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Ergonomic Risk Factor Priority Evaluation of Hand Fabric Painters based on Hybrid ISM– Spherical Fuzzy DEMATEL Approach

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This study addresses the imperative need to mitigate ergonomic risks faced by hand painting workers, who are highly susceptible to musculoskeletal disorders (MSDs) due to the complexity of their tasks. The research employs an innovative methodology combining Interpretive Structural Modeling (ISM) and Spherical Fuzzy Decision-making trial and error laboratory (SF-DEMATEL) techniques to thoroughly examine contributing factors. Additionally, Matrice d'ImpactsCroisés Multiplication Appliquée à un Classement (MICMAC) analysis is performed to categorize these factors, and sensitivity analysis is carried out to ensure the robustness of the results. Through this unique approach, the study identifies eleven critical ergonomic risk factors affecting MSDs, emphasizing the importance of task design, worker posture, workstation design, and task sequencing in mitigating risks. The findings highlight the necessity of holistic approaches in addressing ergonomic challenges, promoting proactive measures for safer work environments. By integrating ISM and Spherical Fuzzy DEMATEL methodologies, the research offers a novel framework for targeted interventions. The study's novelty lies in its comprehensive understanding of ergonomic risks specific to hand painting work and its innovative methodology, with the validation of findings through rank comparison and sensitivity analysis reaffirming the robustness and credibility of its contributions to the field of ergonomics.

Keyword: Decision, Ergonomic risks, MCDM, Musculoskeletal disorders, Sensitivity analysis

Introduction

Ergonomics involves designing and organizing products, systems, and environments to enhance individuals' well-being and performance.[1,2] It involves applying knowledge from fields such as anatomy, physiology, psychology, and engineering to design products, workstations, and tasks that are compatible with the physical and cognitive capabilities of people.[3] Ergonomics covers a wide range of topics, including workplace design, equipment design, product design, and organizational design.[4] Ergonomic risks refer to factors in the workplace that may cause physical or mental strain on workers and may lead to discomfort, pain, or injury.[5] These risks can be related to the workstations, tools, equipment etc.[6] Some common causes of ergonomic risks include:

- Awkward postures: Reaching, bending, twisting, or working in an uncomfortable position for an extended period can cause musculoskeletal disorders.[7,8]
- Repetitive motions: Repeating the same motion or using the same muscles repeatedly can cause strains, tendinitis, and other injuries.[9]
- Excessive force: Lifting or pushing heavy loads or using too much force when working can cause strains and injuries.[10]
- Poor workstation design: Poorly designed workstations, such as chairs with no back support, can lead to discomfort and pain.[11]
- Insufficient rest breaks: Failing to take regular rest breaks can lead to fatigue and reduce productivity.[12]
- Poor lighting: Insufficient lighting or glare can cause eye strain and headaches.[13]
- Environmental factors: Temperature, humidity, noise, and air quality can all affect worker comfort and productivity.[14]

Research Background

Hand painting workers, particularly those who perform detailed work, such as artists and illustrators, are at risk for a range of ergonomic injuries and strains.[15] These workers are required to maintain consistent, precise hand movements for extended

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periods, which can cause repetitive motion injuries.[16] These injuries are caused by repeated stress on the tendons, nerves, and muscles of the hand and wrist, leading to inflammation and pain.[17] Awkward postures can also contribute to ergonomic risks for hand painting workers.[18] Workers may need to hold their arms or hands in awkward positions for long periods to reach certain areas, such as above their heads or on the ground.[19] This can lead to strain and injury in the shoulders, neck, and upper back, as well as in the hands and wrists. Eye strain is another common ergonomic issue for hand painting workers.[20] These workers need to focus on detailed work for long periods, often under dim lighting conditions, which can lead to eye strain, headaches, and even long–term vision problems. Respiratory problems are also a concern for hand painting workers. Exposure to the fumes and chemicals in paints and solvents can cause respiratory problems, such as asthma and other respiratory illnesses.

To address these ergonomic risks, employers can implement several measures. Providing workers with appropriate equipment and tools, such as ergonomic paintbrushes with soft grip handles, can help reduce strain on the hands and wrists.[21] Ergonomic chairs and adjustable workstations can help workers maintain good posture and avoid awkward positions.[22] Employers can also provide training on proper techniques for handling tools and materials and encourage workers to take frequent rest breaks to avoid fatigue. In addition, employers can implement ventilation systems and use less hazardous chemicals to minimize the risk of respiratory problems. Employers can also adjust lighting to reduce eye strain and provide appropriate protective gear, such as respirators and gloves, to reduce exposure to harmful fumes and chemicals. By addressing these ergonomic risks, employers can create a safer and healthier work environment for hand painting workers. Ergonomic risks can be addressed by implementing ergonomic design principles, such as adjusting workstations to fit individual workers, providing appropriate equipment and tools, and ensuring that workers take regular rest breaks.[23] Employers can also provide training and education to help workers identify and prevent ergonomic risks in the workplace.

There are many factors which plays an important role in providing safer work environment to workers which can be seen from the above literature cases cited. Prioritizing ergonomic risks is crucial for effective risk management and resource allocation in the workplace. By ranking these risks, employers can identify the most pressing hazards that pose the greatest threat to workers' health and safety. This allows them to allocate resources efficiently, focusing on interventions that will have the most significant impact on reducing injuries and improving overall workplace safety. Prioritization also enables employers to implement preventive measures proactively, addressing critical risks before accidents occur. Moreover, prioritizing ergonomic risks ensures compliance with regulations and standards governing workplace safety, as it demonstrates a commitment to identifying and mitigating hazards in accordance with legal requirements.

Research Gaps/Study Objectives

While literature does offer insights into the evaluation of ergonomic risks specific to hand painters, a comprehensive framework for improving overall workstation ergonomics remains notably absent. Existing research tends to focus on identifying and addressing individual ergonomic risks faced by hand painters, such as repetitive motion injuries or eye strain. However, there is a distinct lack of a cohesive framework that encompasses all relevant ergonomic factors and provides actionable recommendations for optimizing the overall design of hand painting workstations. While certain studies may touch upon elements of workstation design, such as the importance of adjustable furniture or proper lighting, there is a clear need for further research to develop a comprehensive framework that addresses the full spectrum of ergonomic considerations in hand painting workstations. Such a framework would serve as a valuable tool for employers, designers, and occupational health professionals, guiding them in creating work environments that promote the comfort, productivity, and safety of hand painters.

To develop the required framework, ISM along with SF-DEMATEL had proven its effectiveness in the existing literature. ISM allows for the creation of a hierarchical structure that elucidates the interdependencies among various ergonomic factors relevant to hand painting workstations. By systematically organizing these factors into a hierarchical framework, ISM enables researchers and practitioners to gain a comprehensive understanding of how different elements interact and influence one another within the workstation environment. This structured approach facilitates the identification of key factors that have a significant impact on overall workstation ergonomics, thus providing valuable insights into where interventions should be focused.

On the other hand, DEMATEL is particularly useful for analyzing the cause-and-effect relationships between different factors identified within the ISM framework. By quantitatively assessing the strength and direction of these relationships, DEMATEL helps prioritize which factors are most influential in driving overall workstation ergonomics. This prioritization allows stakeholders to allocate resources more effectively, focusing on addressing the most critical factors that have the greatest impact on improving workstation design for hand painters.

Furthermore, the integration of ISM and DEMATEL provides a holistic approach to problem-solving, combining qualitative and quantitative methods to address the complexity of ergonomic considerations in workstation design. Together, these methodologies offer a systematic and rigorous approach for developing a comprehensive framework for improving workstation ergonomics for hand painters, ultimately leading to the creation of safer, more comfortable, and more productive work environments.

Based on the above description, the following research gaps are identified and addressed in this paper

1. Identification of all ergonomic factors, shortlisting significant ergonomic factors and derive their interrelationships for hand fabric painting workers.
2. Develop IS model for reducing perceived exertion.
3. Development of a hybrid ISM–DEMATEL framework to priortise ergonomic risks under spherical fuzzy environment.

Identification of Contributing Factors

A comprehensive literature review was conducted to identify factors contributing to ergonomic hazards in the workplace. In the initial phase, relevant research papers were sourced from scholarly databases, including ScienceDirect, google scholar etc. The search employed specific keywords and phrases such as 'ergonomic risk factor,' 'work-related hazards,' 'risk at workplace,' 'injuries,' 'musculoskeletal disorders,' and 'ergonomic evaluation factors.' This systematic review yielded a list of contributing factors (CFs). In the subsequent phase, a conversation was held with a panel of three experts, comprising two academic scholars and one industry professional. This expert consultation facilitated the identification and classification of eleven pertinent CFs, as detailed in Table 1.

Materials and Methods

This research paper investigates the effectiveness and receiving ability of the ISM and Spherical Fuzzy DEMATEL techniques in addressing decision–making problems. These methods are preferred over other multi–criteria decision–making approaches because of their integration capabilities, making them powerful tools for decision–making. The ISM technique uses a binary comparison matrix comprising only of 0's and 1's to analyse causal relationships among different criteria, while the SPF DEMATEL technique represents these relationships with positive integers. The study's research methodology flowchart is illustrated in Fig. 1.

Spherical Fuzzy Sets (SFS)

SFS is an extension of fuzzy sets that combines Pythagorean fuzzy sets (PFS) and Neuromorphic sets.[35] SFS enables decision–makers to express their uncertain opinions through following settings.

Definition 1. A SFS $\tilde{A}_S$ of a universe of discourse X can be stated as in Eq. (1–2).

$$\tilde{A}_S = \left\{\left\langle \mathrm{x}, \mu_{\tilde{A}_S}(\mathrm{x}), v_{\tilde{A}_S}(\mathrm{x}), \pi_{\tilde{A}_S}(\mathrm{x}) \mid \mathrm{x} \in \mathrm{X}\right\rangle\right\} \quad \text{... (1)}$$

where,

$$\mu_{\tilde{A}_S}(x): X \to [0,1], v_{\tilde{A}_S}(x): X \to [0,1], \pi_{\tilde{A}_S}(x): X \to [0,1]$$
$$and$$
$$0 \le \mu^2_{\tilde{A}_S}(x) + v^2_{\tilde{A}_S}(x) + \pi^2_{\tilde{A}_S}(x) \le 1, \forall x \in X \quad \text{... (2)}$$

The membership degree, non–membership degree, and hesitancy degree of x to $\tilde{A}_S$ are denoted by $\mu_{\tilde{A}_S}(x)$, $v_{\tilde{A}_S}(x)$, and $\pi_{\tilde{A}_S}(x)$, respectively, for each x in X. Numerical operations have been developed by examining the relationship between SFS and PFS.

Definition 2. The following definitions pertain to basic operators (Eqs 3–7) for two spherical fuzzy sets (SFSs) from universes of discourse X_1 and X_2, represented as $\tilde{A}_S = (\mu_{\tilde{A}_S}, v_{\tilde{A}_S}, \pi_{\tilde{A}_S})$ and $\tilde{B}_S = (\mu_{\tilde{B}_S}, v_{\tilde{B}_S}, \pi_{\tilde{B}_S})$, respectively, in this research paper. Let X_1 and X_2 denote the two universes of discourse:

Addition

$$\tilde{A}_S \oplus \tilde{B}_S = \left\{\left(\mu^2_{\tilde{A}_S} + \mu^2_{\tilde{B}_S} - \mu^2_{\tilde{A}_S}\mu^2_{\tilde{B}_S}\right)^{\frac{1}{2}}, v\tilde{A}_S v_{\tilde{B}_S}, \left((1 - \mu^2_{\tilde{B}_S})\pi^2_{\tilde{A}_S} + (1 - \mu^2_{\tilde{A}_S})\pi^2_{\tilde{B}_S} - \pi^2_{\tilde{A}_S}\pi^2_{\tilde{B}_S}\right)^{\frac{1}{2}}\right\} \quad \text{... (3)}$$

Table 1 — Identified factors

S.N	Factor	Description
1	Tasks requirements[24]	Task requirements may include the necessary tools, equipment, and materials, the physical demands of the task, the duration and frequency of the task, and the cognitive demands, such as the mental workload and required decision–making.
2	Working height/area[25]	The working height/area refers to the appropriate ergonomic positioning of the work surface and equipment in relation to the worker's body dimensions and the type of task being performed to minimize discomfort and risk of injury.
3	Sit/Stand arrangement[26]	A sit/stand arrangement allows workers to alternate between sitting and standing positions during work tasks to reduce the risks associated with prolonged sitting or standing and promote better circulation and musculoskeletal health.
4	Posture[27]	Posture refers to the alignment and positioning of the body during work tasks, which can affect musculoskeletal health and work performance.
5	Repetitive movements[28]	Repetitive movements involve performing the same or similar motions repeatedly, which can cause fatigue, strain, and injury to the muscles, tendons, and nerves, and ergonomic interventions aim to reduce or modify repetitive movements to minimize these risks.
6	Rest periods[29]	Rest periods are designated breaks from work tasks that allow workers to recover from physical or mental fatigue, reduce the risk of injury, and promote work performance and well–being, and ergonomic guidelines may provide recommendations for appropriate rest periods depending on the nature of the work tasks.
7	Perceived exertion[30]	Perceived exertion is a subjective measure of the physical and mental effort required to perform a task, and it can be influenced by various factors such as individual characteristics, task demands, and environmental conditions, and ergonomic assessments may include measures of perceived exertion to inform modifications to work tasks or environments.
8	Task illumination[31]	Task illumination refers to the level and quality of lighting provided for work tasks, which can affect visual acuity, eye strain, and overall work performance, and ergonomic principles aim to optimize task illumination to reduce the risk of visual discomfort, errors, and accidents.
9	Environmental conditions[32]	Environmental conditions refer to factors such as temperature, humidity, noise, and vibration in the workplace that can affect worker comfort, safety, and well–being, and ergonomic interventions may aim to modify or control these conditions to minimize their negative impact on workers.
10	Positioning of painting tools[33]	The positioning of painting tools in the workplace involves the arrangement of equipment such as paintbrushes, rollers, and sprayers in a manner that minimizes physical strain, reduces the risk of injury, and optimizes performance and efficiency during painting tasks.
11	Physical attributes/Anthropometry[34]	It refers to the human body size, shape, and proportions, which are important considerations in ergonomic design to ensure that workstations and equipment are appropriate for the intended user population.

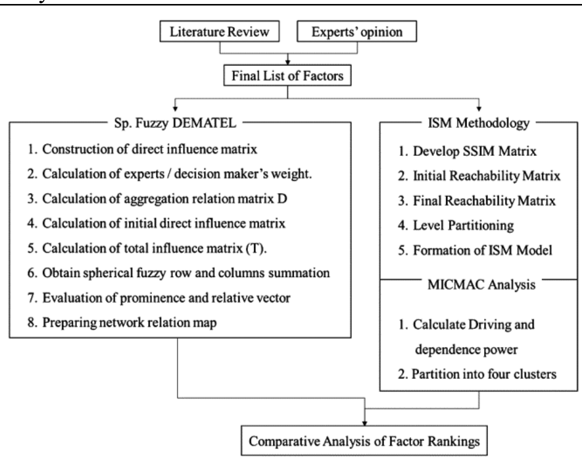

Fig. 1 — Research methodology

Multiplication

$$\tilde{A}_S \otimes \tilde{B}_S = \left\{\mu_{\tilde{A}_S}\mu_{\tilde{B}_S}, \left(v_{\tilde{A}_S}^2 + v_{\tilde{B}_S}^2 - v\tilde{A}_S^2 v_{\tilde{B}_S}^2\right)^{\frac{1}{2}}, \left(\left(1 - v_{\tilde{B}_S}^2\right)\pi_{\tilde{A}_S}^2 + \left(1 - v\tilde{A}_S\right)\pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2\pi_{\tilde{B}_S}^2\right)^{\frac{1}{2}}\right\} \quad \text{... (4)}$$

Scalar Multiplication (λ> 0)

$$\lambda_* \tilde{A}_S = \left\{\left(1 - \left(1 - \mu_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}, v\tilde{A}_S, \left(\left(1 - \mu_{\tilde{A}_S}^2\right)^{\lambda} - \left(1 - \mu_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}\right\} \quad \text{... (5)}$$

Power of $A\tilde{S}$ (λ> 0)

$$\tilde{A}_S^{\lambda} = \left\{\mu_{\tilde{A}_S}^{\lambda}, \left(1 - \left(1 - v_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}, \left(\left(1 - v_{\tilde{A}_S}^2\right)^{\lambda} - \left(1 - v_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\right)^{\lambda}\right)^{\frac{1}{2}}\right\} \quad \text{... (6)}$$

Definition 3. To facilitate aggregation, the SWAM indicating spherical weighted arithmetic means defined as follows (Eq. 7), where the w = (w_1, w_2, …, w_n) has values in the range [0,1] and satisfies the condition $\sum_{i=1}^{n} w_i = 1$.

$$SWAM_w(\tilde{A}_{S1},\tilde{A}_{S2},\dots,\tilde{A}_{Sn})$$

$$= w_1\tilde{A}_{S1} + w_2\tilde{A}_{S2} + \cdots + w_n\tilde{A}_{Sn}$$

$$= \left\{\left[1 - \prod_{i=1}^{n}\left(1-\mu_{\tilde{A}_{Si}}^{2}\right)^{w_i}\right]^{\frac{1}{2}}, \prod_{i=1}^{n} v\tilde{A}_{Si}^{w_i}, \left[\prod_{i=1}^{n}\left(1-\mu_{\tilde{A}_{Si}}^{2}\right)^{w_i} - \prod_{i=1}^{n}\left(1-\mu_{\tilde{A}_{Si}}^{2}-\pi_{\tilde{A}_{Si}}^{2}\right)^{w_i}\right]^{\frac{1}{2}}\right\} \quad \dots (7)$$

Spherical Fuzzy DEMATEL

This approach offers a solution to the uncertainties and ambiguities associated with decision–making problems, by extending the traditional DEMATEL method to consider the hesitancy of experts.[36] Unlike traditional DEMATEL, Spherical Fuzzy DEMATEL takes into account the indirect and direct impact of different criteria on each other, while allowing decision–makers to consider more complex and uncertain scenarios. Several researchers have used this approach in their studies. This method is particularly useful when dealing with complex systems with uncertain or imprecise data, where traditional decision–making methods may not be effective. This technique has found practical applications in fields such as finance, engineering, and environmental management, proving to be an effective tool for solving real–world decision–making problems.

The methodology is adopted from the research[36] which is explained below.

Step 1 – Finalizing Factors and Experts

In the present decision–making problem, the potential decision is influenced by n attributes and m experts. The selection of decision–makers and their level of expertise must be clearly explained, along with the factors chosen and appropriate justifications for their selection, such as references to relevant scientific literature or industrial cases. In case any factor includes sub–factors, they must be appropriately represented to ensure clarity and accuracy.

Step 2 – Construction of Direct Influence Matrix

In order to gather input from the experts regarding the potential relationships among the factors, they are requested to express their preferences or opinions. To aid in this process, a linguistic term set has been provided, which is shown in Table 2. The corresponding values are assigned a score index (SI). SI is calculated using Eq. 8.

$$SI = \sqrt{\left|100 * \left[(\mu-\pi)^2 - (v-\pi)^2\right]\right|} \quad \dots (8)$$

Table 2 — Linguistic Terms

Definition	Strong	Moderate	Weak	No influence
Abb	S	M	W	NI
μ	0.85	0.6	0.35	0
ν	0.15	0.2	0.25	0.3
π	0.45	0.35	0.25	0.15
SI	3	2	1	0

Step 3: Estimation of Experts' Weightage

In this step, it was assumed that each of the experts have a weightage value in relation to their skill and level of experience. The spherical fuzzy depiction of the experts is denoted by $E_e = (\mu_e, v_e, \pi_e)$, and the corresponding weight was calculated using Eq. 9.

$$\omega_e = \frac{1-\sqrt{\{(1-\mu_e)^2 + v_e^2 + \pi_e^2\}/3}}{\sum_e\left(1-\sqrt{\{(1-\mu_e)^2 + v_e^2 + F\pi_e^2\}/3}\right)} \quad \dots (9)$$

where, $\sum_{e=1}^{m}\omega_e = 1$ and $0 \le \mu_e^2 + v_e^2 + \pi_e^2 \le 1$.

Step 4 – Calculation Aggregation Relation Matrix D^{agg}

Using the Eq. 10 to calculate the values for the D^{agg} matrix. The direct impact assessment matrices from the various decision–makers are combined using the spherical weighted arithmetic mean (SWAM).The resulting D^{agg} matrix is an aggregation of the direct influence matrix and is calculated using Eq. 11.

$$D^{agg} = SWAM_\omega(D^1, D^2, \dots, D^m) = \omega_1 D^1 + \omega_2 D^2 + \cdots + \omega_m D^m = \left\langle \mu_{ij}^{agg}, v_{ij}^{agg}, \pi_{ij}^{agg}\right\rangle$$

$$= \left\{\left[1 - \prod_{e=1}^{m}\left(1-\left(\mu_{ij}^{e}\right)^2\right)^{\omega_e}\right]^{\frac{1}{2}}, \prod_{e=1}^{m}\left(v_{ij}^{e}\right)^{\omega_e}, \left[\prod_{e=1}^{m}\left(1-\left(\mu_{ij}^{e}\right)^2\right)^{\omega_e} - \prod_{i=1}^{m}\left(1-\left(\mu_{ij}^{e}\right)^2-\left(\pi_{ij}^{e}\right)^2\right)^{\omega_e}\right]^{\frac{1}{2}}\right\} \quad \dots (10)$$

$$D^{agg} = \begin{bmatrix} 0 & \langle \mu_{12}^{agg}, v_{12}^{agg}, \pi_{12}^{agg}\rangle & \cdots & \langle \mu_{1n}^{agg}, v_{1n}^{agg}, \pi_{1n}^{agg}\rangle \\ \langle \mu_{21}^{agg}, v_{21}^{agg}, \pi_{21}^{agg}\rangle & 0 & \cdots & \langle \mu_{2n}^{agg}, v_{2n}^{agg}, \pi_{2n}^{agg}\rangle \\ \vdots & \vdots & \ddots & \vdots \\ \langle \mu_{n1}^{agg}, v_{n1}^{agg}, \pi_{n1}^{agg}\rangle & \langle \mu_{n2}^{agg}, v_{n2}^{agg}, \pi_{n2}^{agg}\rangle & \cdots & 0 \end{bmatrix} \quad \dots (11)$$

Step 5: Formation of the Initial Direct Influence Matrix (IDIM)

In order to handle the three elements in each comparison pair, the aggregated direct influence matrix (D^{agg}) needs to be divided into three submatrices. The submatrices corresponding to the membership, non–membership, and hesitancy degrees are subjected to matrix operations, normalized, and then combined into a single matrix to construct the IDIM. Normalization is performed using formula in Eq. 12, and resulting matrix is expressed in form of Eq. 13.

$$X = sD, \text{ where } s = \min\left[\frac{1}{\max_i \sum_{j=1}^{n} |d_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |d_{ij}|}\right] \quad \dots (12)$$

$$X^{\mu} = \begin{bmatrix} 0 & \mu_{12} & \cdots & \mu_{1n} \\ \mu_{21} & 0 & \cdots & \mu_{21} \\ \vdots & \vdots & \ddots & \vdots \\ \mu_{n1} & \mu_{n2} & \cdots & 0 \end{bmatrix}; X^{v} = \begin{bmatrix} 0 & v_{12} & \cdots & v_{1n} \\ v_{21} & 0 & \cdots & v_{21} \\ \vdots & \vdots & \ddots & \vdots \\ v_{n1} & v_{n2} & \cdots & 0 \end{bmatrix}; X^{\pi} = \begin{bmatrix} 0 & \pi_{12} & \cdots & \pi_{1n} \\ \pi_{21} & 0 & \cdots & \pi_{21} \\ \vdots & \vdots & \ddots & \vdots \\ \pi_{n1} & \pi_{n2} & \cdots & 0 \end{bmatrix} \quad \dots (13)$$

Step 6: Forming Total Influence Matrix (TIM–> T)

To obtain the TIM of T, the IDIM is used as a base. The submatrices of X are transformed into submatrices of T using Eq. 14. To make these submatrices compatible with the principles of fuzzy logic, they need to be adjusted through Euclidean normalization. The combined T matrix can be formed using Eq. 15.

$$\mathrm{X}' = \mathrm{X}^2 + \mathrm{X}^3 + \mathrm{X}^4 + \cdots + \mathrm{X}^{\infty} = \mathrm{X}^2(\mathrm{I} - \mathrm{X})^{-1} \quad \dots (14)$$

$$T = \begin{bmatrix} \langle \mu_{11}^T, v_{11}^T, \pi_{11}^T \rangle & \langle \mu_{12}^T, v_{12}^T, \pi_{12}^T \rangle & \cdots & \langle \mu_{1n}^T, v_{1n}^T, \pi_{1n}^T \rangle \\ \langle \mu_{21}^T, v_{21}^T, \pi_{21}^T \rangle & \langle \mu_{22}^T, v_{22}^T, \pi_{22}^T \rangle & \cdots & \langle \mu_{2n}^T, v_{2n}^T, \pi_{2n}^T \rangle \\ \vdots & \vdots & \ddots & \vdots \\ \langle \mu_{n1}^T, v_{n1}^T, \pi_{n1}^T \rangle & \langle \mu_{n2}^T, v_{n2}^T, \pi_{n2}^T \rangle & \cdots & \langle \mu_{nn}^T, v_{nn}^T, \pi_{nn}^T \rangle \end{bmatrix} \quad \dots (15)$$

Step 7 – Calculation of SF Summation of Row and Columns

Eq. 3 is used to define the addition operation, which is employed to calculate the row (r_i) and column (c_j) sums. The operational details are presented in Eqs 16 & 17.

$$r_i = \sum_{i=1}^{n} \langle \mu_{ij}^T, v_{ij}^T, \pi_{ij}^T \rangle \quad \dots (16)$$

$$c_j = \sum_{j=1}^{n} \langle \mu_{ij}^T, v_{ij}^T, \pi_{ij}^T \rangle \quad \dots (17)$$

At the end of this stage, the strength (r_i) and weakness (c_j) values associated with each factor is determined and represented as SF numbers. De–fuzzification of these numbers can be done using Eq. 18.

$$\text{Score } = (2\mu - \pi)^2 - (v - \pi)^2 \quad \dots (18)$$

Step 8 – Calculation of r+c and r–c and Building Network Relation Map (NRM)

To elaborate on this, the prominence (r+c) of an attribute refers to its overall strength, which takes into account both the direct and indirect impact on the other attributes. The relation of an attribute, on the other hand, refers to its role in the network of causal dependencies among the attributes, indicating whether it is primarily a cause or an effect in the system. The sign of the relation value determines the group to which the attribute belongs. If the relation value is positive, the attribute is in the cause group, and if it is negative, the attribute is in the effect group.

The NRM (Network Relationship Map) represents the causal dependencies or influences among the attributes. The horizontal axis of NRM represents the attribute's prominence value, and the vertical axis shows its relation value. To identify the significant influences among attributes, the TIM is filtered with respect to a threshold (α) which is the average of all the defuzzified values.

Interpretive Structural Modelling

The ISM was developed by Warfield.[37] In this approach, each level of the hierarchy represents a set of components that are interrelated and hold a similar level of importance within the system. The hierarchy delineates the components, with the most important elements positioned at the top and the least important ones at the bottom.The ISM model has been used in various domains in the past.[38,39]

ISM is formed using following steps:

Step 1 – Develop Structural Self–Interaction Matrix (SSIM)

To form the SSIM matrix, experts' views were collected to map relationships between factors (Fig. 2). Experts compared each factor pair "and indicated relationships using four variables: 'V' (i influences j), 'A' (j influences i), 'X' (i and j influence each other), and 'O' (no relation). The final SSIM matrix is shown in Table 3.

Step 2 and 3 – Preparing Initial and Final Reachability Matrix (RM)

To transform the SSIM into a reachability matrix, 'V', 'A', 'X', and 'O' were replaced with either 1 or 0 based on the following rules:

- When SSIM at (i, j) is 'V', RM at (i, j) becomes 1, while RM at (j, i) becomes 0.
- When SSIM at (i, j) is 'A', RM at (i, j) is set to 0, and RM at (j, i) is set to 1.

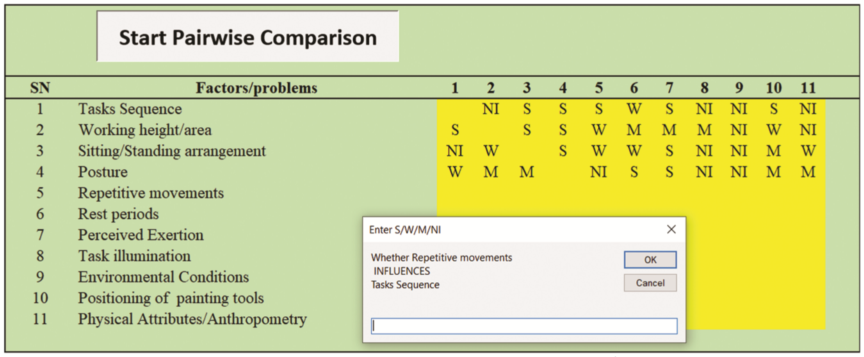

Fig. 2 — Sample front end for opinion collection

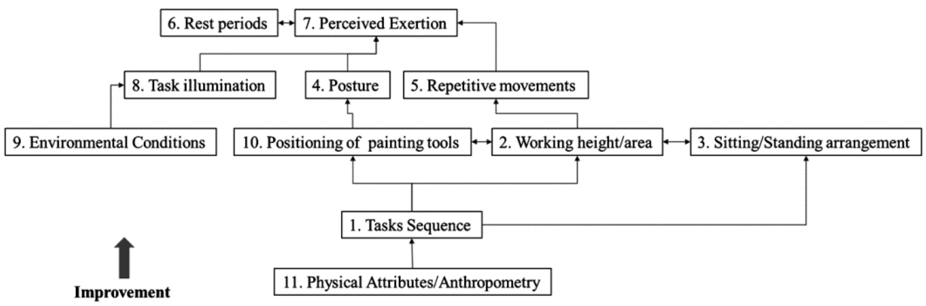

Fig. 3 — ISM Model

Table 3 — Final Reachability Matrix (FRM)

S N	Factors/Problems	1	2	3	4	5	6	7	8	9	10	11	DR.P
1	Tasks sequence	1	1	1	1	1	1	1	1	0	1	0	9
2	Working height/area	0	1	1	1	1	1	1	1	0	1	0	8
3	Sitting/Standing arrangement	0	1	1	1	1	1	1	1	0	1	0	8
4	Posture	0	0	0	1	0	1	1	0	0	0	0	3
5	Repetitive movements	0	0	0	0	1	1	1	0	0	0	0	3
6	Rest periods	0	0	0	0	0	1	1	0	0	0	0	2
7	Perceived exertion	0	0	0	0	0	1	1	0	0	0	0	2
8	Task illumination	0	0	0	0	0	1	1	1	0	0	0	3
9	Environmental conditions	0	0	0	0	0	1	1	1	1	0	0	4
10	Positioning of painting tools	0	1	1	1	1	1	1	1	0	1	0	8
11	Physical attributes/Anthropometry	1	1	1	1	1	1	1	1	0	1	1	10
	DEPENDENCE POWER	2	5	5	6	6	11	11	7	1	5	1	**60**

- If SSIM at (i, j) is 'X', then RM at both (i, j) and (j, i) are assigned a value of 1.
- If SSIM at (i, j) is 'O', then RM at both (i, j) and (j, i) are assigned a value of 0.

Step 4 – Level Partitions

The reachability set was formed for each factor where there is a 1 in the ith row, and the antecedent set was prepared where there is a 1 in the jth column. The intersection set, consisting of common factors between the reachability and antecedent sets, was then computed for all factors. The ith factor with identical elements in its reachability and intersection sets was assigned to level I. This factor was subsequently omitted, and the process was repeated to form new intersection sets until all factors were partitioned into levels. This iterative level partitioning resulted in levels I to V, as shown in Table 4, aiding in constructing the digraph and the final ISM model.

Step 5– Replacing Criteria Nodes with Relationship and Forming ISM

The information presented in Table 4 comprises the level partition tables utilized in creating the ISM model (Fig. 3). Factors are interconnected based on their respective relationships with one another.

MICMAC Analysis

MICMAC analysisis a strategic management tool designed for assessing the interrelationships among a set of variables or factors. Frequently applied in strategic planning, marketing, and environmental management, MICMAC helps decision–makers understand the dynamics within a system by categorizing factors into those with high driving power and those with high dependence.

The driving power (DP) of a factor denotes its ability to exert influence on other elements within the system. Factors with high driving power are recognized as influential forces that significantly shape the overall system. On the other hand, dependence (D) reflects how much a factor is influenced by other elements. Factors with high

Table 4 — Level Partitioning

S. N	Factors/Problems	Reachability set	Antecedent set	Level
1	Tasks sequence	1,2,3,4,5,6,7,8,10,	1,11,	IV
2	Working height/area	2,3,4,5,6,7,8,10,	1,2,3,10,11,	III
3	Sitting/Standing arrangement	2,3,4,5,6,7,8,10,	1,2,3,10,11,	III
4	Posture	4,6,7,	1,2,3,4,10,11,	II
5	Repetitive movements	5,6,7,	1,2,3,5,10,11,	II
6	Rest periods	6,7,	1,2,3,4,5,6,7,8,9,10,11,	I
7	Perceived exertion	6,7,	1,2,3,4,5,6,7,8,9,10,11,	I
8	Task illumination	6,7,8,	1,2,3,8,9,10,11,	II
9	Environmental conditions	6,7,8,9,	9,	III
10	Positioning of painting tools	2,3,4,5,6,7,8,10,	1,2,3,10,11,	III
11	Physical attributes/Anthropometry	1,2,3,4,5,6,7,8,10,11,	11,	V

dependence are considered more passive, as they are influenced by other variables.

The analysis involves constructing a matrix that illustrates the intricate relationships between different factors. Decision–makers use MICMAC to prioritize and concentrate efforts on the most influential elements within a system, aiding in the development of effective and targeted strategies. However, it's crucial to recognize that MICMAC analysis requires expertise for accurate interpretation and application in specific contexts.

MICMAC analysis assesses factors' driving force and dependence on a problem or goal. According to its principle, if X influences Y (X –> Y) and Y influences Z (Y –> Z), then X indirectly influences Z (X –> Z). MICMAC categorizes factors into Autonomous, Dependent, Linkage, and Driving groups, shown in Fig. 4.

Various studies have integrated ISM with MICMAC analysis for more detailed analysis. By integrating ISM and MICMAC analyses, decision–makers can create a comprehensive framework for strategic planning, ensuring a more informed and effective approach to address the complexities of the analyzed system. In a study[55], analysis of infrastructure influence in supporting submarine operations was performed using integrated ISM–MICMAC analysis.

Results

In the present study, integrated approach combining ISM and DEMATEL with Spherical fuzzy membership functions are used. Literature review along with expert opinions was utilized to shortlist eleven factors. Two methodologies were used to evaluate the influence of the factors. The results of this study are divided into two parts. The first part consists of the results obtained after application of SF DEMATEL method. The second part consists of application of ISM methodology followed by MICMAC analysis.

Table 5 — Relationship mapping done by expert 1(Sample)

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
F1	0	M	S	S	S	W	S	S	NI	S	W
F2	S	0	S	S	W	M	M	W	NI	W	NI
F3	NI	W	0	S	W	M	S	NI	NI	M	W
F4	W	M	M	0	NI	S	S	NI	NI	M	M
F5	W	W	M	S	0	S	S	NI	NI	M	S
F6	NI	NI	M	NI	NI	0	S	NI	NI	NI	NI
F7	NI	NI	W	M	W	S	0	NI	NI	NI	W
F8	W	W	NI	W	NI	M	W	0	NI	M	NI
F9	M	NI	NI	NI	NI	M	M	M	0	NI	NI
F10	M	W	M	S	M	S	S	NI	NI	0	NI
F11	M	S	S	S	W	M	M	NI	NI	M	0

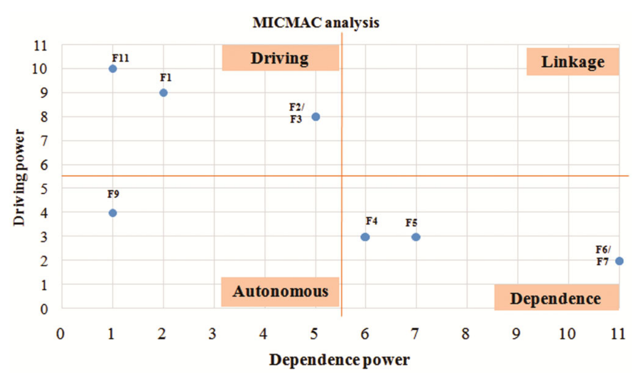

Fig. 4 — MICMAC analysis

Application of SF DEMATEL

In step 1, a group of three experts, including two from academia and one from industry were selected for taking suggestions. The eleven factors were shortlisted after taking inputs from the experts. Each expert was asked to map the relationship between two variables as S indicating strong influence, M indicating medium influence, W indicating weak influence and NI indicating no influence respectively. The linguistic terms used and their associated SI score is shown in Table 2. A sample relationship mapping is shown in Table 5. The SI score was identified using Eq. 8. Step 3 involves calculation of decision makers’ weights values. It is calculated based on Eq. 9. The decision makers; weights (ω1, ω2, ω3) are approximated as 0.3637, 0.3724, and 0.2639 respectively. The summation of weights equals one. In step 4, the aggregated direct relation matrix (D^{agg}) was prepared using Eq. 10. Each column represents $\left\langle \mu_{ij}^{agg}, v_{ij}^{agg}, \pi_{ij}^{agg} \right\rangle$ values as depicted in Eq. 11. The separated submatrices representing membership, non–membership and hesitancy (Dμ, Dv, Dπ), are subjected to matrix operations, normalized, and then combined into a single matrix to construct the initial direct influence matrix. Normalization of D matrix is accomplished using Eq. 12 denoted by (Xμ, Xv, Xπ). Using Eqs 13 & 14, the total influence matrix is obtained indicated by (Tμ, Tv, Tπ). The obtained matrices are again integrated to form combined total influence matrix (Tμ,v,π) as shown in Table 6. In order to determine the significance of the criteria, a set of calculations were performed using Eqs 16 & 17 for the row sum and column sum respectively. Using Eq. 18 the Prominence and Relation values, which were then converted into score numbers are calculated. The resulting scores were employed to rank the criteria and establish cause–and–effect groups, as shown in Table 7.

The significance level of the criteria is as follows: F3> F1> F4> F11> F10> F2> F5> F8> F9> F7>F6 based on (r–c) values and F5>F11>F10>F6>F2>F7> F1>F8>F9>F4>F3 based on (r+c) values respectively. The study revealed that repetitive movements is one of the most influential factors to musculoskeletal risks involved in painting task. Additionally, these eleven criteria were categorized into two groups (Cause and Effect) to present the interactional relations between them clearly. Criteria belonging to the cause group are 'Tasks requirements', 'Sit/Stand arrangement', 'Posture', and 'Physical attributes/Anthropometry'. The remaining criteria belong to the effect group, including 'Working height/area', 'Repetitive movements', 'Rest periods', 'Perceived Exertion', 'Task illumination', 'Environmental conditions', and 'Positioning of painting tools'. The study found that the four criteria in the cause group are crucial in the evaluation process and have a direct impact on the remaining criteria. Therefore, it is recommended that decision–makers prioritize and consider the above stated cause factors for improvement. The task requirements need to be rectified correctly at the beginning of work allocation. As per task requirements, sit/stand arrangement is properly planned. Everything must be designed as per the human anthropometric dimensions. Workstation design should be such that it must ensure a good posture at workplace. If these factors are controlled, then chances of occurrence of MSDs will be minimized.

To determine the significance and relationships between assessment criteria, both (r–c) and (r+c) values were used for ranking. The network relationship map was created using an α value of 0.102, which was the average of the total relation matrix. The Network Relationship Map (NRM) is shown in Fig. 5. The cause–and–effect or NRM graph was divided into four parts, labeled I to IV. Part I includes Physical attributes/Anthropometry (F11) which is the causal criteria that have the most significant impact. Tasks requirements (F1), Posture (F4), and Sit/Stand arrangement (F3) are located in Part II and are classified as low prominence and high relation criteria. In Part III, Task illumination (F8) and Environmental conditions (F9) are independent of the system due to their low prominence and relation values. Finally, working height/area (F2), Repetitive movements (F5), Rest periods(F6), Perceived exertion (F7), and Positioning of painting tools (F10) are situated in Part IV and are highly influenced by other factors.

Application of ISM

In ISM, influence is measured in binary form i.e. in 0 and 1 only. There is no value in between indicating medium or weak influence as like in SF DEMATEL method. The experts were asked to map the relationship of influence between all the factors considering two factors at one time. To map the relationship, form shown in Fig. 2 was used. The relationship was mapped using V, A, X and O letters indicating i^{th} factor influencing j^{th} factor, j^{th} factor influencing i^{th} factor, both factors trying to influence each other, and no relation between the factors. The structural self–interaction matrix (SSIM) is formed by considering maximum number of experts giving the same judgment (Table 8). The initial reachability matrix (IRM) which was formed by utilizing the rules mentioned Step 2 and Step 3 of ISM methodology section. The row–wise summation of values provided in Table 3 indicates driving power of that factor. The column–wise summation of values indicates the dependence of that factor on the other factors.

To obtain the reachability set for factor 1, the corresponding row is searched for the value of '1' in

Table 6 — Total influence matrix (T)

		F1			F2			F3	
F1	0.178	0.484	0.313	0.292	0.574	0.393	0.408	0.501	0.497
F2	0.254	0.610	0.364	0.155	0.570	0.250	0.343	0.561	0.417
F3	0.166	0.636	0.302	0.234	0.631	0.330	0.215	0.495	0.309
F4	0.195	0.617	0.327	0.252	0.616	0.346	0.321	0.557	0.410
F5	0.203	0.603	0.341	0.254	0.609	0.356	0.342	0.543	0.432
F6	0.097	0.715	0.235	0.107	0.735	0.231	0.193	0.641	0.309
F7	0.077	0.709	0.235	0.121	0.722	0.242	0.175	0.646	0.298
F8	0.126	0.690	0.264	0.148	0.701	0.267	0.165	0.645	0.302
F9	0.182	0.656	0.326	0.083	0.711	0.249	0.145	0.639	0.307
F10	0.227	0.589	0.353	0.219	0.621	0.331	0.337	0.542	0.440
F11	0.287	0.562	0.410	0.327	0.572	0.409	0.412	0.512	0.475
		F4			F5			F6	
F1	0.436	0.478	0.521	0.269	0.609	0.391	0.385	0.499	0.494
F2	0.358	0.532	0.434	0.158	0.714	0.273	0.314	0.548	0.418
F3	0.355	0.521	0.432	0.176	0.690	0.283	0.355	0.521	0.456
F4	0.242	0.460	0.339	0.161	0.691	0.280	0.378	0.507	0.476
F5	0.390	0.502	0.479	0.143	0.573	0.248	0.415	0.490	0.504
F6	0.125	0.638	0.280	0.094	0.791	0.211	0.133	0.524	0.257
F7	0.218	0.594	0.335	0.114	0.768	0.228	0.274	0.566	0.378
F8	0.196	0.603	0.330	0.079	0.771	0.223	0.250	0.574	0.373
F9	0.123	0.613	0.312	0.070	0.764	0.229	0.231	0.569	0.378
F10	0.373	0.504	0.457	0.225	0.652	0.325	0.396	0.492	0.483
F11	0.431	0.486	0.493	0.208	0.648	0.321	0.409	0.489	0.491
		F7			F8			F9	
F1	0.478	0.436	0.582	0.202	0.602	0.340	0.011	0.708	0.218
F2	0.361	0.500	0.459	0.098	0.722	0.239	0.042	0.788	0.194
F3	0.400	0.470	0.485	0.052	0.712	0.224	0.009	0.778	0.182
F4	0.413	0.462	0.501	0.058	0.702	0.233	0.009	0.766	0.189
F5	0.449	0.448	0.531	0.063	0.680	0.247	0.009	0.742	0.200
F6	0.272	0.532	0.387	0.062	0.798	0.188	0.004	0.879	0.145
F7	0.162	0.469	0.293	0.030	0.789	0.183	0.004	0.863	0.150
F8	0.274	0.531	0.423	0.035	0.678	0.155	0.005	0.851	0.158
F9	0.263	0.521	0.430	0.141	0.744	0.251	0.003	0.743	0.122
F10	0.419	0.459	0.518	0.060	0.690	0.239	0.008	0.753	0.193
F11	0.446	0.454	0.527	0.111	0.660	0.271	0.012	0.726	0.208
		F10			F11				
F1	0.358	0.533	0.446	0.190	0.634	0.325			
F2	0.208	0.642	0.322	0.104	0.727	0.248			
F3	0.253	0.603	0.353	0.148	0.701	0.266			
F4	0.288	0.582	0.393	0.172	0.679	0.290			
F5	0.286	0.575	0.388	0.243	0.637	0.349			
F6	0.116	0.707	0.247	0.054	0.803	0.193			
F7	0.098	0.701	0.248	0.115	0.773	0.225			
F8	0.182	0.665	0.301	0.058	0.777	0.210			
F9	0.094	0.686	0.267	0.053	0.771	0.215			
F10	0.179	0.514	0.289	0.116	0.690	0.265			
F11	0.313	0.563	0.404	0.127	0.564	0.244			

Table 7 — Prominence and relation values

	r				c						
	µ	v	π	Score	µ	v	π	Score	Rank (r–c)	Rank (r+c)	Group
F1	0.8406	0.0013	0.5232	1.0687	0.7584	0.0053	0.6011	0.4835	2	7	Cause
F2	0.7822	0.0054	0.5571	0.7101	0.8305	0.0073	0.5168	1.0495	6	5	Effect
F3	0.7827	0.0041	0.5581	0.7080	0.6223	0.0020	0.6231	0.0003	1	11	Cause
F4	0.8032	0.0033	0.5447	0.8340	0.7205	0.0011	0.5872	0.3853	3	10	Cause
F5	0.8466	0.0023	0.5026	1.1674	0.9365	0.0179	0.3465	2.2223	7	1	Effect
F6	0.5327	0.0188	0.6201	–0.1632	0.9257	0.0008	0.3706	2.0560	11	4	Effect
F7	0.5602	0.0148	0.6258	–0.1287	0.9071	0.0003	0.4115	1.7986	10	6	Effect
F8	0.6121	0.0132	0.6322	–0.0328	0.8866	0.0213	0.4450	1.5849	8	8	Effect
F9	0.5869	0.0121	0.6561	–0.1469	0.8903	0.0647	0.4397	1.6574	9	9	Effect
F10	0.8186	0.0027	0.5335	0.9364	0.8261	0.0045	0.5202	1.0156	5	3	Effect
F11	0.8846	0.0017	0.4485	1.5444	0.8472	0.0202	0.4995	1.1978	4	2	Cause

Table 8 — Structural self–interaction matrix (SSIM)

S. N	Factors/Problems	1	2	3	4	5	6	7	8	9	10	11
1	Tasks sequence	–	O	O	V	V	V	V	O	O	V	A
2	Working height/area		–	V	V	O	V	V	V	O	A	A
3	Sitting/Standing arrangement			–	V	V	V	V	O	O	V	O
4	Posture				–	O	V	V	O	O	A	A
5	Repetitive movements					–	V	V	O	O	A	A
6	Rest periods						–	X	O	O	O	A
7	Perceived exertion							–	A	A	A	A
8	Task illumination								–	A	O	O
9	Environmental conditions									–	O	O
10	Positioning of painting tools										–	A
11	Physical attributes/Anthropometry											–

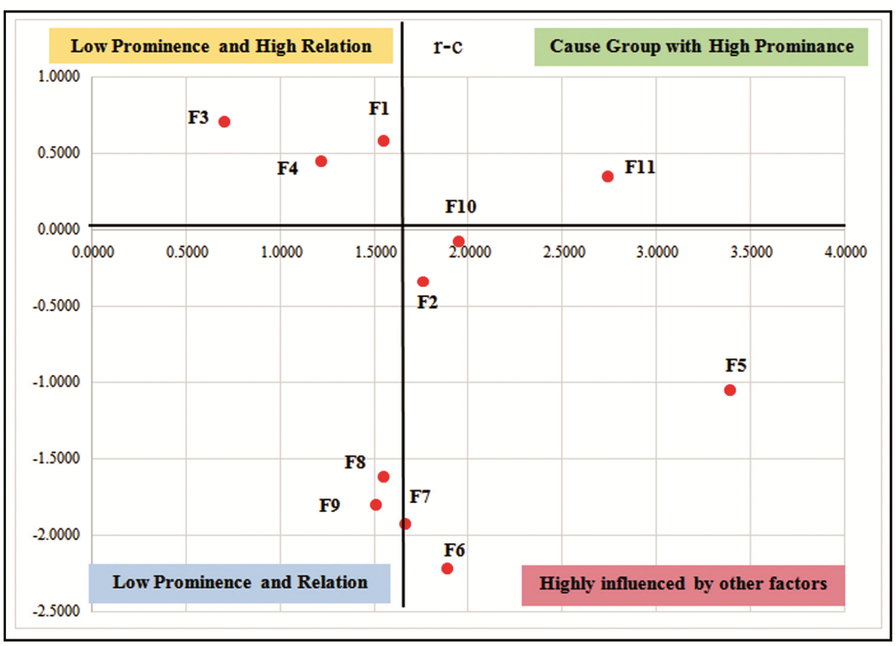

Fig. 5 — Network relationship map having 4 groups

Table 9 — MICMAC ranking of the factors

Factor	Factors/Problems	Dependence power	Driving Power	Driving/ Dependence power	MICMAC Rank
1	Tasks sequence	2	9	4.50	2
2	Working height/area	5	8	1.60	4
3	Sitting/Standing arrangement	5	8	1.60	4
4	Posture	6	3	0.50	7
5	Repetitive movements	6	3	0.50	7
6	Rest periods	11	2	0.18	10
7	Perceived exertion	11	2	0.18	10
8	Task illumination	7	3	0.43	9
9	Environmental conditions	1	4	4.00	3
10	Positioning of painting tools	5	8	1.60	4
11	Physical attributes/Anthropometry	1	10	10.00	1

Table 3. To obtain the antecedent set for factor 1, the corresponding column is searched for the value of ‘1’ in Table 3. The driving and dependence power for each factor is calculated in similar way explained earlier. The factors such as Physical Attributes/Anthropometry (F11), Tasks Sequence (F1) have more driving power than the other factors. The factors such as Rest periods (F6) and Perceived Exertion (F7) have the highest dependence power. Level partitioning consisting of reachability set and antecedent and associated levels is shown in Table 4. Reachability set /antecedent set consists of all such factors where it appears ‘1’. The factors got classified on five levels as shown in the Table 4. The developed ISM model is shown in Fig. 3. The arrows indicate the direction of improvement. The level I factors are the highly dependent factors. On the other hand, the base level factors are the driving factors for the improvement.

MICMAC Analysis

The values in Table 9 represent the driving, and dependence powers. The ranking based on MICMAC analysis is done based on the ratio of driving power to the dependence power of the factor in consideration. The Physical Attributes/Anthropometry (F11) is ranked 1 and Rest periods (F6) and Perceived Exertion (F7) attained the last rank. The MICMAC analysis diagram is represented in the Fig. 4. F1, F2, F3, and F11 are classified as driving factors. Factor such as (F9) is an autonomous factor. The factors involving (F4), (F5), (F6), and (F7) are categorized into dependent factors. On the other hand, no factor is grouped into linkage factors.

Discussion

The ISM and SF DEMATEL approaches can be implemented in prioritizing factors in workstation design to reduce occurrence of MSDs for a painting task. It is to analyze the relationships among different design factors and identify the most critical ones. The ISM approach can help identify the hierarchical structure of the design factors, showing how they are interrelated and how they contribute to the overall design. This can help designers to prioritize design factors based on their importance, and to identify the underlying drivers of design decisions. The DEMATEL approach can help identify the causal relationships between design factors and their impact on the overall design. It can also help identify the most critical design factors that have the greatest impact on the user experience. By using these approaches, designers can gain a deeper understanding of the complex relationships between design factors, and can make more informed design decisions. This can lead to the creation of more effective and user–friendly interfaces that meet the needs and expectations of the target audience.

AS per the ISM model shown in Fig. 3, the workstation designer/ ergonomic practitioners must focus physical attributes/ anthropometry of a worker working on that workstation. Based on anthropometry, task sequence can be planned. As per the task sequence, prepositioning of painting tools, deciding working area/height requirements, sitting standing position requirement may be formulated. Positioning of painting tools, working height/area, sit/stand arrangement will decide the nature of task, frequency of repetitive movement, posture of worker. Environmental conditions will decide the need of task illumination. Eventually, all these factors will decide the rests periods to be given for the task and exertion perceived by the worker. The objective is to minimize perceived exertion as well as fatigue caused due to working.

It is anticipated that this research will highlight some of the key factors which are to be properly designed for minimizing MSDs at workplace.

Rank Comparison

The comparison of the ranking of the factors obtained as per MICMAC analysis and SPF DEMATEL methods based on (r–c) values indicating relationships is provided in Fig. 6. The comparative analysis of factors influencing occupational safety and ergonomics, as assessed through both MICMAC and DEMATEL methods, reveals nuanced insights into their relative importance. "Physical Attributes/ Anthropometry" emerges as a pivotal factor, holding the top rank with a MICMAC Rank of 1, signifying its profound impact. However, the DEMATEL analysis places it at a slightly lower rank of 4, suggesting that while highly influential, its relative importance may be subject to contextual variations. "Factor Tasks Sequence" obtains a MICMAC Rank of 2, indicating substantial influence, and aligns with its DEMATEL rank of 2, emphasizing its consistent significance across both methodologies. Conversely, "Factor Repetitive Movements" garners a MICMAC Rank of 7 and DEMATEL rank of 7, implying a relatively lower impact, which aligns consistently across both analyses.

Notable variations arise with "Factor Sitting/ Standing Arrangement," which holds a MICMAC Rank of 4 but is perceived as significantly more influential with a DEMATEL rank of 1. This discrepancy suggests that while the factor may have a moderate impact according to the MICMAC model, it is deemed considerably more critical in the DEMATEL analysis. The "Factor Working Height/Area" attains a MICMAC Rank of 4, in line with its DEMATEL rank of 6, indicating a moderately impactful role. "Factor Posture" exhibits a MICMAC Rank of 7 and a DEMATEL rank of 3, showcasing differences in perceived importance across the two methodologies. The factors "Rest Periods" and "Perceived Exertion" both secure a MICMAC Rank of 10, while their DEMATEL ranks differ at 11 and 10, respectively. These factors may have a relatively lower impact according to the MICMAC model, but their significance may be subject to variations in the DEMATEL framework."Factor Task Illumination" and "Factor Environmental Conditions" display divergent ranks with MICMAC Ranks of 9 and 3, respectively, and DEMATEL ranks of 8 and 9. These differences suggest varying degrees of influence, emphasizing the importance of considering both models for a comprehensive understanding of their impact.

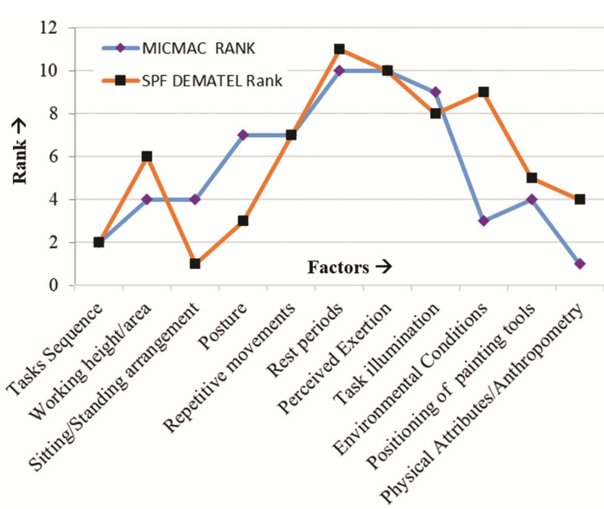

Fig. 6 — Rank Comparison based on relationship

Lastly, "Factor Positioning of Painting Tools" holds a MICMAC Rank of 4 and a DEMATEL rank of 5, showcasing its moderate influence on occupational safety according to both methodologies. Overall, the comparative analysis highlights the complex and context–dependent nature of factors influencing occupational safety and the importance of employing multiple analytical approaches for a thorough assessment. It is evident that ranks obtained in both the methods are approximately the same with slight deviation. Hence the use of SF DEMATEL method is validated for the case of ergonomic risk priority evaluation of hand fabric painters based on hybrid ism–DEMATEL approach under spherical fuzzy environment.

The Spearman's rank correlation coefficient analysis was performed to examine the relationship between the ranks assigned to factors in the MICMAC and DEMATEL analyses. The calculated differences (d) between corresponding pairs of ranks were then utilized to determine the correlation. The Spearman's rank correlation coefficient (ρ) was found to be 0.655, indicating a moderate positive correlation between the two sets of ranks. This suggests that as the rank of a factor increases in one analysis, it tends to increase in the other analysis, and vice versa. Notably, the correlation reveals insights into the consistency and agreement between the two methodologies, emphasizing the interconnectedness of the factors' perceived importance in both the MICMAC and DEMATEL frameworks.

Sensitivity Analysis

Conducting sensitivity analysis is crucial to assess the dependability of decisions made by evaluators.

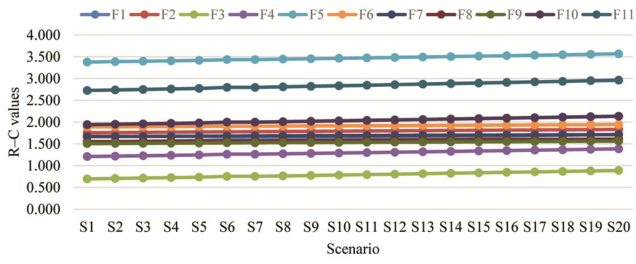

Fig. 7 — Sensitivity analysis

This involves examining the impact of different combinations of decision criteria weights, including scenarios where equal weightings are maintained and adjustments are made to assign more weight to specific evaluators. This approach allows for a comprehensive understanding of the effects associated with varying decision criteria weights.[40]

The creation of 20 distinct scenarios involves a 5% reduction in the weight assigned to the most crucial expert in each scenario. The alterations in the decision maker's weights have no discernible effect on the overall ranking of the factors (Fig. 7). This substantiates the model's stability and reliability.

Conclusions

The research sheds light on the ergonomic risks faced by hand painting workers, including musculoskeletal disorders, eye strain, and respiratory problems, due to factors such as awkward postures and repetitive motions. Eleven important success indicators are highlighted in the current work for developing an effective framework for MSDs risk reduction through the creation of ISM. The study underscores the paramount importance ofrepetitive movements, physical attributes/anthropometry in minimizing ergonomic risks. The study's validation of the decision–making approach's stability and adaptability, along with its application across diverse industries, further emphasizes its potential as a valuable tool for addressing vague or uncertain ergonomic data.

This study's model is based on the subjective opinions of a panel of experts. Therefore, structural equation modeling (SEM), also known as the linear structure relationship technique, can be applied in the future for the statistical validation of this model. Acknowledging limitations such as expert subjectivity is crucial. The future of risk evaluation/decision-making involves integrating big data, machine learning, behavioral analysis, and block chain.

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