EVALUATION OF PHYSICAL AND MENTAL FATIGUE IN AN ASSEMBLY LINE

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Keywords

Physical Fatigue, Mental Fatigue, MURI, REBA, NASA-TLX, AHP

Abstract

Employees in production industries are exposed to different physical and mental loads due to individual differences or job requirements. Because of the fatigue caused by these loads varies, there is a need to evaluate the resting shares given to employees at various workstations accordingly. Giving the employees the same resting allowance for the types of work that vary depending on the workstations does not ensure the ergonomic adaptation of the work to the person. In this study, the impact of the activities carried out in the automotive production industry's seat assembly line on the rest allowances given to the employees has been handled with an integrated system and the fatigue values due to the changes in the job type are reflected in the rest shares. In the evaluation of the physical fatigue of the employees, working posture was examined by REBA (Rapid Entire Body Assessment) and movements were analysed by MURI. Mental demand, physical demand, effort, performance, temporal demand and frustration were studied with NASA-TLX (NASA Task Load Index) to assess mental fatigue. The data obtained from these 3 methods were combined with the multi-criteria decision making method AHP (Analytic Hierarchy Process), and weights related to physical and mental fatigue were formed. The general fatigue score developed based on these weights was used in the calculation of variable rest allowances. Thus, the effect of fatigue values obtained as a result of ergonomic analysis methods on rest shares for different workstations was calculated instead of the standard rest allowances given to employees equally for each station and it was ensured that employees are given rest breaks that vary according to different loads at the workstation.

BİR MONTAJ HATTINDA FİZİKSEL VE MENTAL YORGUNLUĞUN DEĞERLENDİRİLMESİ

Anahtar Kelimeler

Fiziksel Yorgunluk, Zihinsel Yorgunluk, MURI, REBA, NASA-TLX, AHP.

Öz

Üretim endüstrilerinde çalışanlar, bireysel farklılıkları veya işin gereği nedeni ile fiziksel ve zihinsel yönden farklı yüklere maruz kalmaktadır. Bu yüklerin oluşturduğu yorgunluklar değişkenlik gösterdiği için çeşitli iş istasyonlarındaki çalışanlara verilen dinlenme paylarının da bu doğrultuda değerlendirilmeye alınmasına ihtiyaç vardır. Çalışanlara, iş istasyonlarına bağlı olarak değişkenlik gösteren iş tipleri için aynı dinlenme payının verilmesi, ergonomik açıdan işin insana uyumunu sağlamamaktadır. Bu çalışmada, otomotiv üretim endüstrisi koltuk montaj hattında gerçekleştirilen faaliyetlerin çalışanlara verilen dinlenme paylarına etkisi bütünleşik bir sistem ile ele alınmış ve iş tipinde görülen değişikliklere bağlı yorgunluk değerleri dinlenme paylarına yansıtılmıştır. Çalışanların fiziksel yorgunluklarının değerlendirilmesinde çalışma postürü REBA (Hızlı tüm vücut değerlendirmesi) ve hareketleri MURI metodları ile incelenmiştir. Zihinsel talep, fiziksel talep, çaba, performans, zamansal talep ve tatmin düzeyi NASA-TLX (NASA Task Load Index) ile analiz edilmiştir. Bu 3 yöntem sonucu elde edilen veriler çok kriterli karar verme metodu olan AHP(Analitik Hiyerarşi Süreci) ile birleştirilerek fiziksel ve zihinsel yorgunluğa ilişkin ağırlıklar oluşturulmuştur. Bu ağırlıklara bağlı olarak geliştirilen genel yorgunluk puanı değişken dinlenme paylarının hesaplanmasında kullanılmıştır. Böylece, her istasyon için çalışanlara eşit verilen standart dinlenme payları yerine, farklı iş istasyonları için ergonomik analiz yöntemleri sonucu elde edilen yorgunluk değerlerinin dinlenme paylarına etkisi hesaplanmış ve çalışanlara iş istasyonunda oluşan farklı yüklere göre değişkenlik gösteren dinlenme paylarının verilmesi sağlanmıştır.

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1. Introduction

Employees in the manufacturing industries have a working environment where energy-based manuel works and knowledge-based mental works coexist. Workload is defined as any kind of pressure, which has a negative effect on the performance level and reactions of the employee (Becker, Warm, Dember and Hancock, 1995). In the long term, overload causes work-related musculoskeletal disorders (WMSDs). WMSDs are the most common discomfort among assembly line workers (Xu, Ko, Cochran and Jung, 2012). Workload causes fatigue on employees and this fatigue is examined under two categories: mental and physical fatigue. To prevent high workloads and work-related disorders of employees is a milestone for their physical and mental health. Ergonomics offers many different analyses and methods to create optimal conditions by observing people and intervening in the environment in case of adverse conditions (Ide, Tokcalar and Gunduz, 2018). "Ergonomics (or human factors) is the scientific discipline on the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize well-being and overall performance" according to final report of the IEA (International Ergonomics Association) Future of Ergonomics Committee (Dul, Bruder, Buckle, Carayon, Falzon and Marras, 2012). The compliance of the employee to the job, and vice versa, are important, due to their importance on employee performance. In working environments where this compliance cannot be achieved, the functional ability of an organ, a muscle or of the whole organism decreases. This functional ability can be relieved by resting (Babalık, 2016).

WMSDs are one of the main causes of productivity reduction in fact, especially in manual assembly systems, workers have to perform repetitive movements with a high level of stress and fatigue and awkward postures (Finco, Battini, Delorme, Persona and Sgarbossa, 2020). This leads causing a reduction of workers' well-being, product quality and efficiency (Otto and Scholl, 2011). Employees are given relaxation allowance to relieve the workload stress. This relaxation allowance is a combination of personal allowance and fatigue allowance (Figure 1). It is very important to determine the appropriate relaxation allowance in order to balance the fatigue due to physical and mental workload in employees. While the standard times are determined in the working areas, the relaxation allowances allocated to the employee vary according to the used method. For instance, in the MTM (Methods Time Measurement) method, which consists of predetermined times and is used for the design of working processes, the relaxation allowance is 6% for each operation. In our case at the assembly plant, the workloads of the employees were not uniform ergonomically, however the same relaxation allowance was given for all types of work.

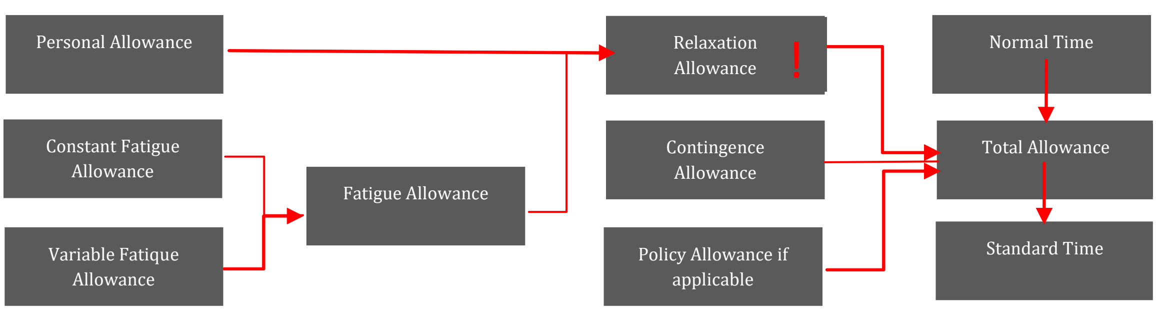

Figure 1. Various Allowances to Build Standard Time (Poyraz, 2011)

In recent years, studies in which ergonomic risk assessment methods are used together or compared with each other are frequently encountered. In 2015, Ayan measured the efficiency of ergonomic studies and the work at the assembly line of the Turkish Tractor Factory was brought from the risky level to the low risk level with REBA. Oral, Gönen, Karaoğlan, Tuncer and Kundakçı (2017) conducted analyses using Cornell Musculoskeletal Discomfort Questionnaires (CMDQ), REBA and OWAS methods in order to make ergonomic improvements in the assembly line of the company that manufactures power and power transformers. They investigated working positions of the personnel working in assembly works. A systematic ergonomic risk assessment approach was carried out with the REBA method in order to prevent work-related musculoskeletal disorders in employees (Felekoglu and Tasan, 2017). Ekinci and Can (2018) used REBA analysis to examine the working postures in the context of by evaluating the ergonomic risk levels through the perceived workloads of the operators. In a company that produces metal accessories, while analysing the workstations that are not suitable for design as a result of the analysis of ergonomic conditions, the postures of the employees were analysed with the Fuzzy REBA method, which was developed by adding a triangular fuzzy scale to the Rapid Entire Body Assessment (REBA). In the production and assembly activities carried out during the elevator production process; In order to prevent unnecessary muscle movements that negatively affect production time, ergonomic analysis of working postures has been examined with MURI and REBA methods. Kahya, Özkan and Ulutaş (2018) used NASA-TLX in a study that investigated the cognitive loading of automobile drivers while driving. A driving simulator was used in the study and they stated that as a result, using a mobile phone while driving has a negative effect on reaction time and this effect is felt more as the age increases. Multi-criteria decision making methods are also integrated with ergonomic studies, bringing the methods together with a wider perspective. Emeç and Akkaya (2018) has hybridized the NASA Task Load Index (NASA-TLX) measurement method with the Analytical Hierarchy Process (AHP) method to evaluate the mental workload of physicians. Marciano, Rossi, Cabassa and Cocca (2018) has presented an AHP-based methodology developed to support the selection of the most ergonomic ultrasound device among some alternative devices. Karabacak (2016) is evaluated dentists' fatigue with RULA and Cornell ergonomic analyzes. Kahraman (2012) is used REBA, RULA and AHP methods for fatigue assessment in the marble operation.

NASA-TLX was used to measure cognitive load. The NASA-TLX is developed to measure workload in laboratory-based aviation settings and has since been applied to workload measurement in sectors such as nuclear energy, transportation, and increasingly in health care (Tubbs-Cooley, Mara, Carle and Gurses, 2018). NASA TLX Method has been used to determine the mental work load in various sectors.

Matthews, Legg and Charlton (2003) used subjective methods to determine the cognitive loads created by the motorists' conversations during driving by NASA-TLX. Delice (2016) determined the mental workload of emergency service doctors by NASA-TLX. Lee and Liu (2003) measured the MWL (Mental Workload) of the pilots during the flight using physiological and multi-dimensional subjective parameters.

In literature, mental fatigue and physical fatigue are usually handled separately. There is no study in which physical and mental loads are evaluated together and this evaluation result is reflected in the relaxation allowances of the employees. However, in this study, both mental and physical fatigue are considered to form a unique fatigue interpretation, and therefore are combined methodologically.

This work is carried out at a car seat production assembly line. MURI, REBA and NASA-TLX (NASA Task Load Index) analyses are performed to measure physical and mental fatigue, respectively. General fatigue figure is calculated by AHP, which is a multi-criteria decision making method. Thus, a structure was established in which physical and mental fatigue were combined. The standard share time has been flexible by determining the appropriate resting shares for the scale.

2. Methods

The mental workload levels of the employees are determined by NASA TLX, and physical workload levels by MURI and REBA. Working posture is examined by REBA and movements are analysed by MURI. Below the details of these methodologies are provided

2.1 MURI

MURI analysis is a dynamic analysis that considers the body movements of employees. Posture and motion analyses are scored during work (Figure 2). Three levels are used to score each of the 11 motions; i.e. bending of the waist, the waist rotation, the working height of the arms, the knees bending/ stretching, bending of the elbows and wrists, getting the parts/materials, working area body rotation, walking, carrying, elongation of the neck and of the wrist (Ohno, 1998).

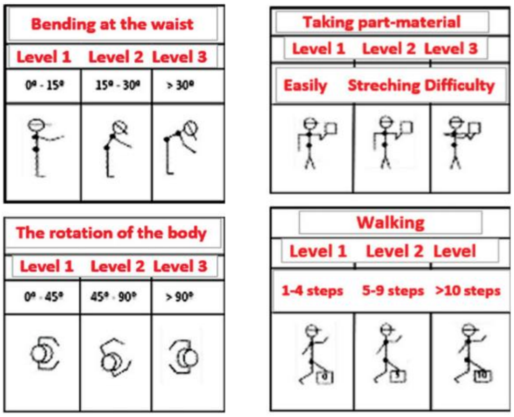

Figure 2. Working Movements

The analyses are made based on the employee. Each move of the employee is recorded and analyzed in detail. The total score is calculated by summing the score of each operation, and risk level of each operation is determined. If the score is over 25 points, this pertains to the red zone. If the score is above of 17 points, this relates to the yellow zone (Figure 3). If the score is below 11 points, this risk free level pertains to the green zone.

movement in operation	bending at the waist			the rotation of the waist			working height of arms			bending-stretching of knees			rotation of elbows			taking part-material			working area(the rotation of the			walking			carrying			the rotation of the wrist			rotating the neck			
score	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
Criterion / manual working process	0-15 degree	15-30 degree	>30 degree	0-15 degree	15-45 degree	>45 degree	waist level	shoulder level	on the shoulder	0-30 degree	30-60 degree	>60 degree	0-90 degree	90-180 degree	>180 degree	easily take(without	take streching the arms	taking with difficulty	0-45 degree	45-90 degree	>90 degree	0-4 step	5-9 step	>10 step	0-3 kg	3-5 kg	>5 kg	0-15 degree	15-45 degree	>45 degree	0-15 degree	15-30 degree	>30 degree	Total

Level3 : 3 Score Level2 : 2 Score Level1 1 Score

Figure 3. Ergonomics Assessment Matrix on Working Movements in Manuel Processes

2.2 REBA

The REBA (Rapid Entire Body Assessment) method was developed in 1995 and is widely used. REBA method analyses the body in two parts. Score A represents the summation of the posture scores for the trunk, neck and legs and the Load/Force score. Score B is the sum of the posture scores for the upper arms, lower arms and wrists and the coupling score for each hand. The A and B scores are combined in a Table, called Table C, and finally an activity score is added to give the final REBA score (McAtamney and Hignett, 1995). In generally, REBA analysis was used in physical fatigue studies. REBA is designed to assess the risk exposure associated with the appearance of musculoskeletal discomfort based on the posture of the operator at work (Lasota, 2014). With this method, working positions are obtained numerically (Figure 4). It divides the working body into two groups A and B. The limbs that make up the A group are the trunk, neck and legs. A score formed by evaluating these scores together with the help of the A table transforms the stance angles into a numerical form. After obtaining the numerical transformations belonging to the group A, an A score is obtained by adding the Force / Load score. Group B is the upper arms, lower arms and wrists. With the help of table B, angles are converted into values with a score obtained from the combination of these scores. Group B score is determined by adding the score value in the coupling score table to this value. Using a common C table, the obtained A and B scores transform the angles related to the joint movements of the employee into numerical data between 1 and 15 and use them in ergonomic risk assessments. If the score for each assessed posture is 11-15 points, it is considered to be very risky. If the score is 8-10 points, it is defined as the risky level. A score of 4-7 is considered moderate risk. A score of 2-3 points identifies a low risk and a score of 1 indicates insignificant risk.

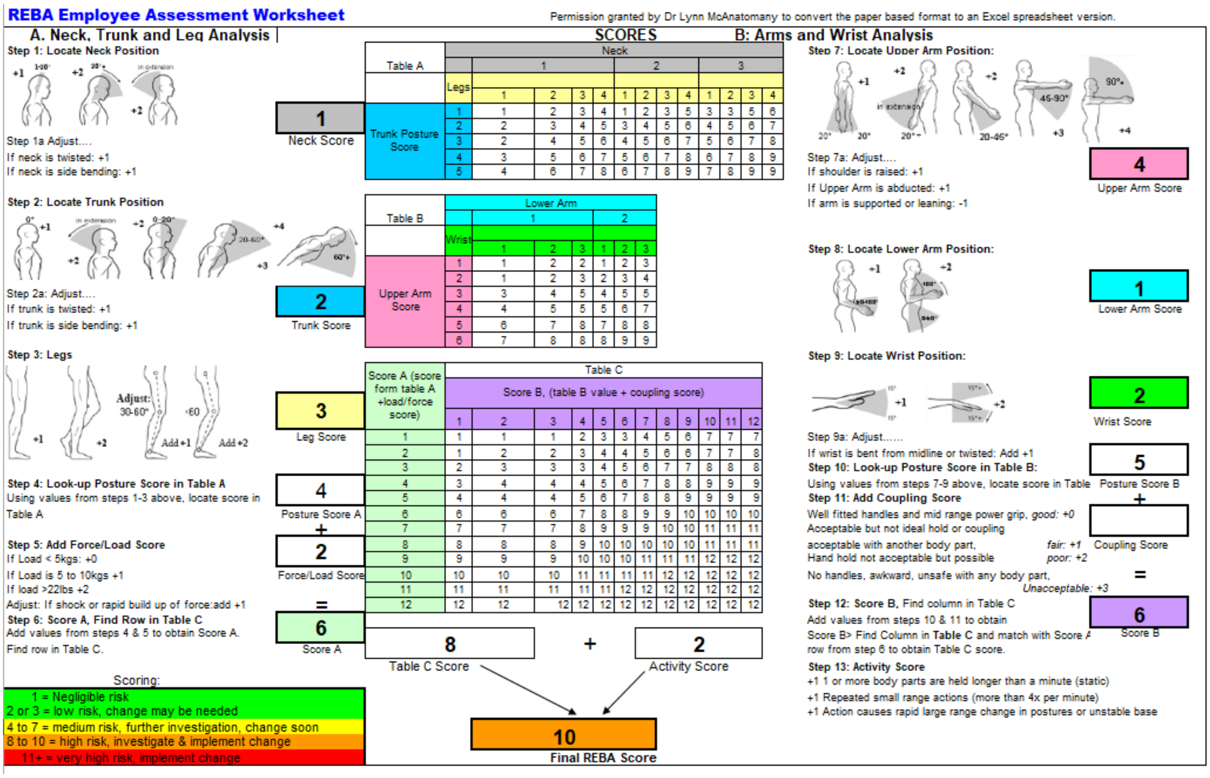

Figure 4. REBA Employee Assessment Work Sheet (Hedge, 2019)

2.3 NASA-TLX

One of the most widely used measurement tools to assess subjective workload of individuals operating in high-risk, time sensitive industries is the National Aeronautics and Space Administration Task Load Index (NASA-TLX). This method was developed by Hart and Staveland in 1988. In this study, NASA-TLX method is used to measure mental fatigue. This subjective workload measure comprises six items, tapping mental demand (MD), physical demand(PD), temporal demand(TD), performance(P), effort(E), and frustration(F). Each item weighs differently. The response scale ranges from 0 to 20 (Hart and Staveland, 1988). A questionnaire consisting of 6 questions is applied to the employee to determine these characteristics (Figure 5).

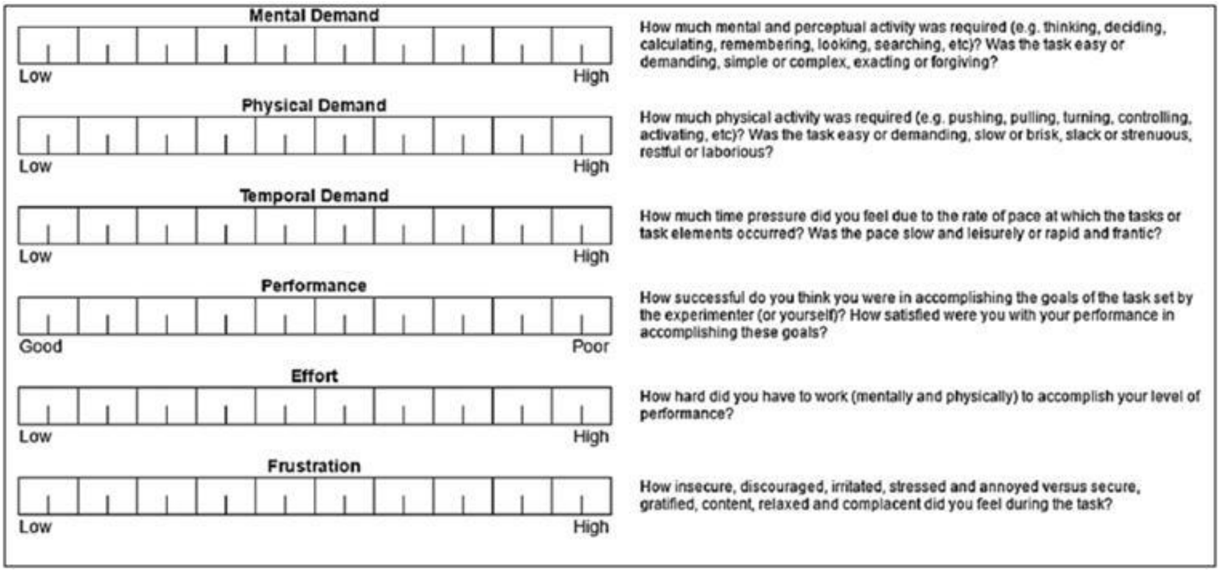

Figure 5. Nasa-TLX Rating Scale (Arce, Romero-Dessens and Leon-Duarte, 2018)

Answers are scored between 0 and 100. Weight must be determined for each characteristic. In the second step of the method, these weights in 15 paired comparison sets of 6 factors are calculated. Pairwise Technique (PWT), known as the pairwise comparison technique, is used for the calculation. Minimum and maximum weight scores for individual measurement are 0 and 5, respectively. The characteristic that appears as the highest value among these weights is the most important factor contributing to the perceived mental workload (Dey and Mann, 2010).

Finally, the workload index (TLX) is obtained by multiplying the ratio value of each characteristic and their weight value and adding them together Equation (1). In this formulation, A_{ii} is weight values of the characteristic, MD, PD, TD, P, E ve F are indicated the score values of the factors between 0 and 100.

TLX = $MD*A_{MD} + PD*A_{PD} + TD*A_{TD} + P*A_P + E*A_E + F*A_F$ (1)

2.4 AHP

AHP is a theory of relative measurement of intangible criteria. It has been one of the most widely used multiple criteria decision-making tools (Vaidya and Kumar, 2006). It is used by decision makers and researchers, because it is a simple and powerful tool (Forman and Gass, 2001). In this study, the AHP method is a decision-making technique which is used to solve complex multi-criteria problems. AHP method was developed in 1988 by Thomas L. Saaty. The most important feature of AHP is that it can include both objective and subjective thoughts of the decision maker in the decision process (Kuruüzüm and Atsan, 2001). Solution of decision problems with AHP can be given as hierarchical structure (decomposition), binary comparisons, calculation of relative priorities (synthesis) and calculation of priority values, respectively (Alp and Engin, 2011). The main objective, criteria, sub-criteria and alternatives of the decision problem are prepared in a hierarchical structure as indicated in Figure 6. In this method, 1-9 comparisons were used for pair comparisons.

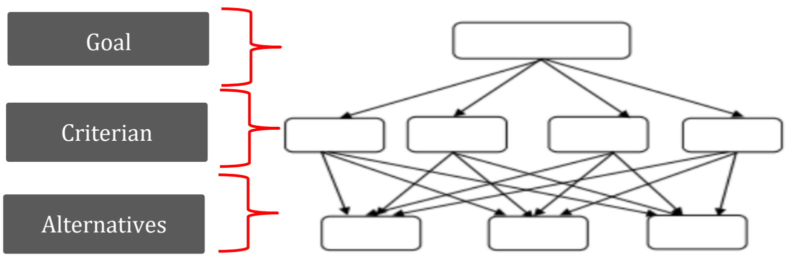

Figure 6. Hierarchical Structure of AHP

During the implementation of AHP, face-to-face meetings with the people directly related to the subject of interest are obtained through a questionnaire or interview. Paired comparisons matrix is created in AHP depending on the judgments. If the specified level of the hierarchy contains n elements to be compared, a total of n (n-1) / 2 binary comparisons are required. This matrix is created by converting judgments into numerical values. The priority (relative importance) of each element compared is calculated. This part of AHP is called "synthesis". The synthesis part involves the calculation and normalization of the largest eigenvalue and the eigenvector corresponding to this eigenvalue. The row sum of the values obtained by the normalization method is taken and this total is divided by the number of elements in the row. The final stage of AHP is the resolution of the decision problem. At this stage, a mixed (composite) priorities vector is formed that will serve as the ranking of decision alternatives in the realization of the main goal of the problem. To construct this vector, the priority vectors determined for each variable are weighted. The final priorities obtained can also be called decision alternative scores and represent the intensity of judgmental perceptions of the decision maker regarding alternative choices (Kuruüzüm and Atsan, 2001). All evaluation steps of AHP are given together in Figure 7.

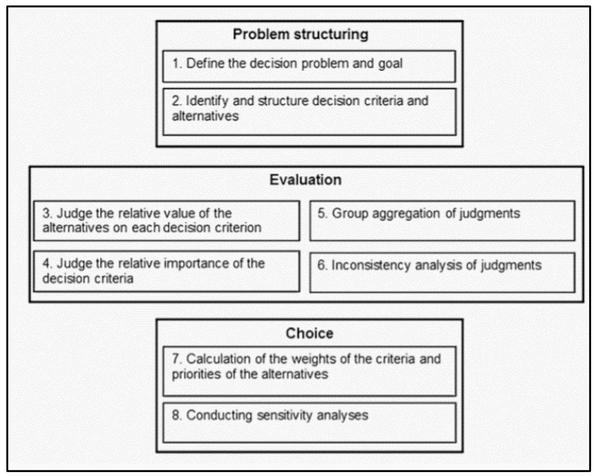

Figure 7. Visual Representation of All the Steps (Hummel, Bridges and IJzerman, 2014)

2.5 Resting Time

In literature, the resting time is applied between 5-7% (Karger and Bayha, 1977; Barnes, 1980; Caragnano, 2007; Kamon, 1982). Fundamental fatigue allowances are given to cover the effort spent on the job and to free the employee from monotonicity. The general figure is 4% of the basic time. Variable work conditions bring additional fatigue and fluctuating load to the employee (Niebel and Freivalds, 2003). Fatigue allowance can be given as a percentage of the basic time. For example, in good working conditions, it is thought that the addition of a fatigue share of 4% of the basic time will be sufficient for a worker who normally uses her/his hands, legs, sensory organs and works in a light job by sitting (Kayacan, 2001). Williams' fatigue allowance worksheet (1973) includes a basic combined personal and fatigue allowance of 10% (the basic minimum allowance including personal needs); he does not, in his article, attempt to decompose what part of this is personal and what part is fatigue (Lund and Mericle, 2000).

The International Labour Organization (ILO) has not adopted any standards for tolerances, however recommends a minimum of 9% for each work item (Niebel and Freivalds, 2003). The 6% resting time is accepted as the standard level in MTM (Methods of Time Measurements). The lowest resting rate in literature is denoted as 4%, and thus can be used as the lower-level fatigue share.

2.6 Application

The study was carried out in a company producing automotive seats with the company's own employees. Applications have been carried out on the assembly line given in Figure 8. In total, there are more than 2000 employees in the company. Employees work in 3 shifts. In this study, 10 stations were examined:

1. Cushion Trimming-1
2. Cushion Trimming-2
3. Backrest Cushion Assembly
4. Plastics Assembly-1
5. Plastics Assembly-2
6. Ironing
7. Backrest Trimming-1
8. Backrest Trimming-2
9. Backrest Trimming-3
10. Packaging

First, the seat frame is fixed and the seat cover is dressed. After the correction process, the back frame is dressed. Backrest and seat parts are combined. Finally, Backrest Cushion Assembly, Plastics Assembly-1, Plastics Assembly-2, Ironing and Packaging operations are performed. All the operations in these assembly steps are measured and analysed in this study using proper techniques (Figure 9).

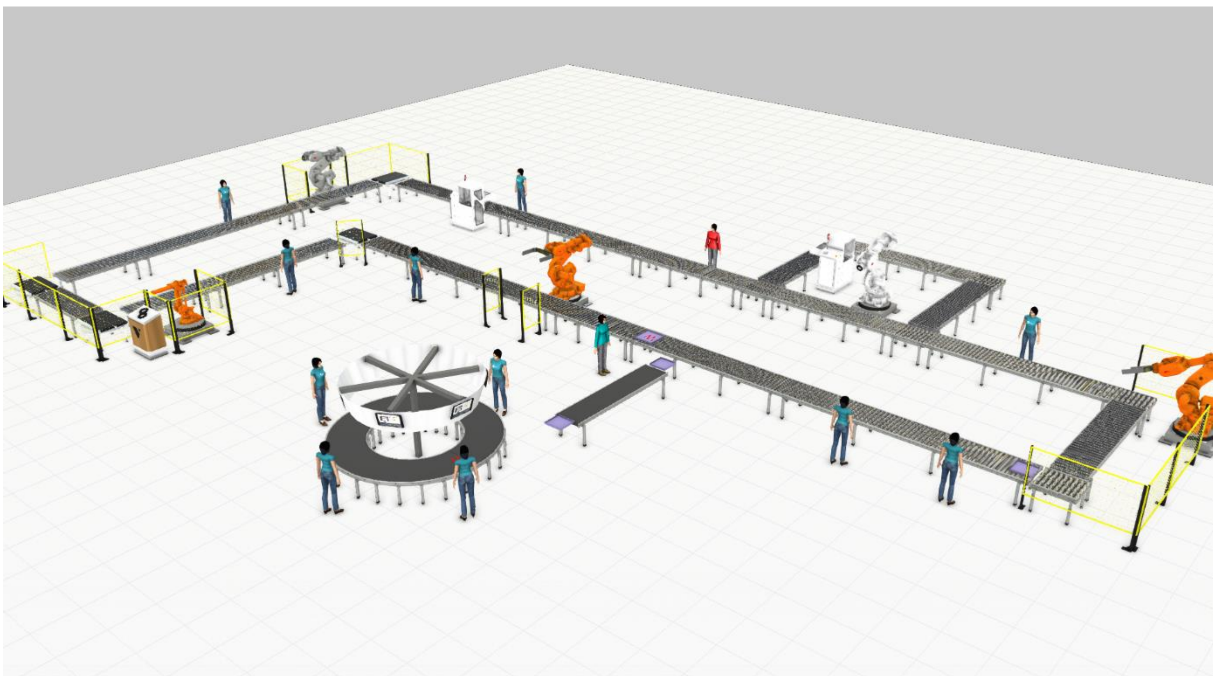

Figure 8. Assembly Line Layout

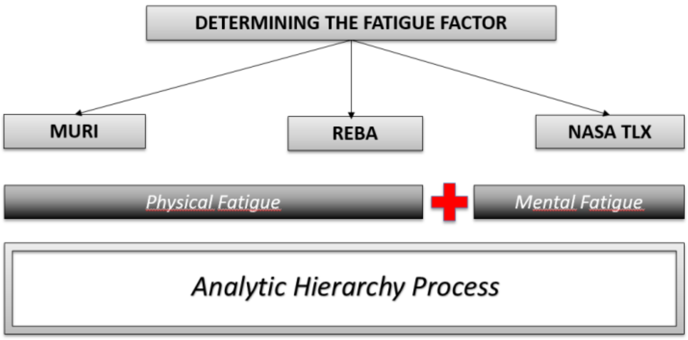

Figure 9. Methods Used in the Study

4. Results and Discussion

MURI and REBA, in which physical loads are evaluated, and NASA-TLX methods, in which mental loads are analysed, were used in the study. The integrated structure created in the study consists of MURI and REBA methods where physical loads are evaluated, and NASA-TLX methods where mental loads are analysed. In the formulation recommended for calculation of general fatigue scores, weights were formed by the AHP method. According to the general fatigue scale that was finally formed, the choice of resting time to be given to the employees was made. The results were separated according to the flow.

4.1 MURI Analysis

During MURI analysis, a table with 11 defective movements are evaluated according to posture and movement analysis. Three different levels are considered for each of the 11 defective movements. The scores are "1" for low, "2" for medium and "3" for high. After scoring each operation, the total score was calculated by taking the sum of rows and columns of each operation. The total scores, as a result of examining 10 stations, are as in Table 1.

Table 1
Results of MURI Analysis

Operation Name	MURI Score
Cushion Trimming- 1	12
Cushion Trimming -2	7
Backrest Cushion Assembly	8
Plastics Assembly-1	6
Plastics Assembly-2	8
Ironing	6
Backrest Trimming- 1	13
Backrest Trimming- 2	13
Backrest Trimming- 3	9
Packaging	7

4.2 REBA Analysis

While applying REBA, the body was examined in two sections, as group A and group B. In group A, body, neck and leg sections are evaluated, and in group B upper arm, lower arm and wrist sections are evaluated. REBA tables are used for determining risk scoring. The total scores are in Table 2.

Table 2
Results of REBA Analysis

Operation Name	REBA Score
Cushion Trimming- 1	11
Cushion Trimming -2	8
Backrest Cushion Assembly	7
Plastics Assembly-1	7
Plastics Assembly-2	5
Ironing	5
Backrest Trimming- 1	10
Backrest Trimming- 2	11
Backrest Trimming- 3	9
Packaging	6

4.3 NASA-TLX Method

Whereas REBA and MURI methods are quite straightforward, NASA-TLX requires more elaborate thinking and design, and requires cognitive judgement, since it is used to measure mental fatigue. A questionnaire, which consists of 6 questions was applied to the employee to determine the characteristics. Answers were scored between 0-20. In addition, employees were asked to make pairwise comparisons for each sub-factor. Once the answers are received, the answers are subjected to Pairwise Weighting Technique (PWT), which reveals the importance of each criterion. Then, the weighted averages are calculated by multiplying the weights with the results. The results obtained are in Table 3-4.

Table 3
NASA-TLX Weights

Factor	Total Score	Weight Coefficient (A_{ii})
MD	57	0,127
PD	88	0,196
TD	73	0,162
P	99	0,220
E	103	0,229
F	30	0,067

Table 4
NASA-TLX Method Results

Operation Name	NASA-TLX Score
Cushion Trimming- 1	13.43
Cushion Trimming -2	12.55
Backrest Cushion Assembly	8.19
Plastics Assembly-1	11.67
Plastics Assembly-2	13.32
Ironing	10.68
Backrest Trimming- 1	15.98
Backrest Trimming- 2	11.71
Backrest Trimming- 3	14.56
Packaging	7.97

4.4 AHP Method

Three different AHP applications were made for the seat assembly line as starting, cladding and other. The reason why it is examined in this way is that similar body movements of the employees are taken into account. Within the scope of line start, cushion trimming-1 and backrest trimming-1, for cladding, cushion trimming-2, backrest cushion assembly and backrest trimming-2, for other backrest trimming-3, plastics assembly-1, plastics assembly-2, ironing and packaging stations were examined.

The criteria were compared to each other based on the judgment of the decision maker, and the priority of each element was calculated MURI, REBA and NASA-TLX (Table 5). The weights of each sub-factor were calculated as a result of these paired comparisons. Then, the normalization of the matrices was performed to find the weight for each criterion. The coefficients calculated for the beginning of assembly are as in Table 6-7-8.

Tablo 5
Paired-Wise Comparisons

Main factor comparison-Starting				**Main factor comparison-Cladding-**				**Main factor comparison-Other-**			
	MURI	REBA	NASA-TLX		MURI	REBA	NASA-TLX		MURI	REBA	NASA-TLX
MURI	1	5	0.33	MURI	1	0.2	0.40	MURI	1	4	0.50
REBA	0.2	1	0.33	REBA	5	1	0.13	REBA	0.25	1	0.50
NASA-TLX	3	3	1	NASA-TLX	2.5	8	1	NASA-TLX	2	2	1

Table 6
Coefficients for Starting of the Assembly Line

	MURI	**REBA**	**NASA-TLX**	**Alternative Superiority Weight**
Weight	0.32	0.12	0.56	1.00
Physical Fatigue	0.9	0.9	0.55	0.705
Mental Fatigue	0.1	0.1	0.45	0.295

Table 7
Coefficients for Cladding of the Assembly Line

	MURI	**REBA**	**NASA-TLX**	**Alternative Superiority Weight**
Weight	0.126	0.416	0.458	1.00
Physical Fatigue	0.9	0.9	0.65	0.787
Mental Fatigue	0.1	0.1	0.35	0.213

Table 8
Coefficients for Other of the Assembly Line

	MURI	**REBA**	**NASA-TLX**	**Alternative Superiority Weight**
Weight	0.16	0.30	0.54	1.00
Physical Fatigue	0.9	0.9	0.64	0.7621
Mental Fatigue	0.1	0.1	0.36	0.2379

In order to calculate a combined measure of fatigue, coefficients obtained from AHP method were used. However, the calculations were not on a single scale, and a coefficient was necessary to standardize the scores on a single scale. Therefore, a coefficient was determined for each group in order to evaluate the results between 0-100. This coefficient was calculated as follows (Table 9).

Table 9
Combined Fatigue Scale

0-25	Low	50-75	High
25-50	Medium	75-100	Very-high

$$Coefficient = \frac{\sum General\ Fatigue}{\sum \frac{Mental\ Fatigue}{Physical\ Fatigue}} \quad (2)$$

The coefficients were calculated as 2.38 for physical fatigue (PF), 8.03 for mental fatigue (MF) and 3.01 for general fatigue (GF).

$$PF = (0.9 * MURI + 0.9 * REBA + 0.55 * NASA) * 2.38 \quad (3)$$

$$MF = (0.1 * MURI + 0.1 * REBA + 0.45 * NASA) * 8.03 \quad (4)$$

$$GF = (0.66 * MURI + 0.66 * REBA + 0.52 * NASA) * 3.008 \quad (5)$$

When the obtained coefficients are used in the formula, the results are normalized to a range of 0-100. Fatigue calculations for starting of the assembly line using the formulas above are as in Table 10.

Table 10
Fatigue Calculation

Operation Name	General Fatigue	Operation Name	General Fatigue
Cushion Trimming- 1	66.9511	Ironing	38.8413
Cushion Trimming -2	49.7105	Backrest Trimming- 1	70.9425
Backrest Cushion Assembly	42.7540	Backrest Trimming- 2	66.1900
Plastics Assembly-1	44.3784	Backrest Trimming- 3	58.8553
Plastics Assembly-2	47.0219	Packaging	38.4506

4.5 Resting Time Determination

The standard 6% resting share given in MTM is accepted as medium level. When the literature is examined, it is determined as low level fatigue share, since the resting share is given at least 4%. Due to these two assumptions, determining the levels of rest with a difference of 2%; Very high levels of fatigue were decided to be 10%, high to 8%, medium to 6% and low to 4%. Resting shares were evenly distributed using the standard fatigue scale (Table 11)

Table 11.
Resting Times for Created Scale

General Fatigue Scale Created	Resting Time
0-25: Low	4 %
25-50: Medium	6 %
50-75: High	8 %
75-100: Very High	10 %

The resting shares in Table 10 are re-assigned as in Table 12 according to the scale in Table 11.

Table 12
Resting Time Determined for Seat Assembly Line

Operation Name	General Fatigue	Resting Time
Cushion Trimming- 1	66.9511	8 %
Cushion Trimming -2	49.7105	6 %
Backrest Cushion Assembly	42.7540	6 %
Plastics Assembly-1	44.3784	6 %
Plastics Assembly-2	47.0219	6 %
Ironing	38.8413	6 %
Backrest Trimming- 1	70.9425	8 %
Backrest Trimming- 2	66.1900	8 %
Backrest Trimming- 3	58.8553	8 %
Packaging	38.4506	6 %

5. Conclusion

In this study, physical and mental fatigue measurements were made at an assembly line in an automotive company. Previous studies evaluate physical and mental workload differently, whereas this study combines them in an original way. Physical workload was measured by MURI and REBA, whereas mental workload was evaluated using NASA-TLX. Consequently, fatigue calculations were performed by combining mental and physical fatigue analyses via AHP, and an overall fatigue figure value was attained. Finally, resting time is determined according to this combined fatigue value.

This study adhered to the research and publication ethics. Ethics Committee Approval was not required as no experiments were conducted on humans or animals. This study was carried out in a car seat company with the permission given on 15 June 2020.

Future studies will be evaluated by creating hybrid systems with different ergonomic analysis methods for physical and mental evaluation, different multi-criteria decision-making methods. This study can be applied to different industry employees.

Conflict of Interest

No conflict of interest has been declared by the authors.

Contribution of Researchers

In this study; Aslı KAHYA, Ayça RECAL and Yasemin SEVİNCER contributed to article writing, scientific publication research, implementation of the study and interpretation of the results. Tülin GÜNDÜZ and Seda ÖZMUTLU contributed to the design of the study, management and interpretation of the results.

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