# AN INTEGRATED MENTAL WORKLOAD ASSESSMENT METHOD BY USING AHP

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**ABSTRACT**

Until the last decades, the workload assessment factors have pointed to labor-intensive works of employees for measuring workloads in a jobshop. By increase in planning and coordination-type works, computers have started to be put into use in production and these tasks have usually turned into mental workload. In today's competitive market, mental workload assessment has become more important especially for white collar employees in several businesses. An example of high risk level prevalence of mental workload is encountered in academic studies at the universities affecting whole staff. Some ergonomic regulations are essential in order to test the efficiency of scientific studies, and they also prevent mental risks on the staff of a faculty. There are some methods available in the literatures that are conflicting with or complementary to each other. Most of them have some disadvantages or restricted usage area as well. Therefore, an integrated mental workload assessment method is proposed in this study. With the help of the hierarchy of AHP, the subjective techniques (MCH, SWAT, NASA-TLX) are stated in the first level and their subfactors are stated in the second level. The pairwise comparison matrices are performed by the consensus of an expert team. The local and global weights of the factors and subfactors are calculated according to the procedure of AHP method. The faculty staffs are mentally assessed by a proposed methodology and mental workload for each staff is calculated.

Keywords: mental workload, NASA-TLX, SWAT, MCH, AHP method.

## 1. Introduction

In recent years, the workload has turned into mostly mental workload in business planning and coordination works. This is increased the importance of the concept of mental workload. Mental workload is defined as the difference between the task during the processing capacity to the level of human information processing system and the capacity available to affect the actual performance (Eggemeier and Wilson,1991; Yeh and Wickens, 1988).

Assessing mental workload is inevitable in ergonomic approaches applied in the organization and employee satisfaction in taking exact measures, performance and quality. In addition, mental workload for the job profile of manpower in accordance with the requirements of the decision-maker with the significant advantages of assessment will be provided.

As regards the definition of its nature and a lot of divergence of mental workload, as a concept, is considered to be measured (Hancock and Meshkati, 1988). Although there is no consensus on the definition of the workload, almost all scientists agreed that mental workload is multi-dimensional. Subjective techniques are applied one-dimensional and multi-dimensional scales in order to determine the

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workload of the operator and they are easy to use (Hancock and Caird, 1993). 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 some advantages and disadvantages over each other as well. NASA-TLX technique's capability to represent the mental workload is higher compared to the other two techniques (Hill et al., 1992). MCH technique appears to be a method that is applied only to pilots in the literature (Hart and Wickens, 1990). SWAT sensitivity does not change which has been translated into other languages (Hancock and Caird, 1993; Pfendler and Widdel, 1988; Byers et al., 1988; Battiste and Bortolussi, 1988; Luximon and Goonetilleke, 2001). Therefore, a common measurement scale proposed in this study is aimed to achieve the most realistic and sensitive results.

One of the environments which have relatively high prevalence of mental workload is academic areas. 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 of an integrated scale for the measurement and assessment of exposure to mental workload of the working group that take into account the subjective measurement techniques which are NASA-TLX, SWAT and MCH. The literature on the mental workload measurement techniques and AHP have presented in section 2. In section 3, these techniques have applied with the help of the holistic scale on the subjects by using AHP steps. This study has been completed with conclusion remarks.

## 2. Subjective Workload Assessment Techniques and Multi-criteria Assessment

The studies of mental workload measurement techniques are gathered in three main categories: Performance-based, physiological, and subjective techniques.

*The performance-based techniques* evaluate workload of the operator when carrying out duties or functions of the installed system. During the evaluation of mental workload measurement it is taken into account some events such as the related entries, the central mental processes, and writing. Physiological *techniques* carry out the task of measuring the physiological responses of operator and make a workload assessment accordingly (Hancock and Caird, 1993). Medical devices and equipments are needed. *Subjective techniques* comprise the most common and current data of the operator when the system functions or duties in relation to the judgments of the workload uploaded. The subject signs the impressions on the form after completing the evaluation.

As mentioned above, primarily subjective techniques being more practical and applicable are seen as NASA-TLX (NASA Task Load Index), MCH (Modified Cooper Harper Scale) and SWAT (Subjective Workload Assessment Technique) techniques.

NASA-TLX technique is responsive to change the experimental workload and is currently composed of six sub-scales which are mental and physical requirements, time requirement, effort, performance and stress (Hancock and Meshkati, 1988). SWAT is based on the comparison of three different mental workload subfactors. These subfactors are time requirement, effort, and stress. In this study, MCH methodology was revised for the academic, administrative and technical staff.

Analytical Hierarchy Process (AHP) have been added to literature in 1977 by Saaty for full of understanding and defining the problem, creating a hierarchical structure, evaluating certain numbers and consequences of making judgments. Hierarchy is the most effective way to organize complex systems (Saaty, 1980). The structure of AHP is based on pairwise comparison matrices. The smallest element is given “1” and a decision is made for other elements according to superior degree. Expert knowledge is preferred for the judgments since the results of AHP will completely depend on them.

## 3. Assessment of the Mental Workload of Staffs using AHP

This study aims to measure the exposure of mental workload 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 it consists of establishing a holistic scale. The opinions of the expert team are provided for the each step of the study such as structuring the hierarchy and setting the pairwise comparison matrices.

### 3.1 Analysis of the questionnaires

In the beginning of the study, a questionnaire is prepared to collect the demographic and evolutionary data of the related staff. 60 out of 83 (73%) delivered questionnaires are returned which are performed by 23 (38%) female and 37 (62%) male subjects. 14 subjects who filled out the questionnaire (23%) are under the age of 30 and 28 subjects (47%) are in the age group between 30-35. When the educational background is analyzed, 2 subjects (3%) are high school graduates, bachelor's degree is 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 Structuring the hierarchy

In this study, by the help of the hierarchy of AHP, the staffs of the faculty are stated in the first level, the subjective techniques (MCH, SWAT, NASA-TLX) are stated in the second level and their related subfactors are stated in the third level. The pairwise comparison matrices are performed by the consensus of an expert team. The local and the global weights of the factors and subfactors of each level are calculated according to the procedure of AHP method in the hierarchy. The subfactors of the NASA-TLX are consist of 6 subscales which are mental, physical and time requirements, effort, performance and stress level. The SWAT's subfactors are time requirement, effort and stress level. The subfactors are evaluated in the third level.

In this experiment, a three-leveled hierarchy is used. The first level included of the academic, administrative and technical staff. The second level consists of the subjective techniques which are NASA-TLX, SWAT and MCH. The last level is constructed by subfactors of the related techniques. The created hierarchical structure is given in Figure 1:

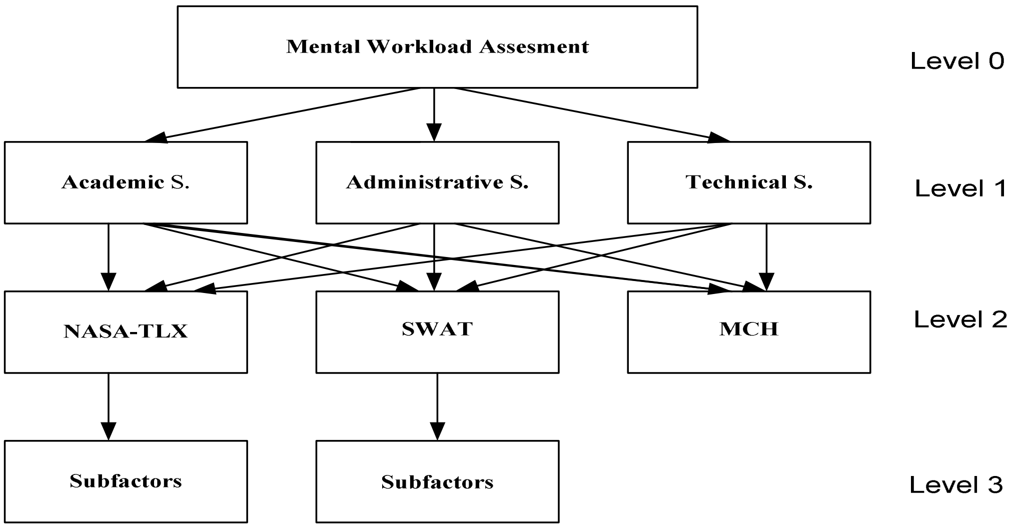


Figure 1. The created hierarchy for assessment

According to the hierarchical structure shown in Figure 1, the pairwise comparison matrices of staffs for the first level are set by expert team as shown in Table 1 and local weights are calculated:

Table 1. Pairwise comparison of the first level

| Staffs | Academic | Administrative | Technical | Local Weights |
|---|---|---|---|---|
| Academic | 1 | 5 | 7 | 0.731 |
| Administrative | 1/5 | 1 | 3 | 0.188 |
| Technical | 1/7 | 1/3 | 1 | 0.081 |

Then, comparison matrix is created separately for each technique of NASA-TLX, SWAT and MCH. The judgments for academic staff are given in Table 2 as an example:

Table 2. The comparison of the techniques for academic staff

| Techniques | NASA-TLX | SWAT | MCH | Local Weights |
|---|---|---|---|---|
| NASA-TLX | 1 | 3 | 7 | 0.649 |
| SWAT | 1/3 | 1 | 5 | 0.279 |
| MCH | 1/7 | 1/5 | 1 | 0.072 |

After this stage, pairwise comparison matrices for factors/subfactors of the techniques were created in respect to academic staff below according to the expert team's opinions (See Table 3 and Table 4).

Table 3. The pairwise comparison for factors/subfactors of NASA-TLX

| Subfactors | Mental req. | Physical req. | Time req. | Effort | Perfor mance | Stress level | Local Weights |
|---|---|---|---|---|---|---|---|
| Mental requirement | 1 | 9 | 3 | 5 | 5 | 7 | 0.463 |
| Physical requirement | 1/9 | 1 | 1/7 | 1/5 | 1/5 | 1/3 | 0.028 |
| Time requirement | 1/3 | 7 | 1 | 3 | 3 | 5 | 0.242 |
| Effort | 1/5 | 5 | 1/3 | 1 | 1 | 3 | 0.112 |
| Performance | 1/5 | 5 | 1/3 | 1 | 1 | 3 | 0.093 |
| Stress level | 1/7 | 3 | 1/5 | 1/3 | 1/3 | 1 | 0.062 |

Table 4. The pairwise comparison for factors/subfactors of SWAT

| Subfactors | Time requirement | Effort | Stress level | Local Weights |
|---|---|---|---|---|
| Time requirement | 1 | 1/3 | 7 | 0.290 |
| Effort | 9 | 1 | 9 | 0.655 |
| Stress level | 1/7 | 1/9 | 1 | 0.055 |

Similarly, in accordance with the hierarchical structure, comparison matrices were also performed for all staffs and the local weights are calculated. To provide the consistency of the analysis, each created comparison matrix does not exceed 10% of the inconsistency.

**3.3 Assessment of mental workload**

The faculty staffs are mentally assessed by a proposed methodology regarding the three subjective mental workload assessment methods. An integrated scale value of mental workload for each staff is calculated then. Four types of risk levels are defined. At the ends of the study, the risky groups of the staff are determined using an integrated scale value and some ergonomic regulations are recommended to the staffs/departments at high risk for mental workloads.

Using the weight vectors, first, the integrated risk score for each subject is calculated. Here, multiplying the values of related criteria weights of each level, the global weights are revealed. The risk scores for each employee are obtained by multiplying global weights of subfactors with the same circles. The results of the homogeneous risk groups are categorized in order to determine the distribution of mental workload. The determined risk zones are divided into 4 groups in this study:

- *Red Zone:* Mental workload is very high that these positions are immediately being driven ergonomic regulations.
- *Orange Zone:* Mental workload is high that the staffs in the zone are needed ergonomic regulations in a short period of time.
- *Yellow Zone:* Medium levels of mental workload are observed. Ergonomic regulations in the region can be developed over time.
- *Green Zone:* An acceptable level of mental workload is calculated and the ergonomic regulations are not needed.

According to the new risk assessment shown in Table 5, academic staff lies in all the zones but mostly in red and orange zones. 36.36% of orange zone belongs to the administrative staff, and 44.50% of the green zone belongs to technical staff.

In respect to the proposed method, the mental workload of academic staff appears very high and is needed immediately to be driven ergonomic regulations. Moreover, the results are shown that, the extreme two scores mostly appear among academic staff. These are a research assistant and an assistant professor.

The risk level of the administrative staff is concluded that it must be kept under control. The highest workload of administrative staff belongs to dean secretary. The observed mental workload of technical personnel is at acceptable level and not suggested any regulation.

Table 5. Comparison of the staffs for categories

| Staffs | Academic | Administrative | Technical |
|---|---|---|---|
| Red Zone | 30.00 | 27.27 | - |
| Orange Zone | 40.00 | 36.36 | 33.33 |
| Yellow Zone | 17.50 | 27.27 | 22.22 |
| Green Zone | 12.50 | 9.10 | 44.50 |

According to the results, some ergonomic regulations to improve the working conditions of risk positions are proposed. The dimension of these studies in business environment should be intended to workplace environment, climate effects, lighting, health drawbacks, energy need of the human body (Pellegrino, 2011; Hwang et al., 2009; Mathiassen, 2006; Kuijer et al., 2005), and psycho-sociological problems (Schermon and Osborn, 2003) of employee.

## 4. Discussion and Conclusion

The development of computer technology in everyday made the measurement and evaluation of mental workload more important. In this study, subjective measurement methods have been applied for the measurement of mental workload of the faculty staff. AHP evaluation was used to evaluate the obtained results in a hierarchy which contains NASA-TLX, SWAT and MCH methods.

The advantages of the proposed approach were reflected in the hierarchy of the workloads of administrative and technical staff. The largest mental loading of both an assistant professor and PhD level research assistant were acceptable in respect of the functions of these positions. As a manager in the case of the administrative staff, faculty secretary excelled in its category. Technical staff is limited to laboratory studies of mental load.

In conclusion, the risky groups of the staff are determined using an integrated scale value and some ergonomic regulations are recommended to the staffs/departments at high risk for mental workloads. In this respect, integrated risk values according to the mental workload of academic staffs were very high and appeared immediately be driven regulations.

Consequently, including the standard balanced-distribution of workload among employees in terms of mental workload will provide some relaxation in the staff. Job rotation and job enrichment on issues such as business expansions are exposed to intense mental workload and increasing the motivation of staff.

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

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