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MENTAL WORKLOAD ASSESSMENT USING A FUZZY MULTI-CRITERIA METHOD

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Original scientific paper
The workload factors for labor-intensive works of employees are always taken into account in measuring workloads. However, with the introduction of computers to work planning and coordination, the tasks have often begun to take on mental workload. Mental workload is encountered in academic studies in relatively high prevalence. In this regard, it is important to examine the efficiency of scientific studies to support the academic, administrative, and technical staff of a faculty. Many methods having certain disadvantages are available in the literature which is either conflicting or complementary to each other. Therefore, an integrated mental workload assessment method is needed. In this study, a new hierarchical method was proposed and by help of a scale developed, taking the subjective techniques (MCH, SWAT, NASA-TLX) into account, the faculty staff was holistically assessed in a fuzzy multi-criteria decision making processes. The subjects were selected in an engineering school at a private university. Four risk categories are defined that contain homogenous risk scores. At the end of the study, some ergonomic regulations are recommended to the persons/departments at high risk categories to reduce mental workloads.

Keywords: *fuzzy multi-criteria assessment; MCH; NASA-TLX; subjective mental workload; SWAT*

Procjena mentalnog opterećenja primjenom neizrazite metode s više kriterija

Izvorni znanstveni članak
Faktori opterećenja kod radno-intenzivnih poslova zaposlenika uvijek se uzimaju u obzir pri mjerenju opterećenja. Međutim, uvođenjem računala u planiranje rada i koordinaciju, radnim se zadacima često pridodaje mentalno (intelektualno) opterećenje. Ono uvelike prevladava u znanosti. U tom je pogledu važno istražiti učinkovitost znanstvenih istraživanja kao podršku znanstvenom, administrativnom i tehničkom osoblju fakulteta. U literaturi su dostupne mnoge metode s izvjesnim nedostacima, koje su u suprotnosti jedna s drugom ili se međusobno dopunjuju. Zbog toga je potrebna jedna cjelovita metoda kojom će se procijeniti intelektualno opterećenje. U ovom se radu predlaže nova metoda kojom se, pomoću razvijene tabele, uzimajući u obzir subjektivne metode (MCH, SWAT, NASA-TLX), fakultetsko osoblje cjelovito procijenilo postupcima donošenja odluka neizrazitom metodom s više kriterija. Ispitanici su izabrani s tehničkog fakulteta privatnog sveučilišta. Određene su četiri kategorije s ujednačenim stupnjevima ugroženosti. Na kraju istraživanja preporučuju se neka ergonomska pravila kojih bi se osoblje/odjeli ugroženih kategorija trebali pridržavati kako bi se smanjilo mentalno opterećenje.

Ključne riječi: *MCH; NASA-TLX; subjektivno mentalno opterećenje; SWAT; više kriterijska neizrazita procjena*

1 Introduction

So far, factors affecting the performance of the work environment have always been designed for labor-intensive jobs; they were measured, developed and installed in this respect. Taking the same course, ergonomic studies have focused on muscular activities.

After 1960's, due to the increase in the level of technology used in business, the workforce faced mental factors more than physical factors [1]. In the following years, the workload mostly has turned into mental workload in business planning and coordination works. This has increased the importance of the concept of mental workload. Increases in work intensity generate mental overload and reduce work performance. Consequently, the study of mental workload factors and the way they interact is essential if we are to improve workers' wellbeing and safety at work [2].

Mental workload therefore refers to "a composite brain state or set of states that mediates human performance of perceptual, cognitive, and motor tasks" [3]. Mental workload is defined as the difference between the processing capacity level of the human information processing system and the capacity required to affect the actual performance. Essentially, mental workload can be defined as the processing capacity level [4 ÷ 9].

Regarding the definition of workload as a concept, although there is a great deal of dissidence among scientists it is considered to be measurable phenomenon. [10]. Although there is no consensus on the definition of the workload, almost all scientists have agreed on the multi-dimensionality of mental workload. Defining human mental workload is a non-trivial problem: the literature suggests it is hard to define due to its multifaceted and multidimensional nature which is dependent on the capabilities and effort of the operators in the context of specific situations [5].

Since the early 1960s, studies related to mental workload on industrial basis have gradually come in to prominence [8]. Mental workload measurements can be performed with three techniques categorized as subjective techniques, physiological techniques, and performance-based techniques. Physiological techniques are not usually preferred because of too many difficulties in implementation and the need for equipment. Performance-based techniques are not sensitive to changes in workload.

Subjective techniques are applied by one-dimensional and multi-dimensional scales in order to determine the workload of the operator and they are easy to use [9]. For these reasons, the application of these techniques is frequently preferred.

The common subjective measurement techniques are NASA-TLX (NASA Task Load Index), MCH (Modified Cooper Harper Scale) and SWAT (Subjective Workload Assessment Technique). These techniques have advantages and disadvantage of their own. NASA-TLX technique has a higher ability to represent the mental workload than the other two techniques [10]. In addition, compared to other techniques of measuring the workload, it has a wide field of use. MCH technique appears to be a method in literature that is applied only to pilots [11].

SWAT is a technique which retains its sensitivity when translated into other languages [12]. NASA-TLX is believed to be much more valid than SWAT and MCH [9, 13, 14, 15]. However, MCH is the simplest technique of higher intelligibility than others.

Mental workload is encountered in academic studies in relatively high prevalence. In this regard, providing support to the academic, administrative, and technical staff of a faculty will eventually increase the efficiency of scientific studies. Academic staffs consist of professors, assistant professors, associated professors, instructors and research assistants. Technical staffs also consist of laboratory technician, mechanical technician, and electrical technician in the university. At the same time faculty secretary, department secretaries and the others form administrative staffs. In this study, in an engineering faculty of a private university, all the personnel were selected as the subject group.

The purpose of this study is to develop an integrated scale for the measurement and assessment of exposure to mental workload of the working group, utilizing subjective measurement techniques. In order to reduce the subjectivity of the answers given to the questions for these techniques, fuzzy logic is used. During the operation, it is aimed to reveal the effects of the demographic characteristics on mental workload such as education, age, occupation, gender and so on. In section 2, the literature on mental workload measurement techniques is presented and AHP and Fuzzy AHP are discussed. In section 3, these techniques are applied with the help of the holistic scale on the selected faculty staff. This study has been completed with concluding remarks by interpretation of the study findings.

2 Subjective workload assessment techniques and multi-criteria assessment

The studies on mental workload measurement techniques are gathered in three main categories such as performance-based, physiological, and subjective techniques that are taken into account [9].

The performance-based techniques evaluate the workload of the operator when carrying out his/her duties or functions of the installed system. During the evaluation of mental workload measurement, some events such as the related entries (recognition, classification, technical description), the central mental processes (decision making, problem solving, memory throwing), and writing [6] are taken into account. Principle of "increased workload implementation results in decreased values of speed and accuracy" is applied.

Physiological techniques involve the task of measuring physiological responses of the operator and make a workload assessment accordingly [9]. The need for medical devices and equipment needed in the implementation of these techniques is high.

Subjective techniques comprise the most common and current data of the operator when the system functions or duties are related to the judgments on the workload. The subject marks the choice in the form which fits best to his/her impressions, after finishing evaluation. Fuzzy evaluation is mostly recommended in order to reduce subjective judgments [9]. There are some studies in the literature which used fuzzy approach in different ways to assess the subjective mental workload. For instance, to investigate the potential dangerous situations of overload in a road environment (to the drivers) [15], to construct the real-time warning model for teamwork performance in a nuclear plant [17], and to process ECG and EEG signals for quantification of workload [18], fuzzy models have been applied. In these sorts of studies, generally, the simplified fuzzy arithmetic [19] or generalized fuzzy numbers [20] are used.

In their study Torres-Salomao et al. used Interval Type-2 Fuzzy Logic (IT2FL) and Genetic Algorithm for modeling mental workload in an automation-enhanced? In another study a fuzzy linguistic multi-criteria approach with triangular and trapezoidal fuzzy numbers to express the overall mental workload [21].

Cabin Air Management System simulator [22]. Mouse-Amady et al. offered a new version of NASA TLX for assessment of mental workload. They built up an algorithm for computing weights from qualitative fuzzy integrals. They applied it to the NASA TLX method [23]. In his study Chen presents a new method by using simplified fuzzy number arithmetic operations for subjective mental workload assessment and fuzzy risk analysis [24].

Although there exists a considerable effort in the literature to implement objective, measurable and automated mental workload techniques, subjective methods still remain popular [8]. As mentioned above, primarily subjective techniques are more practical and applicable. All techniques were investigated in detail to figure out the pros and cons of each, therefore comparative examination is performed.

2.1 Subjective workload assessment techniques

NASA-TLX technique is responsive to changes in the experimental workload and currently provides the most sensitive information on mental workload. NASA-TLX is composed of six sub-scales which are: mental and physical requirements, time requirement, effort, performance and stress. First, these subfactors are attributed subjective scores from 1 to 20. Then, source of load is calculated by 15 pairwise comparisons of the subfactors [7]. At the last stage, the index number of mental workload is calculated according to the weighted average of the given scores and the index values.

SWAT can be used in a wide area [7]. SWAT is based on the comparison of three different mental workload subfactors. These subfactors are time requirement, effort, and stress. To start the measurement, 1-3 scale values of these factors are assigned. Table 1 is used for this assignment process.

According to the ratings, 27 different combinations based on scoring and evaluation can be made. For example, the evaluation of (3, 3, 2) produces a risk score of 26 in the form. MCH technique is developed by George Cooper, after World War II in Ames Laboratories US, in order to measure the quality of flights and is used to scale the standard systems. This scale is a one-dimensional rating scale from 1 to 10, where "1" corresponds to the best use. NASA-TLX and Cooper-Harper methods were later studied in combination with each other [7, 14, 15]. In this study, MCH methodology was revised for the academic, administrative and technical staff. In Tab. 2, scoring form is demonstrated according to the answers given to questions.

Table 1 Scale values of SWAT

	Time requirement	Effort	Stress
1	Frequently there is free time.	Very little attention and mental effort required.	Work does not cause anxiety and irritability. Risk is less.
2	There's free time.	Moderate attention and mental effort required.	Work causes anxiety and frustration. The job is risky.
3	There is almost no free time.	A lot of attention, mental effort, and concentration required.	Work creates anxiety, stress. The job is very risky.

Table 2 The revised procedure for MCH

<table>
<tr><th>Questions</th><th>Answers</th><th>Questions</th><th>Scoring form</th></tr>
<tr><td>Are you able to do your purpose most of the time even though you encounter great problems during your work?
(YES ↓)</td><td>NO</td><td>This is the end of interview.</td><td>10</td></tr>
<tr><td rowspan="3">Is it more or less trivial mistakes you make during your work?
(YES ↓)</td><td rowspan="3">NO</td><td>Are you losing time to take the errors reasonable level?
(YES →)</td><td>9</td></tr>
<tr><td>Are you losing time in order to avoid more errors?
(YES →)</td><td>8</td></tr>
<tr><td>Do the occurred errors prevent your work?
(YES →)</td><td>7</td></tr>
<tr><td rowspan="6">Is your work exposure to an acceptable level of workload?</td><td rowspan="3">NO</td><td>Maximum workload?
(YES →)</td><td>6</td></tr>
<tr><td>High workload?
(YES →)</td><td>5</td></tr>
<tr><td>Moderate workload?
(YES →)</td><td>4</td></tr>
<tr><td rowspan="3">YES</td><td>Maximum level of workload.</td><td>3</td></tr>
<tr><td>Moderate level of workload.</td><td>2</td></tr>
<tr><td>Minimum level of workload.</td><td>1</td></tr>
</table>

2.2 Fuzzy multi-criteria decision making (FAHP)

Analytical Hierarchy Process (AHP) has been annexed to literature in 1977 for the purpose of understanding and defining the problem, creating a hierarchical structure, evaluating certain numbers and consequences for making judgments. This method, which is a successful one for analyzing hierarchical structure, is intended to provide people with a more effective decision making tool where hierarchy is the most effective way to organize complex systems [25].

The structure of AHP is based on pairwise comparison matrices. The smallest element is set to be "1" and decisions for superior degrees assume other higher elements. A pairwise comparison matrix is created by converting judgments to numeric values using 1-9 scale. The priority will be obtained from the weight vector W ($W = w_1, w_2, ..., w_n$). w_i's are defined as eigenvectors.

Fuzzy numbers represent quite accurately the nature of the inconsistency of measurement. Fuzziness and fuzzy numbers are used to express a broad perspective in this respect [26].

If A is a convex fuzzy set and α-cut is a closed set, the parameters defining this cluster are called fuzzy numbers. Fuzzy numbers can be defined in various types such as trapezoidal and triangular numbers which are most commonly used. The membership function ($\mu_A(x)$) is shown in Eq. (1). $\tilde{A} = \{a_1, a_2, a_3; h\}$ is called triangular fuzzy number, where h indicates the height of a fuzzy set [27].

Triangular fuzzy membership function used in the study is as follows in Eq. (1):

$$\mu_A(x) = \begin{cases} 0 & , \quad x < a_1 \\ \dfrac{w(x-a_1)}{a_2-a_1} & , \quad a_1 \le x < a_2 \\ \dfrac{w(a_3-x)}{a_3-a_2} & , \quad a_2 \le x \le a_3 \\ 0 & , \quad x \ge a_3 \end{cases} \tag{1}$$

AHP disregards the significant influence of the uncertainties of the criteria and the alternatives in the decision-making processes [28]. There is the possibility of change of a concatenation of judgments which does not guarantee accurate results. In this study, AHP and fuzzy logic are employed together, using fuzzy numbers or linguistic variables rendering the evaluation easier. In multi-criteria decision making problems FAHP approach's results is similar with human's appraisal of ambiguity. This feature allows for converting crisp judgments to fuzzy judgments. Many decision making problems include fuzziness and vagueness. FAHP method uses this type of problems. FAHP makes possible to use linguistic terms. According to this decision maker can make evaluations more accurate. Fuzziness is used to simplify complex problems which are at the forefront of human judgment and for obtaining more efficient and flexible results. Some of the fuzzy AHP methods are based on entropy weight fuzzy AHP method proposed by Chen in 1996 [29] and linguistic weighting method [30]. The fuzzy scale for comparison transformation matrix used in this study is shown in Tab. 3 [31].

Table 3 The fuzzy scale for pairwise comparison

Scale values	Fuzzy number equivalent
1	1,1,1
3	2/3,1,3/2
5	3/2,2,5/2
7	5/2,3,7/2
9	7/2,4,9/2

Triangular fuzzy arithmetic operations on fuzzy numbers are used by the equation developed by Kaufman and Gupta. At the end of operations, fuzzy numbers are converted to crisp numbers (Eq. (2)) [32].

$$A = \frac{(a_1 + 2b_1 + c_1)}{4}, \tag{2}$$

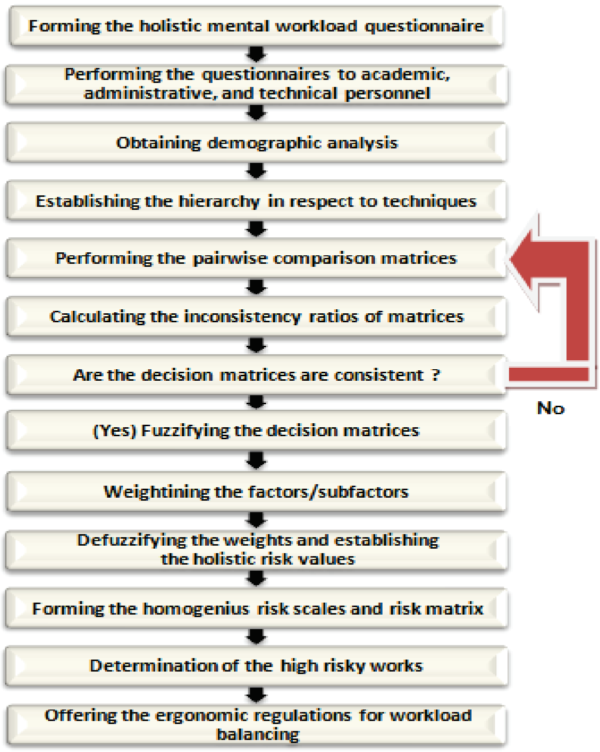

Figure 1 The application steps of mental workload assessment

3 Assessment of the mental workload on engineering faculty personnel

This study is meant to measure the mental workload exposure of academic, administrative and technical personnel of an engineering faculty of a private university located in Ankara. Subjective mental workload measurement techniques such as NASA-TLX, SWAT and MCH are performed and they consist of establishing a holistic scale containing each of the three methods. An expert team (was) consulted for their opinions, for each step of the study such as structuring the hierarchy and setting the pairwise comparison matrices. The application steps are demonstrated in Fig. 1.

3.1 The demographic analysis

Demographic features concerning the questionnaire study performed on the faculty staff is given below:

- 60 out of the distributed 83 questionnaires (73 %) are returned.
- 14 subjects who filled out the questionnaire (23 %) are under the age of 30 and 28 subjects (47 %) are in the group between 30 and 35.
- 23 subjects (38 %) are female and 37 (62 %) are male.
- When the educational background is analyzed, 2 subjects (3 %) are high school graduates, with bachelor's degree are 21 (35 %), and 37 subjects (62 %) have completed a master's or a doctorate degree.
- In addition, 40 subjects (67 %) are academic staff, 11 (18 %) are administrative, and remaining 9 (15 %) are technical staff.

3.2 Assessment of the mental workload

In this experimental study a hierarchical structure was created first and the Fuzzy AHP method was used. The pairwise comparison matrices were set based on the hierarchical structure. By the fuzzy comparison matrices in each step of the hierarchy, fuzzy weight vectors transactions were made. After the calculation of weight vectors, the crisp number of subjects in the questionnaire was translated taking into account their linguistic values. Consequently, the integrated risk score was obtained for each user.

3.2.1 Structuring the hierarchy

This problem necessitates a multi-criteria evaluation under the hierarchy. In this experiment, a three-level hierarchy was used. The first level covers the academic, administrative and technical staff. The second level consists of the techniques which are NASA-TLX, SWAT and MCH. The last level has been constructed by the factors or sub-factors of techniques.

The created hierarchical structure is given in Fig. 2.

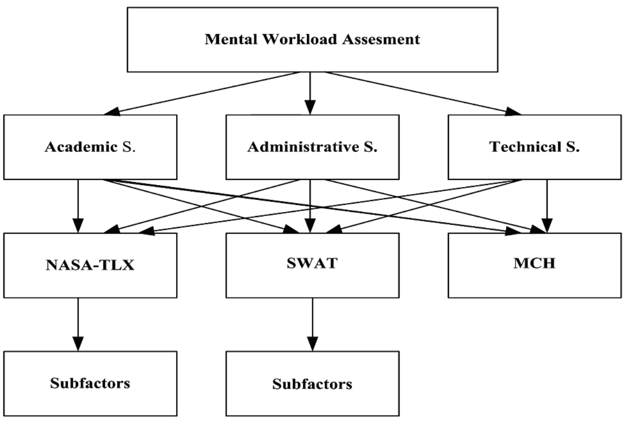

Figure 2 The created hierarchy for fuzzy assessment

3.2.2 Establishing the pairwise comparison matrices

According to the hierarchical structure shown in Fig. 2, the pairwise comparison matrices of staffs for the first level are set by a team including 9 experts as shown in Tab. 4. Expert team consists of academic staffs (include authors and the other academicians). As a result of expert's evaluations the most repeated scores are used.

Table 4 Pairwise comparison of the first level

Staffs	Academic	Administrative	Technical
Academic	1	5	7
Administrative	1/5	1	3
Technical	1/7	1/3	1

Then, comparison matrix is created separately for each technique of NASA-TLX, SWAT and MCH. As an example, the judgments of academic staff are given in Tab. 5.

After this stage, pairwise comparison matrices for factors/sub-factors of the techniques were created in respect to academic staff.

Table 5 The comparison of the techniques for academic staff

Techniques	NASA-TLX	SWAT	MCH
NASA-TLX	1	3	7
SWAT	1/3	1	5
MCH	1/7	1/5	1

Similarly, in accordance with the hierarchical structure, comparison matrices were structured for administrative and technical staff. To provide consistency to the analysis, the comparison matrix inconsistency does not exceed 10 %.

Table 6 Fuzzy pairwise comparisons of staffs

Staffs	Academic	Administrative	Technical
Academic	1,1,1	3/2,2,5/2	5/2,3,7/2
Administrative	2/5,1/2, 2/3	1,1,1	2/3,1,3/2
Technical	2/7,1/3, 2/5	2/3,1,3/2	1,1,1

Table 7 The defuzzified weight vectors

Weight vectors	Crisp weight vectors
W_{staff}	(0,5667; 0,2427; 0,2250)
$W_{technique}$	(0,4766; 0,3835; 0,1740)
$W_{nasa\text{-}academic}$	(0,3100; 0,0868; 0,2183; 0,1570; 0,1570; 0,1195)
$W_{nasa\text{-}administrative}$	(0,2218; 0,0533; 0,2415; 0,1387; 0,1387; 0,2843)
$W_{nasa\text{-}technical}$	(0,1023; 0,1210; 0,1468; 0,2855; 0,2698; 0,1133)
$W_{swat\text{-}academic}$	(0,4075; 0,4870; 0,1273)
$W_{swat\text{-}administrative}$	(0,4405; 0,3373; 0,2783)
$W_{swat\text{-}technical}$	(0,3836; 0,4763; 0,1740)

3.2.3 The calculation of the fuzzy weight matrix

At this stage, the pairwise comparison matrices are expressed in fuzzy numbers. Crisp numbers are converted to fuzzy numbers to eliminate the problems caused by subjectivity and to achieve more accurate judgments. Using the fuzzy comparison matrices, fuzzy weight vectors are calculated. Here, Tab. 3 was taken into account and fuzzy comparison matrix form in Tab. 6 has been constructed.

After the calculations with respect to fuzzy comparison matrices the fuzzy weight vectors are obtained for all positions.

3.2.4 Defuzzification of fuzzy weight vectors

The weight vectors of fuzzy numbers are defuzzified using the formula developed by Kaufman and Gupta [32]. Accordingly, the obtained crisp numbers of weight vectors shown in Tab. 7 are used and then holistic risk scores are calculated.

3.2.5 Calculation of the risk values with a holistic scale

Using the defuzzified weight vectors integrated risk scores for each subject are calculated by a holistic risk scale. The calculation steps are given below:

- Multiplying the crisp values of related criteria weights of each level, the global weights are revealed in the same circle.
- The risk scores of the subjects are calculated for the three techniques.
- The risk scores obtained from the techniques are converted to the percentile weights regarding their possible maximum and minimum scales.
- The total risk scores for each employee are obtained by multiplying global weights of subfactors with their percentile weights.
- The homogeneous risk groups are categorized with respect to the distribution of mental workload.

According to the results of the distribution of mental workload, the risk zones emerge in 4 groups in this study:

Red Zone: Mental workload is so high that these posts should immediately be subject to ergonomic measures Risk score in the red zone is above 5,5.

Orange Zone: Mental workload is at such a level that would mandate the staff in the zone to take ergonomic measures in a short period of time. Risk score in the orange zone is between 5 and 5,5 points.

Yellow Zone: Medium levels of mental workload are observed. For this region Ergonomic regulations can be employed in course of time. The risk score of yellow zone is between 2,4 and 5.

Green Zone: An acceptable level of mental workload is calculated and the ergonomic regulations are not needed. In this zone, the risk score is below 2,4.

The obtained zones are shown in Fig. 3 in respect to the integrated risk matrix as follows.

According to the new fuzzy risk assessment matrix in Fig. 3, all academic staffs are stated in the red and orange zones. 76,5 % of the yellow zone and 23,5 % of the green zone belongs to the administrative staff. 56,25 % of the green zone belongs to technical staff.

According to the integrated risk triangle, the mental workload of academic staff appeared very high and needed immediate ergonomic measures in the shape of regulations. The risk level of the administrative staff leads to a concussion that it must be kept under control. The observed mental workload of technical personnel is at acceptable level and no improvements are suggested. The obtained results for each individual have also been evaluated in respect to risk scores and the most extreme tasks within the organization are determined. Accordingly:

- The extreme two scores are appearing different in academic staff (6,2157 and 6,0384). These are a research assistant and an assistant professor.
- The highest workload of administrative staff belonged to the dean's secretary (2,9788).

In this study, the calculations were made using fuzzy approach. If the scores of all the techniques are taken into account without fuzziness (classical approach), different results come out. The comparison results of the fuzzy and the classical studies are given in Tab. 8.

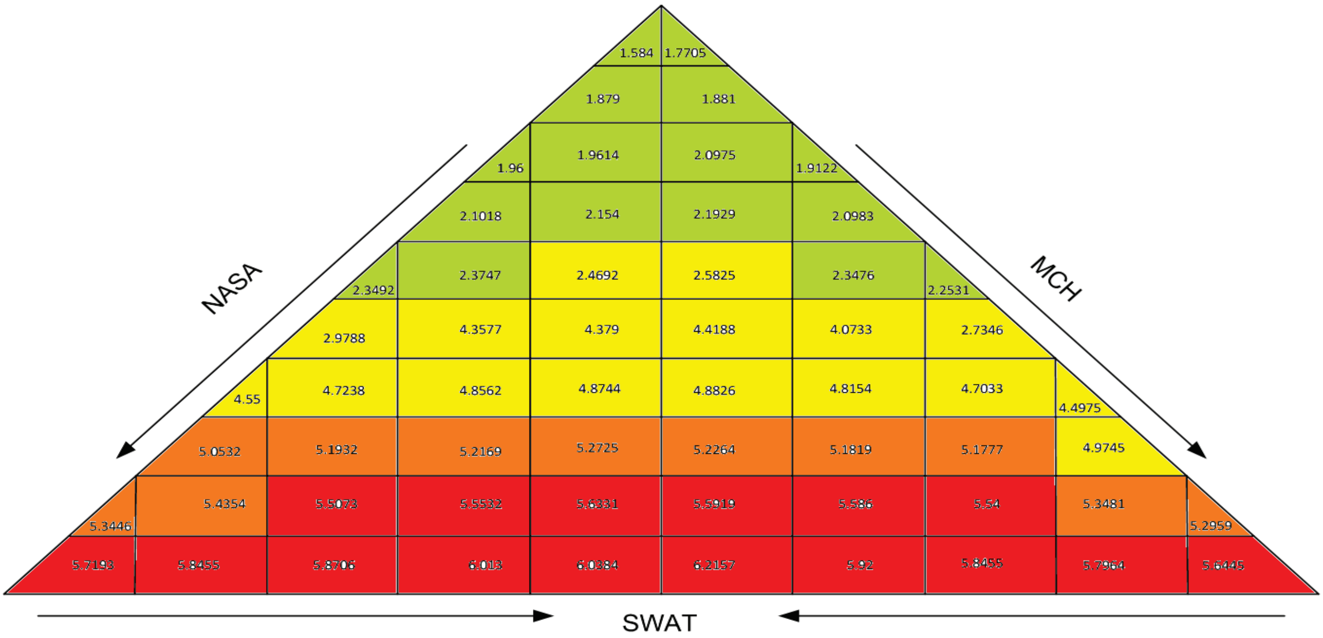

Figure 3 The fuzzy assessment triangle for the risk zones

Table 8 Comparison of the classical and fuzzy approaches

Staffs	Academic		Administrative		Technical	
Approaches	Classical approach (%)	Fuzzy hierarchical approach (%)	Classical approach (%)	Fuzzy hierarchical approach (%)	Classical approach (%)	Fuzzy hierarchical approach (%)
Red Zone	30,00	39,03	27,27	-	-	-
Orange Zone	40,00	60,97	36,36	-	33,33	-
Yellow Zone	17,50	-	27,27	76,50	22,22	43,75
Green Zone	12,50	-	9,10	23,50	44,50	56,25

As seen in Tab. 8, more accurate objective results are obtained in the fuzzy hierarchical approach and thus better regulations could be proposed.

Considering the results, some ergonomic measures to improve the working conditions of employees are proposed and discussed below.

3.3 Ergonomic measures for balancing mental workload

Using the mental workload levels of the faculty staff, some ergonomic activities should be conducted in order to reduce the workload of the employees. Dimensions of these studies carried out in academicals environments, should also be intended for workplace environments climate effects, lighting, health drawbacks, energy need of the human body, and psycho-sociological problems of employees.

Primarily, in order to maintain the highest level of physical comfort, physical abilities, materials, working planes and volumes must have appropriate sizes. The dynamic anthropometric design is a very important subject to examine. Air temperature, humidity and air movements are the main factors that affect the environmental conditions. To work efficiently, the optimal air temperature should be between 19,4 ÷ 22,8 °C and lighting should be 300 lux for academic staff in universities [30]. Long-term sensitive work of technical personnel requires more lighting in order to prevent eye strain. Noisy working environment certainly causes negative impact on labor productivity and accidents. On the other hand, monotonous and very quiet rooms cause sleepiness.

In addition to environmental factors and physical conditions described above, fatigue and deprivation increase absenteeism and certain measures should be taken for psycho-sociological problems. Group works are recommended and offered here to increase efficiency. To balance mental load among team members, job rotation, job enlargement or job enrichment should be used [34]. Work expanding applications and job rotation comprising task circulation between jobs prevent monotony of the work. Herzberg suggests that job enrichment should be a key factor in any policy of motivation [35, 36, 37].

4 Discussion and conclusion

The development of computer technology in everyday and business life has made the measurement and evaluation of mental workload more important. In this study, subjective measurement methods have been applied to the measurement of mental workload of the faculty staff.

Fuzzy AHP evaluation was used to evaluate the obtained results in practice, as NASA-TLX, SWAT and MCH methods are subjective methods and people who answered the questionnaire were in different mental situations. In this respect, the fuzzy evaluation prevents undesirable results.

The advantages of the proposed fuzzy hierarchical approach can be apparently noticed in the results. Hierarchical structure is a suitable approach for multiple conflicting decision criteria that complicate decision making. Also it is useful for identifying complex relations between these criteria to assess decision alternatives. Human decision making system contains subjectivity and it is difficult to measure this with exact model. For this reason in this type of problems using fuzzy logic gives more realistic results. The workloads of administrative and technical staff were obtained above the desired level in the classical approach, but by the introduction of the hierarchy and the fuzzy evaluation the realistic and objective conclusions were achieved. The maximum mental load of both assistant professor and a PhD level research assistant were acceptable considering the duties of these posts bearing the role of a manager in the administrative staff, faculty secretary in its category. Technical staffs are limited to laboratory studies of mental load.

Job definitions of subjects are examined as a basis. The technical staff is primarily in charge of assisting other academic personnel on issues such as laboratory equipment etc. while the administrative staff is responsible for paperwork and of the academic staff. The academic staff is responsible for lecturing, management of student advisory and quality improvement in activities such as academic publications.

Consequently, balanced-distribution of workload among employees in terms of mental workload will provide contentment in the staff.

This study only focused on mental workload. Physical, psycho-social and postural evaluations are excluded from the scope of this study. Evaluations of the performances of employees in terms of an integrated consideration of the mentioned issues constitute the subject of a future study.

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