Case Report

Fuzzy Group Decision Making Approach for Ranking Work Stations based on Physical Pressure

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This paper proposes a Fuzzy Group Decision Making approach for ranking work stations based on physical pressure. Fuzzy group decision making approach allows experts to evaluate different ergonomic factors using linguistic terms such as very high, high, medium, low, very low, rather than precise numerical values. In this way, there is no need to measure parameters and evaluation can be easily made in a group. According to ergonomics much work contents and situations, accompanied with multiple parameters and uncertainties, fuzzy group decision making is the best way to evaluate such a chameleon of concept. A case study was down to utilize the approach and illustrate its application in ergonomic assessment and ranking the work stations based on work pressure and found that this approach provides flexibility, practicality, efficiency in making decision around ergonomics areas. The normalized defuzzification numbers which are resulted from this method are compared with result of quantitative assessment of Automotive Assembly Work Sheet auto, it's demonstrated that the proposed method result is 10% less than Automotive Assembly Work Sheet, approximately.

Keywords: Automotive Assembly Work Sheet, Fuzzy Group Decision Making, Physical Pressure, Ergonomic assessment

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Introduction

Having written and designed methods of job physical pressure measurement in dozen of articles, demonstrate its importance and Automotive Assembly Work Sheet (AAWS) is a method which have been utilized in car industry (1), Most of these methods are designed for particular posture of physical pressure, including Rapid Upper Limb Assessment (RULA) (2), Concise Exposure Index (OCRA) (3), OVAKO Working Posture Analysing System (OWAS) (4), and National Institute of Occupational Safety and Health (NIOSH) (5). The common feature of the above mentioned methods is particularity. For instance, RULA method is utilized for upper extremity part of physical posture. OCRA (3) method is used for fast and repetitive motions measurement. NLOSH (5) method is instructed for cargo bearing and carrying measurement. And finally, OWAS (4)method is conducted for whole body posture and partially concentrated force pressure measurement.

Undoubtedly, you can't fully utilize the above mentioned methods, because they are so time consuming and not covering all the matters. Albeit, these methods have been conformed and conditioned according to different industries specifically automobile. In car industry, methods have got compatible with systematic classification of physical pressures (mostly occur in such industry) and covered its effective factors, utmost. Therefore, you can easily measure physical pressures and analyze its various types thoroughly. New Production Work Sheet (NPW) (6) by OPEL, Design Check (7) by Porsche and AAWS (1) by VW are definitive examples of comprehensive methods which have been utilized in car industry. Given ISO 11226 (8)and ISO 11228 (9), laboratory research findings and ex-mentioned methods result are employed for its designing; AAWS (1)is much more acclaimed in car industry, especially in Germany. The European Assembly Work sheet (EAWS) is developed version of this method, recently utilized in car industries whole over the Europe .However, when the case is a job with vast variety of physical pressure and long work cycle, registering all physical pressure quantitatively is arduous task, with multiple hurdles

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even via the above mentioned method. For instance, you can neither measure exerted pressure nor joints angle through working; hence they should be estimated by assessor that results in different results. Authors of this article make efforts to estimate the effective factors in AAWS qualitatively, employing FGDM fuzzy method in order to not only facilitate assessor task but also provide different experts idea combination**.**

Basic concept on fuzzy set theory

Fuzzy sets are generalizations of crisp sets and were first introduced by Zadeh (10) , resembles human reasoning in its use of approximate information and uncertainty to generate decisions. It was specifically designed to mathematically represent uncertainty and vagueness and provide formalized tools for dealing with the imprecision intrinsic to many problems (11). Fuzzy numbers are introduced to appropriately express linguistic variables. A linguistic variable is a variable whose values are not numbers but words or sentences in a natural or artificial language (12). A fuzzy number is a fuzzy set on the real line that satisfies the conditions of normality and convexity (13). It is a quantity whose value is imprecise, rather than exact as is the case with “ordinary” (single-valued) numbers. A triangular or trapezoidal fuzzy numbers usually adopted to express the decision group’s perception of alternatives’ performances with respect to each criteria (14, 15) Each fuzzy set is specified by a membership function, which assigns to each element in the universe of discourse a value within the unit interval [0, 1]. The assigned value is called degree (or grade) of membership, which specifies the extent to which a given element belongs to the fuzzy set or is related to a concept. If the assigned value is 0, then the given element does not belong to the set. If the assigned value is 1, then the element totally belongs to the set .If the value lies within the interval (0, 1), then the element only partially belongs to the set. Therefore, any fuzzy set can be uniquely determined by its membership function In fact, a triangular fuzzy number is a special case of a trapezoidal fuzzy number. When the two most promising values are the same number, the trapezoidal fuzzy number becomes a triangular fuzzy number (15). In this section, describe some basic concepts and operational laws related to **triangular** fuzzy numbers are briefly described.

Definition1: A triangular fuzzy numbers $\tilde{a}$can be defined by a triplet (a^L, a^M, a^U). The membership function $\mu_{\tilde{a}}(x)$is defined as:

$$\mu_{\tilde{a}}(x)=\begin{cases} 0 & x < a^L \\ \frac{x-a^L}{a^M-a^L} & a^L \le x \le a^M \\ \frac{x-a^U}{a^M-a^U} & a^M \le x \le a^U \\ 0 & x \ge a^U \end{cases}$$

Where$0 < a^L \le a^M \le a^U$, $a^L$and a^Ustand for the lower and upper values of the support of$\tilde{a}$, respectively, and $a^M$for the modal value. Basic operation on triangular fuzzy sets gave been introduced.

Definition 2: An important concept related to the applications of fuzzy numbers is defuzzification, which converts a fuzzy number into a crisp value. Such a transformation is not unique because different methods are possible. The most commonly used defuzzification method is the centroid defuzzification method, which is also known as center of gravity or center of area defuzzification. The centroid defuzzification method can be expressed as follows (16) for triangular fuzzy number is defined as:

$$\bar{x}_0(\tilde{A}) = \frac{a^L+a^M+a^U}{3} \qquad \text{Eq.1}$$

The proposed method

Group decision making problems are driven from decision division. Frequently, these problems are not crystal clear in real world—their objectives and parameters are blurry. Experts’ first priority to represent their opinions is numbers. When the numbers are oblique, linguistic assessments are utilized instead. (17-20). Ergonomics is like a tangled skein full of dozens of different parameters, including posture, action forces load onto joints, used tools, weight of loads, frequency of load manipulations and etc which are effective in physical pressure. Have these multiple factors formulated is an arduous task (even impossible). Therefore, experts prefer linguistic terms rather than numerical to represent their evaluation of physical pressures. In this way, the fuzzy set theory is a tool to overcome physical pressure evaluation problems. The propose method which facilitates pressure evaluation process for experts are listed below. In this method, criteria and parameters listed in AAWS method are used with FGDM approach, so to enable experts to state their ideas about each criterion, considering parameters affecting physical pressure. In previous methods, it is impossible to reach consensus between different expert’s opinions, without losing information. Proposed group decision making method is proposed to surmount this problem. This method can not only sharpen physical pressure estimation, but let experts to rank various workplaces in accordance with physical pressure. Group decision making method implementation and calculations have are represented as follow:

Collect a group of experts to establish a decision group - At the commencement, a group of experts (familiar with AAWS method) in field of ergonomics is opted.

Introduction of criteria - According to FGDM method, criteria should be identified in this step and then to simplify physical stress evaluation process, AAWS criteria is utilized. The criteria are divided into three main categories including posture, force and manual handling. And, several sub criteria as follow:

1. Body posture: here there are four types of body posture: standing, sitting, kneeling, and lying that have been divided into some sub criteria. Pictures are clear. Every criterion must be used and examined as its application.
2. Forces: there are four types of forces which can occur in each work station. Joint position: forces which enter to joint positions- especially wrist. Load onto fingers: forces enter onto fingers. Action forces required: actions that operator will be shown in special conditions and finally vibration, returned forces and impulses.
3. Manual handling: Parameters (caused by manual handling of materials) which affects the stress to the body are divided into four main groups: Weights of loads, Posture position of load, work conditions and frequency of load, travel distance and holding time. According to the type of movements, these parameters examination will be changed. For instance, holding a piece for a while, is kind of “holding”, moving a piece (pull or push) for less than 5 meters, is kind of “pull & push < 5m “, moving something for more than 5 meters, is kind of “pull & push > 5m” and lifting a piece, is kind of “load lifting”. The type of movement affects examinations and calculations. Presume that in a particular workplace a combination of several modes can be occurred. Consequently, table (1), (2), and (3) are needed in accordance with each type of manual handling which are different in
4. Comparison with the previous ones.

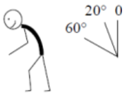
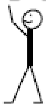
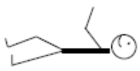
Table 1. Force’s criteria

Force		
$C_{2.1}$	Joint position (specially wrist)	
$C_{2.2}$	Load onto fingers (e.g. clips, plugs)	
$C_{2.3}$	Action forces required (no forces)	
$C_{2.4}$	Vibration, returned forces, impulses	

Table 2. Manual handling’s criteria

Manual handling	
$C_{3.1}$	weights of loads
$C_{3,2}$	Posture position of load
$C_{3.3}$	Work conditions
$C_{3.4}$	Frequency of load , Travel distance, Holding time

Table 3. Body posture's criteria

Body posture			
	C_{111}		upright-slowly bent forward , backward
	C_{112}		bent forward (20-60)
Standing (C_{11})	C_{113}		strongly bent forward > 60
	C_{114}		upright - arms at / above shoulder level
	C_{115}		upright -arms above head level
	C_{121}		upright- slowly bent forward , backward
Sitting (C_{12})	C_{122}		Bent
	C_{123}		upright - arms at / above shoulder level
	C_{124}		upright -arms above head level
	C_{131}		Upright
Kneeling (C_{13})	C_{132}		bent
	C_{133}		arms at / above shoulder level
Lying (C_{14})	C_{141}		(on back, breast or side) , arms above head

At this stage, have considered physical stress entering the body, experts are asked to examine the importance of each criterion and to cite his opinion, using qualitative levels as bellow: There are some fuzzy linguistic rating levels which are used for each criterion and could be presented as VH (*very high)*,H*(high)*, M *(medium)*,L *(low)*,VL *(very low)*. Experts can utilize them to express their opinions. Membership functions for linguistic weighting values are shown in table (4).

Table 4. Membership functions for linguistic weighting value

Linguistic variable	Abbreviation	Triangular fuzzy numbers: $\tilde{w}$
Very high	VH	(0.75,1,1)
High	H	(0.5,0.75,1)
Average	A	(0.25,0.5,0.75)
Low	L	(0,0.25,0.5)
Very Low	VL	(0,0,0.25)

Note: there are 4 types of tables for manual handling tables that are different from each other. The 1st table refers to the case where an operator holds a piece for a while, 2nd one refers to the case where the operator pulls or pushes a piece in less than 5 meters, the 3rd one refers to cases where he pulls or pushes the piece in more than 5 meters and finally the last table will review cases in which the operator pick up a piece.

After collecting these data, total weights of each criterion must be calculated. Eventually, there should be one result for each which emanates from all experts' opinion. Here are the calculations:

Body posture and *forces*:

$$\tilde{A}_j = \frac{\sum_{i=1}^{i=n} \tilde{W}_{ij}}{n} \; ; j = 1,2,..,a \qquad \text{Eq.2}$$

$$TW_j = \frac{\bar{A}_j}{\sum_{j=1}^{m} \bar{A}_j} \; ; j = 1,2,..,a \qquad \text{Eq.3}$$

$\tilde{W}_{ij}$: Opinion of expert i about criterion j's weight i = 1,2 …, n j = 1, 2…, a

$\tilde{A}_j$: Average of all opinions around criterion j = 1,2 …, a

$\bar{A}_j$: Defuzzification of $\tilde{A}_j$

TW_j: Total weight of criterion j

n = number of experts a = number of criteria

Manual handling

$$\tilde{A}_{jk} = \frac{\sum_{i=1}^{i=n} \tilde{W}_{ijk}}{n} \; ; \; j = 1,2,..,a \; ; \; k = 1,2 \ldots, 4 \qquad \text{Eq.4}$$

$$TW_{kj} = \frac{\bar{A}_j}{\sum_{j=1}^{m} \bar{A}_j} \; ; \; j = 1,2,..,a \; ; \; k = 1,2 \ldots, 4 \qquad \text{Eq.5}$$

$$TW_j = \frac{\sum_{k=1}^{4} TW_{kj}}{4} \; ; \; j = 1,2 \ldots, a \qquad \text{Eq.6}$$

$\tilde{W}_{ijk}$: Opinion of expert i about criterion j's weight at type of k

$\tilde{A}_j$: Average of all opinions around criterion j at type of k

$\bar{A}_j$: Defuzzification of $\tilde{A}_j$

TW_{jk}: Total weight of criterion j at type of k

TW_j: Total weight of criterion j

k = counter of existing types for manual handling

Determination of work stations: Physical stress evaluation is calculated according to the stress, entered to a certain worker (person), in a certain work station. In evaluating physical stress in long duration and work stations with multi task content, our new proposed method avoid repeated calculations in each sub task. In this step, work stations will be determined and introduced to experts.

Determining presence Percent of each criterion: After determination of work stations, experts are requested to settle the duration of each criterion at work station in form of percentage of whole cycle duration.

Determination of severity

Body postures: In this section, experts should use linguistic terms, in order to set and record body postures occurring in selected work stations. Given conventional ergonomic procedure, the stress or strain is defined in terms of level and duration (time spent in this posture). Calculation process is divided into two sections: 1rst determination of each body posture's criteria level and 2nd, determination of specified level duration which is dedicated to each body posture in time interval of occurrence that body posture. These two steps have to be carried out simultaneously, indeed. Accordingly, experts should fill related abbreviation (*VH,H,A,L,VL*) in the body posture evaluation table for each work station. Linguistic terms that are used in determination of body posture's level and the triangular fuzzy numbers that are denoting the evaluation value, are listed in table (5).

Table 5. Linguistic variables and triangular fuzzy numbers for linguistic weight and severity value

Linguistic variable	Abbreviation	Triangular fuzzy numbers: $\tilde{s}$
Very high	VH	(0.75,1,1)
High	H	(0.5,0.75,1)
Average	A	(0.25,0.5,0.75)
Low	L	(0,0.25,0.5)
Very Low	VL	(0,0,0.25)

It should be noted that the time intervals defined by linguistic terms (Always, Frequently,...), shows the duration--each criterion (C_{111},C_{112},…) has the specified physical stress. Experts should not only partake of their knowledge and expertise to choose each linguistic term, but they should consider factors such as the amount of trunk lateral bending , forward bending, trunk twisting and far reach position. The linguistic terms which are used to determination of level's duration and the triangular fuzzy numbers that are denoting the evaluation value, are listed in table (6).

Table 6. Linguistic variables and triangular fuzzy numbers for duration, frequency and distance

Linguistic variable of duration	Linguistic variable of frequency	Linguistic variable of distance	Triangular fuzzy numbers: $\widetilde{TS}$
Always	Very high	Very long	(0.85, 0.85,1)
Frequently	High	Long	(0.5, 0.85,1)
Usually	Medium	Medium	(0.15,0.5, 0.85)
Sometimes	Low	Short	(0,0.15,0.5)
Rarely	Very low	Very short	(0,0,0.15)

Each expert decision for each body posture's criteria can be computed as below:

$$\widetilde{D}_{ijk} = \frac{\sum_{w=1}^{w=5} \tilde{S}_{jkw} \otimes \tilde{T}_h}{\sum_{w=1}^{w=5} \tilde{T}_h} \otimes P_{ijk} \qquad for\ each\ \ i = 1,2,\dots,n\ \ ;\ j = 1,2,\dots m\ ;\ \ k = 1,2,\dots,a \qquad \text{Eq.7}$$

Where:

$\tilde{S}_{jkw}$: Severity of criterion "j" in work station "w" in time interval " h"

$\tilde{T}_h$: Time interval of each Severity in column "h"

P_{ijk} :Percentage of criterion "j" in workstation" w" determined by expert "i "

$\widetilde{D}_{ijk}$: Decision of expert "i" in work station "w" about criterion "j"

n: Number of experts m: Number of work stations a: Number of criteria

Forces: According to AAWS method forces were divided into action forces and a repetitive load. In fact, they are evaluating extreme joint angles, forces exerted by the finger-hand or arm-shoulder systems, vibrations, reactive forces and impulses. Given determination of body posture, In this section, experts should express their opinion in appropriate linguistic terms in tables (5) and (6), considering time interval. All joint angles occurring either as static postures or in association with application of forces (static or dynamic) are rated. Rating is influenced by duration, frequency of stress/strain and degree of applied force.

Decision of each expert for each force's criteria can be computed as below:

$$\widetilde{D}_{ikj}^{w} = \frac{\sum_{h=1}^{5} \tilde{s}_{ijkw} \otimes \tilde{T}_h}{\sum_{h=1}^{5} \tilde{T}_h} \otimes P_{ikj} \qquad for\ each\ \ i = 1,2,\dots,n\ \ ;\ j = 1,2,\dots m\ ;\ \ k = 1,2,\dots,a \qquad \text{Eq.8}$$

Where:

$\tilde{S}_{ijk\,h}$: Severity of criterion "j" in work station "w" in time interval " h"

$\tilde{T}_h$: Time interval of each Severity h = counter of columns

P_{ijw} :Percentage of criterion "j" in workstation" w" determined by expert "i "

$\widetilde{D}_{ijw}$: Decision of expert " i " in work station "w" about criterion "j"

n: Number of experts m: Number of work stations

a: Number of criteria

Manual handling: As noted before, manual handling of materials make stress entered to the body. They are parameters which affect the stress, divided into four main groups: Weights of loads, Posture position of load, work conditions and frequency of load, travel distance, holding time. Parameters examination is changed, depending on movement type. Accordingly, each expert should consider the movement type and then fill related tables.

Last criteria and the parameters at the top of the tables (duration, frequency, and distance) make difference in comparison with previous ones. In "Introduction of criteria's" section, it was mentioned that holding a piece for a while, is kind of "holding", moving a piece (pull or push) for less than 5 meters, is kind of "pull & push < 5m ", moving something for more than 5 meters, is kind of "pull & push > 5m" and lifting a piece, is kind of "load lifting".

$$\tilde{D}_{ikj}^{w} = \frac{\sum_{h=1}^{5} \tilde{S}_{ikj\,h}^{w} \otimes \tilde{F}_{kh}}{\sum_{h=1}^{5} \tilde{F}_{kh}} \;; \quad i = 1, \ldots, n \quad , \; j = 1, \ldots, a \quad , \; w = 1, \ldots, m$$

Eq.9

$$\tilde{D}_{ij}^{w} = \frac{\sum_{k=1}^{4} \tilde{D}_{ikj}^{w} \otimes TW_{kj}}{\sum_{k=1}^{4} TW_{kj}} \;; \quad i = 1, \ldots, n \quad , \; j = 1, \ldots, a \quad , \; w = 1, \ldots, m$$

Eq.10

Where:

$\tilde{S}_{ikj\,h}^{w}$: Severity of criterion "j" in kind of "k" at workstation "w" at column "h" by expert "i"

$\tilde{F}_{kh}$: Interval of manual handling's table in kind of "k" and column "h" by expert "i"

$\tilde{D}_{ikj}^{w}$: Decision of decision maker "i" for criterion "j" for kind of "k" at workstation "w"

TW_{jk} : Total weight of criterion" j" at type of "k"

$\tilde{D}_{ij}^{w}$: Final decision of criterion "j" by expert "i" at workstation "w

Ranking work stations: Ranking alternatives is the final step of FGDM. In this step, score of each alternative will be evaluated by determining weights of each criterion and calculating weighted average as follow. At the end, the alternatives will be ranked over their evaluated scores. Here, work stations will be ranked based on "physical stress and ergonomic requirement". For this purpose, a fuzzy evaluating matrix for every criterion should be constructed for each work station as below:

$$\tilde{f}_{jw} = \frac{\sum_{i=1}^{i=n} \tilde{D}_{ijw}}{n}$$ q.11

Where," $\tilde{f}_{jw}$ " is a fuzzy number denoting the evaluating value of criterion "j" in work station "w" by experts and $\tilde{D}_{ijw}$ is decision of expert "i" in work station "w" about criterion "j". Then the evaluating matrix for each work station can be obtained as below:

$$\tilde{F}_{w} = \left[\tilde{f}_{1w}\,\tilde{f}_{2w}\; \ldots \; \tilde{f}_{aw}\right]$$ For each w = 1,2,… m

Eq.12

Based on the total weight of each criterion and fuzzy evaluation matrix $\tilde{F}_{w}$ the overall mark can be obtained as bellow:

$$overall\ mark_{\,w} = \sum_{j=1}^{a} \bar{f}_{jw} \times TW_{j} \quad ; for\ each\ w = 1,2,..m$$

Eq.13

Where $\bar{f}_{jw}$ defuzzification of triangular is fuzzy number $\tilde{f}_{jw}$ that calculated by Eq (1). Then work places will be ranked based on their overall mark in descending order.

Case study

Having demonstrated the application for the method and go through detail, work stations are selected to evaluate the physical stress loads on workers. Given this purpose, ergonomics expert which are familiar with AAWS method, requested to fill the forms of evaluation and taken the steps of the method Calculations which are performed by MS Excel 2010:

Establish the expert group: The expert group is composed of 3 experts in the filled of ergonomics and familiar with AAWS method.

Introduction of criteria: In this step, in order to evaluate the physical stress, criteria are divided in to three main sections as shown in table (1) to (3)

Determination of weight of each criterion: Each expert expresses his/her opinion about each criterion importance via linguistic terms. The results of calculations are shown in table (7 - 9)

Table 7. The weights of the posture's criteria assigned by experts

Body posture						
ID	Posture's criteria	Expert1	Expert 2	Expert 3	$\widetilde{A_j}$	TW_j
1	C11	A	L	VL	(0.08,0.25,0.5)	0.032
2	C12	H	H	H	(0.50,0.75,1)	0.086
3	C13	VH	VH	H	(0.67,0.92,1)	0.099
4	C14	H	H	H	(0.50,0.75,1)	0.086
5	C15	VH	VH	VH	(0.75,1,1)	0.105
6	C21	L	L	VL	(0.00,0.17,0.42)	0.022
7	C22	H	H	H	(0.50,0.75,1)	0.086
8	C23	H	H	H	(0.50,0.75,1)	0.086
9	C24	VH	VH	VH	(0.75,1,1)	0.105
10	C31	L	H	A	(0.25,0.5,0.75)	0.058
11	C32	A	VH	H	(0.50,0.75,0.92)	0.083
12	C33	VH	VH	H	(0.67,0.92,1)	0.099
13	C41	VL	H	A	(0.25,0.42,0.67)	0.051

Table 8. The weights of the force's criteria assigned by experts

ID	Holding	Expert1	Expert 2	Expert 3	$\widetilde{A_j}$	TW_{1j}
18	weights of loads	H	H	H	(0.5,0.75,1)	0.33
19	posture, position of load	H	H	A	(0.42,0.67,0.92)	0.29
20	work conditions	L	L	VL	(0,0.17,0.42)	0.09
21	Holding	H	H	A	(0.42,0.67,0.92)	0.29
ID	pulling & pushing < 5m	Expert1	Expert 2	Expert 3	$\widetilde{A_j}$	TW_{2j}
18	weights of loads	A	A	L	(0.17,0.42,0.67)	0.27
19	posture, position of load	A	A	A	(0.25,0.5,0.75)	0.33
20	work conditions	VL	L	L	(0,0.17,0.42)	0.13
21	pulling & pushing < 5m	A	A	L	(0.17,0.42,0.67)	0.27
ID	pulling & pushing > 5m	Expert1	Expert 2	Expert 3	$\widetilde{A_j}$	TW_{3j}
18	weights of loads	H	H	H	(0.5,0.75,1)	0.31
19	posture, position of load	H	H	H	(0.5,0.75,1)	0.31
20	work conditions	L	L	L	(0,0.25,0.5)	0.1
21	pulling & pushing > 5m	H	H	A	(0.42,0.67,0.92)	0.28
ID	load lifting	Expert1	Expert 2	Expert 3	A_j	TW_{4j}
18	weights of loads	VH	VH	H	(0.67,0.92,1)	0.27
19	posture, position of load	VH	VH	H	(0.67,0.92,1)	0.27
20	work conditions	H	A	A	(0.33,0.58,0.83)	0.18
21	load lifting	VH	VH	H	(0.67,0.92,1)	0.27

The fuzzy number in column of $\widetilde{A_j}$ in table (7) and (8) are calculated by Eq (2) and $\widetilde{A_j}$ in table (9) is calculated by Eq (4) .in order to compute total weights of each criterion(TW_j) for table (7) and (8) are calculated by Eq(3) and for table (9) are calculated by use of Eq(5) and Eq (6).

Table 9. The weights of the manual handling's criteria assigned by experts

ID	Holding	Expert1	Expert 2	Expert 3	$\widetilde{A_j}$	TW_{1j}
18	weights of loads	H	H	H	(0.5,0.75,1)	0.33
19	posture, position of load	H	H	A	(0.42,0.67,0.92)	0.29
20	work conditions	L	L	VL	(0,0.17,0.42)	0.09
21	Holding	H	H	A	(0.42,0.67,0.92)	0.29
ID	pulling & pushing < 5m	Expert1	Expert 2	Expert 3	$\widetilde{A_j}$	TW_{2j}
18	weights of loads	A	A	L	(0.17,0.42,0.67)	0.27
19	posture, position of load	A	A	A	(0.25,0.5,0.75)	0.33
20	work conditions	VL	L	L	(0,0.17,0.42)	0.13
21	pulling & pushing < 5m	A	A	L	(0.17,0.42,0.67)	0.27
ID	pulling & pushing > 5m	Expert1	Expert 2	Expert 3	$\widetilde{A_j}$	TW_{3j}
18	weights of loads	H	H	H	(0.5,0.75,1)	0.31
19	posture, position of load	H	H	H	(0.5,0.75,1)	0.31
20	work conditions	L	L	L	(0,0.25,0.5)	0.1
21	pulling & pushing > 5m	H	H	A	(0.42,0.67,0.92)	0.28
ID	load lifting	Expert1	Expert 2	Expert 3	A_j	TW_{4j}
18	weights of loads	VH	VH	H	(0.67,0.92,1)	0.27
19	posture, position of load	VH	VH	H	(0.67,0.92,1)	0.27
20	work conditions	H	A	A	(0.33,0.58,0.83)	0.18
21	load lifting	VH	VH	H	(0.67,0.92,1)	0.27

Determination of work stations: Four different work places are selected. Work Station 1 is related to one of automobile manufacturer assembling. In WS1 not only assembly operations but also control operation for diagnoses, maintenance is carried out by workers. Most of operations are in a way that elbows are on the top of worker head it's not an appropriate posture. Work Station 2 is related to a supplier company of automobile parts (mirror). In WS2 workers are in an appropriate posture. They assemble parts in a standing posture. Work Station 3 is related to road construction operation. Workers are operating with heavy machinery and their postures are predominantly inappropriate (with exerting too much force and energy consumption). Work Station 4 is related to gardening operation. Almost all of operations are carried out manually. In some cases, some operations like pruning are executed repeatedly and increase body pressure on operator. At each of the above mentioned workplace, According to the "proposed" method, experts compare them with each other in physical entered stress.

Body posture: In this section, physical stress is examined in terms of body posture. Therefore, experts consider actual posture of the operator so to discuss their opinion. The purpose is comparing physical stress of the above mentioned workplaces. In this step, manual handling materials are checked. Previous steps should be done again. Final results of this poll will be listed in tables. These results via noted calculations are converted to crisp values.

Ranking work stations: Work places are ranked based on final decision of experts, considering overall marks which include physical stress and ergonomic requirements.

Overall marks are computed via Eq (13) and fuzzy evaluation matrix (table 10). The overall mark represents level of physical stress, the greater as it be, the more unsuitable work condition in that work station is.

Table 10. Final ranking of work stations based on physical pressure

Criteria	Sub criteria ID (j)	TW_j	Work place 1 w=1	Work place 2 w=2	Work place 3 w=3	Work place 4 w=4
posture	1.1.1	0.032	4.230	17.471	7.768	3.939
	1.1.2	0.086	2.149	5.865	4.986	4.663
	1.1.3	0.099	1.858	1.261	3.353	2.828
	1.1.4	0.086	2.418	0.747	1.289	1.230
	1.1.5	0.105	2.185	0.921	1.289	1.230
	1.2.1	0.022	0.231	0.233	2.391	1.743
	1.2.2	0.086	2.656	0	0	0
	1.2.3	0.086	1.037	0	0	0
	1.2.4	0.105	2.761	0	0	0
	1.3.1	0.058	0	0	0	1.544
	1.3.2	0.083	0	0	0	3.173
	1.3.3	0.099	0	0	0	1.341
	1.4.1	0.051	0	0	0	0
force	2.1	0.099	5.218	4.104	3.591	7.034
	2.2	0.0169	2.087	5.088	1.662	8.328
	2.3	0.296	1.044	1.026	12.012	5.174
	2.4	0.437	2.052	1.026	5.134	1.272
manual handling	3.1	0.329	0.108	0.117	0.278	0.174
	3.2	0.293	0.127	0.118	0.272	1.124
	3.3	0.085	0.120	0.116	0.276	0.943
	3.4	0.293	0.123	0.118	0.279	1.086
	Overall mark		3.749	3.489	8.141	6.540
	Rank		2	1	4	3

According to Eq (12) and (13), table (10) is computed. The results show that first rank goes to work station 2 (automotive mirror assembly) – it is in the good condition of physical stress. The Work Station 3 has unsuitable condition.

Discussion

This article tries to consider physical pressure as a group thinking issue. Having input linguistic and fuzzy parameters instead of definitive numbers and utilized these parameters in work positions which mentioned in AAWS method, facilitates work stations measurement from physical pressure view. Appropriate work place can be selected by ranking work stations according to body pressure status while using human forces depending on person physical abilities in order to bear pressure which is proportionate for him or her.

Consequently, results of the proposed method are compared with AAWS method to reach the final conclusion. One for one comparison is not possible; hence normalized numbers (results) of two methods are compared (table 11). When normalized Defuzzification numbers which are resulted from this method are compared with result of quantitative assessment of AAWS, it's demonstrated that the proposed method result is 10% less than AAWS, approximately.

Table 11. Comparison between proposed method and AAWS method

	Final Fuzzy Result of FGDM	Normalized Final result FGDM	Final Result of AAWS
Workplace 1	3.749	46.051	70
Workplace 2	3.489	42.857	50
Workplace 3	8.141	100	100
Workplace 4	6.540	80.334	90

While comparison is based on Defuzzification of fuzzy numbers and fuzzy numbers are defined in continuous interval, big fuzzy numbers Defuzzification make them small proportionally and for small numbers vice versa. Since big numbers are shortening, trifle variance between two methods final result is reasonable.

In the present paper, the proposed method utilized in order to ranking various work stations based on physical pressure so, authors of this article are consider to provide a method that can evaluate work pressure of each work stations directly by use of fuzzy sets and linguistic terms for their future research.

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