	0.000	-21.99681 -7.761832
Education	0.2333091	0.1681665	1.39	0.169	-0.1009949 0.5676131
Experience	0.0835151	0.1255672	0.67	0.508	-0.1661043 0.3331345
Exp_square	-1.380103	1.540343	-0.90	0.373	-4.442203 1.681997
_cons	4.257427	3.495152	1.22	0.227	-2.690707 11.20556

Some of the possible improvement strategies that may be employed for improving values of CNC e-learning process quality area: a)Constant following of IT trends with respect to CNC equipment; b) alignment of training contents for CNC programming and CNC equipment manipulation. In addition, it is necessary for the participants who attend the training to possess the fundamental IT knowledge. Furthermore, it is important to adjust the training materials separately according to each participant group. The training content are defined with respect to two essential requirements: 1) have to be in accordance with the State Ministry of Education predefined education programs and study profiles and 2) should allow for skills and knowledge improvement of the participants in the area of CNC machines (beneficial to participants that reached M. Sc. / Ph. D level and are employed at the High School with technical orientation). The fulfillment of above mentioned requests bears certain limitations, for instance: available resources, motivation of teaching stuff towards professional improvement, an insight that a leading stuff has in IT development and the desire to implement this development, adequate selection of lecturers according to their affinities and professional goals, etc.

VI. Conclusion

Taking into account the requirement for a continuous improvement of an education process, as well as rapid, perpetual IT development and the customer demands, it can be said that the lack of constant education, especially at High Schools within technical area, prevents a fast recovery when the business disturbances occur. The assessment and management of the considered education process quality may be introduced through identification of satisfaction level of participants over time. The solution of the considered problem is obtained in exact way because the solution is less burdened by the subjective judgments of decision makers.
All uncertainties in relative importance of evaluation criteria, and their values are described by predefined linguistic expressions. Decision makers present their opinion by using linguistic expression in more precise way than by using precise numbers. Linguistic variables are modeled by TFNs.
The AHP framework is used for the rating of the relative importance of evaluation criteria since it is closer to the human way of thinking. The determination of elements values of constructed fuzzy pair-wise comparison matrix is stated as a fuzzy group decision making. The aggregation of individual opinions into a group consensus is given by the proposed method which can be found in the appropriate literature. By using the procedure for the handling of fuzzy AHP, the weights of evaluation criteria are given by TFNs. The RF values are assessed by participants.

The weighted value of each identified criterion is calculated by using fuzzy averaging method and fuzzy algebra rules. The overall satisfaction level of participants with respect to all criteria is calculated by using union operation of TFNs.The efficiency and reliability of the proposed methods for evaluating the education processes' quality properties are described using the IF-THEN rules.

The proposed procedure is illustrated by real-life data from secondary technical schools in central Serbia. The outputs of the proposed fuzzy model represent the base for definition of strategy that should be oriented to enhancement of the education process quality. Furthermore, the quantitative assessment of the e-learning impact on participants` satisfaction with the conducted training represents the major contribution of the article. We find that CNC training conducted online will hinder the results of participants *per se*, and we calculate its magnitude on 14.88 measurement points. Conversely, other authors account for a positive impact of e-learning, albeit not precisely targeting the CNC machine training. The formation of "safety area" is another genuine contribution of the research paper. The comparison with other authors is not possible since the scarcity of quantitative findings in other articles prevents us to conduct the parallel comparisons. Additionally, we find that the application of freeware software instead of licenced software did not affect the work confidence of the applicants and the overall training quality. The arguments are to be found in the questionnaire T4, e.g. quaetion no. 7 and no.8. Both versions of software were applied in each session, i.e. 2 days training for each version. These all account for major benefits of conducted research. In this way, the costs and time needed for improvement of the treated process may be decreased and optimized. The presented approach is novel and presents one of the first steps in mathematical modeling of CNC e-learning education process quality. Contributions of this paper are the following: (1) it proposes a new fuzzy model for calculating the quality estimation for each CNC e-learning education criterion, and (2) it handles uncertainty within considered criteria using fuzzy sets.

Besides the advantages, the proposed model has certain constraints. Having in mind the main constraints of the proposed fuzzy model are: the number of evaluation criteria, number of trainers and participants. The sample used for testing the proposed fuzzy model is constrained by: the number of High School with technical orientation that offer this study programme; the needs of the enterprises that operate in domestic market; tendency of the top management in industrial enterprises to educate their employees with relevant CNC programming skills; relatively low financial capabilities of considered enterprises (e.g. generally all enterprises on domestic market belong to a group of small and medium size enterprises); etc. One of future directions is set to development of software based on the proposed model. In addition, the software solution could be expanded with additional functionalities for better education process management.

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