# Integration of Analytic Hierarchy Process Technique and Knowledge-Based System to Prioritize Essential Critical Risk Factors Using the Web-Based Approach

**Fazilah Abdul Aziz, Nik Mohd Zuki Nik Mohamed, and Ahmad Nasser Mohd Rose**

**Abstract** Web-based expert systems have proved an exceptional tool for creating intelligent decision-making systems based on experts' knowledge and opinions. This work presents an approach for assessing ergonomics risk factors based on integrating the analytic hierarchy process (AHP) method and knowledge-based system (KBS) using a web-based interface approach. A web-based ergonomics assessment system (W-BEAS) was developed and validated by comparing the assessment results using the existing method risk priority number (RPN). Physical, psychosocial, individual and organizational ergonomics are the four critical factors prioritized by the W-BEAS. Arrangements of priority weight and rank position obtained by W-BEAS and RPN provided reasonable evidence of validity for prioritizing the critical risk factors. Validation results prove that the W-BEAS can produce outcomes relative to the current ergonomics assessment approach. W-BEAS is capable of assessing complex ergonomics risk factors and continuing to support better workplace ergonomics. In addition, the W-BEAS employs a macro-ergonomics approach to evaluate the multi-factorial risk related to WMSD. Through W-BEAS, workers can share their knowledge and concern with the system to prioritise critical risk factors more accurately. A field study was conducted using for the first time an integrated web-based system as an intervention tool in assessing workplace ergonomics risk. Workers used it independently without personal expert training. Results indicated that workers could evaluate their workplace hazards anywhere and anytime.

**Keywords** Work related musculoskeletal disorders (WMSD) · Ergonomics risk factor · Analytical hierarchy process (AHP) · Knowledge-based system (KBS) · Web-based expert system (WBES)

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## 1 Introduction

Any company intending to compete entirely in their respective industries should prioritize employee wellness [1, 2]. The workplace has a direct impact on employee health. The productivity and efficiency of work organizations have an impact on employee wellness as well. Because of the critical role of humans in industry, these facts demonstrate that workplace ergonomics plays an essential part in long-term sustainability. Workplace ergonomics, linked to safety and health concerns, demand an organizational strategic direction to attain long-term viability [3]. Furthermore, a better working environment for workers is linked to long-term development [4]. Workers will be endangered by work-related musculoskeletal diseases (WMSDs) if their physical abilities do not match the job's physical requirements due to inadequate workplace ergonomics. WMSDs are painful muscle, tendon, and nerve disorders. Because of their widespread use and detrimental impact on job productivity, WMSDs have resulted in economic losses worldwide [5]. As a result, holistic systems and strategies linking workplace ergonomics management to long-term organisation growth are required.

The importance of researching workplace ergonomics risk factors and creating musculoskeletal disorders (MSD) prevention techniques has grown. The MSD hazard and risk factors can be decreased early in developing a new product and process employing risk management in the organization [6]. In addition, the majority of MSD disorders are caused by a combination of risk factors [7]. To recognise critical risks and eliminate crucial risk factors, occupational safety and health (OSH) practitioners need a decision instrument that includes a systematic, participative ergonomics and risk-based method. As a result, this study employs a systematic approach using the analytic hierarchy process (AHP), one of the multi-criteria decision analysis techniques (MCDA), in a decision-making aid for multi-factorial investigations. The AHP is a structured approach based on mathematics and psychology for preparation and analysing complex decisions. AHP also is an effective and powerful technique for decision making [8]. Moreover, AHP can measure and synthesise many criteria [9] and helpful in complex issues [10].

In the ergonomics field, knowledge-based systems (KBS) have been used in a variety of ways. KBS is a software program that generates and employs a knowledge base to undertake complicated issues. KBS can collaborate with or take the place of human experts in workplace ergonomics assessments [11]. KBS, or computer-based information systems, can represent expert knowledge. KBS can achieve the level of skill required to resolve workplace hazard situations at an expert level [12]. Moreover, using KBS in ergonomics assessments can help workers rapidly and properly discard various risk concerns [13]. Employees and employers must have ergonomic knowledge and be informed of workplace ergonomics assessments to avoid the risk. Hence, KBS is critical in promoting proactive ergonomics to improve an organization's long-term sustainability in work activities, workplaces, and working environments.

**Table 1** The AHP uses a pair-by-pair comparison scale

| Importance intensity | Score | Meaning | Description |
|---|---|---|---|
| 1 | 1 | Equally vital | Two elements influence the property in equal measure |
| 2 | 3 | The importance of one over the other is moderate | One has a minor advantage over the other based on experience and judgment |
| 3 | 5 | Importance is essential or significant | Experience and judgement vastly prefer one over the other |
| 4 | 7 | The significance is enormous | An element is heavily favoured, and its domination may be seen in action |
| 5 | 9 | Extremely vital | One of the most significant levels of affirmation is evidence that favours one element over another |
| Reciprocals | | When one of the numbers mentioned above is chosen for the activity i opposed to j; the activity j analysed to I is set to its inverse | |
| Ratio | | Rates resulting from requiring constancy in decisions | |

Adapted from Saaty [8]

Many academics have worked on KBS to evaluate the ergonomic risk associated with WMSD [14–16]. Most KBSs for ergonomics assessments operate on a stand-alone mode that performs its function without a network link. Consequently, this study combines the AHP approach, KBS, and a web-server application to construct a web-based ergonomics assessment system (W-BEAS). Web-based apps are applications that use a web browser to communicate with a remote server. W-BEAS is a computer software tool that uses the internet to imitate ergonomics experts' critical thinking abilities.

This study, which contributes to the ergonomics risk assessment literature and practice, demonstrates the use of a W-BEAS in deciding the essential workplace risk factors connected to WMSD.

## 2 AHP and KBS are Integrated to Create a W-BEAS

### *2.1 AHP Technique for Critical Risk Factor Prioritization*

Workplace risk factors connected to physical, organizational, and psychosocial components have been linked to WMSDs, which reduce workers' wellness and well-being [2, 17–19]. A macro-ergonomic assessment approach includes individual (IF), organizational (OF), physical (PhyF), and psychosocial (PsyF) variables to assess the critical WMSD risk factors. There are four primary factors and 26 sub-factors in the AHP (refer to Fig. 1 and Table 3). Figure 1 describes the formation of the

**Table 2** W-BEAS validation members' demographic information

| Demographic dimension | | Freq. | % |
|---|---|---|---|
| Working time | Normal | 3 | 15 |
| | Shift | 17 | 85 |
| Working position | Supervisor | 13 | 65 |
| | Executive | 3 | 15 |
| | Engineer | 3 | 15 |
| | Assistant manager | 0 | 0 |
| | Manager | 1 | 5 |
| Working department | Production assembly | 5 | 25 |
| | Production stamping | 4 | 20 |
| | Engineering | 4 | 20 |
| | Safety, health, and environment | 3 | 15 |
| | Logistics | 4 | 20 |
| | Shift | 17 | 85 |
| Working experience (years) | 11–15 | 2 | 10 |
| | 16–20 | 18 | 90 |
| | > 20 | 0 | 0 |
| | Shift | 17 | 85 |
| Education level | SPM | 12 | 60 |
| | Certificate | 2 | 10 |
| | Diploma | 5 | 25 |
| | Degree | 1 | 5 |
| Age (years) | 25–34 | 0 | 0 |
| | 35–44 | 14 | 70 |
| | 45–55 | 6 | 30 |
| Gender | Male | 20 | 100 |
| | Female | 0 | 0 |

AHP. Procedures to detecting ergonomic risk factors and sub-factors and a pairwise comparison to determine priority weight are included in the AHP structure.

The AHP model includes procedures for identifying ergonomic risk factors and sub-factors and a pairwise comparison to determine weight. The AHP process included the following steps:

1. Designing a decision form and conducting pair-wise comparisons, users were required to determine the significance of risk factors between certain ergonomic factors and sub-factors. Table 1 presents a mathematical scale for pairwise comparisons. This method included the formation of the square matrix $A_{n\times n}$. Equation 1 represents the $A_{n\times n}$.

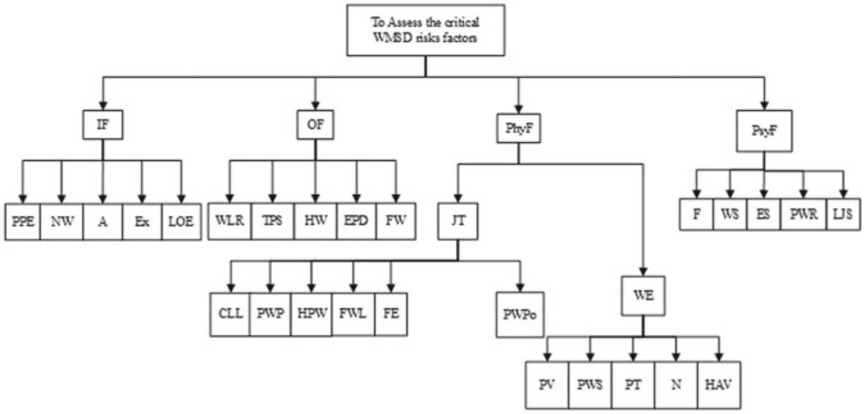


**Fig. 1** The hierarchy for critical risk factors correlated to WMSD

$$A_{n \times n} = \left[ a_{11} a_{21} a_{12} a_{22} \cdots a_{1n} a_{2n} \vdots \ddots \vdots a_{n1} a_{n2} \cdots a_{nn} \right] \quad (1)$$

where $a_{ij}$ was the factor in the pair-wise comparison matrix. It delivered the comparative importance of criterion $i$ concerning criterion $j$. Matrix $A_{n \times n}$, $a_{ij} = 1$ when $i = j$ and $a_{ij} = \frac{1}{a_{ij}}$ when $i \neq j$.

2. Combining the results. The method outputs a vector of local weights or priorities for every risk factor based on the overall goal. The Geometric mean ($GM_i$) was used to calculate the aggregate expert judgments.

$$GM_i = \left[ \prod_{j}^{n} a_{ij} \right]^{\frac{1}{n}}, \quad (2)$$

where $n$ = number of members.

3. Determining the local weights. The Eqs. (3) and (4) can define the principal Eigenvector and Eigenvalues individually.

$$w_i = \frac{GM_i}{\sum_{i=1}^{n} GM_i}, \quad (3)$$

$$\lambda_{\max} = \frac{\sum_{i}^{n} w_i}{n}, \quad (4)$$

where $n$ = number of factors.

4. Confirming the pair-wise comparison's consistency. Equations (5)–(7) can be used to describe the consistency index (CI) and consistency ratio (CR).

**Table 3a and b** The RPN technique and the W-BEAS prioritized risk factors are compared

| Ergonomic risk factors | W-BEAS | | RPN | |
|---|---|---|---|---|
| | Priority Weight (%) | Ranking | Priority Weight (%) | Ranking |
| **(a)** | | | | |
| *Individual* | | | | |
| Negligence of workers (NW) | 21 | 2nd | 22 | 2nd |
| Improper use of personal protective equipment (PPE) | 13 | 4th | 16 | 4th |
| Level of education (LOE) | 45 | 1st | 29 | 1st |
| Working experience (Ex) | 17 | 3rd | 22 | 2nd |
| Age (A) | 4 | 5th | 11 | 5th |
| Total | 100 | | 100 | |
| *Organisational* | | | | |
| High workload (HW) | 17 | 2nd | 22 | 2nd |
| Worker lack of rest (WLR) | 10 | 4th | 16 | 4th |
| Frequent workdays (FW) | 9 | 5th | 11 | 5th |
| Exposure to physical demands (EPD) | 50 | 1st | 29 | 1st |
| Tight production schedule (TPS) | 14 | 3rd | 22 | 2nd |
| Total | 100 | | 100 | |
| *Physical-Job task factors* | | | | |
| Work that requires a lot of lifting (FWL) | 8 | 6th | 13 | 5th |
| Lifting and carrying (CCL) | 15 | 3rd | 15 | 3rd |
| Working conditions are poor (PWPr) | 10 | 5th | 10 | 6th |
| Work that is physically demanding (HPW) | 14 | 4th | 15 | 3rd |
| Effort put forth in a job assignment with a lot of force (FE) | 28 | 1st | 27 | 1st |
| Working posture is poor (PWPo) | 25 | 2nd | 20 | 2nd |
| Total | 100 | | 100 | |
| **(b)** | | | | |
| *Physical-workplace and equipment* | | | | |
| Insufficient ventilation in the workplace (PV) | 7 | 5th | 12 | 5th |
| Inadequate working conditions (PWS) | 23 | 2nd | 24 | 2nd |
| In the workplace, the temperature is too hot (PT) | 16 | 3rd | 18 | 3rd |
| Noise in working environment (N) | 14 | 4th | 16 | 4th |
| Hand arm vibration (HAV) | 39 | 1st | 31 | 1st |
| Total | 100 | | 100 | |
| *Psychosocial* | | | | |
| Fatigue (F) | 15 | 4th | 16 | 4th |

(continued)

**Table 3a and b** (continued)

| Ergonomic risk factors | W-BEAS | | RPN | |
|---|---|---|---|---|
| | Priority Weight (%) | Ranking | Priority Weight (%) | Ranking |
| Work stress (WS) | 7 | 5th | 11 | 5th |
| Emotional stress (ES) | 18 | 2nd | 22 | 2nd |
| Frustration with work-related and unrelated (FWR) | 18 | 2nd | 22 | 2nd |
| Low job support (LJS) | 42 | 1st | 29 | 1st |
| Total | 100 | | 100 | |

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \tag{5}$$

$$\lambda_{\max} = \sum_{i=1}^{n}\left[\left(\sum_{i=1}^{n} GM_i\right)(w_j)\right], \tag{6}$$

where $\lambda_{\max}$ is the maximum eigenvalue and $n$ is the number of factors

$$CR = \frac{Consistency\, index(CI)}{Random\, index(RI)} \leq 0.10, \tag{7}$$

If the CR value is less or equal to 0.1, it is acceptable. It must be replaced if the subjective judgment is more than 0.1 or 10%.

## 2.2 Integrated W-BEAS Design

W-BEAS' core structure consists of a user interface (UI), an AHP inference engine (IE), and a knowledge base. W-BEAS was served with XAMPP as the AHP IE, and the database used MySQL. W-BEAS contains three parts: UI, a web server (WBS), and a KBS database, as presented in Fig. 2.

The integrated web-based system is divided into five main components, as shown in Fig. 3:

a. Database—after user retrieval, all factor information is recorded and stored in the knowledge database.
b. Input process—refers to the user's preference for studying data retrieved from a database.
c. Processing of data—the server performs the consistency test and calculates each component and sub-factor weights using the AHP method.
d. Process of output—the ergonomic risk factors and sub-factors connected to WMSD are prioritized.

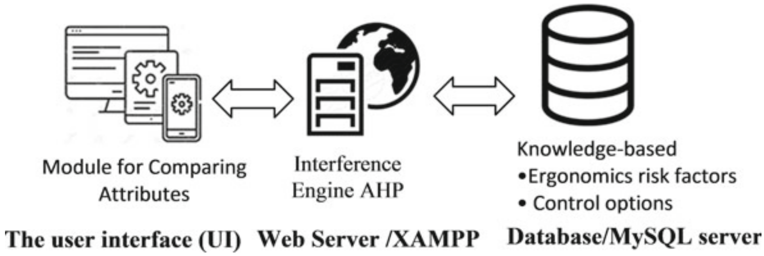


**Fig. 2** The structure of W-BEAS

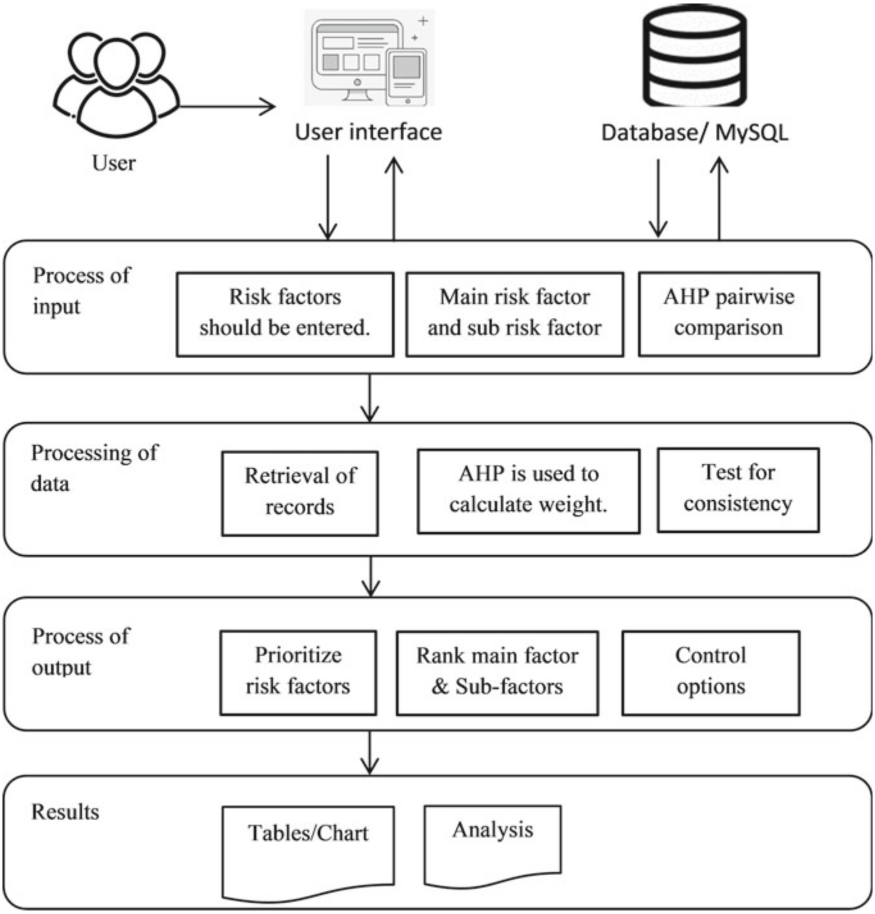


**Fig. 3** Parts of the W-BEAS integrated system and their functionalities

e. Analyze and report the results of the ergonomics evaluation in the form of charts and tables.

## 2.3 W-BEAS User Interface

Figures 4, 5 and 6 depict the W-BEAS interface. Before logging into the system, users were required to register (see Fig. 4). The comparison module page opened

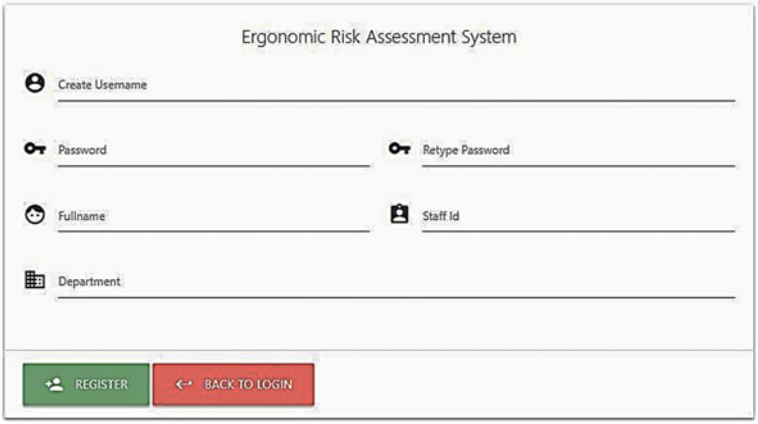


**Fig. 4** A page for registering system

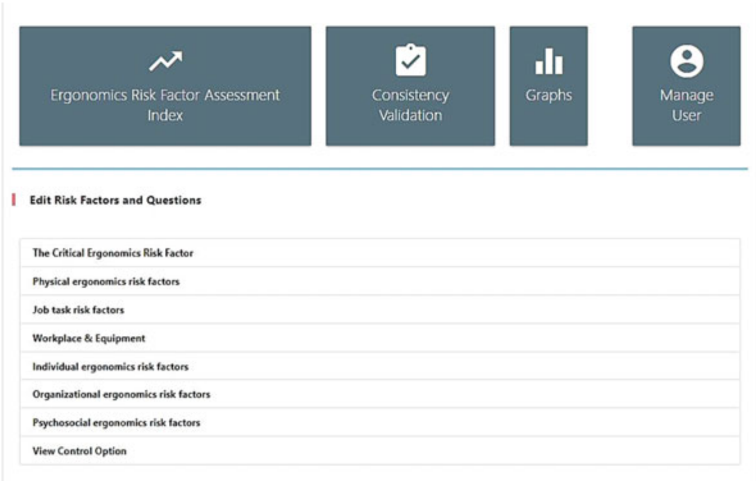


**Fig. 5** System home page

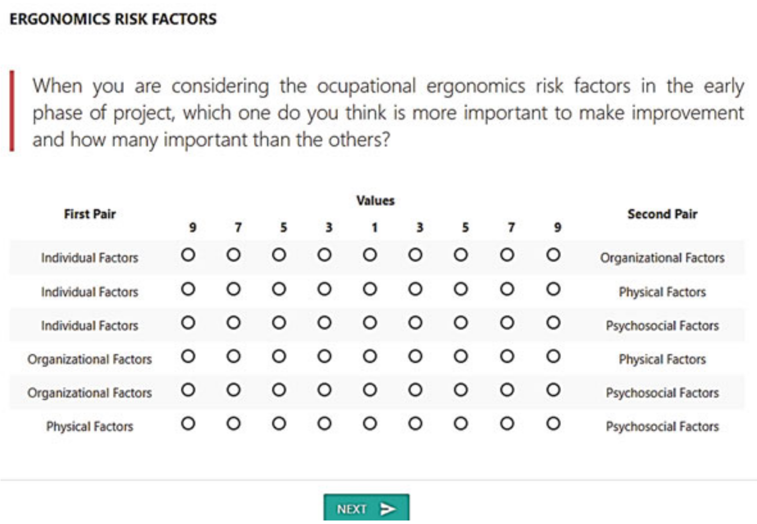


**Fig. 6** Ergonomics risk factors comparison module in system

after logging in. Every questionnaire was addressed in this module under different potential threats, and the scale was determined.

# 3 Validation of W-BEAS

## 3.1 *Validation Method*

The primary goal of the W-BEAS was to demonstrate the efficacy and logic of the proposed web-based expert system in practice. The W-BEAS was validated using real-world data. The validation method compares the results collected by the W-BEAS and the existing assessment method, risk priority number (RPN).

The W-BEAS validation was carried out at a local automotive component manufacturer, with twenty senior personnel chose based on expertise, abilities, and work experience. The demographic data of the W-BEAS validation respondents is presented in Table 2.

This study employed the RPN method to determine the weights of factors and sub-factors for validation reasons. RPN is the current failure mode and effect analysis to rank each failure mode. The W-BEAS was validated using the RPN procedures listed below:

*Step 1*: The workplace risk factors were assessed by assessing the Likelihood (L) of the risk happening, using a scale of 1 = rare, 2 = unlikely, 3 = likely, and 4 = almost certain.

*Step 2*: The workers were required to examine the severity (S) of risk factors if any relevant incident occurred, using a scale of 1 = minor/negligible, 2 = moderate, 3 = major, and 4 = severe/catastrophic.

*Step 3*: The following equation was adopted to measure the risk priority number (RPN).

$$RPN = L \times S \quad (8)$$

Each risk factor's priority weight percentage was determined.

### 3.2 Validation Results

The findings of the W-BEAS and RPN are compared in Table 3a and b. Refer to Table 3, the first-place rank of risk factors estimated by the W-BEAS and RPN methods is comparable. The rank arrangement reveals a slight variance for the sub-risk variables of individual, organization, and physical-job task. On the other hand, ranked risk factors differently by only one position deemed unimportant. ES must usually exhibit reasonable efficiency at some stage during development [20].

These results show that the W-BEAS can produce results that are comparable to the current assessment method. These validation results are similar to a previous study done by Falamarzi et al. [21] in that the developed web-based system percentages of answers were equivalent to those produced by the previous system. W-BEAS, on the other hand, produced more precise results [22]. Also, it improved the effectiveness of the ergonomics assessment method [23, 24]. Besides, the W-BEAS provides a more thorough indicator of WMSD risk variables than other techniques by employing a macro-ergonomics approach.

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## 4 Conclusions

A web-based expert system was produced and validated for this study, using practical online ergonomics assessment advantages. This W-BEAS is valid and reliable in prioritizing the critical workplace risk factors. W-BEAS will help the OSH practitioners identify the critical risk factors needed to resolve the hazards at the workplace.

This study indicates that workers are provided with a flexible ergonomics assessment system through a web-based approach. The worker can assess their ergonomics workplace individually at anywhere and anytime.

Workers must be informed of the critical risk factor of their workplaces and make plans to prevent the WMSD. W-BEAS support the organization to protect and promote the worker's well-being and workplace sustainability. Thus, the results of this validation proof of concept suggest that a W-BEAS appears to be a promising straightforward alternative to the partly expensive and time-consuming expert training. We intend to apply the procedure illustrated in this paper to some other classification problems arising in different sectors for further research.

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