

Application of MEAD method for occupational disease risk control in hotel housekeeping department

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Article history:

Received: 28 November 2025

Revised: 22 December 2025

Accepted: 29 December 2025

Published: 30 December 2025

Keywords:

Occupational health

Macroergonomic analysis and design

Job safety analysis

Hotel housekeeping department

ABSTRACT

Housekeeping activities in the hospitality industry are essential for service quality but are frequently associated with occupational health risks that may reduce productivity and increase employee health problems. Most existing prevention efforts focus on task-level hazards, with limited consideration of organizational and macro-level factors. Therefore, this study applies the Macroergonomic Analysis and Design (MEAD) method to address occupational disease risks in a hotel housekeeping department. Four major risk factors were identified: environmental exposure to chemical odors and waste; equipment and facility limitations, including restricted trolley mobility and inadequate Personal Protective Equipment (PPE); worker-related health complaints, reported by 67% of workers for skin and respiratory symptoms and by 50% for eye irritation, abrasions, and skin redness, with overlapping symptoms; and organizational factors related to insufficient operational supervision. Using the ten-stage MEAD framework, the housekeeping work system was redesigned through administrative controls, PPE provision, and safety awareness interventions. Post-implementation evaluation using Job Safety Analysis (JSA) showed a clear reduction in health complaints, with respiratory and skin irritation decreasing from frequent to rare and eye irritation and abrasions declining from occasional to non-occurring. These results demonstrate that MEAD is an effective framework for improving occupational health and safety in hotel housekeeping operations.

DOI:

<https://doi.org/10.31315/opsi.v18i2.16028>

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1. INTRODUCTION

Humans are the most critical element in any industrial work system, including in the service sector such as hospitality [1]. A work system consists of interactions among workers, technology, the environment, and

organizational design, all of which mutually influence the achievement of work objectives [2]. One of the key aspects of an effective work system is the establishment of a healthy and safe working environment [3]. Ensuring a healthy and safe working environment is therefore essential not only to protect workers but also to maintain operational efficiency and service reliability [4].

Housekeeping activities in the hospitality industry are essential for maintaining service quality but are frequently associated with occupational health risks that may reduce productivity and increase employee health problems [5]. The housekeeping department plays a vital role in maintaining cleanliness and comfort throughout hotel facilities [6]. Employees in this department generally work eight hours per day with a one-hour break. However, field observations and interviews revealed several persistent problems that adversely affect both work performance and occupational safety among housekeeping staff [7]. These problems include frequent exposure to hazardous chemical agents during cleaning and waste-handling activities, inadequate ventilation in the temporary waste storage (TWS) area, poor maintenance and limited mobility of cleaning equipment such as trolleys, insufficient availability and inconsistent use of personal protective equipment (PPE), and weak supervision of Occupational Safety and Health (OSH) practices [8]–[10].

In daily operations, housekeeping workers are routinely exposed to chemical substances such as methanol, hydrochloric acid, aldehydes, and ketones, as well as gases generated from decomposing organic and biological waste. Such exposure has been associated with respiratory disorders, skin irritation, and eye inflammation. As part of a preliminary field assessment, interview results indicated that 67% of workers frequently experienced skin irritation or itching, while 50% reported respiratory problems, eye irritation, abrasions, and skin redness, with several workers experiencing overlapping symptoms. Continuous exposure to chemical odors and waste contaminants throughout full work shifts further increases the risk of pulmonary function impairment and other occupational diseases [11], [12]. The absence of a specific department or personnel responsible for OHS monitoring aggravates these conditions [7]. In response to these risks, existing research has largely focused on hazard identification at the task level or compliance with occupational safety procedures [7], [13] – [15].

Despite these contributions, most previous studies adopt task-based or hazard-specific approaches, which primarily address immediate operational risks. While effective in identifying specific hazards, these approaches often overlook organizational, behavioral, and system-level factors, such as supervision quality, work organization, equipment maintenance policies, and safety culture, that significantly influence occupational health outcomes. As stated by [16], many studies consider human factors in the measurement or control of occupational health issues in industry; however, they tend to overlook higher-level regulatory and organizational factors, which can significantly influence safety outcomes. As a result, there is limited empirical research that integrates environmental, human, and organizational dimensions into a single framework for occupational disease prevention in housekeeping work systems, particularly within the hospitality industry.

Macroergonomics provides a systems-oriented perspective that emphasizes the alignment between organizational design, work processes, and human capabilities to improve safety and performance [17]. The Macroergonomic Analysis and Design (MEAD) method offers a structured ten-stage framework for analyzing and redesigning work systems by simultaneously considering technical, human, and organizational components [18]. Although MEAD has been applied in various industrial and manufacturing contexts, its application to occupational disease risk management in hotel housekeeping operations remains limited. This represents a clear research gap, particularly in understanding how macroergonomic interventions can complement conventional task-level safety assessments in service-sector environments.

Accordingly, the novelty of this study lies in the application of the MEAD method to address occupational disease risks in a hotel housekeeping department, integrating environmental exposure, worker health complaints, equipment and facility conditions, and organizational supervision into a unified macroergonomic framework. This research emphasizes system-level redesign and organizational interventions as key mechanisms for occupational disease prevention.

Therefore, this study aims to: (1) identify critical occupational disease risk factors within the housekeeping work system from a macroergonomic perspective; (2) analyze the interrelationships among environmental, human, equipment, and organizational factors using the MEAD framework; and (3) propose and evaluate integrated improvement strategies to reduce occupational health risks. Accordingly, this study contributes both methodologically and practically by advancing the application of macroergonomic principles for occupational health management in hospitality work systems.

2. MATERIALS AND METHODS

The study was conducted in the housekeeping department of a hotel industry located in Yogyakarta, Indonesia, between October 2024 and May 2025. The participants consisted of 6 housekeeping workers who were actively involved in daily cleaning and waste-handling activities. Inclusion criteria were full-time housekeeping employees with a minimum of 5 years of work experience. This study employed a mixed-methods approach with a single-group pre-post intervention design. Qualitative data were used to identify system-level problems, while quantitative data supported the evaluation of occupational health risk changes before and after the intervention.

The study was conducted through a systematic research procedure, beginning with preliminary observations to obtain an overview of the existing housekeeping work system and to identify potential occupational health risks. Data collection was carried out using direct observation, semi-structured interviews, document review, and the administration of a Job Safety Analysis (JSA) questionnaire. Direct observations were conducted during routine housekeeping activities to identify work processes, equipment usage, environmental conditions, and potential sources of occupational health risks. Interviews were conducted with housekeeping workers and supervisory personnel to obtain primary qualitative data regarding daily work practices, perceived health complaints, safety awareness, and existing occupational safety and health (OSH) procedures. In addition, secondary data, including the organizational structure and organizational profile, were obtained through the interviews. As part of a preliminary field assessment, interviews involved a purposive selection of participants representing different work tasks within the housekeeping department. Quantitative data were collected using a JSA-based questionnaire, which was distributed to all respondents to assess perceived hazard severity and frequency before and after the intervention. The JSA questionnaire consisted of five-point risk rating scale: 1 = never, 2 = rarely (once every 2 weeks–1 month), 3 = occasionally (once a week), 4 = often (2–4 times per week), 5 = very often (daily). The JSA instrument was adapted from standard JSA procedures commonly applied in occupational health and safety studies. The JSA is an occupational health and safety management technique used to systematically identify existing workplace hazards and associated risks by examining the interactions among workers, tasks, work environments, and equipment, as well as to define appropriate control and mitigation measures to prevent accidents [19].

The collected data were then processed and analyzed using the Macroergonomic Analysis and Design (MEAD) approach at the data analysis stage. In this study, MEAD was applied through ten sequential steps: (1) defining organizational subsystems; (2) defining the type of work system and performance expectations; (3) identifying operational units and work processes; (4) identifying key variances affecting performance and occupational health; (5) constructing a variance matrix; (6) analyzing personnel roles and responsibilities; (7) determining function allocation and design integration; (8) analyzing role perceptions and role clarity; (9) designing or improving support subsystems and work system interfaces; and (10) implementing the proposed improvements [20]. These steps were used to systematically evaluate the interactions among human, equipment, environmental, and organizational factors within the housekeeping work system.

Based on the MEAD analysis, system-level improvement recommendations were formulated and subsequently implemented. To evaluate the effectiveness of the implemented improvements, a post-intervention assessment was conducted using the JSA questionnaire. The same JSA instrument used during the pre-intervention stage was redistributed to the same participants after a sufficient adaptation period following implementation to assess changes in occupational health risk levels. Pre- and post-intervention JSA results were then compared to evaluate the impact of the macroergonomic interventions on occupational health risks among housekeeping workers. Descriptive statistics were used to summarize occupational health risk levels. Pre- and post-intervention data were compared using mean score differences to identify changes in risk levels following the intervention.

3. RESULTS

3.1. MEAD Results

3.1.1. Defining Organizational Subsystems

The initial stage of the MEAD analysis involved scanning environmental and organizational subsystems to define system boundaries and identify misalignments between organizational objectives and actual housekeeping practices. The work system was conceptualized with chemicals, equipment, and labor as inputs; cleaning and waste-handling activities as core processes; and hygienic hotel facilities as outputs. Despite a

formal emphasis on service quality, occupational health was not explicitly integrated into operational goals, revealing a gap in risk management. Field observations and interviews identified four critical system variances: physical environmental factors (chemical exposure and inadequate ventilation), equipment and facility limitations (poor trolley conditions and insufficient PPE), worker-related factors (recurring health complaints), and organizational factors (weak supervision and lack of dedicated OSH monitoring). These findings indicate suboptimal alignment among technical, social, and organizational subsystems, underscoring the need for macroergonomic system redesign in subsequent MEAD stages.

3.1.2. Defining the Type Of Work System and Performance Expectations

Based on the system scan, the housekeeping department was classified as a service-oriented, labor-intensive work system characterized by high human involvement, repetitive tasks, and continuous interaction with the physical work environment. The hotel's operational system comprises nine departments: housekeeping, engineering, security, food & beverage service, sales and marketing, human resources, food & beverage production, accounting, and front office. Performance expectations were established in accordance with organizational goals and work process requirements. The identified problem factors are summarized in Table 1.

Table 1. Problem factors

No.	Actual Condition	Identified Problem	Expected Condition
1.	Physical work environment factors: The disorganized condition of the room leads to the accumulation of various types of waste, which consequently generates an unpleasant odor.	Poor air circulation causes unpleasant odours.	Air circulation in the temporary waste disposal area must be well maintained to prevent unpleasant odours.
		The accumulation of rubbish causes an unpleasant smell.	Standard Operating Procedures (SOPs) relating to waste management and odour control must be implemented.
2.	Equipment and facility factors: The mobility of equipment used has decreased.	Lack of equipment maintenance schedule.	The equipment maintenance schedule needs to be improved, and new equipment needs to be purchased to replace broken equipment.
		Inadequate provision of Personal Protective Equipment (PPE) for handling waste and chemical substances.	Adequate personal protective equipment (PPE) must be provided to prevent exposure to chemicals and waste.
3.	Worker condition factors: Workers experience health problems.	Lack of worker awareness regarding Occupational Safety and Health (OSH). Unavailability of Personal Protective Equipment (PPE). Workers do not consistently use Personal Protective Equipment (PPE) when working.	To prevent exposure to chemicals and waste, workers must be consistently provided with and required to use adequate Personal Protective Equipment (PPE) while performing their duties.
4.	Policy factor: The company does not assign a specific division responsible for monitoring occupational safety and health (OSH) compliance.	There is no specific division responsible for managing and supervising the implementation of occupational health and safety in the company.	There is supervision and monitoring of workers' compliance with Occupational Safety and Health (OSH) implementation.

Physical work environment problems, such as poor air circulation and waste accumulation, reflect inadequate environmental control and the absence of standardized waste management procedures, leading to unpleasant odors and increased exposure to airborne contaminants. These conditions increase the risk of respiratory and dermatological health complaints among workers. Equipment and facility-related issues, including reduced equipment mobility, lack of structured maintenance, and insufficient PPE provision, indicate weaknesses in technical support systems that compromise work efficiency and worker safety. Worker-related health problems and unsafe behaviors are closely associated with low OSH awareness and inconsistent PPE use, which are further reinforced by limited PPE availability. This indicates that unsafe behaviors are not solely individual failures but are also shaped by system-level constraints. From a macroergonomic perspective, these conditions demonstrate the interaction between human behavior, organizational resources allocation, and safety performance expectations, underscoring the need for integrated system-level interventions addressed in subsequent MEAD stage.

3.1.3. Identifying Operational Units And Work Processes

At this stage, the operational units and core work processes within the housekeeping department were identified. The primary operational units included room cleaning, public area cleaning, and waste-handling activities, each involving repetitive manual tasks, chemical usage, and equipment handling. Those four main work activities were identified as a potential cause health issues among housekeeping workers. Potential hazards were analyzed using the JSA method and classified into four types: (1) physical hazards: falling, cuts, and abrasions, (2) chemical hazards: skin irritation, eye irritation, respiratory disorders, and poisoning, (3) biological hazards: infections and skin diseases, and (4) environmental hazards: air pollution and respiratory disturbance. The pre-intervention JSA questionnaire was administered at this stage to assess occupational risks within the work system.

3.1.4. Identifying Key Variances

Key variances affecting system performance and occupational health were identified by comparing expected work conditions with actual practices observed in the field. This stage aimed to identify and categorize existing problems into structured variables. The collected variance data are summarized in [Table 2](#).

Table 2. Variances data

Variance Factor	Identified Variance
Physical Work Environment	Odor in waste disposal area
	Disorganized room
Equipment And Facilities	Equipment Malfunction
	Lack of Equipment Maintenance Schedule
	Inadequate Personal Protective Equipment (PPE) facilities
Worker Condition	Workers experience health problems
	Low awareness of Occupational Safety and Health (OSH) among workers
	Workers not using Personal Protective Equipment (PPE)
	Workers require Personal Protective Equipment (PPE)
Company Policy	Ineffective OHS supervision

The identified variances indicate that occupational health risks in the housekeeping department arise from systemic misalignments among the work environment, equipment and facilities, worker behavior, and organizational policies. Poor air circulation and disorganized work areas reflect inadequate environmental control, leading to continuous exposure to chemical and biological contaminants that increase the risk of respiratory and dermatological health problems. Equipment-related issues, including malfunctioning tools, the absence of a structured maintenance schedule, and insufficient PPE availability, highlight weaknesses in technical support systems that compromise safe work execution. Worker-related variances represent the most complex and interrelated issues within the system. The coexistence of reported health problems, low OSH awareness, inconsistent PPE use, and explicit worker demand for PPE suggests that unsafe behaviors are not

solely behavioral failures but are strongly influenced by inadequate resources, limited training, and insufficient organizational support.

3.1.5. Constructing the Variance Matrix

The variance matrix was developed to determine interrelationships between identified variances and to identify key factors. Based on the results of the variance matrix analysis, the key variance identified was worker health disturbances, with a total score of six, indicating that the primary variance was associated with the worker condition factor. The key factor was associated with seven related variances: unpleasant odor in waste disposal rooms, absence of PPE facilities, workers experiencing health problems, lack of K3 (occupational safety) awareness, workers not using PPE, workers expressing need for PPE, and ineffective OHS supervision. The variance matrix is shown in Table 3.

3.1.6. Analyzing Personnel Roles

The personnel role analysis was conducted to identify variance control mechanisms and clarify the responsibilities of stakeholders involved in addressing key variances within the housekeeping department. The key variances primarily occurred within the housekeeping department and were closely related to worker conditions. Supervisors of the housekeeping department, along with hotel management and maintenance units, were identified as the main parties responsible for monitoring and controlling these variances, while workers were the primary affected stakeholders. Existing supporting activities were limited, such as the installation of exhaust fans and supervisory guidance on chemical handling, indicating that current controls were insufficient and highlighting the need for strengthened administrative measures, PPE provision, and supervisory enforcement.

Table 3. Variance matrix

Variance Factor	Variance	Odor in waste disposal area	Disorganized room	Equipment Malfunction	Lack of Equipment Maintenance Schedule	Inadequate PPE facilities	Workers experience health problems	Low awareness of OSH among workers	Workers not using PPE	Workers require PPE	Ineffective OHS supervision	Total
Physical Work Environment	Odor in waste disposal area	■	X				X					2
	Disorganized room	X	■					X				2
	Equipment Malfunction			■	X							1
Equipment And Facilities	Lack of Equipment Maintenance Schedule				■							1
	Inadequate PPE facilities					■	X		X	X		3
	Workers experience health problems	X				X	■	X	X	X	X	6
Worker Condition	Low awareness of OSH among workers		X				X	■			X	3
	Workers not using PPE					X	X		■	X	X	4
	Workers require PPE					X	X		X	■		3
Company Policy	Ineffective OHS supervision						X	X	X		■	3

3.1.7. Determining Function Allocation and Design Integration

Three alternative improvement designs were proposed to address the identified problems. Alternative 1 focused on physical work environment improvements through the provision of supporting facilities, including the design and installation of warning displays to promote PPE compliance and recommendations for enhancing ventilation by installing additional exhaust fans. Alternative 2 emphasized behavioral and administrative interventions, consisting of PPE provision and structured socialization programs to increase workers' awareness and correct use of PPE. Alternative 3 addressed organizational strengthening by proposing the addition of occupational health and safety (K3) personnel, the establishment of a dedicated division for supervising safety issues, and the implementation of systematic K3 training and education programs. These alternatives represent complementary macroergonomic strategies targeting physical, behavioral, and organizational dimensions of the housekeeping work system.

3.1.8. Analyzing Role Perception and Responsibility

The macroergonomic intervention alternatives were selected through a weighting process. The selected interventions include the provision and socialization of PPE usage, the installation of visual warning displays to reinforce PPE compliance in work areas, and the implementation of exhaust fan systems to improve ventilation and reduce chemical exposure.

3.1.9. Designing or Improving Support Subsystems and Interfaces

Based on the identified variances and role analyses, improvements were proposed for support subsystems and organizational interfaces. These included hazard and risk control through administrative control, such as installation of safety display signae and the use of personal protective equipment (PPE), including masks, safety goggles, and rubber gloves. PPE usage is reinforced through worker training and awareness programs to emphasize its importance. Two types of visual displays are implemented: white text on a blue background for guidance (Figure 1) and black text on a yellow background for warnings (Figure 2).



(a) Warning sign displaying the mandatory use of mask and gloves for safety



(b) Warning sign displaying the mandatory use of PPE



(c) Hand washing warning display

Figure 1. First type of display sign



Figure 2. Second type of display sign

3.1.10. Implementing The Proposed Improvements

The final stage involved implementing the proposed macroergonomic interventions within the housekeeping department. Improvements focused on administrative controls, such as provision of six sets of PPE (rubber gloves, masks, and safety glasses), conducting safety briefings and socialization sessions on PPE use, and Installation of display signage in relevant work areas.

3.2. JSA Results

JSA was performed pre- and post-MEAD intervention to evaluate changes in worker risk levels. Mean risk scores were compared descriptively to assess the effectiveness of the implemented improvements. The summarized JSA results are presented in [Table 4](#).

Table 4. Recapitulation of JSA questionnaire results

No.	Question	Pre-Intervention		Post-Intervention	
		Total Score	Category	Total Score	Category
1.	Do you often experience respiratory problems while working?	21	Frequently occurs	12	Occasionally occurs
2.	Do you often experience eye irritation while working?	19	Occasionally occurs	7	Never occurs
3.	Do you experience itching on certain areas of your body while working?	23	Frequently occurs	11	Never occurs
4.	Do you often experience abrasions on certain parts of your body while working?	16	Occasionally occurs	8	Never occurs
5.	Do you experience redness on certain areas of your body while working?	18	Occasionally occurs	7	Never occurs
6.	Do you experience peeling or flaking of the skin while working?	6	Never occurs	6	Never occurs
7.	Do you often slip while working?	7	Never occurs	8	Never occurs
8.	Have you ever fallen from the evacuation stairs while working?	6	Never occurs	6	Never occurs
9.	Do you often experience poisoning due to chemical exposure while working?	6	Never occurs	6	Never occurs
10.	Do you often experience hearing problems while working?	7	Never occurs	7	Never occurs
11.	Do you feel exposed to bacterial infections while working?	6	Never occurs	6	Never occurs
12.	Do you often experience electric shocks while working?	14	Rarely occurs	8	Never occurs
13.	Do you often trip over trolley wheels while carrying a trolley?	14	Rarely occurs	8	Never occurs

No.	Question	Pre-Intervention		Post-Intervention	
		Total Score	Category	Total Score	Category
14.	Have you ever been struck by the floor polishing machine?	6	Never occurs	6	Never occurs

Prior to the intervention, the highest risk categories were associated with chemical exposure-related symptoms, particularly respiratory problems (total score = 21, frequently occurs), skin itching (23, frequently occurs), eye irritation (19, occasionally occurs), and skin redness and abrasions (total scores = 18 and 16, respectively). These findings indicate that housekeeping workers were predominantly affected by inhalation and dermal exposure to cleaning chemicals and waste contaminants.

Post-intervention results show substantial improvements across these dominant risk indicators. Respiratory complaints decreased from frequently occurs to occasionally occurs, while eye irritation, skin itching, abrasions, and redness all shifted to the never occurs category. These reductions suggest that the combined implementation of administrative controls, consistent PPE provision, safety training, and visual safety cues effectively minimized direct exposure to hazardous substances and improved protective behaviors among workers.

In contrast, risks related to physical accidents (e.g., slips, falls, and machine-related incidents) and biological exposure remained consistently low in both pre- and post-intervention assessments, indicating that these hazards were already well controlled within the existing work system. Minor reductions were also observed in electrical shock and trolley-related tripping risks, shifting from rarely occurs to never occurs, reflecting secondary benefits of improved awareness and supervision.

4. DISCUSSION

This study demonstrated that macroergonomic analysis using the MEAD framework effectively identified and addressed key occupational health risks in the housekeeping department. The MEAD analysis revealed that the primary contributors to risk were physical work environment, equipment and facilities, worker factors and organizational factors. These findings align with the macroergonomic principle that the work system must be understood as a sociotechnical whole, wherein environmental, organizational, and human factors interact to influence safety outcomes [21]–[23]. In the environmental factor, workers were exposed to unpleasant odors from chemical cleaning agents and waste materials, particularly in the temporary waste disposal area. The equipment and facility factor involved limited equipment mobility, particularly with cleaning trolleys and insufficient provision of personal protective equipment (PPE) for workers. In the worker factor, health-related issues were prevalent: several employees reported skin irritation, respiratory problems, redness, and abrasions resulting from prolonged exposure to chemicals and waste. Meanwhile, the organizational factor reflected insufficient supervision and low adherence to safety instructions from supervisors, resulting in inconsistent occupational safety behavior among workers. The observed occupational health risks not only compromise worker safety but also negatively influence worker productivity, which itself is linked to safety outcomes [24], [25]. Empirical studies indicate that when occupational health and work environment conditions improve, productivity increases significantly, as workers experience fewer health complaints and can perform tasks more safely and efficiently [26]–[28]. Additionally, chronic exposure to hazards such as chemicals and ergonomic stresses contributes to cumulative health deterioration that reduces workers' capacity to sustain performance and maintain safe behaviors over time [29], [30].

The JSA results underscored that respiratory irritation and skin-related symptoms were the most frequent risk outcomes prior to intervention, underscoring the impact of chemical exposures and insufficient protective measures. After implementing combined administrative and PPE control strategies, significant reductions in JSA score of these risks were observed. The observed reduction in respiratory and skin-related symptoms suggests that reducing direct chemical exposure and improving protective behaviors effectively mitigated health risks. The reduction in JSA scores for respiratory and skin-related risks can be explained by the combined effect of exposure administrative control and behavioral modification [31].

The application of administrative controls, such as worker training and socialization on proper PPE use, is supported by occupational safety literature showing that educational and behavioural interventions significantly improve PPE compliance and knowledge, which in turn reduces incidence of exposure-related symptoms [32]. Specifically, previous studies have found that structured education programs can increase PPE

compliance rates substantially, reinforcing the importance of continuous training as part of risk control strategies [33], [34].

In addition to training, the provision and consistent availability of appropriate PPE (e.g., masks, safety glasses, gloves) was essential in mitigating risks associated with chemical exposures. It is well-established that consistent and proper PPE use can reduce workplace accident and injury rates when combined with organizational safety policies and enforcement mechanisms [35]. Previous studies have demonstrated that chemical exposure is strongly associated with respiratory and dermatological symptoms, and that consistent PPE use significantly reduces such outcomes [36], [37]. This finding stresses that PPE should not be viewed as an isolated control measure but as a component of a broader safety system that includes administrative support, supervision, and safety culture.

The integration of warning displays further complemented these efforts by enhancing hazard awareness and reinforcing the required safety behaviours among workers. Visual cues as part of administrative controls have been shown to support compliance and risk recognition in occupational settings, particularly when workplace signage is clear, context-specific, and strategically placed within work zones [37], [38].

Despite the positive outcomes, this study has several limitations. First, the evaluation relied on descriptive comparisons without inferential statistical testing, which limits causal generalization. Second, the post-intervention assessment was conducted shortly after implementation, preventing evaluation of long-term sustainability. Third, the interventions focused primarily on administrative and PPE controls, which are lower in the hierarchy of hazard control, and thus future studies should explore engineering or elimination-based solutions.

In conclusion, this study confirms that macroergonomic interventions structured through MEAD can substantially enhance occupational safety in hotel housekeeping operations by addressing systemic factors and layering administrative and PPE controls. The results emphasize that a systems-based approach to risk identification and intervention planning, that integrates worker participation, training, visual communication, and protective equipment, can meaningfully improve health and safety performance in service-sector work environments. Such a holistic approach supports ergonomic principles of participatory design and systemic optimization, contributing to both worker wellbeing and operational safety outcomes [39].

5. CONCLUSION

Based on the macroergonomic analysis, occupational health risks in the housekeeping department were found to be embedded in system-level interactions among environmental exposure, equipment and PPE availability, worker safety behavior, and organizational supervision, rather than isolated task-level hazards. Worker health disturbances emerged as the key variance, showing strong interdependencies with chemical exposure, ventilation conditions, PPE use, and the absence of structured OSH oversight. The implementation of integrated improvement strategies—including administrative controls, systematic PPE provision, safety training and socialization, visual warning displays, and ventilation enhancement—resulted in a clear reduction in occupational health risks. This improvement was evidenced by substantial decreases in post-intervention JSA scores, particularly for respiratory and dermatological symptoms, which were the dominant complaints prior to the intervention. These findings confirm that addressing system-level misalignments through a macroergonomic approach can produce meaningful improvements in worker health outcomes. The study demonstrates that MEAD-based interventions are effective for managing occupational health risks in hotel housekeeping operations by integrating organizational responsibility, worker behavior, and environmental controls. Future research should explore higher-level hazard controls and longer-term evaluations to ensure the sustainability of these improvements.

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